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Full Length Research Paper

Determination of seed yield and yield components of some safflower (*Carthamus tinctorius* L.) Cultivars, Lines and Populations under the Semi-Arid Conditions

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This research was conducted to determine yield and yield components of 26 safflower cultivars, lines and populations in semi-arid conditions during the 2001-2002 and 2002-2003 growing seasons. The experimental plots were arranged in a randomized complete block design with three replications. In this study, seed yield (kg ha^{-1}), plant height (cm), number of branch per plant, number of head per plant, 1000 seed weight (g), oil content (%) and oil yield (kg ha^{-1}) properties were investigated. According to the average of two years study, the highest seed yields were obtained from cultivars Syria Hama (1585 kg ha^{-1}), Hartinan (1543 kg ha^{-1}) and S-541-2 (1582 kg ha^{-1}) lines, while the lines 250540 (34.8%) and S-541-2 (34.2%) had the highest oil contents. The highest oil yields were obtained from Syria Hama (530 kg ha^{-1}) cultivar and S-541-2 (541 kg ha^{-1}) line.

Keywords: Safflower, cultivar, seed yield, oil content.

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is an important annual industrial crop. The stem, leaves, seeds and flowers are used for different purposes. In India and Pakistan, herbalists sell all parts of the crop for the treatment of various diseases, and the flowers of the crop are used in the food, cosmetics, paint and pharmaceutical industries (Dajue and Mundel, 1996). Safflower is an oil crop that can be grown in arid agricultural areas due to its high tolerance to heat and cold, and can also be grown in irrigated agricultural areas due to its tolerance to salinity and weeds (Karaca et al., 1989; Kaya et al., 2003; Dordas and Sioulas, 2008).

Safflower seeds contain 13 to 46% oil, and approximately 90% of this oil is composed of unsaturated fatty acids, namely oleic and linoleic acids (Johnson et al., 1999). Safflower oil, which on average contains 75% linoleic acid, also contains tocopherols, known to have antioxidant effect and high vitamin E content. For this reason, safflower oil is used in the diets of patients with cardiovascular disease, and bears great importance for its anti-cholesterol effect (Pongracz et al., 1995; Arslan et al., 2003). Ogut and Oguz (2006) reported that safflower oil is very suitable for biodiesel production. *Cartharmin*, which is a substance obtained from the flowers of safflower, is an important natural raw material of dye (Nagaraj et al., 2001). Safflower oil cake is a valuable animal feed (Weiss, 2000). For economic safflower farming, as well as cultural processes, the selection of appropriate varieties is also important. Many breeding methods are used for cultivar selection or development of cultivars. One of these is introduction and adaptation work. Based on this, the recognition of the plant characteristics of varieties and seed yield potential must be determined. Thus, the preliminary information will be available on the types and cultivars and recommended for field trials registration (Copur et al., 2009)

The South-eastern Anatolia region has a great

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potential in the satisfactory levels of yield which are achieved in arid areas even in years of drought and the resulting by-products are profitable. In particular, the petals of safflower, which are used in the production of food dyes and spices, have the potential to increase the produce per unit area of farmers performing arid agriculture (Ozel et al., 2002). However, studies have not been performed previously on the development of cultivars that would be preferred by producers and are adapted to the region. Therefore, the investigation of appropriate cultivars and lines that may be adapted to the region bears great importance. Previously conducted studies in Turkey have demonstrated that seed yield varied between regions, and that this was related to climatic conditions and the particular cultivars concerned. It was reported that seed yield of safflower ranged between 570 and 2515 kg ha^{-1} by Esendal (1973), 997 and 2483 kg ha^{-1} by Gur and Ozel (1997), 401 and 925 kg ha^{-1} by Ozel et al. (2002), 851 and 2104 kg ha^{-1} by Killi and Kucukler, (2005) and 913 and 2482 kg ha^{-1} by Camas et al. (2007). It was reported by various researchers (Esendal, 1973; Sinan, 1984; Gencer et al., 1987; Hulihalli et al., 1997; Ozel et al., 2004; Uysal et al., 2006; Camas et al., 2007) that the growth of cultivars differs with arid and lowland conditions, while seed yield increases with irrigation and rainfall during the branching and seed formation periods, and it indicated that yield and crop traits vary with cultivar, ecological conditions and cultivation techniques.

