Journal of Asian Scientific Research, 2015, 5(9): 465-472

Journal of Asian Scientific Research
ISSN(e): 2223-1331/ISSN(p): 2226-5724

URL: www.aessweb.com

EVALUATION OF TRAITS RELATED TO DROUGHT STRESS IN SESAME *(SESAMUM INDICUM* L.*)* GENOTYPES

Masoud Golestani[1†] --- **Hassan Pakniyat**[2]

[1]*Department of Agriculture, Payame Noor University (PNU), Tehran, Iran*

[2]*Department of Crop Production and Plant Breeding, College of Agriculture Shiraz University, Shiraz, Iran*

ABSTRACT

In order to evaluate traits related to drought stress in eight sesame (sesamum indicum L.*) genotypes, two experiments were carried out in randomized complete design with three replications in the field of the Research Station of College of Agriculture, Shiraz University, Iran. The two experiments differed with respect to their irrigation regimes. Yield related traits (number of days to maturation, NDM; number of capsules per plant, NCP; 1000 seed weight, TSW; harvest index, HI; biological yield, BY and grain yield, GY) and physiological traits(canopy temperature,* T_C*, leaf water potential, LWP; leaf osmotic potential, LOP; initial water content, IWC and rate of water loss, RWL) were evaluated under both conditions. The results showed that drought decreased all yield related traits except HI, significantly. LWP and LOP decreased under drought stress, while RWL increased, significantly.* T_C *and IWC did not show significant changes under drought stress. Based on the results, it is reasonable to assume that high yield of sesame plants under drought conditions could be obtained by selecting breeding materials with lowest reduction in NDM, NCP, TSW, BY, GY, LWP and LOP and the highest reduction in RWL. Under non-stress condition LOP in both stages was the best traits. Under drought condition LWP, LOP at both stages and RWL at grain filling stage were the most suitable traits.*

Keywords: Drought stress, Physiological traits, Sesame genotypes, Yield related traits, Irrigation regimes.

Contribution/ Originality

This study is one of very few studies which have investigated the effects of drought stress on physiological and yield related traits of sesame genotypes.

1. INTRODUCTION

Sesame *(Sesamum indicum* L.*)* is a one of the oldest oil seed crops, growing widely in tropical and subtropical areas [1]. Sesame seeds contain oil (44-58%), protein (18-25%), carbohydrate

† Corresponding author
DOI: 10.18488/journal.2/2015.5.9/2.9.465.472
ISSN(e): 2223-1331/ISSN(p): 2226-5724

(~13.5%) [2] and also two unique substances: sesamin and sesamolin known to have a cholesterol lowering effect in humans [3]. Drought is one of the most important abiotic stresses which affect almost every aspect of plant growth [4]. The arid and semi-arid regions where sesame is grown are specified by high temperatures, high evaporation demand and occurrence of unpredictable drought [5]. This plant is relatively drought tolerant [6]. Resistance to water stress in sesame is important in many country with low rainfall. Traits correlated with drought tolerance such as yield components and physiological traits are suitable indicators for selection of drought tolerant genotypes in breeding programs to reduce the impact of water deficit on crop yield [7]. Understanding of physiological mechanisms that enable plants to adapt to water deficit and maintain growth and productivity during stress period could help in screening and selection of tolerant genotypes and using these traits in breeding programs [8]. Therefore, the use of physiological traits as an indirect selection would be important in augmenting yield-based selection procedures. In the present study, the effects of drought stress on traits such as yield related traits (NDM, NCP, TSW and HI) and physiological traits (T_C, LWP, LOP, IWC and RWL) was studied. Efforts have been made to enhance the efficiency of selection for drought tolerant genotypes based on yield and specific physiological traits [9]. T_C has already been considered to be effective for drought resistance screening in pearl millet *(Pennisetum glaucum)* [10] safflower *(Carthamus tinctorius* L.*)* [11] and sunflower *(Helianthus annuus* L.*)* [12]. LWP and LOP are other criterion used by several researchers in safflower [11] wheat [13] and sunflower [14]. Several researchers have used IWC and RWL from excised leaves as screening criteria in drought resistance breeding programs [5, 11, 15]. The objectives of this study were to investigate the effects of drought stress on yield related traits and physiological traits under drought stress of 8 sesame genotypes and identify the efficient traits for screening drought tolerant genotypes.

