YIELD, YIELD COMPONENTS AND OIL RATIOS OF IRRIGATED AND RAINFED SAFFLOWER CULTIVARS (*CARTHAMUS TINCTORIUS* L.) UNDER SEMI-ARID CLIMATE CONDITIONS

BEYYAVAS, V.* – DOGAN, L.

Department of Field Crops, Faculty of Agriculture, Harran University, Osmanbey Campus, Sanliurfa 63050, Turkey

**Corresponding author*
e-mail: vbeyyavas@harran.edu.tr; phone: +90-530-333-6478

(Received 22nd Nov 2021; accepted 4th Feb 2022)

Abstract. The field experiment was conducted in the experimental area of the Faculty of Agriculture in Harran University during of 2019-20, 2020-21 growing seasons to determine the yield and yield components of some safflower cultivars under irrigated and rainfed conditions. The experimental layout was divided into plots in randomized block desing with three replicates. Five safflower varieties (Göktürk, Koç, Dinçer, Safir and Balcı) were used as the plant material. Plant height (cm), number of lateral branches (number plant^{-1}), number of capitula (capitula plant^{-1}), number of seeds per capitulum (number capitulum^{-1}), 1000-seed weight (g), seed yield (kg ha^{-1}), crown yield (g), crude oil content (%) and crude oil yield (kg ha^{-1}) were investigated. Yields of irrigated cultivars (2425.8 and 2308.9 kg ha^{-1}) in both years were higher than those grown under rainfed conditions (857.3 and 578.1 kg ha^{-1}). The best performance under rainfed conditions was obtained from Dinçer cultivar, and the performance of Dinçer and Balci cultivars under irrigated conditions were better than of other three cultivars. In addition, oil content of varieties grown under irrigation were higher than varieties grown under rainfed conditions. Balcı variety had the highest oil content and best performance under rainfed and irrigated conditions for oil content.
Keywords: *safflower, yield components, irrigation, oil rate, economic analysis*

Introduction and literature review

Safflower (*Carthamus tinctorius* L.) an industrial plant has many different uses with its stem, leaves, seeds as well as flowers. The safflower is an ancient cultivar that was cultivated in the Middle East 3000 years ago (Knowles, 1982), and whole plant is used for the treatment of different diseases in India and Pakistan (Nimbkar, 2002). The flowers of safflower plants are used in food, cosmetics and paint-pharmaceutical industries (Abd El-Mohsen and Mahmoud, 2013). Safflower is an important alternative crop that can be cultivated in rainfed agricultural lands with its high tolerance to cold and heat, and in irrigated agricultural lands due to its tolerance to salinity and weeds (Kaya et al., 2003; Hussain et al., 2015; Emongor et al., 2015). Safflower (*Carthamus tinctorius* L.), which can be grown in winter, is an important annual oil plant (Eslam, 2010; Gürsoy et al., 2018). The safflower grows in wide range of environments and is more resistant to drought and low temperatures that can be used in fallow areas unlike other oil crops (Jhonson et al., 1993; Hussain, 2015; Emongor et al., 2015; Yeilaghi et al., 2015). Aforementioned characteristics reveal that safflower can be grown in rotation with wheat, barley, singular, etc. under rainfed conditions and can be considered an important oil seed crop for vegetable oil deficit of the country (Eryiğit et al., 2015; Köse, 2017).

Safflower seeds contain 13-46% oil (Doğan, 2021; Beyyavas and Haliloglu, 2021), of which approximately 90% consists of unsaturated fatty acids (oleic and linoleic acid)

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_18071820

(Jhonson et al., 1993; Belgin et al., 2007). Safflower oil, which contains an average of 75% linoleic acid, also contains tocopherols with antioxidant effect and high vitamin E value (Weiss, 2000). Safflower is an important oilseed plant that grows optimally in rainfed conditions. However, lack of adequate moisture due to the severe drought conditions during phenological periods such as germination, stem elongation and branching and flowering negatively affect crop growth (Dajue and Mündel, 1996; Ekin, 2005).

Although safflower is a resistant crop to drought, the yield increases when irrigated during critical periods. The most critical periods for safflower seed yield are stem elongation and pre-blooming periods. Additional irrigation during these critical periods, when there is severe drought and insufficient moisture in the soil, will increase the yield of safflower (Omidi, 2012; Mohammedi et al., 2018; Santos et al., 2018; Koç, 2019; Doğan, 2021). This study was carried out to determine the effects of drought and yield of safflower cultivars, and suitable varieties by economic analyzes on the performance of five safflower cultivars grown under rainfed and irrigated conditions.

Materials and methods

Materials

The experiment was conducted in the Agricultural Research and Experimental Fields of Agriculture Faculty in Harran University during 2019-20 and 2020-21 growing seasons. Göktürk and Koç varieties obtained from Konya Bahri Dağdaş International Agricultural Research Institute, Balcı and Dinçer varieties from Eskişehir Transition Zone Agricultural Research Institute and Safir variety from Şanlıurfa GAP Agricultural Research Institute were used as plant safflower varieties.

Soil and climate characteristics

Soil samples were collected from 0-30 cm depth of the experimental site, and some of soil chemical characteristics of experimental site are given in *Table 1*.

