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VARIATIONS IN THE AGRONOMIC AND QUALITY CHARACTERISTICS OF DOMESTIC AND FOREIGN SAFFLOWER (*Carthamus tinctorius* L.) GENOTYPES

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ABSTRACT

The present study was carried out to determine the agronomic and quality characteristics of domestic and foreign safflower (*Carthamus tinctorius* L.) genotypes in the 2011-2012 growing season in Isparta. In the study, 39 safflower genotypes were used as the plant material. The highest 1000 seed weight and hull content were detected in Ziyang. Arizona SC III was determined as the genotype with the lowest 1000 seed weight, hull content, seed yield, and oil yield. The highest seed yield was recorded in UC-1 (215.9 kg da^{-1}). Oil contents of the genotypes ranged from 22.6 to 33.8% on average and Arizona SC III, Oleic Leed, Centennial, Finch, Ole, S-517, Enana and Leed were determined as the genotypes with the highest oil content. Variation for oleic acid was between 11.1 and 68.3% in 2011 and between 12.0 and 71.6% in 2012. Linoleic acid content varied between 18.0 and 74.7% in 2011 and between 14.2 and 73.9% in 2012. Montola 2000, Ole, UC-1, NO 55-663 and S-517 were found to contain more than 60% oleic acid. Both performances of the genotypes used in the study could further examined by cultivating in different locations and a successful hybridization program compatible with the desired goals of breeding may be drawn up using wide variations reported among the examined morphological and agronomic characters.

Keywords: adaptation, *Carthamus tinctorius*, Safflower, yield and oil composition

INTRODUCTION

Safflower (*Carthamus tinctorius* L., Compositeae) is an important oilseed crop which began to be cultivated in the Middle East 3 000 years ago. Approximately 647.000 tons of safflower is produced in an area of 782.000 ha worldwide (Anonymous, 2015a). India, USA, Mexico, Ethiopia and Argentina account for approximately 95% of the world's safflower production. Some 70.000 tons of safflower seeds are produced in an area of 43.107 ha in Turkey in 2015 (Anonymous, 2015b). The production of oilseed crops is not at sufficient level in Turkey to meet edible oil demand; therefore large imports of both seed and oil are necessary. The annual oil seed production of Turkey was 2.7 million tons in 2014. Turkey imported 6.3 million tons of vegetable oil, oil seeds, and oil-cakes in total, which amounted to $4.3 billion-3.1 million tons of oil seeds ($1.8 billion), 1.6 million tons of crude oil ($1.9 billion), and 1.6 million tons of oil-cakes ($597 million) in 2014 (Anonymous, 2015a).

In comparison with other oilseed crops, safflower is a crop with high adaptation ability in regions where winter months are cool and summer months are arid. Especially due to its high tolerance for aridity and moderate tolerance to the cold, it is one of the alternative crops to be utilized in the arid and semi-arid agricultural lands of Turkey, particularly in Eastern Anatolia, South-eastern Anatolia, and Central Anatolia Regions (Baydar and Erbas, 2007; Öztürk, 2008). Even though genotypes with high oil content (above 40%) have been identified thorough germplasm screenings, the oil content of the current safflower cultivars remains far below this level (Johnson et al., 1999). To obtain crops from safflower in economic terms and in order for them to compete with other oil seed crops such as; sunflower, soybean, and canola, cultivars with high oil content and seed yield should be developed and cultivated (Pahlavani 2005). Thus increased seed yield and oil content are two important aims of the most of the safflower breeding programs.

Besides cultural treatments, the identification and selection of appropriate cultivars is also essential for safflower cultivation. The proper selection of those cultivars which will particularly be able to adapt to dry land conditions will contribute to the obtaining competitive yields to cultivate safflower economically. Therefore, in order to determine the cultivars suitable for a region, it is important to use a large number of genotypes to establish their agronomic and quality characters through adaptation experiments. Various researchers reported that the growth of cultivars varied by arid and low land conditions and that irrigation and rainfall increased the seed yield at the stages of branching and seed formation; furthermore, yield and crop traits were shown to vary by cultivar, ecological conditions, and agronomic practices. The large number of genotypes allows observation of exiting genetic variation which could be used to develop hybridization programs among the genotypes for the development of new cultivars with high yield potential, high oil content, and different fatty acid compositions (Mary and Gopalan 2006; Karademir et al. 2007). In the present study, safflower genotypes originated from different countries were evaluated for their adaptation ability in Isparta ecological condition to reveal suitable types for further studies.

