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EVALUATION OF DROUGHT TOLERANCE IN DIFFERENT GENOTYPES OF SESAME (*SESAMUM INDICUM* L.)

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ABSTRACT

In order to study the effect of drought stress on sesame (*Sesamum indicum* L.) genotypes, a split plot experiment was carried out based on a Randomized Completely Block Design with two replications. The irrigation regimes compromised of Full irrigation (I_1), Moderate drought stress (I_2) and severe drought stress (I_3). The subplots were allocated to ten different genotypes of sesame. In this experiment different characteristics including plant height, number of the primary branches, number of capsules, 1000- seed weight, number of seeds per capsule, seed yield, biological yield and harvest index were measured. Analysis of variance showed that there was significant difference between genotypes for all of the studied traits, except for harvest index (%). Irrigation intervals had significant effects on number of primary branches per plant, seeds per capsule, 1000-seed weight, biological yield and seed yield. Interaction effect of irrigation ×genotype was significant for plant height, number of capsules per plant, seed yield and biological yield. Different tolerance indices including MP, TOL, SSI, STI and HM were calculated the highest value for seed yield was observed in in Darab14 (2079.1) (Kg/m^2). So, this superior genotype could be proposed for cultivation in arid regions.

INTRODUCTION

Drought is a wide spread problem that seriously influencing on crop production, mostly in arid and semi-arid regions (Blum, 1988). It is one of the most important abiotic stresses which affect almost every aspect of plant growth (Golbashy *et al.,* 2010). Drought tolerance consists of plant ability to growth under water deficit conditions (Hong *et al.,* 1985; Blum, 1988; Stewart, 1992). Current estimates indicate that about 30% of the world's agricultural lands are now affected by water stress (Geertans and Raes, 2009). The effects of drought stress depend on timing, duration and magnitude of water deficiency (Blum, 1988). Sesame yield could be improved by using appropriate management for adaptation to environmental stresses.

Understanding the response of plant to dry environments has great importance and also a fundamental part of producing stress tolerant crops (Reddy *et al.,* 2004). Improvement of drought tolerance genotypes is the best option for crop production under drought stress. . Drought susceptibility of genotype is often measured by reduction in yield under drought stress (Blum, 1988).

Assessment of drought tolerance indices is a basic approach to identify superior genotypes defined stress tolerance (TOL) as the differences in yield between the stress (Ys) and non-stress (Yp) environments and mean productivity (MP) as the average yield of Ys and Yp. Stress sensitivity index (SSI) was measured according to Fischer and Maurer, (1978).

SSI= $\frac{1-(Y_S/Y_P)}{S_I}$, where SI: Stress Intensity = 1-$\frac{\overline{Y}_s}{\overline{Y}_P}$.

Lower SSI meaning higher drought tolerance. Fernadez, (1992) defined an advanced index (STI= stress tolerance index), which can be used to identify genotypes that produce high yield under both stress and non-stress conditions. Geometric mean product (GMP) is calculated based on the formulae of GMP= $\sqrt{(Y_s)(Y_p)}$ (Fischer and Maurer, 1978). Harmonic mean (HM) have been defined another tolerance index by Hossain et al. (1990). The optimal selection criterion should distinguish genotypes that express uniform superiority in both stressed and non-stressed environments from the genotypes that are favorable only in one environment.

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Evaluation of drought tolerance indices have been studied in different oilseeds such as soybean (Zeinali Khanghah *et al.,* 2004), safflower (Pasban Eslam, 2011), rapeseed (Yarnia *et al.,* 2011), corn (Golbashy *et al.,* 2010), and sesame (Hassanzadeh *et al.,* 2009, Golestani and Pakniat, 2007). Sesame (*Sesamum indicum* L.) is considered as oil seed crop with medicinal properties (Weiss, 2000). Sesame is a drought tolerant crop (Weiss, 2000; Boureima *et al.,* 2011). The arid and semi-arid regions where sesame is grown are specified by high temperatures, high values of solar radiation, high evaporation demand and occurrence of unpredictable drought (Witcombe *et al.,* 2007). Sesame cultivation is extended in tropical and subtropical regions of the world (Roebbelen *et al.,* 1989). The effects of water stress on sesame yield have an important goal in research activities in Iran. Improvement of drought tolerance genotypes of sesame is one of the major objectives of sesame breeding programs in marginal and arid regions of its cultivation.
The objective of the present study were (1) to determine the effects of drought stress on some of the agronomical traits of sesame genotypes (2) to compare the efficiency of different selection indices for selection of drought tolerant genotypes (3) determine the best genotype of sesame in water deficit stress.

