ISSN 0258-7122 (Print), 2408-8293 (Online)
Bangladesh J. Agril. Res. 49(3): 259-277, September 2024

EFFECT OF DROUGHT STRESS ON GROWTH AND YIELD OF BARI RELEASED TOMATO VARIETIES

M. MONIRUZZAMAN[1], R. KHATOON[2] AND A. H. M. FAZLUL KABIR[3]

Abstract

The experiment was conducted at the Plant Physiology field of Horticulture Research Center, Bangladesh Agricultural Research Institute (BARI) during 2021-22 and 2022-23 in winter season to study the responses of BARI released open pollinated tomato varieties to drought stress. Tomato plants of eight varieties [V_1 = BARI Tomato-2, V_2 = BARI Tomato-14, V_3 = BARI Tomato-16, V_4 = BARI Tomato-17, V_5 = BARI Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20 (cherry tomato) and V_8 = BARI Tomato-21) were grown under two different conditions of water availability i.e., controlled condition (100% field capacity-FC) and drought condition (60% FC). The pooled results of two years are presented. All the parameters studied except total soluble solid (TSS) and proline content were negatively affected by drought. Fruit TSS and leaf proline content were increased at drought stress. With regard to plant height and SPAD value, the lowest reduction was noted in BARI Tomato-18 but the lowest reduction of relative water content (RWC) was observed in BARI Tomato-18 and BARI Tomato-20. In context to relative value of the characters such as number of fruits/plants, individual fruit weight, fruit set, yield/plant and yield/ha, the varieties BARI Tomato-18 and BARI Tomato-20 showed the higher relative percentage at 60% FC. Maximum TSS and proline content increase were observed in BARI Tomato-7 and BARI Tomato-18 varieties. Based on the results, it may be concluded that BARI Tomato-18 and BARI Tomato-20 perform better at drought condition (60% FC) and these two tomato varieties may be considered as medium drought tolerant.

Keywords: Tomato**,** Field capacity, Drought stress, RWC, Proline, Yield.

Introduction

Drought is one of the major limiting factors for crop expansion and it will become increasingly important due to changes in the global climate. Now-a-days, attention is focused on improving crop genotypes for drought-prone areas. It is one of the most important abiotic stresses which affect crop growth and yield (Lutts *et al.,* 2004; Mahajan and Tuteja, 2005; Castillo *et al.,* 2007; Khan *et al.,* 2010; Bakht *et al.,* 2010). The stage at which the drought stress occurs plays a major role in the final yield of the crop. Drought has become recurrent natural phenomenon of north-western part of Bangladesh.

[1]Chief Scientific Officer, Planning & Evaluation Wing, Bangladesh Agricultural Research Institute (BARI), Gazipur, [2]Senior Scientific Officer, Plant Physiology Section, HRC, BARI, Gazipur, [3]Pricipal Scientific Officer, Planning & Evaluation Wing, BARI, Gazipur, Bangladesh.

Tomato (*Solanum lycopersicum* L.) is one of the most important popular vegetables in the tropical and subtropical areas including Bangladesh. Now, tomato varieties are available for cultivation in both winter and summer season. Tomato is sensitive to a number of environmental stresses, especially extreme temperature, drought, salinity and inadequate moisture stress (Kalloo, 1993). Drought is an environmental stress that reduces plant growth and productivity. Generally, tomato is cultivated in winter. During winter rainfall is insufficient and during summer rainfall in not uniformly distributed all over the country. In nature, water is usually the most limiting factor for plant growth. Thus, it has become necessary and select the ones which are tolerant to drought stress. Therefore, the experiment was conducted to study the changes in morphological and physiological parameters of tomato plant under drought stress condition and observe the suitability of BARI released open pollinated tomato varieties under drought condition.

Materials and Methods

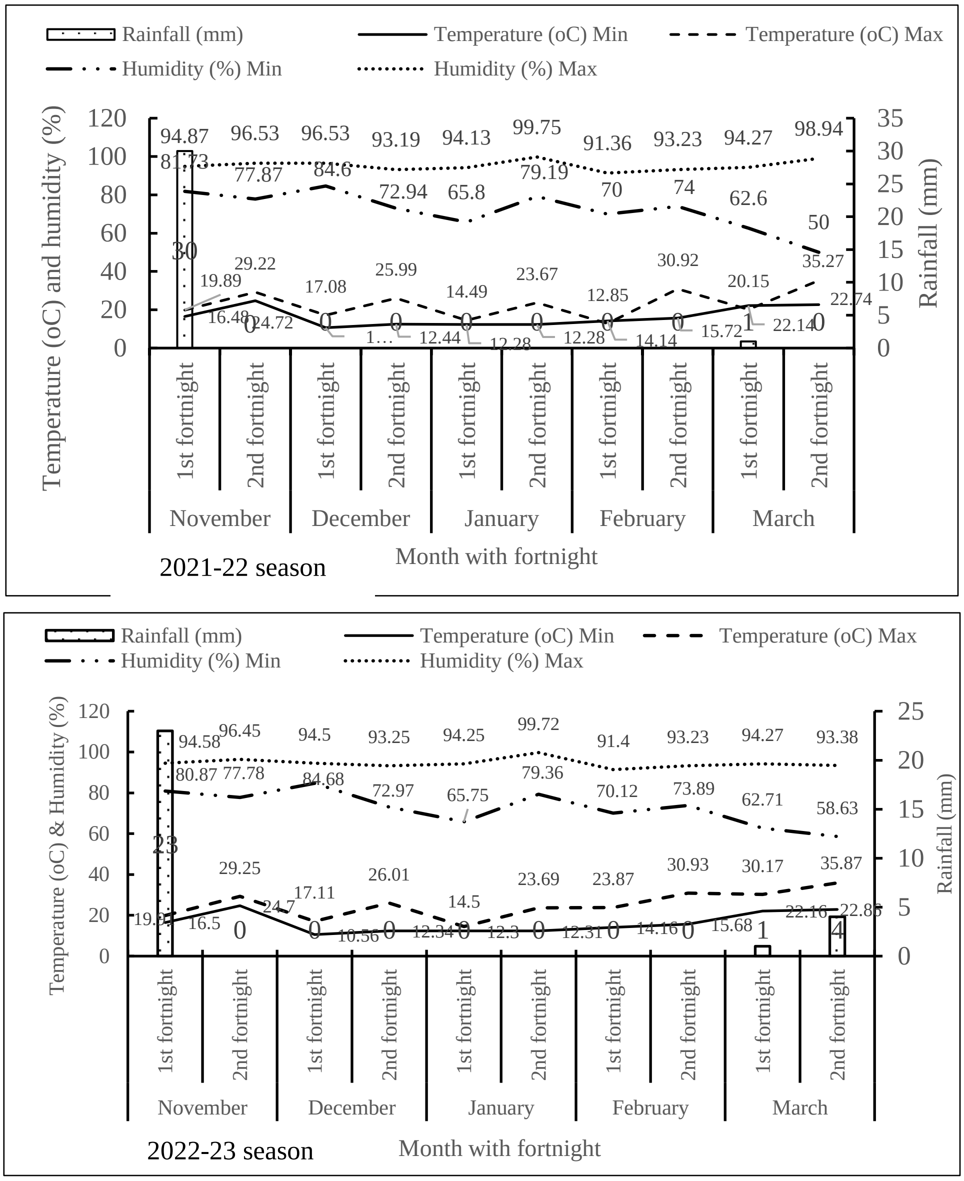
The experiment was conducted at the research field of Plant Physiology Section, Horticulture Research Center (HRC), Bangladesh Agricultural Research Institute (BARI) (23°59′34″ N latitude and 90°24′39″ E longitude) from November to March during 2021-22 and 2022-23. Eight varieties of tomato (V_1 = BARI Tomato-2, V_2 = BARI Tomato-14, V_3 = BARI Tomato-16, V_4 = BARI Tomato-17, V_5= BARI Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20and V_8 = BARI Tomato-21) collected from the Olericulture Division of HRC, BARI, Joydebpur, Gazipur, were evaluated at two conditions of water availability (i) non stress- water applied upto 100% of field capacity (FC) and ii) drought stress-water applied up to 60% of FC (40% less than 100% FC). The moisture per cent of soil was monitored during experimental period two weeks interval in 2021-22 and 2022-23 seasons by Soil Moisture Meter (Model: PMS-714, Taiwan (Fig. 2). The weather data of two years 2021-22 and 2022-23 are presented in Fig. 1. The crop received 31.0 mm and 28.0 mm rainfall in 2021-22 and 2022-23 seasons, respectively. The experimental soil was silty clay loam in texture having the soil moisture at field capacity and bulk density of 29.5% and 1.35 g/cm^3, respectively. The study was conducted under Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 2.0 m x 2.0 m and plant spacing was 50 cm x 50 cm. Plot to plot and replication to replication distance were 60 cm and 75 cm, respectively. Twenty eight day-old seedlings were transplanted in the field on 28 November, 2021 and 26 November, 2022. Irrigation was started on 14 days after transplanting of seedlings. Measured amount of irrigation water (IW) was applied with the help of a 20 L calibrated plastic bucket. To maintain 100% FC, irrigation was done at 2-3 days interval and 60% FC, irrigation was done at 5-6 days interval. At 100 FC and 60% FC, 35 times and 18 times irrigation were applied to the plot, respectively. The required depth of irrigation was calculated using the following equation (Michael, 1978): $d = \{(M_{FC} – M_{PI}) / 100\} \text{ x } \rho b \text{ x } D$;

