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Grain yield performance of *Carthamus tinctorius* L. cultivars under water deficient condition

Behnam Tahmasbpour*[1], Mehdi Younessi-Hamzekhanlu[2], Davood Mahdavisafa[3], Mohsen Sabzi Nojadeh[2]

[1]*Department of Agronomy and Plant Breeding, University of Mohaghegh Ardabili, Ardabil, Iran*

[2]*Ahar Faculty of Agriculture and Natural Resources, University of Tabriz, Ahar, Iran*

3Department of Plant Production and Genetics, Faculty of Agriculture, University of Maragheh, Maragheh, East Azerbaijan Province, Iran

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Abstract

To evaluate the effect of drought stress (control and no irrigation at budding and flowering stages) on growth and grain yield of three spring safflower (Saffeh, Goldasht and Sina), a factorial experiment based on randomized complete block design with three replications was performed in Khsroshar of Tabriz, during 2014-15 growing season. There were significant differences between cultivars according to traits including dry plant weight, 1000 seed weight, number of fertile boll, number of buds, plant height and petal weight. Drought stress effect was significant on all of the traits except of root dry weight. The interaction effects of two factors were significant on all of the traits except of seed yield per plant, harvest index, seed weight per boll, boll weight and root dry weight. Sina was as a best cultivar due to seed yield per plant, harvest index, seed weight per boll, boll weight and root dry weight. Drought stress caused a significant reduction in seed yield per plant, harvest index, seed weight per boll and boll weight. Water deficiency stress at budding and flowering stages also caused 40.92 and 35.35 percent reduction in seed yield compared to control (no stress). Seed yield per plant had positive and significant correlation with number of boll per plant, seed weight per boll, boll weight, number of fertile boll and number of buds. Stepwise regression showed seed yield per plant increased with increase of seed weight per boll and number of fertile boll.

***Corresponding Author:** Behnam Tahmasbpour ✉ tahmasbpor@yahoo.com

Introduction

Safflower (*Carthamus tinctorius* L.) is a plant of Compositae set that is full foliage, grass, quasi barbed and one year. Its height varies from 20-150 cm. Its seeds oil content is about 27-40 percent and has between 15-19% protein and its seeds are like small sunflower seeds that is known as Achen in terms of botanical expression that is reserved in a hole and is not loss during the harvest. This plant has two spring and autumn types, which the spring type has a higher yield than winter type. This plant is native to the Middle East and ecologically is compatible with Iranian climate (Emongor, 2010). Despite domestic production of oilseeds in the country, the vast majority of domestic oil used is procured from abroad. So with the population growing and per capita consumption of oil, the increase of area under oilseeds cultivation and increase their performance is necessary to reduce dependence on other countries. Among oilseeds that are compatible with Iranian climate, safflower has a special place and has good compatibility in areas with drought stress and water shortages (Hussain *et al*., 2016). Safflower in Iran mostly cultivated in dry land or planted in fields with small amount of irrigation. In the past, several studies about the compatibility of different cultivars of this plant have been conducted in different regions of the country (Zareie *et al*., 2013).

The results of safflower in Canada indicates the needs to irrigation before planting (wet work) which makes deployment and optimum growth as well as the creation and formation of appropriate branching and finally the flowering of healthy seed per boll plant (Flemmer *et al*., 2015). The amount of extracted oil in seed under favorable conditions is up to 45 per cent depending on cultivar (Ebrahimi *et al*., 2016). Safflower is grown almost in 60 countries and its area under cultivation in the world was equal to 691 000 hectares in 2008 (FAO, 2008). Since Iran located in the arid and semi-arid part of the world, therefore, selection of safflower as a drought tolerant and native plant can be replaced the genotypes and drought-sensitive oily plant. Drought stress during vegetative growth decreased dry matter production and yield reduction plant by reducing the leaf area index.

In the area of modified safflower genotypes under drought stress, Khalili *et al* (2014) stated that the selection of genotypes in both stress and non-stress causes the accumulation of favorable alleles and genotypes with higher performance at hand (Khalili *et al*., 2014).