MATERIALS AND METHODS

This experiment was conducted at the Agricultural Research Center of Hajiabad region in Iran (Latitude 28°15 N, longitude 55°54 E and altitude 1200 asl). The experiment was carried out in a split plot design based on complete block design with tow replications. Three intervals of irrigation (10, 20 and 30 days) with ten genotypes of sesame were considered as main factor and sub factor, respectively. Seeds were sown on July, 2011. Each genotype was sown in four 5 m rows spaced 50 cm apart. Distance of plants in each row was 5 cm in depth of 1-2 cm. Each subplot was 10 m^2. Sesame genotypes were collected from different geographical regions of Iran. Application of different irrigation treatments was started at four leaves stage.

Different agronomic traits including: the number of primary branches per plant, plant height (cm), number of capsule per plant, number of seeds per capsule, 1000-seed weight (g) and harvest index (%) were recorded using ten randomly plant selected in each plot. Seed yield (Kg/m^2) and biological yield (Kg/m^2) were determined by harvesting plants from one meter lengths of the middle row in each plot. Analysis of variance was carried out with SAS, 1997 software. Mean comparisons were done using least significant difference (LSD) test.

RESULTS AND DISCUSSION

Analysis of variance was showed that irrigation treatments had significant effects on primary branches, number of seeds per capsule, 1000-seed weight, seed yield and biological yield (Table 1). There were significant differences between evaluated genotypes for all of the studied traits, except for harvest index (Table 1). This result implied that there was a considerable genetic variation among evaluated genotypes. The interaction effect of genotype ×irrigation was significant for the number of seeds per capsule, 1000-seed weight, biological yield and seed yield (Table 1).

The comparison between different intervals showed that increasing of intervals of irrigation has reduced the mean of primary branches per plant, the number of seeds per capsule, 1000-seed weight, seed yield and biological yield, significantly. (Table2). Our results are in agreement with the reports of Heidari et al. (2011) and Golestani and Pakniat, 2007 that reported the reduction of seed yield and its components with increasing of water deficit levels in sesame. It could be concluded that in drought stress, reduction of seed yield was mainly related to reduction of number of seeds per plant and seed weight. In this study seed weight was very sensitive to drought stress. Westage and Boyer (1998) found that water stress during reproductive stages inhibits photosynthesis and consequently the reduction of carbohydrate reservoirs caused the insufficient growth of seeds and production of unfilled seeds in capsule. Pasban Eslam (2011) reported that in normal and stress conditions, the number of seeds per capsule and seed weight had the greatest positive effects on seed yield in safflower.

In this study, different stress levels (I_1 and I_2) have not significantly reduced the number of capsules per plant rather than control treatment (I_1) (Table 2). This result was inconsistence with the reports of Heidari et al, (2011). Drought stress had a significant effect on biological yield (Table 2). Fredrick *et al.,* (2001) reported that biological yield was significantly reduced in soybean genotypes. With increasing of drought tension Harvest index (%) has not reduced significantly reduction by increasing in drought tension (Table 2). Also, Lovelli *et al.,* (2007) reported that harvest index did not significantly change in different irrigation regimes in safflower.

Mean comparisons showed that there was significant variation among evaluated genotypes for plant height (Table 3). The highest and the least values of plant height were belonged to Hajiabad (147.42) (cm) and Gorgan (99.33) (cm) genotypes, respectively (Table 3). The reduction of plant height in drought stress has been reported by other studies (Hassanzadeh *et al.,* 2009; Heidari et al, 2011). The highest number of primary branches per plant was observed in Shiraz (5.21) genotype (Table 3). According to Table 3, the highest and the least content of number of capsules per plant and number of seeds per capsule was observed in Darab14 genotype and Gorgan genotypes, respectively (Table 3). There was a significant variation among evaluated genotypes for 1000-seed weight (Table 3). It was ranged between 2.72 (g) in Darab14 to 0.05 (g) in Gorgan genotype. The reduction of seed weight has been reported in different oilseeds such as corn (Hall *et al.,* 1997; Golbashy *et al.,* 2010) and canola

Table 1 Analysis of variance for agronomical traits in sesame genotypes under drought condition

