Evaluation of the Drought Stress Effects on Cotton Genotypes by Using Physiological and Morphological Traits

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Abstract: ***Drought stress is the major environmental factor that negatively impacts cotton yield throughout the world. Thus, there is a need for a protocol to offer new opportunities for improving drought tolerance in cotton. By understanding the correlation between yield and morphological traits (root length, shoot length, root/shoot ratio), and physiological traits (relative water content (RWC), electrolyte leakage percentage (EL%), membrane stability index (MSI%), Chlorophyll a, chlorophyll b, total chlorophyll, chlorophyll a/b ratio, chlorophyll stability index (CSI)), we can develop efficient screening method able to screen large amounts of plant material in the shortest time possible. In the current study, 21 cotton genotypes (6 parents and their 15 F_1 crosses) were evaluated under two irrigation treatments i.e., 100 % ETc, 1269 mm/season (normal) and 60 % ETc, 761 mm/season (drought). The morphological and physiological traits were studied. Also, correlation between yield and physiological and morphological traits were determined. The results revealed high significant difference among genotypes for all the studied physiological and morphological traits under normal and drought treatments. Although all studied traits in all genotypes were significantly affected by drought but some genotypes such as Tamcot C. E. x Deltapine, Giza 90x (Giza 90X Australian) and Giza 80x Deltapine showed drought tolerance by maintaining the highest values of root length, shoot length, root/shoot ratio, RWC, MSI, Chlorophyll a, b, total chlorophyll, chlorophyll a/b ratio, CSI and lowest values of EL% under drought stress. Yield was correlated with each of the morphological and physiological traits under normal and drought conditions. Therefore, it could be concluded that the morphological and physiological traits could be used as selection criteria for high yield under drought stress.***

Keywords: Cotton Genotypes, Drought, Yield, Correlation, Morphological and Physiological traits

1. Introduction

Drought is the most important factor limiting crop productivity around the world. Among the environmental stresses, drought is one of the most adverse factors for plant growth and productivity (**Reddy *et al.*, 2004** and **Makbul *et al.*, 2011)** and is a complex physical- chemical process **(Apel** and **Hirt, 2004** and **Moaveni, 2011).** Cotton production is adversely affected by water stress **(Pettigrew, 2004; Dağdelen *et al.*, 2006 and Basal *et al.*, 2009)**. Insufficient soil water content during the sensitive growth stages such as the blooming, flowering and fruit-setting stages can lead to a reduced plant height, fresh and dry weight, number of fruiting branches, boll shedding, developed bolls and seeds, seed cotton yield and yield attributes (**Yazar *et al.*, 2002 ; Pettigrew, 2004 and Aujla *et al.*, 2005).**

Root length of plants subjected to low levels of water content registered high significant increases in root length above those of plants irrigated with high water content **(Cook** and **El-Zik, 1992; Prior *et al.*, 1997; Chaitante *et al.*, 2000** and **Abdalla** and **El-Khoshiban, 2007)** and be deeper under drought conditions than irrigated environment **(Hurd** and **Spratt, 1975; Pace *et al.*, 1999; Howard *et al.*, 2001; Basal *et al.*, 2003; Kamara *et al.*, 2003; Rizza *et al.*, 2004; Moinuddin *et al.*, 2005** and **Hufstetler *et al.*, 2007).** Plant growth is one of the most drought-sensitive physiological processes due to the reduction in turgor pressure (**Taiz** and **Zeiger, 2006**) and increasing the severity and duration of drought caused decline in shoot length (**Schuzendubel *et al.*, 2002** and **Abdalla** and **El-Khoshiban, 2007**). The Root/shoot length ratio is adaptive mechanism in response to water deficit, it is considered an important indicator for the ability of a genotype to tolerate drought stress. Root/shoot ratio increased under water stress condition to facilitate water absorption **(Lambers *et al.*, 1998)**.

