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Physiological Studies on Effect of Drought during Flowering in Foxtail Millet (*Setariaitalica* L.)

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One of the major impacts of climate change is increasing the occurrence of drought, leading to drastic reduction in yield in many crop plants. Foxtail millet is thought to be an excellent experimental model in studying abiotic stress tolerance due to its small genome, conserved genome structure, short life cycle and inbreeding nature. Present study was conducted with twenty foxtail millet genotypes with objective to identify tolerant genotypes to drought under pot culture. The drought imposed by withholding irrigation for fifteen days during flowering stage and various physiological parameters measures such as, chlorophyll fluorescence, chlorophyll meter reading, relative water content, chlorophyll stability index, excised leaf water loss were measured. Among the twenty genotypes of foxtail millet, the genotypes, ISe 27, PS 4, AP 4, ISe 138 and ISe 174 were showed better results. Based on drought tolerance associated traits, genotypes were grouped as drought tolerant genotypes which could be used for breeding programme to develop drought tolerant varieties or parents for developing mapping population to identify QTL associated with drought.

Key words: Foxtail millet, Chlorophyll fluorescence, Relative water content, Drought

Drought is considered to be a moderate loss of water, which leads to stomatal closure and limitation of gas exchange and more extensive loss of water, which can potentially lead to gross disruption of metabolism and cell structure (Bray *et al*., 2000). Understanding plant responses to drought is a great importance and also a fundamental part for making the crops as stress tolerant (Zhao *et al*., 2008). Foxtail millet (*Setariaitalica* L.), is an important food and fodder grain crop in arid and semi-arid regions of Asia and Africa. It is self-pollinating, C_4 crop, and it has short generation time. It is sensitive to water deficits, particularly during flowering to seed development stage. Foxtail milletis found in a wide range of environments which suggests that the germplasm may also be a rich source of genetic variation for genes controlling abiotic stress tolerance. To increase the productivity and to stabilize production in the ever-changing environment, development of genotypes that are capable to survive better under abiotic stresses is essential. Therefore, it is imperative to understand the responses of foxtail millet genotypes to drought especially in flowering stage in terms of changes in physiological traits.

Material and Methods

Seeds of twenty foxtail millet genotypes obtained from Department of Pulses, Tamil Nadu Agricultural University, Coimbatore were used for study and foxtail millet genotypes are AP 3, AP 4, GS 1918, GS 2184, ISe 1, ISe 27, ISe31, ISe 138, ISe 174, ISe 281, ISe 317, ISe 789, ISe 1230, Lepakshi, PS 4, Prasad, SiA 326, SiA 805, SiA 2854 and SiA 3156.

Pot culture experiment

One hundred and twenty medium sized pots were filled with 11 kg of soil per pot containing mixture of red soil, FYM and sand in the ratio of 3:2:1. Twenty Foxtail milletgenotypes were sown in Completely Randomized Design (CRD) with three replications uniformly in the well prepared pots. The irrigation was provided immediately after sowing. Control and drought pots were maintained at field capacity till panicle initiation stage and irrigation was withheld for 15 days in drought imposed pots during the panicle initiation stage. The following parameters were measured at the time of drought imposition (15 days) in control and drought pots.

Chlorophyll fluorescence

Chlorophyll fluorescence was measured using chlorophyll fluorescence meter (opti-sciences OS-5p). The key fluorescence parameters F_o (Initial fluorescence), F_m (Maximum fluorescence), F_v (Variable fluorescence) and the ratio of F_v / F_m were measured.

$$\frac{F_v}{F_m} = \frac{\text{Variable fluorescence}}{\text{Maximum fluorescence}}$$

Chlorophyll meter readings

Chlorophyll reading was recorded using a

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portable Chlorophyll Content Meter (CCM-200) at the flowering stage. Three readings were taken from each replication and the average values computed using method described by (Minolta, 1989; Monje and Bughree, 1992).

