Available online at http://www.ijabbr.com

International journal of Advanced Biological and Biomedical Research

Volume 1, Issue 9, 2013: 1086-1093

# Evaluation of drought tolerance in Safflower (*Carthamus tinctorius* L.)under Non Stress and Drought Stress Conditions

**Seyed Mehdi Safavi [1*], Seyyed Saeid Pourdad [2], Seyed Afshin Safavi [3]**

[1]Department of Agronomy and Plant Breeding, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran

[2] Dry-land Agricultural Research Institute (DARI), Kermanshah, Iran

[3] Kermanshah agri-jahad organization, Kermanshah, Iran

## ABSTRACT

This study was conducted to determine drought tolerance genotypes with superiority in different stressed environments. To screening quantitative indices of drought tolerance, genotypes of safflower (*Carthamus tinctorius* L.) were tested in a complete randomized block design with three replications under two different water regimes (irrigated and rainfed). Significant positive correlation was found between grain yield in the stress condition (Ys) with indicators stress tolerance index (STI), harmonic mean (HAR) and geometric mean productivity (GMP) indicating that these indices are suitable criteria for screening drought tolerant genotypes. No significant correlation was observed between Ys with tolerance index (TOL) and mean productivity (MP), hence they can be discarded as the desirable markers for identifying drought tolerant genotypes. Principal component analysis (PCA), indicated that the first and second components justified 98.45% of variations between the criteria. Screening drought tolerant genotypes using mean rank, standard deviation of ranks and biplot analysis, discriminated genotype G1 (44) as the most drought tolerant. In conclusion, The indices STI, GMP, MP and HAR genotype G1 (44) were identified as spring planting drought resistant genotype. This genotype had the highest grain yield under stress and non-stress conditions was also high performance.

**Key words**: Safflower genotypes, Stress tolerance index, Drought tolerance, Biplot

## INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is one of the plants which have a high adaptation to different conditions such as resistance to drought and it is suited to be grown in arid and semi-arid regions (Khalili Mosavi et all., 2009). The importance of oil crops such as safflower has increased in recent years, especially with the interest in the production of biofuels (Dordas and Sioulas, 2008). Generally safflower is produced on marginal lands that are relatively dry and relatively deprived the benefit of fertilizer inputs or irrigation. Attempts to improve seed yield and quality by developing new genotypes and agronomic practices are underway throughout the world. The fact that water stress effects on growth and yield are genotype-dependent is well known (Bannayan et al., 2008). There is limited researches around the world on safflower production under irrigated conditions that revealed it is a sensitive crop to water (Quiroga et

**Corresponding Author E-mail:** seyedmehdisafavi@yahoo.com 

al., 2001; Bassil and Kaffka, 2002a,b) and moderately tolerant to salinity. Some other research found safflower can be a candidate crop in dryland agroecosystems due to the potential for growth under water stress and the economic value in terms of both oil and seed (Yau, 2004; Kar et al., 2007); therefore this finding may be coming from the variability of safflower genotypes. In Iran water is a scarce resource due to the high variability of rainfall. The effects of water stress depend on the timing, duration and magnitude of the deficits (Pandey et al., 2001). Because of water deficit in most arid regions, resistance of crop plants against drought has always been of great importance and has taken into account as one of the breeding factors (Talebi, 2009). A long term drought stress effects on plant metabolic reactions associate with plant growth stage, water storage capacity of soil and physiological aspects of plant. Drought tolerance in crop plants is different from wild plants. In case crop plant that encounters with severe water deficit, they die or seriously lose yield while in wild plants, they survive under this conditions but yield losses is not taken into consideration (Khayatnezhad et al., 2010). Achieving a genetic increase in yield under these environments has been recognized to be a difficult challenge for plant breeders while progress in yield grain has been much higher in favorable environments (Richards et al., 2002). Thus, drought indices which provide a measure of drought based on yield loss under drought conditions in comparison to normal conditions have been used for screening drought tolerant genotypes (Mitra, 2001). To evaluate response of plant genotypes to drought stress, some selection indices based on a mathematical relation between stress and optimum conditions have been proposed (Clarke et al., 1992; Fernandez, 1992; Sio-Se Mardeh et al., 2006; Shirani Rad and Abbasian, 2011). Rosielle and Hamblin (1981) 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. Fischer and Maurer (1978) proposed a stress susceptibility index (SSI) of the cultivar. Fernandez (1992) defined a new 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 productivity (GMP) and stress tolerance index (STI) (Fernandez, 1992) have been employed under various conditions. Fischer and Maurer (1978) explained that genotypes with an SSI of less than a unit are drought resistant, since their yield reduction in drought conditions is smaller than the mean yield reduction of all genotypes (Bruckner and Frohberg 1987). Other yield based estimates of drought resistance,are harmonic mean (HM) (Dehdari, 2003; Yousefi, 2004).
The present investigation was carried out for screening quantitative criteria of drought tolerance using safflower genotypes.

