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Determination of Yield and Quality in Some Safflower (Carthamus tinctorius L.) Cultivars Under Diyarbakır Ecological Conditions

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ABSTRACT: *Safflower oil is used as both cooking oil and industrial oil. Safflower is tolerant to cold, drought, and salinity conditions. This study was conducted to determine the safflower cultivars suitable for Diyarbakır ecological in conditions, and was performed during the 2014-2015, 2015-2016, and 2016-2017 growing seasons. The experiments were conducted in the trial field of "GAP International Agricultural Research and Educational Center. This experiment was designed according to the Randomized Block with three replications. Balcı, Dinçer, Linas, Olas and Remzibey-05 varieties were used in the experiment. Seeds were sown with 30 cm row spacing. In terms of three year average values, significant differences were observed at the 1 % level among the safflower varieties for plant height, head number per plant, thousand seed weight, crude oil ratio, and seed yield. According to the results, the highest seed yield was obtained in the Remzibey-05 cultivar (1882 kg ha^{-1}), and the lowest yield was obtained from Balcı variety (1514 kg ha^{-1}). In addition, plant height (110.2-116.7 cm), head number per plant (13.9-17.5), head diameter (2.18-2.21 cm), thousand seed weight (33.4-36.2 g), and crude oil ratio (26.67 - 35.75 %) were determined. To conclude, based on three years of study, it was observed that the Remzibey-05 cultivar could be recommended for Diyarbakır ecological conditions.*

Keywords: *Head diameter, safflower, Carthamus tinctorius L., seed yield, oil ratio.*

Diyarbakır Ekolojik Koşullarında Bazı Aspir (Carthamus tinctorius L.) Çeşitlerinin Verim ve Kalite Bakımından Belirlenmesi

ÖZ: *Aspir yağı, hem yemeklik yağ hem de endüstriyel yağ olarak kullanılır. Ayrıca, aspir bitkisi, soğuğa, kuraklığa ve tuzluluk koşullarına dayanıklıdır. Bu çalışma, 2014-2015, 2015-2016 ve 2016-2017 yetiştirme sezonlarında, Diyarbakır ekolojik koşullarına uygun Aspir çeşitlerinin belirlenmesi amacıyla yürütülmüştür. Denemeler GAP Uluslararası Tarımsal Araştırma ve Eğitim Merkezi deneme tarlasında yürütülmüştür. Bu deneme, tesadüf blokları deneme desenine göre üç tekerrürlü olarak tasarlanmıştır. Denemede Balcı, Dinçer, Linas, Olas ve Remzibey-05 çeşitleri kullanılmıştır. Tohumlar 30 cm sıra arasına ekilmiştir. Üç yıllık ortalama değerler açısından; bitki boyu, bitkide başak sayısı, bin tohum ağırlığı, ham yağ oranı ve tohum veriminde aspir çeşitleri arasında % 1'e göre önemli farklılıklar bulunmuştur. Deneme sonuçlarına göre en yüksek tohum verimi Remzibey-05 çeşidinden (188,2 kg/da), en düşük verim ise Balcı çeşidinden (151,4 kg/da) elde edilmiştir. Ayrıca, bitki boyu (110,2-116,7 cm), bitki başına tabla sayısı (13,9-17,5), tabla çapı (2,18-2,21 cm), bin tane ağırlığı (33,4-36,2 g) ve ham yağ oranı (%26,67 – 35,75) belirlenmiştir. Sonuç olarak, üç yıllık bu çalışmanın sonuçlarına dayanarak, Remzibey-05 çeşidi Diyarbakır ekolojik koşulları için önerilebilir.*

Anahtar kelimeler*: Tabla çapı, aspir, Carthamus tinctorius L., tane verimi, yağ oranı.*

INTRODUCTION

Safflower (*Carthamus tinctorius* L., 2n = 2x = 24) is a valuable annual and herbaceous cultivar from the Asteraceae (Knowles, 1980). Safflower (*C. tinctorius* L.), is reported to have originated in southern Russia, Iran, Türkiye, Jordan, Iraq, and Israel (Knowles, 1989; Yaşar and Sezgin, 2023). Safflower is a very important plant in terms of contributing to the biodiesel and dye industries and has a fatty acid composition suitable for human consumption (Huth *et al.* 2015; Subaşı *et al.*, 2023). Safflower is considered tolerant to cold, drought, and salinity conditions compared to other oil crops. Thus, it has important potential to contribute to the production of edible oil

in *Türkiye*. Having these features, the cultivation of safflower is significant for the national economy (Kayaçetin *et al.,* 2012). Oil quality of safflower is very high due to its fatty acid composition. Safflower oil is an important source of polyunsaturated fatty acids, which are accepted as healthy fatty acids for people (Shivani *et al.,* 2010).

