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Genetic Diversity among Sesame Genotypes under Drought Stress Condition by Drought Implementation

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ABSTRACT

Drought stress is one of the most important abiotic stresses that affect crop yield. The tolerance of 22 selected sesame (*Sesamum indicum* L.) genotypes originated from Iran, India, Pakistan, China and South America were assessed under field conditions in North-western part of Iran during 2007 and 2008. The responses of genotypes were studied under optimal and limited irrigation conditions using common quantitative indices of stress tolerance. Highly significant differences were observed among the genotypes for grain under both normal and limited irrigation conditions and stress tolerance indices. This indicates the existence of considerable genetic variation among the genotypes and thus the possibility of identifying drought- tolerant genotypes within sesame germplasm. Principal component analysis (PCA) revealed a high-level of genetic diversity among the genotypes. The first and the second principal components showed 92.76% of the total variation. Iranian sesame genotypes were highly tolerant under drought stress compared to those from other parts of the world. Considering correlation between indices and grain yield under stress and normal conditions, stress tolerance index (STI) was identified as the best index for selection of drought-tolerant sesame cultivars, which are capable of producing high yields under normal conditions.

Keywords: Abiotic stresses, oilseed crop, principal component analysis, *Sesamum indicum*, stress tolerance index, water stress, yield.

Abbreviations:

MP: Mean Productivity; **PCA:** Principal Component Analysis; **SSI:** Stress Susceptibility Index; **STI:** Stress Tolerance Index; **TOL:** Tolerance Index; **YP:** Yield Mean in Normal Condition; **YS:** Yield Mean in Stress Condition.

INTRODUCTION

Drought stress is responsible for the most important crop losses around the world and are expected to worsen, heightening international interest in crop drought tolerance and expected due to climate projections and increasing competition for water among urban, industrial, and agricultural demand (IPCC, 2012; Haro von Mogel, 2013). Also drought is one of the major constraints limiting crop productivity in Iran (Sabbaghpour, 2006).

Originated from India, Sesame (*Sesamum indicum* L.) is known to be the most ancient oilseed crop (3050–3500 BC) (Bedigian and Harlan, 1986; Bedigian, 2011). Sesame is an autogamous species and its populations often exist as a composite of various homozygous individuals. Genetic advance in this crop can easily be gained through the exploitation of existing diversity after selection for a few generations, because of a combination of autogamy and heterogeneity (Amani et al., 2012). Despite the existing genetic variation, sesame yield is poor and genetic improvement is required to overcome many production constraints. The success in genetic improvement of the crop, however, depends on the availability of diverse genetic resources (Arriel et al., 2007). Evaluation of agro-morphological variation in sesame has been reported earlier and the value of the genetic diversity in local populations of sesame was documented by several scientists in India, Turkey, China and Iran (Bisht et al., 1998; Bhat et al., 1999; Baydar and Gurel, 1999; Xiurong et al., 2000; Kadkhodaje, 2013).

Principal component analysis (PCA) has been used to analyse genetic diversity and identify traits contributing to the divergence in yield (Sabbaghpour, 2006; Arriel, et al., 2007). The genetic diversity has also been reported among sesame germplasm of Turkey (Furat and Uzun, 2010) as well as in Iranian genotypes (Amani et al., 2012) using PCA. Using both morphological and physiological methods could give better results than using only one of these methods (Bourema et al., 2012). The use of effective evaluation, or screening criteria, is of paramount importance in characterizing genetic resources for complicated traits, such as, drought tolerance.

In addition to quantitative agronomic traits, like, yield components, some quantitative indices, including stress tolerance index (STI), stress susceptibility index (SSI), and tolerance index (TOL) have been recommended for this purpose (Fernandes, 1992). For screening of drought-tolerant wheat genotypes, some scientists have suggested a two-stage selection procedure. In first stage, the genotypes are screened based on yield performance under drought stress conditions. The second stage of screening takes place within the selected genotypes of the first stage, based on morphological traits associated with drought tolerance (Fisher and Maurer, 1978). However, there is limited information on the diversity of sesame genetic resources and the possible use of such resources for developing high-yielding and drought- tolerant sesame varieties. Some sesame breeding lines were evaluated using common quantitative indices of stress tolerance, suggesting the usefulness of these indices for evaluation of sesame germplasm for drought tolerance (Golestani and Pakniyat, 2007).