2. MATERIAL AND METHODS

Field experiments. The field experiments were conducted in the Research Station of the Agriculture College of Shiraz University, Iran (29° 50´ N and 52° 46´ E, 1810 m altitude) during 2003. The soil texture was clay loam (fine, mixed, mesic and calcixerollic xerochrepts). Eight sesame genotypes (Table 1) were provided from Agricultural and Natural Resources Research Center of Fars, Iran. These genotypes were evaluated in a randomized complete block design with three replications in two separate experiments under drought stress and non-stress conditions. Non-stress experiment was irrigated by 100% of calculated crop water requirement (CWR) [16] while drought stress experiment was irrigated by 60% of calculated CWR. Each plot consisted of six 4-m long rows spaced 50 cm apart with a 10 cm plant distance in the rows. The four middle rows were used for sampling.

Fertilizer was applied at the rate of 120 Kg/ha N and 50 Kg/ha P_2O_5. Crops received one half of N in urea form and total amount of P_2O_5 at planting, while the remaining N was applied at tillering stage. Planting time was in 9th June in 2003.

Determination of yield related traits. Before harvesting, 10 plants were selected from two middle rows and then their NCP and TSW were measured. The plants were harvested from an area of 3 m^2 in October when they almost turned yellow but the capsules were not split yet.

Table-1. Names and origin of 8 sesame lines

Entry	Lines	Origin
1	TN 240	Seed and Plant Improvement Institute
2	TN 239	Seed and Plant Improvement Institute
3	TN 238	Seed and Plant Improvement Institute
4	Progeny of the landrace of Dezfoul	Dezfoul
5	Sesame landrace of Dezfoul	Dezfoul
6	Darab 14	Darab
7	Line 1 from progeny of the landrace of Darab	Darab
8	Line 2 from progeny of the landrace of Darab l	Darab

Source: Agricultural and Natural Resources Research Center of Fars, Iran

Then BY and GY (kg/ha) were determined. The Harvest Index (HI) was calculated as the ratio between GY and BY.

Determination of physiological traits. The canopy temperature (T_C) of each plot was measured at the flowering and grain filling stages at 15:30 hour in both experiments using an infrared thermometer (Kane-May Model Infratrace 800). The instrument was pointed down at three random points in each plot and held at an oblique angle to the canopy surface to minimize the influence of soil exposure [15]. The leaf water potential (LWP) was measured at the flowering and grain filling stages using a pressure chamber (PMS Model) technique [11]. The leaf osmotic potential (LOP) was measured at the flowering and grain filling stages, after sap extraction using the Cryoscopy method and a digital thermometer ETI-2001 Model. LOP [15] was determined as:

$$LOP = [(T/1.86) \times 2.27]$$ Where, T= freezing point of sap

The rate of water loss (RWL) from excised leaves and initial water content (IWC) were measured at the flowering and grain filling stages [17] by following equations:

$$RWL = \{[(W_0 - W_2) + (W_2 - W_4) + (W_4 - W_6)]/[3 \times W_d \times (T_2 - T_1)]\}$$

$$IWC = [(W_0 - W_d)/W_d]$$

Where, T_2-T_1= time interval between two subsequent measurements (2 h), W_0= fresh weight, (W_2, W_4 and W_6) = weight after 2, 4 and 6 hours in a controlled chamber at 25°C, and W_d= oven-dry at 50°C for 24 hours.

Statistical analysis. The data were statistically analyzed by software SAS [18]. Differences among yield related traits and physiological traits were analyzed using t-test and Duncan test at 5% level. The correlation between drought indices and physiological traits were analyzed using SAS [18].

