MORPHOLOGICAL AND YIELD CHARACTERS OF DIFFERENT TOMATO (*Lycopersicon esculentum* L.) GENOTYPES AS INFLUENCED BY DROUGHT STRESS

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CERTIFICATE

This is to certify that the thesis entitled **"MORPHOLOGICAL AND YIELD CHARACTERS OF DIFFERENT TOMATO (*Lycopersicon esculentum* L.) GENOTYPES AS INFLUENCED BY DROUGHT STRESS"** submitted to the Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **AGRICULTURAL BOTANY**, embodies the result of a piece of bonafide research work carried out by **MAHMUDA SULTANA** , Registration No. 1809023 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

June, 2020
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Dedicated to
My
Beloved Parents

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The Author

MORPHOLOGICAL AND YIELD CHARACTERS OF DIFFERENT TOMATO (*Lycopersicon esculentum* L.) GENOTYPES AS INFLUENCED BY DROUGHT STRESS

ABSTRACT

An experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from October 2018 to February 2019, to find out the morphological and yield characters of different tomato (*Lycopersicon esculentum* L.) genotypes as influenced by drought stress. Three varieties *viz*. V_1 (BARI tomato-2), V_2 (BARI tomto-5) and V_3 (BARI tomato-7) and four drought stress *viz*. T_0 (control; no stress), T_1 (Drought stress at early fruiting stage), T_2 (Drought stress at mid fruiting stage) and T_3 (Drought stress at late fruiting stage) were considered for two factors experiment under the present study. Results showed that the variety, V_3 (BARI tomato-7) gave the best result regarding yield (60.96 t ha^{-1}) under no stress (T_0) condition compared to V_1 (BARI tomato-2) and V_2 (BARI tomto-5) even under drought stress regarding T_1 (Drought stress at early fruiting stage), T_2 (Drought stress at mid fruiting stage) and T_3 (Drought stress at late fruiting stage) the highest yield was obtained from V_3 (BARI tomato-7) (43.72, 56.87 and 68.08 t ha^{-1}, respectively) compared to performance of other varieties under drought stress. Considering relative performance on total dry weight $plant^{-1}$ (shoot + root), V_1T_3, V_2T_3 and V_3T_3 showed better performance. So, it can be decided that the variety V_1 (BARI tomato-2), V_2 (BARI tomto-5) and V_3 (BARI tomato-7) can be considered as more tolerant against drought stress but V_3 (BARI tomato-7) showed best performance in terms of best morpho-physiological parameters and yield. Treatment T_3 (Drought stress at late fruiting stage) showed better result on growth and yield performance whereas drought stress at early fruiting stage to till harvest (T_1) was the most affected fruiting stage considering. Regarding combined effect of variety and drought stress, V_3T_3 (drought stress at late fruiting stage with variety BARI tomato-7) gave best performance regarding morpho-physiological and yield performance excluding control.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* L.) is a popular and economically important crop plants around the world. It contains a valuable compound, lycopene, which possesses anti-oxidative and anticancer properties. Therefore, tomato production and consumption are permanently increasing (Raiola *et al*. 2014). In 2013 tomato was 7th in global production, achieving a world production of approximately 164,000,000.00 million tonnes on a total area of nearly 4.8 million hectares (FAOSTAT 2013). Being a tropical plant, tomato is well adapted to almost all climatic regions of the world; however, environmental stress factors are the primary constraints of this crop's yield potential.

The cultivated tomato *Lycopersicon esculentum* Mill. belongs to the Solanaceae family of plants. All nine species of the genus Lycopersicon have 2n = 24 chromosomes (KALLOO, 1991).

It is popular of its diversified use like salad, stewed, juices, sauce, pickles and preserved. Bangladesh produces 137 thousand tones of tomato from 15.39 thousand hectares of land, the average yield being 8.90 t/ha and percent of tomato production is 2.30 (Anon., 2007).

Tomato is generally accepted to have originated in new world (America) i.e. the Andean region composed of part of Bolivia, Chile, Colombia, Ecuador and Peru. Evidence from the diversity of cultivated type culinary use and from the abundance of the names of the tomato was originally domesticated in Mexico (Jenkins, 1948). At present, tomato is one of the widest grown vegetable in the world. Plant explorers have found wild relatives of the tomato in the tropical rain forests of South America as well as in arid regions of the native Mexico (Villareal, 1980).

Tomatoes are rich in nutrients, especially potassium, folic acid, and vitamin C, and contain a mixture of different carotenoids, including vitamin A, effective

6-carotene, as well as lycopene (Wilcox *et al.* 2003). Lycopene one of nature's most powerful antioxidant, is present in tomatoes, and, especially when tomatoes are cooked, had been found beneficial in preventing prostate cancer. The consumption of tomatoes rich in lycopene leads directly to a decreased incidence of cancer in mouth, pharynx, esophagus, stomach, large intestine, and rectum (Franceschi *et al.* 1994).

Tomatoes are very high in vitamin value as it contains Calories 97, Iron 2.7 mg, Protein 4.5 g, Vitamin A 4,080 I.U, Fat 0.9 g, Thiamine 0.23 mg, Carbohydrates 17.7 g, Riboflavin 0.15 mg, Calcium 50 mg, Niacin 3.2 mg, Phosphorus 123 mg and Ascorbic acid 102 mg per 1 pound edible portion (Lester, 2006). 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. 2014). In Bangladesh, it is cultivated as a winter vegetable, which occupies an area of 58,854 acres in 2009-10 (BBS. 2015). The total production of tomato in 2008 was 339 lac tons in China, 137 lac tons in the USA, 109 lac tons in Turkey, 103 lac tons in India and 92 lac tons in Egypt in 2008 (FAO. 2014). In Bangladesh, in the year of 2009-2010, the total production of tomato was 190 thousand metric tons (BBS. 2015). The average tomato production in Bangladesh is 50-90 tons/ha. 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 several 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 *et al*., 1997).

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.

Drought is one of the most important environmental stresses limiting crop productivity. Plant species adapt to this adverse condition through different ways. Some plants can (a) complete their life cycle under optimum conditions, (b) reduce water loss by reducing leaf size or reducing stomatal pores, (c) maintain growth even during water deficit by retaining water content, or (d) increase water use efficiency (WUE) of limited available water (Bressan *et al*., 2002).

Plant growth is seriously affected by abiotic stresses such as drought, salinity or temperature. Drought is one of the most important limiting factors for agricultural crops and vegetable production in particular all around the world. Drought stress during vegetative or early reproductive growth usually reduces yield by reducing the number of seeds, seed size and seed quality (Pervez and Ayub, 2009).

Corn, soybeans, beans and peas are considered to be moderately water stress sensitive while tomatoes belong to the extremely drought sensitive group (Heszky *et al*., 2007, Patanè *et al*., 2011). The responses of plant species significantly depend on the intensity and duration of stress and their stages of development. The spring-sown green pea utilizes the precipitation well (if there is any) and requires a low temperature during vegetative growth but during the flowering and seed development periods it is sensitive to water deficiency. The crops require a warm temperature, even though they have different ripening times, snap beans have short (60 days), sweet corn has medium (75–90 days) and tomatoes have long ripening times (110–130 days), their generative stages of development coincided with dry June and July, thus they require irrigation.

In sweet corn, ear differentiation begins at the six- or eight-leaf stage growth when the water deficiency decreases the length of ears and the numbers of ear rows (Moser *et al*., 2006), but during tasselling the water deficiency causes significant yield reduction (Öktem, 2008, Uçak *et al*., 2016). Tomatoes are most sensitive to water deficiency at fruit setting and intensive fruit development periods, when the increasing water stress resulted in a 25 to 50% decrease in the yield (Patanè *et al*., 2011, Helyes and Varga, 1994, Patane *et al*., 2010, Pires *et al*., 2011). During early flowering of tomatoes, water scarcity causes flower shedding and lack of fertilization, and during fruit setting, plants with small sized fruits are produced (Patanè *et al*., 2011, Helyes *et al*., 2010).

The effect of water stress on morphology and anatomy of plants has been studied by several researchers under controlled conditions (Zhu *et al*., 2016, Nankishore and Farrell, 2016, Agbna *et al*., 2017, Rodriguez-Ortega *et al*., 2017, Gurumurthy *et al*., 2019). Therefore, the changes in physiological responses have been less investigated under field conditions. The physiological characteristics that have an important role in the defence against drought can be measured by remote sensing techniques using non-destructive methods in open field conditions.

However, considering the above findings, the present research work has been done with the following objectives:

1. To study the changes of morphological and yield parameters of tomato varieties under drought stress
2. To find out the most affected fruiting stage of tomato varieties under drought stress

CHAPTER II

REVIEW OF LITERATURE

Several research works also have been done to find out the Morphological and yield characters of different tomato (*Lycopersicon esculentum* L.) genotypes as influenced by drought stress in different countries of the world but those works are little relevant to agro- ecological situation of Bangladesh. However, literature available in this respect at home and abroad have been reviewed below will contribute to the present study.

2.1 Effect of variety

Das *et al.* (2011) conducted a field experiment variation in growth and yield quality of tomato varieties under different showing time. Result found that BARI Tomato-2 (Ratan) performed the best in yield in association with November 09 planting.

Hamid *et al.* (2005) carried out an experiment to study the performance of five Russian (Raickoi Naclazdenie, Belai Nalev, Ceberckoi Ckorocpelai, Novichok, Patris) and one local variety of tomato under Rawalakot conditions during the year 2003. The results indicated that maximum plant height, leaf number and size of fruit were observed in variety Raickoi. Naclazdenie, whereas maximum number of flower clusters and fruits per plant were observed in Patris'. Minimum plant height, leaf number, number of flower clusters and fruits were noted in Novichok, where as minimum number of branches and fruit weight per plant noted in Local Kashmir. Varieties Ceberckoi ekorocepali and Patris gave maximum fruit weight of 4.96 and 4.85 kg plant^{-1} compared to the minimum of 1.60 kg plant^{-1} by local check and Novichok. Exotic varieties Patris and Ceberckoi ckorocpali are recommended for commercial Cultivation due to high production.

Hossain (2001) conducted an experiment at the Horticulture Farm, BAU, Mymensing with four tomato varieties namely BARI Tomato-4, BARI Tomato-5, BARI Tomato-7, BARI Tomato-8 and three planting dates (October -25, December-25, and February-24). Planting dates and varieties had significant influence on growth, yield contributing parameters and yield of tomato. The highest yield of tomato (86.40 t ha^{-1}) was obtained from October 25 planting compared to lowest in Tomato-7 gave the highest yield (100.13 t ha^{-1}) in October 25 planting.

Rashid *et al.* (2000) carried out an experiment to evaluate thirty seven tomato varieties or lines for resistance to bacterial within the sick bed in replicated trial. Result found that, 26, 66, 33.33 and 30% incidence of wilt in BARI Tomato-4, BARI Tomato-10 respectively.

Nessa *et al.* (2000) conducted an experiment to study the comparative performance of ten genotypes of tomato in late planting and reported that the genotype BAU/TM 0058 was the best in late planting. It was closely followed by BAU/TM 0041. They also state that, fruit number and fruit weight should be considered as important criteria for higher yield.

Islam (2000) conducted a field experiment with four dates of planting (16 October, 15 November and 14 January) and four varieties (BINA Tomato-2, BARI Tomato- 3, BARI Tomato- 4, BARI Tomato- 5 at the horticulture farm, BAU, Mymensingh during the period from September, 1999 to May, 2000, to extend the pocking period of tomato through selection of variety and adjustment of date of planting. He mentioned that, the highest yield of tomato (53.65 t ha^{-1}) was achieved from 16 October planting. The variety BARI tomato-3 produced the highest yield (50.65 t ha^{-1}) and BINA Tomato- 2 gave the lowest yield (34.80 t ha^{-1}).

Khalid (1999) conducted an experiment with two winter (Ratan and Bahar) and three summer (BINA Tomato-2, BINA Tomato-3 and E-6) varieties of tomato during the winter season of 1998-99 at the Horticulture farm, BAU, Mymensingh. He observed that, the highest yield per plant was obtained from

BINA Tomato-2 (1.74 kg), followed by BINA Tomato-3 (1.67 kg). But the yields of these varieties were statistically similar to each other.

The floral characteristics of heat-tolerant and heat sensitive tomato cultivars at high temperature was studied by Lohar and Peat (1998) in Nepal. They observed that, flowering was earliest in Pusa Ruby at 28-23° C (day/night) and latest in CL- 1131 at 15/10° C. They also indicated that, cv. CL- 1131 was suitable for cultivating at high temperature and producing an earlier crop. Cultivar Pusa Ruby produced fewer flowers and fruits at high temperature than CL-1131, but not in 15/10° C regime.

An experiment eriment was conducted with two summer tomato varieties (BINA Tomato-2 and 3) to study the yield performance at 3 locations (Magura, Comilla and Khulna) during the summer season (BINA, 1998). It was observed that, BINA Tomato-2 produces higher fruit yield at Magura (38 t ha^{-1}) and Khulna (17 t ha^{-1}), while BINATomat-3 gave higher yield (29 t ha^{-1}) at Comilla. However, mean fruit yield from three locations showed that, the variety BFNA Tomato-2 produced higher fruit yield than BINA Tomato-3.

Singh and Sahu (1998) conducted a field experiment at Keonjhar, Orissa, India during *robi* 1991-92 and 1992-93 to evaluate 23 tomato cultivars to find out a suitable variety for winter season cultivation. They reported that, BT 12 produced the highest yield (34.09 t ha^{-1}) closely followed by BT 17, PED, BT14, Sel 120, BT 1 and punjab Chhuhara. The variety Sel 120 had the highest weight and girth of fruit, whereas Punjab chhuhara produced the maximum number of fruit per plant and took less time to mature. The variety Arka Alok was earliest and large fruits.