		Mean squares							
Source of variation	**df**	**Plant height**	**Primary branches per plant**	**Number of capsules per plant**	**Number of seeds per capsule**	**1000-seed weight**	**Seed yield**	**Biological yield**	**Harvest index (%)**
Block	1	0.3	5.3**	0.01	35.5**	0.001	23.56	2881.20	0.002
Irrigation intervals	2	30.7	3.5	6.1	617. 7**	0.03**	247886.6**	1205700.4**	0.012
Error (a)	2	54.8**	0.17	566.5**	11.94	0.04	22.75	3095.5	0.015
Genotype	9	2382.56**	5.16**	8.5**	990.93**	11.72**	432773.7**	1827164.93**	0.013
Genotype× Irrigation intervals	18	206.94*	0.62	46.20**	10.04	0.007	7.42*	8514.26**	00.011
Error (b)	27	143.47**	0.68	1.92	5.8	0.009	22.53	2613.78	0.012

** and * significant at $P<0.01$ and $P<0.05$, respectively.

Table 2 Mean comparisons of agronomical traits in sesame genotypes under different intervals of irrigations

Irrigation treatments	Plant height	Primary branches per plant	Number of capsules per plant	Number of seeds per capsule	1000-seed weight	Seed yield	Biological yield	Harvest index (%)
(I_1)	135.13[a]	4.38[a]	27.36[a]	31.02[a]	50.67[a]	1486.1[a]	1.36[a]	0.13[a]
(I_2)	111.56[a]	3.91[a]	27.13[a]	31.02[a]	46.21[b]	1179.3[b]	1.15[b]	0.12[a]
(I_3)	133.66[a]	3.82[b]	26. 6[a]	29.92[b]	42.83[c]	993.1[c]	1.02[c]	0.12[a]

I_1, I_2 and I_3 are 10, 20 and 30 days for irrigation intervals.

Table 3 The mean comparison of evaluated traits in different genotypes of sesame

Genotype	Plant height (cm)	Primary branches per plant	Nubmer of capsules per plant	Number of seeds per capsule	1000-seed weight(g)	Seed yield (Kg/m^2)	Biological yield	Harvest index (%)
Darab14	141.19[ab]	4.91[a]	30.21[a]	67.37[bc]	2.72[a]	2079.1[a]	1.6[b]	0.15[ab]
Shiraz	145.11[a]	5.21[a]	29.10[b]	46.97[c]	2.38[b]	1971.1[b]	1.64[a]	0.13[ab]
Hajiabad	147.42[a]	4.63[ab]	27.36[c]	50.15[b]	2.03[d]	1843.9[c]	1.66[a]	0.12[ab]
Sirjan	131.95[bcd]	3.98[bc]	28.08[c]	44.78[d]	2.12[c]	1573.1[d]	1.41[c]	0.12[ab]
Orzoieh	144.53[a]	3.55[c]	27.93[c]	51.74[b]	1.54[e]	1184.1 [e]	1.35[d]	0.09[ab]
Safiabaf	126.9[d]	3.81[c]	27.5 [c]	42.64[e]	0.71[f]	828.4[f]	0.91[e]	0.09[ab]
Markazi	137.9[abc]	3.35[c]	27.93[d]	45.49[cd]	0.53[g]	782.3[gh]	0.89[ef]	0.08[ab]
Birjand	138.35[ab]	3.90[c]	25.35[de]	44.77[d]	0.43[h]	745.8[h]	0.85[f]	0.16[a]
Ardestan	128.51[cd]	3.28[c]	27.78[ef]	39.11[f]	0.26[i]	785.8[g]	0.9[e]	0.15[ab]
Gorgan	99.33[e]	3.43[c]	24.05[f]	32.7[g]	0.05[j]	401.4[i]	0.59[g]	0.07[b]

In each column the same alphabetic letters are not significantly, different

Table 4 Comparison of different drought tolerance indices for sesame genotypes

Genotype	Yp	Ys	SSI	TOL	STI	GMP	HM
Darab14	2.33	1.83	-1.46	0.5	1.95	2.07	1.02
Shiraz	2.45	1.65	-1.11	0.8	1.84	2.01	0.96
Hajiabad	2.11	1.56	-1.32	0.54	1.50	1.82	0.87
Sirjan	2.08	1.22	-0.84	0.85	1.16	1.59	0.69
Orzoieh	1.52	0.84	-0.73	0.68	0.59	1.13	0.42
Safiabaf	0.96	0.70	-1.28	0.26	0.31	0.82	0.26
Markazi	0.99	0.63	-0.97	0.37	0.28	0.79	0.27
Birjand	0.89	0.65	-1.28	0.24	0.26	0.76	0.28
Ardestan	0.99	0.64	-1.03	0.34	0.29	0.80	0.35
Gorgan	0.50	0.30	-0.84	0.21	0.07	0.39	0.11

