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Evaluation of cotton (*Gossypium hirsutum* L.) genotypes to drought stress

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Abstract

Drought stress is one of the most important abiotic stresses in plants. To evaluate the effect of drought stress on some cotton traits, 15 cotton genotypes were studied in a randomized complete block design with three replications at Agriculture Research station of Firoozabad, Fars, Iran during spring 2012. Two greenhouse experiments were performed under complete irrigation as control and under drought stress condition. The irrigation was done on every alternate day with normal tap water. After 45 days from sowing, a drought cycle was induced by restricting irrigation for 7 days. Normal regime was irrigated regularly. The studied traits were plant height, leaf area, number of nodes/plant, number of branch/plant, plant dry matter weight, number of bolls/plant and seed cotton yield. Seed cotton yield was reduced by drought stress (%47.03) that was probably due to decrease number of bolls/plant. In this study, the studied varieties were differed in their responses to drought stress. Therefore, it was possible to discriminate among these varieties on the basis of these parameters and there was a clear-cut distinction between varieties for tolerance and susceptibility to water stress. Based on the results, Mehr, Sahel and Varamin genotypes were suitable genotypes under drought stress and non-stress conditions and Shirpane 603 was the worst genotype.

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Introduction

Cotton (*Gossypium hirsutum* L.) is the leading natural fiber crop and is grown on 33.9 million hectares worldwide which produces 120.3 million bales. It contributes more than 60% of the total foreign exchange in the economy of Iran (Alishah and Ahmadikhah, 2009). Like other crops, the cotton production has reached a plateau because of narrow genetic base (Rahman *et al.,* 2008). In the present scenario, cotton production fluctuates substantially because of abiotic and biotic stresses. Among the abiotic stresses, drought is recognized as the most devastating which limits the cotton production markedly. Due to quantitative expression of drought tolerance trait, breeding efforts have not met the expectations (Parida *et al.,* 2007). Drought stress significantly reduces crop production by affecting many agronomic traits like reduction in size and number of bolls per plant, plant height, above ground fresh weight, seed cotton yield etc. (Malik *et al.,* 2006).

For successful breeding of cotton cultivars tolerant to drought through conventional approach, basic information about the breeding material must be available to the breeders. Firstly, there must be significant variability in genotypic responses to water stress and secondly, this variation must be genetically controlled. Thus, an understanding of the knowledge of these two components about the breeding material under consideration is necessary (Mitra, 2001). Pettigrew (2002) indicated that moisture deficit created by the dry land treatment consistently affected reproductive part development at all stages. Flowering was primarily affected late in the growing season. The plants in the irrigated plots consistently produced significantly higher number of blooms per unit ground area than did plants in dry land plots. Payton *et al.,* (2004) reported that when water was withheld from flowering cotton plants for 7 days, many of the bolls that were at elongation phase abscised and those that did not abscise were found to have drastically reduced size.

Kar *et al.* (2001) reported that yield and yield attributes decreased significantly in all the varieties in response to water stress imposed at flowering stage. The flowering stage in cotton was found to be critical to moisture stress. Significant genotypic difference for physiological attributes and seed cotton yield existed both under irrigated and water stress conditions. However, the genotypic differences were non-significant for dry stem weight and boll weight (Ahuja and Tuteja, 2001).

The aim of this study was to evaluate of genetic variability of drought tolerance among fifteen cotton cultivars in greenhouse experiments.

Material and methods

Fifteen cotton (*Gossypium hirsutum* L.) varieties (Deltapayne-25, Bakhtegan, Varamin, Mehr, Say okra, Shirpane 603,Armaghan, Sahel, Khordad, Oltan, Golestan, N-200, SB_{35}, 84-39-T_3 and SP731) were obtained from Agricultural Research Center, Karaj, Iran. Two greenhouse experiments were conducted at Agriculture Research station of Firoozabad, Fars, Iran during spring 2012 (located at 52°, 15´N & 52°, 40S) and 1876 m altitude. The minimum and maximum cultivation temperatures were 21.1 and 38.1°C, respectively. The annual raining was 550 mm by average and it had a relative humidity of 36%. Response of 15 genotypes of *G. hirsutum* was assessed in greenhouse. The optimum temperature in glasshouse was maintained at 35/21°C (day/night).

