https://doi.org/10.17221/591/2019-PSE

# Effect of drought stress on oil content and fatty acids composition of some safflower genotypes

*Yousef Joshan[1], Behzad Sani[1]*, Hamid Jabbari[2], Hamid Mozafari[1], Payam Moaveni[1]*

*[1]Department of Agronomy, Shahr-e-Qods Branch, Islamic Azad University, Tehran, Iran*
*[2]Seed and Plant Improvement Institute, Agricultural Research, Education and Extension Organization, Karaj, Iran*
**Corresponding author: dr.b.sani@gmail.com*

**Citation**: Joshan Y., Sani B., Jabbari H., Mozafari H., Moaveni P. (2019): Effect of drought stress on oil content and fatty acids composition of some safflower genotypes. Plant Soil Environ., 65: 563–567.

**Abstract**: To assess the response of promising safflower genotypes to late-season drought stress in delayed planting conditions, an experiment was conducted in two years (2016–2017 and 2017–2018) in Iran. The irrigation regime was specified in two levels, including normal irrigation and irrigation cut off in the seed filling stage in main plots, and five safflower genotypes, including Soffe, Goldasht, Golmehr, Padideh, and Parnian were categorized in subplots. Applied drought stress significantly reduced the seed yield and yield components of all genotypes, which accompanied with a substantial decrease in oil content and oil yield of all genotypes. However, the highest seed and oil yield in drought stress conditions obtained in the Parnian genotype by value 2338 and 561 kg/ha, respectively. Moreover, a significant drought-induced increase in palmitic, stearic, and oleic acids, as well as a decrease in linoleic acid content, was observed in all genotypes. Parnian genotype with high unsaturated fatty acids content (90.9%) and the minimum amount of saturated fatty acids (8.7%) might be a promising genotype to starting a formal crop improvement program to achieve more drought-tolerant safflower genotype.

**Keywords**: *Carthamus tinctorius* L.; harvest index; oilseed crop; semi-arid ecosystem; water stress

Drought as critical environmental stress negatively affects the growth and production of crop plants. Safflower (*Carthamus tinctorius* L.) is considered as a crucial annual oilseed crop, which contains 30–40% oil and 15–20% protein (Rahamatalla et al. 2001). Fatty acids in safflower seeds mostly possess stearic acid (2–3%), oleic acid (16–20%), palmitic acid (6–8%), and linoleic acid (71–75%) (Nagaraj 1993). Safflower tolerance to drought conditions with low yield reduction has made it as an alternative crop in semi-arid ecosystems (Kar et al. 2007). The result of researches on drought response of safflower showed that drought stress at vegetative, flowering and/or seed filling stage substantially decreases the sunflower yield and oil content (Razi and Assad 1999). In spring safflower genotypes, drought at the late flowering and seed filling stages, reduced oil yield by declining yield components like the thousand seed weight, the number of seeds in the capitulum, and harvest index (Eslam et al. 2010). However, response to drought stress is varied among different safflower genotypes (Aprile et al. 2013, Zandalinas et al. 2016). Breeding by the goal of drought-tolerant crops mainly needs the availability of the high diversity genetic resources for tolerance, precise screening techniques, determination of main tolerance components, and reach to drought-tolerant genotype with reliable yield components. Also, due to the dependence of water scarcity effects on the genotype (Bannayan et al. 2008), particularly in developing steps (Ozturk et al. 2006), it is important to identify adapted safflower cultivars which able to grow water-limited environments. Results of the evaluation of ten Iranian safflower genotypes in response to drought occurring in the flowering stage by emphasis to substantial differences among the genotypes for all the studied characters showed that the flowering period as the most sensitive stage to

https://doi.org/10.17221/591/2019-PSE

the water shortage that in turn decreases performance (Zareie et al. 2013). Therefore, the present work was carried out in aiming to a comparison of Iranian safflower genotypes in response to drought occurring in the flowering stage, with particular emphasis on changes in oil quality characteristics.

