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Evaluation of drought stress effect in summer Safflower genotypes

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ABSTRACT: The development of safflower cultivation is very important for Iran to meet the country's demand for edible oil. Although, safflower is a native plant of Iran and has the advantage of good resistance to salt and drought stress, only limited research has been carried out to identify specific crop traits that contribute to this tolerance. This experiment aimed to evaluate the effect of drought stress on seed and oil yields, yield components, oil percentages and some agronomic characteristics of spring safflower genotypes. The experiment was, factorial using complete randomized block design with three replications; normal irrigation and water deficit stress at both the stem elongation and flowering stages using six genotypes. The results revealed that the flowering time was the most sensitive stage to water deficit. Analysis of variance showed high genetic diversity between the genotypes for the studied traits: genotypes 34069, K.H.64.68 and340779 had the highest averages of traits in normal and stress conditions. The results indicated by the stress tolerance indices, geometric mean productivity and arithmetic mean productivity can potentially be used for selection of superior genotypes for cultivation under drought stress conditions.

Keywords: Drought stress, Oil and seed yield, Safflower, Tolerance indices

INTRODUCTION

In terms of supply, most of the oil consumed in Iran is imported from foreign sources and in the context of rising population and per capita oil consumption, an increase in cultivation and productivity of oil seeds is of vital importance. Plants, such as safflower have fairly good resistance to soil salinity and drought stress conditions and can be cultivated in dry and semi-arid areas (Yazdi Samadi 1977). Although safflower is a native plant of Iran and wild species are plentiful (Ahmadi *et al.*1998), the species has not gained much recognition and very little research has been done on the seed. The average grain yield of safflower in Iran is about 500 kg per ha, compared with the global average of 795 kg per ha (FAO 2005). Safflower seed potential yield is about 4 tons per hectare however, the results of some experiments, have harvested more than 4/5 tons of grain per hectare. A high yield of 2 tons per hectare is considered desirable (OmidiTabrizi *et al.* 2000). Safflower oil consists of about 90 percent unsaturated fatty acids, placing it as one of the best oils for popular consumption. There is approximately 270 mg Tukofrol Per kg of safflower oil and this particle maintains the oil's stability even at high temperatures (Demurin *et al.* 1996, Pasban Eslam 2003). Zope and his colleagues (1988) studied four different varieties of safflower seeds with different filling periods. They reported a significant correlation between the grain filling period and days of cultivation to flowering time, and days of cultivation on product maturity and seed yields, (Tiwari and Namdeo 1990) attributed seed weight variation to; differences in grain filling periods, weather conditions and the differences in crop density among the contributing factors. Esendel and colleagues (1992) in the study of different cultivars of safflower and environmental effects on safflower grain yields, declared that grain yields of safflower were affected by amounts of rainfall and lower temperatures during germination to flowering period as well as during the stage of lowering to maturity and noted a significant correlation. However, at a temperature two degrees higher than the optimum the correlation was negative. Also, there was a positive relationship between the rate of seed oil to low rainfall and temperature during the flowering to maturity stage and there was negative correlation at high temperature during the germination to flowering stage.

Mathur and colleagues, (Mathur *et al.* 1976) in a study on the diversity of different traits of safflower cultivars found that a significant difference between various safflower cultivars in terms of number of branches, number of days to flowering, height of plant, number of weight seeds per capitula, seed weight (of one thousand seeds). Barzegar and Rezai (1998) reported wide variations between cultivars in terms of seed weight during the study of different cultivars of safflower. One of the most important issues in the evaluation of cultivars for drought resistance was measured by quantitative criteria of drought resistance (Clarke *et al.* 1992). In the semi-arid regions where rainfall distribution is inadequate, high yield under drought stress is not considered as the best indication of resistance to drought stress. Yield stability (a comparison of crop performance under normal and stress induced conditions) has been accepted as the appropriate index to study the stress responses of genotypes to humidity stress (Simane *et al.* 1993). Different indices for evaluating the responses of genotypes in different environmental conditions and their sensitivity and resistance are presented by Rosielle and Hambline (1981) in the forms of tolerance index (TOL) and the average productivity index (MP). A high TOL score indicated high relative response of the genotype to stress symptoms. The stress susceptibility index (SSI) was introduced by Fischer and Maurer (1978). A low SSI score shows low yield changes of genotypes in both stress and desirable conditions, an indication of a good level of tolerance. A further stress tolerance index (STI) was introduced by Fernandez (1992) on the basis that stable genotypes had higher STI scores and were therefore more favorable. The GMP index also by Fernandez (1992) identified the geometric mean yield of a genotype under both stress and normal conditions. A high correlation between STI and GMP index was identified (Fernandez 1992). The purpose of this experiment was to select superior genotypes in terms of different traits under different drought and water stress conditions and to evaluate drought resistance at the stem elongation and flowering stages.