Relative water content (RWC) is a measure of the amount of water present in the leaf tissue. High RWC under drought stress conditions would be preferable to maintain water balance. Higher RWC in leaf has been reported as selection criteria to breed plants tolerate to drought stress **(Clarke** and **McCaig, 1982; Malik *et al.* 1999** and **Rahman *et al.*, 2000).** Biological membranes are the first target of many abiotic stresses. Membrane stability index (MSI) is reciprocal to cell electrolyte leakage (EL) and both of them are physiological indices widely used for evaluating drought tolerance **(Premachandra *et al.*, 1991).** The drought stress lead to increase in electrolyte leakage in plant leaves **(Sairam** and **Saxena 2000** and **Sibet** and **Birol 2007**). Cell membrane stability index was found to be higher in tolerant genotypes than susceptible genotypes under stress conditions **(Dhanda *et al.*, 2004; Arvin** and **Donnelly, 2008** and **Collado *et al.*, 2010**). Chlorophyll contents as chlorophyll 'a' and chlorophyll 'b' plays a vital role in photosynthetic process which ultimately increases crop growth and yield **(Taiz** and **Zieger, 2006).** Drought stress is one of the factors affecting chlorophyll 'a', 'b', total chlorophyll and a/b ratio **(Ashraf *et al.*, 1994; Havaux, 1998; Delfine *et al.*, 1998; Ashraf** and **Ahamad 2000; Kiani *et al.*, 2008; Massacci *et al.*, 2008** and **Hamayun *et al.*, 2010**). By studying the effect of drought stress on chlorophyll, it was found that drought stress had decreased chlorophyll 'a', 'b', total chlorophyll and a/b ratio **(Araus *et al.*, 1998; Anjum *et al.*, 2003; Kiani *et***

al., 2008; Massacci *et al.*, 2008 and **Hamayun *et al.*, 2010).** Chlorophyll stability index (CSI) is the ratio between total chlorophyll under drought to total chlorophyll under normal irrigation. High CSI is an indicator to drought tolerance. So, **Patil *et al.* (2011)** revealed that CSI was higher in drought tolerant genotypes compared to other susceptible genotypes. The key to an efficient screening method is the ability to screen large amounts of plant material in the shortest time possible. Effective screening methods must evaluate plant performance at critical developmental stages **(Johnson, 1980).** The screening method must be incorporated into plant breeding programs to facilitate meaningful genetic improvement. Plant physiological and morphological traits are now incorporated into the breeding program by using them as selection criteria relevant to the designated plant ideotype and subsequent plant performance in the stress environment. Breeder offers a great potential for the improvement of breeding efficiency towards drought stress **(De Ronde, *et al.*, 2000).** Morphology and Physiology as screening criteria are able to measure various plant characteristics that correlated with drought tolerance, such as root length, shoot length, root/shoot ratio, relative water content, electrolyte leakage percentage, membrane stability index, Chlorophyll a, chlorophyll b, total chlorophyll, chlorophyll a/b ratio, chlorophyll stability index.

2. Material and methods

Plant material: Six divergent parental cotton genotypes and their F_1crosses were used in this investigation to study drought tolerance in cotton (*Gossypium* spp.). The parental cotton genotypes including two exotic varieties belong to G. *hirsutum* L., namely; Deltapine and Tamcot Camd E. (Tamcot C.E.), and four local Egyptian cultivars namely; Giza 80, Giza 86, Giza 90, Giza 90 x Australian (new promising cotton hybrid) belong to G. *barbadense* L. Pure seeds of these varieties were supplied by Cotton Breeding Section, Cotton Research Institute, Agriculture Research Center at Giza, Egypt. The genotypes, pedigree and characterization of these genotypes are presented in **Table 1.**

Table 1: The names, pedigree and the main characteristics of six cotton genotypes used as parents in the present study.

Genotypes	Pedigree	Characteristics
Giza 80	G.66 x G. 73	A long staple cotton variety, early maturity, high yield, good yarn, high lint % and tolerance to high temperature and cultivated in upper Egypt
Giza 86	G.75 x G.81	A long staple cotton variety, characterized by late maturity, high yield and strong lint and cultivated in Delta
Giza 90	Dandara x G.83	A long staple cotton variety, early maturity, high yield, good yarn, high lint % and tolerance to high temperature and cultivated in upper Egypt
Giza 90X Australian	G. 90 x Australian	A long staple cotton variety, characterized by high yielding, early maturity, high lint%, resistance to fuzariam and tolerance to high temperature.
Deltapine	Upland cotton	High yield, high lint %, early maturity, fiber length ranged from 28- 30.
Tamcot Camd E.	Upland cotton	High yield, high lint %, early maturity, fiber length ranged from 28- 30.

Experimental Site: The six parents were crossed in all possible combinations, excluding reciprocals in 2012 growing season at the farm of Fac., Agric., Ain-Shams univerisity, Shoubra El-Kheima, Qalyubia governorate, Egypt. to obtain a total of 15 F_1 hybrids. In 2013 growing season, the six parents and their 15 F_1's (21 genotypes) were planted on 2^{nd} of April and evaluated for drought tolerance in sandy soil conditions in a private farm at Shebin El-Kanater, Qalyubia governorate, Egypt.