## MATERIAL AND METHODS

This study was carried out with 15 genotypes based on Randomized Complete Blocks Design (RCBD) with three replications under two different environments (irrigated and rainfed) at the rain-fed research farm in Sararood station, Kermanshah, Iran, 2011-2012 cropping season. The Sararood research station is located in west of Iran (Latitude 34°20'North and Longitude 47°20'East) at an elevation of 1351 m, and receives an average of 472 mm of precipitation per year. The genotypes used in this study are given in Table 1. Drought tolerance indices were calculated based on grain yield per plot for stress (Ys), non-stress (Yp) and total mean of grain yield for stress ($\bar{Y}s$ ) and non-stress ($\bar{Y}p$ )conditions as follows:

1- Stress susceptibility index (SSI) (Fischer and Maurer, 1978):

$$SSI = \frac{1-\left(\frac{Y_S}{Y_P}\right)}{SI} . SI = 1-\frac{\bar{Y}_S}{\bar{Y}_P}$$

2- Tolerance (TOL) and mean productivity (MP) (Rosielle and Hambelen, 1981):

TOL = YP – YS

MP = $\frac{Yp + Ys}{2}$

3- Stress tolerance index (STI) and geometric mean productivity (GMP) (Fernandes, 1992):

STI = $\frac{YS \times YP}{Yp\ 2}$

GMP= $\sqrt{(YS \times YP)}$

Analysis of variance, mean comparison using Duncan,s multiple range test (DMRT), correlation analysis between mean of the characters measured were performed by MSTAT-C, SPSS ver. 16 and STATISTICA ver. 8.

## RESULTS AND DISCUSSION

Resistance indices were calculated on the basis of grain yield of cultivars (Table 2). Selection based on a combination of indices may provide a more useful criterion for improving drought resistance of safflower but study of correlation coefficients is useful in finding the degree of overall linear association between any two attributes. Accordingly, high levels indicators STI, MP, GMP, YI and YSI values and low index of TOL and SSI indicator of resistance to stress conditions were figured. Fernandez (1992). To determine the most desirable drought resistance criteria, Spearman's rank correlation between yield under stress and non-stress conditions and indices of drought resistance were calculated (Table 3). The results indicated that TOL, MP, STI, SSI and GMP had a significant ($P<0.01$) positive correlation with yield under non-stress condition. The indices STI and HAR revealed a significant ($P<0.01$) positive correlation with yield under stress condition, while SSI showed a significant ($P<0.01$) negative correlation. Some researchers believe in selection based on only favorable condition (Betran et al., 2003), and/or only stress condition (Gavuzzi et al., 1997) but others have chosen a mid-point and believe in selection based on both favorable and stress conditions (Fernandes, 1992 ; Byrne, 1995) . Farshadfar et al. believe that most suitable indices for selection of drought resistance cultivars, is an indicator which has a relatively high correlation with grain yield in both conditions (Farshadfar et al., 2001). Farshadfar et al. (2001) believed that most appropriate index for selecting stress-tolerant cultivars is index which has partly high correlation with seed yield under stress and non-stress conditions. The observed relations were consistent with those reported by Fernandez (1992) in mungbean, Farshadfar and Sutka (2002) in maize and Golabadi et al (2006) in durum wheat. The results of mean comparison by LSD procedure at 5% and 1% probability levels is given in Table 2. The genotypes Zarghan-279 and 357/S6/697 had the highest drought resistance based on SSI, and TOL. The genotype Farman revealed the highest yield in non stress condition, while the highest yield in stress condition were observed for 44. The genotypes 44 had the highest drought resistance based on STI, GMP, MP and HAR. The relationships among different indices are graphically displayed in a biplot of PCA1 and PCA2 (Figure 1). The first and second components justified 98.45% of the variations between criteria. The PCA1 and PCA2 mainly distinguish the indices in different groups. One interesting interpretation of biplot is that the cosine of the angle between the vectors of two indices approximates the correlation coefficient between them. The cosine of the angles does not precisely translate into correlation coefficients, since the biplot does not explain all of the variation in a data set. Nevertheless, the angles are informative enough to allow a whole picture about the interrelationships among the drought indices (Yan and Kang 2003). Ys refer to group 1= G1. The PCs axes separated HAR, STI and GMP in a single group (G2) and MP, $Y_P$,TOL and SSI in a single group (G3). The vector view of the biplot (Figure 1) provides a summary of the interrelationships among the drought indicators. Biplot indicated that the genotypes G1 (44) in the vicinity of the vectors of drought tolerance indices HAR, STI and GMP and the yield stress is close to vector. The first and second components of genotype was high in the area and are tolerant of drought and high performance in both conditions were. Genotype G6 (366/S6-697) The second component is the highest stress was located in the vicinity of the vector. The genotypes with the highest yield stress of genotype 44, respectively. On the other genotypes G3, G12, G11, G8 and G13 (respectively 376, Kurdestan Local, 27 - 41/1, PI-258417 and Sina) in the region of low-level components first and second and none were yield and drought resistance indices of the vectors are so close they were to susceptible genotypes. New figures Faraman (G14) adjacent vectors yield stress, tolerance index (TOL) and stress susceptibility index (SSI) have been exhausted and therefore as a potential high-stress conditions during the rainy sensitive Drought was identified. Three genotypes G9, G7, and G4 (respectively 27-N/825, 62 and 386) in the vector indices of stress tolerance and yield under both conditions were included in the average performance. The distribution of genotypes in the biplot indicates genetic diversity of cultivars under drought stress. Different indices showed that indices STI, GMP, MP and HAR have been better able to identify drought resistant genotypes and the correlations between these parameters and variables in the angle between the vectors in the biplot stress tolerance index (STI) as a suitable index for selecting drought tolerant genotypes were found in safflower.