The plants crisis need to water is during flowering stage and under water deficit conditions of soil, one step at a irrigation time increased dry weight and performance (Santos *et al*., 2017). Appling drought stress at flowering stage is the major cause of yield loss. The results of studies on safflower in relation to grain yield in different areas, under drought stress showed that seed yield is variable from 0.7 to 3.7 tons per hectare (Kocaman *et al*., 2016). Safflower in the growth stage than later stage is more resistant to water shortage and lack of irrigation at this stage cause the development of the root system and the resistance of plants to hot and dry conditions; therefore it is recommended that after germination and establishment of safflower, the dry period is given to the plant. The water stress during the final stages of reproductive accelerated aging and reduce the safflower seed filling period (Emongor, 2010).

Studies showed that leaf area, plant height, number of branches and number of heads of safflower decreased as a result of drought and despite the reduction in dry shoot and root material, the ratio of root to shoot increased (Sharrifmoghaddasi, Omidi, 2010). It has been shown that safflower seed weight is dependent on the genotype (Talebi , Abhari, 2016).

In another study it was observed that the effect of the genotypes on safflower seed oil and seed oil yield under drought stress was significant. So, the Montola-2000 in both normal and stress conditions had the lowest amount of oil. But Dincer genotype with 31.88 percent of oil in non-stress and 31.45 percent of oil had the highest oil content in seed oil under stress (Öztürk *et al*., 2008). There are some studies indicating that drought stress decreases relative leaf water content, grain yield, one thousand grain weight and oil yield in safflower (Gholinezhad *et al*., 2009; Nazari *et al*., 2017).

Most affected drought stress was in plants flowering stress treatment. Also drought stress at flowering and seed formation reduced grain yield with 59.81 and 29.80 percent, respectively, compared to the control (no stress).

Shahrokhania and Sepaskhan (2016) evaluated two irrigation strategies; ordinary furrow irrigation (OFI) and variable alternate furrow irrigation (VAFI) on yield performance of safflower. Their results showed that VAFI technique saved applied water by 30% against only a 13% reduction in seed yield that was not significant. Therefore, VAFI method would be more capable in water deficient environments in compared with OFI method (Shahrokhnia, Sepaskhah, 2016).

Amini and Saeedi (2006) by studying the local safflower reported that domestic seed yield and number of pod per plant and seed per pod are significantly correlated. Also by stepwise regression analysis, they showed that the number of seed per pod and the number of pod per plant had the highest share in variations of yield (Amini, Saeedi, 2006). The aim of the present study was to evaluate the effects of three levels of irrigation (normal, stress in the blooming stage, stress at flowering stage), on cultivation genotypes of safflower in order to understand how plants respond to drought stress and select the best varieties of important Figs. in the region and the effect of water stress on grain yield in the plants.

Materials and methods

Plant materials and experimental design

This research implemented in Khosroshahr research farm in Tabriz with geographical characteristics of 46 degrees 2 minutes east, 37 degrees 58 minutes north in 2014-15 agricultural years. Studied genotypes in a factorial experiment in a randomized complete block design with three replications were compared. The first factor of three genotypes of safflower names, Goldasht and Sina and the second factor with different levels of irrigation (stress at blooming stage, stress at flowering stage and control with no stress), respectively.

Irrigation in control group, according to regional conditions and temperature, was done at intervals of 8 to 10 days. Treatments relates to drought with irrigation from the budding and flowering until the end of the period. Each unit of experiment consisted of 6 rows with distances of 30 cm and a length of 5 m. Plant spacing of 10 cm was set. Planting depth of seeds was considered as 4-3 cm. To improve the nutrition of plants before planting, 100 kg of potassium sulfate and 100 kg triple super phosphate fertilizer in hectare was applied. During the vegetative stage twice of urea (per 100 kg per hectare) in farm was performed.