Water treatments: Two separate experiments were carried out one for each water treatment. The first water treatment was irrigation at 100% Etc, 1269 mm/season which represent normal water treatment, and the second was irrigation at 60% Etc, 761 mm/season which represent drought stress. The total amount of irrigation water was calculated according to Penman-Montieth method **(Allen *et al.*, 1996),** Penman-Monteith method gives more consistently accurate ETo estimates than other ETo methods**.** Drip irrigation system was installed; the drip lateral had emitters spaced 30 cm apart with a nominal discharge of 4 liters/h. Blocks were irrigated using an electric timer with appropriate run times to give the desired application of water.

Experimental design: The experimental design was arranged in a randomized complete blocks with three replicates. Ridges were 6 m long and 120 cm width and seeds were planted on the both ridge sides, each genotype on one side. Hills were spaced at 25 cm on the ridge side with two seedlings per hill.

Soil preparation: During land preparation, the soil was fertilized by 30 m^3 compost. Phosphorous fertilizer as superphosphate (15.5% P_2O_5) at a rate of 22.5 kg P_2O_5/fed, nitrogen fertilizer as ammonium nitrate (33.5% N) at a rate of 90 kg N/fed, and potassium fertilizer as potassium sulfate (48% K_2O) at a rate of 50 K_2O/fed. were applied in five equal doses with irrigation water as recommended by Cotton Research Institute, Agriculture Research Center at Giza, Egypt. Picking of experiments was carried out on 26^{th} of October.

Measurements

After 60 days from sowing (blooming stage), ten plants were randomly selected from each replicate and the following parameters were determined;

Morphological traits:-
1) Root length: plants were cultivated in plastic tubes 75 cm tall x 12 cm wide and filled with fine sand (**Riaz et al., 2013**),
2) Shoot length,
3) Root/shoot ratio.

Physiological traits:-
1) Relative water content (RWC%) **(Weatherley, 1950),**

2) Electrolye leakage (EL%) **(Arora et al. 1992),**
3) Membrane stability index (MSI) (**Premachandra et al., 1990**),
4) Chlorophyll a (mg g-1 FW) (**Hiscox and Israelstam, 1979**),
5) Chlorophyll b (mg g-1 FW) (**Hiscox and Israelstam, 1979),**
6) Total Chlorophyll (mg-1 g FW) **(Hiscox and Israelstam, 1979),**
7) Chlorophyll a/b ratio,
8) Chlorophyll stability index: determined as the ratio between total chlorophyll under drought to total chlorophyll under normal irrigation.

Seed cotton yield, at maturity ten plants were randomly selected from each replicate.

Statistical analysis: Analysis of variance and the expectations of mean squares for single and combined data were performed according to **Gomez and Gomez (1984).** Differences between means were tested using the least significant difference (L.S.D.) test according **Waller** and **Duncan (1969)** at the 5% level of probability. Correlation coefficients between any two characters were performed as described by **Mode** and **Rhobinson, (1959)** and modified by **Singh and Narayanan, (1993).**

3. Results and Discussion

Morphological traits

Data presented in **Table 2** indicate mean performance of morphological traits under normal and drought treatments. Regarding root length, the data show that the root length significantly increased by decreasing water treatment, it reached to its maximum length by drought treatment and its minimum length under normal treatment**.** The results indicate that water stress treatment had positive effect on root length. The highest root length was obtained from Deltapine, P5xP6 and P2xP4 under normal water and P5xP6, P3xP4 and P1xP6 under drought. Combined analysis results show that P5xP6 produced longest roots under normal and drought treatments. The root length of plants subjected to low levels of water content registered high significant increase in root length above those plants irrigated with high water content, such increase in linear growth of roots is attributed to either the increase in the gibberellins and cytokinin contents or to the ability of roots to branch and elongate quickly in an attempt to reach deeper levels to absorb its needs from underground water which thus enable plants to survive properly irrespective of water stress **(Zhong and Lauchli, 1993; Rizza et al., 2004; Mahajan and Tuteja, 2005; Moinuddin et al., 2005; Abdalla and El-Khoshiban, 2007; Hufstetler et al., 2007 and Afshari et al., 2011).**