3. RESULT AND DISCUSSION

The mean of GY and some related traits for both experiments are shown in Table 2. Analysis of variance revealed that genotypes differed significantly for the most traits under drought stress and non-stress conditions. There were significant differences between genotypes in NCP, TSW, HI, BY and GY in both conditions while in NDM only in drought stress conditions. Drought stress reduced significantly the NDM, NCP, TSW, BY and GY of genotypes while it did not reduced HI significantly. NDM showed a significant reduction of 7.41 percent under drought stress. Drought stress accelerated all growth stages, reduced the normal growth and development periods, dry matter production and final yield. These results were consistent with the results of Pouresmaiel, et al. [19]. There was significant decrease in the flowering period in all genotypes under stress condition but physiological maturity period was the lowest as compared with flowering period. NCP and TSW suffered a significant reduction of 53.71 and 23.21, respectively. The significant decrease in TSW showed that irrigation at reproductive growth and seed development was very important. Decrease in TSW observed under water stress was in accordance with the findings of Razi and Assad [20] in sunflower and Pouresmaiel, et al. [19] in sesame. GY in non-stress conditions varied from 1090 to 1757.6 kg/ha, and under drought condition they varied from 580 to 1120 kg/ha. BY and GY reduction occurred to the extent of 36.82 and 37.34 percent under drought condition, significantly. GY suffered a maximum reduction of 52.05 percent. GY was greater in non-stress conditions than stress conditions, a consequence of more NDM, NCP and TSW. Genotypes did not differ significantly in respect to HI under drought stress compared with non-stress conditions and this could emphasize that the range of reduction in GY was similar to the rate of biomass under drought stress.

Mean of water-related traits in sesame genotypes at the flowering and grain filling stages under non-stress and stress conditions are shown in Table 3. Genotypes differ significantly in respect to LWP at the flowering stage while did not differ at grain filling stage under non-stress conditions ($p<0.05$). There were significant differences between LWP of genotypes in both stages under drought conditions ($p<0.05$). LWP decreased in all genotypes under stress conditions at both stages, significantly. This result is consistent with that of Golestani and Assad [15] who observed decrease in the LWP under drought condition in wheat. Genotypes were significantly different with regard to LOP in both stages under both conditions ($p<0.05$). The trend of LOP reduction at both stages was similar to LWP under stress conditions. Other investigators [21-23] also reported that drought resistant cultivars had lower ψs values as compared with susceptible wheat cultivars. Sesame genotypes did not differ significantly in respect to RWL under non-stress conditions in both stages while differ significantly under drought conditions in both stages. RWL increased significantly ($P<0.01$) under drought stress condition as compared with non-stress conditions. The changes in IWC of genotypes were significant in both stages under both conditions ($p<0.05$). The results showed that IWC increased in the majority of genotypes except one genotype at flowering stage and two genotypes at grain filling stage under drought stress conditions. The differences in the T_C of genotypes were not significant in both stages under both conditions ($p<0.05$). Pinter, et al. [24] and Golestani and Assad [15] reported that (Ta - Tc) is a valuable technique in screening drought resistant genotypes while in this study T_C could not apply in discriminating between genotypes.

Table-2. Mean of number of days to maturation (NDM), number of capsules per plant (NCP), 1000 seed weight (TSW) , harvest index (HI), biological yield (BY) and grain yield (GY) in sesame lines under non-stress and stress conditions.