This study was aimed at the investigation of the adaptation, seed yield and yield components of 26 safflower cultivars, lines and populations (8 cultivars, 15 lines and 3 populations), which can be grown as an alternative to wheat, barley and particularly, tobacco, in the arid agricultural areas of (Adiyaman-Kahta) South eastern Anatolia.

MATERIALS AND METHODS

The experimental material comprised of a total of 26 safflower cultivars, lines and populations, including the cultivars Cyprobren, Dinçer, Gila, Hartinan, Syrian, Syrian-1, Syria Hama and Yenice, the lines CW74, CW4440, MKH-8, MKH-9, S-541, S-541-2, 198290, 250536, 250537, 250540, 251982, 251984, 258417, 301055, 537636, and the Afyon, Cyprus and Sivas populations obtained from International Centre for Agricultural Research in the Dry Areas (ICARDA), the Anatolian Agricultural Research Institute (Eskisehir) and the Department of Field Crops of the Faculty of Agriculture, University of Cukurova.

Field experiments were performed in the winter cultivation periods of 2001-2002 and 2002-2003 under the prevailing conditions of the Kahta district of Adiyaman province in a randomized complete block design with three replications. The experimental field was of deep profile soil composed of mainly alluvium, which had an almost flat inclination. The soil used in the field experiments was of clay texture and alkaline (pH 7.79), had a total salt content of 0.065%, was rich in lime (22.0%) with available phosphorus of 128.6 kg ha^{-1} P_2O_5 and potassium of 972 kg ha^{-1} K_2O, and was poor in organic matter (1.59%) (Anonymous, 2001).

During the period between November and July when safflower was grown in the field, minimum and maximum temperatures, relative humidity and rainfall ranged between 3.0 and 30.7°C, 23.3 and 76.0% and 0.5 and 277.8 mm, respectively. The long-term average temperature, relative humidity and total rainfall values of the experimental field for the period between November and July were 14.5°C, 50.7% and 603 mm, respectively. The temperatures for the period between November and July were lower in the second year, when compared to the first year of the study. The average temperatures and relative humidity rates of both growth periods were close to the long-term values, while the total rainfall values were higher than the long-term average value (Anonymous, 2007).

Safflower seeds were sown on 17 November 2001 in the first year of the experiment and 19 November 2002 in the second year of the experiment. Sowing was performed manually in 5 rows of 6 m long plots with a row spacing of 30 cm and a sowing depth of 3 to 4 cm. After growth, thinning was performed such that the intra row spacing was 15 cm. Observations were made in the area remaining after leaving 1 m side effect from the start and end of the 3 middle rows of each plot. During the experiment, 50 kg of pure P_2O_5 and 50 kg of pure N (half of which was applied during sowing and the other half during stem growth) were applied per hectare. The management required from sowing to harvest was performed using standard techniques. The trial was performed under natural conditions without irrigation.

Harvesting was performed manually in the first week of July in the area remaining after leaving 1 m side effect from the start and end of the 3 middle rows of each plot. In the study, seed yield (kg ha^{-1}), plant height (cm), number of branch per plant, number of head per plant, 1000 seed weight (g), oil content (%) and oil yield (kg ha^{-1}) were determined as described by Esendal et al. (1992).

The two years data were combined and subjected to variance analyses. Analysis of variance was performed using the MSTAT-C software (Michigan State University). Significant differences among mean values were compared by the LSD test ($P < 0.05$). Correlation coefficients were determined by using the TARIST software (Acikgoz et al., 1994).

RESULTS AND DISCUSSION

Significant differences ($P < 0.01$) were determined between the genotypes for all the traits investigated in both years of the study and according to the two-year combined analysis. The two-year combined analysis demonstrated that no significant difference existed between the years for seed yield and oil yield. However, significant differences at a level of 1% were determined for plant height, number of branch per plant, number of head per plant, 1000 seed weight and oil content. The year x genotype interaction was found to be significant, at a level of 1% for all the traits investigated.