Evaluated traits and statistical analysis

In this study, thousand grain weight, number of seeds per pod, seed weight per pod, pod weight, number of fertile pod, number of empty capsule, plant height, petals weight, dried leaves after the stress, harvest index, plant dry weight and yield per plant were evaluated. To determine the height of plant, number of seed per pod, seed weight per pod, pod weight per plant, number of pod fertile, number of empty capsules, petals weight, in each plot, 20 plants were randomly selected and measured. Other performance components were determined from the same plant. Finally, after the product ripening after removing two side rows and 0.5 meters from each end of each plot as margin, all plots were harvested and grain yield were determined. Measured data were analyzed by using the SAS and MSTAT-C statistical software and comparison of means was performed by using Duncan (LSR).

Results and discussion

Analysis of variance

The results of evaluated variance analysis are listed in Table 1. These results demonstrated that among safflower genotypes, there is significant differences of 1% of probability at the level traits such as dry weight of the plant, grain weight, the number of fertile seed, number of flowered bud, plant height, the distance of the first branch from the soil surface and petals weight and selection program can be suitable to exploit this diversity. Also, the results showed that in all characters except for root dry weight, there was a significant difference between levels of drought stress.

Table 1. ANOVA for evaluated traits under different treatments.

		Mean of squares														
SV[a]	DF	YP	DWP	HI	1000SW	NSB	SWB	BW	NFB	NIFB	NFlB	PH	DFBS	PW	RDW	NDLS
replicate	2	**2.521	9.010	**0.234	*2.147	8.037	*0.243	**4.417	8.037	**2.458	9.000	**0.301	0.141	**0.005	1.970	**1.620
Variety	2	0.453	**0.921	0.055	**9.294	*300.259	0.015	0.145	**6.370	0.091	**8.333	**3.985	**8.366	**0.145	2.009	*0.274
Stress	2	**2.055	**21.833	*0.155	**11.534	**816.259	**0.415	*1.158	**8.037	**1.745	**2.333	**0.298	*1.315	**0.145	3.002	**35.228
Stress × Variety	4	0.268	**7.455	0.022	**3.961	**333.093	0.057	0.181	**3.704	**0.553	**3.333	**0.103	0.447	**0.122	1.912	**0.274
Error	16	0.229	0.30	0.030	0.531	0.037	0.052	0.202	0.407	0.057	0.4	0.15	0.276	0.051	1.922	0.054
C.V (%)		8.03	8.30	0.84	1.94	0.84	44.02	36.84	9.15	17.30	18.56	0.52	0.85	55.62	26.85	4.79

a. * and ** denote significance at the 5% and 1% levels, respectively.

SV: Source of Variation, DF: degree of freedom, PYP: yield per plant (g), DW: Dry weight per plant (g), HI: Harvest index, 100SW: 1000 seed weight (g), NSB: Number of seeds per boll, SWB: Seed weight per boll (g), BW: Boll weight (g), NFB: number of fertile bolls, NIFB: number of infertile bolls, NFlB: Number of flower buds, PH: Plant height (cm), DFBS: Distance of the first branch from the soil surface (cm), PW: Petal weight (g), RDW: Root dry weight (g), NDLS: Number of dried leaves after stress

The difference between the three studied cultivars for most traits, indicates the existence of genetic variation among varieties, of these traits is in normal conditions and under stress. In all traits except grain yield, harvest index, seed weight per pod, pod weight, root dry weight and the distance between the first branch from soil surface interaction of genotype × stress levels were significantly increased. In accordance with the results of this study which showed the significant effect of drought stress at flowering and budding stage some studies reported the effects of water stress on yield and yield components of safflower (Ebrahimi *et al.*, 2016).