Table 1. *Some of chemical properties of soils in experimental field*

Depth (cm)	pH	Organic matter (%)	Lime (%)	Macro and micro nutrients (mg kg^{-1})						
				P	K	Mg	Fe	Zn	Cu	Mn
0.30	7.92	1.12	29.6	4.70	180	303	3.46	0.72	4.64	0.44

Soil organic matter content (1.12%) of experimental site was low, and soil was slightly alkaline, very calcareous, slightly saline, clay-loam textured, low phosphorus and moderate potassium content (Ramazanoglu, 2019).

Şanlıurfa province is located in the Southeastern Anatolia Region of Turkey, between 36° 40’ and 38° 02’ north latitudes and 37° 50’ and 40° 12’ east longitudes. The continental transition climate prevails in the area, with hot and dry summers and cold winters. Average temperature and precipitation data of 2019-2020 and 2020-2021 growing periods and long-term (1929-2020) for Sanlıurfa province are given in *Table 2*. (Anonymous, 2021).

The average temperature values of the first and second years of the experiment were 14.99 and 15.97 °C. The average temperature value of long-term was 13.65 °C. Total

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_18071820

precipitation in the first and second years of the experiment was 584 and 249 mm, and long-term average precipitation was 425.8 mm (*Table 2*). The second growing period was quite dry and the drought had a significant negative impact on yield and yield components.

Table 2. *Some climate data of Şanlıurfa province for 2019-2020, 2020-21 and long-term (between 1929-2020)*

Months	2019-2020		2020-2021		Long-term average 1929-2020	
	Avg. temp. (°C)	Total prep. (mm)	Avg. temp. (°C)	Total prep. (mm)	Avg. temp. (°C)	Total prep. (mm)
November	14.8	6.7	13.5	60.9	12.18	44.9
December	9.0	277.7	9.4	61.5	7.5	80.1
January	6.6	76.9	8.1	76.4	5.5	87.6
February	7.0	24.1	10.4	13.4	7.0	69.5
March	13.3	90.8	11.7	33.7	10.8	62.8
April	17.1	68.3	19.1	0.4	16.1	49.8
May	23.2	39.1	26.6	2.7	22.1	26.7
June	28.9	0.4	29.0	0.0	28.0	4.4
Total	-	584	-	249	-	425.8
Average	14.99		15.97		13.65	

Experimental design and treatment

The research was carried out in the experimental field of Field Crops Department, in Agricultural Faculty of Harran University (*Fig. 1*). Experimental layout was divided plots in randomized blocks. The treatments (irrigation and rainfed, IR) were placed in the main plots, and the cultivars were placed in the sub plots.

The plots were 6 m long and consisted of 5 rows, and the interrow and intra row distance was 30 and 10 cm, respectively. The experimental field was tilled with a plow and an herbicide (with *Trifluarin* active substance) was applied before planting using a hand pulverizer. Afterwards, the field was tilled with a cultivator at shallow depth and made ready for planting by pulling the tap. The sowing was carried using an experiment seeder on 5 November 2019 in the first year and on 8 November 2020 in the second year. After emergence, the plants were thinned in the 3-4 leaf period. Fertilizers were applied manually in a band on one side of the plant rows. Diammonium phosphate (80 kg P ha^{-1}; 30 kg N ha) was applied for the P requirement of the plant. Seven kg of urea (46% pure N) in the form of N was applied in February as top fertilizer. The rainfed plots were not irrigated and the plants were grown under natural precipitation conditions. Irrigation was carried out in the irrigation treatment plots, considering the climatic conditions. In the first, irrigation was applied 3 times (225 mm in total) during the flowering and seed setting periods, and in the second year, 4 times (300 mm) during the stem elongation, flowering and seed setting periods. Irrigation was applied homogeneously to the plots using a sprinkler system. On April 22 2020, 20 g L^{-1} acetamiprid active ingredient powder pesticide, effective against leafworm (*Spodoptera littoralis*) and aphid (*Aphidoidea*) pests, was applied to the experimental field.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_18071820

Figure 1. *Location of experiment area in Harran University*

Observations

When the plants reached the harvest maturity, one row from each side of plots and 1 m from the lower and upper parts of plots were cut with a sickle as a side effect, and the remaining 2 rows (0.6 m × 4.0 m = 2.4 m^2) were harvested. Plant height (cm), number of lateral branches (number $plant^{-1}$), number of capitula (piece $plant^{-1}$), number of seeds (number $capitulum^{-1}$), thousand seed weight (g), seed yield (kg ha) and crown yield (g) from 10 randomly selected plants from each plot were determined and averaged (Esendal,1992). To determine the oil content (%), 10 g of seeds from each variety were grounded, and dried in an oven at 70 °C for 72 h. Five g dried samples were taken and boiled for 6 h using n-hexane in the Soxhlet device and oil ratios (%) were determined (Bilsborrow et al., 1993). The results of percent oil content were multiplied by the seed yield per hectare and the results were converted to kg^{-1} ha by dividing 100 (*Fig. 2*).

Figure 2. *Observations in the experimental field*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_18071820

Data analysis

The data were analyzed using JMP 11 (SAS Institute, 2013) according to the experimental design of divided plots in randomized blocks. Means were grouped by the Tukey test (0.05).

Results and discussion

Plant height (cm)

As a result of the combined years analysis (ANOVA), there was a statistically significant difference between the years in terms of characteristics examined, and the data of each year were analyzed separately.