Seed yield (kg ha^{-1})

Higher seed yields were obtained from line S-541-2

Table 1. Overall means of seed yield (kg ha^{-1}), plant height (cm) and number of branch per plant.

	Seed Yield (kg ha-1)			Plant Height (cm)			Number of branch per plant		
Cultivars, Lines and Populations	**2001-2002**	**2002-2003**	**mean**	**2001-2002**	**2002-2003**	**mean**	**2001-2002**	**2002-2003**	**Mean**
Cyprobren	1525 abc*	1481 cd	1503 bc	126.0 a-d	106.9 a-d	116.5 abc	8.6 abc	5.6 def	7.1 a-d
Dinçer	1222 i	1256 hı	1239 hı	115.2 cde	98.9 d	107.1 bcd	7.3 d-g	5.4 ef	6.3 cde
Gila	1288 ii	1229 ii	1259 h	125.5 a-d	106.7 a-d	116.1 abc	7.9 b-f	6.7 a-e	7.3 a-d
Hartinan	1526 abc	1560 ab	1543 ab	124.7 a-d	103.5 bcd	114.1 abc	6.6 g	6.4 b-e	6.5 b-e
Syrian	1236 i	1177 i	1207 ı	116.7 a-e	82.3 e	99.5 d	6.9 efg	3.9 f	5.4 e
Syrian-1	902 k	1022 j	962 j	120.9 a-e	118.1 ab	119.5 a	6.7 fg	8.4 ab	7.6 a-d
Syria Hama	1585 ab	1584 a	1585 a	110.2 de	101.2 cd	105.7 cd	7.6 e-g	6.2cde	6.9 a-e
Yenice	1231 i	1228 ii	1230 hı	129.1 abc	109.5 a-d	119.3 a	8.1 a-e	6.7 a-e	7.4 a-d
CW74	1438 de	1320 gh	1379 f	118.4 a-e	95.2 de	106.8 bcd	6.9 efg	5.5 ef	6.2 de
CW4440	1365 fgh	1286 ghı	1325 g	122.6 a-e	107.9 a-d	115.3 abc	7.7 b-g	6.2 cde	6.9 a-e
MKH-8	1454 cd	1480 cde	1467 cd	120.2 a-e	107.1 a-d	113.6 abc	7.2 d-g	6.1 c-f	6.6 a-e
MKH-9	979 j	948 k	964 j	107.1 e	107.9 a-d	107.5 bcd	9.4 a	5.8 def	7.6 a-d
S-541	1416 d-g	1452 cde	1434 de	111.5 de	115.6 abc	113.6 abc	7.5 b-g	8.3 abc	7.9 abc
S-541-2	1600 a	1563 a	1582 a	125.3 a-d	106.6 a-d	116.0 abc	8.8 ab	7.1 a-e	7.9 ab
198290	993 j	968 jk	981 j	132.2 ab	108.6 a-d	120.4 a	7.7 b-g	5.9 def	6.8 a-e
250536	1396 d-h	1406 ef	1401 ef	119.4 a-e	104.2 a-d	111.8 abc	6.7 fg	6.8 a-e	6.8 a-e
250537	1394 d-h	1423 de	1409 ef	124.3 a-d	116.7 abc	120.5 a	7.4 c-g	6.3 b-e	6.9 a-e
250540	1334 hı	1305 gh	1320 g	107.9 e	110.7 a-d	109.3 a-d	7.9 b-g	8.2 abc	8.1 a
251982	1247 i	1277 ghı	1262 h	122.5 a-e	118.1 ab	120.3 a	7.0 d-g	7.7 a-d	7.3 a-d
251984	1003 j	939 k	971 j	116.2 b-e	111.1 a-d	113.6 abc	8.0 b-f	7.1 a-e	7.5 a-d
258417	1343 ghı	1412 def	1377 f	132.5 a	106.2 a-d	119.4 a	8.8 ab	5.8 def	7.3 a-d
301055	1466 cd	1510 abc	1488 bc	121.0 a-e	118.7 ab	119.9 a	7.0 d-g	7.2 a-e	7.1 a-d
537636	1042 j	1033 j	1038 i	122.1 a-e	109.1 a-d	115.6 abc	7.4 c-g	5.8 def	6.6 a-e
Afyon Population	1432 def	1506 abc	1469 cd	114.0 cde	120.1 a	117.1 ab	7.4 c-g	8.6 a	8.0 ab
Cyprus Population	1372 e-h	1343 fg	1358 fg	121.1 a-e	118.8 ab	119.9 a	8.2 abcd	7.8 a-d	8.0 ab
Sivas Population	1519 bc	1505 bc	1512 bc	113.9 cde	101.1 cd	107.5 bcd	7.5 b-g	5.0 ef	6.3 be
C.V. (%)	14.87	15.12	14.95	7.32	8.31	9.37	12.85	19.63	17.75
L.S.D. (5%)	47.9	33.0	48.1	10.77	6.66	9.74	1.32	1.24	1.30