## MATERIAL AND METHODS

**Experimental design and procedure**. In this research, five safflower genotypes were cultivated in a field for two growing seasons (2016–2017 and 2017–2018) under two different watering regimes. Field experiments were conducted at the experimental field of seed and plant improvement institute (SPII) in Alborz province, Iran (35°49'12''N, 51°06'33''E, 1321 m a.s.l.). To investigate the effects of drought stress on the safflower yield, a factorial split-plot test conducted in a complete randomized blocks design with three replications in which a combined analysis over five genotypes and two irrigation treatments carried out. The irrigation was performed in two levels: regular watering (control) and the cut off the watering after late of the flowering stage in main plots and five safflower genotypes, including Soffe, Goldasht, Golmehr, Padidehh and Parnian in subplots.

Before planting, the experimental field was disked and tilled to combine residue and to form a seedbed. Based on the results of the soil tests, fertilisers applied with 150 kg N/ha and 55 kg P/ha in 2016 and 2017. Safflower genotypes were planted on October 15 (2016) and October 11 (2017), respectively, using a plot drill (Wintersteiger, Ried, Austria). Each experimental plot included six four-meter lines with 30 cm spacing and plant spacing on the line was 5 cm, with two lateral lines as margins.

**Measurements**. Matured plants were harvested in July of 2017 and 2018, then oven-dried at 70°C. After separating, the seed and straw were weighted, and the harvest index was calculated as the proportion of seed weight to the total plant biomass. The number of seeds per plant and thousand seed weight also was measured. Oil content was calculated by the nuclear magnetic resonance spectrometer (NMR) at 25°C (Colnago et al. 2011). Oil content uttered based on a dry weight (DB, %), and oil yield was determined as kg/ha. The composition of fatty acid in obtained oil was analysed by gas chromatography (Agilent, Santa Clara, USA) equipped with an FID and a capillary column (CP-Sil88, 50 m, 0.25 mm, 0.2 μm). Initially, the oil converted to fatty acid methyl esters (FAME) by hexane and potassium methylate. The initial column temperature was 150°C, then increased to 240°C at the rate of 5°C/min. The injector and detector temperatures were, respectively, 250°C and 280°C. Peaks were recognized by comparing retention times with those of a commercial standard FAMEs mixture. The details on the GC running program are provided in Reiahisamani et al. (2018).

**Statistical analysis**. Analyses of variance carried out by SAS statistical analysis software (v9.1 package, SAS Institute, Cary, USA). The least significant difference (*LSD*) test was used to compare treatment means with a probability threshold of 0.05.

## RESULTS AND DISCUSSION

**Yield and yield components**. The results showed a significant decrease in the growth and yield of all of the genotypes in drought stress conditions (Table 1). In normal conditions, the highest plant height value recorded in the Golmehr genotype with an average of 142 cm. Drought stress reduced plant height by 5.34% compared to normal condition; the highest decrease of plant height at drought condition was observed in the Parnian genotype (Figure 1). Among genotypes, the highest total seed number (TSN), thousand seed weight (TSW) recorded in Parnian genotype at both normal and drought stress conditions (Table 1). TSN and TSW significantly dropped in drought stress conditions by 28.2% and 6.2%, respectively. The highest reduction of TSN and TSW was observed in the Soffe genotype (Figure 1). Seed yield (SY) of safflower genotypes significantly reduced in drought conditions by 17.2% compared to normal conditions. Parnian genotype showed the highest SY in both normal and drought stress conditions by 2760 and 2338 kg/ha, respectively (Table 1). The highest reduction of SY at drought conditions was observed in the Soffe genotype (Figure 1). The present results demonstrated natural diversity among the safflower genotypes studied, showing differential growth properties of them in drought conditions. Results showed that different safflower genotypes differ in biomass yield components and oil productivity in water-deficient conditions. Yield decreasing in water shortage due to low biomass production is related to reduced photosynthesis in these conditions (Pinheiro and Chaves 2011). Pourdad (2008) has also reported a decrease in seed yield in droughted safflower. Previous studies have also mentioned the impact