Ajlouni *et al.(* 1996) conducted a field trial in Jordan 1993 to study the yield of 13 local and introduced open pollinated tomato cultivars, and to compare the yields to that of 3 common hybrids (Maisara F1, 898 F1 and GS12F1) in relation to seasonal distribution of marketable and unmarketable yield and fruit number. The cultivars varied in their marketable yield during the harvested period (10 weeks from 22 June 1993). The results indicated that the cultivars Rio Grande, Nagina and T2 improved were superior to the hybrids.

Berry *et al.* (1995) conducted an experiment at Wooster, USA with the hybrid processing tomato Ohio Ox 38. It was observed that, the yields of this variety in 1992 and 1993 were higher (70.3 and 80.4 t ha^{-1}, respectively) compared to other cultivars.

Bhangu and Singh (1993) conducted a field trial with some tomato cultivars (Punjab Kesari, Punjab Chhuhara, Punjab Tropic, PNR-7, S-12, Pusa Ruby and the Hybrid THL-23l2) in 1990 and 1992. Mean annual yield was highest in Punjaab Kesari and lowest in Punjab Tropic. The number of fruits per plant was highest in Punjab Kesari (123). Punjab Tropic produced the largest fruits (66.69g).

Kallo (1989) worked with some tomato varieties (Pusa Early Dwarf, HS 102, Hisar Arun (Sel 7) And Punjab Chhuhara) in northern India. Result found that, HS 102 and Punjab Chhuhara were fit for summer cultivation, and Pusa Early Dwarf and Hisai Arun were suitable for getting early fruits.

Ahmed *et al.* (1986) assessed eight F-7 lines of tomato at the Horticulture Farm, Bangladesh Agricultural University, Mymensingh. All the lines had shown indifference in plant height and fruit size. In contrast, fruit number had shown significant difference among the varieties. The line 0014-60-3-9-1-0 gave the highest yield of fruit (56.9 t ha^{-1}), followed by 0013-52-10-27-32-0 (50.0 t ha^{-1}).

Hossain and Haque (1984) carried out an experiment under a BARC financed project BVRD, at its Joydebpur Sub-Centre, Gazipur during the summer season of 1976 with three tomato varieties. It was found that, the variety Hope-1 was more adapted to our summer climate than the other two. Although Hope-1 produced smaller fruits, it produced the highest number of fruits (16) per plant, as well as the highest yield (9.24 t ha^{-1}), indicating that the variety could tolerate heat and high humidity of Bangladesh better than the other two varieties.

Narayan *et al.* (2007) reported that, the tomato hybrid Vijita gave the highest mean number of fruits per plant (29.65). Hossain (2007b) observed highest number of fruits per plant in M-20 (34.66) and the lowest in M-83 (14.66). Amin (2006) conducted an experiment and reported that maximum number of fruits per plant was 33.52 and minimum number of fruit per plant was 12.70. Ahmed *et al.* (2005) reported that Shalkot cultivar of tomato showed highest number of fruits per plant (41.93).

Habber *et al.* (2004) conducted field experiment during the summer season of 1999-2000 and 2000-2001 in India, to study the effect of fertigation with sources and levels of fertilization and method of fertilizer application on growth, yield and fertilizer efficiency of hybrid tomato in red sandy loam soil. There were 8 treatments including furrow- irrigated and drip-irrigated controls, which were replicated three times. They reported that, WSF fertigation recorded significantly higher number of fruits per plant (56.9).

Jane and Bhattarchaya (2001) reported that, under direct sowing, Naveen gave the highest number of fruits per plant (61.77) and under the transplanting method Abinash-2 gave the highest number of fruits per plant (69.07). Islam *et al.* (1999) studied 10 components in 26 diverse genotypes of tomato and observed highest genetic variability for number of fruits per plant.

Hossain (2007b) found that fruit weight per Diant was sienificantlv influenced bv different genotypes of tomato. The highest weight of fruit (1.25 kg) per plant was recorded in M-58 and the lowest (0.65 kg) was obtained in M-83. Rahim (2006) stated that the yield of fruit per plant varied significantly among the genotypes. The highest yield of fruit (2.98 kg) per plant was obtained from the genotype CLN-2026, but the lowest (1.70 kg) was recorded from the genotype J-5 which is statistically identical with CLN-2443. Jane and Bhattarchaya (2001) reported that under direct sowing Naveen gave the highest fresh of fruit yield (4.30 kg) per plant and under the transplanting method Naveen gave the highest fresh of fruits yield (4.33kg) per plant.

Carmello and Anti (2007) conducted an experiment on a farm owned by Uniliver Best Food Brazil, they observed the hybrid variety 'Heinz 9992' with potential production of 130-140 t/ha was used in fully randomized experimental design with double rows. Huang-Ting Ting *et al.* (2007) reported that Shalong a new mid-ripening, high yielding tomato hybrid from China mid-type fruit with regular shape, had fruit yield more than 150 t/ha. The tomato hybrid Vijeta gave 52.1 t/ha fruit yield (Narayan *et al.* 2007).

Hossain (2007a) conducted an experiment with 9 AVRDC heat tolerant lines (ST- 002, ST-004, ST-005, ST-006, ST008, ST-014, ST-015, ST-016 and ST-021) and BARI Tomato-10. He reported that the hybrid BARI Tomato-10 produced the highest yield (30.73 t/ha) and ST-004 produced the lowest yield (4.58 t/ha). Hossain (2007b) reported the fruit yield was significantly influenced by different genotypes. The highest yield (65.53 t/ha) was recorded in M-58 with same rank M-76, while the lowest (33.40 t/ha) was obtained in M-83, which was statistically identical in M-6.

Mohindra-kaur and Kanwar (2006) conducted an experiment during 2002-2003, in Ludhiana, Punjab, India to investigate the effect of planting date (20 November, 5 December and 5 January) on the seed quality of 6 tomato genotypes (VFN-8, ACC-8, W-321, Punjab Chhuara, ACC-2 and 1-181). The higher fruit yield (87.98 t/ha) was recorded in crop planted on 20 November, and among the genotypes, maximum fruit yield (74.77 t/ha) was obtained in W-321.

An experiment was conducted with 4 Tomato varieties (BARI Tomato-4, BARI Tomato-5, BARI Tomato-7 and BARI Tomato-8) to study the yield performance at Horticulture Farm of Bangladesh Agricultural University, Mymensingh, Bangladesh during 2000-2001. It was observed that the variety of BARI Tomato-7 produced the highest yield (57.07 t/ha) and BARI Tomato-

5 produced the lowest yield (51.38 t/ha) (Hossain, 2001).

Another experiment was conducted with 10 Tomato varieties during the summer season. It was observed that the cultivar Tanja gave the highest yield of 41.45 t/ha. It was followed by Choico-III and Sorrento which exhibited average yield of 40.32 and 49.13 t/ha, respectively (Hussain, 2001). Biswas *et al.* (2000) reported that among the 19 different hybrid of tomato evaluated in field conditions at

Pithoragarh (Utter Pradesh, India) during the kharif season of 1998, the hybrid DARL-304 recorded the highest yield (41.91 t/ha) followed by DARL-303 (38.50 t/ha), which may be recommended as most suitable genotypes for the central Himalayan conditions.

An experiment was conducted during the winter season of 1998-1999 at Horticulture Farm, Bangladesh Agriculture University, Mymensingh with two winter (Ratan and Bahar) three summer (BINA Tomato-2, BINA Tomato-3 and E- 6) varieties of tomato. It was found that the highest yield/plant was obtained from BINA Tomato-2 (1.74 kg), followed by BINA Tomato 3 (1.67 kg). But the yield of these varieties was statistically similar to each other (Khalid, 1999).

An experiment was conducted with two summer tomato varieties (BINA Tomato- 2 BINA Tomato-3) to study the yield performance at 3 locations of Bangladesh (Magura, Comilla and khulna) during the summer season. It was observed that BINA Tomato-2 produced higher fruit yield at Magura (38 t/ha) and Khulna (17 t/ha), while BINA Tomato-3 gave the higher yield (29 t/ha) at Comilla. However, mean fruit yield from three locations showed that the variety BINA Tomato-2 produced the higher yield than BINA Tomato-3 (Anon., 1998).

2.2 Effect of drought stress

Following world population growth need for agricultural water for irrigation is become increasing but quantity of water with a sufficient quality is declining which can further enhanced by an increasing demand to shii more of the water used in agriculture to higher-value urban and industrial uses. Suitable water utilization in agriculture is critical and has to be practiced. Deficit irrigation is an optimization strategy that allows to some extent of water stress during a certain cropping stage or the whole season without a significant reduction in yield. Drought, caused by insufficient rainfall and/or altered precipitation patterns, is often accompanied by relatively high temperatures, with increased evapotranspiration which affects photosynthetic kinetics and crop productivity (Nahar and Ullah, 2011). Under water deficit, plants may escape drought stress by shortening the life cycle (Chaves and Oliveira, 2004; Nahar and Ullah, 2011). However, the oxidative stress of rapid dehydration is damaging to the photosynthetic processes, the capacity for energy dissipation, and metabolic protection against reactive oxygen species; these are key to survival under drought conditions (Ort, 2001; Chaves and Oliveira, 2004; Nahar and Ullah, 2011). Severe dehydration tolerance is not common in crops but is found in species native to dry environments (Ingram and Bartels, 1996). Genetic variability for drought tolerance in S. lycopersicum is limited and inadequate

Cui (2020) conducted field and pot experiments in order to investigate the drought sensitivity of tomato (*Lycopersicon esculentum* Mill.) yield and quality during different growth stages. The experiments consisted of four treatments. Crops were drip-irrigated to 100 % of field capacity at all growth stages divided into treatment T1 (control) and the treatment group T2, T3 and T4 receiving half the amount of irrigation as T1 when the soil water content reached 70 % of field capacity, the vegetative phase (stage I) T2, the flowering and fruit development phase (stage II) T3, and the fruit ripening phase (stage III) T4. Compared to the control treatment, drought stress at stages II and III caused a decrease in yield of 13 % and 26 %, respectively. Fruit firmness and color index were positively affected by drought stress, while fruit water content and shape index did not show any differences between treatments. Taste and nutritional quality parameters, such as total soluble solids, soluble sugar, organic acids and vitamin C improved in response to limited water supply ($p \leq 0.05$). Despite having a negative effect on fruit yield, drought stress applied at stage III tended to enhance fruit quality traits. This study found that applying drought stress at stage I can be a positive management approach as it saves water and has fewer negative effects compared to applying drought stress at the other critical growth stages, thereby minimizing the adverse effects of drought stress.

Nemeskéri and Helyes (2019) observed that the frequency of drought periods influences the yield potential of crops under field conditions. The change in morphology and anatomy of plants has been tested during drought stress under controlled conditions but the change in physiological processes has not been adequately studied in separate studies but needs to be reviewed collectively. This review presents the responses of green peas, snap beans, tomatoes and sweet corn to water stress based on their stomatal behaviour, canopy temperature, chlorophyll fluorescence and the chlorophyll content of leaves. These stress markers can be used for screening the drought tolerance of genotypes, the irrigation schedules or prediction of yield.

Banjaw *et al*. (2017) found from a study that tomato production and productivity affected by biotic and abiotic factors. Water quality and deficit irrigation has been considered as factor in its production, yield and quality as reported by many authors worldwide. Salinity, toxicity of heavy metals, temperature, microorganisms and presence of organic matters are some concern of water quality that influence tomato yield and quality. Use of municipal waste water for irrigation enhances toxic elements that further affect human health and several reports indicated that industrial waste water has to be treated before using for irrigation. Irrigation management practices such as amount, time of application and frequency of water affect tomatoes yield and quality. Deficit irrigation with its several advantages affects negatively tomato yield but it increases fruit quality. Hence, based on reports of scientific findings, effects of these two factors reviewed in this paper for further information provision.

Khan *et al*. (2015) conducted an experiment to study “the effect of drought stress on Tomato (*Lycopersicon esculentum*) Cv. Bombino”. Tomato plants were grown in green house under two different conditions of water availability i.e.- controlled and drought. The parameters studied were relative water content (%), proline content (µmoles) and relative growth rate (week^{-}1). Drought stress has significant effect on all parameters studied. The relative water content of plant body decline during drought due to less water availability. In controlled environment, the mean value of relative water content was 89.28 while that observed in drought condition was 87.73. Proline was observed on rise due to continuous decrease in water quantity in cell sap. The value of proline content is 4.4 µmoles g^{-1} fresh weight in controlled condition whereas that the plants in drought condition had 5.8 µmoles g^{-}1 fresh weight. Due to less water, photosynthesis was negatively affected which resulted in less energy production and finally low growth. In controlled condition the relative growth rate week^{-1} on fresh weight was 1.37 gm whereas that of plant in drought condition was 0.57 gm.

Pervez and Ayub (2009) conducted a study to assess the effect of drought stress on seed yield, seed quality and growth of tomato cv. ‘Moneymaker’, the experiment was conducted in green house in plastic pots. There were four treatments i.e. early stress (when first truss has set the fruits), middle stress (when fruits in first truss were fully matured and started changing their colour), late stress (when fruits on first truss were ripened fully), whereas in control no stress was imposed. Analysis of data regarding various attributes (fruit weight and shoot dry weight per plant, number of seeds per fruit, total number of seeds and seed weight per plant and vigour of seed) showed that drought stress had non-significant effect on vigour, quality and yield of tomato seed. Plant height, number of leaves and number of fruits per plant showed significant results toward drought stress signifying drought effects on growth of tomato.