MATERIALS AND METHODS

In this study, 39 safflower genotypes were used as the plant material. Genotypes of Turkish origin (Remzibey-05, Dincer 5-118, and Yenice 5-38) were obtained from Ege Agricultural Research Institute, and the other genotypes were provided by USDA Western Regional PI Station in Pullman, WA, USA (Table 1).

Table 1. Safflower genotypes used in the study as the plant material

Gen Bank No	Genotype	Phenotype*	Origin	Registration	Gen Bank No	Genotype	Phenotype	Origin	Registration
PI 537110	Quiriego 88	Y-S	Mexico	Cultivar	PI 538779	Centennial	Y-S	USA	Cultivar
PI 537111	Sahuaripa 88	O-S	Mexico	Cultivar	PI 601506	S-517	O-S	USA	Cultivar
PI 561703	San Jose 89	O-S	Mexico	Cultivar	PI 572472	Rehbein	Y-S	USA	Cultivar
PI 572475	Saffire	R-S	Canada	Cultivar	PI 525458	Finch	Y-S	USA	Cultivar
PI 592391	AC Sunset	R-S	Canada	Cultivar	PI 572436	Leed	O-S	USA	Cultivar
PI 559909	AC Stirling	Y-S	Canada	Cultivar	PI 572415	No 55-633	O-S	USA	Cultivar
PI 603206	Lesaf 414	R-S	Canada	Pure line	PI 508098	Hartman	Y-S	USA	Cultivar
PI 610263	Enana	O-S	Spain	Pure line	PI 537695	Ole	O-S	USA	Cultivar
W6 16828	Rinconada	Y-S	Spain	Cultivar	PI 572434	UC-1	Y-S	USA	Cultivar
W6 16833	CH-353	Y-S	Spain	Pure line	PI 572414	US-10	Y-S	USA	Cultivar
TR 69497	Dincer 5-118	O-Sl	Turkey	Cultivar	PI 572471	Sidwill	Y-S	USA	Cultivar
TR 69498	Yenice 5-38	R-Sl	Turkey	Cultivar	PI 537694	Royal	O-S	USA	Cultivar
TR 69499	Remzibey-05	Y-S	Turkey	Cultivar	PI 537692	Gila	O-S	USA	Cultivar
PI 538025	Montola 2000	Y-S	USA	Cultivar	PI 514632	Ziyang	R-S	China	Cultivar
PI 601166	Oker	O-S	USA	Cultivar	PI 514631	Yuyao	R-S	China	Cultivar
PI 572465	4022	R-S	USA	Pure line	PI 514624	Shufu	R-S	China	Cultivar
PI 572439	PCA	Y-S	USA	Pure line	PI 514620	Huaxian	R-S	China	Cultivar
PI 572418	Arizona SC III	W-S	USA	Pure line	PI 506426	FO-2	R-S	China	Cultivar
PI 572421	Frio	Y-S	USA	Cultivar	-	Gifford	R-S	USA	Cultivar
PI 560177	Oleic Leed	O-S	USA	Cultivar					

*The phenotype of safflower genotypes is classified according to flower color and spininess. R, Red; O, Orange; Y, Yellow; W, White; S, Spiny; Sl, Spineless

The research was conducted in Isparta (37º45' N and 30º33' E, 997 m), located in the inner Mediterranean Region of Turkey, in 2011 and 2012. The major soil characteristics of the research area, based on the method described by Rowell (1996), were as follows: the soil texture was clay loam; the organic matter was 1.1% by the Walkley-Black method; lime was 7.2% by Schiebler calcimeter; total salt was 0.38%; exchangeable K was 119 mg kg^{-1} by 1N NH_4OAc; extractable P was 3.9 mg kg^{-1} by 0.5N $NaHCO_3$ extraction; and the pH in a soil saturated extract was 7.5. The climatic data for the experimental area were given in Table 2.