Relative water content

The Relative Water Content (RWC) was estimated according to Barrs and Weatherley (1962) and calculated by using following formula and expressed as per cent.

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

Chlorophyll stability index

The protocol of Koleyoras (1958) was followed to estimate CSI.

$$CSI = \frac{\text{Chlorophyll content (treated)}}{\text{Chlorophyll content (control)}} \times 100$$

Excised leaf water loss

Excised leaf water retention capacity was measured according to Rahman*et al*. (2000) by using following formula and expressed as gram per gram.

$$ELWL = \frac{\text{Fresh weight} - \text{Wilted weight}}{\text{Dry weight}} \times 100$$

Results and Discussion

Chlorophyll fluorescence indices provide direct information on functionality and the effectiveness of photosynthesis (Lichtenthaler*et al.*, 2005). Under drought condition, the genotype ISe 174 (0.04) followed by ISe 138 (0.13), PS 4 (0.17), AP 4 (0.39) and ISe 27 (0.40) lower per cent reduction of chlorophyll fluorescence ratio over control showed in Table 1. Fluorescence yield will be high when PS II reaction centre is least damaged by photo inhibition.F_v/F_mvalues indicate the photosynthetic efficiency of photo system II.In present investigations, the fluorescence values were declined in all the genotypes in drought conditions. Among them, the genotypes ISe 174, ISe 138, PS 4, AP 4 and ISe 27 maintained higher F_v/F_mratio even under drought.

The chlorophyll content meter is an indicator of the photosynthetically active light-transmittance characteristics of the leaf, which is dependent on the unit amount of chlorophyll per unit leaf area (Richardson *et al*., 2002).

Table 1. Effect of drought on chlorophyll fluorescence ratio (Fv/Fm) and chlorophyll meter reading of foxtail millet genotypes

Genotypes	Chlorophyll fluorescence (F_v/F_m)			Chlorophyll meter reading		
	Control	Drought	% decrease over control	Control	Drought	% decrease over control
AP 3	0.759	0.733	3.42	34.3	19.8	42.3
AP 4	0.768	0.765	0.39	14.7	13.1	11.2
GS 1918	0.762	0.722	5.29	26.3	10.8	58.9
GS 2184	0.763	0.716	6.16	24.6	11.4	53.6
ISe 1	0.768	0.744	3.13	20.3	10.8	46.8
ISe 27	0.751	0.748	0.40	12.4	11.1	10.2
ISe 31	0.778	0.746	4.11	27.7	10.0	63.8
ISe 138	0.767	0.766	0.13	14.0	13.1	6.8
ISe 174	0.766	0.766	0.04	12.8	8.0	37.5
ISe 281	0.765	0.759	0.87	30.5	24.2	20.6
ISe 317	0.764	0.744	2.58	27.5	15.1	45.1
ISe 789	0.759	0.738	2.72	22.0	11.6	47.4
ISe 1230	0.758	0.748	1.41	19.4	10.0	48.7
Lepakshi	0.716	0.678	5.30	26.4	12.1	54.3
PS 4	0.776	0.775	0.17	23.9	21.3	10.9
Prasad	0.762	0.757	0.61	21.4	16.4	23.4
SiA 326	0.774	0.762	1.64	19.7	9.9	49.7
SiA 805	0.773	0.699	9.53	26.4	10.9	58.8
SiA 2854	0.772	0.766	0.86	13.1	8.9	32.6
SiA 3156	0.752	0.704	6.39	27.2	9.0	66.9
	0.763	0.742	2.76	22.2	12.9	39.5
	G	T	G X T	G	T	G X T
	0.003	0.001	0.004	0.78	0.25	1.10
	0.006**	0.002**	0.008**	1.55**	0.49**	2.19**

G: Genotype T: Treatment G x T: Genotype and treatment interaction

In present study, the adverse effect of drought stress on greenness of leaf could be inferred through 39.5 per cent mean reduction in chlorophyll meter readings over control. The genotypes, ISe 138 (6.8), ISe 27 (10.2), PS 4 (10.9) and AP 4 (11.2) recorded less reduction in chlorophyll meter reading in drought condition (Table 1). Consequently, this trait could be well used as selection criteria for identifying drought tolerant crops.