Comparison of means for evaluated traits

Tables 2 and 3 show mean comparisons of traits that the interaction of genotype × stress is not significant to them. In terms of yield per plant and pod weight between the control and drought stress in both budding and flowering stage, there was significant difference; So that most of these traits were obtained in the absence of stress. Performance reduction in reproductive stage was done by reducing the grain filling period, small grain and the grain weight reduction. The number of seed reduction may be due to the reduction of grain endosperm generated at grain filling stage and the effect of drought on the grain weight in the grain filling period. Drought stress during budding and flowering led to a shrinking of the leaf area, leaf area index and an increase in the number of dried leaves and therefore dry matter accumulation and grain yield under these conditions decreases. It also can reduce yield by reducing the number of grains and grain weight in stress condition in seeding and flowering stages. Marita and Muldoon (1995) reported that in the process of safflower stem rapid growth and flowering, different irrigation regimes led to a significant reduction in grain yield per hectare, they stated that flowering stage was the most sensitive stage for the water need in safflower, also the highest performance is achieved when that is done only by the irrigation time at flowering stage (Marita , Muldoon, 1995). Also in accordance with the result of this study, Khalili *et al* (2014) stated that irrigation in the bud and flowering reduced the seed yield (Khalili *et al.*, 2014).

Table 2. Comparison means for evaluated traits in different drought stress.

Stress levels	YP[a]	HI	GWB	BW	DFBS	RDW
Stress in budding stage	4.702[b]	12.5[b]	0.421[b]	1.090[b]	65.285[a]	6.9620[a]
Stress in flowering stage	5.145[b]	14.5[b]	0.267[b]	0.951[b]	65.472[a]	4.3805[b]
Control	7.959[a]	33.17[a]	0.995[a]	1.630[a]	55.11[b]	4.1524[b]

a. YP: yield per plant, HI: harvest index, GWB: Grain weight per boll (g), BW: Boll weight (g), DFBS: Distance of the first branch from the soil surface (cm), RDW: Root dry weight (g).

Table 3. Comparison means for evaluated traits in three spring safflower cultivar.

Cultivars	YP[a]	HI	GWB	BW	DFBS	RDW
Sofeh	7.35[b]	10.70[c]	0.565[a]	0.751[c]	80.33[a]	4.443[b]
Goldasht	5.921[b]	20.80[b]	0.336	1.281[b]	56.100[b]	4.477[b]
Sina	7.35[a]	30.70[a]	0.653[a]	1.630[a]	49.411[c]	6.573[a]

Different letters in each column denote significance difference at the 5% level.

a. YP: yield per plant, HI: harvest index, GWB: Grain weight per boll (g), BW: Boll weight (g), DFBS: Distance of the first branch from the soil surface (cm), RDW: Root dry weight (g).

Between the levels of stress in terms of root dry weight; there were significant differences; so that this trait was in maximum level at stress condition in the blooming stage. Between the levels of stress in terms of weight of seeds per pod and harvest index there exist showed significant differences, so that the control condition (no stress) values of these attributes were maximum. Harvest index which is obtained by dividing the grain yield to biological yield based on percentage and a measure of the efficiency of photosynthesis in plants to seed was also affected by drought stress and the lowest level in terms of stress at blooming stage were obtained. In accordance with the result of this research, Istanbulluoglu *et al.* (2009) showed that water stress significantly reduced the 1000 kernel weight, and grain yield. The greatest impact of moisture stress on the yield stress was in plants stress treatment (Istanbulluoglu *et al.*, 2009).

Like the results of the present study, they know that the reduction in seed yield was at flowering stage which is as a result of the reduced number of seed per pod and reduction in one thousand seed weight. Khalili *et al* (2014) also showed that drought stress in a heading and flowering stages had greatest effect on grain yield than grain filling stage (Khalili *et al.*, 2014). As was observed in the analysis of variance table, plant dry weight, one thousand grain weight, number of fertile pod, the number of flower buds, plant height, distances of first branch from soil surface and petals weight was different in different varieties. Sina genotype had the highest amounts of plant yield, harvest index, boll weight and root dry weight, respectively. This result is in accordance with Yari *et al.* (2014) which they showed that the Sina genotype in terms of grain yield, oil yield and thousand grain weight had the highest rate in normal conditions, stress and seed flowering stress (Yari *et al.*, 2014).