https://doi.org/10.17221/591/2019-PSE

Table 1. Yield and yield components of safflower genotypes in different irrigation regimes

| Irrigation | Cultivar | PH | TSN | TSW | SY | BY | HI | OP | OY |
|---|---|---|---|---|---|---|---|---|---|
| Normal | Sofe | 141[a] | 959[b] | 27.3[d] | 2233[b] | 13 090[b] | 17.3[ab] | 29.4[ab] | 655[ab] |
| | Goldasht | 112[f] | 730[d] | 42.3[a] | 2273[b] | 12 283[c] | 19.3[a] | 25.7[e] | 577[bcd] |
| | Golmehr | 142[a] | 786[c] | 25.6[e] | 2021[bc] | 11 542[d] | 17.5[a] | 29.6[a] | 597[abc] |
| | Padide | 129[c] | 694[d] | 28.1[d] | 2062[bc] | 10 129[f] | 20.4[a] | 28.5[cd] | 585[bcd] |
| | Parnian | 134[b] | 1031[a] | 41.3[b] | 2760[a] | 14 392[a] | 20.2[a] | 25.5[ef] | 691[a] |
| Drought stress | Sofe | 132[b] | 607[e] | 23.6[g] | 1490[d] | 10 733[ef] | 13.9[b] | 29.1[ab] | 435[e] |
| | Goldasht | 113[f] | 513[f] | 40.5[b] | 2070[bc] | 10 243[f] | 20.1[a] | 25.2[f] | 514[cde] |
| | Golmehr | 134[b] | 531[f] | 24.6[f] | 1698[cd] | 9342[g] | 18.5[a] | 28.9[bc] | 488[de] |
| | Padide | 125[d] | 544[f] | 27.2[d] | 1797[cd] | 8770[g] | 21.0[a] | 28.2[d] | 507[cde] |
| | Parnian | 122[e] | 816[c] | 39.0[c] | 2338[b] | 11 336[d] | 20.5[a] | 24.2[g] | 561[bcd] |

Means followed by same letter do not significantly ($P < 0.05$) vary from one another based on least significant difference. PH – plant height (cm); TSN – total seed number; TSW – thousand seed weight (g); SY – seed yield (kg/ha); BY – biological yield; HI – harvest index (%); OP – oil percent (%); OY – oil yield (kg/ha)

of drought on a total seed number, thousand seed weight, and seed yield of safflower (Istanbulluoglu et al. 2009, Abd El-Lattief 2013). It has been reported previously that safflower seed yield impacted by drought mainly in flowering and heading stages (Koutroubas and Papakosta 2010, Zharghami et al. 2011). Under drought stress, the translocation of pre-anthesis assimilates to the seed is a vital functional process at the filling phase. Biological yield (BY) of safflower genotypes significantly reduced in drought stress by 17.9%, compared to normal condition. The most decrease of BY by drought stress recorded in the Parnian genotype (Figure 1). However, among the genotypes highest BY values at both normal