Türkiye's safflower production was 39,000 tons, on 32,129 ha. The provinces with the highest safflower production ratio in 2023 were Kayseri at 29.5%, Isparta at 13.1%, Konya at 12.4%, Kırşehir at 9.3%, Nevşehir at 8.8%, Ankara at 6.2% and Aksaray at 5.9% of production. In Türkiye, 85.2% of total safflower production occurs in these provinces. Diyarbakır province's production was 12 tons, on 9.9 ha with an average yield of 1,210 kg ha^{-1} in 2023 (Anonymous, 2023). The world's safflower production was 653,030 tons, on 816,699 ha with an average yield of 799 kg ha^{-1} in 2020 (Anonymous, 2021). In Türkiye, edible vegetable oil production does not meet the domestic need which results in vegetable oil deficiency (Babaoglu and Guzel, 2015). In 2022, 3.17 billion dollars were paid for oilseed imports, and 3.02 billion dollars were paid for vegetable and animal oils in Türkiye (Duru, 2024). The worldwide vegetable oil crisis and price hikes have increased the importance of safflower oil sources, which may be used as an alternative to other oil plants such as palm, soybean, rapeseed, sunflower, and peanut. Safflower, which completes its biological growth and development cycles within 4-5 months, is gradually increasing its importance as an alternative plant that can be utilized, especially in agricultural areas where irrigation is not available in dry farming conditions (Baydar and Erbaş, 2014). The oil percentage of registered commercial safflower varieties in Türkiye varies between 24-41%, and varieties that are rich in linoleic and oleic acid are cultivated (Arslan *et al.,* 2019). The nutrient content of safflower meal varies depending upon the method used for extraction. With regard to nutrients, dehulled safflower meal is almost equivalent to soybean meal (Ozek, 2016).

Safflower is used in a wide range of sectors from drug making, paint industry, cosmetic product development, various food production, ruminant, and poultry nutrition to biodiesel production, which has a place in traditional and modern medicine (Kütük Dinçel, 2024).

For the cultivation of safflower, Türkiye has very favorable climatic and soil conditions (Eryılmaz *et al.*, 2014). Safflower can be sown as winter and summer crops in Türkiye. The gene center of the safflower plant is Anatolia, it has a high adaptability to different ecologies, its cultivation is similar to grain production that the farmer is used to, it is compatible with grain mechanization, and can be planted in summer and winter. Kahraman *et al.* (2014) reported that Remzibey-05 cultivar with sowing dates of 15st November and 15th December can be suitable in Diyarbakır conditions with respect to yield and the other characters.

The main goal of safflower breeding studies has been to develop new safflower varieties with high grain yield and/or oil content, taking into account the needs of different demand groups, and to include them in the production chain (Köse, 2016). Today, as a result of breeding studies, new varieties that are superior in terms of yield and agricultural characters are being developed. It is known that the newly developed varieties give different results in different regions. Therefore, regional adaptation studies are especially important for new varieties. This study was conducted to determine which safflower cultivars can be cultivated under the conditions of Diyarbakır, Türkiye.

MATERIALS AND METHODS

This study was conducted in Diyarbakir, Türkiye during the 2014-2015, 2015-2016, and the 2016-2017 growing seasons. The research site is located on 37°30′ and 38°43′ north latitude and 40°37′ and 41°20′ east longitude, 600 meters above sea level. In the province of Diyarbakır where the field experiments were conducted, the annual rainfall mostly happens between October and June. The proportional humidity rate is relatively low. Summers are mostly hot, dry, and clear, while winters are cold and partly cloudy. The annual average rainfall of the region was 474 mm in the 2014-2015, 2015-2016, and 2016-2017 years (Table 1). Planting was performed at GAP International Agricultural Research and Training Center research area.