*: Different letters in each column indicates that the means differ significantly ($p<0.05$).

(1600 kg ha^{-1}) and cultivar Syria Hama (1585 kg ha^{-1}) between 2001- 2002; and from the cultivars Syria Hama (1584 kg ha^{-1}) and Hartinan (1560 kg ha^{-1}) in 2002 - 2003, when compared with the other cultivars, lines and populations.

According to the two-year average, seed yields ranged from 962 to 1585 kg ha^{-1}. The highest yields per hectare were obtained from the cultivars Syria Hama (1585 kg ha^{-1}) and Hartinan (1543 kg ha^{-1}) and the line S-541-2 (1582 kg ha^{-1}) (Table 1). The results obtained in the study suggest that genotype, environmental factors and cultivation techniques had influence on the variation between cultivars and lines for seed yield. The values obtained in this study are in agreement with the yields reported by Esendal (1973), Hullihalli et al. (1997), Gur and Ozel (1997), Killi and Kucukler, (2005) and Camas et al. (2007).

Plant height (cm)

In the first year of the study, greater plant heights were obtained from lines 258417 (132.5 cm) and 198290 (132.2 cm), while in the second year, higher values were obtained from the Afyon population (120.1 cm), Cyprus population (118.8 cm), cultivar Syrian-1 (118.1 cm) and lines 301055 (118.7 cm) and 251982 (118.1 cm), when compared with the other cultivars, lines and populations.

According to the two-year averages, the highest plant heights were obtained from lines 250537 (120.5 cm), 198290 (120.4 cm), 251982 (120.3 cm), 301055 (119.9 cm), and 258417 (119.4 cm) and cultivars Syrian-1 (119.5 cm) and Yenice (119.3 cm), and the populations of Afyon (119.9 cm) and Cyprus (117.1 cm) (Table 1). Ozel et al. (2004) and Camas et al. (2007) suggested that the

variations observed between cultivars for plant height were related to the cultivars being grown under arid conditions, genotypic variations, and irregularity and inadequacy of rainfall for different years. The results obtained in this study are in agreement with those reported by the earlier mentioned researchers.

Number of branch per plant

Between 2001 and 2002 period, the highest number of branch per plant was found in line MKH-9 (9.4 branch plant^{-1}) and the lowest number of branch per plant was in cultivar Hartinan (6.6 branch plant^{-1}). In 2002 - 2003, the highest number of branch per plant was determined in Afyon population (8.6 branch plant^{-1}), while the lowest number of branch per plant was in cultivar Syrian (3.9 branch plant^{-1}). According to the two-year averages, the highest numbers of branch per plant were obtained from lines 250540 (8.1 branch plant^{-1}) and S-541-2 (7.9 branch/plant) and Afyon (8.0 branch plant^{-1}) and Cyprus populations (8.0 branch plant^{-1}), while the lowest number of branch per plant was determined in cultivar Syrian (5.4 branch plant^{-1}) (Table 1). The variations were considered to be related to the cultivars used, the cultivation techniques applied, the climatic conditions and genetic structure. The results obtained in this study are in agreement with those reported by Ozel et al. (2004), Killi and Kucukler, (2005) and Camas et al. (2007).