In tomatoes, high transpiration rates reduce photosynthetic capacity and induce drought stress (Blanke and Cooke, 2004). Large water potential gradients between the xylem and the site of evaporation (leaves) result in reduced photosynthesis (Sharkey, 1984, Blanke and Cooke, 2004). It was observed that the net photosynthetic rate *(A)* and transpiration rate declined with an increase in drought stress (Teraza *et al*., 1999; Rao *et al*., 2000; Flexas *et al*., 2004).

Under drought stress, stomata close and this affects CO_2 flux. Stomatal closure is one of the first responses to drought stress (Hommel *et al*., 2014; Xie *et al*., 2014). Stomata close when plant water potential reduces or if the leaf turgor reduces. The response limits CO_2 exchange in leaves (Chaves *et al*., 2002) and the rate of photosynthesis decreases. Photosynthetic system in plants depends on the availability of CO_2, especially in photosystem II (PSII).

Drought-induced yield reduction has been reported in many crop species, which depends upon the severity and duration of the stress period. Water deficit leads to decrease in the number of flowers and consequently the number of fruit and ultimately to less marketable yield (Rahman *et al*., 1999; Veit-Kohler *et al*., 1999).

Quaglietta-Chiaranda and Zerbi (1981) conducted an experiment with lysimeter-grown greenhouse tomatoes and observed a remarkable sensitivity of the crop to water stress during the vegetative and the flowering periods, with respect to early and late harvesting records.

Franco *et al*. (1999) showed that at higher irrigation levels there was a high yield potential and less blossom-end rot affected fruit. They also found that total and marketable yields were increased by increasing soil water tension and by varying night temperature (14 ± 1°C to 10 ± 1°C). Fruit cracking decreased with increasing soil water tensions.

Quality of the fruit in terms of total soluble solids, acidity (Shinohara *et al*., 1995; Colla *et al*., 1999; Veit- Kohler *et al*., 1999), viscosity, and vitamin C is improved by water deficit (Veit-Kohler *et al*., 1999; Zushi and Matsuzoe, 1998).

High sugar content in tomato is a desirable character, which can be achieved by decreased irrigation (Veit-Kohler *et al*., 1999). A decrease up to 20% irrigation or even lesser percentage of irrigation shows significant improvement in tomato fruit flavor components (Veit-Kohler *et al*., 1999), in addition accelerated development of color and increased amount of p-carotene content in cherry tomato due to water deficit is observed.

Thus, producing more with less such as deficit irrigation has been considered as important option in agricultural crops production. Wahb-Allah and Al-Omran (2012) reported as negative effect of deficit irrigation was more obvious when coupled with salt stress and concerning crop developmental stage it was indicated as fruiting and vegetative growth stages were the most tolerant to deficit irrigation whereas, the reproductive stage was the most sensitive one

Application of deficit irrigation in crop production is an approach to save water in areas of water shortage and longer drought during production period so as to maximize water productivity. Regulated deficit irrigation saves substantial amount of irrigation water and increases water use efficiency quoted (Birhanu and Tilahun, 2010, Kirda, 2000). Besides, deficit irrigation reduces production costs, conserves water and minimizes leaching of nutrients and pesticides in to ground water (Nurrudin *et al*., 2003) and mostly practiced in areas where water scarcity exists. According to Nahar and Gretzmacher (Nahar and Gretzmacher, 2002), glucose, fructose, sucrose, malic acid, ascorbic acid and citric acid content increased significantly with water stress and sweetness of tomatoes and quality enhanced. Another finding suggested as decreased level of irrigation exerted beneficial effects upon fruit quality, mostly with respect to total soluble solid and soluble sugar contents (Shao *et al*., 2014).

On the other hand, decrease in total tomato plant biomass, number and size of tomato fruits as well as increase in fruit dry matter and harvest index (fruit dry matter weight/plant dry matter weight) with irrigation water stress level was reported in Ethiopia. The authors included as total soluble content was increased with stress level and varies among cultivars while the fruit water content was decreased: Melkassa Marglobe cultivar had higher total soluble solute content than Melka Shola cultivar and the higher total soluble solute content of Melkassa Marglobe might be the reason why this cultivar is preferred by consumers for use as a salad (Birhanu and Tilahun, 2010).

The relation between irrigation timing and water use efficiency is another issue while dealing with irrigation management practices in tomato cultivation. According to Marouelli *et al*. (2004) the highest tomato water use efficiency was observed when the last irrigation occurred between 37 and 45 days after blossom, respectively for fruit and pulp yield and also indicated reduction of fruit number per plant associated with higher number of irrigations performed throughout the maturation stage that might be due to the increase of the rotten fruit rate.

Furthermore, Ismail *et al*. (2007) reported as the lower the amount of water used to produce 1 kg tomato the higher the water use efficiency observed: the results revealed that early morning irrigation for 3-days frequency gave the highest water use efficiency while early morning irrigation for 1-day frequency gave the smallest. It was also indicated that 5-days irrigation interval increased water use efficiency (amount of water required to produce 1 gram dry matter) by 18% and 12% compared to 1 and 3 days frequencies respectively even though irrigation at every early morning at 3-days interval resulted highest yield that of 1-day interval. This implies that time and frequency of irrigation utilization play great role in tomato production. Thus, identification of final irrigation timing has various merits with respect to tomato production apart from wise use of irrigation water available.

Studies on the amount of water on tomato yield at North West Ethiopia showed that 440 mm/ha water with straw mulch under drip irrigation was recommended for similar agro ecologies as it was found to be economical and agronomical feasible (Berihanu, (2011). Moreover, Tanaskovik *et al*. (2011) the advantages of drip irrigation over conventional methods for better tomatoes water use efficiency was reported together with the fact that fertigation frequencies longer than four days resulted significant tomato yield reduction due to the increased water deficit and water stress. This implies that duration of deficit irrigation has to be seen carefully. Another interesting finding with respect to tomato water use efficiency evaluation was reported as water potential, water content of the leaf and growth were decreased under partial root drying and regulated deficit irrigation and the plants met stronger water stress under regulated deficit irrigation than under partial root drying regime (Lei *et al*., 2009).

2.3 Performance of tomato genotypes against drought stress

Akter and Haq (2019) conducted a pot experiment to observe the performances of fifteen tomato genotypes under three different drought treatments. Two factorial experiments included 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 (BD7301), G10 (BARI Tomato-11), G11 (BARI Tomato-9), G12 (BARI Tomato-8), G13 (BARI Tomato7), 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 different tomato genotypes and drought treatments had significant influence independently and also in interaction on agro-morphogenic traits of the tomato plant. Almost all traits responded negatively as the drought level increased except days to first flowering, maturity. Considering the yield and yield contributing characters, genotype G4, G5 and G6 showed tolerance at moderate drought stress and G6, G7 and G13 showed tolerance at 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.

Mahmoud and Wahb-Allah (2011) conducted a study to evaluate drought tolerance and to develop initial material for a drought tolerance breeding program with 4 commercial tomato cultivars (Imperial, Pakmore VF, Strain-B and Tnshet Star), a drought-tolerant breeding line (L 03306) and their hybrid combinations. Four-weeks-old seedlings were transplanted into soil under greenhouse conditions. Six irrigation treatments (T = 20, T = 40, T = 60, T = 80, T (control) = 100 and T = 120% of the 12345 6 estimated evapotranspiration, ET) were imposed during a 140-day growing period through a drip irrigation c system. Vegetative growth, flowering and yield traits were measured while water use efficiency (WUE) was determined. All vegetative and fruit traits decreased significantly as deficit irrigation levels increased. For T1 and T, yield was reduced by 46.7 and 33.5%, respectively, compared with T. WUE was increased significantly 25 as the amount of irrigation water decreased. The relationship between production and water amount was a second-degree polynomial. Significant differences among genotypes were found for all traits, suggesting that they could be taken into account when selecting for drought tolerance. Pakmore VF and the breeding line L 03306 had good yield performance under different deficit irrigation treatments. These genotypes could be selected for in a breeding program as recurrent (female) and donor (male) parents, respectively.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from October 2018 to February 2019. The materials and methods those were used and methods followed for conducting the experiment have been presented under the following headings.

3.1 Experimental site

This study was conducted in the research field of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. The location of the experimental site is 23°74′N latitude and 90°35′ E longitude at an altitude of 8.6 meter above the sea level.

3.2 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract under AEZ No. 28. The characteristics of the soil under the experiment were analyzed in the Laboratory of Soil science Department, SAU, Dhaka and details of soil characteristics have been presented in Appendix I.

3.3 Climatic condition of the experimental site

The experimental site is situated in the subtropical monsoon climatic zone, which is characterized by heavy rainfall during the months from April to September (*Kharif* season) and scanty of rainfall during rest of the year (*Rabi* season).

3.4 Planting materials

Three varieties of tomato viz. BARI tomato-2, BARI tomto-5 and BARI tomato-7 were used. The seeds of tomato were grown at the research field in Sher-e-Bangla Agricultural University.

3.5 Treatments of the experiment

The two factorial experiments will be carried out in Randomized Complete Block Design (RCBD) with four replications having

3.5.1 Factor A: Variety

1. V_1 = BARI tomato-2
2. V_2 = BARI tomto-5
3. V_3 = BARI tomato-7

3.5.2 Factor B: Drought stress

1. T_0 = Control (no stress)
2. T_1 = Drought stress at early fruiting stage
3. T_2 = Drought stress at mid fruiting stage
4. T_3 = Drought stress at late fruiting stage

3.5.3 Treatment combinations: Twelve treatment combinations are as below:

V_1T_0, V_1T_1, V_1T_2, V_1T_3, V_2T_0, V_2T_1, V_2T_2, V_2T_3, V_3T_0, V_3T_1, V_3T_2 and V_3T_3.

3.6 Design and layout of the experiment

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three tomato varieties and four levels of drought stress. Five replications were maintained in this experiment. The total number of unit pots was 36 and each plot size was 1.5 m × 1.5 m = 2.25 m^2. The 12 treatment combinations of the experiment were assigned. The distance maintained between two blocks and two plots were kept 1.0 m and 0.5 m respectively. The layout of the experiment is shown in figure 1.

3.7 Raising of seedlings

The land selected for nursery beds were well drained and were sandy loam type soil. The area was well prepared and converted into loose friable and dried mass to obtain fine tilth. All weeds and dead roots were removed and the soil was mixed with well rotten cowdung at the rate of 5 kg/bed. Seed bed size was 3m × 1m raised above the ground level. One seed beds was prepared for raising the seedlings. Ten (10) grams of tomato seeds were sown in the seed bed on 7 October, 2018. After sowing, the seeds were covered with light soil. Complete germination of the seeds took place with 5 days after seed sowing. Necessary shading was made by bamboo mat (chatai) from scorching sunshine or rain. No chemical fertilizer was used in the seed bed.

3.8 Preparation of the main field

The plot selected for the experiment was opened in the last week of October, 2018 with a power tiller, and was exposed to the sun for a few days, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for transplanting. The land operation was completed on 30 October 2018. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.9 Fertilizers and manure application

Manures and fertilizers were applied to the experimental plot considering the recommended fertilizer doses of BARI (2017).

Nutrients	**Manures/fertilizers**	**Doses ha^{-1}**
-	Cowdung	10 ton
N	Urea	300 kg
P	TSP	200 kg
K	MoP	220 kg

The total amount of cowdung, TSP and MOP was applied as basal dose at the time of land preparation. The total amount of urea was applied in three installments at 10, 30 and 50 days after transplanting.

3.10 Transplanting of seedlings

Healthy and uniform sized 30 days old seedlings were taken separately from the seed bed and were transplanted in the experimental field on 7th November, 2019 maintaining a spacing of 60 cm × 40 cm. The seed bed was watered before uprooting the seedlings so as to minimize the damage of the roots. This operation was carried out during late hours in the evening. The seedlings were watered after transplanting. Shading was provided by piece of banana leaf sheath for three days to protect the seedlings from the direct sun. A strip of the same crop was established around the experimental field as border crop to do gap filling and to check the border effect.

3.11 Intercultural operations

3.11.1 Weeding

Weeds were uprooted by hand when necessary.

3.11.2 Irrigation

Irrigation was done as per treatment. Three types of irrigation was managed to observe drought stress. As per treatment, three water stresses was created at three crop duration viz. early fruiting stage, mid fruiting stage and late fruiting stage.

3.11.3 Stalking

As tomato is a herbaceous plant with higher fruit weight it was needed a high level of support at its growth and developmental stages. So, after the well establishment of the plants, staking was done to each plant by means of bamboo sticks to keep them upright.

3.11.4 Plant protection measures

Furadan 10G an insecticide @ 0.5 g pot^{-1} was applied during the filling of pots to control cut worm and other soil insects. Aphid a leaf sucking insect infested the crop at vegetative and early reproductive stage, which was controlled by Emitaf 20 SL @ 0.25 ml L^{-1} of water at 7 days interval for three weeks. During the summer season, white fly infested the crop at early reproductive stage, which was controlled by means of spraying with Admire 200 SL @ 0.5 ml L^{-1}.

3.12 Harvesting

Harvesting of tomato (November 7, 2018 transplanting) was started from 27 January 2019 and was continued up to February 28, 2019. During this season, fruits were harvested at 5-days intervals at ripening stage when they attained slightly red color.