Where, d = depth of irrigation requirement (cm), M_{FC} = Soil moisture percentage at field capacity, M_{PI}= Soil moisture percentage in field prior to irrigation, ρb = Bulk density (g cm^{-3}), D = Rooting depth (cm) (assuming 25 cm for tomato). The formula of quantifying total volume of water required to irrigate the plot is = A x d m^3, where A = plot area and d= depth of irrigation) (Akanda *et al*., 1994). Then the measured amount of water was applied to the plot with the help of calibrated plastic bucket. The crop was fertilized with N-P-K-S-Zn-B-Mg@ 250-90-125-20-5-2-9 kg /ha, respectively (Anonymous, 2021). Cow dung was applied @10 t/ha. Half of the quantity of cow dung, entire P and half of K, entire S, Zn, B and Mg were applied during final land preparation. The rest half of cow dung was applied in the pit. The remaining K and entire N were applied at three equal installments at 15, 30 and 45 days after transplanting (Anonymous, 2021). Weeding was done as per requirements. Rovral 50 WP was sprayed @ 0.2% two times at 25 days after transplanting (DAT) and 50 DAT when symptom of early blight of tomato was seen. Ridomyl Gold was also sprayed three times at 15 days interval starting from 55 DAP for precautionary measure of late blight disease of tomato. Final harvest of tomato was done on 30 March, 2022 and 29 March 2023. Data (from 5 plants) were collected on plant height at 60 and 90 DAT, chlorophyll content (SPAD value) at 60 and 90 DAT, relative water content (RWC) at 60 and 90 DAT, no. of fruits/plant, individual fruit weight, %fruit set and fruit yield/plant. Plot yield was converted to per hectare yield. The SPAD value was taken by SPAD meter (SPAD-500 plus, Minolta Konica Inc, Japan). RWC was measured using leaves (7^{th} no. leaf from the tip of the plant) after imposing drought conditions. Immediately after cutting at the base of lamina, leaves were sealed within plastic bags and quickly transferred to the laboratory. Fresh weights were determined within 2 h after excision. Turgid weights were obtained after soaking leaves in distilled water in plastic bowls for 16 to 18 h at room temperature (about 25°C) and under the low light conditions of the laboratory. During soaking bowls were covered with polythene. After soaking, leaves were quickly and carefully blotted dry with tissue paper in preparation for determining turgid weight. Dry weights were obtained after oven drying the leaf samples for 72 h at 70°C. RWC was calculated from the equation of Schonfeld *et al*. (1988):

$$\% \text{ RWC} = \frac{\text{Fresh weight- dry weight}}{\text{Turgid weight} - \text{dry weight}} \times 100$$

TSS (%) of ripe tomato fruit was measured by a Handheld Refractometer (HRb-18 T, made in Germany). The 1-2 drops of tomato juice (after blending the fruit) were taken on the prism of refractometer and TSS data was recorded. Proline content was recorded from 5^{th} leaf of tomato plants from the apex. Proline content was estimated according to the method proposed by Bates *et al* (1973) using L-proline as standard. A one-gram sample was homogenized in 5 ml of aqueous sulfosalicylic acid (3%) and centrifuged at 14,000 g for 15 min. Two ml of supernatant was added to 2 ml of mixed acetic acid and ninhydrin, and heated for

1 h at 100^{0}C. The mixture was then cooled rapidly in an ice-bath, and added to 4 mL of toluene. Absorbance was recorded n a spectrophotometer (UV-200 UV Spectrophotometer, Japan) at 525 nm. Proline content was reported as µmol g^{-1} FW. The pooled data of two years were analyzed through MSTAT C software and mean separation was done by Tukey's W test at 5% probability level.



Source: Weather office, Gazipur

Fig. 1. Weather data (Temperature, rainfall and humidity) during experimentation in 2021-22 and 2022-23 seasons.

Results and Discussions

Monitoring of moister per cent

Two weeks interval moisture (%) was monitored from transplanting to last harvest (17 December to 30 March) in 2021-22 and 2022-23 seasons (Fig. 2). In 2021-22 season, soil moisture ranged from 13.25% to 15.25% and 23.42% to 25.97% at 60% FC and 100% FC, respectively. But, in 2022-23 season, soil moister ranged from 12.58% to 15.32% at 60% FC treatment, whereas, at 100% FC, soil moister ranged from 22.85% to 25.98%. At FC and wilting point, soil moisture was 29.5% and 13.42%, respectively. The Fig. 1 shows that, during growth stage the crop faced to moisture crisis under 60% FC in some days.

Requirement of Irrigation and total water

During experimental period the crop received 31 mm (effective rainfall: 31 x 0.6 = 18.6 mm) and 28 mm rainfall (effective rainfall: 28 x 0.6 = 16.8 mm) in 2021-22 and 2022-23 seasons, respectively. For tomato production, in 100% FC treatment, 584.3 mm and 560.6 mm irrigation was required in 2021-22 and 2022-23 seasons, respectively, while in 60% FC treatment, 270.04 mm and 265.2 mm irrigation was required in 1st and 2nd year, respectively. So, the actual irrigation requirement under 100% RC treatment in 1st and 2nd year was 565.7 mm and 543.8 mm, respectively, whereas, under 60% FC, the actual irrigation requirement was 251.8 mm and 248.4 mm in 1st and 2nd year respectively.

In 100% FC treatment, total amount of required water to irrigate one hectare land was 5258.6 m^3/ha, but in 60% FC treatment, the amount of required water for irrigation to one ha land was 2430.3 m^3/ha during 2021-22 season. But during 2022-23 season, in 100% FC treatment, the amount of required water was 5160.4 m^3/ha but, in 60% FC treatment the amount of required water was 2398.5 m^3/ha.

At 100% FC treatment, the average available water was 16.54% for the tomato plant in both years and 60% FC treatment, the average available water was 14.29% for both years.

Plant height

Plant height was declined due to drought stress (Table 1). At 60 days after transplanting (DAT), Plant height ranged from 73.83 cm (V_1) to 111.90 cm (V_{20}) at 100% FC (field capacity) while at 90 DAT, the range of plant height was 93.56 cm (V_8) to 160.53 cm (V_7) at 60% FC. At 60 DAT the range of plant height was 68.50 cm (V_1) to 105.80 cm (V_7) at 60% FC; whereas, at 90 DAT the plant height was in the range of 88.54 cm (V_3) to V_7 (151.60 cm). At 60% FC, the maximum reduction in plant height was observed in V_1 (7.22%) followed by V_2 (7%), V_3 (7%), V_4 (7.00%) and V_6 (7.11%) at 60 DAT, while, the lowest reduction was recorded in V_5 (4.05%) followed by V_8 (5.42%) and V_7 (5.45%). Again, at 90 DAT, the highest reduction in plant height was observed in V_3 (10.00%) followed by V_4

(9.00%) and V_1 (8.00%) and the lowest reduction was noticed in V_5 (4.00%) followed by V_8 (4.55%) at 40-50% FC. Buhroy *et al.* (2017) reported 10% decrease in plant height occurred at 50% FC in tomato.