The rainfed-irrigation and variety treatments and rainfed-irrigation × variety interaction had a significant effect ($P < 0.01$) on plant height in both growing seasons (*Table 8*). The highest plant height value under rainfed-irrigation treatment in the first year was recorded in Dinçer variety (130.0 cm). This difference can be partially explained by the fact that the varieties grown under rainfed and irrigated conditions were not irrigated until May and the plants continued to grow with the precipitation. In the second year of the experiment, mean plant height measured under rainfed (60.88 cm) and irrigated (101.47 cm) varieties was significantly different from each other. The highest plant height was recorded in Koç variety (104.56 cm) (*Table 3*). Adverse climatic conditions and severe drought in the 2020-2021 growing season caused shortening the plant height of varieties grown under rainfed conditions. The results reported in the previous studies investigating the effects of rainfed and irrigated cultivation on plant height were in agreement with our findings. Öztürk et al. (2009) reported that plant height under rainfed and irrigated conditions was 86.9 and 108.2 cm, respectively, Jabbari et al. (2010) stated that irrigation levels had an important effect on plant height of safflower genotypes, Singh et al. (2016) reported that irrigation levels affected plant height, and Santos et al. (2018) found that the plant height in different irrigation periods was higher than that measured in the control plots.

Table 3. *Mean plant height (cm) and number of lateral branches (pieces/plant) of some safflower (Carthamus tinctorius L.) cultivars grown under rainfed and irrigated conditions*

Variety	Plant height (cm)				Number of lateral branches (piece/plant)			
	2019-2020		2020-2021		2019-2020		2020-2021	
	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
Safir	122.33bc	120.00cd	70.06c	100.10ab	5.47ab	5.30ab	4.96ab	5.63a
Koç	120.67c	120.67c	53.30d	104.56a	4.83b	5.27ab	4.03bc	4.63ab
Göktürk	124.67b	120.00cd	55.00d	102.90ab	6.00ab	5.30ab	3.36c	5.50a
Balcı	119.67cd	117.00d	56.03d	98.66b	6.27a	5.93ab	4.03bc	5.70a
Dinçer	130.00a	125.00b	70.00c	99.50ab	5.33ab	6.03ab	3.93bc	5.66a
Mean	123.46a	120.53b	60.88b	101.47a	5.58a	5.56a	4.06b	5.42a

Means that do not share a letter are significantly different. $^{*}p \leq 0.05$, $^{**}p \leq 0.01$

Number of lateral branches (piece plant^{-1})

The effects of rainfed-irrigation factor and rainfed-irrigation × variety interaction on the number of lateral branches were not statistically significant in 2019-2020 growing

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_18071820

season. In contrast, the effects of rainfed-irrigation and variety factors and rainfed-irrigation × variety interaction had significant effect on the number of lateral branches in 2020-2021 growing season (*Table 8*). In the first year, the number of lateral branches counted under rainfed (5.58 pieces plant^{-1}) and irrigation (5.56 pieces plant^{-1}) conditions were similar. The highest number of lateral branches under rainfed conditions was obtained in Balcı variety (6.27 pieces plant-1) under rainfed-irrigation treatment. The similarity in the number lateral branches between rainfed and irrigation conditions can be attributed to the lack of water during vegetative period, the same amount of precipitation (no irrigation till May) and cultivation under the same growing conditions. In contrast, the difference in the number of lateral branches between rainfed (4.06 pieces plant^{-1}) and irrigation conditions (5.42 pieces plants^{-1}). The highest number of lateral branches (5.72 pieces plant^{-1}) among the varieties was counted in Balcı variety (*Table 3*). The irrigation during vegetation period increased the number of lateral branches. Similarly, Muhammedi et al. (2018) indicated that water stress decreased the number of lateral branches in plants.

Number of capitula (piece plant^{-1})

The effects of rainfed-irrigation and variety treatments and rainfed-irrigation interaction on the number of capitula were statistically significant (P < 0.01) in both years of the experiment (*Table 8*). The number of capitula in both years of the experiment was higher for irrigated varieties (9.16 and 8.04 piece plant^{-1}) compared to rainfed varieties (7.44 and 5.35 piece plant^{-1}). The highest number of capitula under irrigated and rainfed conditions was recorded in Dinçer variety (*Table 4*). Similar to the number of capitula recorded in this study, Santos et al. (2018) found higher number of capitula in different irrigation periods compared to the control.

Table 4. *Mean number of capitula (piece/plant) and number of seeds (piece/capitula) of some safflower (Carthamus tinctorius L.) cultivars grown under rainfed and irrigated conditions*

Variety	Number of capitula (piece/plant)				Number of seeds (piece/capitula)			
	2019-2020		2020-2021		2019-2020		2020-2021	
	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
Safir	7.40c	8.23c	6.83bc	7.10b	14.30ef	29.40bc	14.56c	18.35b
Koç	5.03d	8.70bc	4.20e	5.90cd	11.42f	27.52c	13.38c	18.87b
Göktürk	8.90bc	7.70c	5.30d	8.50a	19.27d	31.28ab	13.84c	18.53b
Balcı	7.87c	10.10ab	5.10de	9.40a	17.22de	32.51a	16.32bc	22.81a
Dinçer	8.00c	11.06a	5.33d	9.33a	19.22d	27.27c	18.95b	24.63a
Mean	7.44b	9.16a	5.35b	8.04a	16.28b	29.59a	15.41b	20.64a