3.13 Collection of data

Data were collected on different parameters of tomato which are as follows:

1. Plant height (cm)
2. Number of leaves $plant^{-1}$
3. Root dry weight
4. Shoot dry weight
5. Total dry weight $plant^{-1}$ (g)
6. SPAD value in leaf
7. Number of flower cluster $plant^{-1}$
8. Number of flowers $cluster^{-1}$
9. Number of fruits $cluster^{-1}$
10. Fruit diameter (cm)
11. Number of fruits $plant^{-1}$
12. Single fruit weight (g)
13. Fruit weight $plant^{-1}$
14. Fruit yield (t ha^{-1})

3.14. Detailed procedures of data collection

Plant height (cm)

Plant height was recorded at 20 days interval starting from 50 days of transplanting (Early fruiting stage) up to 90 days after transplanting of plants. Plant height was measured from 5 selected plants and mean values were recorded as plant height in cm.

Number of leaves plant^{-1}

The number of leaves of the sample plant were counted at the times of the crop duration from 5 selected palnts and the average number of leaves produced per plant was recorded.

Root and shoot dry weight

After the final harvest, the total plant fresh biomass was collected. The shoot was collected by cutting the plant at soil level with the help of sharp knife. The root was collected by washing out soil from pot through high pressure water flow and roots were washed in fresh water to remove soil particles and other adhesive substances. After collecting, the plant parts were sun dried and put into paper bag separately. Then the collected plant parts were oven dried for 72 hours at 70°C. Root, shoot and total vegetative dry weight were taken with the help of an electronic balance.

Total dry weight plant^{-1} (g)

Total dry weight per plant was counted from summation of root dry weight and shoot dry weight and was expressed in gram (g).

Relative performance against drought stress (%)

Relative performance on different parameters against drought stress was calculated by the following formula

$$\text{Relative performance} = \frac{\text{Variable measured under stress condition}}{\text{Variable measured under control condition}} \times 100$$

SPAD value in leaf

SPAD meter reading of fresh leaves was recorded to compare relative chlorophyll content of leaves. 5 reading were taken from leaves of each sample plant avoiding the mid-rib region carefully and average value was presented as SPAD value of leaves. Higher SPAD value was considered as higher total chlorophyll (pigments) content of leaf.

Number of flower cluster plant^{-1}

The numbers of flower clusters per plant were counted from the sample plants and the average number of flower clusters produced per plant was recorded at the time of final harvest.

Number of flowers cluster^{-1}

Total number of flower was counted from all clusters of sample plants and mean was calculated by the following formula:

$$\text{Flowers cluster}^{-1} = \frac{\text{Total number of flowers from 5 sample plants}}{\text{Total number of clusters from 5 sample plants}}$$

Number of fruits cluster^{-1}

Total number of fruit was counted from all clusters of sample plants and mean was calculated by the following formula:

$$\text{Fruits cluster}^{-1} = \frac{\text{Total number of fruits from 5 sample plants}}{\text{Total number of clusters from 5 sample plants}}$$

Fruit diameter (cm)

Diameter of fruit was measured at the middle portion of 30 randomly selected fruit from three sample plants of each replication with the help of a slide calipers.

Number of fruits plant^{-1}

It was recorded by the following formula:

$$\text{Number of fruits per plant} = \frac{\text{Total number of fruits from 5 sample plants upto final harvest}}{5}$$

Single fruit weight (g)

Among the total number of fruits during the period from first to final harvest the fruits, except the first and final harvests, were considered for determining the individual fruit weight by the following formula:

$$\text{Weight of individual fruit (Kg)} = \frac{\text{Total weight of fruits from 10 harvest of sample plant}}{\text{Total number of fruits from 10 harvest of sample plant}}$$

Fruit weight plant^{-1}

It was measured by the following formula:

$$\text{Weight of fruits per plant (Kg)} = \frac{\text{Total weight of fruits in 5 sample plants}}{5}$$

Fruit yield (t ha^{-1})

It was measured by the following formula,

$$\text{Fruit yield per hectare (ton)} = \frac{\text{Fruit yield per plot (kg)} \times 10000}{\text{Area of plot in square meter} \times 1000}$$

3.15 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means were estimated by the LSD Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The present study was conducted to determine the Morphological and yield characters of different tomato (*Lycopersicon esculentum* L.) genotypes as influenced by drought stress. Data on different growth, yield contributing characters and yield parameters were recorded. The analysis of variance (ANOVA) of the data on different parameters is given in Appendix. The results have been presented and discussed, and possible interpretations were given under the following headings.

4.1 Growth parameters

4.1.1 Plant height (cm)

Effect of variety

Significant variation was recorded on plant height of tomato at different growth stages as influenced by different variety (Table 1 and Appendix 5). It was found that at 50 DAT, the highest plant height (73.92 cm) was recorded from the variety V_3 (BARI tomato-7) followed by V_1 (BARI tomato-2) whereas the lowest plant height (67.51 cm) was recorded from the variety V_2 (BARI tomto-5). At 70 DAT, the highest plant height (101.50 cm) was recorded from the variety V_3 (BARI tomato-7) whereas the lowest plant height (95.28 cm) was recorded from the variety V_2 (BARI tomto-5) which was statistically identical with V_1 (BARI tomato-2). At 90 DAT, the highest plant height (111.70 cm) was recorded from the variety V_3 (BARI tomato-7) followed by V_1 (BARI tomato-2) whereas the lowest plant height (100.50 cm) was recorded from the variety V_2 (BARI tomto-5). As a result, the maximum plant height (73.92, 101.50 and 111.70 cm at 50, 70 and 90 DAT, respectively) was recorded from the variety V_3 (BARI tomato-7) whereas the minimum plant height (70.33, 97.31 and 107.90 cm at 50, 70 and 90 DAT, respectively) was recorded from the variety V_2 (BARI tomto-5). Similar result was also observed by Hamid *et* *al.* (2005) and Ahmed *et al.* (1986) who found that plant height differed significantly due to varietal difference.

Effect of drought stress

There was a significant variation on plant height of tomato at different growth stages affected by different drought stress (Table 1 and Appendix 5). Results revealed that at 50 DAT, the highest plant height (73.57 cm) was recorded from control treatment T_0 (no stress) which was significantly different from other treatments followed by T_3 (Drought stress at late fruiting stage) whereas the lowest plant height (68.39 cm) was recorded from the treatment T_1 (Drought stress at early fruiting stage) which was statistically identical with T_2 (Drought stress at mid fruiting stage). At 70 DAT, the highest plant height (101.30 cm) was recorded from control treatment T_0 (no stress) which was statistically identical with T_3 (Drought stress at late fruiting stage) whereas the lowest plant height (94.42 cm) was recorded from the treatment T_1 (Drought stress at early fruiting stage). At 90 DAT, the highest plant height (112.50 cm) was recorded from control treatment T_0 (no stress) followed by T_3 (Drought stress at late fruiting stage) whereas the lowest plant height (101.30 cm) was recorded from the treatment T_1 (Drought stress at early fruiting stage). As a result, the maximum plant height (73.57, 101.30 and 112.50 cm at 50, 70 and 90 DAT, respectively) was recorded from control treatment T_0 (no stress) whereas the minimum plant height (68.39, 94.42 and 101.30 cm at 50, 70 and 90 DAT, respectively) was recorded from the treatment T_1 (Drought stress at early fruiting stage). The result obtained from present study was similar with the findings of Pervez and Ayub (2009) who found plant height showed significant results toward drought stress signifying drought effects on growth of tomato.

Combined effect of variety and drought stress

Significant variation was observed on plant height of tomato at different growth stages influenced by combined effect of different variety and drought stress (Table 1 and Appendix 5). Results indicated that at 50 DAT, the highest plant height (77.84 cm) was recorded from the treatment combination of V_3T_0 which was significantly different from other treatment combinations followed by V_3T_3. The lowest plant height (65.72 cm) was recorded from the treatment combination of V_2T_1 which was statistically identical with V_2T_2. At 70 DAT, the highest plant height (105.30 cm) was recorded from the treatment combination of V_3T_0 which was statistically identical with V_3T_3 whereas the lowest plant height (92.88 cm) was recorded from the treatment combination of V_2T_1 which was statistically similar with the treatment combination of V_1T_1 and V_2T_2. At 90 DAT, the highest plant height (118.50 cm) was recorded from the treatment combination of V_3T_0 followed by V_3T_3 whereas the lowest plant height (95.24 cm) was recorded from the treatment combination of V_2T_1 which was statistically identical with V_2T_2. As a result, the maximum plant height (77.84, 105.30 and 118.50 cm at 50, 70 and 90 DAT, respectively) was recorded from the treatment combination of V_3T_0 whereas the minimum plant height (65.72, 93.88 and 95.24 cm at 50, 70 and 90 DAT, respectively) was recorded from the treatment combination of V_2T_1.

Table 1. Plant height of tomato as influenced by different variety and drought stress

Treatments	Plant height (cm)		
	50 DAT	70 DA	90 DAT
Effect of variety			
V_1	70.33 b	97.31 b	107.9 b
V_2	67.51 c	95.28 b	100.5 c
V_3	73.92 a	101.5 a	111.7 a
$LSD_{0.05}$	2.147	2.985	3.082
CV(%)	6.14	8.36	6.29
Effect of drought stress			
T_0	73.57 a	101.3 a	112.5 a
T_1	68.39 c	94.42 c	101.3 c
T_2	69.17 c	96.83 b	104.0 c
T_3	71.21 b	99.50 a	109.1 b
$LSD_{0.05}$	1.612	1.880	3.096
CV(%)	6.14	8.36	6.29
Combined effect of variety and drought stress			
V_1T_0	72.64 c	101.3 b	112.6 c
V_1T_1	69.12 efg	93.88 fg	102.8 f
V_1T_2	68.76 fg	95.75 ef	107.9 d
V_1T_3	70.80 de	99.26 cd	108.3 d
V_2T_0	70.22 ef	97.37 de	106.5 de
V_2T_1	65.72 h	92.88 g	95.24 g
V_2T_2	66.60 h	94.39 fg	96.72 g
V_2T_3	67.48 gh	95.49 ef	103.4 f
V_3T_0	77.84 a	105.3 a	118.5 a
V_3T_1	70.33 ef	96.49 e	105.7 e
V_3T_2	72.14 cd	100.4 bc	107.3 de
V_3T_3	75.36 b	103.7 a	115.4 b
$LSD_{0.05}$	1.794	2.059	2.103
CV(%)	6.14	8.36	6.29

In a column, means followed by same letter(s) do not differ significantly at 5% level of significant by LSD.

V_1 = BARI tomato-2, V_2 = BARI tomto-5, V_3 = BARI tomato-7
T_0 = Control (no stress), T_1 = Drought stress at early fruiting stage, T_2 = Drought stress at mid fruiting stage, T_3 = Drought stress at late fruiting stage

4.1.2 Number of leaves plant^{-1}

Effect of variety

Significant variation was recorded on number of leaves plant^{-1} of tomato at different growth stages as influenced by different variety (Table 2 and Appendix 6). It was found that at 50 DAT, the highest number of leaves plant^{-1} (32.11) was recorded from the variety V_3 (BARI tomato-7) followed by V_1 (BARI tomato-2) whereas the lowest number of leaves plant^{-1} (27.48) was recorded from the variety V_2 (BARI tomto-5). At 70 DAT, the highest number of leaves plant^{-1} (34.68) was recorded from the variety V_3 (BARI tomato-7) whereas the lowest number of leaves plant^{-1} (30.16) was recorded from the variety V_2 (BARI tomto-5) which was statistically identical with V_1 (BARI tomato-2). At 90 DAT, the highest number of leaves plant^{-1} (40.86) was recorded from the variety V_3 (BARI tomato-7) whereas the lowest number of leaves plant^{-1} (36.81) was recorded from the variety V_2 (BARI tomto-5) V_1 (BARI tomato-2). As a result, the maximum number of leaves plant^{-1} (32.11, 34.68 and 40.86 at 50, 70 and 90 DAT, respectively) was recorded from the variety V_3 (BARI tomato-7) whereas the minimum number of leaves plant^{-1} (27.48, 30.16 and 36.81 at 50, 70 and 90 DAT, respectively) was recorded from the variety V_2 (BARI tomto-5). The result obtained from present study was similar with the findings of Hamid *et al.* (2005) who found leaf number varied significantly due to varietal difference.

Effect of drought stress

There was a significant variation on number of leaves plant^{-1} of tomato at different growth stages affected by different drought stress (Table 2 and Appendix 6). Results revealed that at 50 DAT, the highest number of leaves plant^{-1} (30.72) was recorded from control treatment T_0 (no stress) which was statistically identical with T_3 (Drought stress at late fruiting stage) whereas the lowest number of leaves plant^{-1} (28.59) was recorded from the treatment T_1 (Drought stress at early fruiting stage) which was statistically identical with T_2

(Drought stress at mid fruiting stage). At 70 DAT, the highest number of leaves plant^{-1} (34.93) was recorded from control treatment T_0 (no stress) followed by T_3 (Drought stress at late fruiting stage) whereas the lowest number of leaves plant^{-1} (30.23) was recorded from the treatment T_1 (Drought stress at early fruiting stage) which was statistically identical with T_2 (Drought stress at mid fruiting stage). At 90 DAT, the highest number of leaves plant^{-1} (41.48) was recorded from control treatment T_0 (no stress) followed by T_2 (Drought stress at mid fruiting stage) and T_3 (Drought stress at late fruiting stage) whereas the lowest number of leaves plant^{-1} (32.10) was recorded from the treatment T_1 (Drought stress at early fruiting stage). As a result, the maximum number of leaves plant^{-1} (30.72, 34.93 and 41.48 at 50, 70 and 90 DAT, respectively) was recorded from control treatment T_0 (no stress) whereas the minimum number of leaves plant^{-1} (28.59, 30.23 and 32.10 at 50, 70 and 90 DAT, respectively) was recorded from the treatment T_1 (Drought stress at early fruiting stage). The result obtained from present study was similar with the findings of Pervez and Ayub (2009) who found number of leaves showed significant results toward drought stress signifying drought effects on growth of tomato.

