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Original article

Effect of water stress and plant density on yield and yield components of safflower (*Carthamus tinctorius* L.) in south Kerman, Iran

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Extended abstract

Introduction

Safflower (*Carthamus tinctorius* L.) is one of the world's oldest cultivated crops. It is traditionally grown for its seeds and used for coloring and flavoring foods and for making red and yellow dyes. The total area of safflower harvested in Iran was 490 thousand ha, and in South Kerman was 7000 ha in 2017. Safflower is an oilseed crop, from the Asteraceae family, not very popular compared to other oil crops such as soybean, sunflower and peanut because it is not widely cultivated around the world. Safflower is a C3 plant tolerant to drought, salinity stress and highly adaptable to various environmental conditions because of having deep rooting ability, water uptake from soil, and different osmolyte accumulation. Drought stress is one of the most limiting factors in agricultural productivity because of its highly negative effect on photosynthesis, growth of plants and productivity worldwide. Water deficiency usually promotes the degradation of chlorophyll, caused by photo-inhibition, reduction of photosynthetic efficiency or other processes, such as cell division and expansion. Fernanda et al., (2017) reported that water stress decreased photosynthetic pigments, chlorophyll a, chlorophyll b, grain yield, oil content, oil yield, and increased electrolyte leakage. Nabipour et al., 2007. Water stress decreased 1000 seed weight, seed in capitul, capitul in plant, seed yield and oil content in safflower. Also, plant density is an important crop management that affects the seed yield. However, increasing plant density can be decreased grain yield, due to the competition for water and nutrients between the roots of the neighboring plants. The purpose of the present study was to investigate the response of safflower yield and yield component to water deficit and plant density.

Materials and methods

In other to study the effect of plant density and water stress on grain yield, yield components and oil content safflower. An experiment was conducted in Agricultural Research and Education Center Jiroft, Iran during 2012- 2013. This experiment was carried out as strip plot based on randomized complete blocks design with three replications. Treatments were water stress as vertical factor in four levels including normal irrigation (control), cut-off irrigation in capitul emergence stage before flowering (code 50 BBCH-scale), cut-off irrigation in 50 percent flowering (code 65 BBCH-scale), cut-off irrigation at the end of flowering and begins to expand as fruits develop (code 71 BBCH-scale), and

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density plant as horizontally factor in four levels including 30, 35, 40 and 45 plant/ m2. Traits were measured including plant height, 1000 seed weight, capitul number in plant, grain number in capitul, grain yield and oil content. The data were statistically analyzed using combined variance of analysis and the differences among mean values of the treatments were compared by LSD test ($p \leq 0.05$) using SAS 9.1 software.

Results and discussion

The results showed that water stress, plant density and water stress × plant density had significant ($p<0.05$) effect on 1000 seed weight, capitul number in plant, grain number in capitul, grain yield and oil content. Plant density had not significant effect on plant height, while water stress had significant effect on plant height. Water stress decreased plant height, 1000 seed weight, capitul number in plant, grain number in capitul, grain yield and oil content significantly. The highest grain yield and oil content were obtained when applied treatment of cutoff irrigation in capitul emergence stage plus 40 $pl.m^{-2}$, by 2852 and 884 kg ha^{-1} respectively. The lowest grain yield and oil content achieved when applied treatment of cut-off irrigation in the end of flowering plus 45 $pl.m^{-2}$, by 718 and 204 kg ha^{-1} respectively. Also, application of treatment normal irrigation (control) plus 40 plant/ m2 had the highest grain yield and oil yield by 4101 and 1239 kg ha^{-1} respectively.

Conclusions

The result of our study showed that there is a strong relationship between time cut-off irrigation and reduce of seed yield and yield component. The highest seed yield under water stress condition achieved when applied cut-off irrigation at the end of flowering, cut-off irrigation in 50 percent flowering and cut-off irrigation in capitul emergence respectively.