The present study was conducted to identify the best drought-tolerant genotypes for using in sesame breeding programs. The aim of the present study was to determine the responses of sesame accessions of different origins to drought stress and consequently identify drought-tolerant lines-accession in drought stress areas in Iran. Selected sesame genotypes from different regions of Iran, India, China and Panama were evaluated under normal and water deficit (limited irrigation) conditions, and comparatively analysed the diversity for drought tolerance in sesame germplasm.

MATERIALS AND METHODS

Plant Material:

Twenty-two sesame genotypes acquired from Iran, India, China and Panama were used in this study (Table 1). Genotypes were sown in the field during summer (early July–mid-October) 2007 and 2008 in a randomized-block design (RBD) with 3 replications. The experiment was conducted at Moghan agricultural research station, in north-western part of Iran at the Caspian Sea border. This station is located at the geographical position of 47° 36′ 2″ N, 39° 36′ 45″ E latitude North and 72.6 m above sea level. The region is considered semi-arid with an annual precipitation of 246 mm, hot summers and mild winters. Other climatic details are given in Table 2.

Table 1. Studied sesame genotypes and their origin.

Variety Code	Variety name	Country of origin
1	Karaj-1	Iran
2	Yekta	Iran
3	Oltan	Iran
4	Moghan17	Iran
5	Naz	Iran
6	J-1	India
7	Borazjan 2	Iran
8	Borazjan 5	Iran
9	Darab 14	Iran
10	Varamin 37	Iran
11	Varamin237	Iran
12	Varamin2822	Iran
13	I.S	Palestine
14	Indian9	India
15	China	China
16	Yellow White	Pakistan
17	Punjab 89	Pakistan
18	Panama	Panama
19	CO-1	Panama
20	TKG-21	India
21	Indian12	India
22	RT-54	South America

Treatment:

The experiment was conducted under normal (optimal irrigation) and drought stress (without irrigation at 50% flowering) conditions at two separate plots side by side. Each replication contained three 2-m long rows, with a spacing of 60 cm between the rows and 15 cm between the plants in a row. Normal recommended cultural practices and plant protection measures were followed in the region.

Studied Traits:

Ten competitive plants were randomly selected for recording grain yield in 1.2 m^2. Based on potential yield and yield under stress, quantitative indices of drought tolerance, such as, stress susceptibility index (SSI) (Fisher and Maurer, 1978), stress tolerance index (STI) (Fernandes, 1992), tolerance index (TOL), mean productivity (MP) (Fisher and Maurer, 1978) were recorded.

Data Analysing:

The original mean values were transformed to normalize variables. Principal component analysis (PCA) was conducted on the normalized data. The data were analysed using biometrical methods and statistical MSTAT-C, SPSS and excel software (Rao, 1952; Dhopte and Manuel, 2002).

RESULTS AND DISCUSSION

Combined analysis of variance (ANOVA) for two years data showed significant differences among genotypes for grain yield under both normal and drought stress conditions (Table 3), indicated a high level of genetic variation among the genotypes, and thus the possibility of selecting drought-tolerant genotypes. Most significant differences were found among the genotypes for all six quantitative indices of drought tolerance or sensitivity (YP, YS, STI, MP, TOL and SSI), computed based on the grain yield obtained under normal and drought stress conditions (Table 4).

Table 2. Meteorological features of Moghan research station.