Table 2. Effect of drought on relative water content (%) and chlorophyll stability index (%) of foxtail millet genotypes

Genotypes	Relative water content (%)			Chlorophyll stability index (%)
	Control	Drought	% decrease over control	
AP 3	76.32	40.34	47.1	48.3
AP 4	70.77	66.03	6.6	85.6
GS 1918	86.18	27.03	68.6	29.0
GS 2184	80.08	55.50	30.7	21.8
ISe 1	70.84	61.19	13.6	44.0
ISe 27	61.41	60.23	1.9	96.7
ISe 31	73.46	60.42	17.7	22.9
ISe 138	65.41	61.27	6.3	91.4
ISe 174	75.28	69.66	7.4	74.0
ISe 281	68.15	62.93	7.6	72.9
ISe 317	66.76	61.39	8.0	48.2
ISe 789	73.38	56.34	23.2	50.5
ISe 1230	66.40	56.88	14.3	58.9
Lepakshi	70.45	39.19	44.3	23.6
PS 4	62.82	59.09	5.9	94.2
Prasad	52.63	49.81	5.3	75.4
SiA 326	70.84	46.80	33.9	47.8
SiA 805	56.62	50.23	11.2	30.6
SiA 2854	67.84	62.83	7.3	66.7
SiA 3156	72.69	45.43	37.5	35.1
69.42				
G				
0.53				
1.10**				

G: Genotype T: Treatment G x T: Genotype and treatment interaction

Plant water stress was measured in terms of leaf water potential or leaf relative water content (Deivanai*et al*., 2010). Most important and primary effects of drought stress include reduction in leaf water status (Farooq*et al*., 2010). Relative Water Content (RWC) of drought plants was found to be lower when compared to plants grown under control conditions. In the present study, the genotypes, ISe 27, Prasad and PS 4 maintained higher relative water content with less reduction percentage (1.9, 5.3 and 5.9) comparable to control conditions (Table 2). Thus, higher rate of water flow from the soil to plant helps in better stomatal conductance and more leaf area which help to sustain better transpiration thereby improving the earhead numbers, its size (in terms of length) and final grain yield.

Chlorophyll stability index (CSI) is an important parameter that reflects the ability of the affected plant to sustain photosynthesis under stress and also is a measure of integrity of membrane (Sayed, 1999). In present study, the genotypes ISe 27 (96.7), PS 4 (94.2), ISe 138 (91.4) and AP 4 (85.6) showed higher CSI values (Table 2) indicating that imposed stress did not have a major detrimental effect on chlorophyll content of the tolerant genotypes and thus, helps to maintain photosynthetic machinery.

Rate of water loss from excised leaf conferred the drought tolerance mechanism of low water loss through leaf cuticles (Salim*et al*., 1969). The genotypes PS 4 (1.31), Prasad (1.39), ISe 174 (1.70) and ISe 27 (1.70) showed lower leaf water loss after six hours under drought stress (Table 3). So this lower water loss indicating that these genotypes loose water slowly thus maintains the water status of plants.

A significant negative correlation between excised leaf water loss and relative water content was observed in drought stress (Fig. 1). This might be due to high loss of water from leaf, reduces the

Table 3. Effect of drought on excised leaf water loss (g/g) of foxtail millet genotypes