Shoot length increased by increasing the water treatment **Table 2,** it reached its minimum length by subjecting plants to normal irrigation **(Pace et al., 1999; Basal et al., 2003 and Abdalla and El-Khoshiban, 2007).** Significant differences among genotypes under both water treatments were observed. The longest shoots were recorded by the genotypes P1xP3, P3xP6 and P3xP4 under normal treatment and P3xP4, P5xP6 and P1xP5 under drought stress. Combined analysis results reveal that the genotypes P3xP4 and P5xP6 maintained the longest shoots in both water treatments. **Basal et al. (2003); Taiz and Zeiger (2006) and Abdalla and El-Khoshiban (2007)** declared that increase the severity and duration of drought resulted in decline in shoot length. Such decrease in shoot elongation in response to drought may be to decrease in cell elongation resulting from water shortage and/or due to blocking up of xylem and phloem vessels **(Abdalla and El-Khoshiban 2007).**

Data presented in **Table 2** indicate the root/ shoot ratio. Root /shoot ratio increased by decreasing water treatment. Under normal irrigation, it's found that Tamcot C.E., Deltapine, P2xP4 and P5xP6 recorded the highest performance in comparison with the others. Under drought, the genotypes Tamcot C.E., Deltapine and P2xP6 gave highest performance. Combined analysis reported that Deltapine and Tamcot C.E. maintained highest performances under the two water treatments. Root/shoot ratio increased under water stress condition to facilitate water absorption and increased in drought tolerant

genotypes under drought **(Lambers et al., 1998; Pace et al., 1999; Kumar 2010; Shah et al., 2011 and Sumartini et al., 2013).**

Table 2: Mean performance of cotton genotypes for morphological traits under normal (N) and drought (D) treatments

Genotypes	Root length (cm)			Shoot length (cm)			Root/Shoot ratio		
	N	D	Combined	N	D	Combined	N	D	Combined
Giza 80 (P1)	23.77	43.68	33.72	42.37	37.32	39.84	0.57	1.18	0.87
Giza 86 (P2)	19.95	33.72	26.83	41.63	32.73	37.18	0.48	1.03	0.76
Giza 90 (P3)	21.12	43.83	32.47	52.57	37.62	45.09	0.41	1.17	0.79
Giza 90 x Australian (P4)	31.78	38.24	35.01	47.9	35.93	41.92	0.67	1.08	0.87
Tamcot C. E . (P5)	26.48	45.66	36.07	31.11	24.81	27.96	0.88	1.84	1.36
Deltapine (P6)	42.51	34.26	38.38	48.62	21.5	35.06	0.88	1.6	1.24
Mean	27.6	39.9	33.75	44.03	31.65	37.84	0.65	1.32	0.98
P1xP2	28.3	33.63	30.96	53.85	33.1	43.47	0.53	1.02	0.77
P1xP3	22.26	40.97	31.61	58.63	38.69	48.66	0.38	1.06	0.72
P1xP4	19.48	43.69	31.59	52.69	40.48	46.59	0.37	1.08	0.73
P1xP5	24.47	45.84	35.16	53.94	46.87	50.4	0.48	0.98	0.73
P1xP6	26.86	52.87	39.87	46.03	44.43	45.23	0.59	1.19	0.89
P2xP3	28.09	29.8	28.94	50.24	32.56	41.4	0.56	0.92	0.74
P2xP4	33.58	29.78	31.68	41.53	34.3	37.91	0.82	0.87	0.84
P2xP5	25.89	41.12	33.51	43.74	42.14	42.94	0.6	0.98	0.79
P2xP6	23.05	43.74	33.39	38.63	28.5	33.57	0.6	1.54	1.07
P3xP4	22.28	55.83	39.06	55.23	49.5	52.37	0.48	1.01	0.75
P3xP5	26.02	30.17	28.1	40.44	24.9	32.67	0.65	1.22	0.94
P3xP6	19.54	54.54	37.04	56.81	44.14	50.47	0.35	1.24	0.8
P4xP5	28.43	37.32	32.87	37.73	29.09	33.41	0.75	1.29	1.02
P4xP6	27.86	44.21	36.03	38.29	34.15	36.22	0.73	1.3	1.01
P5xP6	36.11	55.59	45.85	49.46	46.74	48.1	0.78	1.13	0.95
Mean	26.15	42.61	34.38	47.82	37.97	42.89	0.58	1.12	0.85
Grand mean	26.87	41.25	34.06	46.74	36.17	41.46	0.61	1.22	0.92
L.S.D. 0.05									
Genotypes (G)	5.34	3.54	3.15	7.5	3.11	3.43	0.2	0.19	0.13
Irrigation (I)			0.97			1.06			0.04
G x I			4.46			4.85			0.19

4. Physiological Traits

Data in **Table 3** show that significant reduction was observed in leaf relative water content % (RWC) for all the genotypes under drought stress similar results were observed by **Malik et al. (1999); Rahman et al. (2000); Siddique et al. (2000) and Parida et al. (2007).** Significant differences among cotton genotypes under both treatments were observed.