Also Goldasht genotype in terms of harvest index, pod weight, the distance of first branch from the ground, had intermediate values. The Safeh genotype from the point of harvest index and pod weight had the lowest value (Table 3). The result is consistent with the findings of previous findings which indicating different response of safflower genotypes in terms of yield and its components (Eslam *et al.*, 2010; Öztürk *et al.*, 2008).

Table 4 compares the average interaction of genotype × drought stress for the traits that interaction of genotype × drought stress was significant for those traits. Pod in Table 4, Goldasht genotype in control, maximum plant dry weight and the least amount of flowering stress was the lowest value. In accordance with the result of the other works (Ashkani *et al.*, 2010; Yari, Keshtkar, 2016) our results showed that biological yield under drought conditions is significantly affected and reduced.

Biological yield reduction was due to dry matter accumulation reduction. Since the process of budding and flowering, accumulation of the plant's dry matter continues. The stop of irrigation causes more damage to dry matter accumulation and ultimately biological function. Reduced dry matter accumulation in safflower or biological function by stopping the irrigation have also been reported by Yari and colleagues (Yari, Keshtkar, 2016). Maximum thousand grain weight in Goldasht genotype under budding stress condition were observed at least in the Safeh genotype under stress conditions at flowering stage. The maximum thousand seed weight in Goldasht genotype under budding stress may be due to the reduction of grain per pod under irrigation excision and irrigation at a later stage and when the grain filling is complete.

Table 4. Comparison means cultivar and stress interactions for evaluated traits in spring safflower.

Treatments		PY	1000SW	NSB	NFB	NIFB	PH	PW	NDLS
Cultivar	stress								
	Budding	f 6.625	bc 37.436	c 28	b 3	d 0.111	c 81.957	a 0.698	b 9.983
Sofeh	Flowering	e 6.54	d 35.315	i 6	d 1	a 3.958	a 93.992	bc 0.3696	c 0.10
	Control	d 6.95	c 37.317	b 34	c 2	c 0.468	b 87.954	b 0.3798	c 0.112
	Budding	i 4.043	a 40.520	h 9	d 1	b 1.910	g 64.995	b 0.3797	a 16.98
Goldasht	Flowering	h 4.81	c 36.417	g 21	d 1	b 1.910	e 68.998	bc 0.3689	c 0.111
	Control	a 10.02	b 38.753	d 25	a 4	c 0.648	e 68.998	d 0.3497	c 0.112
	Budding	g 5.56	c 36.657	e 24	b 3	c 0.648	f 67.998	bc 0.3697	a 15.99
Sina	Flowering	c 7.24	c 36.99	f 23	b 3	b 1.910	d 70.998	c 0.3590	c 0.110
	Control	b 7.99	bc 37.79	a 41	a 4	c 0.648	h 63.997	b 0.3798	c 0.111

Different letters in each column denote significance difference at the 5% level.

a. PY: plant yield per plant (g), 1000SW: 1000 seed weight (g), NSB: Number of seeds per boll, NFB: Number of fertile boll, NIFB: number of infertile boll, PH: Plant height (cm), PW: Petal weight (g), NDLS: Number of dried leaves after stress.

In each Fig., the highest number of seed per boll was observed in non-stress condition and by applying the stress, grain per pod was reduced significantly. Sina and Goldasht genotypes under no stress were at maximum level; but Safeh genotype under flowering stress had lowest number of fertile pod. The number of empty pod in the Safe genotype under flowering stress and budding tension were highest and lowest values, respectively. Drought stress during flowering impairs insemination and reduce florets and thus reduce the number of seeds per pod, whatever the tension is closer to the flowering stage, reducing the number of seeds per pod is higher (Khalili *et al.*, 2009; Santos *et al.*, 2017). Drought at flowering stage cause drying the pollen seed and drop inoculated flowers, as a result, it causes the percentage of unfilled grains in pod or reduce the number of seed per pod (Khalili *et al.*, 2009; Santos *et al.*, 2017). Reducing the number of pod per plant under stress conditions by Omidi Tabrizi (2009) and Singh *et al.* (1995) have also been reported. The number of lateral branches plays an important role in terms of the number of pod per plant, grain per pod and grain yield (Khalili *et al.*, 2009).