This experiment was designed with a Randomized Complete Block Design with three replicates. The varieties that were used in the experiment were Balcı, Dinçer, Linas, Olas, and Remzibey-05 (Table 2). Before planting, soil (15-20 cm deep) was plowed and harrowed. The seeds were mechanically sowed as 120 seeds per square meter on the dates 27.12.2014, 27.11.2015, and 12.12.2016. Each plot consisted of four rows, 30 cm inter-row, and 5 meters in length. Safflower maximum seed yield Ayaz variety using was determined (30×10 cm) 1577 kg ha^{-1} (Gürsoy *et al.*, 2018). To the parcels, in total 100 kg ha^{-1} of nitrogen (N) was applied in two parts, 50 kg ha^{-1} of the nitrogen was applied before planting, while the rest was applied when the plants reached 20-30 cm tall. Additionally, 50 kg ha^{-1} phosphorous (P) was applied before planting.

During the growing season, irrigation was not supplied. Plants in each plot were harvested mechanically for the grain yields on 20.07.2015, 13.07.2016, and 28.07.2017. After harvest, safflower seeds were kept in the oven at 70° for 48 hours to remove moisture. The percent crude oil ratio of 4 g seeds with moisture removed was calculated in the Nuclear Magnetic Resonance (NMR) device. Analysis of variance was calculated for each trait and LSD (Least significant difference) test was applied (at the 0.05 level) to determine statistical significance (Steel *and* Torrie, 1980). Safflower varieties in three-year mean values and statistical groups are given.

Table 1. Climate data of Diyarbakır province for the long years and 2014-2015, 2015-16 and 2016-17 years.
Çizelge 1. Diyarbakır ilinin uzun yıllar ve 2014-2015, 2015-16 ve 2016-17 yıllarına ait iklim verileri.

	Average Temperature (°C)				Total Precipitation (mm)			
Months	2014-15	2015-16	2016-17	LY	2014-15	2015-16	2016-17	LY
October	17.5	18.4	18.8	17.2	34.2	84.2	13.6	34.7
November	8.3	9.8	8.2	9.2	97.6	10.4	52.0	51.8
December	6.7	3.9	2.4	4.0	73.6	31.6	135.6	71.4
January	2.3	1.1	1.5	1.8	64.6	77.2	20.6	68.0
February	5.4	7.9	1.5	3.5	55.2	69.2	3.8	68.8
March	8.2	9.7	9.4	8.5	127.0	55.6	90.2	67.3
April	12.4	15.7	12.8	13.8	48.6	29.0	98.8	68.7
May	18.8	19.9	18.8	19.3	48.2	41.4	30.6	41.3
June	26.1	26.8	26.9	26.3	7.4	18.4	2.6	7.9
Mean	11.7	12.6	11.1	11.5	Total 556.4	417.0	447.8	479.9

LY: Long Years

Table 2. Comparison of some properties of registered safflower varieties.
Çizelge 2. Tescilli aspir çeşitlerinin bazı özelliklerinin karşılaştırılması.

Cultivars	Thorniness	Flower color	Plant height (cm)	Crude oil ratio (%)	Seed yield (in the dry) (kg ha^{-1})	Seed yield (in water) (kg ha^{-1})	Registration year
Balcı	thorny	yellow	55-70	38-41	1200-2400	-	2011
Dinçer	thornless	red	90-110	28-32	1000-2500	3500-4000	1983
Linas	thorny	yellow	85-90	37-38		3000-3500	2013
Olas	thorny	yellow	90-100	39-41	2400-2500	-	2015
Remzibey-05	thorny	yellow	60-80	35-38	1000-2000	2000-3500	2005

Reference: Arslan *et al.*, 2019.

RESULTS AND DISCUSSION

Significant differences ($p<0.01$) among the cultivars were determined in terms of plant height, head number per plant, thousand-seed weight, seed yield and crude oil ratio. According to the findings of this experiment, the highest plant height was obtained from the Linas cultivar with 116.7 cm, while the Balcı cultivar was shortest at 110.2 cm (Table 3). Coskun (2014) stated that the plant height of safflower ranges between 108.89-118.67 cm. Likewise, Oz (2016) stated that the plant height of safflower varied between 100.5-158.6 cm. In another study, Atan *et al.* (2019) observed that the plant height of safflower ranged between 143.83-163.67 cm. Sayılır *et al.* (2019) observed that the plant height of safflower varied between 86.3-103.3 cm. Our height results were lower than the findings of Atan *et al.* (2019), but higher than those of Sayılır *et al.* (2019), and similar to the findings of others. Research has reported that plant height in safflower varies depending on location, agricultural practices, climatic conditions and varieties. Sayılır *et al.* (2019) used less fertilizer than we did, while Atan *et al.* (2019) used more fertilizer than we did.