The highest RWC% was maintained by P1xP5, P3xP4 followed by Giza 86 (P2) under normal irrigation and P3xP4 followed by P1xP5 then P1xP4 and P5xP6 under drought stress. Combined analysis data reveal that the highest value of RWC% obtained by P1xP5 and P3xP4 genotypes under both normal and stress treatments. Oxidative injury at the cellular level under water stress has high lipid peroxidation which decreased stability of cell membrane and led to lose more water from cells **(Sairam and Saxena, 2000; Sanchez-Blanco et al., 2006 and Abdalla and Khoshiban, 2007)**

Electrolyte leakage (EL %) is routinely used as indicator to assess the integrity and permeability of cell membrane and resulting in leakage of intracellular contents **(Arvin and Donnelly, 2008).** EL % was relatively changed in the genotype leaves under normal and stress treatments as shown in **Table 3.** Results show that the normal water treatment caused significant decrease in EL % of the genotypes leaves in comparison with drought stress. P2xP3, Giza 86 followed by P4xP6 and P3xP4 recorded the lowest values of EL % under normal water condition. P3xP4 followed by P1xP5, P1xP4, Giza 86 and P5xP6 recorded the lowest values of EL % under drought stress. Combined analysis results elucidate that the genotypes P1xP5 and P3xP4 could survive better under non-stressed and stressed conditions. Similar trends were obtained by **Premachandra et al., (1991); Sairam and Saxena (2000); Bajji et al., (2002); Sibet and Birol, (2007).** The plasma membrane is generally protected from desiccation-induced damage by presence of membrane-compatible solutes, such as sugars and amino acid. Therefore, a link may exist between the capacity for osmotic adjustment and degree of membrane protection **(Sibet and Birol, 2007).** The water stress-induced decrease in membrane stability indicates the extent of lipid peroxidation caused by active oxygen species **(Menconi et al., 1995 and Sibet and Birol, 2007).**

Membrane stability index (MSI %) has been measured as percentage injury of leaf tissues of cotton genotypes under drought stress, it can be used to screen for drought stress. Considerable genotypic variation for cell membrane stability index was present among the cotton genotypes **Table 3.** The highest values of MSI% were recorded by the genotypes P5xP6 followed by Giza 86, P3xP4 and Giza 90 under the normal irrigation and P3xP4, P1xP5, P5xP6 and Tamcot C.E. under drought stress. The combined analysis data indicate that higher MSI% was recorded by the genotypes P5xP6, P3xP4 under both treatments. These results were similar to those obtained by **(Premachandra et al., 1991; Tripathy et al., 2000; Bajji et al., 2002 and Ashraf, 2009).** The plasma membrane is generally protected from desiccation-induced damage by presence of membrane-compatible solutes, such as sugars and amino acid. Therefore, a link may exist between the capacity for osmotic adjustment and degree of membrane protection **(Sibet and Birol, 2007).** The drought stress induces decreasing in membrane stability which indicates that the extent of lipid peroxidation caused by active oxygen species **(Dhindsa et al., 1981; Menconi et al., 1995 and Sibet and Birol, 2007).**

Concerning chlorophyll 'a', 'b', total chlorophyll, chlorophyll a/b ratio and chlorophyll stability index (CSI %), it's found significant differences for chlorophyll 'a', 'b', total chlorophyll, chlorophyll a/b ratio and CSI % among the cotton genotypes under normal and drought conditions as shown in **Table 3.** Results in the present study indicate that the highest values were recorded by Giza 86 followed by P3xP4 and P5xP6 for chlorophyll 'a' ; P3xP4 followed by P5xP6 and Giza 80 for chlorophyll 'b'; P3xP4 followed by P5xP6 and Giza 80 for total chlorophyll and P2xP4 followed by P2xP6, P1xP6 and P1xP2 for chlorophyll a/b under normal irrigation. Exposing plants to drought stress exerted minimum chlorophyll content of leaves in comparison with normal treatments. Highest values were recorded by P5xP6 followed by Tamcot C.E. and P3xP4 for chlorophyll 'a' ; P3xP4 followed by P1xP3 for chlorophyll 'b'; P5xP6 followed by P3xP4 and Tamcot C.E. for total chlorophyll and Giza 90xAustralian, Giza 86 and Deltapine for chlorophyll a/b ratio. Highest CSI % was recorded by P3xP5, P1xP3, Tamcot C.E. and P5xP6. Combined analysis results elucidated that P3xP4 and P5xP6 had highest values under normal and drought treatments in compared to the others **Table 3.** Similar trends were obtained by **(Ashraf et al., 1994; Havaux, 1998; Anjum et al., 2003; Kiani et al., 2008; Massacci et al., 2008 and Patil et al., 2011).** The decrement of chlorophyll content during drought stress could be related to photo-oxidation resulting from oxidative stress which reduces photosynthetic process **(Delfine et al., 1998; Ashraf, 2009 and Hamayun et al., 2010).**