Seeds of 15 genotypes were planted during April, 2012 in pots measuring 25 cm × 15 cm, filled with about 1.5 kg of silt mixed with 100 g farm yard manure. The pH of soil was of 8.4, EC 1.2 dS/m, saturation 31%. Soil in the bags was saturated to field capacity before planting overnight soaked seeds. Ten holes, each 3 cm deep, were made in each pot and ten seeds were sown in one hole. After germination, seedlings were thinned to one seedling per hole and thus, there were four seedlings per pots. There were two sets of experiment, each having 15 genotypes. In each treatment, the pots were arranged following

Randomized Complete Block design in triplicate. Initially, seedlings in both the sets were watered and fertilized till the development of first true leaf. Thereafter, in one set, supply of water was withheld to develop water stressed conditions, whilst in other set; seedlings were grown under normal moisture condition to designate as control.

The irrigation was done on every alternate day with normal tap water. After 45 days from sowing, a drought cycle was induced by restricting irrigation for 7 days. Normal regime was irrigated regularly. The seeds were treated in concentrated sulfuric acid for 20 minutes to remove the extra lint from surface. The seeds were washed thoroughly and soaked for 12 hours in tap water and surface dried in shade to remove extra moisture. For recording various biometric observations, five plants were selected randomly in each pot and tagged and observations were recorded at physiological maturity. The studied traits were plant height (cm), leaf area (cm^2), number of nodes/plant, number of branches/plant, plant dry matter weight (g), number of bolls/plant and seed cotton yield (g/plant). Leaf area was calculated by using the formula given by Ashley *et al.,* (1963).

Leaf area=W×L×0.77 Where, W=leaf width and L=leaf length.

The plant samples were partitioned into leaves, stem and reproductive parts and dried separately at 80°C in hot air oven for 72 hours. Completely dried samples were weighed and the dry weight of different plant parts was expressed in g per plant basis. The total number of bolls set on a plant was recorded on five tagged plants from each pot and mean was worked out. Reduction percentage was calculated as follows:

% Reduction = $\frac{Yp-Ys}{Yp} \times 100$ (Choukan *et al.,* 2006).

Where, Yp is the yield under non-stress condition, Ys the yield under stress, $\bar{Y}p$ and $\bar{Y}s$ the mean yields of all genotypes under non-stress and stress conditions, respectively.

Statistical analysis

The data were tested for skewness, kurtosis, homogeneity of variance and normality by Minitab (1998) statistical software. Then, Analysis of variance based on Randomized Complete Block design was performed by SAS software. We applied Duncan's Multiple Range Test at 0.05 probability levels using SAS (2001) and MSTAT-C (1990) softwares.

Results and discussion

The data was tested for normality and uniformity of variance. Then, analysis of variance based on randomized complete block design (RCBD) was performed (Table 1). The results showed that effect of genotype on all studied traits were significant at 1% probability level under drought stress and non-stress conditions, indicating the existence of genetic variability for these traits.

Table 1. Analysis of variance for studied traits of fifteen cotton genotypes under non-stress and stress conditions.

SOV	df	Mean Squares (MS)													
		Plant height (cm)		Leaf area (cm^2)		Number of nodes/plant		Number of branches/plant		Plant dry matter weight (g)		Number of bolls/plant		Seed cotton yield (g/plant)	
		Non-stress	Stress	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress
Block	2	11.23 **	0.012 ns	252.26 **	6.48 ns	4.28 **	1.08 ns	11.28 **	1.66 ns	15.94 **	2.04 ns	48.6 **	8.08 *	56.96 **	13.79 ns
Genotype	14	40.16 **	2.47 **	1118.4 **	93.95 **	5.74 **	6.87 **	5.8 **	6.46 **	168.8 **	54.1 **	23.9 **	11.1 **	27.7 **	44.2 **
Error	28	0.289	0.34	4.06	2.036	0.169	1.12	0.265	1.54	0.251	2.28	0.909	2.27	2.59	4.77
CV (%)		0.66	1.44	2.44	5.8	3.01	8.1	4.5	11.58	0.36	2.35	3.6	14.27	2.39	6.14

CV: Coefficient of Variation, ns, * and **: Not significant, significant at the 5% and 1% levels of probability, respectively.