MATERIALS AND METHODS

This study and research was carried out at the Agricultural Research Station farm located at Tabriz University Karkaj, 12 km away on the road to Basmenj-East of Tabriz in year of 2005, (longitude 46 degrees 17 minutes and latitude 38 degrees 5 minutes). The genotypes were compared in a study designed as a factorial experiment in a randomized block design with three replications.

Factor (A) consisted of the six safflower genotypes; Spring K.H.64.68, Iraqi 222, 340779, 34069, CART.90.94 and CART.77.191. Factor (B) was3 different levels of irrigation (no stress, stress and stress at stem elongation and flowering stages). With regard to region and temperature conditions; irrigation to the controlled units was applied at time intervals of 8 to 10 days. Plots under drought stress at the stem elongation stage, and irrigation at the stem elongation stage were in accordance with normal routines however, irrigation was cut at the start of stem elongation. The plots under drought stress at the flowering stage were irrigated with the normal procedure at, and irrigation was also interrupted once at this stage had been reached. Each experimental unit consisted of four rows with distances of 30 cm and lengths of 5 meters. In order to establish the target number of plants per experimental unit, a larger amount of seeds were planted and then at the appropriate time, tender operation was performed on the plant rows and 10 cm distances were set. A seed planting depth of 3-4 cm was determined. In order to improve the nutrition of the plants before planting 100 kg potassium sulfate fertilizer and 100 kg triple phosphate fertilizer per ha was applied to the soil. During the vegetative stage, urea fertilizer was automatically given twice to the soil (100 kg per ha at each application). During the test period, normal farm management operations were carried out including periodic farm pest and weed control. The dominant fly pest in the field was the safflower fly, Diazinon toxin at a concentration density of 2 per thousand was used to combat the pest. The traits evaluated in this study were:

NSP: number of seed per plant
NLP: number of leaf per plant
DFHG: distance of first head from ground
SD: stem diameter
NDPM: number of days to physiological maturity
DTNS: distance of two constant nodes on stem
NB: number of branches
SWH: seed weight of head
LDWFS: leaf dry weight at flowering stage
NAB: number of accessorial branches
ASB: angle between stem and branch
NSH: number of sterile head

The data for variance analysis was established and analyzed then the mean results were applied to Duncan's test at the level of 5 percent. For the determination of genotype sensitivity rate or tolerance to drought stress, indicators SSI, STI, GMP, TOL and MP were used as follows:

$$TOL = YP - YS$$

$$MP = \frac{YS + YP}{2}$$

$$SSI = \frac{1 - \frac{YS}{YP}}{1 - \frac{\bar{Y}S}{YP}}$$

$$GMP = \sqrt{YS.YP}$$

$$STI = \frac{YP.YS}{(YP)^2}$$

YP: yield under non-stress conditions
YS: yield under stress conditions
MEAN YS: The average yield of all genotypes in stress conditions
MEAN YP: The average yield of all genotypes under non-stress conditions
Genotype under non-stress conditions for statistical analysis, and drawing diagrams of software SAS, MSTATC and STAT Graph was used.