Combined effect of variety and drought stress

Significant variation was observed on number of leaves plant^{-1} of tomato at different growth stages influenced by combined effect of different variety and drought stress (Table 2 and Appendix 6). Results indicated that at 50 DAT, the highest number of leaves plant^{-1} (32.76) was recorded from the treatment combination of V_3T_0 which was statistically identical with V_3T_1 and V_3T_3. The lowest number of leaves plant^{-1} (25.38) was recorded from the treatment combination of V_2T_1 which was statistically similar with the treatment combination of V_2T_0, V_2T_2 and V_2T_3. At 70 DAT, the highest number of leaves plant^{-1} (36.75) was recorded from the treatment combination of V_3T_0 which was statistically similar with the treatment combination of V_3T_3 whereas the lowest number of leaves plant^{-1} (27.93 was recorded from the treatment combination of V_2T_1which was statistically identical with V_2T_2. At 90 DAT, the highest number of leaves plant^{-1} (43.44) was recorded from the treatment combination of V_3T_0 which was statistically similar with V_3T_3 and V_1T_0 whereas the lowest number of leaves plant^{-1} (32.33) was recorded from the treatment combination of V_2T_1 which was significantly different from other treatmentcombinations. As a result, the maximum number of leaves plant^{-1} (32.76, 36.75 and 43.44 at 50, 70 and 90 DAT, respectively) was recorded from the treatment combination of V_3T_0 whereas the minimum number of leaves plant^{-1} (25.38, 27.93 and 32.33 at 50, 70 and 90 DAT, respectively) was recorded from the treatment combination of V_2T_1.

Table 2. Number of leaves plant^{-1} of tomato as influenced by different variety and drought stress

Treatments	Number of leaves plant^{-1}		
	50 DAT	70 DA	90 DAT
Effect of variety			
V_1	29.65 b	32.24 b	35.44 b
V_2	27.48 c	30.16 b	36.81 b
V_3	32.11 a	34.68 a	40.86 a
$LSD_{0.05}$	1.651	2.107	2.981
CV(%)	7.37	8.42	10.39
Effect of drought stress			
T_0	30.72 a	34.93 a	41.48 a
T_1	28.59 b	30.23 c	32.10 c
T_2	29.31 b	31.28 c	37.72 b
T_3	30.37 a	33.00 b	39.51 b
$LSD_{0.05}$	0.9771	1.354	1.894
CV(%)	7.37	8.42	10.39
Combined effect of variety and drought stress			
V_1T_0	30.77 b	34.27 bc	41.72 ab
V_1T_1	27.92 d	30.19 e	33.85 f
V_1T_2	29.80 bc	31.26 de	36.14 e
V_1T_3	30.12 b	33.24 c	38.57 cd
V_2T_0	28.62 cd	33.77 bc	39.27 c
V_2T_1	25.38 e	27.93 f	32.33 g
V_2T_2	27.41 d	28.46 f	36.88 de
V_2T_3	28.50 cd	30.46 e	37.22 de
V_3T_0	32.76 a	36.75 a	43.44 a
V_3T_1	32.48 a	32.57 cd	37.11 de
V_3T_2	30.72 b	34.12 bc	40.14 bc
V_3T_3	32.48 a	35.29 ab	42.75 a
$LSD_{0.05}$	1.357	1.700	1.862
CV(%)	7.37	8.42	10.39

In a column, means followed by same letter(s) do not differ significantly at 5% level of significant by LSD.

V_1 = BARI tomato-2, V_2 = BARI tomto-5, V_3 = BARI tomato-7
T_0 = Control (no stress), T_1 = Drought stress at early fruiting stage, T_2 = Drought stress at mid fruiting stage, T_3 = Drought stress at late fruiting stage

4.1.3 Dry weight plant^{-1} (g)

4.1.3.1 Root dry weight

Effect of variety

Significant variation was recorded on root dry weight plant^{-1} of tomato at harvest as influenced by different variety (Table 3 and Appendix 7). It was found that the highest root dry weight plant^{-1} (1.65 g) was recorded from the variety V_3 (BARI tomato-7) whereas the lowest root dry weight plant^{-1} (1.35 g) was recorded from the variety V_2 (BARI tomto-5) which was statistically identical with V_1 (BARI tomato-2). Result also revealed that the highest relative performance on root dry weight (84.65%) was found from V_2 (BARI tomto-5) under drought stress whereas the lowest (74.51%) was performed by V_3 (BARI tomato-7) which means that BARI tomto-5 was less affected due to drought stress treatments regarding root dry weight.

Effect of drought stress

There was a significant variation on root dry weight plant^{-1} of tomato at harvest affected by different drought stress (Table 3 and Appendix 7). Results revealed that the highest root dry weight plant^{-1} (1.26 g) was recorded from control treatment T_0 (no stress) followed by T_3 (Drought stress at late fruiting stage). The lowest root dry weight plant^{-1} (1.78 g) was recorded from the treatment T_1 (Drought stress at early fruiting stage) which was statistically similar with T_2 (Drought stress at mid fruiting stage). It is evident that from the study, increased water stress duration showed decreased root dry weight of plants. Results also showed that T_3 (Drought stress at late fruiting stage) gave better relative performance (87.56%) among the drought stress condition compared to control (100%) whereas the lowest (71.45%) was observed in T_1 (Drought stress at early fruiting stage) treatment which might be due to cause of water stress duration. Under the present study, T_1 (Drought stress at early fruiting stage) showed higher water stress duration whereas T_3 (Drought stress at late fruiting stage) showed lower water stress duration.

Combined effect of variety and drought stress

Significant variation was observed on root dry weight plant^{-1} of tomato at harvest influenced by combined effect of different variety and drought stress (Table 3 and Appendix 7). Results indicated that the highest root dry weight plant^{-1} (2.04 g) was recorded from the treatment combination of V_3T_0 which was significantly different from other treatment combinations. The lowest root dry weight plant^{-1} (1.18 g) was recorded from the treatment combination of V_2T_1 which was statistically similar with the treatment combination of V_1T_1 and V_2T_2. Results also indicated that the highest relative performance on root dry (94.74%) weight was found from the treatment combination of V_2T_3 whereas the lowest (70.06%) was found from the treatment combination of V_1T_1 which indicated that the variety BARI tomato-2 was very sensitive to drought stress at early fruiting stage to harvest compared to others.

4.1.3.2 Shoot dry weight

Effect of variety

Significant variation was recorded on shoot dry weight plant^{-1} of tomato at harvest as influenced by different variety (Table 3 and Appendix 7). It was found that the highest shoot dry weight plant^{-1} (34.44 g) was recorded from the variety V_3 (BARI tomato-7) which was significantly different from other varieties whereas the lowest shoot dry weight plant^{-1} (30.87 g) was recorded from the variety V_2 (BARI tomto-5) which was statistically identical with V_1 (BARI tomato-2). Result also revealed that the highest relative performance on shoot dry weight (90.79%) was found from V_1 (BARI tomato-2) which was relatively nearest to V_2 (BARI tomto-5) and V_3 (BARI tomato-7) under drought stress whereas the lowest (89.06%) was performed by V_3 (BARI tomato-7). This result on shoot dry weight indicated that all the three varieties was more or less same capability to drought stress tolerance considering shoot dry weight per plant.

Effect of drought stress

There was a significant variation on shoot dry weight plant^{-1} of tomato at harvest affected by different drought stress (Table 3 and Appendix 7). Results revealed that the highest shoot dry weight plant^{-1} (35.23 g) was recorded from control treatment T_0 (no stress) followed by T_3 (Drought stress at late fruiting stage). The lowest shoot dry weight plant^{-1} (30.16 g) was recorded from the treatment T_1 (Drought stress at early fruiting stage) which was statistically identical with T_2 (Drought stress at mid fruiting stage). It is evident that from the study, increased water stress duration showed decreased shoot dry weight of plants. Results also showed that T_3 (Drought stress at late fruiting stage) gave better relative performance (94.56%) among the drought stress condition compared to control (100%) whereas the lowest (85.65%) was observed in T_1 (Drought stress at early fruiting stage) treatment which might be due to cause of water stress duration. Under the present study, T_1 (Drought stress at early fruiting stage) showed higher water stress duration whereas T_3 (Drought stress at late fruiting stage) showed lower water stress duration.

Combined effect of variety and drought stress

Significant variation was observed on shoot dry weight plant^{-1} of tomato at harvest influenced by combined effect of different variety and drought stress (Table 3 and Appendix 7). Results indicated that the highest shoot dry weight plant^{-1} (37.52 g) was recorded from the treatment combination of V_3T_0 which was significantly different from other treatment combinations followed by V_3T_3. The lowest shoot dry weight plant^{-1} (28.52 g) was recorded from the treatment combination of V_2T_1 which was significantly different from other treatment combinations. Results also indicated that the highest relative performance on shoot dry weight (85.65%) was found from the treatment combination of V_1T_3 whereas the lowest (84.54%) was found from the treatment combination of V_3T_1 which indicated that the variety V_3 (BARI tomato-7) was very sensitive to drought stress at early fruiting stage to harvest compared to others regarding relative performance on shoot dry weight.

4.1.3.3 Total dry weight plant^{-1} (g)

Effect of variety

Significant variation was recorded on total dry weight plant^{-1} of tomato at harvest as influenced by different variety (Table 3 and Appendix 7). It was found that the highest total dry weight plant^{-1} (36.09 g) was recorded from the variety V_3 (BARI tomato-7) whereas the lowest total dry weight plant^{-1} (32.22 g) was recorded from the variety V_2 (BARI tomto-5) which was statistically identical with V_1 (BARI tomato-2). Result also revealed that the highest relative performance on total dry weight (root + shoot) (90.12%) was found from V_1 (BARI tomato-2) which was very close to the variety V_2 (BARI tomto-5) and V_3 (BARI tomato-7) under drought stress whereas the lowest (88.31%) was performed by V_3 (BARI tomato-7) which means that all the three varieties were less affected due to drought stress treatments regarding total dry weight plant.

Effect of drought stress

There was a significant variation on total dry weight plant^{-1} of tomato at harvest affected by different drought stress (Table 3 and Appendix 7). Results revealed that the highest total dry weight plant^{-1} (37.00 g) was recorded from control treatment T_0 (no stress) followed by T_3 (Drought stress at late fruiting stage) whereas the lowest total dry weight plant^{-1} (31.42 g) was recorded from the treatment T_1 (Drought stress at early fruiting stage) T_2 (Drought stress at mid fruiting stage). It is evident that from the study, increased water stress duration showed decreased root dry weight of plants. Results also showed that T_3 (Drought stress at late fruiting stage) gave better relative performance (94.21%) on total dry weight per plant among the drought stress condition compared to control (100%) whereas the lowest (84.95%) was observed in T_1 (Drought stress at early fruiting stage) treatment which might be due to cause of water stress duration. Under the present study, T_1 (Drought stress at early fruiting stage) showed higher water stress duration whereas T_3 (Drought stress at late fruiting stage) showed lower water stress duration. Similar result was also observed by Birhanu and Tilahun, 2010) and Ismail *et al*. (2007).

Combined effect of variety and drought stress

Significant variation was observed on total dry weight plant^{-1} of tomato at harvest influenced by combined effect of different variety and drought stress (Table 3 and Appendix 7). Results indicated that the highest total dry weight plant^{-1} (39.56 g) was recorded from the treatment combination of V_3T_0 which was significantly different from other combinations followed by V_3T_3. The lowest total dry weight plant^{-1} (29.70 g) was recorded from the treatment combination of V_2T_1 which was statistically similar with the treatment combination of V_1T_1 and V_2T_2. Results also indicated that the highest relative performance on total dry weight (94.81%) was found from the treatment combination of V_1T_3 which was very close to V_2T_3 (94.40%) and V_3T_3 (93.43%) whereas the lowest (83.62%) was found from the treatment combination of V_3T_1 which indicates that the variety BARI tomato-7 was very sensitive to drought stress at early fruiting stage to harvest compared to others considering total dry weight per plant.

Table 3. Dry weight plant^{-1} of tomato as influenced by different variety and drought stress

Treatment	Dry weight plant^{-1} (g) at harvest					
	Root dry weight	Relative performance on root dry weight (%)	Shoot dry weight	Relative performance on shoot dry weight (%)	Total dry weight plant^{-1} (g)	Relative performance on total dry weight (%)
Effect of variety						
V_1	1.46 b	76.84	32.46 b	90.79	33.93 b	90.12
V_2	1.35 b	84.65	30.87 b	90.32	32.22 b	90.07
V_3	1.65 a	74.51	34.44 a	89.06	36.09 a	88.31
$LSD_{0.05}$	0.131	--	1.630	--	1.883	--
CV(%)	6.274	--	7.588	--	7.036	--
Effect of drought stress						
T_0	1.78 a	100.00	35.23 a	100.00	37.00 a	100.00
T_1	1.26 c	71.45	30.16 c	85.65	31.42 c	84.95
T_2	1.36 bc	76.99	31.68 c	89.97	33.04 c	89.34
T_3	1.55 b	87.56	33.31 b	94.56	34.85 b	94.21
$LSD_{0.05}$	0.207	--	1.622	--	1.636	--
CV(%)	6.274	--	7.588	--	7.036	--
Combined effect of variety and drought stress						
V_1T_0	1.77 b	100.00	34.87 b	100.00	36.64 bc	100.00
V_1T_1	1.24 de	70.06	30.24 d	86.72	31.48 ef	85.92
V_1T_2	1.36 cd	76.84	31.48 d	90.28	32.84 e	89.63
V_1T_3	1.48 c	83.62	33.26 c	95.38	34.74 d	94.81
V_2T_0	1.52 c	100.00	33.29 c	100.00	34.81 cd	100.00
V_2T_1	1.18 e	77.63	28.52 e	85.67	29.70 f	85.32
V_2T_2	1.24 de	81.58	30.26 d	90.90	31.50 ef	90.49
V_2T_3	1.44 c	94.74	31.42 d	94.38	32.86 e	94.40
V_3T_0	2.04 a	100.00	37.52 a	100.00	39.56 a	100.00
V_3T_1	1.36 cd	66.67	31.72 d	84.54	33.08 de	83.62
V_3T_2	1.48 c	72.55	33.29 c	88.73	34.77 cd	87.89
V_3T_3	1.72 b	84.31	35.24 b	93.92	36.96 b	93.43
$LSD_{0.05}$	0.161	--	1.527	--	1.871	--
CV(%)	6.274	--	7.588	--	7.036	--

In a column, means followed by same letter(s) do not differ significantly at 5% level of significant by LSD.