Number of head per plant

Between 2001 and 2002 period, the highest number of head per plant was obtained in cultivar Syria Hama (21.3 number plant^{-1}), while the lowest number of head per plant was determined in Cyprus population (11.4 number plant^{-1}). Furthermore, in 2002 and 2003 period, the highest number of head per plant was determined in line S-541-2 (17.9 number plant^{-1}), while the lower number was obtained in line 537636 (10.0 number plant^{-1}). According to the two-year averages, the highest number of head per plant was observed in the cultivar Syria Hama (19.5 number plant^{-1}), while the lowest number of head per plant was obtained from line MKH-9 (11.7 number plant^{-1}) (Table 2). It is known that the number of head per plant is one of the most significant traits that directly influence the yield. Although greatly affected by environmental conditions (particularly from sowing frequency), the number of head per plant is one of the traits most influential on safflower cultivars with high yield, and for modern cultivars of safflower, well-developed 12 to 14 heads are sufficient (Weiss, 2000). The cultivar Syria Hama, which was determined to have the highest number of head per plant, according to the two-year averages, exhibited a greater number of head per plant than that reported by the indicated researcher. As it can be seen in Table 2, the numbers of head per plant were lower in the second year of the study, when compared with the first year. This was considered to may have come from the average temperature of the second year of the study been lower than the long-term average and the average of the first year of the study. The results obtained in this study are in agreement with those reported by Arslan et al. (2003), Ozel et al. (2004) and Killi and Kucukler, (2005).

1000 seed weight (g)

According to the results obtained in 2001 - 2002 and 2002 - 2003 and the two-year averages, the greatest 1000 seed weight was obtained in cultivar Syria Hama (41.2 g) and lines MKH-8 (40.0 g) and 301055 (39.5 g) (Table 2). 1000 seed weight is one of the major factors which affect seed yield. Furthermore, genetic structure and ecological factors are two major factors, which are influential on 1000 seed weight. The evaluation of 1000 seed weight values demonstrated that variations existed between the cultivars. These variations were considered to may have been from the reactions of the different cultivars and lines to different ecological conditions. In fact, the cultivar Syria Hama, which displayed the highest 1000 seed weight, was also included in the first group with the highest seed yield. Similarly, Ozel et al. 2002, reported that they obtained the greatest 1000 seed weight from cultivar Syrian Hama (41.22 g), in a study conducted under the conditions of the Harran Plain. The values obtained in this study are exactly the same with the values reported by the researchers. The results obtained in this study for 1000 seed weight are in agreement with those reported by Gencer et al. (1987), Arslan et al. (2003), Uysal et al. (2006) and Camas et al. (2007).

Oil content (%)

The cultivars investigated in this study displayed significant variations for oil content. In the first year of the study, the lines 250540 (34.9%), S-541-2 (33.9%), MKH-9 (33.7%), 250536 (33.7%) and cultivar Gila (33.6%) were in the same group, while in the second year of the study, lines 250540 (34.6%), S-541-2 (34.5%), 250536 (34.3%), MKH-9 (33.8%), CW74 (33.6%) and the cultivars Gila (34.4%), Syrian (33.5 %) and Syria Hama (33.3%) belonged to the same group, with respect to oil content. In both years, the highest oil contents were

Table 2. Overall means of number of head per plant, 1000 seed weight (g) and oil content (%).