Most researchers agree that trait is genetic and it is considered by the genotype (Kocaman *et al.*, 2016) suggested that interaction of genotype and irrigation and interaction between and watering, genotype and density had a significant effect on the number of lateral branches. Safeh genotype under the flowering stress conditions had the highest plant and Sina genotype under non-stress condition had the lowest plant height.

Petals weight on the Safeh genotype under heading and Goldasht genotype under normal conditions were maximum and minimal, respectively. Goldasht genotype under budding stress conditions had the maximum number of dry leaves, after the stress at the blooming stage. One of the factors in the production of photosynthesis in all plants is the number of leaves per plant. By increasing or decreasing too leaves per plant, plant photosynthesis will be faced with a drop in production. of course the number of leaves per plant of safflower under natural conditions is unknown, because this trait depends on the time of planting, regional climate, soil type, etc. those have changed and specific basis cannot be considered for that. In terms of non-stress condition, persistence of leaves surface cause to create enough physiological source to use light and therefore to increase dry matter production. Yari *et al.* (2014) have announced that drought stress causes premature yellowing of leaves and leaf area index is in safflower canopy (Yari *et al.*, 2014).

Table 5. Pearson correlation coefficients for evaluated traits in three spring safflower.

Traits	YP[a]	NBP	NSB	SWB	BW	NFB	NIFB	NFlB	PH	NDLS	RDW	PW	DFBS
YP	1												
NBP	**0.651	1											
NSB	0.143	0.205	1										
SWB	**0.748	**0.503	**0.509	1									
BW	**0.543	**0.564	**0.360	**0.605	1								
NFB	**0.455	**0.748	**0.684	**0.634	**0.599	1							
NIFB	*0.364	*0.428	**-0.609	-.020	0.246	-0.192	1						
NFlB	**0.558	**0.945	0.030	0.307	*0.353	**0.599	**0.505	1					
PH	0.106	-0.178	-0.295	-0.100	-0.112	*0.336	*0.347	-0.077	1				
NDLS	*-0.347	*-0.435	*-0.368	*-0.421	-0.288	**-0.454	0.166	-0.314	**0.857	1			
RDW	-0.112	-0.228	0.167	0.076	0.043	0.172	-0.311	-0.283	0.269	*0.423	1		
PW	0.219	0.192	0.317	0.259	0.161	0.227	-0.093	0.116	-0.202	-0.165	-0.058	1	
DFBS	-0.321	-0.239	-0.222	-0.149	-0.065	-0.032	-0.139	-0.185	-0.287	0.025	0.274	-0.145	1

* and ** denote significance at the 5% and 1% levels, respectively.

a. YP: yield per plant (g), NBP: number of boll per plant, NSB: Number of seeds per boll, SWB: Seed weight per boll (g), BW: Boll weight (g), NFB: number of fertile bolls, NIFB: number of infertile bolls, NFlB: Number of flower buds, PH: Plant height (cm), NDLS: Number of dried leaves after stress, RDW: Root dry weight (g), PW: Petal weight (g), DFBS: Distance of the first branch from the soil surface (cm).

Evaluated traits correlation and regression

Simple Pearson correlation coefficients for evaluated traits showed that among seed weight per boll, and number of flower buds with grain yield, there was positive and significant correlation at 1% (Table 5) which is in accordance to other studies results (Ahmadzadeh *et al.*, 2012; Eslam *et al.*, 2010).