## CONCLUSION

In conclusion, The indices STI, GMP, MP and HAR genotype G1 (44) were identified as spring planting drought resistant genotype. This genotype had the highest grain yield under stress and non-stress conditions was also high performance. Faraman the new varieties have the highest yield in stress and non-stress conditions, the highest yield loss in the absence of stress, respectively. The reason that autumn sowing varieties, selection and introduction of new Faraman for autumn sowing and spring sowing of plant available water content of less the plant water stress imposed the. Different indices showed that indices STI, GMP, MP and HAR have been better able to identify drought resistant genotypes and the correlations between these parameters and variables in the angle between the vectors in the biplot stress tolerance index (STI) as a suitable index for selecting drought tolerant genotypes were found in safflower.

## ACKNOWLEDGEMENTS

This work was supported by grant from Research Council of Islamic Azad University Kermanshah Branch, Iran.

## REFERENCES

Bannayan M, Nadjafi F, Azizi M, Tabrizi L, Rastgoo M (2008). Yield and seed quality of *Plantago ovata* and *Nigella sativa* under different irrigation treatments. Ind Crops Prod. 27: 11–16.

Bassil ES, Kaffka SR (2002a). Response of safflower (*Carthamus tinctorius* L.) to saline soils and irrigation I. Consumptive water use. Agr Water Manage. 54: 67–80.

Bassil ES, Kaffka SR (2002b). Response of safflower (*Carthamus tinctorius* L.) to saline soils and irrigation II. Crop response to salinity. Agr Water Manage. 54: 81–92.

Betran FJ, Beck D, Banziger M, Edmeades GO, (2003). *Crop Sci*, 43: 807-817.

Bruckner PL, Frohberg RC (1987). Rate and duration of grain fill in spring wheat. Crop Sci 27:451-455.

Byrne PF, Bolanos J, Edmeades GO, Eaton DL, (1995). *Crop Sci*, 35: 63-69.

Clarke JM, de Pauw RM, Townley-Smith TM (1992). Evaluation of methods for quantification of drought tolerance in wheat. Crop Sci 32:728-732.

Dehdari A (2003). Genetic analysis of salt tolerance in wheat crosses. Ph.D. thesis. Isfahan University of Technology, Isfahan, Iran, 141 p.

Dordas CA, Sioulas C (2008) Safflower yield, chlorophyll content, photosynthesis, and water use efficiency response to nitrogen fertilization under rainfed conditions. Ind Crops Prod. 27: 75–85.

Farshadfar E, Rasoli V, Teixeira da Silva JA, Farshadfar M, (2011). *Aust J Crop Sci*, 5 (7): 870-878.