		Genotypes								
Traits	Conditions	1	2	3	4	5	6	7	8	Mean
NDM	Non-stress	125.0^{A-a}	126.0^{A-a}	125.6^{A-a}	124.0^{A-a}	124.0^{A-a}	128.0^{A-a}	125.6^{A-a}	126.0^{A-a}	125.4^{a}
	Stress	121.0^{A-a}	120.3^{AB-a}	117.3^{ABC-b}	114.0^{BC-b}	112.0^{C-b}	115.0^{ABC-b}	114.3^{ABC-b}	115.0^{ABC-b}	116.1^{b}
NCP	Non-stress	45.0^{E-a}	48.0^{E-a}	50.3^{CDE-a}	54.7^{ABC-a}	51.3^{BCD-a}	56.0^{AB-a}	59.3^{A-a}	55.3^{ABC-a}	52.5^{a}
	Stress	24.0^{BC-b}	25.6^{ABC-b}	24.0^{BC-b}	27.3^{AB-b}	23.0^{CD-b}	22.0^{CD-b}	20.0^{D-b}	28.0^{A-b}	24.3^{b}
TSW	Non-stress	3.10^{CD-a}	2.94^{D-a}	3.25^{BCD-a}	3.35^{ABC-a}	3.43^{ABC-a}	3.69^{A-a}	3.54^{AB-a}	3.55^{AB-a}	3.36^{a}
	Stress	2.40^{B-b}	2.43^{B-b}	2.40^{B-b}	2.63^{AB-b}	2.78^{A-b}	2.64^{AB-b}	2.64^{AB-b}	2.71^{AB-b}	2.58^{b}
HI	Non-stress	22.48^{B-a}	22.24^{B-a}	22.29^{B-a}	24.69^{A-a}	24.67^{A-a}	23.93^{AB-a}	$22.74A^{B-a}$	22.59^{B-a}	$23.,2^{a}$
	Stress	22.39^{C-b}	22.22^{C-b}	22.13^{C-b}	24.35^{A-b}	24.25^{AB-b}	23.73^{ABC-b}	22.59^{ABC-b}	22.52^{BC-b}	23.02^{b}
BY	Non-stress	5380.0^{E-a}	5345.6^{E-a}	4882.6^{F-a}	6679.6^{B-a}	7118.6^{A-a}	6306.6^{C-a}	5911.6^{D-a}	6556.6^{BC-a}	6022.7^{a}
	Stress	2589.6^{F-b}	$3124.^{6E-b}$	3535.0^{D-b}	4261.6^{BC-b}	4615.6^{A-b}	3938.0^{C-b}	4335.6^{AB-b}	$4038.6B^{C-b}$	3804.9^{b}
GY	Non-stress	1209.6^{EF-a}	1189.3^{F-a}	1090.0^{F-a}	1650.6^{AB-a}	1757.6^{A-a}	1510.0^{BC-a}	1344.6^{DE-a}	1482.0^{CD-a}	1404.3^{a}
	Stress	580.0^{F-b}	691.6^{E-b}	785.6^{D-b}	1037.3^{AB-b}	1120.0^{A-b}	934.6^{C-b}	979.6^{BC-b}	909.3^{C-b}	879.8^{b}

Means within each row (column) followed by same capital (small) letters are not significantly different at DMRT (t test) (probability level 5%).

Table-3. Mean of physiological traits including canopy temperature (TC), leaf water potential (LWP), leaf osmotic potential (LOP), initial water content (IWC) and rate of water loss (RWL) in sesame lines at the flowering (F) and grain filling (G) stages under non-stress and stress conditions.