Means that do not share a letter are significantly different. *p ≤ 0.05, **p ≤ 0.01, ns: non-significant

Number of seeds (piece capitulum^{-1})

The number of seeds per capitulum in both years was significantly different under rainfed-irrigated treatments. The effects of variety had also a significant effect (P < 0.01) on the number of seeds per capitulum in both years. The effect of rainfed × irrigation interaction on the number of seeds per capitulum was significant (P < 0.01) in 2019-20 growing season, while it was not significant in 2020-2021 growing season

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_18071820

(*Table 8*). The number of seeds per capitulum for all varieties under irrigated conditions (29.59 and 20.46 piece plant^{-1}) was significantly (P < 0.01) higher in both years of the experiment than that obtained under rainfed conditions (16.28 and 15.41 piece plant^{-1}). The highest number of seeds under rainfed and irrigated conditions was obtained in Dincer and Balcı variety (*Table 4*). Öztürk et al. (2008) reported that the number of seeds per capitulum under irrigated condition was higher than that of the rainfed conditions, and the number of seeds per capitulum has significantly changed with genotypes and years. Similarly, Jabbari et al. (2010) indicated that irrigation has significant effect on the number of seeds per capitulum, the highest number of seeds per capitulum was 26.56 seed capitula^{-1} with irrigation during flowering and capitula formation periods. Similar to the findings reported by Jabbari et al. (2010) and Zarghami et al. (2011) stated that drought particularly during flowering and capitula formation has significant effect on safflower seed yield.

Thousand seed weight (g)

The variance analysis revealed that the treatments had a significant effect (P < 0.01) on 1000-weight in the first year, while the effect of rainfed-irrigation × variety interaction was not significant (*Table 8*). The one thousand seed weight under irrigated conditions (32.82 g) was significantly higher than that obtained under rainfed conditions (26.15 g). In the second year, the effect of rainfed-irrigation treatment on 1000-seed weight was not significant. The highest 1000- seed weight in the first and second year of the experiment was obtained Balcı (34.05 g) and Dinçer (40.38 g) variety (*Table 5*). Similarly, Omidi et al. (2012) and Muhammedi et al. (2018) found that cultivars and irrigation issues had a significant af1000- seed weight, and Santos et al. (2018) found that 1000-seed weight in different irrigation periods was higher than that obtained in the control plot.

Table 5. *Thousand seed weight (g) and yield (kg ha^{-1}) of some safflower (Carthamus tinctorius L.) cultivars grown under rainfed and irrigated conditions*

Variety	Thousand seed weight (g)				Yield (kg ha^{-1})			
	2019-2020		2020-2021		2019-2020		2020-2021	
	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
Safir	28.08c	33.11ab	36.42bc	37.28bc	866.5d	2339.8b	451.4fg	2250.5c
Koç	20.97e	31.59b	36.55bc	36.02c	420.9e	2180.8b	351.9g	1968.5d
Göktürk	28.71c	32.75ab	35.48c	35.71c	1003.1cd	221.98b	643.2ef	2295.1bc
Balcı	25.19d	34.05a	37.85abc	36.30bc	856.5d	2724.4a	655.9e	2464.9ab
Dinçer	27.83c	32.63ab	39.06ab	40.38a	1139.7c	2664.3a	787.8e	2565.7a
Mean	26.15b	32.82a	37.07a	37.14a	857.3b	2425.8a	578.1b	2308.9a

Means that do not share a letter are significantly different. *p ≤ 0.05, **p ≤ 0.01, ns: non-significant

Seed yield (kg ha^{-1})

The effect of all treatments on seed yield in 2019-2020 growing period was significant (P < 0.01). The effects of rainfed-irrigation and variety factors were also significant (P < 0.01) in 2020-21, while the effect of rainfed × irrigation interaction on seed yield was not significant (*Table 8*). The seed yields obtained under irrigated

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_18071820

conditions (2425.8 and 2308.9 kg ha^{-1}) were higher in both years of the experiment compared to those obtained under rainfed conditions (857.3 and 578.1 kg ha^{-1}). Low yield of the varieties grown under rainfed conditions in the second year of the experiment may be associated with the negative climatic conditions, the absence of precipitation during the periods desired by safflower and severe drought throughout the year (*Table 5*). The best performance under rainfed conditions was obtained in Dinçer variety, and Dinçer and Balcı varieties under irrigated conditions (*Table 5*). The findings reported by other researchers were in agreement with our findings. Omidi et al. (2012) showed that the decrease in available water content causes a 10 to 38% decrease in yield. Nacar et al. (2016) stated that the yield increased with irrigation and Santos et al. (2018). determined that the yield was higher in irrigation compared to the control plots. Muhammedi et al. (2018) found that water stress reduced seed yield, and Koç (2019) revealed that precipitation in April, May and June has direct effect on seed yield.