Table 2. Total precipitation, mean humidity and mean temperatures and long term averages of experimental site.

Month	Precipitation, L m^2			Mean temperature, ºC			Mean humidity, %		
	1975-2012	2011	2012	1975-2012	2011	2012	1975-2012	2011	2012
March	51.8*	50.4	21.4	6.1	6.3	5.2	65.1	70.2	58.1
April	56.1	42.8	53.4	10.7	10.3	11.7	61.1	68.5	57.6
May	46.1	42.5	108.4	15.5	14.4	14.5	58.3	64.8	65.6
June	28.3	61.8	18.2	20.3	19.8	22.4	49.9	56.6	46.1
July	12.4	1.8	0.0	23.7	25.0	25.4	44.2	42.3	42.1
August	12.4	0.6	0.2	23.2	22.9	22.8	39.8	40.7	43.2

*Turkish State Meteorological Service

The experiments in both years were evaluated in a randomized complete block design with three replications. Seeds of the genotypes were sown by hand on March 26 and 30, 2011 and 2012, respectively. Spacing between rows was 0.50 m and within rows spacing was 0.15 m. The plot length was 5 m and each plot contained 5 rows. All genotypes were fertilized with 8 kg da^{-1} of P and 10 kg da^{-1} of N. Diammonium phosphate (18% N, 46% P) and ammonium nitrate (33% N) were used as fertilizers. Weed control was performed by mechanical rotary tillage and manual weeding. Experiments were not irrigated. Genotypes were harvested on the first week of October in both years and only the three middle rows were harvested by hand. Agronomic and quality characteristics were determined in 10 randomly selected plants. The following observations were made: plant height (cm), branches number (no plant^{-1}), head number (no plant^{-1}), head diameter (mm), 1000 seed weight (g), harvest index (%), hull content (%), seed yield (kg da^{-1}), oil content (%), oil yield (kg da^{-1}), and fatty acid composition (%).

The oil content and fatty acid composition were determined by Nuclear magnetic resonance (NMR, Bruker, the USA) and Gas chromatography (GC, Perkin Elmer Auto System XL, the USA), respectively. For the determination of oil content, the seeds of the genotypes were oven-dried at 35ºC for 2 days in a ventilated oven till reaching constant moisture content and then the oil content of 2.5 g of seed was detected in NMR with 3 replications. To determine the fatty acid composition, the oil extracted with hexane/methanol (4:1, v/v) from the seeds and oil was converted to its fatty acid methyl esters as described by Marquard (1987). The methyl esters of the fatty acids (1.0 µl) were analyzed in a GC equipped with a flame ionizing detector (FID) and a fused silica capillary column (MNFFAP (50 m x 0.32 mm i.d.; film thickness = 0.25 µm)). A GC analysis was performed as follows: the oven temperature was kept at 120ºC for a min and programmed to 250ºC at a rate of 6 ºC min^{-1} and then constant at 240ºC for 15 min; total run time: 60 min; injector temperature: 250ºC; detector (70 eV) temperature: 260ºC; the flow rate for helium: 40 ml min^{-1}; and split ratio: 1/20 ml min^{-1}. Peak identification was conducted by comparing the relative retention times with those of a commercial standard mix of fatty acid methyl esters. The contents of palmitic (C16:0), stearic (C18:0), oleic (C18:1), and linoleic (C18:2) acids were determined in percentage. Samples were injected 1 µl. All data were analyzed using GLM producers of SAS (1999) and means were compared using Tukey's Multiple Range Test at the probability level of 0.05.

RESULTS AND DISCUSSION

The results of the analysis of variance on the agronomic and quality characteristics examined in the research are given in Table 3. According to the ANOVA results, the differences among the genotypes were found statistically significant (P<0.01) for all characteristics in 2011 and 2012. Likewise, according to the results of the combined ANOVA test, both cultivars and years and the year × genotype interaction were found to be significant. Since the differences between the years were significant in all characteristics, the years were given individually (Table 3).

Table 3. Results of the analysis of variance on the agronomic and quality characteristics.