Farshadfar E, Ghannadha M, Zahravi M, Sutka J, (2001). *Acta Agron Hungarica,* 49(1): 59-66.

Fernandez, GCJ. (1992). Effective selection criteria for assessing stress tolerance. Proceedings of the International Symposium on Adaptation of Vegetables and Other Food Crops in Temperature and Water Stress Tolerance. Asian Vegetable Research and Development Centre, Taiwan, 257-270 p.

Fischer RA, Maurer R, (1978). *Aust J Agric Res,* 29: 897 – 912.

Gavuzzi P, Rizza F, Palumbo M, Campanile RG, Ricciardi GL, Borghi B (1997). Evaluation of field and laboratory predictors of drought and heat tolerance in winter cereals. Can J Plant Sci 77:523-531.

Kar G, Kumar A, Martha M (2007) Water use efficiency and crop coefficients of dry season oilseed crops. Agr Water Manage. 87: 73-82.
Khalili Mosavi A, Taghizadeh R, Khazaei H, Omidi Tabrizi A. H., *J. on Plant Science Res*, (2009), 13, 1.

Khayatnezhad M, Gholamin R, Jamaati-e-Somarin S, Zabihi-e-Mahmoodabad R (2010). Study of drought tolerance of maize genotypes using the stress tolerance index. Am-Eur J Agricult Environ Sci 9:359-363.

Mitra J (2001). Genetics and genetic improvement of drought resistance in crop plants. Current Sci 80:758-762.

Pandey RK, Maranville JW, Admou A (2001). Tropical wheat response to irrigation and nitrogen in a Sahelian environment. I. Grain yield, yield components and water use efficiency. Eur J Agron. 15: 93–105.

Quiroga AR, Dı´az-Zorita M, Buschiazzo DE (2001). Safflower productivity as related to soil water storage and management practices in semiarid regions. Commun Soil Sci Plant Anal. 32 (17 and 18): 2851–2862.

Richards RA, Rebetzke GJ, Condon AG, Herwaarden AF (2002). Breeding opportunities for increasing the efficiency of water use and crop yield in temperate cereals. Crop Sci 42:111-121.

Rosielle AT, Hambelen J, (1981) *Crop Sci*, 21: 943–946.

Sio-Se Mardeh A, Ahmadi A, Poustini K, Mohammadi V (2006). Evaluation of drought resistance indices under various environmental conditions. Field Crops Res 98:222-229.

Shirani Rad AH, Abbasian A (2011). Evaluation of drought tolerance in winter rapeseed cultivars based on tolerance and sensitivity indices. Žemdirbystė Agricult 98:41-48.

Talebi R (2009). Effective selection criteria for assessing drought stress tolerance in durum wheat (*Triticum durum* Desf.). Gen Appl Plant Physiol 35:64-74.

Yau SK (2004). Safflower agronomic characters, yield and economic revenue in comparison with other rainfed crops in a highelevation, semiarid Mediterranean environment. Exp Agric. 40: 453–462.

Yousefi M (2004). Evaluation of selection efficiency for drought tolerant in wheat. M.Sc. Thesis. Isfahan University of Technology, Isfahan, Iran, 109 p. (in Farsi).

**Table 1:** The safflower genotypes used in the present study

| Genotype Number | Genotype Name | Flower Color | Leaf Spin |
|---|---|---|---|
| 1 | 44 | Red | - |
| 2 | 357/S6/697 | Red | + |
| 3 | 376 | Yellow | + |
| 4 | 386 | Red | + |
| 5 | PI-592391 /Sunset | Orange | + |
| 6 | 366/S6-697 | Yellow | + |
| 7 | 62 | Yellow | + |
| 8 | PI-258417 | Red | + |
| 9 | 27 - N-825 | Red | Mix(+/-) |
| 10 | 324-S6-697 | Yellow | + |
| 11 | 27 - 41 / 1 | Yellow | + |
| 12 | Kurdestan Local | Red | + |
| 13 | Sina | Yellow-Orange | + |
| 14 | Farman | Red | - |
| 15 | Zarghan-279 | Red | + |