Petal yield (g plant^{-1})

The effect of all treatments on petal yield in 2019-2020 growing season was not significant. In contrast, the effects of rainfed-irrigation and variety factors on petal yield was statistically significant at $P < 0.01$ level in 2020-2021 growing period, and the effect of rainfed-irrigation × variety interaction was significant at $P < 0.05$ level (*Table 8*). The petal yield of cultivars grown under irrigation condition in the 2020-2021 growing season was higher than the petal yield of cultivars grown in rainfed conditions. Safir and Göktürk varieties had the best performance. Özel et al. (2004) reported that the petal yield varied between 0.46-1.60 g plant-1 depending on the planting time and the interrow distance, and Doğan (2021) indicated that the crown yield was between 0.38-0.67 g in irrigated and rainfed conditions.

Oil ratio (%)

The effect of all treatments in both growing seasons on oil ratio was significant ($P < 0.01$) (*Table 8*). The oil ratio of varieties under irrigated conditions was higher than the oil ratio record under rainfed conditions (*Table 6*). The highest oil ratio under rainfed and irrigation conditions was recorded in Balcı variety. The oil ratio under rainfed and irrigation conditions was reported between 40.3-44.2% by Bergman et al. (2001). Öztürk et al. (2009) indicated that mean crude oil ratio under rainfed and irrigated conditions was 28.3 and 32.7%, respectively. Eslam et al. (2010) reported that water deficit during seed filling period caused a decrease in oil ratio and yield. Similarly, Santos et al. (2018) showed that oil ratios of safflower varieties decreased with increasing drought, and Koç (2019) showed that irrigation had a positive effect on oil ratio.

Oil yield (kg ha^{-1})

The rainfed and irrigated treatments had a significant effect on oil rate in both growing seasons (*Table 8*). The cultivars grown under irrigation had higher oil content than cultivars grown under rainfed conditions (*Table 7*). In both years, Balcı variety had the best performance under rainfed and irrigated conditions and had the highest oil yield (705.1 and 911.6 kg ha^{-1}). Oil yields found in previous studies are consistent with the oil rates determined in this study. The oil yield reported by Öztürk et al. (2009) was 624 kg ha^{-1} and 264 kg ha^{-1} under irrigated and rainfed conditions; crude oil yield found

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_18071820

by Sirel (2011) was between 180.6 and 392.3 kg ha^{-1}, and Yurteri (2016) indicated that the crude oil yield in summer and winter sowing was between 244.4 and 505.5 kg ha^{-1}, respectively. Similar to our findings, Santos et al. (2018) stated that safflower oil yield increased with irrigation; Mohammadi et al. (2018) indicated that lack of water reduces seed and safflower oil yield and safflower varieties showed different water stress responses; Ebrahimian et al. (2019) revealed that irrigation increased oil yield.

Table 6. *Mean petal yield (g $plant^{-1}$) and oil ratio (%) of some safflower (Carthamus tinctorius L.) cultivars grown under rained and irrigated conditions*

Variety	Petal yield (g plant $^{-1}$)				Oil ratio (%)			
	2019-2020		2020-2021		2019-2020		2020-2021	
	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
Safir	0.43^{ns}	0.54^{ns}	0.35c	0.48a	27.09bc	28.76ab	30.64b	34.91a
Koç	0.38	0.50	0.23d	0.38bc	25.38cd	25.91cd	34.93a	37.52a
Göktürk	0.55	0.44	0.25d	0.48a	28.89ab	28.09b	34.66a	37.50a
Balcı	0.44	0.53	0.24d	0.47ab	30.41a	26.02cd	35.53a	37.37a
Dinçer	0.67	0.64	0.23d	0.46ab	24.29d	20.51e	28.91b	29.03b
Mean	0.49	0.53	0.25b	0.46a	25.85b	27.21a	32.93b	35.26a

Means that do not share a letter are significantly different. *$p \leq 0.05$, **$p \leq 0.01$, ns: non-significant

Table 7. *Mean oil yield (kg ha^{-1}) of some safflower (Carthamus tinctorius L.) cultivars grown under rained and irrigated conditions*

Variety	Oil yield (kg ha^{-1})			
	2019-2020		2020-2021	
	Rainfed	Irrigated	Rainfed	Irrigated
Safir	234.7e	672.8ab	144.7de	785.9bc
Koç	106.8f	564.6cd	123.6e	738.5c
Göktürk	289.6e	623.7bc	223.2de	860.7ab
Balcı	260.4e	705.1a	244.6d	921.6a
Dinçer	276.9e	546.5d	227.7de	744.7c
Mean	233.6b	622.5a	192.8b	810.3a

Means that do not share a letter are significantly different. *$p \leq 0.05$, **$p \leq 0.01$, ns: non-significant

Economic analysis

Economic analysis were performed by collecting input and output data, and benefit cost ration was determined by dividing net return on total cost as described (Ali et al., 2019). Incomes from safflower varieties grown under rainfed and irrigated conditions in the 2019-2020 and 2020-2021 growing seasons were calculated (*Table 9*). The input cost (fertilizer, irrigation and spraying costs), total income and net income received by the farmer were calculated. Price of one kg of safflower seed for 2020 and 2021 was 0.45 $ kg^{-1} and 0.54 $ kg^{-1} respectively. Crop incentive by the government was 0.07/$ kg^{-1}. Net income of safflower cultivars grown under irrigated conditions was higher than those grown under rainfed conditions. The highest net income under irrigated conditions was obtained by Balcı and Dinçer cultivars (*Fig. 3*).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_18071820