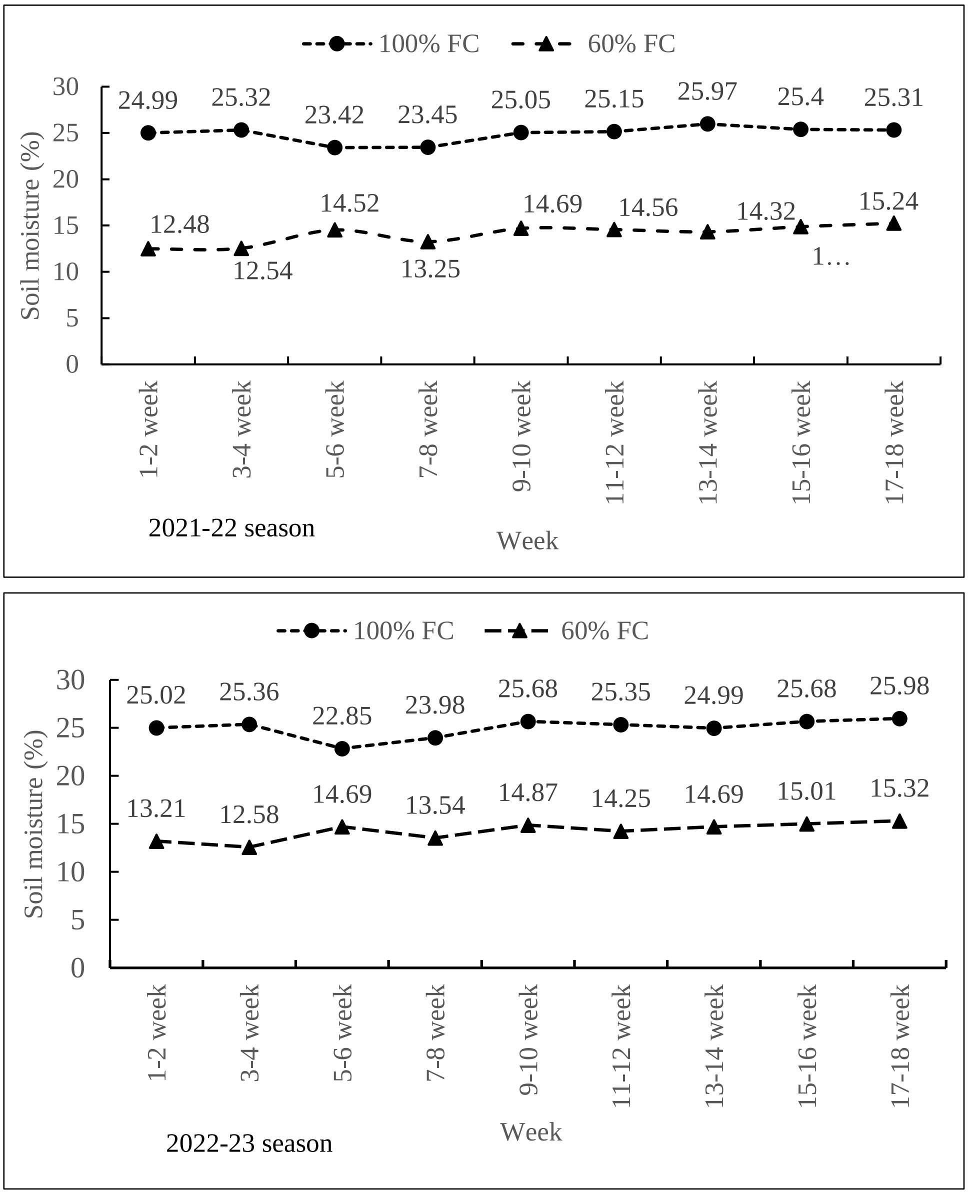


Fig. 2. Two weeks interval soil moisture (%) in tomato research field at 10 cm soil depth

Table 1. Effect of drought stress on plant height at two growth stages in tomato varieties

Variety	Plant height at					
	60 DAT			90 DAT		
	100% FC	60% FC	Reduction% at 60% FC	100% FC	60% FC	Reduction% at 60% FC
V_1	73.83f	68.50f	7.22	97.46c	89.66d	8.00
V_2	100.03b	93.03b	7.00	150.00b	137.48b	8.35
V_3	74.53f	69.31e	7.00	98.38c	88.54d	10.00
V_4	79.33ef	73.78e	7.00	95.60c	87.00d	9.00
V_5	86.07de	82.58d	4.05	94.52c	90.74d	4.00
V_6	94.37bc	87.66c	7.11	101.42c	95.33c	6.00
V_7	111.90a	105.80a	5.45	160.53a	151.60a	5.56
V_8	89.67cd	84.81cd	5.42	93.56c	89.30	4.55
Mean	88.72	83.18	6.28	111.40	10.71	6.91
CV (%)	9.21	9.21	-	8.89	8.89	-

Figures within a column having different letter (s) do not differ significantly at 5% level

V_1 = BARI Tomato-2, V_2 = BARI Tomato-14, V_3 = BARI Tomato-16, V_4 = BARI Tomato-17, V_5= BARI Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20, V_8 = BARI Tomato-21

SPAD value

SPAD value was reduced by moisture deficit (Table 2). Variation among varieties was also presented and ranged from 41.65 (V_3) to 47.93 (V_5) (100% FC) and 33.20 (V_2) to 45.14 (V_5) (60% FC) at 60 DAT. At 60 DAT, the highest reduction in SPAD value was in V_2 (26.22%) followed by V_1 (25.76%), V_6 (25.50%), V_4 (22.32%) and the lowest reduction in from V_7 (3.58%) followed by V_5 (5.82%). At 90 DAT SPAD value ranged from 42.03 (V_8) to 48.99 (V_3) (100% FC) and 31.23 (V_1) to 44.06 (V_5) (60% FC). At this stage, the highest reduction in SPAD value was in V_1 (28.04%) followed by V_4 (27.31%), V_6 (26.07%) and V_2 (25.88%) and the lowest reduction in V_5 (4.49%).This was in agreement with the results of Gong *et al.* (2005) and Tembe *et al.* (2017) who found that reduction in chlorophyll content under moisture deficit could be attributed to the fact that water stress damages the photosynthetic apparatus by causing changes in the chlorophyll contents and components. Lessani and Mojtahedi (2002) opined that water deficit can destroy the chlorophyll and prevent making it. A reason for decrease in chlorophyll content as affected by water deficit is that drought stress by producing reactive oxygen species (ROS) such as O^{2-} and H_2O_2, can lead to lipid peroxidation and consequently, chlorophyll destruction (Mirnoff, 1993; Foyer *et al*., 1994). Sivakumar and Srividhya (2016) obtained 7.42% decrease in SPAD value at drought condition.