Keywords**:** Cut- off irrigation, Capitul emergence, Density, Fruit develop, Oil content

Table 1. Soil physical and chemical properties of experimental location

Depth	EC	pH	K_2O	P_2O_5	Organic carbon	Soil texture
(cm)	(ds/m)		------ (mg/kg) ------		(%)	
0-30	2.35	7.4	205	4.2	0.2	Sandy loam

Table 2. Rainfall amount (mm) during the during experiment 2011-2012

June	May	April	March	February	January	December	November
4.9	1	1.2	1.9	59	47	58.2	0

Table 3. ANOVA results of plant density and water stress on measured traits of safflower

Source of variation	df	Height plant	1000 seed weight	Seed number in capitul	Capitul number in plant	Diameter of capitul	Seed yield	Oil content
Replication	2	366.76^{ns}	1.05^{ns}	24.87^{ns}	11.66*	28.2**	18965^{ns}	6314^{ns}
Density (D)	3	77.42^{ns}	26.49**	99.04**	66.25**	23.69**	584109**	66258**
Error 1	6	21.91	0.74	7.65	1.51	1.12	24072	5781
Stress (S)	3	2102**	222**	1193**	154.78**	110**	13310319**	1173059**
Error 2	6	116	0.59	14.63	0.59	0.57	51889	4781
D × S	9	41.4^{ns}	3.32*	38.1*	6.07*	9.02**	137702*	13172**
Error 3	18	142.09	1.38	14.6	2.41	3.65	52851	4188
CV%		8.13	4.75	8.72	7.75	7.98	10.25	9.27

ns, * and **; non significant, significant at 5% and 1% levels of probability, respectively

Table 4. Effects plant density and water stress on measured traits of safflower

Plant density	Water deficit	Plant height	1000 seed weight	Seed per capitul	Capitul per plant	Capitul diameter	Seed yield	Amount of oil
cm		cm	g	---------- No. ----------		mm	--------- kg/ha ---------	
30	**CE**	136.5^{d-f}	19.88^{h}	35.53^{h-i}	19.88^{c-e}	23.63^{b-d}	995.7^{hi}	265.9^{jk}
	F (50%)	141.65^{d-f}	24.33^{ef}	40.07^{e-h}	20.40^{b-e}	24.86^{a-d}	1792^{g}	538.2^{hg}
	EF	150.94^{a-b}	26.4^{cd}	47.86^{b-d}	20.63^{b-d}	25.62^{a-c}	2413^{ef}	726.4^{e}
	Control	161.42^{a-c}	28.72^{b}	63.53^{a}	28.17^{a}	27.15^{a}	3089.9^{c}	918.7^{c}
35	**CE**	139.45^{d-f}	20.48^{gh}	34.73^{h-j}	17.97^{e-f}	22.19^{d}	1140.7^{h}	372.2^{ij}
	F (50%)	143.24^{b-f}	25.87^{de}	40.43^{e-h}	19.87^{c-e}	24.14^{a-d}	1893^{g}	591^{fg}
	EF	152.11^{a-d}	26.77^{b-c}	45.87^{c-e}	21.84^{bc}	25.48^{a-c}	2427^{ef}	797de
	Control	163.35^{ab}	32.91^{a}	61.87^{a}	26.11^{a}	27.27^{a}	3181^{c}	960.6^{c}
40	**CE**	130.25^{ef}	18.92^{h}	33.50^{ij}	15.86^{g}	18.21^{e}	1186.7^{h}	437^{hi}
	F (50%)	142.25^{d-f}	25.37^{de}	44.87^{c-f}	18.83^{d-f}	23.83^{b-d}	2034^{fg}	700.9^{ef}
	EF	147.54^{a-d}	26.17^{c-e}	37.63^{g-i}	19.87^{c-e}	24.68^{a-d}	2952^{dc}	884.9^{cd}
	Control	164.8^{a}	28.17^{bc}	53.50^{b}	22.84^{b}	26.65^{ab}	4101.7^{a}	1239^{a}
45	**CE**	125.3^{f}	16.61^{i}	30.43j	10.87^{h}	14.81^{f}	718.7^{i}	204.7^{k}
	F (50%)	138.95^{d-f}	22.37^{fg}	38.73^{f-h}	16.50^{fg}	23.37^{cd}	1820^{g}	579.9^{g}
	EF	142.68^{d-f}	25.46^{de}	42.40^{d-g}	18.83^{d-f}	24.31^{a-d}	2584de	866.7^{cd}
	Control	167.1^{a}	27.07^{b-d}	50.77^{bc}	21.87^{bc}	26.36^{a-c}	3590.3^{b}	1097^{b}
LSD (0.05)		*20.45*	*2.02*	*6.56*	*2.66*	*3.28*	*394.36*	*111.02*

Means within each column followed by same letter are not significantly different, Capitul emergence (CE), End of flowering (EF), 50% of flowering (F 50%)