Plant height

Based on the results of mean comparison, 84-39-T3 and Say okra genotypes had the highest and lowest amount of plant height in non-stress condition (90.1 and 75.7 cm, respectively) (Table 2). So, 84-39-T3 genotype can be used for increasing plant height. SB35 and Sahel genotypes had the highest and lowest amount of plant height in stress condition (42.77 and 39.53 cm, respectively), indicating the effect of drought stress on this trait (Table 2).

Table 2. Effect of genotypes on traits in cotton genotypes under non-stress and stress conditions.

Genotype	Plant height (cm)		Leaf area (cm²)		Number of nodes/plant		Number of branches/plant		Plant dry matter weight (g)		Number of bolls/plant		Seed cotton yield (g/plant)	
	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress
Deltapayne-25	82.1 d	41 bcd	119.07 a	29.8 ab	13.33 ef	11.33 ef	10.67 f	8.67 ef	145.5 c	71.89 a	25 cd	9.33 bc	64.4 ef	35.58 bcd
Bakhtegan	78.1 gh	40.13 def	58.13 j	19.7 e	12.67 fg	12.3 c-f	10.67 f	10 b-f	125.3 k	61.33 cde	22.33 ef	11.33 b	62.13 f	38.28 bc
Varamin	80.8 e	40.43 c-f	84.12 f	19.8 e	14.67 bc	14.3 abc	11.67 de	11.3 a-d	137.7 f	62.83 cd	28.67 b	11.67 b	69.4 abc	38.66 b
Mehr	82.5 d	41.1 bcd	70.98 h	29.3 ab	15.33 ab	15 ab	12.67 bc	12.7 a	140.6 d	68.89 b	27.33 b	14.67 a	69.6 abc	43.53 a
Say okra	75.7 i	40.63 c-f	70.8 h	23.6 d	13.33 ef	11.7 def	11.67 de	9.3 c-f	126.3 j	59.42 ef	24 cde	9.33 bc	66.8 cde	34.36 cde
Shirpane 603	85.6 b	41.5 bc	64.59 i	31.5 a	14.67 bc	13.7 bcd	12 cd	12 ab	147.5 b	67.91 b	25.33 c	9.67 bc	63.6 f	31.45 def
Armaghan	78.5 g	40.23 def	78.77 g	15.38 f	12.33 g	11.7 def	9.33 g	9 def	137.6 f	63.87 cd	23.3 def	9 bc	66.8 cde	30.51 ef
Sahel	77.3 h	39.53 f	54.34 k	19.9 e	14.33 cd	13.3 b-e	12.33 cd	10.7 a-e	138.2 f	61.62 cde	28.33 b	14.67 a	69.4 abc	38.97 b
Khordad	84 c	41.97 ab	71.47 h	25.8 cd	15.67 a	15.67 a	13.67 a	13 a	140.5 d	67.26 b	31 a	9.33 bc	70.78 ab	34.33 cde
Oltan	78.8 fg	39.63 ef	99.93 d	27.6 bc	13 efg	12.3 c-f	10.33 f	9.7 b-f	134 h	64.2 c	25.33 c	10 bc	68.3 bc	34.39 cde
Golestan	80.7 e	40.67 cde	89.32 e	25.4 cd	12.67 fg	11.7 def	10.33 f	10 b-f	131.4 i	58.44 f	27.33 b	11 bc	62.37 f	39.53 b
N-200	83.7 c	40.2 def	106.41 c	30.1 ab	13.67 de	13.7 bcd	11 ef	11 a-e	139.1 e	62.85 cd	23.3 def	8.33 c	69.4 abc	37.98 bc
SB_{35}	82.5 d	42.77 a	79.02 g	17.4 ef	13.33 ef	12.3 c-f	11 ef	10 b-f	138.5 ef	61.06 def	29 b	9.67 bc	67.8 bcd	29.86 f
84-39-T_3	90.1 a	42 ab	110.97 b	31.2 a	15.67 a	14.3 abc	13.33 ab	11.7 abc	154.1 a	71.81 a	29 b	11.33 b	71.6 a	33.46 def
SP731	79.4 f	40.9 bcd	77.83 g	17.5 ef	10.67 h	10.33 f	8.67 g	8 f	135.4 g	61.73 cde	21.67 f	9.33 bc	65 def	32.62 def

Means in each column, followed by similar letter(s) are not significantly different at 5% probability level, using Duncan's Multiple Range Test.