Table 2. Effect of drought stress on SPAD value at two growth stages in tomato varieties

Variety	SPAD value at					
	60 DAT			90 DAT		
	100% FC	60% FC	Reduction% at 60% FC	100% FC	60% FC	Reduction% at 60% FC
V_1	45.97c	34.13ef	25.76	43.40d	31.23e	28.04
V_2	45.00d	33.20f	26.22	48.30a	35.80c	25.88
V_3	41.65e	36.65d	12.00	48.99a	32.13e	34.42
V_4	44.93d	34.90e	22.32	47.20b	34.31d	27.31
V_5	47.93a	45.14a	5.82	46.13c	44.06a	4.49
V_6	46.83b	34.89e	25.50	46.53bc	34.40d	26.07
V_7	45.03d	43.42b	3.58	46.47bc	41.82b	10.01
V_8	47.00b	39.48c	16.00	42.03e	36.14c	14.01
Mean	45.54	37.73	17.15	46.13	36.24	21.44
CV (%)	5.64	5.64	-	6.52	6.52	-

Figures within a column having different letter (s) do not differ significantly at 5% level

V_1 = BARI Tomato-2, V_2 = BARI Tomato-14, V_3 = BARI Tomato-16, V_4 = BARI Tomato-17, V_5= BARI Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20, V_8 = BARI Tomato-21

Table 3. Effect of drought stress on relative water content (RWC) at two growth stages in tomato varieties

Variety	Relative water content (RWC) at					
	60 DAT			90 DAT		
	100% FC	60% FC	Reduction% at 60% FC	100% FC	60% Fc	Reduction% at 60% FC
V_1	83.60c	79.61b	4.77	70.19d	65.97c	6.01
V_2	83.20c	73.79cd	11.31	74.97c	61.97d	17.34
V_3	79.50d	66.78e	16.00	64.39e	56.76e	11.85
V_4	86.48b	73.02d	15.56	77.06b	71.09b	7.75
V_5	87.60ab	85.04a	2.92	78.55a	72.86a	7.24
V_6	88.50a	74.96c	15.30	76.99b	71.06b	7.70
V_7	86.80b	85.42a	1.59	77.88ab	73.54a	5.57
V_8	76.23e	62.50f	18.01	60.98f	50.23f	17.63
Mean	83.99	75.14	10.54	72.63	65.44	10.13
CV (%)	9.65	8.52	-	7.32	6.54	-

Figures within a column having different letter (s) do not differ significantly at 5% level.

V_1 = BARI Tomato-2, V_2 = BARI Tomato-14, V_3 = BARI Tomato-16, V_4 = BARI Tomato-17, V_5= BARI Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20, V_8 = BARI Tomato-21.

Relative water content

Drought (water stress) had significant effect on relative water content among different varieties observed (Table 3). Relative water content (RWC) at 60 DAT ranged from 76.23% (V_8) to 88.50% (V_6) with 100% FC and 62.50% (V_8) to 85.42% (V_7) with 60% FC. The highest reduction in RWC was in the variety V_8 (18.01%) followed by V_3 (16.00%), V_4 (15.56%) and V_6 (15.30%) and it was recorded lowest in V_7 (1.59%) and V_5 (2.92%) at 60 DAT. While at 90 DAT the highest reduction was observed in V_8 (17.63) followed by V_2 (17.34%) and V_3 (11.85%) and the lowest reduction value was found in V_7 (5.57%) followed by V_1 (6.01%) and V_5 (7.24%). According to Yamasaki and Dillenburg (1999), RWC is an appropriate physiological measure of plant water status under water stress (drought) condition. Alizade (2002) reported that leaf RWC is of one of the best growth/biochemical indices revealing the stress intensity. In this study RWC decreased at 40-50 % FC. Sibomana *et al.* (2013) noted that decreased leaf water potential leads to stomatal closure and ultimately results in low transpiration. Varieties/genotypes, which showed higher RWC ensure more favourable internal water relations of tissue and showed better drought tolerance quality. Similar results were reported earlier by Srinivas and Bhatt (1992) and Sivakumer (2017) in tomato. Since the rate of RWC is seen higher in varieties V_5, V_6 and V_7, it might be inferred that those varieties have tolerance against drought. Buhroy *et al.* (2017) reported that 11.97% reduction in RWC at 50% FC compared to 100% FC.

Number of fruits/plant and Relative no. of fruits/plant

Average number of fruits/plants ranged from 19.00 to 159.73 (100% FC) and 12.00 to 137.40 (60% FC) (Fig. 3). In both non-stress and stress condition, the maximum number of fruits/plants was recorded in V_7 (159.73 and 137.4), respectively followed by V_6 (71.60 and 55.33), respectively. The highest reduction was noticed in V_4 (36.84%) followed by V_1 (26.99%) and V_2 (27.47%) and the lowest reduction was recorded in V_7 (13.98%) and V_5 (15.86%) (Fig. 4). The lowest relative no. of fruits/plant was recorded in V_4 (63.16%) followed by V_2 (72.53%) and the highest relative fruit number was observed in V_7 (86.02%) followed by V_5 (84.14%) (Fig 4). Buhroy *et al.* (2017) reported that 39.66% in relative no. of fruits/plant at 50% FC.

Individual fruit weight and Relative fruit weight

Individual fruit weight ranged from 27.41 g to 251.67 g with 100% FC and 21.10 g to 165.41 with 40-50% FC (Fig. 5). Maximum individual fruit weight was recorded in V_4 at both 100 and 50% FC followed by V_1 and V_5 and the least individual fruit weight was obtained from V_7. The highest reduction in individual fruit weight was observed in V_8 (53.44%) followed by V_6 (36.0%) and V_4 (34.28%) and the lowest reduction was noticed in V_5 (18.86%) followed by V_1 (22.52%) and V_7 (23.02%) (Fig. 6). Maximum relative individual fruit weight was recorded in V_5 (81.14%) closely followed by V_1 (77.48%) and V_7 (76.98%); while, the lowest relative individual weight was recorded in V_8 (46.56%) (Fig. 6). Sivakumar and Srividhya (2016) obtained 32.10% decrease in tomato fruit weight at drought stress.

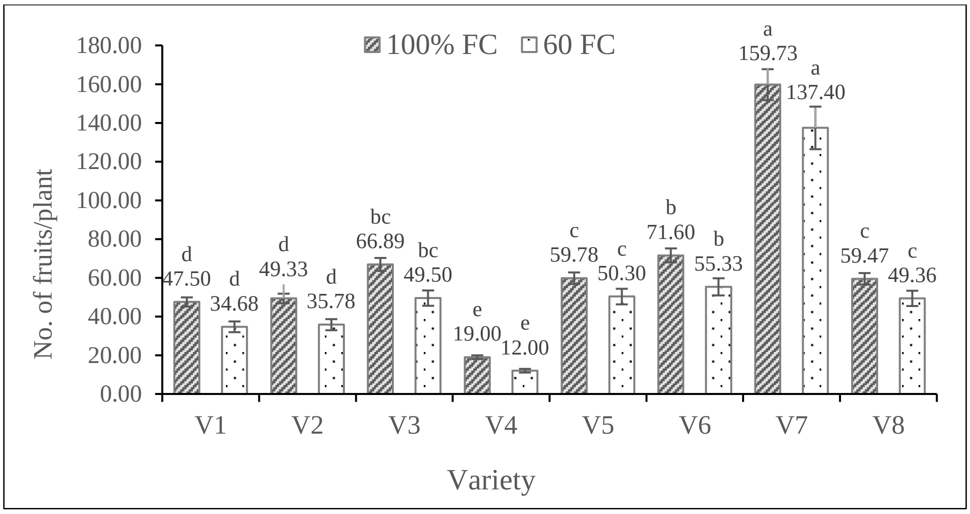


Fig. 3. Effect of drought stress on no. of fruits/plant in tomato varieties. Vertical bars show ±SE of three replicates.

Figures on top of the bars having different letter (s) do not differ significantly at 5% level.

V_1 = BARI Tomato-2, V_2 = BARI Tomato-14, V_3 = BARI Tomato-16, V_4 = BARI Tomato-17, V_5 = BARI Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20, V_8 = BARI Tomato-21

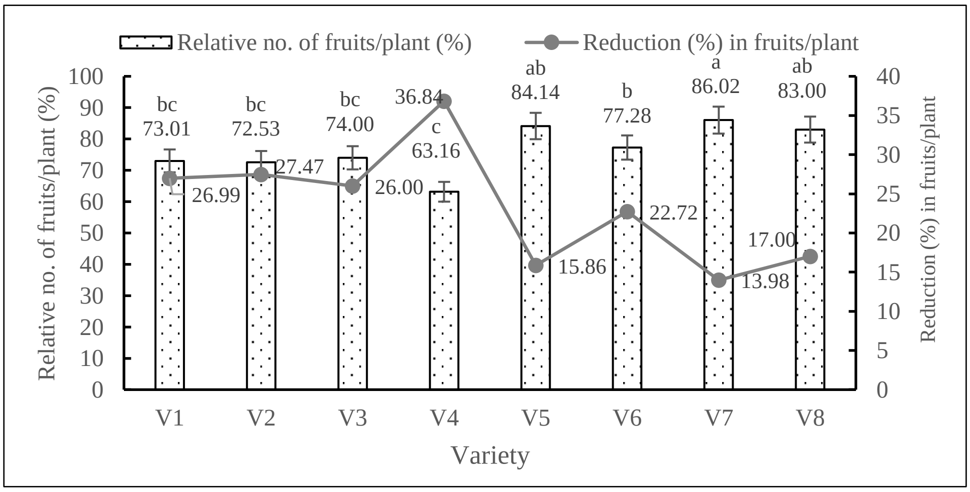


Fig. 4. Effect of drought stress on relative no. of fruits/plant and fruits/plant reduction in tomato varieties. Vertical bars show ±SE of three replicates.

