Original Research Article

Traits Associated with Drought Tolerance of Tomato (*Solanum lycopersicum* L.)

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ABSTRACT

Across the globe, tomato (*Solanum lycopersicum* L.) is a commonly used vegetable for culinary purposes. Despite its economic importance, its production is decreasing nowadays due to the occurrence of various abiotic stresses like drought. Hence, it is important to understand the mechanism of drought tolerance to sustain tomato production. A field experiment was conducted with drought tolerant and susceptible genotypes to understand the mechanism of tolerance or susceptibility. Drought stress was imposed during the flowering stage for 19 days. The physiological traits like relative water content, pigmentation, flower abscission percentage and fruit set percentage were recorded. The results showed that relative water content was decreased by 20.47 % in the SL CBE G 26 and 40.98 % in the SL CBE G 23. However, the flower drop was highest in the line SL CBE G 23 (23.29%) and lowest in SL CBE G 26 (19.14 %) under drought stress. The line SL CBE G 23 had lower fruit set than SL CBE 26. Hence, the study confirmed that SL CBE G 26 is a drought tolerant line and drought tolerance is associated with increased water retention in the tissue, eventually resulting in decreased flower drop and increased fruit set percentage.

Keywords: Drought, Tomato, Tolerance, Root length, Leaf rolling, Adaptations

1. INTRODUCTION

In general, drought stress is defined as a prolonged period of soil dryness which can cause an extensive damage to the crop. Agronomic drought occurs when the amount of water in the plant's rhizosphere is insufficient to meet the needs of the plant for optimal growth and biomass production [1]. Across the globe, drought is one of the major environmental factors that affects plant growth and development resulting in decreased crop yield [2]. Around the world, land degradation due to drought and desertification accounts for 1.9 billion ha, which had affected 1.5 billion people [3]. Hence, it is imperative to understand the mechanism of plant adaptation to drought stress. Similar to other abiotic stresses, plants can respond to drought stress through various anatomical, morphological and physiological attributes [4]. Drought stress significantly reduced the leaf vascular bundle area in radish (*Raphanus sativus* L.) cultivars [5].

In vegetables like tomato (*Solanum lycopersicum* L.) drought stress causes a severe yield decrease. In tomato, drought stress decreased shoot height, leaf number, leaf area, total shoot fresh weight, total shoot dry weight, relative water content, chlorophyll content, stress tolerance index, flower number, fruit number and fruit weight than irrigated control [6]. Results indicated that more than 50% yield reduction could happen in tomato if the drought stress occurred at most critical growth stages namely early flowering and fruit setting. To overcome the deleterious effect of drought stress on plants, the plant had developed defence mechanisms to counteract the negative effects of drought by decreasing the leaf number and size, increasing the root length, managing the stomatal closure and maintaining cell turgor by accumulating suitable osmolytes [7]. Another approach, by which plants cope with drought stress is through decreased production of reactive oxygen species and increased antioxidant enzyme activity [8].

Increasing yield under drought stress is an important task for the plant breeders. To evolve a drought tolerant line, it is critical to understand the mechanism of drought tolerance, so that the traits associated with tolerance can be a marker for selection [9]. Therefore, the present experiment was conducted to identify the traits associated with drought tolerance in tomato.

2. MATERIAL AND METHODS

A field experiment was conducted at the Department of Vegetable Science, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during the summer season of 2022. The experimental material was SL CBE G 26 and SL CBE G 23. Our previous study has indicated that SL CBE G 26 was a drought tolerant line and SL CBE 23 as a drought sensitive line.

2.1 Crop husbandry

The tomato seeds were sown in the nursery on 10th Dec 2021 and the seedlings were pulled out on 45th DAS to transplant on the main field. Recommended package of practices were followed.

2.2 Drought stress treatment imposition

The plants were irrigated from transplanting to flowering stage at 5 days intervals. The plants in irrigated plots were irrigated once in 5 days from transplanting to harvest. However, for the drought stress, the irrigation was withheld for 19 days from flowering to fruit set stages. After the stress period, both irrigated and drought-stressed plants were irrigated once in 5 days till harvest**.**

2.3 Traits recorded

The parameters like root length, leaf thickness, leaf rolling, relative water content RWC), chlorophyll *a, b* and total chlorophyll, number of flowers cluster^{-1}, flower abscission percentage and fruit set percentage were studied.

2.3.1 Root length (cm)

After the expiry of the drought stress period, all the plots were irrigated to field capacity. Immediately after irrigation, the plants were carefully uprooted without any damage to the roots. After this, the roots were completely washed in distilled water to remove the adhering soil particle and wiped with tissue paper, then the maximum root length was measured as the distance between base of the stem to the tip of the root.

2.3.2 Leaf thickness (mm)

Leaf thickness was measured in the third leaf from the top by using Digital Vernier Calliper (Code no 500-144, Mitutoya, China).