Table 8. *F value for some safflower (Carthamus tinctorius L.) cultivars in rainfed and irrigated conditions, the degree of importance and % CV values*

	F value								
2019-2020	**Plant height (cm)**	**Number of lateral branches (pieces plant^{-1})**	**Number of capitula (piece plant^{-1})**	**Number of seed (piece capitula^{-1})**	**Thousand seed weight (g)**	**Yield (kg ha^{-1})**	**Petal yield (g plant^{-1})**	**Oil ratio (%)**	**Oil yield (kg ha^{-1})**
Rainfed-irrigated	60.50**	ns	81.45**	1239.47**	599.69**	4398.18**	ns	36.64**	2794.27**
Variety	65.08**	5.19**	23.55**	31.44**	36.68**	74.54**	ns	105.78**	49.04**
Rainfed-irrigated*variety	5.73**	ns	20.90**	15.52**	22.56**	23.33**	ns	28.00**	25.44**
% CV	1	8	6	5	3	4	23	2	5
2020-2021									
Irrigated-rainfed	3130.26**	83.11**	419.85**	147.69**	ns	5349.28**	255.21**	37.93**	2253.24**
Variety	20.28**	5.32**	40.95**	28.14**	15.04**	56.27**	9.86**	59.09**	17.49**
Rainfed-irrigated*variety	39.14**	4.25**	33.05**	ns	ns	ns	3.56*	ns	ns
% CV	2.43	8.61	5.38	6.53	2.67	4.48	9.63	3.03	7.10

Means that do not share a letter are significantly different. *$p \leq 0.05$, **$p \leq 0.01$, ns: non-significant. CV: coefficient of variations

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_18071820

Table 9. *Economic analysis for safflower (Carthamus tinctorius L.) cultivars under rainfed and irrigated conditions*

Period	Safflower varieties	Yield (kg ha^{-1})	Total income ($ ha^{-1})	Total cost ($ ha^{-1})	Crop incentive ($ ha^{-1})	Net income ($ ha^{-1})	Benefit cost ratio
	Rainfed						
2019-2020	Safir	866.50	351.28	132.43	0.07	218.93	2.65
	Koç	420.90	170.64	132.43	0.07	38.28	1.29
	Göktürk	1003.70	406.66	132.43	0.07	274.30	3.07
	Balcı	856.50	347.23	132.43	0.07	214.87	2.62
	Dinçer	1193.70	462.34	132.43	0.07	329.68	3.49
	Irrigated						
	Safir	2339.80	948.57	259.46	0.07	689.18	3.66
	Koç	2180.80	884.11	259.46	0.07	624.72	3.41
	Göktürk	2219.80	899.92	259.46	0.07	640.53	3.47
	Balcı	2724.40	1104.49	259.46	0.07	845.10	4.26
	Dinçer	2664.30	1080.12	259.46	0.07	820.74	4.16
	Rainfed						
2020-2021	Safir	451.40	213.68	128.99	0.07	84.75	1.66
	Koç	351.90	166.58	128.99	0.07	37.65	1.29
	Göktürk	643.20	304.47	128.99	0.07	175.54	2.36
	Balcı	655.90	310.49	128.99	0.07	181.56	2.41
	Dinçer	787.80	372.92	128.99	0.07	243.99	2.89
	Irrigated						
	Safir	2250.50	1065.33	252.07	0.07	813.32	4.23
	Koç	1968.50	931.83	252.07	0.07	679.83	3.70
	Göktürk	2295.10	1086.44	252.07	0.07	834.43	4.31
	Balcı	2464.90	1166.82	252.07	0.07	914.81	4.63
	Dinçer	2565.70	1214.53	252.07	0.07	962.53	4.82

August 2020 1 TL (Turkish Lira): $7.40; August 2021 1 TL: $8.40
2020 crop income kg^{-1}: 0.45$; 2021 crop income kg^{-1}: 0.54$

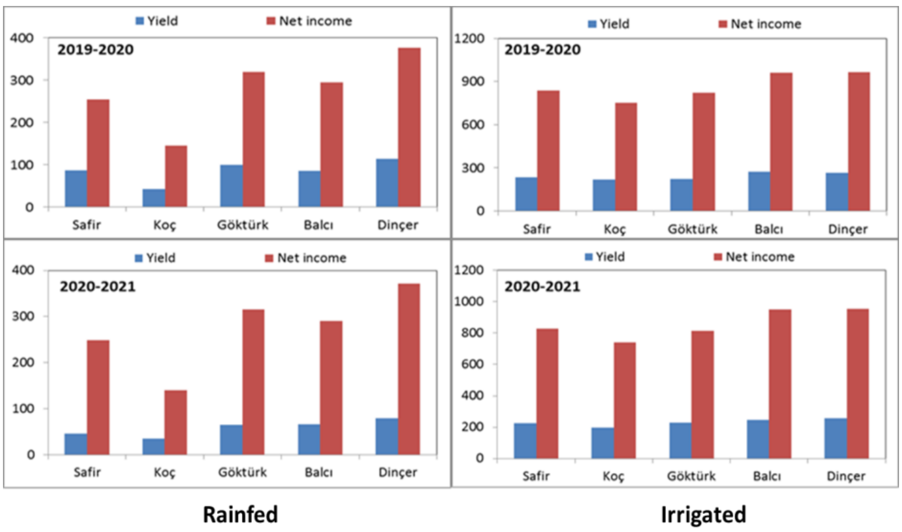

Figure 3. *Comparison of yield and net income for safflower (Carthamus tinctorius L.) cultivars under rainfed and irrigated conditions*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_18071820