			Genotypes								
Traits	Stages	Conditions	1	2	3	4	5	6	7	8	Mean
T_C	F	Non-stress	25.67^{A-a}	25.73^{A-a}	25.93^{A-a}	25.01^{A-a}	25.37^{A-a}	25.10^{A-a}	24.93^{A-a}	24.66^{A-a}	25.30^{a}
		Stress	25.63^{A-a}	25.74^{A-a}	25.80^{A-a}	25.36^{A-a}	25.58^{A-a}	25.47^{A-a}	25.23^{A-a}	25.16^{A-a}	25.49^{a}
	G	Non-stress	27.36^{A-a}	27.42^{A-a}	27.64^{A-a}	28.01^{A-a}	27.96^{A-a}	28.71^{A-a}	28.53^{A-a}	28.21^{A-a}	27.99^{a}
		Stress	28.08^{A-a}	27.87^{A-a}	28.46^{A-a}	28.19^{A-a}	27.70^{A-a}	27.70^{A-a}	28.34^{A-a}	28.26^{A-a}	28.11^{a}
LWP	F	Non-stress	-12.10^{A-a}	-12.20^{AB-a}	-12.40^{ABC-a}	-13.27^{C-a}	-13.10^{BC-a}	-12.63^{ABC-a}	-12.72^{ABC-a}	-13.01^{BC-a}	-12.68^{a}
		Stress	-13.25^{A-b}	-13.40^{AB-b}	-13.33^{AB-b}	-14.75^{D-b}	-14.63^{CD-b}	-13.90^{ABC-b}	-13.98^{ABCD-b}	-14.10^{BCD-b}	-13.92^{a}
	G	Non-stress	-13.47^{A-a}	-13.53^{A-a}	-13.63^{A-a}	-14.13^{A-a}	-14.20^{A-a}	-13.80^{A-a}	-13.96^{A-a}	-14.00^{A-a}	-13.84^{a}
		Stress	-14.11^{A-b}	-14.18^{AB-b}	-14.22^{AB-b}	-16.11^{D-b}	-15.91^{D-b}	-14.66^{ABC-b}	-14.72^{BC-b}	-14.88^{C-b}	-14.85^{a}
LOP	F	Non-stress	-2.68^{A-a}	-2.70^{AB-a}	-2.75^{AB-a}	-3.18^{D-a}	-3.10^{CD-a}	-2.92^{BC-a}	-2.90^{ABC-a}	-2.87^{AB-a}	-2.89^{a}
		Stress	-3.03^{A-b}	-3.12^{AB-b}	-3.21^{ABC-b}	-5.20^{D-b}	-5.40^{D-b}	-3.27^{BC-b}	-3.31^{BC-b}	-3.42^{C-b}	-3.74^{a}
	G	Non-stress	-3.27^{A-a}	-3.31^{A-a}	-3.42^{AB-a}	-4.14^{E-a}	-4.08^{DE-a}	-3.84^{CD-a}	-3.74^{C-a}	-3.62^{BC-a}	-3.67^{a}
		Stress	-3.64^{A-b}	-3.82^{A-b}	-3.74^{A-b}	-6.97^{C-b}	-7.33^{D-b}	-5.01^{B-b}	-4.96^{B-b}	-4.90^{B-b}	-5.06^{a}
IWC	F	Non-stress	3.956^{AB-a}	3.806^{B-a}	4.026^{A-a}	3.873^{AB-a}	3.770^{B-a}	3.326^{D-a}	3.440^{CD-a}	3.566^{C-a}	3.720^{a}
		Stress	3.860^{A-a}	3.840^{A-a}	3.926^{A-a}	3.733^{A-a}	3.920^{A-a}	3.780^{A-a}	3.763^{A-a}	3.710^{A-a}	3.816^{a}
	G	Non-stress	2.210^{BC-a}	2.140^{CD-a}	2.030^{DE-a}	1.680^{G-a}	1.800^{FG-a}	2.380^{A-a}	1.1910^{EF-a}	2.300^{AB-a}	2.056^{a}
		Stress	2.493^{B-a}	2.456^{B-a}	2.620^{A-a}	1.960^{D-a}	1.386^{E-a}	2.043^{CD-a}	2.120^{C-a}	2.090^{C-a}	2.146^{a}
RWL	F	Non-stress	0.1630^{A-a}	0.1641^{A-a}	0.1652^{A-a}	0.1683^{A-a}	0.1670^{A-a}	0.1609^{A-a}	0.1622^{A-a}	0.1594^{A-a}	0.1638^{a}
		Stress	0.1731^{AB-a}	0.1697^{AB-a}	0.1710^{AB-a}	0.1658^{AB-a}	0.1787^{A-a}	0.1588^{A-a}	0.1590^{A-a}	0.1596^{A-a}	0.1670^{a}
	G	Non-stress	0.1788^{A-a}	0.1730^{A-a}	0.1780^{A-a}	0.1718^{A-a}	0.1740^{A-a}	0.1750^{A-a}	0.1763^{A-a}	0.1773^{A-a}	0.1755^{a}
		Stress	0.2076^{A-a}	0.1980^{B-a}	0.2026^{AB-a}	0.1380^{D-a}	0.1400^{D-a}	0.1802^{C-a}	0.1840^{C-a}	0.1821^{C-a}	0.1791^{a}

Means within each row (column) followed by same capital (small) letters are not significantly different at DMRT (t test) (probability level 5%).

Correlation between suitable drought resistance indices in these sesame lines including mean productivity (MP), geometric mean productivity (GMP), harmonic mean (HM) and stress tolerance index (STI) [25] with physiological traits (table 4) was used to determine the suitable physiological traits in screening resistant sesame lines. Under non-stress condition LOP in both stages were the best traits because of significant correlation between these traits with drought resistance indices. Under drought condition LWP, LOP at both stages and RWL at grain filling stage were the most suitable physiological traits.