Parameters	Month			
	July	August	September	October
Absolute minimum temperature (º C)	16	16	12	9.4
Absolute maximum temperature (º C)	39.8	37.4	32.4	27
Mean minimum temperature (º C)	819.	19.8	17.8	13
Mean maximum temperature (º C)	34.9	35.3	27.6	23.4
Mean temperature (º C)	27.4	27.5	22.7	18.2
Precipitation (mm)	6.6	2.3	48.3	74.3
Relative humidity (%)	55	55.9	68.1	76.1
Average evaporation (mm)	8.2	9.2	5	1.9

Table 3. ANOVA of sesame grain yield.

Source of Variation	df	Mean of Square	
		Grain Yield in Normal Condition	Grain Yield in Stress Condition
Year	1	2200*	2028**
Error	2	225	767
Genotype	21	238900**	140950**
Year × Genotype	21	20253**	10258**
Error	42	382	83
C.V.%		12.25%	10.28%

Based on the analysis of drought indices genotypes, Karaj-1, Yekta, Oltan, Naz, Varamin 2822 and Indian 9, showed the highest STI and these were identified as genotypes with higher performance and yield potential under both stress and normal conditions. However, based on the TOL index, different results were obtained; genotype Darab 14 and China were recognized as the most tolerant and genotypes Moghan 17 and Naz as the most sensitive ones under drought stress. Earlier studies on common bean have also demonstrated that TOL index was incapable of identifying genotypes with high performance under normal and stress conditions (Ramirez–Vallejo and Kelly, 1998). This indicates that different indices may produce different results. Among the four indices used for screening drought-tolerant genotypes in sesame STI and MP were closely correlated with each other and with both yield performance under normal (Yp) and stress conditions (Ys). On the contrary, SSI and TOL were close to each other and showed close association with yield under stress conditions (Fig. 1).

Therefore, synchronic application of all these indices together can provide more reliable estimation than using each index independently for drought tolerance in sesame. Hence, performing a multivariate analysis, such as PCA will be appropriate than other analysis methods for distinguishing drought-tolerant genotypes (Mollasadeghi et al., 2011).

In principal component analysis, the first and second principal components showed 92.76% of total variation (Table 5). The bi-plot of PC1 and PC2 (Fig. 1) identified genotypes of Iran, Pakistan and India, as closely related and distinctly separated from genotypes of China, Palestine, Panama and South America. These results indicates that Iranian varieties may share same origin with sesame varieties of the Indian subcontinent. Most of the indices YP, YS, STI, MP contributed to the first principal component, whereas, indices TOL and SSI showed largest contributions to the second component. A sizeable correlation was observed between yield and the drought tolerance-associated indices MP and STI (Fig. 1). In addition, the correlation between yield under drought stress conditions (Ys) and STI was considerably higher (R=83.4%) than that of Yp and STI (r=0.44.7). This indicates that genotypes selected through STI have higher probability of producing higher yield than other genotypes studied under stress conditions (Fernandes, 1992; Sabbaghpour, 2006; Mollasadeghi et al., 2011).

Most of the selected genotypes (Karaj 1, Yekta, Oltan, Varamin 37, Varamin 237, Varamin 2822 and Naz) are derived from Iranian local landraces, and hope that better drought-tolerance characteristics have been developed in Iranian sesame germplasm, based on their environmental conditions throughout centuries of cultivation of this ancient crop.

Table 4. Drought stress indices and grain yield of sesame varieties.