In accordance with the result of this study, with the increase in any of the above traits plant yield increases. The weight of seed in pod, the number of fertile pod and flower bud number was positively correlated with the number of bolls per plant is at 1%. According to Table 5, among the number of fruitful pod and seed weight in pod with the number of seeds in pod there was a positive and significant correlation at 1%; while the number of empty boll and seed number per pod there is a negative and significant correlation at 1%. With the increasing number of seed per pod, the number of empty pod decreases.

On the other hand boll weight and boll number of fertile seeds per boll weight and a significant positive correlation. With the increase in seed weight per pod, pod weight increases. Positive and significant show the correlation of the number of flower bud with the number of fertile pod which suggest that with the increasing number of flower bud, the number of empty and fertile increases (Table 5).

Table 5 shows the increase in plant height, distance of first lateral branch from soil surface.

The result of linear regression analysis (Tables 6 and 7) showed that the number of fertile pod and seed weight in pod entered in regression model and 68% of variation in grain yield (dependent variable) justified, respectively. These traits have positive and significant regression coefficients that indicate a positive relationship with plants and grain yield. This relationship of regression equation is as follows:

$$Y= .967 + 4.543 X_1 + 0.755 X_2$$

Where Y, X_1, and X_2 indicate one plant yield (g), seed weight per pod, and number of fertile pod, respectively.

The above relationship indicates that with an increase of seed weight in pod and the number of fertile pod, plant yield increased. In accordance with the result of this study, Golparvar and Gasemi Pirbaloti (2010) introduced thousand grain weight and number of seeds per plant as the most influential traits on grain yield (Golparvar *et al.*, 2006).

Also other researchers stated that the number of seed per pod and the number of pod in a plant had the most impact on justified performance (Amini , Saeedi, 2006; Tarighi *et al.*, 2012).

Table 6. Results of linear regression analysis for evaluated traits.

Sources of variation	Degree of freedom	Mean of squares
Regression	2	**62.141
Residue	24	2.194

Adjusted R^2= 0.678, R^2=0.702.

Table 7. Regression model derived from regression analysis for evaluated traits.

Model	Unadjusted coefficients	Standard coefficients	test t
Intercept	-.967		-1.56^{ns}
SWB^a (X_1)	4.543	0.755	**6.781
NFB^b (X_2)	0.755	0.379	**3.402

ns and ** denote significance and insignificance at the 1% level, respectively.

a:Seed weight per boll (g), b: Number of fertile boll.

Conclusion

The results showed that drought stress caused a significant reduction in traits except root dry weight. The highest effect on grain yield in drought stress conditions, flowering, were due to reduced grain filling period, shrinking grain and the grain weight loss. Water stress in budding and flowering stage during 40.92 and 35.35 percent respectively decreased compared to control grain yield. Sina genotype from the point of grain yield, harvest index, seed weight per pod, pod weight and root dry weight, respectively. A simple correlation analysis showed a significant positive correlation with yield per plant, seed weight per pod, number of flower buds and pod per plant. Also fertilize and seed weight per pod and pod traits for improved yield through indirect selection is recommended.

Reference

Ahmadzadeh AR, Alizadeh B, Shahryar HA, Narimani-Rad M. 2012. Path analysis of the relationships between grain yield and some morphological characters in spring safflower (*Carthamus tinctorius*) under normal irrigation and drought stress condition. Journal of Medicinal Plants Research **6,** 1268-1271.

Amini F, Saeedi G. 2006. Study on genetic variation in external and Iranian safflower cultivars using agronomic traits. Paper presented at: 9th. Iranian Congress of Crop Sciences. Aburayhan Campus of Tehran University, Pakdasht, Iran.

Ashkani J, Pakniyat H, Emam Y, Assad M, Bahrani M. 2010. The evaluation and relationships of some physiological traits in spring safflower (*Carthamus tinctorius* L.) under stress and non-stress water regimes. Journal of Agricultural Science and Technology **9,** 267-277.

Ebrahimi F, Majidi MM, Arzani A, Mohammadi-Nejad G. 2016. Oil and seed yield stability in a worldwide collection of safflower under arid environments of Iran. Euphytica **212,** 131-144.