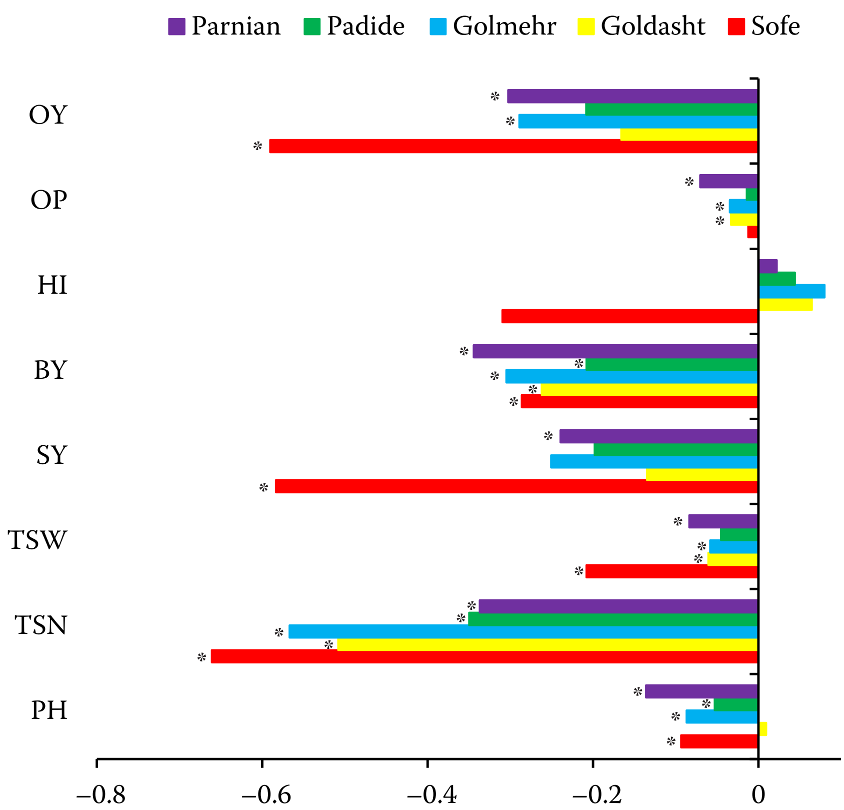


Figure 1. Log2 fold change of yield and yield components of different safflower genotypes in drought stress condition to control. The asterisk indicates significantly change ($P < 0.05$) in comparison to control. OY – oil yield; OP – oil percent; HI – harvest index; BY – biological yield; SY – seed yield; TSW – thousand seed weight; TSN – total seed number; PH – plant height

and drought stress conditions were obtained in the Parnian genotype (Table 1). In contrast, there was no significant effect of drought conditions on harvest index (HI) of different genotypes. Results also demonstrated no significant impact of drought on HI in studied genotypes. Because the safflower needs to water in a productive stage is lower and excessive of irrigation water uses for vegetative growth, it will lead to a reduction in HI compare to drought conditions (Istanbulluoglu et al. 2009).

**Oil yield**. Oil percentage (OP) of different genotypes significantly reduced by drought conditions. In normal condition, Golmehr and Parnian genotypes showed the highest and lowest OP values by 29.6% and 25.5%, respectively; the respective values in drought conditions were obtained in Soffe and Parnian genotypes by 29.1% and 24.2%, respectively (Table 1). Moreover, the highest and lowest OP reduction by drought stress observed in Parnian and Soffe genotypes, respectively (Figure 1). However, the highest oil yield (OY) value at both normal and drought conditions recorded in Parnian genotype by 691 and 561 kg/ha, respectively (Table 1). Furthermore, the results showed a significant decrease of OY in drought stress conditions by 19.3%, so the most OY reduction obtained in the Soffe genotype (Figure 1). Results also showed a reduction in oil yield and oil percentage in response to drought which was more impressive for oil yield. A decrease in safflower oil content with rising in drought has been documented reported by Nabipour et al. (2007) and Ashrafi and Razmjoo (2010).

**Fatty acids composition**. Change in the composition of primary fatty acids in extracted oil from five safflower genotypes in both normal and stress conditions is shown in Figure 2. In all studied safflower genotypes, drought stress led to a substantial decrease in linoleic acid content, the highest and lowest respective decrease in Soffe and Padideh genotypes. Besides, a significant drought-induced increase was observed in palmitic, stearic and oleic acid content, the values recorded in Padideh, Parnian and Soffe genotypes, respectively. Furthermore, the highest content of unsaturated fatty acids in normal and drought stress conditions were obtained in Golmehr and Soffe genotypes, respectively. Analysis of the fatty acid composition of extracted oil from safflower seeds showed that linoleic acid negatively affected by drought while increasing response in palmitic, stearic and oleic acid content was observed. A similar relation between the fatty acids fraction and the salinity stress has been reported for cotton (Smaoui and Chérif 2000), safflower (Yeilaghi et al. 2012), and Salicornia (Reiahisamani et al. 2018). Some evidence confirms that the concept that membrane lipids augmented by the polyunsaturated fatty acid fraction are better able to conserve the plant's photosynthetic system (Allakhverdiev et al. 2001).