Seed cotton yield

Regarding seed cotton yield per plant, data presented in **Table 3** reveal that decreasing water irrigation level significantly decreased cotton yield per plant and reached its maximum values under normal irrigation. Similar results were obtained by **DeTar (2008); Basal et al. (2009); Onder, et al. (2009); Aboeldhab et al. (2012) and Hamoda (2012).** Results indicate that significant differences among genotypes under normal irrigation and highest seed cotton yield per plant was recorded by the genotypes P3xP4, P5xP6 followed by P1xP5. Under the drought stress, P3xP4, P5xP6 followed by Giza 90 and P1xP5 recorded the highest performance for seed cotton yield/plant. Combined analysis data indicate that the highest seed cotton per plant was recorded by genotypes P3xP4, P5xP6 and P1xP5. Water stress during peak flowering had the most detrimental effects on seed cotton yield **(Orgaz et al., 1992 and Krieg, 1997).**

	Relative water content %			Electrolyte leakage %			Membrane stability index			Chlorophyll a (mg g F W.)		
Genotypes	N	D	Combined	N	D	Combined	N	D	Combined	N	D	Combined
Giza 80 (P1)	61.05	37.41	49.23	13.72	46.79	30.25	57.07	17.88	37.48	0.82	0.54	0.68
Giza 86 (P2)	89.18	27.59	58.38	9.14	71.59	40.36	61.31	12.22	36.76	0.94	0.42	0.68
Giza 90 (P3)	77.08	36.37	56.72	9.17	57.18	33.18	60.08	19.94	40.01	0.86	0.51	0.69
Giza 90 x Australian (P4)	71.25	38.81	55.03	20.5	51.2	35.85	48.37	14.98	31.68	0.86	0.46	0.66
Tamcot C. E . (P5)	58.25	31.79	45.02	14.54	60.43	37.48	45.75	23.76	34.76	0.86	0.68	0.77
Deltapine (P6)	57.68	29.83	43.76	20.64	63.06	41.85	36.63	11.75	24.19	0.81	0.38	0.6
Mean	69.08	33.63	51.36	14.62	58.38	36.5	51.54	16.76	34.15	0.86	0.5	0.68
P1xP2	62.21	34.37	48.29	17.56	73.74	45.65	44.06	16.22	30.14	0.89	0.35	0.62
P1xP3	71.11	39.72	55.42	17.33	53.26	35.29	51.4	21.94	36.67	0.78	0.49	0.64
P1xP4	53.53	40.78	47.15	18.15	46.59	32.37	55.05	22.4	38.72	0.82	0.44	0.63
P1xP5	92.95	43.65	68.3	13.72	43.08	28.4	59.37	24.33	41.85	0.88	0.52	0.7
P1xP6	76.47	33.21	54.84	13.76	72.84	43.3	49.47	18.5	33.99	0.75	0.3	0.53
P2xP3	68.84	34.57	51.71	8.91	77.49	43.2	44.55	18	31.27	0.82	0.28	0.55
P2xP4	71.54	29.74	50.64	16.36	73.93	45.15	37.02	17.09	27.06	0.78	0.28	0.53
P2xP5	50.7	31.94	41.32	38.72	66.49	52.6	48.59	19.93	34.26	0.89	0.35	0.62
P2xP6	51.8	28.41	40.1	30.62	71.52	51.07	51.9	12.11	32.01	0.76	0.23	0.5
P3xP4	92.72	44.1	68.41	11.64	36.55	24.1	61.02	25.77	43.39	0.93	0.59	0.76
P3xP5	68.33	39.6	53.97	19.44	48.89	34.17	45.21	19.01	32.11	0.72	0.51	0.62
P3xP6	63.55	33.8	48.67	24.31	66.08	45.2	56.57	16.38	36.47	0.87	0.36	0.62
P4xP5	60.89	36.16	48.52	22.96	70.78	46.87	47.48	12.72	30.1	0.81	0.29	0.55
P4xP6	65.43	33.53	49.48	11.11	55.62	33.36	55.24	18.91	37.07	0.8	0.31	0.56
P5xP6	67.3	40.62	53.96	14.61	47.5	31.06	65.25	23.92	44.58	0.91	0.69	0.8
Mean	67.82	36.28	52.05	18.61	60.29	39.45	51.48	19.15	35.31	0.83	0.4	0.62
Grand mean	68.18	35.52	51.85	17.47	66.46	41.96	51.49	18.46	34.98	0.84	0.43	0.63
L.S.D. 0.05												
Genotypes (G)	1.38	1.09	0.87	1.59	2.09	1.29	0.81	1.48	0.83	0.05	0.03	0.03
Irrigation (I)			0.27			0.4			0.26			0.01
G x I			1.23			1.83			1.18			0.04