V_1 = BARI tomato-2, V_2 = BARI tomto-5, V_3 = BARI tomato-7
T_0 = Control (no stress), T_1 = Drought stress at early fruiting stage, T_2 = Drought stress at mid fruiting stage, T_3 = Drought stress at late fruiting stage

4.1.4 SPAD value in leaf

Effect of variety

Significant variation was recorded on SPAD value in leaf of tomato at harvest as influenced by different variety (Table 4 and Appendix 8). It was found that the highest SPAD value in leaf (52.54) was recorded from the variety V_3 (BARI tomato-7) which was significantly different from other varieties followed by V_1 (BARI tomato-2). The lowest SPAD value in leaf (50.22) was recorded from the variety V_2 (BARI tomto-5).

Effect of drought stress

There was a significant variation on SPAD value in leaf of tomato at harvest affected by different drought stress (Table 4 and Appendix 8). Results revealed that the highest SPAD value in leaf (54.22) was recorded from control treatment T_0 (no stress) followed by T_3 (Drought stress at late fruiting stage). The lowest SPAD value in leaf (46.63) was recorded from the treatment T_1 (Drought stress at early fruiting stage) which was statistically identical with T_2 (Drought stress at mid fruiting stage). Nemeskéri and Helyes (2019) also found similar which supported the present study.

Combined effect of variety and drought stress

Significant variation was observed on SPAD value in leaf of tomato at harvest influenced by combined effect of different variety and drought stress (Table 4 and Appendix 8). Results indicated that the highest SPAD value in leaf (56.36) was recorded from the treatment combination of V_3T_0 which was statistically similar with the treatment combination of V_1T_0. The lowest SPAD value in leaf (44.74) was recorded from the treatment combination of V_2T_1 which was statistically similar with the treatment combination of V_1T_1 and V_2T_1.

Table 4. SPAD value in leaf of tomato as influenced by different variety and drought stress

Treatments	SPAD value in leaf
Effect of variety	
V_1	50.22 b
V_2	47.47 c
V_3	52.54 a
$LSD_{0.05}$	2.080
CV(%)	6.24
Effect of drought stress	
T_0	54.22 a
T_1	46.63 c
T_2	48.29 c
T_3	51.17 b
$LSD_{0.05}$	1.705
CV(%)	6.24
Combined effect of variety and drought stress	
V_1T_0	54.92 ab
V_1T_1	46.78 de
V_1T_2	47.44 d
V_1T_3	51.75 c
V_2T_0	51.37 c
V_2T_1	44.74 e
V_2T_2	45.28 e
V_2T_3	48.47 d
V_3T_0	56.36 a
V_3T_1	48.36 d
V_3T_2	52.14 c
V_3T_3	53.28 bc
$LSD_{0.05}$	2.086
CV(%)	6.24

In a column, means followed by same letter(s) do not differ significantly at 5% level of significant by LSD.

V_1 = BARI tomato-2, V_2 = BARI tomto-5, V_3 = BARI tomato-7
T_0 = Control (no stress), T_1 = Drought stress at early fruiting stage, T_2 = Drought stress at mid fruiting stage, T_3 = Drought stress at late fruiting stage

4.2 Yield contributing characters

4.2.1 Number of flower cluster plant^{-1}

Effect of variety

Significant variation was recorded on number of flower cluster plant^{-1} of tomato at harvest as influenced by different variety (Table 5 and Appendix 9). It was found that the highest number of flower cluster plant^{-1} (5.34) was recorded from the variety V_1 (BARI tomato-2) which was statistically identical with V_3 (BARI tomato-7) whereas the lowest number of flower cluster plant^{-1} (2.69) was recorded from the variety V_2 (BARI tomto-5). The result obtained from present study was similar with the findings of Hamid *et al.* (2005).

Effect of drought stress

There was a non-significant variation on number of flower cluster plant^{-1} of tomato at harvest affected by different drought stress (Table 5 and Appendix 9). However, the highest number of flower cluster plant^{-1} (4.57) was recorded from control treatment T_2 (Drought stress at mid fruiting stage) whereas the lowest number of flower cluster plant^{-1} (4.26) was recorded from the control treatment T_0 (no stress).

Combined effect of variety and drought stress

Significant variation was observed on number of flower cluster plant^{-1} of tomato at harvest influenced by combined effect of different variety and drought stress (Table 5 and Appendix 9). Results indicated that the highest number of flower cluster plant^{-1} (5.67) was recorded from the treatment combination of V_1T_2 which was statistically similar with the treatment combination of V_1T_1. Conversely, the lowest number of flower cluster plant^{-1} (2.57) was recorded from the treatment combination of V_2T_0 which was statistically identical with the treatment combination of V_2T_2, V_2T_1 and V_2T_3.

4.2.2 Number of flowers cluster^{-1}

Effect of variety

Significant variation was recorded on number of flowers cluster^{-1} of tomato at harvest as influenced by different variety (Table 5 and Appendix 9). It was found that the highest number of flowers cluster^{-1} (8.47) was recorded from the variety V_1 (BARI tomato-2) which was significantly different from other varieties whereas the lowest number of flowers cluster^{-1} (7.12) was recorded from the variety V_3 (BARI tomato-7) which was statistically identical with V_2 (BARI tomto-5).

Effect of drought stress

There was a significant variation on number of flowers cluster^{-1} of tomato at harvest affected by different drought stress (Table 5 and Appendix 9). Results revealed that the highest number of flowers cluster^{-1} (9.00) was recorded from control treatment T_0 (no stress) which was significantly different from other treatments followed by T_3 (Drought stress at late fruiting stage). The lowest number of flowers cluster^{-1} (6.78) was recorded from the treatment T_1 (Drought stress at early fruiting stage) which was statistically identical with T_2 (Drought stress at mid fruiting stage).

Combined effect of variety and drought stress

Significant variation was observed on number of flowers cluster^{-1} of tomato at harvest influenced by combined effect of different variety and drought stress (Table 5 and Appendix 9). Results indicated that the highest number of flowers cluster^{-1} (10.38) was recorded from the treatment combination of V_1T_0 followed by the treatment combination of V_1T_3. The lowest number of flowers cluster^{-1} (5.72) was recorded from the treatment combination of V_3T_1 which was statistically identical with the treatment combination of V_2T_2.

4.2.3 Number of fruits cluster^{-1}

Effect of variety

Significant variation was recorded on number of fruits cluster^{-1} of tomato at harvest as influenced by different variety (Table 5 and Appendix 9). It was found that the highest number of fruits cluster^{-1} (6.46) was recorded from the variety V_2 (BARI tomto-5) which was significantly different from other varieties whereas the lowest number of fruits cluster^{-1} (4.58) was recorded from the variety V_3 (BARI tomato-7) which was statistically identical with V_1 (BARI tomato-2). The result obtained from present study was similar with the findings Hamid *et al.* (2005).

Effect of drought stress

There was a significant variation on number of fruits cluster^{-1} of tomato at harvest affected by different drought stress (Table 5 and Appendix 9). Results revealed that the highest number of fruits cluster^{-1} (6.35) was recorded from control treatment T_0 (no stress) which was significantly different from other treatments followed by T_3 (Drought stress at late fruiting stage). The lowest number of fruits cluster^{-1} (4.64) was recorded from the treatment T_1 (Drought stress at early fruiting stage) which was statistically identical with T_2 (Drought stress at mid fruiting stage).

Combined effect of variety and drought stress

Significant variation was observed on number of fruits cluster^{-1} of tomato at harvest influenced by combined effect of different variety and drought stress (Table 5 and Appendix 9). Results indicated that the highest number of fruits cluster^{-1} (7.54) was recorded from the treatment combination of V_2T_0 which was significantly different from other treatment combinations followed by V_2T_3. On the other hand, the lowest number of fruits cluster^{-1} (3.92) was recorded from the treatment combination of V_3T_1 which was significantly different from other treatment combinations.

4.2.4 Fruit diameter (cm)

Effect of variety

Significant variation was recorded on fruit diameter of tomato at harvest as influenced by different variety (Table 5 and Appendix 9). It was found that the highest fruit diameter (7.79 cm) was recorded from the variety V_3 (BARI tomato-7) which was significantly different from other varieties followed by V_1 (BARI tomato-2) whereas the lowest fruit diameter (5.01 cm) was recorded from the variety V_2 (BARI tomto-5). Similar result was also observed by Singh and Sahu (1998) who observed that variety had significant influence on diameter of fruit.

Effect of drought stress

There was a significant variation on fruit diameter of tomato at harvest affected by different drought stress (Table 5 and Appendix 9). Results revealed that the highest fruit diameter (6.84 cm) was recorded from control treatment T_0 (no stress) which was statistically identical with T_3 (Drought stress at late fruiting stage). Conversely, the lowest fruit diameter (5.89 cm) was recorded from the treatment T_1 (Drought stress at early fruiting stage) which was statistically identical with T_2 (Drought stress at mid fruiting stage).

Combined effect of variety and drought stress

Significant variation was observed on fruit diameter of tomato at harvest influenced by combined effect of different variety and drought stress (Table 5 and Appendix 9). Results indicated that the highest fruit diameter (8.24 cm) was recorded from the treatment combination of V_3T_0 which was statistically identical with V_3T_3 followed by V_3T_2. The lowest fruit diameter (4.72 cm) was recorded from the treatment combination of V_2T_1 which was statistically identical with the treatment combination of V_2T_2 and V_2T_3.

Table 5. Yield parameters of tomato as influenced by different variety and drought stress

Treatments	Yield contributing parameters			
	Number of flower cluster plant^{-1}	Number of flowers cluster^{-1}	Number of fruits cluster^{-1}	Fruit diameter (cm)
Effect of variety				
V_1	5.340 a	8.470 a	5.390 b	6.330 b
V_2	2.690 b	7.350 b	6.460 a	5.010 c
V_3	5.110 a	7.120 b	4.580 b	7.790 a
$LSD_{0.05}$	1.082	1.113	0.9549	1.007
CV(%)	5.29	6.24	8.53	7.68
Effect of drought stress				
T_0	4.260	9.000 a	6.350 a	6.840 a
T_1	4.380	6.780 c	4.640 c	5.890 b
T_2	4.570	7.100 c	5.040 c	6.210 b
T_3	4.290	7.710 b	5.880 b	6.560 a
$LSD_{0.05}$	NS	0.5642	0.4544	0.3470
CV(%)	5.29	6.24	8.53	7.68
Combined effect of variety and drought stress				
V_1T_0	5.020 cd	10.38 a	6.240 c	6.880 c
V_1T_1	5.660 ab	6.490 e	4.480 g	5.760 f
V_1T_2	5.670 a	8.240 bc	4.950 f	6.140 e
V_1T_3	5.020 cd	8.770 b	5.880 d	6.520 d
V_2T_0	2.570 e	8.280 bc	7.540 a	5.400 g
V_2T_1	2.740 e	8.140 c	5.520 e	4.720 h
V_2T_2	2.780 e	5.870 f	5.920 d	4.880 h
V_2T_3	2.650 e	7.120 d	6.870 b	5.040 h
V_3T_0	5.200 c	8.330 bc	5.260 e	8.240 a
V_3T_1	4.740 d	5.720 f	3.920 h	7.180 c
V_3T_2	5.270 bc	7.180 d	4.240 g	7.600 b
V_3T_3	5.210 c	7.240 d	4.880 f	8.120 a
$LSD_{0.05}$	0.3935	0.608	0.3076	0.3470
CV(%)	5.29	6.24	8.53	7.68

In a column, means followed by same letter(s) do not differ significantly at 5% level of significant by LSD.

V_1 = BARI tomato-2, V_2 = BARI tomto-5, V_3 = BARI tomato-7

T_0 = Control (no stress), T_1 = Drought stress at early fruiting stage, T_2 = Drought stress at mid fruiting stage, T_3 = Drought stress at late fruiting stage

4.3 Yield parameters

4.3.1 Number of fruits plant^{-1}

Effect of variety

Significant variation was recorded on number of fruits plant^{-1} of tomato at harvest as influenced by different variety (Table 6 and Appendix 10). It was found that the highest number of fruits plant^{-1} (28.57) was recorded from the variety V_1 (BARI tomato-2) which was significantly different from other varieties followed by V_3 (BARI tomato-7) whereas the lowest plant (17.31) was recorded from the variety V_2 (BARI tomto-5).

Effect of drought stress

There was a significant variation on number of fruits plant^{-1} of tomato at harvest affected by different drought stress (Table 6 and Appendix 10). Results revealed that the highest number of fruits plant^{-1} (26.03) was recorded from control treatment T_0 (no stress) followed by T_3 (Drought stress at late fruiting stage) whereas the lowest number of fruits plant^{-1} (19.71) was recorded from the treatment T_1 (Drought stress at early fruiting stage). From the result, it was observed that the lower number of fruit was found with increasing drought stress which might be due to cause of lower nutrient availability due to scarcity of water. Birhanu and Tilahun, 2010 and Pervez and Ayub (2009) also found similar result with the present study.