Conclusion and recommendations

Seed yield of safflower cultivars grown under rainfed and irrigated conditions was significantly different. Safflower is not recommended and not economical due to low yield in arid conditions. The safflower plant, sown in winter, has to be irrigated to compete with wheat-barley plants, and to meet the water needed when plants need water. The possibility of irrigation should be considered especially if the sunflower is recommended to be grown in winter. In the second growing period of the experiment, the decrease in yield is more obvious seen due to insufficient rainfall. Dinçer variety had the best performance under rainfed conditions, and Dinçer and Balcı varieties under irrigated conditions. In addition, varieties grown by irrigation have higher oil content than varieties grown in rainfed conditions. The results revealed that Balcı had a high oil content, and variety showed the best performance under rainfed and irrigated conditions.

Acknowledgements. The first year of the study was published as a MSc. thesis and was supported by Harran University Scientific Research Projects (HÜBAP project no: 20093) Coordinator.

REFERENCES

[1] Abd El- Mohsen, A. A., Mahmoud, G. O. (2013): Modeling the influence of nitrogen rate and plant density on seed yield, yield components and seed quality of safflower. – American Journal of Experimental Agriculture 3(2): 336-360.

[2] Ali, H., Ahmad, A., Hussain, S. (2019): The effect of exogenous phosphorous application on growth, yield, quality and net returns of upland cotton (*Gossipium hirsutum* L.). – Applied Ecology and Environmental Research 18(1): 769-781.

[3] Anonymous (2021): Meteorological Data Obtained from Sanliurfa Meteorological Station. – Sanliurfa, Turkey.

[4] Belgin, C., Bilal, G., Mustafa, K. (2007): Oil content and fatty acid composition of some safflower (*Carthamus tinctorius* L.) varieties sown in spring and winter. – International Journal of Natural and Engineering Sciences 1(3): 11-15.

[5] Bergman, J. W., Riveland, N. R., Flynn, C. R., Carlson, G. R., Wichman, D. M. (2001): Registration of ‘centennial’ safflower. – Crop Science 41(5): 1639-1640.

[6] Beyyavas, V., Haliloglu, H. (2021): Effects of humic acid and iron applications on the yield, some plant characteristics and oil ratio of safflower (*Carthamus tinctorius* L.). – Applied Ecology and Environmental Research 19(1): 307-319.

[7] Bilsborrow, P. E., Evans, E. J., Murray, F., Zhao, F. J. (1993): Glucosinolate changes in developing pods of single and double low varieties of autumn sown oilseed rape (*Brassica napus* L.). – Annals of Applied Biology 122(1): 135-143.

[8] Dajue, L., Mundel, H. H. (1996): Safflower, Promoting the Conservation and Use of Underutilized and Neglected Crops. – 7. Institute of Plant Genetic and Crop Plant Research, Gatersleben/International Plant Genetic Resources Institute, Rome, Italy.

[9] Doğan, L. (2021): Determination of yield components yield and oil ratio of some safflower (*Carthamus tinctorius* L.) cultivars in Sanliurfa ecological conditions. – Master Thesis, Harran University Graduate School of Natural and Applied Sciences Department of Field Crops, Sanliurfa, Turkey.

[10] Ebrahimian, E., Seyyedi, S. M., Bybordi, A., Damalas, C. A. (2019): Seed yield and oil quality of sunflower, safflower, and sesame under different levels of irrigation water availability. – Agricultural Water Management 218: 149-157.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_18071820