Emongor V. 2010. Safflower (*Carthamus tinctorius* L.) the underutilized and neglected crop: A review. Asian J Plant Sci **9,** 299-306.

Eslam BP, Monirifar H, Ghassemi MT. 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.

Flemmer A, Franchini M, Lindström L. 2015. Description of safflower (*Carthamus tinctorius*) phenological growth stages according to the extended BBCH scale. Annals of Applied Biology **166,** 331-339.

Gholinezhad E, Aynaband A, Hassanzade A, Noormohamadi G, Bernousi I. 2009. Study of the effect of drought stress on yield, yield components and harvest index of sunflower hybrid iroflor at different levels of nitrogen and plant population. Notulae Botanicae Horti Agrobotanici Cluj-Napoca **37,** 85.

Golparvar AR, Ghasemi-Pirbalouti A, Madani H. 2006. Genetic control of some physiological attributes in wheat under drought stress conditions. Pak J Bio Sci **9,** 1442-1446.

Hussain MI, Lyra D-A, Farooq M, Nikoloudakis N, Khalid N. 2016. Salt and drought stresses in safflower: a review. Agronomy for sustainable development **36,** 4.

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.

Khalili M, Alireza P-A, Naghavi MR, Mohammad-Amini E. 2014. Evaluation of drought tolerance in safflower genotypes based on drought tolerance indices. Notulae Botanicae Horti Agrobotanici Cluj-Napoca **42,** 214.

Khalili MA, Taghizadeh R, Khazaei H, Omidi TA. 2009. Investigation of variation and determination of genetic distance among 25 genotypes of spring safflower (*Carthamus tinctorius* L.).

Kocaman I, Istanbulluoglu A, Konukcu F. 2016. The effects of deficit irrigation regimes on yield and growth components of winter safflower (*Carthamus tinctorius* L.). Romanian Agricultural Research **33,** 267-274.

Marita T, Muldoon D. 1995. Effect of irrigation schedules and new spacing on the yield of safflower (*Carthamus tinctorius* L.). J Oilseed Res **7,** 307-308.

Nazari M, Mirlohi A, Majidi MM. 2017. Effects of Drought Stress on Oil Characteristics of Carthamus Species. Journal of the American Oil Chemists' Society **94,** 247-256.

Öztürk E, Özer H, Polat T. 2008. Growth and yield of safflower genotypes grown under irrigated and non-irrigated conditions in a highland environment. Plant Soil Environ **54,** 453-460.

Santos RF, Bassegio D, de Almeida Silva M. 2017. Productivity and production components of safflower genotypes affected by irrigation at phenological stages. Agricultural Water Management **186,** 66-74.

Shahrokhnia MH, Sepaskhah AR. 2016. Effects of irrigation strategies, planting methods and nitrogen fertilization on yield, water and nitrogen efficiencies of safflower. Agricultural Water Management **172,** 18-30.

Sharrifmoghaddasi M, Omidi A. 2010. Study of interrupting irrigation effects at different growth stages on grain and oil yield of new safflower varieties. Advances in Environmental Biology **4,** 387-391.

Talebi R, Abhari SA. 2016. Evaluation of genetic diversity in safflower (*Carthamus tinctorius* L.) using agro-morphological, fatty acid composition and ISSR molecular markers. Research Journal of Biotechnology Vol **11,** 7.

Tarighi S, Jamshidi K, Tavakoli A, Moghadam M. 2012. Effect of drought stress and plant density on yield, component yield and content oil of Safflower in province of Zanjan, Iran. Management Science Letters **2,** 2159-2164.

Yari P, Keshtkar A. 2016. Correlation between traits and path analysis of safflower grain yield under water stress conditions. Iranian Journal of Field Crops Research 14.

Yari P, Keshtkar A, Sepehri A. 2014. Evaluation of water stress effect on growth and yield of spring safflower. Plant Products Technology **14,** 101-117.

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.