The outcome of this study showed a significant variation among the Iranian safflower genotypes in biological yield, oil yield, and response to drought conditions, which may be appropriate to start a proper crop development program to increase the

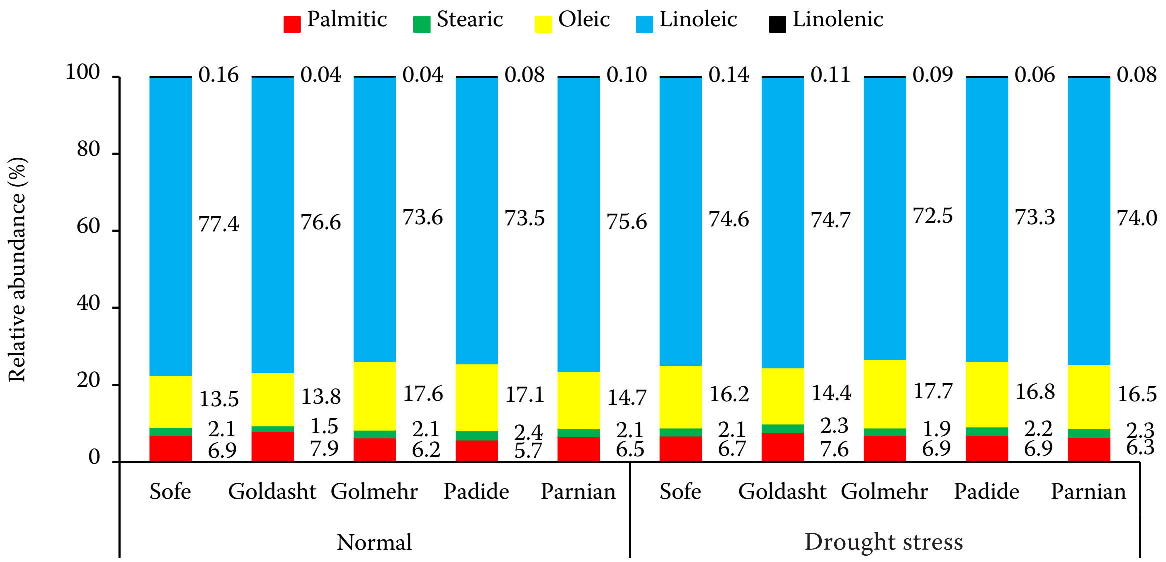


Figure 2. Variation of fatty acids composition in different genotypes (Soffe, Goldasht, Golmehr, Padideh, and Parnian), in normal and drought stress conditions

drought tolerance in safflower plant. The effect of water scarcity on seed oil yield also emphasizes the importance of attention to drought tolerance potential in different safflower genotypes.

## REFERENCES

Abd El-Lattief E.A. (2013): Safflower yields and water use efficiency as affected by irrigation at different soil moisture depletion levels and plant population density under arid conditions. Archives of Agronomy and Soil Science, 59: 1545–1557.

Allakhverdiev S.I., Kinoshita M., Inaba M., Suzuki I., Murata N. (2001): Unsaturated fatty acids in membrane lipids protect the photosynthetic machinery against salt-induced damage in *Synechococcus*. Plant Physiology, 125: 1842–1853.

Aprile A., Havlickova L., Panna R., Marè C., Borrelli G.M., Marone D., Perrotta C., Rampino P., De Bellis L., Curn V., Mastrangelo A.M., Rizza F., Cattivelli L. (2013): Different stress responsive strategies to drought and heat in two durum wheat cultivars with contrasting water use efficiency. BMC Genomics, 14: 821.

Ashrafi E., Razmjoo K. (2010): Effect of irrigation regimes on oil content and composition of safflower (*Carthamus tinctorius* L.) cultivars. Journal of the American Oil Chemists' Society, 87: 499–506.

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. Industrial Crops and Products, 27: 11–16.