Cultivar, line and population	Number of head per plant			1000 Seed weight (g)			Oil content (%)		
	2001-2002	2002-2003	Mean	2001-2002	2002-2003	Mean	2001-2002	2002-2003	Mean
Cyprobren	14.0 f-j*	11.9 f-i	13.0 ghı	37.7 cde	37.1 cde	37.4 cd	32.2 c-f	32.7 bc	32.4 def
Dinçer	13.2 iij	11.4 hıi	12.3 h-ı	36.2 c-h	33.2 i-k	34.7 h-k	28.4 jkl	27.8 hıi	28.1 iij
Gila	13.4 h-j	13.5 d-ı	13.4 f-ı	37.0 c-g	36.9 d-g	36.9 cde	33.6 abc	34.4 a	34.0 abc
Hartinan	15.6 e-ı	12.8 e-i	14.2 e-h	36.5 c-h	36.3 d-h	36.4 def	29.3 ijk	28.7 ghı	29.0 hı
Syrian	13.2 iij	10.3 i	11.8 ı	37.3 c-f	35.6 e-ı	36.5 def	32.7 b-e	33.5 ab	33.1 cd
Syrian-1	16.0 d-ı	15.7 a-e	15.9 de	33.1 ı	35.0 g-j	34.1 i-l	26.8 lmn	25.8 k	26.3 k
Syria Hama	21.3 a	17.8 ab	19.5 a	41.1 a	41.2 a	41.2 a	33.6 abc	33.3 ab	33.5 bcd
Yenice	21.3 a	15.7 a-e	18.5 abc	34.0 ı-l	32.2 k	33.1 ı	29.3 ijk	29.1 gh	29.2 h
CW74	13.4 h-j	11.5 g-i	12.5 hı	36.2 c-ı	36.1 e-h	36.1 d-g	33.2 bcd	33.6 ab	33.4 bcd
CW4440	16.9 c-f	11.8 g-i	14.3 e-h	33.6 kl	33.8 ı-k	33.7 j-l	30.5 h-i	31.0 def	30.8 g
MKH-8	19.7 abc	17.3 abc	18.5 abc	39.8 ab	40.2 ab	40.0 a	28.0 kl	27.1 ijk	27.6 j
MKH-9	12.4 ij	10.9 ii	11.7 ı	33.8 j-l	33.1 jk	33.5 kl	33.7 ab	33.8 ab	33.8 abc
S-541	16.5 d-h	14.7 b-g	15.6 def	38.1 bc	36.0 e-h	37.1 cde	30.8 f-ı	31.9 cde	31.4 g
S-541-2	20.6 ab	17.9 a	19.3 ab	36.8 c-h	37.0 def	36.9 cde	33.9 ab	34.5 a	34.2 ab
198290	13.6 gj	11.0 ii	12.3 hı	36.3 c-h	35.1 f-i	35.7 e-i	30.7 g-i	31.4 cde	31.1 g
250536	17.5 b-e	15.0 a-f	16.3 cde	36.1 d-ı	36.1 e-h	36.1 d-h	33.7 ab	34.3 a	34.0 abc
250537	16.6 c-g	13.5 d-ı	15.1 d-g	34.2 ı-l	33.2 i-k	33.7 i-l	26.4 mn	26.5 ijk	26.5 k
250540	21.1 a	17.4 abc	19.2 ab	35.2 g-k	34.6 h-j	34.9 g-j	34.9 a	34.6 a	34.8 a
251982	14.5 e-j	15.6 a-e	15.0 d-g	36.5 c-h	37.3 cde	36.9 cde	32.0 d-g	30.8 ef	31.4 g
251984	20.9 a	17.2 abc	19.1 ab	34.5 h-l	34.5 h-j	34.5 ı-l	26.0 n	26.3 jk	26.2 k
258417	20.6 ab	16.2 a-d	18.4 abc	37.3 c-f	37.4 cde	37.3 cd	29.5 iij	29.3 g	29.4 h
301055	16.0 d-ı	10.6 ii	13.3 ghı	39.9 ab	39.1 abc	39.5 ab	28.1 jkl	27.5 iij	27.8 ij
537636	15.3 e-i	10.0 i	12.6 hı	35.8 e-i	34.4 h-j	35.1 f-i	31.6 e-h	33.7 ab	32.7 de
Afyon population	16.9 c-f	17.2 abc	17.0 bcd	30.7 m	30.1 ı	30.4 m	30.9 f-ı	32.7 bc	31.8 efg
Cyprus population	11.4 j	15.5 a-e	13.5 f-ı	37.9 bcd	38.2 bcd	38.1 c	30.8 f-ı	32.4 bcd	31.6 fg
Sivas population	18.9 a-d	14.5 c-h	16.7 cd	35.6 f-j	36.1 e-h	35.9 e-i	27.6 lm	29.9 fg	28.8 hıi
C.V. (%)	19.58	19.20	21.03	6.30	7.07	6.70	8.43	9.28	8.86
L.S.D. (5 %)	2.11	1.49	2.08	0.91	1.31	1.05	0.92	0.72	0.91