Genotypes	Excised leaf water loss (g/g) after			Mean
	2 h	4 h	6 h	
AP 3	2.50	3.42	4.00	3.31
AP 4	1.10	1.58	1.90	1.53
GS 1918	1.69	2.49	3.55	2.58
GS 2184	1.20	2.89	3.33	2.47
ISe 1	1.22	1.88	2.32	1.81
ISe 27	1.05	1.48	1.70	1.41
ISe 31	1.06	1.67	2.59	1.77
ISe 138	0.95	1.63	1.67	1.42
ISe 174	0.75	1.40	1.70	1.28
ISe 281	1.36	1.80	2.11	1.76
ISe 317	1.24	1.97	2.31	1.84
ISe 789	1.37	2.33	2.64	2.11
ISe 1230	1.14	2.18	2.59	1.97
Lepakshi	1.84	3.13	3.49	2.82
PS 4	0.90	0.98	1.31	1.07
Prasad	1.13	1.34	1.39	1.29
SiA 326	1.48	2.60	3.23	2.44
SiA 805	1.49	2.26	3.15	2.30
SiA 2854	1.03	1.68	1.95	1.55
SiA 3156	1.22	1.92	3.38	2.17
1.286	1.29	2.03	1.94	
0.13	0.18	0.25		
0.27**	0.36**	0.50**		

turgidity of leaves and therefore, leading to reduce the RWC under drought stress. The negative correlation between excised leaf water loss and relative water content also found by Arzani and Lonbani (2011) who reported that decreased RWC increased the leaf water loss under drought stress and thus, reduced the leaf water retention.

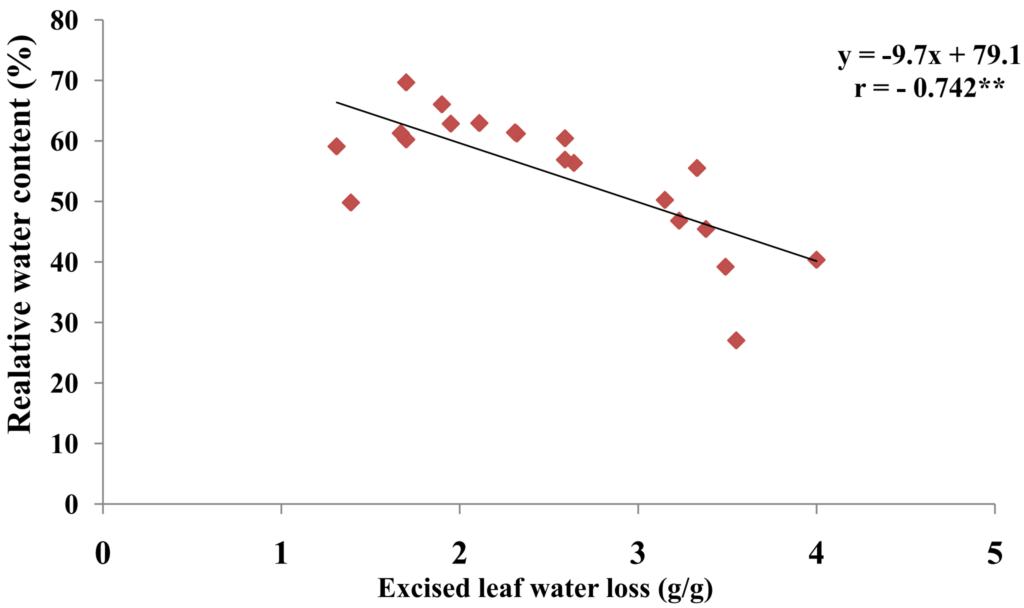

Fig. 1. Correlation between excised leaf water loss (g/g) and Relative Water Content (%) of foxtail millet genotypes in drought

It is concluded that, the present investigation paved a way for identifying tolerant genotypes under drought stress in foxtail millets. The genotypes AP 4 and ISe 138 were showed better results in chlorophyll fluorescence, chlorophyll meter reading, and chlorophyll stability index and classified as drought tolerant genotypes. Finally, the genotypes, ISe 174 and Prasad recorded higher values in two physiological characters therefore, classified as moderate drought tolerant genotypes. This pot culture experiment categorically classified genotypes based on drought associated traits which can be used for breeding programme to develop drought tolerant varieties or parents or developing mapping population to identify QTL associated with drought.

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