Figures on top of the bars having different letter (s) do not differ significantly at 5% level

V_1 = BARI Tomato-2, V_2 = BARI Tomato-14, V_3 = BARI Tomato-16, V_4 = BARI Tomato-17, V_5= BARI Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20, V_8 = BARI Tomato-21

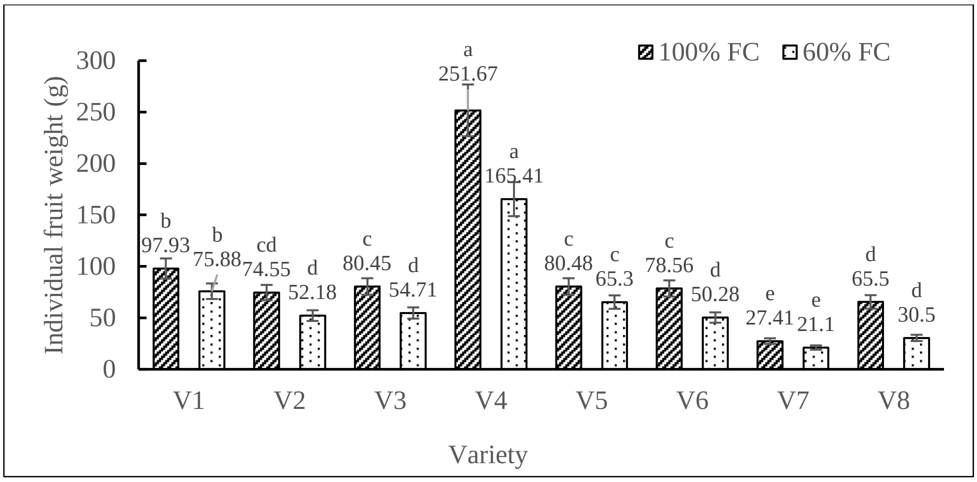


Fig. 5. Effect of drought stress on individual fruit weight in tomato varieties. Vertical bars show ±SE of three replicates.

Figures on top of the bars having different letter (s) do not differ significantly at 5% level.

V_1 = BARI Tomato-2, V_2 = BARI Tomato-14, V_3 = BARI Tomato-16, V_4 = BARI Tomato-17, V_5= BARI Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20, V_8 = BARI Tomato-21.

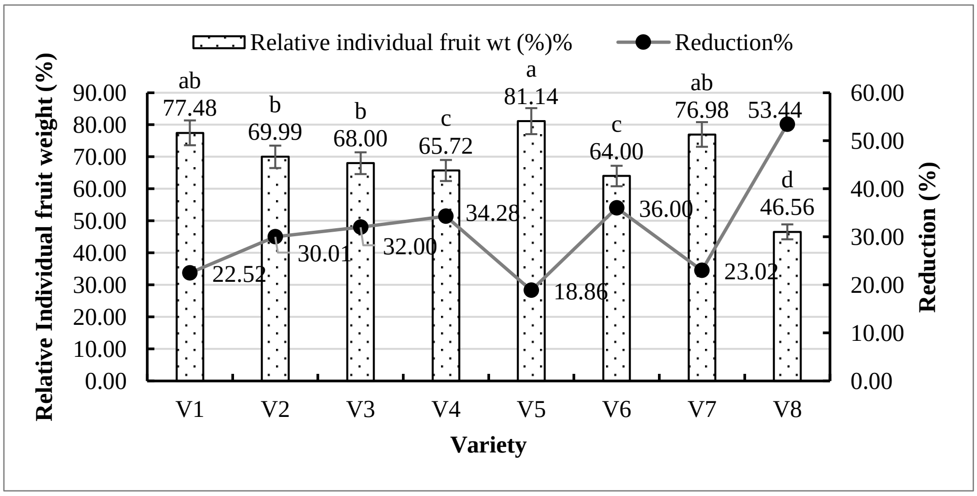


Fig. 6. Effect of drought stress on relative individual fruit weight and fruit weight reduction in tomato varieties. Vertical bars show ±SE of three replicates.

Figures on top of the bars having different letter (s) do not differ significantly at 5% level

V_1 = BARI Tomato-2, V_2 = BARI Tomato-14, V_3 = BARI Tomato-16, V_4 = BARI Tomato-17, V_5= BARI Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20, V_8 = BARI Tomato-21.

Fruit set (%) and Relative fruit set

Fruit set percent was reduced by drought stress (Fig. 7). At 100% FC, maximum fruit set was recorded in V_6 (87.25%) closely followed by V_3 (86.80%), V_2 (86.70%), V_5 (86.70%), V_1 (85.60%) and V_7 (85.60%) and its lowest value was noted in V_8 (84.13%) (Fig. 7). But at 60% FC, the highest fruit set was observed in V_5 (84.56%) closely followed by V_7 (83.04%) and the least was found from V_3 (73.78%) closely followed by V_8 (74.03%). Maximum relative fruit set% was recorded in V_5 (97.53%) which was statistically similar to V_7 (97.01%) and V_4 (96.00%) and the lowest was recorded in V_3 (85.00%) (Fig. 8). This was in agreement with the results of Sivakumar (2017) who reported that flower abscission was higher in 50% FC than 100% FC and flower abscission range was 12.05-17.7% which indicated that fruit set percent in water stress condition was 82.3% to 87.95%. Higher fruit set% in V_5 and V_7 might be due to the maintenance of photosynthesis and efficient translocation of photosynthates to the reproductive parts under drought.

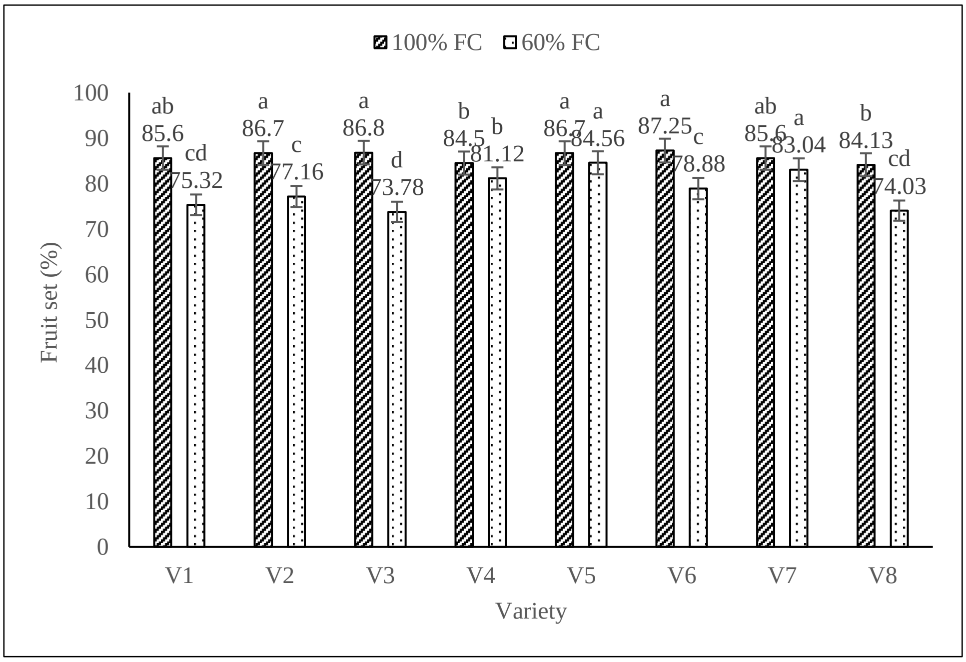


Fig 7. Effect of drought stress on fruit set percentage in tomato varieties. Vertical bars show ±SE of three replicates.