2.3.3 Relative water content % (RWC)

Relative water content was measured as described by Barrs and Weatherley [10]. Third leaf from top was used for quantification of relative water content by fresh weight, turgid weight and dry weight. Relative Water Content was measured as follows:

$$RWC = \frac{\text{Fresh Weight - Dry Weight}}{\text{Turgid Weight - Dry Weight}} \times 100$$

2.3.4 Chlorophyll content

The method described by Lichtenthaler & Vellburn [11] was used to extract pigments from leaf tissue, including chlorophyll *a*, chlorophyll *b* and total chlorophyll content. 250 mg of fresh leaf tissue was homogenised in 10 ml of 80% acetone and centrifuged at 3000 rpm for 30 min. The supernatant was taken and made up to a volume of 20 ml with 80% acetone. The OD value was measured at 646, 652 and 663 nm and represented as mg g^{-1}

The pigments content were calculated using the following equation

$$\text{Chlorophyll } a = 12.21\ A_{663} - 2.81\ A_{646}$$

$$\text{Chlorophyll } b = 20.13\ A_{646} - 5.03\ A_{663}$$

$$\text{Total chlorophyll} = A_{652} \times 1000 / 34.5$$

2.3.5 Leaf rolling

Leaf rolling was scored visually using 1-5 scale given by Sudhakar [12], where 1- unrolled turgid, 2- leaf rim starts to roll, 3- leaf has shape of a “V”, 4- rolled leaf rim covers part of leaf blade and 5- leaf is rolled like an onion leaf.

2.4 Statistical analysis

The experiment was designed in a split plot design with 5 replications. The main plot was irrigation regime and sub-plot was genotype. These data were statistically analysed using AGRES software version 7.01 and the significance was assessed at $P<0.05$ level.

3. RESULTS

3.1 Root length (cm)

The results indicated that drought stress significantly increased the root length of tomato plants (Table 1.). Similarly, there was a significant difference between the tomato lines for root length. SL CBE G 26 had a higher root length 34.01 cm compared to SL CBE G 23 (Table 1.).

3.2 Leaf Rolling, Leaf Thickness and Trichomes density under drought

The genotypes subjected to drought stress showed leaf rolling at various scale. SL CBE G 26 leaves showed mostly ‘V’ shaped rolling (Fig.1). SL CBE G 23 genotype showed more leaf rolling (Fig.2). Under water stress condition increased leaf thickness was also observed.

SL CBE G 26 showed 1.04 mm leaf thickness whereas SL CBE G 06 showed 0.81 mm (Table.1). Apart from this, under drought stress in SL CBE G 26 densely formed trichomes (Fig.3) were present. However, the genotype SL CBE 23 had less hairs (Fig. 4).

3.3 Relative water content in relation to drought

In general, under drought stress, the plants will have a reduced leaf water content due to non-availability of soil water. SL CBE G 23 showed 40.9% (Table 1) reduction and SL CBE G 26 showed only 20.4% (Table 1) reduction under stress condition.

3.4 Chlorophyll content in leaves

In present study the content of chlorophyll *a*, chlorophyll *b* and total chlorophyll was reduced under drought stress condition compared with irrigated plants. In SL CBE G 26 the chlorophyll *a, b* and total chlorophyll contents were decreased by <25%, however, in SL CBE G 23 the reduction was 30, 40 and 48%, respectively (Table 2).

3.5 Flower characters

The number of flowers per cluster was reduced under drought stress conditions. The genotype SL CBE G 26 had a higher number of flowers cluster (5.80) compared to SL CBE G 23 (3.20) (Table 3). In contrast, the genotype SL CBE G 26 showed a lower flower abscission percentage (19.14%) than SL CBE G 23 (23.29%) under drought (Table 3).

3.6 Fruit set percentage under drought

SL CBE G 26 and SL CBE G 23 had a fruit set percentage of 60.21% and 50.05%, respectively (Table 3). Drought stress decreased the fruit set to a higher value in SL CBE G 23 compared to SL CBE G 26.

4. DISCUSSION

Drought stress increases the root length to absorb more water from the deeper layers of soil. The present study showed that the genotype SL CBE G 26 had an increased root length under drought condition, indicating it is a drought tolerant line. Similar results was observed by [13]. Plants show leaf rolling and increasing trichome density as defence mechanism under drought stress condition in order to maintain tissue water content [14]. The genotype SL CBE G 23 had more leaf rolling than SL CBE G 26 because of its decreased leaf tissue water content. The decreased tissue water content might have caused a root to shoot signal causing leaf rolling.

Tomato plants having protruding structures called trichomes which protects plant from different stress condition [15]. SL CBE G 26 showed dense trichomes which might act as protection under abiotic stress condition. In contrast, the genotype SL CBE G 23 had spare trichomes density, which made the genotype to a susceptible genotype. SL CBE G 26 showed increased leaf thickness 1.04 mm under water stress. It might be due to development of wax layer under stress condition which might acted as an hydrophobic barrier to maintain water status of leaf [16].
In general, under drought stress plants will have a decreased RWC [17]. The present study showed that leaf RWC was reduced under drought stress in the both genotypes. However, SL CBE G 26 showed a less reduction compared to SL CBE 23, indicating the increased root length might favoured increased water uptake from the deeper layers of soil. Under

drought stress, a plant's ability to synthesise chlorophyll will be affected. The present study showed drought stress decreased the chlorophyll content and the highest reduction was observed in SL CBE 23 than SL CBE 26. Similar results were observed in tomato [18].