Variety No	Variety Name	Grain yield(KG)		SSI	TOL	MP	STI
		Normal condition	Stress condition				
1	Karaj-1	1884 a	1328 ab	1.11	556.0	1606.00	1.20
2	Yekta	1598 abcde	1386 a	0.50	212.0	1492.00	1.06
3	Oltan	1785 ab	1327 ab	0.97	458.0	1556.00	1.14
4	Moghan17	1588 abcde	883.6 defg	1.68	704.4	1235.80	0.67
5	Naz	1767 abc	1331.0 ab	1.36	636.0	1449.00	0.96
6	J-1	1536 bcdef	1102 abcde	1.07	434.0	1319.00	0.81
7	Borazjan 2	1582 abcde	1019 cdef	1.34	563.0	1300.50	0.77
8	Borazjan 5	1423 cdefg	1011 cdef	1.09	412.0	1217.00	0.69
9	Darab 14	1048 ig	965.1 cdef	0.30	82.9	1006.55	0.49
10	Varamin 37	1451 bcdefgh	1161 abcd	0.75	290.0	1306.00	0.81
11	Varamin237	1535 bcdef	1130 abcd	1.00	405.0	1332.50	0.83
12	Varamin2822	1706 abcd	1164 abcd	1.20	542.0	1435.00	0.95
13	I.S	1531 bcdef	969.4 cdefg	1.39	561.6	1250.20	0.71
14	Indian9	1523 bcdef	1173 abcd	0.87	350.0	1348.00	0.86
15	China	1168 ghij	1139 abcd	0.09	29.0	1153.50	0.64
16	Yellow White	1356 defghi	928.5 defg	1.19	427.5	1142.25	0.60
17	Punjab 89	1373 defghi	924.7 defg	1.23	448.3	1148.85	0.61
18	Panama	1474 bcdefg	1244 abc	0.59	230.0	1359.00	0.88
19	CO-1	1223 fgij	726.9 fg	1.53	496.1	974.95	0.43
20	TKG-21	1164 ghij	1051 bcde	0.37	113.0	1107.50	0.59
21	Indian12	934.7 J	788 g	0.60	149.7	862.85	0.35
22	RT-54	1106 hig	798.0 efg	1.05	308.0	952.00	0.42

Mean comparison: Duncan 5%

SSI: Stress Susceptibility Index; TOL: Tolerance Index; MP: Mean Productivity; STI: Stress Tolerance Index.

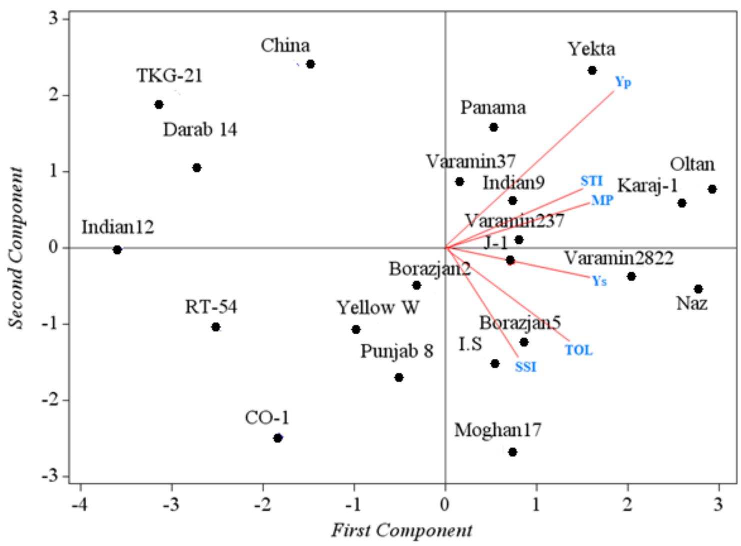

Fig. 1. Sesame germplasm variation of different origins based on the biplot of PC1 and PC2.

Table 5. Cumulative variance explained by characteristics for each of the first two principal components.

Component	Total	Cumulative %	YP	YS	SSI	STI	TOL	MP
1	3.136	52.27	0.761	0.761	0.394	0.927	0.629	0.953
2	2.428	92.75	0.289	-0.634	0.906	-0.342	0.751	-0.268

YP: Yield mean in Normal Condition; YS: Yield mean in Stress Condition; SSI: Stress Susceptibility Index; TOL: Tolerance Index; MP: Mean Productivity; STI: Stress Tolerance Index.