The highest head number per plant was obtained in the Remzibey-05 cultivar with 17.5/plant, whereas the Linas cultivar was the lowest head number with 13.9/plant (Table 3). Katar *et al.* (2014) noted that the head number per plant ranged between 12.5-18.7/plant. In a study conducted by Oz (2016), it was stated that the head number per plant varied between 17.1-29.4/plant. Similarly, Atan *et al.* (2019) observed that the head number per plant varied between 11.83-16.20/plant. Sayılır *et al.* (2019) observed that the head number per plant ranged between 13.38-25.61/plant. Head numbers of our study were found to be lower than the values in the study carried out by Oz (2016) and Sayılır *et al.* (2019). Row and intra row spacing were 40*15 cm by Oz (2016). Differences may vary depending on agricultural practices, climatic conditions (winter sowing and summer sowing, such as amount and time of precipitation) and variety. The average rainfall of the region (in Diyarbakır) was 474 mm over the three-year period. Zarei *et al.* (2011) reported that number of head per plant was greatly affected by environmental conditions particularly plant density.

Table 3. Average values and statistical groups of safflower cultivars in three-year mean.
Çizelge 3. Aspir çeşitlelerinin üç yıllık ortalama değerleri ve istatistiksel grupları.

Cultivars	Plant height (cm)	Head number per plant	Head diameter (cm)	Thousand-seed weight (g)	Seed yield (kg ha^{-1})	Crude oil ratio (%)
Balcı	110.2 c	14.1 bc	2.18	36.2 a	1514 c	34.71 a
Dinçer	113.3 b	15.4 b	2.18	35.2 a	1656 b	26.67 c
Linas	116.7 a	13.9 c	2.19	35.8 a	1522 b	34.71 a
Olas	116.5 a	14.4 bc	2.21	36.1 a	1581 b	35.75 a
Remzibey-05	112.6 b	17.5 a	2.21	33.4 b	1882 a	28.82 b
CV (%)	2.8	9.7	3.76	4.35	8.57	1.75
LSD Variety	3.1**	1.42**	ns	1.5**	135.9**	1.77**

ns: none significant, **: significant at 0.01 level

The head diameter ranged between 2.18-2.21 cm (Table 3). Regarding head diameter, in the study carried out by Hatipoglu *et al.* (2012) head diameters were recorded as 1.63-2.07 cm. Sayılır *et al.* (2019) head diameters were recorded as 1.8-2.3 cm. Aslantas and Akinerdem (2020) stated that head diameters ranged between 2.06-2.25 cm. Çamaş and Esendal (2006) emphasized that environmental conditions have a great effect on this feature. Our findings were higher than the findings of Hatipoglu *et al.* (2012). In general, our results showed partial similarity with other reports.

The highest thousand-seed weight was obtained in the Balcı cultivar at 36.2 g, while the Remzibey-05 cultivar was the lowest at 33.4 g (Table 3). Accordingly, in the study done by Coskun (2014), thousand-seed weight ranged between 33.78-39.00 g. Based on the experimental results observed by Oz

(2016), thousand-seed weight varied between 34.1-36.9 g. Köse *et al.* (2021) stated that thousand-seed weight ranged between 32.1-40.4 g. Yazdani *et al.* (2019) stated that thousand-seed weight ranged between 29.27-47.58 g. Tahernezhad *et al.* (2018) observed that the values for thousand-seed weight are mostly influenced by genetic factors. Differences may be due to environmental (winter sowing and summer sowing, amount and time of precipitation, soil structure) conditions, fertilizer applications and different cultivars used. Our results showed partial similarity with the findings of Köse *et al.* (2021) who examined 12 safflower lines and three varieties in their research.