Drought stress had a severe impact on reproductive process. Studies indicated that pollen are more sensitive to drought stress than pistil [19] eventually fruit set also affected [20]. Drought stress during flowering stage had increased flower abscission rate and between the genotype, SL CBEG 26 had a lower flower abscission rate compared to SL CBE G 23. Similarly, the fruit set percentage was also higher in SL CBE G 26 compared to SL CBE G 23.

Overall, this study showed that the genotype SL CBE G 26 is a drought tolerant genotype. The drought tolerance is associated with increased rooting depth, increased leaf thickness, trichome density and deceased flower and fruit abscission. Hence, these characters may be used for developing tomato plants tolerant to drought stress.

Table.1 The contents of Root length, Leaf thickness and Relative Water Content of both genotypes under control and drought condition. Values are the mean of five independent replicates. Mean difference is significant at p<0.05, LSD- least significant difference

GENOTYPES (G)		**Root length (cm)**		**Leaf thickness (mm)**		**Relative Water Content % (RWC)**	
		Irrigation regime (M)		**Irrigation regime (M)**		**Irrigation regime (M)**	
		Control	Drought	Control	Drought	Control	Drought
SL CBE G 26		26.73	34.01	0.78	1.04	91.69	79.53
SL CBE G 23		25.21	27.27	0.70	0.81	81.21	59.02
Mean		**25.97**	**30.64**	**0.74**	**0.93**	**86.45**	**69.28**
CD (0.05)	M	1.61		0.05		0.67	
	G	1.61		0.06		0.60	
	M at G	2.27		0.08		0.90	
	G at M	2.28		0.09		0.85	

GENOTYPES (G)		Chlorophyll *a* ($mg\ g^{-1}$ FW)		Chlorophyll *b* ($mg\ g^{-1}$ FW)		Total chlorophyll content ($mg\ g^{-1}$ FW)	
		Irrigation regime (M)		**Irrigation regime (M)**		**Irrigation regime (M)**	
		Control	Drought	Control	Drought	Control	Drought
SL CBE G 26		1.20	0.93	0.34	0.30	1.55	1.22
SL CBE G 23		1.15	0.67	0.29	0.14	1.28	0.79
Mean		**1.18**	**0.80**	**0.32**	**0.22**	**1.42**	**1.01**
CD (0.05)	M	0.09		0.02		0.06	
	G	0.07		0.03		0.07	
	M at G	0.10		0.03		0.09	
	G at M	0.09		0.04		0.09	

Table.2 The contents of chlorophyll *a*, chlorophyll *b* and total chlorophyll of both genotypes under control and drought condition. Values are the mean of five independent replicates. Mean difference is significant at $p<0.05$, LSD- least significant difference

Table. 3 The contents of no of flowers cluster^{-1}, flower abscission percentage and fruit setting percentage of both genotypes under control and drought condition. Values are the mean of five independent replicates. Mean difference is significant at $p<0.05$, LSD- least significant difference

GENOTYPES (G)		Number of flowers cluster $^{-1}$		Flower abscission percentage (%)		Fruit set percentage (%)	
		Irrigation regime (M)		Irrigation regime (M)		Irrigation regime (M)	
		Control	Drought	Control	Drought	Control	Drought
SL CBE G 26		6.60	5.80	13.21	19.14	69.35	60.21
SL CBE G 23		6.00	3.20	12.21	23.29	68.86	50.05
Mean		**6.30**	**4.50**	**12.71**	**21.21**	**69.10**	**55.13**
CD (0.05)	M	1.27		2.15		3.17	
	G	1.01		1.53		3.18	
	M at G	1.62		2.64		4.48	
	G at M	1.44		2.16		4.50	

Fig 1. SL CBE G 26

Fig 2. SL CBE G 23

Fig 1,2 showing leaf rolling in the both genotypes under drought

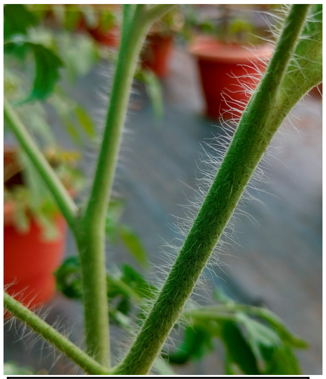

Fig 3. SL CBE G 26

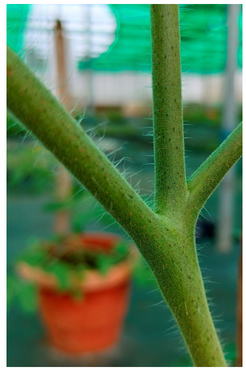

Fig 4. SL CBE G 23

Fig 3,4 showing stem hair (trichome) density in the both genotypes under drought

5. CONCLUSION

Impact of drought is depends on the plant ability to withstand the stress condition. Plants which develop adaptative mechanism can survive even under adverse conditions also. The present study concluded that SL CBE G 26 showed better performance than SL CBE G 23 might be due to its adaptative mechanisms like increased root length, leaf thickness and leaf rolling.

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