Leaf water potential (LWP) at both stages under non-stress condition were not suitable traits in spite of significant correlation between these traits with drought resistance indices because of non-significant differences between genotypes for these traits. Initial water content (IWC) at grain filling under drought condition could not discriminate between lines as well as drought resistance indices in spite of significant correlation between these traits with drought resistance indices. Canopy temperature (T_C) at both stages and both conditions could not discriminate between lines because of non-significant difference between genotypes.

Table-4. Significant pearson correlation coefficient (r) between suitable drought indices including mean productivity (MP), geometric mean productivity (GMP), harmonic mean (HM) and stress tolerance index (STI) with physiological traits including leaf water potential (LWP), leaf osmotic potential (LOP), rate of water loss (RWL) and initial water content (IWC) in sesame genotypes at the flowering (F) and grain filling (G) stages under non-stress and stress conditions.

Drought indices	Stages	Conditions	Physiological traits			
			LWP	LOP	RWL	IWC
MP	F	Non-stress	-0.450*	-0.757**	-	-
		Stress	-0.780*	-0.807**	-	-
	G	Non-stress	-0.433*	-0.893**	-	-
		Stress	-0.797*	-0.928**	-0.880**	-0.889**
GMP	F	Non-stress	-0.471*	-0.767**	-	-
		Stress	-0.785**	-0.801**	-	-
	G	Non-stress	-0.445*	-0.893**	-	-
		Stress	-0.791**	-0.925**	-0.879**	-0.886**
HM	F	Non-stress	-0.488*	-0.773**	-	
		Stress	-0.786**	-0.790**	-	
	G	Non-stress	-0.453*	-0.887**	-	
		Stress	-0.782**	-0.916**	-0.873**	-0.877**
STI	F	Non-stress	-0.460*	-0.767**	-	-
		Stress	-0.792**	-0.830**	-	-
	G	Non-stress	-0.444*	-0.887**	-	-
		Stress	-0.803**	-0.937**	-0.890**	-0.896**

*, ** significant at 0.05 and 0.01, respectively

4. CONCLUSIONS

It is concluded from the results of this study that sesame genotypes respond differentially to drought stress. Under drought stress condition, NDM, NCP, TSW, BY, GY, LWP and LOP significantly ($P < 0.01$) decreased while RWL increased significantly ($P < 0.05$). Based on the results, it is reasonable to assume that high yield of sesame plants under drought conditions could be obtained by selecting breeding materials with the lowest reduction in NDM, NCP, TSW, BY, GY, LWP and LOP and the highest reduction in RWL. Under non-stress condition LOP in both stages was the best traits. Under drought condition LWP, LOP at both stages and RWL at grain filling stage were the most suitable physiological traits.

REFERENCES

[1] D. Bedigian, "Evolution of sesame revisited: Domestication, diversity and prospects," *Genetic Resources and Crop Evolution*, vol. 50, pp. 779 – 787, 2003.

[2] C. Borchani, S. Besbes, C. H. Blecker, and H. Attia, "Chemical characteristics and oxidative stability of sesame seed, sesame paste, and olive oils," *J. Agric. Sci. and Technol.*, vol. 12, pp. 585-596, 2010.

[3] A. Pal, "Nutritional, medicinal and industrial uses of sesame (Sesamum Indicum L.) seeds," *An Overview.Agriculture Conspectus Scientifics*, vol. 75, pp. 159-168, 2010.

[4] M. Golbashy, M. Ebrahimi, K. S. Khavari, and R. Choukan, "Evaluation of drought tolerance of some corn (Zea Mays L.) hybrids in Iran," *Afr. J. Agric. Res.*, vol. 5, pp. 2714-2719, 2010.

[5] J. R. Witcombe, P. A. Hollington, C. J. Howarth, S. Reader, and K. A. Steele, "Breeding for abiotic stresses for sustainable agriculture," *Phil. Trans. R. Soc. B,* vol. 363, pp. 703-716, 2007.

[6] S. Boureima, M. Eylettes, M. Diouf, T. A. Diop, and P. Van Damme, "Sensitivity of seed germination and seedling radicle growth to drought stress in sesame sesamum indicum L," *Res. J. Environ. Sci.,* vol. 5, pp. 557-564, 2011.