[11] Ekin, Z. (2005): Resurgence of safflower (*Carthamus tinctorius* L.) utilization: a global view. – Journal of Agronomy 4(2): 83-87.
[12] Emongor, V. E., Oagile, O., Kedikanetswe, B. (2015): Effects of plant population and season on growth and development of safflower (*Carthamus tinctorius* L.) as an ornamental plant. – Acta Horticulturae 1077(1077): 35-45.
[13] Eryiğit, T., Yıldırım, B., Kumlay, A. M., Sancaktaroğlu, S. (2015): The effects of different row distances and nitrogen fertilizer rates on yield and yield components of safflower (*Carthamus tinctorious* L.) under micro-climate conditions of Igdır plain. – Turkey 3rd International Conference on Biological, Chemical & Environmental Sciences (BCES-2015), 21-22 September, Kuala Lumpur (Malaysia), pp. 17-22.
[14] Esendal, E., Kevseroğlu, K., Uslu, N., Aytaç, S. (1992): The effect of spring and winter planting on yield and important characters of safflower. – University of Ondokuz Mayis, Faculty of Agriculture, Years of Research, Project No: Z-044, pp. 119-121.
[15] 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 Agricculture Forestry 34(4): 373-380.
[16] Gürsoy, M., Başalma, D., Farzad Nofouzi, F. (2018): The effects of different row spacing and spacing on yield and yield components of safflower (*Carthamus tinctorius* L.) cultivars. – Selcuk Journal Agriculture Food Science 32(1): 20-28.
[17] Hussain, M. I., Dionyssia-Angeliki, L., Farooq, M., Nıkoloudakıs, N., Khalid, N. (2015): Salt and drought stresses in safflower: a review. – Agronomy for Sustainable Development 36(4): 1-31.
[18] Jabbari, M., Ebadi, A., Tobeh, A., Mostafai, H. (2010): Effects of supplemental irrigation on yield and yield components of spring safflower genotypes. – Recent Research in Science and Technology 2(1): 23-28.
[19] Johnson, R. C., Stout, D. M., Bradley, V. L. (1993): A rich source of safflower germplasm. – Proceeding of the Third International Safflower Conference, Beijing. Botanical Garden Institute of Botany Chinese Academy of Sciences, June 14-18, Beijing-China, pp. 202-208.
[20] Kaya, M. D., İpek. A., Özdemir. A. (2003): Effect of different soil salinty levels on germanition and seedling growth of safflower (*Carthamus tinctorius* L.). – Tr. Agri. And Forestry 27(2003): 221-227.
[21] Knowles, P. F. (1982): Safflower: genetics and breeding in: improvement of oil seed industrial crops by induced mutations. – International Atomic Energy Agency, Vienna, pp. 89-101.
[22] Koç, H. (2019): Evaluation of safflower cultivars in terms of yield and oil ratio under different precipitation. – Turkish Journal of Agriculture and Natural Sciences 6(3): 518-526.
[23] Kose, A. (2017): Determination of agricultural performance of some safflower (*Carthamus tinctorius* L.) cultivars under Eskişehir conditions. – Selcuk Journal of Agriculture and Food Science 31(2): 1-7.
[24] Mohammadi, M., Ghassemi-Golezani, K., Chaichi, M. R., Safikhani, S. (2018): Seed oil accumulation and yield of safflower affected by water supply and harvest time. – Agronomy Journal 110: 586-593. DOI: 10.2134/agronj2017.06.0365.
[25] Nacar, A. S., Değirmenci, V., Hatipoğlu, H., Taş, M., Arslan, H., Çıkman, A., Şakak, A. (2016): Effects of irrigation on yield and yield components at safflower plant in Harran plain condition. – Journal of Field Crops Central Research Institute 25: 149-154.
[26] Nimbkar, N. (2002): Safflower rediscovered. – Times Agricultural Journal 2(1): 32-36.
[27] Omidi, A. H., Khazaei, H., Monneveux, P., Stoddard, F. (2012): Effect of cultivar and water regime on yield and yield components in safflower (*Carthamus tinctorius* L.). – Turkish Journal of Field Crops 17(1): 10-15.
[28] Özel, A., Demirbilek, T., Gür, M. A., Çopur, O. (2004): Effects of different sowing date and intra-row spacing on yield and some agronomic traits of safflower (*Carthamus

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_18071820

tinctorius L.) under Harran Plain's arid conditions. – Turkish Journal Agric. Forest. 28: 413-419.

[29] Öztürk, O., Ada, R., Akınerdem, F. (2009): Determination of yield and yield components of some safflower cultivars under irrigated and dried conditions. – Selcuk Journal of Agriculture and Food Science 23(50): 16-27.

[30] Ramazanoglu, E. (2019): Determination and mapping of the relationship between potassium and ammonium of calcareous soils with different moisture content. – International Journal of Scientific and Technological Research 5(7): 17-26.

[31] Santos, R. F., Bassegio, D., Silva, M. A., Klar, A. E., Da Silva, A. A. F., Da Silva, T. R. B. (2018): Irrigated safflower in phenological stages of Brazilian southeast dry season. – Irriga 23(3): 493-504.

[32] SAS Institute (2013): JMP 11. – SAS Institute Inc. Cary. NC.

[33] Singh, S., Angadi, S. V., Grover, K., Begna, S., Auld, D. (2016): Drought response and yield formation of spring safflower under different water regimes in the semiarid Southern High Plains. – Agricultural Water Management 163: 354-362.

[34] Sirel, Z. (2011): Agricultural features of some safflower (*Carthamus tinctorius* L.) cultivars and lines. – Eskişehir Osmangazi University, Graduate School of Natural and Applied Sciences Department of Field Crops Master Thesis, Eskisehir, Turkey.

[35] Weiss, E. A. (2000): Safflower. – In: Oilseed Crops. Blackwell Science Ltd., Victoria, Australia, pp. 93-129.

[36] Yeilaghi, H., Arzani, A., Ghaderian, M. (2015): Evaluating the contribution of ionic and agronomic components toward salinity tolerance in safflower. – Agronomy Journal 107(6): 2205-2212. DOI: 10.2134/agronj15.0202.

[37] Yurteri, T. (2016): Investigation of yield and yield components of safflower (Carthamus tinctorius L.) cultivars cultivated in Yozgat conditions in different seasons. – Master Thesis, Bozok University, Graduate School of Natural and Applied Sciences Department of Field Crops, Yozgat, Turkey.

[38] Zarghami, R., Zahravi. M., Aslanzadeh, A., Abbasali, M. (2011): Evaluation of autumn sown genotypes of safflower (*Carthamus tinctorius* L.) for tolerance to drought stress. – Seed Plant Imp J 27(3): 339-355.