Years	Sources of variance	Df	Plant height	Branches number	Head number	Head diameter	1000 seed weight	Harvest index	Hull content	Seed yield	Oil content	Oil yield
2011	Block (B)	2	4.7[a]	0.4	0.6	0.1	5.3	3.2	1.4	40.2	1.3	8.1
	Genotype (G)	38	254.7**	11.4**	29.0**	7.4**	56.9**	80.1**	92.4**	5398.7**	23.9**	479.9**
	Error	76	7.7	0.4	1.0	0.4	3.3	2.7	2.4	137.9	0.9	13.0
	CV (%)		5.3	8.8	8.7	3.0	5.1	8.4	3.4	13.5	3.3	14.2
2012	B	2	0.8	0.5	0.1	1.4	0.1	5.7	1.6	58.9	4.3	22.2
	G	38	250.8**	10.1**	51.6**	9.8**	55.5**	120.3**	32.2**	5940.8**	29.5**	500.1**
	Error	76	8.8	0.7	2.4	1.0	3.8	4.5	2.4	208.3	2.1	17.9
	CV (%)		5.3	9.0	9.8	4.5	5.2	9.8	3.3	13.5	5.0	14.2
Average of two years	Year (Y)	1	91.4**	51.9**	867.6**	150.8**	58.8**	229.0**	162.0**	23282.2**	58.2**	84.9**
	B (Y)	4	2.8	0.4	0.3	0.8	0.7	9.4	2.7	49.6	2.8	1.0
	G	38	465.6**	19.5**	66.1**	14.1**	29.4**	165.3**	161.2**	10714.9**	48.9**	59.2**
	Y x G	38	40.0**	2.0**	14.5**	2.3**	2.3**	35.0**	10.0**	624.5**	4.6**	4.1**
	Error	152	8.1	0.5	1.7	0.7	3.6	3.6	2.4	173.1	1.5	15.5
	CV (%)		5.3	8.9	9.5	3.9	5.1	9.2	3.3	13.6	4.2	14.2

a, mean squares of characters ; Df, degree of freedom; CV, coefficient of variation; **p<0.01

The highest plant height among the genotypes was observed in Yenice 5-38 (84.1 cm) in 2011. In 2012, Yenice 5-38 (85.8 cm) and Shufu (82.4 cm) had the highest plant height. The shortest plant height was detected in Enana (38.2 cm) and Gila (42.6 cm) in 2011, Oleic Leed (43.1 cm) and NO 55-663 (43.9 cm) in 2012. Enana (41.6 cm) and Oleic Leed (43.8 cm) had the shortest plant height according to the average of both years (Table 4). Plant height has moderate to high heritability (50.7-77.0%) (Ramachandram and Goud, 1981; Reddy et al., 2004; Parameshwar, 2009). Therefore it is also affected by the environmental conditions which were reported by different researchers (Camas et al., 2007; Beyyavas et al., 2011). Rainfall during growing period was higher in 2012 than 2011 which might explain observed differences for plant height between the years.

Table 4. Agronomic and quality characteristics of domestic and foreign safflower genotypes