Different letters in each column indicates that the means differ significantly ($p < 0.05$).

obtained from lines 250540 (34.8%), S-541-2 (34.2%) and MKH-9 (33.8 %) and the cultivar Gila (34.0%) (Table 2). Similar to yield, oil content was affected significantly by cultivar, location and the cultivar x location interaction (Rahamatalla et al., 2001). Johnson et al. (1999) showed that the oil content ranged from 13 to 46% in 797 safflower introduction materials. The oil contents determined in this study fell within the range determined by Johnson et al. (1999). The results obtained in the study for oil content are also in agreement with those reported by Ozel et al. (2002) and Camas et al. (2007).

Oil yield (kg ha^{-1})

Oil yields ranged between 242 and 543 kg ha^{-1} in the first year and 247 and 540 kg ha^{-1} in the second year of the study. Based on the average of the combined values of both years, the highest oil yield was obtained from line S-541-2 (541 kg ha^{-1}) and the cultivar Syria Hama (530 kg ha^{-1}), while the lowest oil yields were obtained from cultivar Syrian-1 (Table 3). Based on the results for both years and the two-year average, the same cultivars belonging to the first group demonstrated that the cultivar Syria Hama and the line S-541-2 had adapted to the region for this trait, and that these could be used in future studies. As it is known, oil yield is calculated by the proportion of oil content to the seed yield per hectare. Therefore, cultivars with high oil content and seed yield had high oil yield. Thus, the cultivar Syria Hama was in the first group for seed yield, and the line S-541-2 was in the first group for both seed yield and oil content (Tables

Table 3. Overall means of oil yield (kg ha^{-1}).

	Oil yield (kg ha^{-1})		
Cultivars, Lines and Populations	**2001–2002**	**2002-2003**	**mean**
Cyprobren	490 ^{b*}	484 ^{c}	487 ^{b}
Dinçer	346 ^{kl}	349 ^{ij}	348 ^{j}
Gila	433 $^{f-ı}$	422 ^{fgh}	428 ^{fgh}
Hartinan	448 $^{c-f}$	447 ^{ef}	448 ^{def}
Syrian	404 ^{ıi}	394 ^{hı}	399 ^{ı}
Syrian-1	242 ^{n}	264 ^{l}	253 ^{m}
Syria Hama	533 ^{a}	528 ^{ab}	530 ^{a}
Yenice	360 ^{k}	357 ^{i}	359 ^{ij}
CW74	478 ^{bc}	443 ^{efg}	460 ^{cd}
CW4440	416 $^{y-i}$	399 ^{hı}	408 ^{hı}
MKH-8	407 ^{hıi}	401 ^{hı}	404 ^{ı}
MKH-9	330 ^{lm}	321 ^{jk}	325 ^{kl}
S-541	436 $^{e-h}$	463 ^{cde}	450 ^{de}
S-541-2	543 ^{a}	540 ^{a}	541 ^{a}
198290	304 ^{m}	304 ^{k}	304 ^{l}
250536	471 ^{bcd}	482 ^{cd}	477 ^{bc}
250537	368 ^{jk}	377 ^{ıi}	373 ^{i}
250540	466 $^{b-e}$	452 ^{def}	459 ^{cd}
251982	399 ^{i}	393 ^{hı}	396 ^{ı}
251984	261 ^{n}	247 ^{l}	254 ^{m}
258417	396 ^{ij}	414 ^{gh}	405 ^{ı}
301055	412 ^{hıi}	415 ^{gh}	414 ^{ghı}
537636	329 ^{lm}	349 ^{ij}	339 ^{jk}
Afyon Populasyon	443 $^{d-g}$	492 ^{bc}	468 ^{bcd}
Cyprus Population	423 $^{f-ı}$	435 ^{efg}	429 ^{efg}
Sivas Populasyon	419 $^{f-i}$	451 ^{ef}	435 ^{efg}
C.V. (%)	18.26	17.91	18.63
L.S.D. (5 %)	21.4	10.0	17.3

*: Different letters in each column indicates that the means differ significantly ($p<0.05$).