RESULTS AND DISCUSSION

A. Analysis of variance and comparison of mean traits
The result of variance analysis s' traits is listed in Table 1. Results indicates that the effect of drought stress at different levels (stem growth and flowering stage) in seed weight of head and number of sterile head and number of seed per plant is significant. But there was no significant difference between the different levels of drought stress and normal conditions in the rest of observed traits. Most likely, these results show that in above traits, between studied genotypes in terms of response to environmental conditions of drought stress attack, there was no significant difference. The studied traits number of days to physiological maturity minimum coefficient of variation and the number of accessorial branches, number of sterile head and leaf dry weight at flowering stage had the highest coefficient of variation. It seems that in this study phonological traits, number of days to physiological maturity, are less affected by genotype and environment in terms of the attributes of the act they are independent. Coefficient of variation was a standard and shows the reliability of the characters. An acceptable level of control tests and the coefficient of variation depending on the degree of heritability studies and other factors may vary. Studied genotypes and traits, distance of first head from ground, leaf dry weight at flowering stage, number of sterile head, stem diameter, distance of two constant nodes on stem, number of seed per plant, had significant difference at 1% and the seed weight per head and the angle between stem branch had significant difference at the 5% level that indicates high genetic variation among genotypes for these traits and this diversity can be exploited in a selection program for resistance to drought. Genotype at different levels of drought stress was not significant for all traits which indicate no the interaction of genotype and environment. The genotypes Iraqi 222, CART.77.191, CART.90.94 has highest stem diameter traits and lowest number of seeds per plant (Table 2).On the other hand, as shown in Table 2, Genotype Iraqi222 has the lowest number of sterile head. Leaf dry weight at flowering stage in CART.77.191 genotype had the lowest level. CART.77.191 and CART.90.94 genotypes have lowest distance of first head from ground. According to Table 3, traits the number of seeds per plant and seed weight of head, were assessed the lowest value in water stress at flowering stage. On the other hand, the number sterile was the highest in drought stress of flowering stage. Results Table 1 shows that between genotype and stress levels, there was no significant difference in the number of branches. Drought stress has no effect on the number of branches in flowering stage of plant be cause at the beginning stage of flowering plant appeared all branches. On the other hand, given that the number of branches may be a genetic trait with high heritability, at stem elongation stage, drought had no significant effect on it. In summarizing the above mentioned arguments, it can be concluded that the genotypes 340779, K.H.64.68, 34069 in most of the studied traits averages were higher. In this study flowering stage was the most sensitive to drought stress.

According to the SSI index under drought stress conditions on stage and flowering stem, 34069 and CART.90.94 were identified as the most tolerant and sensitive genotypes respectively (Table 4). In terms of the index TOL, genotype 34069 as drought tolerant genotype at the start of the flowering stage and the start of the stem elongation stage wereidentified (Table 4). On the other hand the indices GMP, MP, and STI with two drought applications showed 34069 and CART.77.191 as the tolerant and sensitive genotypes respectively (Table 4.).

Table 1: Analysis of variance of different characteristics under different levels of stress and genotype effects on safflower cultivars evaluated.

Source of variation	df	Mean squares											
		SWH	NB	NAB	ASB	DFHG	LDWFS	NSH	NDPM	NLP	SD	DTNS	NSP
Replication	2	0/214	0/307	2/556	38/397*	90/092**	22/317*	0/669	0/296	1891/355**	0/005	0/361**	1884/549
Genotype	5	0/642*	1/584	5/070	29/048*	534/091**	20/600**	3/310**	1/007	86/911	0/223	0/268**	27363/740**
Irrigation level	2	0/931*	0/576	0/680	20/090	3/426	8/658	2/58*	0/074	207/807	0/039	0/045	20194/028*
Irrigation level * genotype	10	0/197	0/982	1/646	9/747	7/761	6/149	0/535	0/519	66/845	0/012	0/093	1562/999
Error	34	0/120	1/904	2/188	8/974	13/077	4/567	0/447	1/002	115/334	0/012	0/057	4143/123
Coefficient of variation		%18/72	%18/96	%45/80	%6/66	%9/94	%30/78	%38/31	%0/84	%16/09	%16/22	%8/84	%22/86

* And ** significant at level 5% and 1% respectively.