Combined effect of variety and drought stress

Significant variation was observed on number of fruits plant^{-1} of tomato at harvest influenced by combined effect of different variety and drought stress (Table 6 and Appendix 10). Results indicated that the highest number of fruits plant^{-1} (31.33) was recorded from the treatment combination of V_1T_0 which was statistically similar with the treatment combination of V_1T_3. Conversely, the lowest number of fruits plant^{-1} (15.13) was recorded from the treatment combination of V_2T_1 which was statistically similar with the treatment combination of V_2T_2.

4.3.2 Single fruit weight (g)

Effect of variety

Significant variation was recorded on plant of tomato at harvest as influenced by different variety (Table 6 and Appendix 10). It was found that the highest single fruit weight (116.10 g) was recorded from the variety V_3 (BARI tomato-7) which was significantly different from other varieties followed by V_1 (BARI tomato-2) whereas the lowest single fruit weight (41.05 g) was recorded from the variety V_2 (BARI tomto-5). Similar result was also observed by Singh and Sahu (1998) who observed that variety had significant influence on single fruit weight.

Effect of drought stress

There was a significant variation on single fruit weight of tomato at harvest affected by different drought stress (Table 6 and Appendix 10). Results revealed that the highest single fruit weight (84.31 g) was recorded from control treatment T_0 (no stress) which was significantly different from other treatments followed by T_3 (Drought stress at late fruiting stage). On the other hand, the lowest single fruit weight (71.58 g) was recorded from the treatment T_1 (Drought stress at early fruiting stage). Similar result was also observed by Pervez and Ayub (2009).

Combined effect of variety and drought stress

Significant variation was observed on single fruit weight of tomato at harvest influenced by combined effect of different variety and drought stress (Table 6 and Appendix 10). Results indicated that the highest single fruit weight (123.60 g) was recorded from the treatment combination of V_3T_0 which was statistically similar with the treatment combination of V_3T_3 followed by V_3T_2. The lowest single fruit weight (37.27 g) was recorded from the treatment combination of V_2T_1 which was statistically similar with the treatment combination of V_2T_2 and V_2T_3.

4.3.3 Fruit weight plant^{-1}

Effect of variety

Significant variation was recorded on fruit weight plant^{-1} of tomato at harvest as influenced by different variety (Table 6 and Appendix 10). It was found that the highest fruit weight plant^{-1} (2.74 kg) was recorded from the variety V_3 (BARI tomato-7) followed by V_1 (BARI tomato-2) whereas the lowest fruit weight plant^{-1} (0.72 kg) was recorded from the variety V_2 (BARI tomto-5). Similar result was also observed by Singh and Sahu (1998) who observed that variety had significant influence on fruit weight plant^{-1}. Hossain (2007b) also found similar result with the present study.

Effect of drought stress

There was a significant variation on fruit weight plant^{-1} of tomato at harvest affected by different drought stress (Table 6 and Appendix 10). Results revealed that the highest fruit weight plant^{-1} (2.30 kg) was recorded from control treatment T_0 (no stress) which was statistically identical with T_3 (Drought stress at late fruiting stage) whereas the lowest fruit weight plant^{-1} (1.45 kg) was recorded from the treatment T_1 (Drought stress at early fruiting stage). From the result, it was observed that the lower number of fruit was found with increasing drought stress which might be due to cause of lower nutrient availability due water deficiency. Pervez and Ayub (2009) and Birhanu and Tilahun, (2010) also found supported result with the present study.

Combined effect of variety and drought stress

Significant variation was observed on fruit weight plant^{-1} of tomato at harvest influenced by combined effect of different variety and drought stress (Table 6 and Appendix 10). Results indicated that the highest fruit weight plant^{-1} (3.38 kg) was recorded from the treatment combination of V_3T_0 which was statistically identical with the treatment combination of V_3T_3. The lowest fruit weight plant^{-1} (0.56 kg) was recorded from the treatment combination of V_2T_1 which was statistically identical with the treatment combination of V_2T_0, V_2T_2 and V_2T_3.

4.3.4 Fruit yield (t ha^{-1})

Effect of variety

Significant variation was recorded on fruit yield of tomato at harvest as influenced by different variety (Table 6 and Appendix 10). It was found that the highest fruit yield (60.96 t ha^{-1}) was recorded from the variety V_3 (BARI tomato-7) which was significantly different from other varieties followed by V_1 (BARI tomato-2). On the other hand, the lowest fruit yield (15.88 t ha^{-1}) was recorded from the variety V_2 (BARI tomto-5). Similar result was also observed by Hamid *et al.* (2005), Hossain (2001), Nessa *et al.* (2000) and Islam (2000) who observed that different variety showed significant variation on fruit yield of tomato.

Effect of drought stress

There was a significant variation on fruit yield of tomato at harvest affected by different drought stress (Table 6 and Appendix 10). Results revealed that the highest fruit yield (51.12 t ha^{-1}) was recorded from control treatment T_0 (no stress) which was significantly different from other treatments followed by T_3 (Drought stress at late fruiting stage). The lowest fruit yield (32.24 t ha^{-1}) was recorded from the treatment T_1 (Drought stress at early fruiting stage) which was significantly different from other treatments but closer yield from the treatment T_2 (Drought stress at mid fruiting stage). The result obtained from present study was similar with the findings of Pervez and Ayub (2009) and Birhanu and Tilahun, (2010) who found that drought stress reduce fruit yield significantly. Similar result was also observed by Khan *et al*. (2015).

Combined effect of variety and drought stress

Significant variation was observed on fruit yield of tomato at harvest influenced by combined effect of different variety and drought stress (Table 6 and Appendix 10). Results indicated that the highest fruit yield (75.18 t ha^{-1}) was recorded from the treatment combination of V_3T_0 which was significantly different from other treatment combinations. The second highest yield (68.08 t ha^{-1}) was obtained from V_3T_3 followed by V_1T_0 and also the treatment combination of V_1T_2, V_1T_3 and V_3T_2 gave promising yield under drought stress with varietal combination. On the other hand, the lowest fruit yield (12.53 t ha^{-1}) was recorded from the treatment combination of V_2T_1 which was statistically similar with the treatment combination of V_2T_2 and V_2T_3.

Table 6. Yield parameters of tomato as influenced by different variety and drought stress

Treatments	Yield parameters			
	Number of fruits $plant^{-1}$	Single fruit weight (g)	Fruit weight $plant^{-1}$	Fruit yield (t ha^{-1})
Effect of variety				
V_1	28.57 a	78.81 b	2.26 b	50.28 b
V_2	17.31 c	41.04 c	0.72 c	15.88 c
V_3	23.43 b	116.1 a	2.74 a	60.96 a
$LSD_{0.05}$	3.440	5.498	0.308	5.176
CV(%)	7.24	8.52	6.37	9.45
Effect of drought stress				
T_0	26.03 a	84.31 a	2.30 a	51.12 a
T_1	19.71 d	71.58 d	1.45 c	32.24 d
T_2	22.28 c	77.47 c	1.80 b	39.97 c
T_3	24.39 b	81.27 b	2.08 a	46.16 b
$LSD_{0.05}$	1.357	2.985	0.245	4.460
CV(%)	7.24	8.52	6.37	9.45
Combined effect of variety and drought stress				
V_1T_0	31.33 a	84.62 d	2.650 b	58.91 c
V_1T_1	25.40 d	71.68 f	1.820 e	40.46 f
V_1T_2	28.04 bc	77.40 ef	2.170 cd	48.23 e
V_1T_3	29.52 ab	81.55 de	2.410 bc	53.50 d
V_2T_0	19.40 f	44.72 g	0.870 f	19.28 g
V_2T_1	15.13 h	37.27 h	0.560 f	12.53 h
V_2T_2	16.48 gh	40.42 gh	0.670 f	14.80 gh
V_2T_3	18.22 fg	41.75 gh	0.760 f	16.90 gh
V_3T_0	27.37 cd	123.6 a	3.380 a	75.18 a
V_3T_1	18.60 f	105.8 c	1.970 de	43.72 ef
V_3T_2	22.33 e	114.6 b	2.560 b	56.87 cd
V_3T_3	25.42 d	120.5 ab	3.060 a	68.08 b
$LSD_{0.05}$	2.059	6.692	0.3213	5.136
CV(%)	7.24	8.52	6.37	9.45

In a column, means followed by same letter(s) do not differ significantly at 5% level of significant by LSD.

V_1 = BARI tomato-2, V_2 = BARI tomto-5, V_3 = BARI tomato-7
T_0 = Control (no stress), T_1 = Drought stress at early fruiting stage, T_2 = Drought stress at mid fruiting stage, T_3 = Drought stress at late fruiting stage

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted in the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from October 2018 to February 2019 to find out the Morphological and yield characters of different tomato (*Lycopersicon esculentum* L.) genotypes as influenced by drought stress. Two factors were used in the experiment, *viz*. Factor A; Three tomato variety as V_1 = BARI tomato-2, V_2 = BARI tomto-5 and V_3 = BARI tomato-7 and Factor B; Four drought stress as T_0 = Control (no stress), T_1 = Drought stress at early fruiting stage, T_2 = Drought stress at mid fruiting stage and T_3 = Drought stress at late fruiting stage. The experiment was laid out in a Randomized complete Block Design (RCBD) with five replications. Data on different yield contributing parameters and yield were recorded.

Different variety showed significant variation on growth parameters of tomato. Results showed that the maximum plant height (73.92, 101.50 and 111.70 cm at 50, 70 and 90 DAT, respectively) was recorded from the variety V_3 (BARI tomato-7) whereas the minimum plant height (70.33, 97.31 and 107.90 cm at 50, 70 and 90 DAT, respectively) was recorded from the variety V_2 (BARI tomto-5). Again, the maximum number of leaves plant^{-1} (32.11, 34.68 and 40.86 at 50, 70 and 90 DAT, respectively) was recorded from the variety V_3 (BARI tomato-7) while the minimum number of leaves plant^{-1} (27.48, 30.16 and 36.81 at 50, 70 and 90 DAT, respectively) was recorded from the variety V_2 (BARI tomto-5). Similarly, V_3 (BARI tomato-7) showed highest total dry weight plant^{-1} (36.09 g) whereas the lowest total dry weight plant^{-1} (32.22 g) was recorded from the variety V_2 (BARI tomto-5). The highest SPAD value in leaf (52.54) was recorded from the variety V_3 (BARI tomato-7) whereas the lowest SPAD value in leaf (50.22) was recorded from the variety V_2 (BARI tomto-5).

In terms of yield and yield contributing parameters, affected by variety, the highest number of flower cluster plant^{-1} (5.34), number of flowers cluster^{-1} (8.47) and number of fruits plant^{-1} (28.57) were recorded from the variety V_1 (BARI tomato-2) while the highest number of fruits cluster^{-1} (6.46) was recorded from the variety V_2 (BARI tomto-5). Likewise, the highest fruit diameter (7.79 cm), single fruit weight (116.10 g), fruit weight plant^{-1} (2.74 kg) and fruit yield (60.96 t ha^{-1}) were recorded from the variety V_3 (BARI tomato-7). On the other hand, the the variety V_3 (BARI tomato-7) showed lowest number of flowers cluster^{-1} (7.12) and number of fruits cluster^{-1} (4.58) while the lowest number of flower cluster plant^{-1} (2.69), fruit diameter (5.01 cm), number of fruits plant^{-1} (17.31), single fruit weight (41.05 g), fruit weight plant^{-1} (0.72 kg) and fruit yield (15.88 t ha^{-1}) were recorded from the variety V_2 (BARI tomto-5).

Considering drought effect on tomato, most of the parameters were affected significantly. Result indicated that the maximum plant height (73.57, 101.30 and 112.50 cm at 50, 70 and 90 DAT, respectively) and number of leaves plant^{-1} (30.72, 34.93 and 41.48 at 50, 70 and 90 DAT, respectively) were recorded from control treatment T_0 (no stress) whereas the minimum plant height (68.39, 94.42 and 101.30 cm at 50, 70 and 90 DAT, respectively) and minimum number of leaves plant^{-1} (28.59, 30.23 and 32.10 at 50, 70 and 90 DAT, respectively) was recorded from the treatment T_1 (Drought stress at early fruiting stage). Similarly, the highest total dry weight plant^{-1} (37.00 g) at harvest was recorded from control treatment T_0 (no stress) while the lowest total dry weight plant^{-1} (31.42 g) was recorded from the treatment T_1 (Drought stress at early fruiting stage). The highest SPAD value in leaf (54.22) was recorded from control treatment T_0 (no stress) whereas the lowest SPAD value in leaf (46.63) was recorded from the treatment T_1 (Drought stress at early fruiting stage).

In case of yield and yield contributing parameters, affected by drought stress, the highest number of flower cluster plant^{-1} (4.57) was recorded from control treatment T_2 (Drought stress at mid fruiting stage) but the highest number of flowers cluster^{-1} (9.00), number of fruits cluster^{-1} (6.35), fruit diameter (6.84 cm), number of fruits plant^{-1} (26.03), single fruit weight (84.31 g), fruit weight plant^{-1} (2.30 kg) and fruit yield (51.12 t ha^{-1}) were recorded from control treatment T_0 (no stress). On the other hand, the lowest number of flower cluster plant^{-1} (4.26) was recorded from the control treatment T_0 (no stress) but the lowest number of flowers cluster^{-1} (6.78), number of fruits cluster^{-1} (4.64), fruit diameter (5.89 cm), number of fruits plant^{-1} (19.71), single fruit weight (71.58 g), fruit weight plant^{-1} (1.45 kg) and fruit yield (32.24 t ha^{-1}) were recorded from the treatment T_1 (Drought stress at early fruiting stage).