Figures on top of the bars having different letter (s) do not differ significantly at 5% level.

V_1 = BARI Tomato-2, V_2 = BARI Tomato-14, V_3 = BARI Tomato-16, V_4 = BARI Tomato-17, V_5 = BARI Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20, V_8 = BARI Tomato-21.

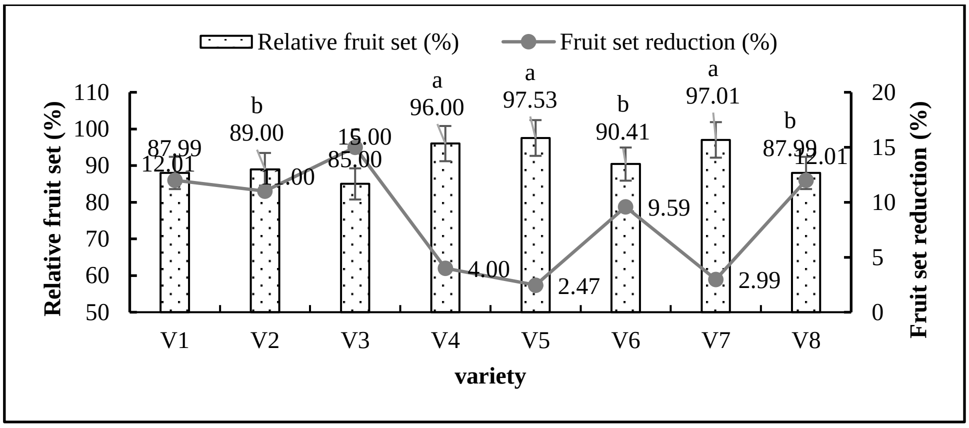


Fig 8. Effect of drought stress on relative fruit set and fruit set reduction in tomato varieties. Vertical bars show ±SE of three replicates.

Figures on top of the bars having different letter (s) do not differ significantly at 5% level

V_1 = BARI Tomato-2, V_2 = BARI Tomato-14, V_3 = BARI Tomato-16, V_4 = BARI Tomato-17, V_5 = BARI Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20, V_8 = BARI Tomato-21

Fruit yield/plant/ha and Relative fruit yield

Fruit yield/plant was decreased due to drought stress (Fig. 9). At 100% FC, fruit yield/plant ranged from 2.22 kg (V_8) to 4.60 kg (V_4), while at 60% FC, it ranged from 0.88 kg (V_8) to 2.57 kg (V_4). Maximum reduction in fruit yield/plant due to drought was observed in V_8 (60.27%) followed by V_6 (50.46%) and V_3 (49.28%) and the lowest reduction was recorded in V_5 (30.08%) closely followed by V_7 (34.42%) and V_1 (42.54%) (Fig. 10). Maximum relative fruit yield/plant was recorded from V_5 (69.92%) followed by V_7 (65.58%) and its lowest value recorded from V_8 (39.73%) (Fig. 10). Fruit yield/ha was also decreased due to drought stress (Fig. 11). At 100% FC, fruit yield/ha ranged from 53.30 t (V_8) to 105.40 t (V_4), while at 60% FC, it ranged from 21.17 (V_8) to 61.63 (V_4). Maximum reduction in fruit yield due to drought was observed in V_8 (60.27%) followed by V_6 (50.46%) and V_3 (49.28%) and the lowest reduction was recorded in V_5 (30.08%) closely followed by V_7 (34.42%) and V_1 (38.97% (Fig. 12). Maximum relative fruit yield/ha was recorded from V_5 (69.92%) closely followed by V_7 (65.58%) and V_1 (61.03%) and its lowest value was recorded from V_8 (39.73% (Fig. 12). This was in line with the report of Ramadasan *et al.* (1993) who explained that the final yield of the crop is a product of combined effects of stress on growth and various physiological processes. Reduction in fruit yield at drought stress could be attributed to decline in photosynthesis due to the decrease in chlorophyll content, fruit number, individual fruit weight and fruit set%. Buhroy *et al*. (2017) reported that 37.66% decrease occurred in fruit yield/plant at 50% FC.

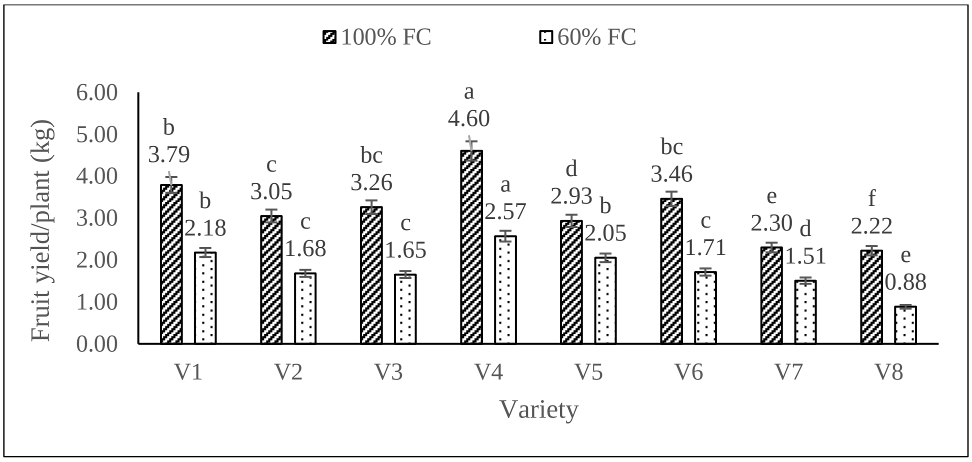


Fig. 9. Effect of drought stress on fruit yield/plant (kg) and relative fruit yield (%) in tomato. Vertical bars show ±SE of three replicates.

Figures on top of the bars having different letter (s) do not differ significantly at 5% level.

V_1 = BARI Tomato-2, V_2 = BARI Tomato-14, V_3 = BARI Tomato-16, V_4 = BARI Tomato-17, V_5= BARI Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20, V_8 = BARI Tomato-21, Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20, V_8 = BARI Tomato-21

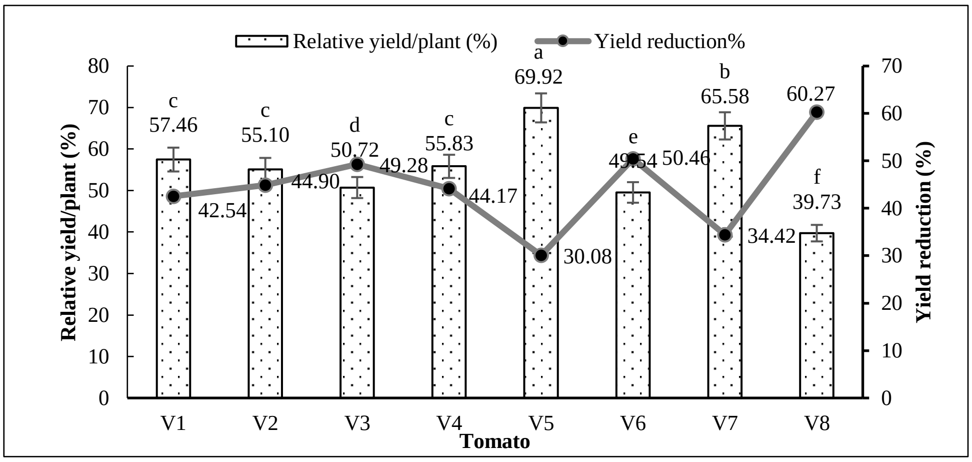


Fig 10. Effect of drought stress on fruit yield/plant (kg) and relative fruit yield (%) in tomato. Vertical bars show ±SE of three replicates

Figures on top of the bars having different letter (s) do not differ significantly at 5% level