Leaf area

The maximum and minimum amounts of leaf area were related to Deltapayne-25 and Sahel genotypes in non-stress condition (119.07 and 54.34 cm², respectively). Therefore, we can use Deltapayne-25 genotype for increasing leaf area in this condition (Table 2). On the other hand, Shirpane 603 and 84-39-T3 genotypes had the highest amount of leaf area (31.5 and 31.2 cm², respectively) and Armaghan genotype had the lowest amount of leaf area in stress condition (15.38 cm²), indicating the effect of drought stress on this trait.

Table 3. Combined analysis of variance for studied traits in cotton.

SOV	df	Mean squares (MS)						
		Plant height (cm)	Leaf area (cm²)	Number of nodes/plant	Number of branches/plant	Plant dry matter weight (g)	Number of bolls/plant	Seed cotton yield (g/plant)
Stress	1	36848.95 **	75982.34 **	13.61 ns	15.21 ns	122491.77 **	5397.88 **	22439.8 **
E (a)	4	5.67	129.37	2.69	6.48	8.99	28.34	35.37
Genotype	14	27.93 **	761.85 **	12.1 **	11.42 **	190.21 **	23.75 **	38.39 **
Stress×Genotype	14	14.72 **	450.41 **	0.52 **	0.85 ns	32 **	11.19 **	33.49 **
Error	56	0.318	3.05	0.64	0.906	1.27	1.594	3.68
CV (%)		0.92	3.28	6.02	8.75	1.11	6.89	3.74

ns, * and **: Not significant, significant at the 5% and 1% levels of probability, respectively.

Number of nodes/plant

The highest number of nodes/plant was related to Khordad and 84-39-T3 genotypes (15.67) and SP731 genotype had the lowest number of nodes/plant in non-stress conditions (10.67). It seems to be that higher plant height was led to higher number of nodes/plant in non-stress condition (Table 2). The highest and lowest number of nodes/plant was belonged to Khordad and SP731 genotypes in stress condition (15.67 and 10.33, respectively). Therefore, we can use Khordad genotype to increase number of nodes/plant in non-stress and stress conditions.

Table 4. Effects of drought stress and genotype on studied traits in cotton.

Treatment		Plant height (cm)	Leaf area (cm²)	Number of nodes/ plant	Number of branches/ plant	Plant dry matter weight (g)	Number of bolls/plant	Seed cotton yield (g/plant)
Stress	S1	81.32 a	82.38 a	13.69 a	11.29 a	138.12 a	26.07 a	67.15 a
	S2	40.85 b	24.27 b	12.91 a	10.47 a	63.34 b	10.58 b	35.57 b
	% Reduction	49.77	70.54	5.68	7.28	53.42	59.42	47.03
Genotype	Deltapayne-25	61.57 d	74.45 a	12.33 e	9.67 fg	108.71 b	17.17 cd	49.98 efg
	Bakhtegan	59.13 f	38.91 i	12.5 e	10.33 d-g	93.33 h	16.83 cde	50.21 def
	Varamin	60.63 e	51.96 f	14.5 bc	11.5 bcd	100.25 de	20.17 ab	54.05 b
	Mehr	61.82 d	50.16 fg	15.17 ab	12.67 ab	104.76 c	21 a	56.58 a
	Say okra	58.17 g	47.22 h	12.5 e	10.5 def	92.88 h	16.67 cde	50.47 def
	Shirpane 603	63.53 b	48.05 gh	14.17 bc	12 bc	107.72 b	17.5 c	47.52 g
	Armaghan	59.35 f	47.08 h	12 e	9.17 gh	100.73 d	16.17 cde	48.66 fg
	Sahel	58.4 g	37.1 i	13.83 c	11.5 bcd	99.89 def	21.5 a	54.18 b
	Khordad	62.97 bc	68.62 gh	15.67 a	13.33 a	103.88 c	20.17 ab	52.55 bcd
	Oltan	59.22 f	63.78 d	12.67 e	10 efg	99.12 ef	17.67 c	51.35 cde
	Golestan	60.67 e	57.36 e	12.17 e	10.17 efg	94.92 g	19.17 b	50.95 def
	N-200	61.93 d	68.25 c	13.67 cd	11 cde	100.99 d	15.83 de	53.67 bc
	SB_{35}	62.63 c	48.22 gh	12.83de	10.5 def	99.78 def	19.33 b	48.84 efg
	84-39-T_3	66.03 a	71.1 b	15 ab	12.5 ab	112.97 a	20.17 ab	52.53 bcd
	SP731	60.17 e	47.67 h	10.5 f	8.33 h	98.58 f	15.5 e	48.82 efg