Regarding combined effect of different variety and drought stress, most of the studied parameters were affected significantly. In terms of growth parameters, results exhibited that the maximum plant height (77.84, 105.30 and 118.50 cm at 50, 70 and 90 DAT, respectively) and number of leaves plant^{-1} (32.76, 36.75 and 43.44 at 50, 70 and 90 DAT, respectively) were recorded from the treatment combination of V_3T_0 whereas minimum plant height (65.72, 92.88 and 95.24 cm at 50, 70 and 90 DAT, respectively) and number of leaves plant^{-1} (27.92, 30.19 and 32.33 at 50, 70 and 90 DAT, respectively) were recorded from the treatment combination of V_2T_1. Similarly, the highest total dry weight plant^{-1} (39.56 g) and SPAD value in leaf (56.36) were recorded from the treatment combination of V_3T_0 while the lowest total dry weight plant^{-1} (29.70 g) and SPAD value in leaf (44.74) were recorded from the treatment combination of V_2T_1.

In case of yield and yield contributing parameters, affected by combined effect of different variety and drought stress, the highest number of flower cluster plant^{-1} (5.67) and number of fruits cluster^{-1} (7.54) were recorded from the treatment combination of V_1T_2 and V_2T_0, respectively while the highest number of flowers cluster^{-1} (10.38) and number of fruits plant^{-1} (31.33) was recorded from the treatment combination of V_1T_0. Similarly, the highest fruit diameter (8.24 cm), single fruit weight (123.60 g), fruit weight plant^{-1} (3.38 kg) and fruit yield (75.18 t ha^{-1}) was recorded from the treatment combination of V_3T_0. Conversely, the lowest number of flower cluster plant^{-1} (2.57) was recorded from the treatment combination of V_2T_0 while the lowest number of flowers cluster^{-1} (5.72) and number of fruits cluster^{-1} (3.92) were recorded from the treatment combination of V_3T_1. Again, the lowest fruit diameter (4.72 cm), number of fruits plant^{-1} (15.13), single fruit weight (37.27 g), fruit weight plant^{-1} (0.56 kg) and fruit yield (12.53 t ha^{-1}) was recorded from the treatment combination of V_2T_1.

In terms of relative performance of root, shoot and total dry weight (root + shoot), considerable variation was found in terms of drought stress association with different tomato variety. All the three varieties; V_1 (BARI tomato-2), V_2 (BARI tomto-5) and V_3 (BARI tomato-7) showed better performance (90.12% and 90.07%, respectively) regarding total dry weight plant^{-1} against drought stress but V_1 (BARI tomato-2) and V_2 (BARI tomto-5) gave best performance. In terms of drought stress treatment, dry weight plant^{-1} was decreased with increasing drought stress duration and with this respect T_3 (Drought stress at late fruiting stage) showed highest relative performance on total dry weight plant^{-1} (root + shoot) (94.21%) whereas the lowest (84.95%) was obtained from T_1 (Drought stress at early fruiting stage). In terms of varietal performance combination with drought stress, V_1T_3 gave highest relative performance on total dry weight plant^{-1} (root + shoot) (94.81%) whereas the lowest (83.62%) was found from V_3T_1.

From the above result it was observed that the variety, BARI tomato-7 with no stress condition (V_3T_0) showed best result but considering varietal performance under drought stress, fruit yield from V_3T_3 is greater than V_1T_3 and V_2T_3. Similarly, the fruit yield from V_3T_2 is greater than V_1T_2 and V_2T_2 and also fruit yield from V_3T_1 is greater than V_1T_1 and V_2T_1. So, from the result it can be concluded that the variety V_3 (BARI tomato-7) showed best performance against all three drought stress compared to V_1 (BARI tomato-2) and V_2 (BARI tomto-5) regarding yield.

It was also observed that under drought stress, different morpho-physiological change was found during different drought stress regarding growth and yield characters, lower duration of drought stress, T_3 (Drought stress at late fruiting stage) showed better result compared to T_2 (Drought stress at mid fruiting stage) and T_1 (Drought stress at early fruiting stage). So, among the drought stress treatment, T_1 (Drought stress at early fruiting stage) is the most affected fruiting stage under drought stress condition.

So, it can be decided that the variety V_1 (BARI tomato-2), V_2 (BARI tomto-5) and V_3 (BARI tomato-7) can be considered as more tolerant against drought stress but V_3 (BARI tomato-7) showed best performance in terms of highest yield. Treatment T_3 (Drought stress at late fruiting stage) showed better result on growth and yield performance specially for relative dry matter content per plant whereas drought stress at early fruiting stage to till harvest (T_1) was the most affected fruiting stage considering morpho-physiological and yield performance. Regarding combined effect of variety and drought stress, V_3T_3 (drought stress at late fruiting stage with variety BARI tomato-7) gave best performance regarding morpho-physiological and yield performance excluding control condition whereas the lower performance was found from V_2T_1 (drought stress at early fruiting stage for variety BARI tomto-5).

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APPENDICES

Appendix 1. Agro-Ecological Zone of Bangladesh showing the experimental location

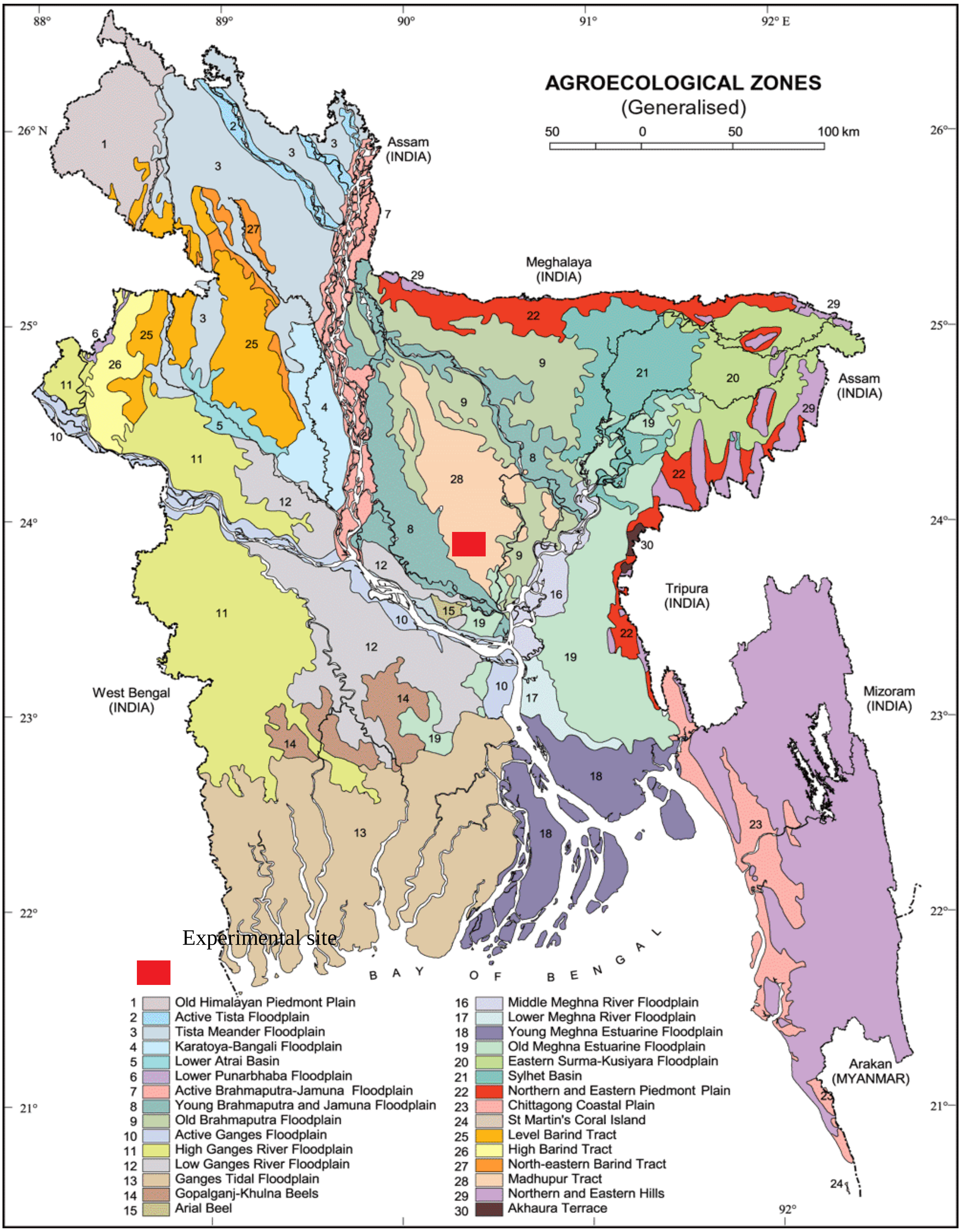


Fig. 1. Experimental site

Appendix 2. Monthly records of air temperature, relative humidity and rainfall during the period from October 2018 to February 2019.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2018	October	30.42	16.24	23.33	68.48	52.60
2018	November	28.60	8.52	18.56	56.75	14.40
2018	December	25.50	6.70	16.10	54.80	0.0
2019	January	23.80	11.70	17.75	46.20	0.0
2019	February	22.75	14.26	18.51	37.90	0.0

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

Appendix 3. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

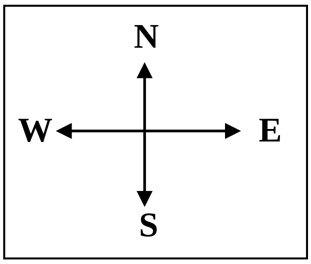
Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix 4. Layout of the experiment field

R1	R2	R3
V_1T_1	V_1T_3	V_2T_0
V_2T_1	V_3T_0	V_1T_1
V_1T_3	V_2T_1	V_3T_1
V_3T_1	V_1T_0	V_1T_3
V_2T_3	V_3T_3	V_3T_3
V_3T_3	V_3T_1	V_2T_2
V_1T_0	V_2T_3	V_3T_0
V_3T_2	V_1T_1	V_3T_2
V_2T_0	V_2T_2	V_1T_2
V_3T_0	V_3T_2	V_2T_3
V_2T_2	V_2T_0	V_1T_0
V_1T_2	V_1T_2	V_2T_1

Legend



Treatments

Factor A: Variety

1. V_1 = BARI tomato-2
2. V_2 = BARI tomto-5
3. V_3 = BARI tomato-7

Factor B: Drought stress

1. T_0 = Control (no stress)
2. T_1 = Drought stress at early fruiting stage
3. T_2 = Drought stress at mid fruiting stage
4. T_3 = Drought stress at late fruiting stage

Fig. 2. Layout of the experimental plot

Appendix 5. Plant height of tomato as influenced by different variety and drought stress

Sources of variation	Degrees of freedom	Mean square of plant height (cm)		
		50 DAT	70 DA	90 DAT
Replication	2	0.245	1.577	2.072
Factor A	2	3.947**	5.87**	4.819*
Factor B	3	78.13*	117.41*	142.36*
AB	6	12.97**	18.116*	16.841*
Error	22	0.407	1.225	2.119

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix 6. Number of leaves plant^{-1} of tomato as influenced by different variety and drought stress

Sources of variation	Degrees of freedom	Mean square of number of leaves plant^{-1}		
		50 DAT	70 DA	90 DAT
Replication	2	1.314	2.071	2.133
Factor A	2	4.856**	6.072**	4.219*
Factor B	3	42.571*	52.37*	37.91*
AB	6	17.363*	8.578*	9.664*
Error	22	1.473	1.611	1.736

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix 7. Dry weight plant^{-1} of tomato as influenced by different variety and drought stress

Sources of variation	Degrees of freedom	Mean square of dry weight plant^{-1} (g) at harvest		
		Root dry weight	Shoot dry weight	Total dry weight plant^{-1} (g)
Replication	2	0.001	0.254	0.102
Factor A	2	2.867**	4.689**	6.756**
Factor B	3	4.356**	13.478**	15.856*
AB	6	1.006**	6.994**	9.172**
Error	22	0.012	0.519	1.022

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix 8. Dry weight plant^{-1} of tomato as influenced by different variety and drought stress

Sources of variation	Degrees of freedom	Mean square of SPAD value in leaf
Replication	2	1.308
Factor A	2	11.160**
Factor B	3	120.49*
AB	6	16.132*
Error	22	1.934

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix 9. Yield parameters of tomato as influenced by different variety and drought stress

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters			
		Number of flower cluster plant^{-1}	Number of flowers cluster^{-1}	Number of fruits cluster^{-1}	Fruit diameter (cm)
Replication	2	0.244	0.385	0.217	0.042
Factor A	2	4.289**	6.519**	3.079*	4.288**
Factor B	3	NS	14.07*	11.06*	8.514**
AB	6	3.228**	5.289*	4.719**	4.369**
Error	22	0.106	0.411	0.364	0.433

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix 10. Yield parameters of tomato as influenced by different variety and drought stress

Sources of variation	Degrees of freedom	Mean square of yield parameters			
		Number of fruits plant^{-1}	Single fruit weight (g)	Fruit weight plant^{-1} (kg)	Fruit yield (t ha^{-1})
Replication	2	28.57 a	78.81 b	2.260 b	2.144
Factor A	2	8.57**	16.31**	21.489*	45.36*
Factor B	3	107.66*	128.64*	209.13*	360.26*
AB	6	11.67*	41.99*	43.100*	55.142*
Error	22	1.741	2.882	3.756	4.096

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level