V_1 = BARI Tomato-2, V_2 = BARI Tomato-14, V_3 = BARI Tomato-16, V_4 = BARI Tomato-17, V_5 = BARI Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20, V_8 = BARI Tomato-21

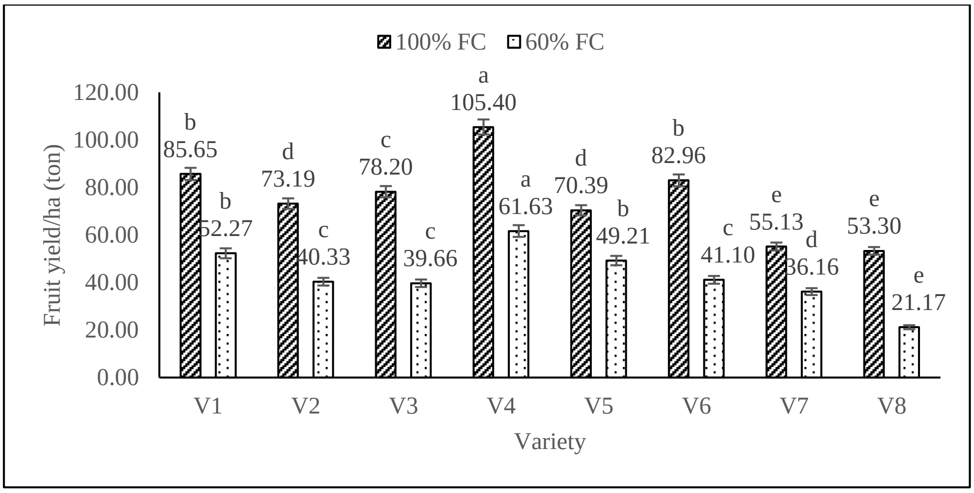


Fig 11. Effect of drought stress on fruit yield/ha (ton) and relative fruit yield (%) in tomato. Vertical bars show ±SE of three replicates

Figures on top of the bars having different letter (s) do not differ significantly at 5% level.

V_1 = BARI Tomato-2, V_2 = BARI Tomato-14, V_3 = BARI Tomato-16, V_4 = BARI Tomato-17, V_5= BARI Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20, V_8 = BARI Tomato-21

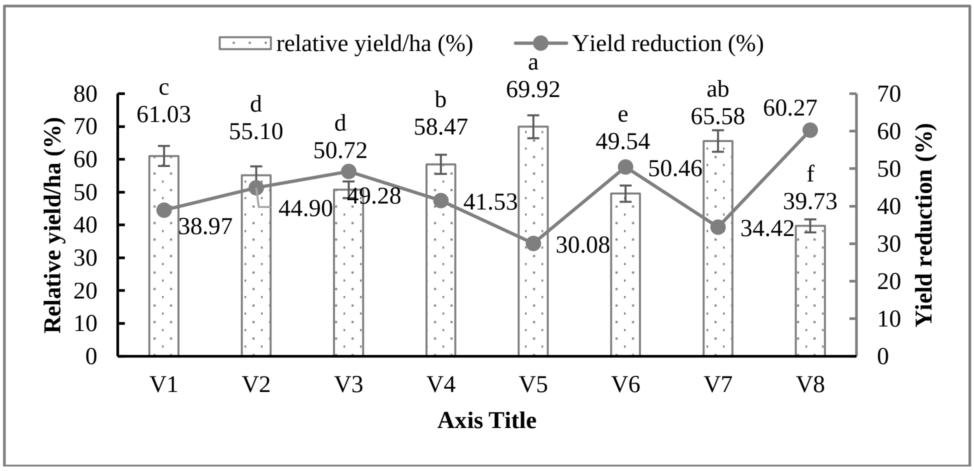


Fig 12. Effect of drought stress on relative fruit yield/ha and yield reduction in tomato. Vertical bars show ±SE of three replicates

Figures on top of the bars having different letter (s) do not differ significantly at 5% level.

V_1 = BARI Tomato-2, V_2 = BARI Tomato-14, V_3 = BARI Tomato-16, V_4 = BARI Tomato-17, V_5= BARI Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20, V_8 = BARI Tomato-21.

Total soluble solid (TSS%)

Total soluble solid (TSS%) was increased due to drought stress (60% FC) (Fig. 13). At 100% FC, maximum TSS was observed in V_7 (7.01%) and the lowest from V_1 (5.20%) closely followed by the remaining varieties. At 60% FC, the highest TSS was recorded by V_7 (7.39%) which was statistically similar to V_5 (7.21%) and the lowest from V_3 identical with V_2, V_4 and V_6. The increase in TSS% in varieties ranged from 5.14-30.81% (Fig. 13). Maximum increase (30.51%) was noted in V_5 followed by V_1 (24.20%). Sivakumar and Srividhya. (2016) obtained 4.15% increase in TSS in tomato fruit at drought stress whereas; Kazemi *et al.* (2021) obtained 14.52% increase in TSS.

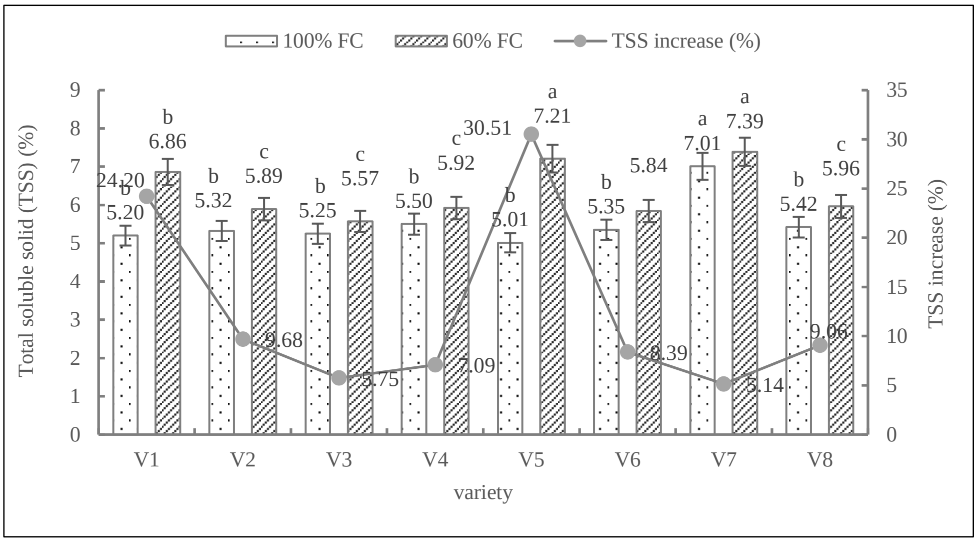


Fig 13. Effect of drought stress on total soluble solid (TSS) and TSS increase in tomato. Vertical bars show ±SE of three replicates

Figures on top of the bars having different letter (s) do not differ significantly at 5% level.

100% FC = 90-100% FC & 40% FC = 40-50% FC; V_1 = BARI Tomato-2, V_2 = BARI Tomato-14, V_3 = BARI Tomato-16, V_4 = BARI Tomato-17, V_5 = BARI Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20, V_8 = BARI Tomato-21.

Proline content

Proline content at 90-100% FC and 60% FC was significantly influenced by drought treatments (Fig. 14) and it was increased due to drought condition. Maximum proline content was obtained from V_5 (2.68 µmolg^{-1} FW) closely followed by V_4 (2.65 µmolg^{-1} FW) and the least from V_7 (2.36 µmolg^{-1} FW) at 100% FC; whereas, at 40% FC, the highest proline content was recorded in V_5 (4.98 µmolg^{-1} FW) which was identical with V_4 (4.87 µmolg^{-1} FW), V_7 (4.87 µmolg^{-1} FW) and V_1 (4.68 µmolg^{-1} FW) and the lowest proline content was obtained from V_3 (3.46 µmolg^{-1} FW). The increase percent of proline content in varieties ranged from 28.37-51.54%. Maximum increase in proline content was seen in V_7 (51.54%) followed by V_5 (46.18%), V_4 (45.59%) and V_1 (45.73%) and the lowest increase from V_8 (29.60%) followed by V_3 (31.07%) (Fig. 14). Accumulation of proline in the plant system lowers the water potential of plant than that of soil, which helps the root to absorb water from soil. Buhroy *et al.* (2017) reported to have 15.23% proline increase in tomato at 50% FC; whereas, Khan *et al*. (2015) obtained 24.14% increased proline in the same crop under drought stress.