[7] S. M. Almeida, D. S. J. A. Gonçalves, J. Enciso, V. Sharma, and J. Jifon, "Yield components as indicators of drought tolerance of sugarcane," *Sci. Agric.,* vol. 65, pp. 620-627, 2008.

[8] M. Zaharieva, E. Gaulin, M. Havaux, E. Acevedo, and P. Monnevaux, "Drought and heat responses in the wild wheat relative aegilops geniculata roth," *Crop Science,* vol. 41, pp. 1321-1329, 2001.

[9] G. C. Wright and N. C. Rachaputi, *Drought and drought resistance. In: R. M. Goodman (Ed). Encyclopedia of plant and crop science*. New York: Marcel Dekker, Inc, 2004.

[10] P. Singh and E. T. Kanemasu, "Leaf and canopy temperature of pearl millet genotypes under irrigated and nonirrigated conditions," *Agronomy Journal,* vol. 75, pp. 497-501, 1983.

[11] J. Ashkani, H. Pakniyat, Y. Emam, M. T. Assad, and M. J. Bahrani, "The evaluation and relationships of some physiological traits in spring safflower (Carthamus Tinctorius L.) under stress and non-stress water regimes," *J. Agric. Sci. Technol.,* vol. 9, pp. 267-277, 2007.

[12] Alza and M. Fernandez-Martinez, "Genetic analysis of yield and related traits in sunflower (Helianthus Annuus L.) in dry land and irrigated environments," *Euphytica,* vol. 95, pp. 243-251, 1997.

[13] R. B. David and J. M. Duniway, "Effects of mycorrhizal infection on drought tolerance and recovery in safflower and wheat," *Plant Soil,* vol. 197, pp. 95-103, 1997.

[14] A. J. Karamanos and A. Y. Papatheohari, "Assessment of drought resistance of crop genotypes by means of water potential," *Crop Science,* vol. 39, pp. 1792-1797, 1999.

[15] A. S. Golestani and M. T. Assad, "Evaluation of four screening technique for drought resistance and their relationship to yield reduction ration in wheat," *Euphytica,* vol. 13, pp. 293-299, 1998.

[16] A. Alizadeh, *Soil, water and plant relationship*, 4th ed. Iran: Emam Reza University Press, 2004.

[17] J. M. Clarke and T. N. McCaig, "Excised-leaf water retention capability as an indicator of drought resistance of triticum genotypes," *Canadian Journal of Plant Science,* vol. 62, pp. 571-578, 1982.

[18] SAS, *Statistical analysis software, version 8*. USA: SAS Institute, 2000.

[19] H. Pouresmaiel, M. H. Saberi, and H. Fanaei, "Evaluation of terminal drought stress tolerance of sesamum indicum L. genotypes under the Sistan region conditions," *International Journal of Science and Engineering Investigations,* vol. 2, pp. 58-61, 2013.

[20] H. Razi and M. T. Assad, "Comparison of selection criteria in normal and limited irrigation in sunflower," *Euphytica,* vol. 105, pp. 83-90, 1999.

[21] R. Grumet, R. S. Albrechtensen, and A. D. Hanson, "Growth and yield of barley isopopulations differing in solute potential," *Crop Science,* vol. 27, pp. 991-995, 1987.

[22] A. Blum, "Osmotic adjustment and growth of barley genotypes under drought stress," *Crop Science,* vol. 29, pp. 230-233, 1989.

[23] J. T. Musick, O. R. Jones, B. A. Stewart, and D. A. Dusek, "Water-yield relationships for irrigated and dryland wheat in the U.S Southern plains," *Agronomy Journal,* vol. 86, pp. 980-986, 1994.

[24] J. P. S. Pinter, G. Zipoli, R. J. Reginato, R. D. Jackson, S. B. Idso, and J. P. Hopman, "Canopy temperature as an indicator of differential water use and yield performance among wheat cultivars," *Agricultural Water management*, vol. 18, pp. 35-48, 1990.

[25] M. Golestani and H. Pakniyat, "Evaluation of drought tolerance indices in sesame lines," *J. Sci. Technol. Agric. Natur. Resour.*, vol. 11, pp. 141-150, 2007.