Colnago L.A., Azeredo R.B.V., Marchi N.A., Andrade F.D., Venâncio T. (2011): Rapid analyses of oil and fat content in agri-food products using continuous wave-free precession time domain NMR. Magnetic Resonance in Chemistry, 49: S113–120.

Eslam B.P., Monirifar H., Ghassemi M.T. (2010): Evaluation of late season drought effects on seed and oil yields in spring safflower genotypes. Turkish Journal of Agriculture and Forestry, 34: 373–380.

Istanbulluoglu A., Gocmen E., Gezer E., Pasa C., Konukcu F. (2009): Effects of water stress at different development stages on yield and water productivity of winter and summer safflower (*Carthamus tinctorius* L.). Agricultural Water Management, 96: 1429–1434.

Kar G., Kumar A., Martha M. (2007): Water use efficiency and crop coefficients of dry season oilseed crops. Agricultural Water Management, 87: 73–82.

Koutroubas S.D., Papakosta D.K. (2010): Seed filling patterns of safflower: Genotypic and seasonal variations and association with other agronomic traits. Industrial Crops and Products, 31: 71–76.

Nabipour M., Meskarbashee M., Yousefpour H. (2007): The effect of water deficit on yield and yield components of safflower (*Carthamus tinctorius* L.). Pakistan Journal of Biological Sciences, 10: 421–426.

Nagaraj G. (1993): Safflower seed composition and oil quality – A review. In: Proceeding of the 3rd International Safflower Conference, Beijing, 58–71.

Ozturk L., Yazici M.A., Yucel C., Torun A., Cekic C., Bagci A., Ozkan H., Braun H.-J., Sayers Z., Cakmak I. (2006): Concentration and localization of zinc during seed development and germination in wheat. Physiologia Plantarum, 128: 144–152.

Pinheiro C., Chaves M.M. (2011): Photosynthesis and drought: Can we make metabolic connections from available data? Journal of Experimental Botany, 62: 869–882.

Pourdad S. (2008): Study on drought resistance indices in spring safflower. Acta Agronomica Hungarica, 56: 203–212.

Rahamatalla A.B., Babiker E.E., Krishna A.G., El Tinay A.H. (2001): Changes in fatty acids composition during seed growth and physicochemical characteristics of oil extracted from four safflower cultivars. Plant Foods for Human Nutrition, 56: 385–395.

Razi H., Assad M.T. (1999): Comparison of selection criteria in normal and limited irrigation in sunflower. Euphytica, 105: 83–90.

Reiahisamani N., Esmaeili M., Khoshkholgh Sima N.A., Zaefarian F., Zeinalabedini M. (2018): Assessment of the oil content of the seed produced by *Salicornia* L., along with its ability to produce forage in saline soils. Genetic Resources and Crop Evolution, 65: 1879–1891.

Smaoui A., Chérif A. (2000): Changes in molecular species of triacylglycerols in developing cotton seeds under salt stress. Biochemical Society Transactions, 28: 902–905.

Yeilaghi H., Arzani A., Ghaderian M., Fotovat R., Feizi M., Pourdad S.S. (2012): Effect of salinity on seed oil content and fatty acid composition of safflower (*Carthamus tinctorius* L.) genotypes. Food Chemistry, 130: 618–625.

Zandalinas S.I., Rivero R.M., Martínez V., Gómez-Cadenas A., Arbona V. (2016): Tolerance of citrus plants to the combination of high temperatures and drought is associated to the increase in transpiration modulated by a reduction in abscisic acid levels. BMC Plant Biology, 16: 105.

Zareie S., Mohammadi-Nejad G., Sardouie-Nasab S. (2013): Screening of Iranian safflower genotypes under water deficit and normal conditions using tolerance indices. Australian Journal of Crop Science, 7: 1032–1037.

Zharghami R., Zahravi M., Aslanzadeh A., Abbasali M. (2011): Evaluation of autumn sown genotypes of safflower (*Carthamus tinctorius*) for tolerance to drought stress. Seed and Plant Improvement Journal, 271: 339–355.

Received on November 3, 2019
Accepted on November 25, 2019
Published online on November 30, 2019