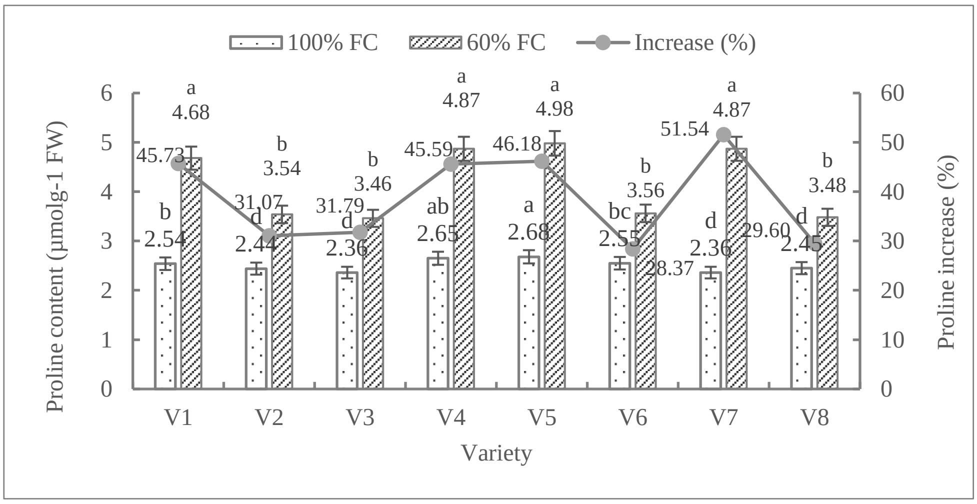


Fig 14. Effect of drought stress on total soluble solid and proline content in tomato. Vertical bars show ±SE of three replicates

Figures on top of the bars having different letter (s) do not differ significantly at 5% level.

V_1 = BARI Tomato-2, V_2 = BARI Tomato-14, V_3 = BARI Tomato-16, V_4 = BARI Tomato-17, V_5 = BARI Tomato-18, V_6 = BARI Tomato-19, V_7 = BARI Tomato-20, V_8 = BARI Tomato-21

Conclusion

Based on the above results, it can be concluded that BARI Tomato-18 and BARI Tomato-20 (cherry tomato) performed better at drought stress than other varieties and selected as moderate drought tolerant varieties.

References

Akanda, M. A. R., M. S. Islam and M. J. Islam. 1994. Response of groundnut to irrigation given at different growth stages. *Bangladesh J. Agril. Res*. **19** (2):182-189.

Alizade A. 2002. *SOIL, Water and Plants Relationship*.3rd Edn. Emam Reza University Press, Mashhad, Iran. ISBN: 964-6582-21-4.

Anonymous. 2021. Vegetable Research Program 2020-2021 for Internal Research Review Workshop. Olericulture Division, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701.

Bakht, J., M. Shafi, M. Yousaf and M. A. Khan. 2010. Effect of irrigation on physiology and yield of sunflower hybrids. *Pak J. Bot.* **42**: 1317-1326.

Bates, L.S., R.P. Waldren and I.D.Teare. 1973. Rapid determination of free proline for water stress studies. *Plant Sci.* **39**: 205–207.

Buhroy, S., T. Arumugam, P. Irene Vethamoni , N. Manivannan and P. Jeyakumar. 2017. Effectiveness of drought tolerance indices to identify tolerant genotypes with high yielding potential in tomato (*Solanum lycopersicum* L.). *Int. J. Curr. Microbiol. App. Sci*. **6** (4): 2093-2103[DOI: https://doi.org/10.20546/ijcmas.2017.604.247].

Castillo, E.G., T. P. Tuong, A. M. Ismail and K. Inumbushi. 2007. Response to salinity in rice: Comparative effects of osmotic and ionic stresses. *Plant Prod. Sci.* **10**: 159-170.

Foyer, C. H., P. Descourvieresand K. J. Kunert. 1994. Photo oxidative stress in plants. *Plant. Physiol*. **92**: 696-717

Gong, H., X. Zhu, K. Chen, S. Wang and C. Zhang. 2005. Silicon alleviates oxidative damage of wheat plants in pots under drought. *J. Plant. Sci.* **169:** 313-321.

Kalloo, G., 1993.*Vegetable Breeding*,Vol.III.CRCpressInc., BocaRaton,Florida.

Kazemi, S., A. Zakerin, V. Abdossi, P. Moradi. 2021. Fruit yield and quality of the grafted tomatoes under different drought stress conditions. *Asian.J. Agric.& Biol.* **1***:* 1-14[DOI: 10.35495/ajab.2020.03.164]

Khan, A. J., F. Azam and A. Ali. 2010. Relationship of morphological traits and grain yield in recombinant inbreed wheat lines grown under drought conditions. *Pak. J. Bot.* **42**: 259-267.

Khan, S. H., A. Khan, U. Litaf, A. S. Shah, M. A. Khan, M. Bilal and M. U. Ali. 2015. Effect of drought stress on tomato cv. Bombino. *J. Food. Process Technol*. **6:**7 [DOI: 10.4172/2157-7110.1000465].

Lessani, H. and M. Mojtahedi. 2002. *Introduction to Plant Physiology* (Translation). 6th Edn,Tehran University press, Iran. pp. 726.

Lutts, S., M. Almansouri and J. M. Kinet. 2004. Salinity and water stress have contrasting effects on the relationship between growth and cell viability during and after stress exposure in durum wheat callus. *Plant Sci.* **167**: 9-18.

Mahajan, S. and N. Tuteja. 2005. Cold, salinity and drought stresses: An overview. *Arch. Biochem. Biophys.* **444**:139-158.

Michael, A. M. 1978. Irrigation: Theory and Practice. Vikas Publishing House Private Limited. New Delhi, 539pp.

Mirnoff, N. 1993. The role of active oxygen in the response of plants to water deficit and desiccation. *New Phytol*. **125**: 27-58.

Ramadasan, A., B. K. Kasturi and S. Shivashanker. 1993. *Selection of coconut seedlings through physiological and biochemical criteria.In*: K.B. Hebbar, K. B. Mukesh Kumar Ben.val, M. Arivalagan and V.K. Chaturvedi, Advances in Coconut Research Development. pp. 201-207.

Schonfeld, M. A., R. C. Johnson, B. F. Carver, and D. W. Mornhinweg. 1988. Water relations in winter wheat as drought resistance indicator. *Crop Sci*. **28**: 526-531.

Sibomana, I. C., J. N. Aguyoh and A. M. Opiyo. 2013. Water stress affects in water relations of wheat. Botanical Bull. *Academia Sinica.* **41:** 35-39.

Sivakumar, R.and S. Srividhya. 2016. Impact of drought on flowering, yield and quality parameters in diverse genotypes of tomato (*Solanum lycopersicum* L.). *Adv. Hort. Sci*. **30**(1): 3-11 [DOI: 10.13128/ahs-18696]

Sivakumer, R. 2017. Effect of drought on plant water status, gas exchange and yield parameters in contrasting genotypes of tomato (*Solanum lycopersicum*). *Ame. Int. J. Res*. in *Formal, Applied & Natural Sciences.* **25 (6):**28-37.

Srinivas, R. N. K. and R. M. Bhatt. 1992. Responses of tomato to moisture stress, plant water balance and yield. *Plant Physiol. Biochem*. **19:**36-41.

Tembe, K. O., N. George, Chemining 'wa', J. Ambuko and W. Owino. 2017. Effect of water stress on yield and physiological traits among selected African tomato (*Solanum lycopersicum*) land races. *Int. J. Agron. Agri.***10 (2):** 78-85.

Yamasaki, S. and L. C. Dillenburg. 1999. Measurements of leaf relative water content in *Araucaria angustifolia*. *Brazilian J. Plant Physiol.* **11 (2):** 69-75.