Genotypes	Chlorophyll b (mg g F W.)			Total Chlorophyll (mg g F W.)			Chlorophyll a/b ratio			Chlorophyll stability %	Seed cotton yield/ plant (g)		
	N	D	Combined	N	D	Combined	N	D	Combined	*CSI%*	N	D	Combined
Giza 80 (P1)	0.53	0.2	0.37	1.36	0.75	1.06	1.55	2.65	2.1	55.42	50.02	29.63	39.82
Giza 86 (P2)	0.52	0.13	0.33	1.47	0.56	1.02	1.79	3.2	2.5	39.65	62.66	18.97	40.82
Giza 90 (P3)	0.47	0.21	0.34	1.34	0.73	1.04	1.83	2.41	2.12	58.01	55.44	33.14	44.29
Giza 90 x Australian (P4)	0.5	0.14	0.32	1.36	0.59	0.98	1.73	3.37	2.55	42.52	49.65	22.32	35.99
Tamcot C. E . (P5)	0.51	0.22	0.37	1.36	0.9	1.13	1.69	3.13	2.41	62.01	63.51	29.61	46.56
Deltapine (P6)	0.44	0.12	0.28	1.26	0.51	0.88	1.83	3.16	2.5	40.17	60.58	20.93	40.75
Mean	0.5	0.17	0.34	1.36	0.67	1.02	1.74	2.99	2.36	49.63	56.98	25.77	41.37
P1xP2	0.44	0.16	0.3	1.33	0.51	0.92	2	2.22	2.11	39.01	61.83	18.02	39.92
P1xP3	0.45	0.29	0.37	1.23	0.78	1.01	1.76	1.68	1.72	64.76	62.89	27.46	45.17
P1xP4	0.47	0.3	0.38	1.3	0.74	1.02	1.75	1.5	1.62	56.32	47.73	24.97	36.35
P1xP5	0.47	0.27	0.37	1.35	0.79	1.07	1.88	1.9	1.89	59.85	71.18	32.49	51.84
P1xP6	0.34	0.17	0.25	1.09	0.47	0.78	2.19	2.04	2.12	45.48	54.24	21.35	37.8
P2xP3	0.45	0.11	0.28	1.27	0.39	0.83	1.84	2.6	2.22	30.41	45.07	15.69	30.38
P2xP4	0.34	0.18	0.26	1.12	0.46	0.79	2.3	1.57	1.94	40.95	42.21	15.85	29.03
P2xP5	0.47	0.24	0.36	1.35	0.6	0.98	1.9	1.45	1.68	43.54	60.35	24.91	42.63
P2xP6	0.35	0.19	0.27	1.11	0.42	0.77	2.2	1.26	1.73	37.93	48.25	19.05	33.65
P3xP4	0.66	0.32	0.49	1.59	0.91	1.25	1.42	1.8	1.61	58.41	85.72	38.52	62.12
P3xP5	0.38	0.2	0.29	1.1	0.71	0.91	1.89	2.5	2.2	64.27	51.82	23.03	37.42
P3xP6	0.46	0.12	0.29	1.34	0.48	0.91	1.88	3.01	2.45	39.13	60.87	23.78	42.32
P4xP5	0.4	0.15	0.28	1.22	0.44	0.83	2.03	1.97	2	34.74	51.45	19.75	35.6
P4xP6	0.49	0.2	0.35	1.3	0.51	0.91	1.64	1.5	1.57	38.97	62.1	25.82	43.96
P5xP6	0.63	0.26	0.45	1.54	0.95	1.25	1.46	2.62	2.04	59.73	80.48	37.26	58.87
Mean	0.45	0.21	0.33	1.28	0.61	0.95	1.88	1.97	1.93	47.57	59.08	24.53	41.8
Grand mean	0.47	0.2	0.33	1.3	0.63	0.97	1.84	2.26	2.05	48.16	58.03	25.15	41.59
L.S.D. 0.05													
Genotypes (G)	0.04	0.03	0.03	0.07	0.04	0.04	0.22	0.36	0.21	3.89	7.31	3.45	3.98
Irrigation (I)			0.01			0.01			0.06				1.23
G x I			0.04			0.05			0.29				5.63