The highest seed yield was obtained in the Remzibey-05 cultivar (1882 kg ha^{-1}), whereas in the Balcı cultivar the yield was the lowest (1514 kg ha^{-1}) (Table 3). Coskun (2014) stated that seed yield ranged between 2643.3-2374.4 kg ha^{-1}. As a cultivar, Remzibey-05 is more suitable for this region than the other two varieties for high seed yield. Katar *et al.* (2014) stated that seed yield varied between 1485-1838 kg ha^{-1}. Ghorbanzadeh *et al.* (2014) found difference results depending on sowing time: 2330 kg ha^{-1} in the autumn sowing time and 1405.4 kg ha^{-1} in the spring. Köse *et al.* (2018) stated that seed yield varied between 1150.8-1990.5 kg ha^{-1}. Atan *et al.* (2019) stated that seed yield ranged between 1883.3-2627.8 kg ha^{-1}. Sayılır *et al.* (2019) stated that seed yield varied between 1560-2500 kg ha^{-1}. Arslan and Culpan (2020), stated that seed yield varied between 982-1712 kg ha^{-1}. Köse *et al*. (2021) stated that seed yield changes varied between 834-1795 kg ha^{-1}. Aslan and Sirat (2022) stated that seed yield ranged between 935.2-1280.6 kg ha^{-1}. Our findings were lower than the findings of Coskun (2014) and Atan *et al*. (2019), higher than the findings of Köse *et al*. (2021), Arslan and Culpan (2020) and Aslan and Sirat (2022). In general, however, our results were mostly similar with others' findings. Differences may be due to environmental (winter sowing and summer sowing, such as amount and time of precipitation, soil structure) conditions, fertilizer applications and different cultivars used. Köse *et al.* (2021), Arslan and Culpan (2020) and Aslan and Sirat (2022) used summer sowing. The yield potential of winter sowing is higher than the yield potential of summer sowing. Besides, the annual average rainfall of the region (in Diarbakır) was 474 mm in the 2014-2015, 2015-2016, and 2016-2017 years which may explain differences among studies.

The crude oil ratio obtained in the Olas cultivar was highest with a 35.75% ratio, while in the Dinçer cultivar this ratio was lowest (26.67%) (Table 3). Likewise, Coskun (2014), Kobuk *et al*. (2019), Sayılır *et al.* (2019), Arslan and Culpan (2020), Aslan and Sirat (2022), Koç (2019) and Atan *et al.* (2019) stated that the crude oil ratio varied between 28.67-30.44%, 25.78-35.16%, 25.35-35.03%, 28.12-36.66%, 26.28-30.92%, 28.8-36.5% and 34.38-38.49%, respectively. Thus, our results were similar to previous findings. The differences may be due to environmental conditions, the use of different genotypes, the oil analysis method, and applications.

A correlation analysis was conducted to determine the relationship between the yield of safflower cultivars and all other parameters (Table 4). It was determined that there were positive and significant relationships between seed yield and plant height, the number of heads per plant and thousand grain weight; whereas, there were negative and significant relationships between grain yield and crude oil ratio.

In previous work, statistically significant positive relationships was found among seed yield and plant height, the number of heads per plant; whereas there were negative and significant relationships between grain yield and oil ratio (Omidi *et al*., 2012; Paseban Eslam, 2015; Oz, 2016). Köse *et al.* (2021) reported that statistically significant positive relationships was found among the seed yield and head diameter (r=401**), oil ratio (r=299**), and number of heads per plant (r=0.182*). In addition, Köse *et al.* (2021) reported that statistically significant negative relationships was found between seed yield and plant height (r=421**).

Table 4. Correlation coefficients among the inspected features.
Çizelge 4. İncelenen özellikler arasındaki korelasyon katsayıları.

	Seed yield	Plant height	Head number per plant	Head diameter	Thousand-seed weight
Plant height	0,3976**				
Head number per plant	0,8916**	0,4272**			
Head diameter	-0,1029	-0,2804	-0,0165		
Thousand-seed weight	0,3789**	0,5098**	0,3766*	-0,2681	
Crude oil ratio	-0,3058*	0,0492	-0,3721*	-0,0208	0,3279*

*Correlation is significant at the 0.05 level. **Correlation is significant at the 0.01 level.

In this study, the Remzibey-05 cultivar had high values in terms of grain yield, head number per plant and head diameter. Besides, Olas, Linas and Balcı varieties showed superior values in terms of oil content. To conclude, based on the three years during which this study was conducted, the Remzibey-05 cultivar is recommended due to its high productivity under Diyarbakır ecological conditions.

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