2 and 3). The results obtained in the study are in agreement with those reported by Camas et al. (2007).

Correlation coefficients for the traits investigated

Simple correlation coefficient calculated between the seed yield and other traits are given in Table 4. The study demonstrated that correlation coefficients of cultivars and lines were positive and significant between seed yield and number of head per plant, 1000 seed weight and oil yield, while it was positive and non-significant between number of branch per plant and oil content, and negative and non-significant between number of branch per plant and plant height.

The correlation coefficients were positive and significant between plant height and number of branch per plant, and plant height and number of head per plant, while the coefficients were positive and non-significant between plant height and oil content, and negative and non-significant between 1000 seed weight and oil yield.

Furthermore, the correlation coefficients were positive and significant between number of branch per plant and number of head per plant, positive and non-significant between number of branch per plant and oil yield, and negative and non-significant between 1000 seed weight and oil content.

It was shown that the correlation coefficients were positive and significant between number of head per plant and oil yield and positive and significant between

Table 4. Correlation coefficients for some traits in safflower cultivars and lines.

	PH	BP	HP	SW	OC	OY
SY	-0.008 ns	0.022 ns	0.265 **	0.410 **	0.109 ns	0.873 **
PH		0.581 **	0.313 **	-0.004 ns	-0.224 **	-0.109 ns
BP			0.423 **	-0.034 ns	-0.002 ns	0.037 ns
HP				0.115 ns	-0.119 ns	0.191 **
SW					0.069 ns	0.370 **
OC						0.569 **

SY: Seed Yield PH: Plant Height BP: Number of branch per plant HP: Number of head per plant SW: 1000 Seed weight OC: Oil content OY: Oil yield. 78_{n-2}=76, r0.05=0.217, r0.01=0.283, ns: non-significant *:0.01≤p≤0.05, **:0.01≤p≤0.01.

number of head per plant and 1000 seed weight, while they were negative and non-significant between number of head per plant and oil content.

This study demonstrated that correlation coefficients were positive and significant between 1000 seed weight and oil yield, and positive and non-significant between 1000 seed weight and oil content. There was a positive and significant correlation between oil content and oil yield (Table 4).

Conclusion

There is a need for winter oil-seed cropping in order to compensate the deficit in oil supplies and the demand of the oil industry without importation and local production. One of the major oil seed crops is safflower, which has a strong root structure and is known to benefit most from water in arid and semi-arid regions.

The Kahta district of Adiyaman province located in south-eastern Anatolia is one of the major areas of tobacco cultivation. However, due to the legal restrictions imposed on tobacco growth in recent years, farmers require alternative crops for cultivation under semi-arid agricultural conditions.

Taking into consideration the needs of producers, the present study, which was conducted under the conditions of Kahta district to determine the performance of 26 safflower cultivars, lines and populations, demonstrated that based on the two-year averages of the experiment, seed yield varied between 962 and 1585 kg ha^{-1} and the highest yield per hectare was obtained from cultivars Syria Hama (1585 kg ha^{-1}) and Hartinan (1543 kg ha^{-1}), and line S-541-2 (1582 kg ha^{-1}).

Significant differences were shown to exist between cultivars for oil content, which is considered as a significant criterion. Based on the average of the two years, the highest rates were produced by lines 250540 (34.8%) and S-541-2 (34.2%), and the highest oil yield per hectare was obtained in cultivar Syria Hama (530 kg ha^{-1}) and line S-541-2 (541 kg ha^{-1}).

In conclusion, in this study, which was conducted to demonstrate the performance of 26 safflower cultivars, lines and populations, the cultivar Syria Hama and the line S-541-2 were shown to have the highest seed yield and oil yield.

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