Correlation study between yield and morphological traits
Under normal and drought treatments **Table 4,** seed cotton yield per plant was positively and significantly correlated with root length (cm). It is notable that shoot length (cm) is negatively and significantly correlated with yield under drought and not under normal. Therefore, it could be concluded that shoot length (cm) could be used as selection criterion for high yield under drought stress. Similar trend were reported by **Afiah and Ghoneim (2000) and Iqbal et al., (2003).**

Table 4: Correlation between yield and morphological traits under normal (upper diagonal) and drought (lower diagonal) treatments

Traits	Root/Shoot ratio	Shoot length (cm)	Root length (cm)	Seed cotton yield/ plant
Root/Shoot ratio	1	-0.702**	0.810**	0.343
Shoot length (cm)	-0.558**	1	-0.185	0.031
Root length (cm)	0.156**	0.721**	1	0.585**
Seed cotton yield/ plant	0.04	0.611**	0.715**	1
* and** denote significant at 0.05 and 0.01 levels of probability, respectively.				

Correlation Study between Yield and Physiological Traits

To identify the most desirable physiological traits as screening criteria, correlation between yield and physiological traits is presented in **Table 5.** Under normal irrigation, correlation analyses reveal that yield was positively and significantly correlated with total chlorophyll, chlorophyll ‘b’, chlorophyll ‘a’, membrane stability index and relative water content% but negatively and significantly correlated with chlorophyll a/b ratio and electrolyte leakage %. Under drought treatment, it’s found that yield was positively and significantly correlated with total chlorophyll, chlorophyll ‘b’, chlorophyll ‘a’, membrane stability index and relative water content % and negatively and significantly correlated with electrolyte leakage %.

Maximum correlation values were recorded by total chlorophyll, chlorophyll ‘b’, chlorophyll ‘a’, and membrane stability index under normal and drought treatments.

Table 27: Correlation between yield and physiological traits under normal (upper diagonal) and drought (lower diagonal) treatments

Traits	Chl. a/b	Total Chl.	Chl. b	Chl. a	MSI	EL %	RWC %	SCY
Chl. a/b	1	-0.820**	-0.935**	-0.550**	-0.447*	0.31	-0.123	-0.566**
Total Chl.	0.25	1	0.960**	0.922**	0.602**	-0.301	0.32	0.714**
Chl. b	-0.419	0.762**	1	0.779**	0.560**	-0.319	0.261	0.698**
Chl. a	0.506*	0.958**	0.546*	1	0.554**	-0.217	0.346	0.639**
MSI	-0.106	0.796**	0.811**	0.675**	1	-0.289	0.427	0.552**
EL %	-0.076	-0.826**	-0.747**	-0.743**	-0.656**	1	-0.637**	-0.183
RWC	-0.011	0.680**	0.668**	0.593**	0.691**	-0.819**	1	0.446*
SCY	0.096	0.897**	0.758**	0.826**	0.767**	-0.816**	0.663**	1

* and** denote significant at 0.05 and 0.01 levels of probability, respectively.

SCY, RWC, EL, MSI, Chl. a, Chl. B, total Chl., Chl. a/b are seed cotton yield/ plant, relative water content%, electrolyte leakage %, membrane stability index, chlorophyll a, b, total chlorophyll (mg g F W.), chlorophyll a/b ratio, respectively.

5. Conclusion

By reviewing the above results, it’s concluded that most morphological and physiological traits are more effective criteria in identifying high yield genotypes under drought and it is better to use each of chlorophyll ‘a’, electrolyte leakage %, membrane stability index and relative water content% as efficient screening method able to screen large amounts of plant material in the shortest time possible and select the most efficient genotypes.

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