Means in each column, followed by similar letter(s) are not significantly different at 5% probability level, using Duncan's Multiple Range Test.

Number of branches/plant

Khordad and SP731 genotypes had the highest and lowest number of branches/plant in non-stress and stress conditions. So, Khordad genotype can be used for increasing number of branches/plant in both conditions (Table 2).

Plant dry matter weight

The maximum and minimum amounts of plant dry matter weight were related to 84-39-T3 and Bakhtegan genotypes in non-stress condition (154.1 and 125.3 g, respectively). Therefore, 84-39-T3 genotype was suitable for increasing plant dry matter weight in this condition (Table 2). Deltapayne-25 and 84-39-T3 genotypes had the highest plant dry matter weight (71.89 and71.81 g, respectively) and Golestan genotype had the lowest plant dry matter weight (58.44 g) in stress condition. So, we can use Deltapayne-25 and 84-39-T3 genotypes to increase plant dry matter weight in stress condition.

Number of bolls/plant

Khordad and SP731 genotypes had the highest and lowest number of bolls/plant in non-stress condition. Therefore, Khordad genotypes can be used for increasing number of bolls/plant in this condition (Table 2). On the other hand, Mehr and Sahel genotypes had the highest and N-200 had the lowest number of bolls/plant in stress condition. So, Mehr and Sahel genotypes were suitable for increasing number of bolls/plant in this condition (Table 2).

Seed cotton yield

The highest seed cotton yield was related to 84-39-T3 genotype (71.6 g) and the lowest seed cotton yield was belonged to Shirpane 603, Golestan and Bakhtegan genotypes (63.6, 62.37 and 62.13 g, respectively) in non-stress condition (Table 2). While, the highest and lowest seed cotton yield was related to Mehr and SB35 genotypes in stress condition (43.53 and 29.86 g, respectively), indicating the effect of drought stress on this trait. It seems to be that higher seed cotton yield was due to higher plant height, number of nodes/plant, number of branches/plant, plant dry matter weight and number of bolls/plant in non-stress condition. While, higher seed cotton yield was due to higher leaf area, number of nodes/plant, number of branches/plant and number of bolls/plant in stress condition.

Table 5. Effects of stress × genotype interaction on studied traits in cotton.