Genotypes	Plant height (cm)			Branches number (no $plant^{-1}$)			Head number (no $plant^{-1}$)			Head diameter (mm)			1000 seed weight (g)		
	2011	**2012**	**Mean**	**2011**	**2012**	**Mean**	**2011**	**2012**	**Mean**	**2011**	**2012**	**Mean**	**2011**	**2012**	**Mean**
Quiriego-88	52.3 f-n	50.1 j-p	51.2 g-o	9.4 b-f	9.0 c-j	9.2 c-g	20.5 a	24.0 ab	22.3 a	20.8 d-k	23.2 a-i	22.0 c-j	38.9 b-f	37.5 e-k	38.2 d-i
Oker	47.2 j-p	49.4 j-p	48.3 l-r	5.8 l-q	6.8 i-m	6.3 m-p	10.2 g-n	16.1 d-j	13.2 f-n	20.3 f-m	21.3 f-l	20.8 h-m	22.6 l	26.8 m	24.7 r
AC Sunset	48.0 h-o	51.5 f-p	49.7 j-r	10.5 b-c	12.0 b	11.3 b	20.0 a	22.2 a-c	21.1 ab	17.6 o	20.7 h-l	19.2 l-o	35.1 d-k	36.9 e-l	36.0 g-o
Enana	38.2 p	45.0 m-p	41.6 s	7.4 f-n	8.8 c-k	8.1 e-k	11.1 e-m	14.1 h-m	12.6 h-p	18.4 l-o	20.9 h-l	19.7 k-o	32.5 g-k	36.5 e-l	34.5 h-q
Sahuaripa-88	45.2 j-p	50.6 i-p	47.9 m-s	7.3 f-o	7.9 e-m	7.6 g-m	12.5 d-I	16.8 d-i	14.7 d-k	21.6 c-i	23.2 a-i	22.4 b-h	42.6 b	42.8 a-e	42.7 bc
Montola-2000	62.0 c-e	50.7 h-p	56.4 d-i	9.0 c-g	9.1 c-j	9.1 c-g	16.1 b-c	21.0 b-d	18.5 bc	21.6 c-i	24.0 a-h	22.8 a-g	36.6 c-i	36.5 e-f	36.6 e-o
AC Stirling	43.6 l-p	50.6 h-p	47.1 n-s	7.3 f-o	8.5 d-l	7.9 e-l	10.7 f-m	16.5 d-i	13.6 f-m	19.7 i-n	21.9 c-k	20.8 h-m	35.9 d-k	39.9 b-h	37.9 d-k
4022	46.4 j-p	60.2 b-h	53.3 f-n	6.8 h-q	8.0 e-m	7.4 h-n	10.4 f-n	20.7 b-e	15.5 d-h	22.4 a-f	22.6 a-j	22.5 b-h	30.3 k	35.1 g-l	32.7 o-q
PCA	47.8 i-o	53.8 d-n	50.8 h-p	6.8 h-q	9.6 b-g	8.2 e-j	9.2i-n	15.1 f-k	12.1 i-p	22.7 a-e	24.8 a-c	23.8 a-c	35.7 d-k	41.4 a-g	38.5 c-h
Frio	47.7 i-o	53.9 d-n	50.8 h-q	8.5 c-h	10.0 b-e	9.2 c-f	10.6 f-m	13.3 i-n	12.0 k-p	21.7 b-i	22.3 a-j	22.0 c-j	39.2 b-e	39.7 b-i	39.4 c-g
Oleic Leed	44.5 k-p	43.1 p	43.8 r-s	6.7 h-q	6.4 k-m	6.6 k-p	11.6d-l	12.8 i-n	12.2 i-p	22.8 a-d	21.7 c-l	22.3 c-i	35.2 d-k	37.4 e-k	36.3 f-o
Dincer 5-118	52.6 f-m	57.0 c-j	54.8 d-k	7.9 e-l	9.3 c-h	8.6 d-i	14.7 b-d	18.8 c-h	16.7 c-e	23.8 a	25.4 a-b	24.6 a	39.9 b-d	41.9 a-f	40.9 b-e
Yenice 5-38	84.1 a	85.8 a	84.9 a	6.3 i-q	7.3 f-m	6.8 j-p	10.7 f-m	15.0 g-k	12.9 g-o	23.7 a-b	24.7 a-e	24.2 ab	37.2 b-h	37.7 d-j	37.5 d-l
Remzibey-05	44.5 k-p	46.8 f-p	45.6 o-s	6.2 j-q	6.4 k-m	6.3 m-p	13.6 c-f	14.2 h-m	13.9 e-m	21.1 c-j	23.8 a-h	22.5 b-h	37.0 b-h	37.9 d-j	37.4 d-m