Table 5 Correlation coefficient between tolerance indices with seed yield in normal (Y_P) and stress condition (Y_S)

Traits	Y_P	Y_S	SSI	TOL	GMP	STI	HM
Y_P	1						
Y_S	0.96**	1					
SSI	-0.28	-0.49	1				
TOL	0.83**	0.66*	0.26	1			
GMP	0.99**	0.99**	-0.39	0.74*	1		
STI	0.96**	0.99**	-0.42	0.69*	0.98**	1	
HM	0.97**	0.98**	-0.43	0.70*	0.99**	0.99**	1

* and ** significant at $P<0.05$ and $P<0.01$, respectively.

shown significant variations (Table 3). Seed yield was ranged from 2079 (Kg/ha) in Darab14 to 401.4 (Kg/ha) in Gorgan genotype (Table 3). In drought stress, water deficiency influences on the procedure of transferring of photosynthetic substances and diminish the seed storage content (8). The reduction of seed yield components could be a main result for reduction of seed yield (Hall *et al.*, 1997). The highest value of biological yield and harvest index (%) was observed in Hajiabad (1.66) and Birjand (0.16) genotypes, respectively (Table 3). The knowledge of relationship between yield component important yield traits and seed yield could be suitable to identify suitable parents for successful breeding programs.

Drought Tolerance Indices

The most content of Yp and Ys was belonged to Darab14 genotype. The genotypes with high values of TOL are sensitive to drought stress. Therefore in stress condition, the selection must be done based on low rates of TOL (Mohammadi *et al.*, 2011). The highest (0.85) and the least (-0.84) values of TOL were observed in Sirjan and Gorgan genotypes, respectively (Table 4). So, it could be concluded that these genotypes had relative yield stability in both conditions. Also, TOL indice could separate the genotypes that produce high yields in non-stress conditions from the ones with the same yields in stress conditions (Rosielle and Hamblin, 1981), hence it seems that application of this index in not suitable for selection of drought tolerance genotypes (Mohammadi *et al.*, 2011). Lower values of SSI indicate the lower changes under both conditions. Therefore the genotypes with high yield in both conditions could be distinguished with this index (Fischer and Maurer, 1978). Guttieri et al. (2001) suggested that higher values from unity for SSI index, indicating higher sensitivity to drought. In view point of SSI index, Darab14 (-1.46), Hajiabad (-1.32) and Shiraz (-1.11) genotypes, had the most tolerance to drought stress in this study. Also, Orzoieh (-0.73) and Gorgan (-0.84) had more sensitivity to drought condition. The highest value of GMP (2.07) and STI (1.95) were belonged Darab 14 (Table 4). Hassanzadeh et al. (2002) found that STI and GMP were more useful in order to select suitable genotypes under stress and non-stress condition. The highest (1.02) and the least (0.11) values of HM were observed in Darab14 and Gorgan genotypes, respectively (Table 4).

The correlation coefficient between different tolerance indices has shown in Table 5. Ys had significant and positive correlation with Yp (Table 5). Ys showed positive and significant correlation with TOL, GMP, STI and HM indices (Table 5). This result was in agreement with the findings of Hassanzadeh *et al.*, (2009) and Golestani and Pakniat, 2007. Seed yield in normal condition (Yp) has significant correlation with TOL, GMP, STI and HM indices (Table 5). This result was similar with the results of Mohammadi *et al.*, (2011) in bread wheat. TOL had significant correlation with GMP, STI and HM indices.

CONCLUSION

Based on overall obtained results from this study it could be concluded that Gorgan genotype could be classified in the group of drought-sensitive genotypes. Hajiabad had moderate tolerance to drought stress. Genotypes of Sirjan, Orzoieh, Safiabad, Markazi, Birjand and Ardestan had medium tolerance to drought conditions. Darab14 and Shiraz genotypes had the most tolerance to drought conditions. So, these tolerance genotypes could be recommended for cultivation in arid and hot climates. Also using from these two superior genotypes in hybridization programs could be a good strategy for enhancement of drought tolerance in sesame genotypes.

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