Interaction	Plant height (cm)	Leaf area (cm^2)	Number of nodes/plant	Number of branches/plant	Plant dry matter weight (g)	Number of bolls/plant	Seed cotton yield (g/plant)
S1 × G1	82.13 d	119.07 a	13.33 cde	10.67 a	145.52 c	25 d	64.38 efg
S1 × G2	78.13 gh	58.13 j	12.67 efg	10.67 a	125.32 h	22.33 ef	62.13 g
S1 × G3	80.83 e	84.12 f	14.67 abc	11.67 a	137.67 e	28.67 b	69.44 abc
S1 × G4	82.53 d	70.98 h	15.33 a	12.67 a	140.64 d	27.33 bc	69.63 abc
S1 × G5	75.7 i	70.80 h	13.33 cde	11.67 a	126.33 h	24 de	66.58 c-f
S1 × G6	85.57 b	64.59 i	14.67 abc	12 a	147.52 b	25.33 cd	63.6 fg
S1 × G7	78.47 fg	78.77 g	12.33 efg	9.33 a	137.6 e	23.33 def	66.81 c-f
S1 × G8	77.27 h	54.34 k	14.33 a-d	12.33 a	138.16 e	28.33 b	69.39 abc
S1 × G9	83.97 c	71.47 h	15.67 a	13.67 a	140.49 d	31 a	70.78 ab
S1 × G10	78.8 fg	99.93 d	13 def	10.33 a	134.04 f	25.33 cd	68.31 a-d
S1 × G11	80.67 e	89.32 e	12.67 efg	10.33 a	131.4 g	27.33 bc	62.37 g
S1 × G12	83.67 c	106.41 c	13.67 b-e	11 a	139.13 de	23.33 def	69.36 abc
S1 × G13	82.5 d	79.02 g	13.33 cde	11 a	138.5 e	29 ab	67.82 b-e
S1 × G14	90.07 a	110.96 b	15.67 a	13.33 a	154.12 a	29 ab	71.6 a
S1 × G15	79.43 f	77.83 g	10.67 h	8.67 a	135.43 f	21.67 f	65.02 d-g
S2 × G1	41 klm	29.83 lm	11.33 gh	8.67 a	71.89 i	9.33 hij	35.58 jk
S2 × G2	40.13 mno	19.69 p	12.33 efg	10 a	61.33 lm	11.33 hi	38.28 ij
S2 × G3	40.43 mno	19.79 p	14.33 a-d	11.33 a	62.83 kl	11.67 h	38.66 ij
S2 × G4	41.1 klm	29.33 lm	15 ab	12.67 a	68.89 j	14.67 g	43.53 h
S2 × G5	40.63 lmn	23.64 o	11.67 fgh	9.33 a	59.42 mn	9.33 hij	34.36 kl
S2 × G6	41.5 kl	31.5 l	13.67 b-e	12 a	67.91 j	9.67 hij	31.45 lmn
S2 × G7	40.23 mno	15.38 q	11.67 fgh	9 a	63.87 k	9 ij	30.51 mn
S2 × G8	39.53 o	19.86 p	13.33 cde	10.67 a	61.62 l	14.67 g	38.97 ij
S2 × G9	41.97 jk	25.78 no	15.67 a	13 a	67.26 j	9.33 hij	34.33 kl
S2 × G10	39.63 no	27.63 mn	12.33 efg	9.67 a	64.2 k	10 hij	34.39 kl
S2 × G11	40.67 lmn	25.4 no	11.67 fgh	10 a	58.44 n	11 hij	39.53 i
S2 × G12	40.2 mno	30.08 lm	13.67 b-e	11 a	62.85 kl	8.33 j	37.98 ij
S2 × G13	42.77 j	17.42 pq	12.33 efg	10 a	61.06 lm	9.67 hij	29.86 n
S2 × G14	42 jk	31.23 l	14.33 a-d	11.67 a	71.81 i	11.33 hi	33.46 klm
S2 × G15	40.9 lm	17.51 pq	10.33 h	8 a	61.73 l	9.33 hij	32.62 k-n

Means in each column, followed by similar letter(s) are not significantly different at 5% probability level, using Duncan's Multiple Range Test.

Results of combined analysis of variance across environments showed that effect of stress on plant height, leaf area, plant dry matter weight, number of bolls/plant and seed cotton yield/plant was significant at 1% probability level, indicating that these traits were highly influenced by drought stress condition (Table 3). While, environment effect was not significant (*P*>0.05) for number of nodes/plant and number of branches/plant, indicating that drought stress after flowering stage had no significant effects on these traits in cotton plant (Table 3). Other authors have found that drought stress effects were significant for plant height (Ranawake *et al.,* 2011; Abass and Mohamed, 2011), leaf area (Basal and Unay, 2007), number of nodes/plant (Zhang *et al.,* 2007), number of branches/plant (Gerik *et al.,* 1996), plant dry matter weight (Abass and Mohamed, 2011), number of bolls/plant (Pettigrew, 2004) and seed cotton yield (Ritchie *et al.,* 2009; Whitaker *et al.,* 2008).