NSP: number of seed per plant
NLP: number of leaf per plant
DFHG: distance of first head from ground
SD: stem diameter
NDPM: number of days to physiological maturity
DTNS: distance of two constant nodes on stem
NB: number of branches
SWH: seed weight of head
LDWFS: leaf dry weight at flowering stage
NAB: number of access oriel branches
ASB: angle between stem and branch
NSH: number of sterile head

Table 2: Comparison of the mean traits of the genotypes studied safflower with Duncan test.

Genotype	SWH (g)	ASB	DFHG (cm)	LDWFS (g)	NSH	SD (cm)	DTNS (cm)	NSP
K.H.64.68	3/65[a]	44/00[bc]	44/73[a]	7/32[a]	1/49[b]	1/21[a]	2/639[bc]	331/04[a]
340779	3/66[a]	44/46[abc]	36/51[b]	7/00[a]	2/01[b]	1/11[a]	2/81[ab]	320/06[a]
34069	3/78[a]	45/02[abc]	41/34[a]	8/33[a]	1/88[b]	1/40[a]	2/979[a]	339/57[a]
CART.90.94	2/45[ab]	42/50[c]	27/58[c]	7/11[a]	2/08[b]	0/84[b]	2/518[c]	235/96[b]
CART.77.191	1/25[b]	47/41[a]	26/52[c]	4/03[b]	2/18[b]	0/82[b]	2/666[bc]	211/42[b]
Iraqi 222	2/45[ab]	46/67[ab]	41/64[a]	7/88[a]	0/83[a]	0/83[b]	2/557[c]	251/43[b]

Different letters in each column indicate a significant level of 5% is likely.
SWH: seed weight of head, ASB: angle between stem and branch, DFHG: distance of first head from ground, SD: stem diameter, LDWFS: leaf dry weight at flowering stage, NSH: number of sterile head, DTNS: distance of two constant nodes on stem, NSP: number of seed per plant.

Table 3: Comparison of the mean traits of the different level of Irrigation.

Stress level	SWH (g)	NSH	NSP
Normal conditions	3/52[a]	1/5[a]	337[a]
Drought stress at stem elongation stage	2/98[a]	2/68[b]	302[b]
Drought stress at flowering stage	1/37[b]	3/51[c]	285[c]

Different letters in each column indicate a significant level of 5% is likely.
SWH: seed weight of head, NSP: number of seed per plant, NSH: number of sterile head

Table 4: Average values of indices of drought tolerance in safflower genotypes studied according to seed yield.

Genotype Tolerance index	K.H. 64.68	340779	34069	CART.90.94	CART.77.191	Iraqi 222
SSI at stem elongation stage	7.249	5.808	0.411	7.528	5.861	3.923
SSI at flowering stage	2.123	1.137	0.126	2.793	1.213	1.983
TOL at stem elongation stage	214.6	178.8	99.3	314.9	127.5	130.1
TOL at flowering stage	173.7	298.1	24.2	225.5	217	312
GMP at stem elongation stage	2122.9	1915	2350	1262	686.8	1373.4
GMP at flowering stage	2166.6	1721.8	2300	1409.1	565.2	1480.1
MP at stem elongation stage	2277.5	2062	2423.5	1405.6	841.6	1513.6
MP at flowering stage	2250.9	1781	2430	1468.9	640.2	1520
STI at stem elongation stage	1.299	1.131	1.353	0.746	0.491	0.815
STI at flowering stage	1.234	0.973	1.354	0.778	0.392	0.820

Evaluation of drought tolerant genotypes Indices:
Genotypes K.H.64.68 and 34069 at both stages drought stress, showed no significant differences with the index (STI). Selection principle based on the MP increased yield in both environments (no stress and stress conditions), (Fernandez 1992). Ashkani and Pakniyat (2002) with the study of genetic quantitative indices of drought resistance in spring safflower realized that the selection of high performance genotypes for yield and protein and oil production was best determined with the MP index. The GMP index determines optimal irrigation conditions and STI index for the selection of high oil yield genotypes with limited irrigation conditions was recommended. Naderi and *et al.* (1999), and Clarke *et al.* (1992) preferred the indices STI and GMP to identify drought tolerant cultivars. The indices STI, GMP and MP were identified as the most appropriate methods to assess drought resistance because the separation of genotypes based on the above indicators were more accurate.

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