**Table 2:** Mean comparasion based on yield of stress and non-stress conditions, drought resistance indices

| Genotype | Yp | Ys | TOL | STI | MP | GMP | SSI | HAR |
|---|---|---|---|---|---|---|---|---|
| 44 | 1527.2 | 1131.2 | 395.4 | 1.16 | 1328.9 | 1314.8 | 0.65 | 1299.6 |
| 357/S6/697 | 681.5 | 671.1 | 10.4 | 0.31 | 676.3 | 676.3 | 0.04 | 676.3 |
| 376 | 1038 | 523.9 | 513.9 | 0.36 | 780.8 | 737.3 | 1.24 | 696.3 |
| 386 | 1469.3 | 708.4 | 760.5 | 0.70 | 1088.6 | 1020.1 | 1.29 | 955.8 |
| PI-592391 /Sunset | 1062.2 | 794.2 | 268 | 0.57 | 928.2 | 918.5 | 0.63 | 908.9 |
| 366/S6-697 | 1213.1 | 960 | 252.6 | 0.78 | 1086.3 | 1078.9 | 0.66 | 1071.6 |
| 62 | 1622.1 | 745.5 | 876.7 | 0.81 | 1183.9 | 1099.7 | 1.35 | 1021.5 |
| PI-258417 | 1173.4 | 594.2 | 579.7 | 0.47 | 883.8 | 834.9 | 1.23 | 788.9 |
| 27 - N-825 | 1500 | 763.4 | 736.6 | 0.77 | 1131.7 | 1070.1 | 1.23 | 1011.9 |
| 324-S6-697 | 986.7 | 763.9 | 222.8 | 0.51 | 875.3 | 868.2 | 0.56 | 861.1 |
| 27 - 41 / 1 | 1082.2 | 571.4 | 510.8 | 0.41 | 826.8 | 786.4 | 1.18 | 747.9 |
| Kurdestan Local | 1089.3 | 548.1 | 540.8 | 0.40 | 818.5 | 772.6 | 1.24 | 729.2 |
| Sina | 1298.1 | 629.6 | 668.2 | 0.55 | 963.7 | 903.9 | 1.29 | 847.9 |
| Farman | 2107 | 597.1 | 1059.6 | 0.84 | 1351.9 | 1121.5 | 1.79 | 930.4 |
| Zarghan-279 | 722.2 | 720.7 | 1.5 | 0.35 | 721.5 | 721.5 | 0.01 | 721.5 |

**Table 3:** Spearman's rank correlation between drought resistance indices and yield of stress and non-stress conditions

| Indices | $Y_S$ | $Y_P$ | TOL | MP | STI | SSI | GMP |
|---|---|---|---|---|---|---|---|
| $Y_P$ | -0.015 | 1 | | | | | |
| TOL | -0.479 | 0.885** | 1 | | | | |
| MP | 0.458 | 0.882** | 0.561* | 1 | | | |
| STI | 0.660** | 0.723* | 0.328 | 0.954** | 1 | | |
| SSI | -0.649** | 0.702** | 0.919** | 0.318 | 0.113 | 1 | |
| GMP | 0.639* | 0.749** | 0.360 | 0.967** | 0.995** | 0.145 | 1 |
| HAR | 0.787** | 0.559* | 0.124 | 0.868** | 0.970** | -0.052 | 0.965** |

*and ** Significant at 1% and 5% level of probabaility, respectively.

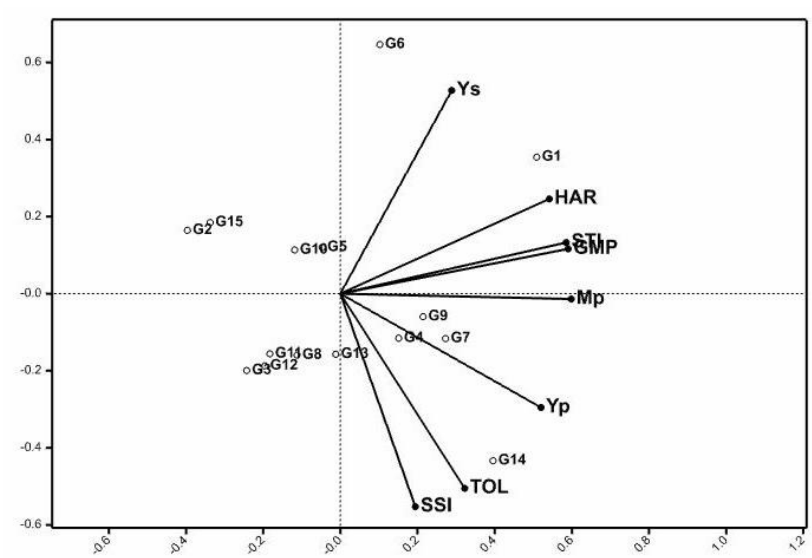


**Figure 1.** Biplot analysis of drought tolerance criteria in safflower