Leaf area and number of nodes/plant had the highest and lowest decrease percent of traits under drought stress condition (70.54 and 5.68, respectively) (Table 4). Seed cotton yield was reduced by drought stress (47.03%) that was probably due to decrease number of bolls/plant (Table 4). Plaut *et al.,* (1992) & De Kock *et al.,* (1993) also reported similar results for seed cotton yield. The results showed that the studied cotton genotypes were significantly different in all traits, indicating the existence of genetic variability for them (Table 3). The highest and lowest plant height was related to 84-39-T3 and Sahel genotypes (66.03 and 58.4 cm, respectively).

Deltapayne-25 genotype had the highest leaf area (74.45 cm^2) and Bakhtegan and Sahel genotypes had the lowest leaf area (38.91 and 37.1 cm^2, respectively) (Table 4). Therefore, Deltapayne-25 genotype was suitable to increase leaf area. Pettigrew (2004) found that soil moisture deficit stress in the humid environment reduces plant stature and leaf area with reductions in solar radiation interception. When evaporative demand exceeds the moisture recharging capacity of the plant and soil, the hydraulic status of the plant deteriorates to the point of causing a reduction in photosynthesis, which was observed in dry land conditions. Khordad and SP731 genotypes had the highest and lowest number of nodes/plant and number of branches/plant, respectively. So, Khordad genotype can be used for increasing these traits. 84-39-T3 genotype had the highest plant dry matter weight (112.97 g) that it was related to higher plant height, leaf area, number of nodes/plant and number of branches/plant and the lowest plant dry matter weight was belonged to Say okra and Bakhtegan genotypes (92.88 and 93.33, respectively) (Table 4). Sahel and Mehr genotypes had the highest number of bolls/plant (21.5 and 21, respectively) and SP731 had the lowest number of bolls/plant (15.5). Considering number of bolls/plant is one of the major components of seed cotton yield, the superiority of number of bolls/plant is important in plant breeding to improve seed cotton yield (Alkuddsi *et al.,* 2013). Therefore, Sahel and Mehr genotypes can be used for increasing number of bolls/plant. The highest seed cotton yield was related to Mehr, Sahel and Varamin genotypes (56.58, 54.18 and 54.05 g, respectively) and the lowest seed cotton yield was belonged to Shirpane 603 genotype (47.52 g). Therefore, Mehr, Sahel and Varamin genotypes were suitable genotypes in both non-stress and stress conditions (Table 4).

Stress×genotype interaction effects were significant for all studied traits, except for number of branches/plant, indicating that genotypes did not respond to the environments similarly for these traits (Table 5). S1×G14 interaction effect had the highest plant height, number of nodes/plant, number of branches/plant, plant dry matter weight and seed cotton yield, indicating that 84-39-T3 was the best genotype under non-stress condition (Table 4). S2×G13, S2×G7 and S2×G6 interaction effects had the lowest seed cotton yield. Therefore, SB_{35}, Armaghan and Shirpane 603 genotypes were the worst genotypes under drought stress condition.

Conclusion

Cotton is one of the most vital crops in the world in terms of economic value. Cotton is the most essential textile fiber worldwide as it currently accounts for 90% of the commercially grown cotton. Cotton is the 2nd most important oil seed crop in the world averaging one fourth that of soybean (Jones and Kersey, 2002). In cotton, drought stress affects the crop by limiting fiber yield and deteriorating lint quality (Mc Williams, 2003). Keeping in view the importance of cotton crop and water scarcity in Iran, it is essential to initiate research activities for improving drought tolerance in cotton by employing physiological strategies to overcome cotton production losses under drought conditions. Based on the results, all the studied traits, except number of nodes/plant and number of branches/plant, were influenced by drought stress condition. Seed cotton yield was reduced by drought stress (%47.03) that was probably due to decrease number of bolls/plant. In this study, the studied varieties were differed in their responses to drought stress. Therefore, it was possible to discriminate among these varieties on the basis of these parameters and there was a clear-cut distinction between varieties for tolerance and susceptibility to water stress. On the basis of morphological character expressions in response to water deficit, it can be concluded that Mehr, Sahel and Varamin genotypes were suitable genotypes under drought stress and non-stress conditions and Shirpane 603 genotype was the worst genotype under stress and non-stress conditions.

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