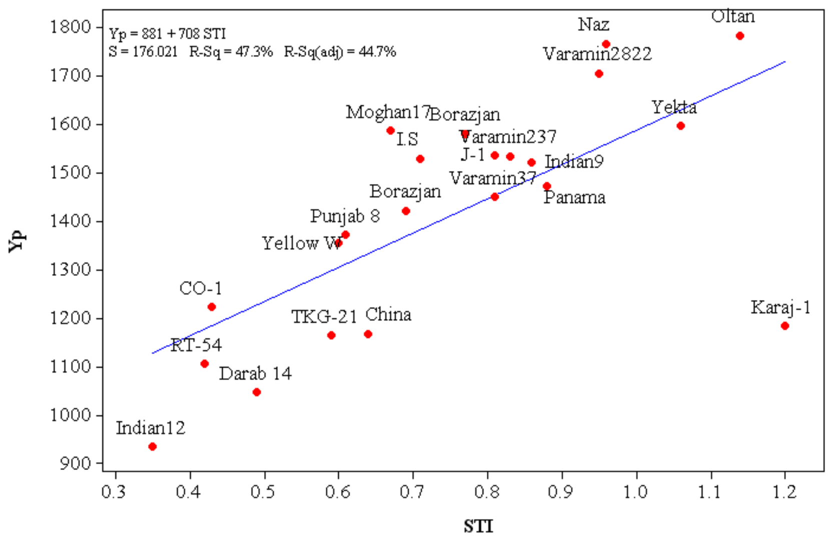

Fig. 2. Correlation between STI (Stress Tolerance Index) and Yp (Yield mean in normal condition) in the studied sesame genotypes

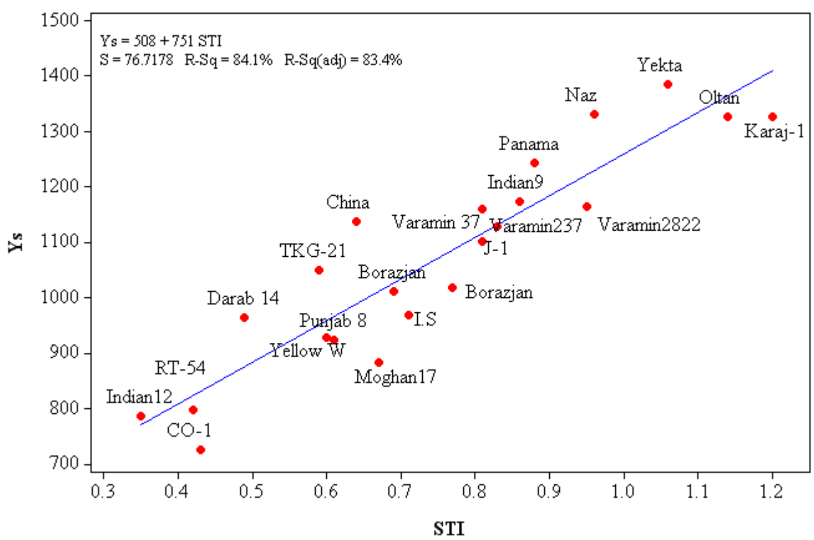

Fig. 3. Correlation between STI (Stress Tolerance Index) and Ys (Yield mean in stress condition) in the studied sesame genotypes.

CONCLUSION

Highly significant variation was found among sesame genotypes for grain yield and drought tolerance indices. Selected genotypes of Iranian origin, such as, Karaj 1, Yekta, Oltan, Naz and Varamin 2822 derived from local landraces, had significantly higher drought tolerance among all studied genotypes, in addition to higher grain yield under both normal and stress conditions. Stress tolerance index was highly correlated with grain yield under both normal (Yp) and stress conditions (Ys) (Fig. 2 and 3). Thus, it would be considered more effective index among all the indices for screening drought-tolerant sesame genotypes, which could also perform well under normal conditions. Synchronic application of all indices together can provide a more reliable estimation than using each index independently of drought tolerance in sesame. The result so of the present study indicate that STI is a more effective index among all indices in screening for drought stress tolerance in sesame crop.

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