Centennial	57.1 c-h	56.6 c-k	56.8 c-h	7.4 f-n	7.8 e-m	7.6 g-m	8.1m-n	14.1 h-m	11.1 m-r	17.9 n-o	18.8 k-l	18.4 o	30.9 l-k	31.8 j-m	31.4 pq
S-517	51.9 g-n	55.8 c-l	53.8 e-m	9.3 b-f	9.6 b-g	9.5 c-e	12.0 d-j	18.7 c-h	15.4 d-h	21.0 c-k	21.1 g-l	21.0 g-l	35.0 d-k	31.2 k-m	33.1 n-q
Lesaf	46.1 j-p	51.8 e-p	48.9 k-r	10.1 b-d	9.8 b-f	9.9 b-d	17.4 a-b	26.3 a	21.9 a	19.7 i-n	20.9 h-l	20.3 j-n	30.3 f-k	30.8 l-m	30.6 q
Saffire	46.4 j-p	54.3 d-m	50.3 i-q	10.0 b-e	10.6 b-d	10.3 bc	13.2 c-g	18.9 c-h	16.1 c-f	18.3 m-o	19.7 j-l	19.0 m-o	36.8 b-i	35.8 f-l	36.3 f-o
Rehbein	45.5 j-p	51.1 h-p	48.3 k-r	5.8 k-q	7.1 h-m	6.5 l-p	8.7 j-n	15.4 f-k	12.0 j-p	19.0 k-o	20.2 i-l	19.6 k-o	33.0 f-k	33.3 i-l	33.1 m-q
Finch	44.3 k-p	44.3 n-p	44.3 q-s	5.3 n-q	5.7 m	5.5 p	7.1 n	9.9 l-n	8.5 q-r	19.9 h-n	21.8 c-l	20.8 h-m	32.0 h-k	35.3 g-l	33.7 k-q
Leed	58.3 c-g	61.4 b-e	59.8 b-e	8.4 c-i	9.3 c-h	8.8 c-h	11.4 d-m	14.5 h-m	12.9 g-o	22.5 a-e	24.8 a-d	23.7 a-d	33.4 e-k	37.4 e-k	35.4 g-p
Arizona SC III	46.0 j-p	49.5 j-p	47.7 m-s	6.8 h-q	7.7 e-m	7.3 h-n	9.3 h-n	10.7 k-n	10.0 o-r	19.8 i-n	21.4 e-l	20.6 h-n	30.2 k	31.8 j-m	31.0 q
NO 55-633	45.2 j-p	43.9 o-p	44.5 p-s	6.6 h-q	6.3 l-m	6.4 l-p	9.1 j-n	13.1 i-n	11.1 m-r	19.3 j-o	21.5 d-l	20.4 i-n	38.1 b-g	44.7 a-c	41.4 b-d
Hartman	65.0 c	67.3 b	66.2 b	5.7 m-q	7.3 g-m	6.5 k-p	10.8 f-m	19.9 b-g	15.3 d-h	22.0 a-g	21.6 c-l	21.8 d-j	31.5 h-k	35.0 g-l	33.3 l-q
Ziyang	43.4 m-p	47.4 k-p	45.4 o-s	4.9 p-q	6.7 j-m	5.8 n-p	10.7 f-m	11.9 i-n	11.3 l-q	20.6 e-k	23.0 a-i	21.8 d-j	49.1 a	46.6 a	47.8 a
Ole	45.6 j-p	46.0 m-p	45.8 o-s	4.7 q	6.4 k-m	5.6 op	8.4 k-n	11.1 j-n	9.8 pr	22.1 a-g	24.4 a-g	23.3 a-e	34.2 d-k	37.0 e-f	35.6 g-p
UC-1	48.2 h-o	49.9 j-p	49.0 k-r	5.2 o-q	9.0 c-j	7.1 i-p	11.1 e-m	15.8 e-j	13.4 f-m	21.9 a-g	24.7 a-e	23.3 a-d	38.5 b-f	42.2 a-f	40.3 b-e
US-10	52.7 f-l	56.9 c-k	54.8 d-l	6.9 g-p	7.4 f-m	7.2 i-o	11.1 e-m	9.5 m-n	10.3 n-r	21.5 c-i	22.2 b-j	21.9 c-j	39.4 b-e	42.4 a-e	40.9 b-e
Rinconada	62.3 c-d	63.3 b-d	62.8 bc	14.1 a	14.7 a	14.4 a	16.6 b-c	14.6 h-l	15.6 c-g	18.6 l-o	21.7 c-l	20.1 j-o	36.3 d-j	40.1 b-h	38.2 d-j
CH-353	53.7 d-j	57.5 c-j	55.6 d-j	7.0 g-p	6.3 k-m	6.6 j-p	11.7 d-k	12.8 i-n	12.3 i-p	21.1 c-j	21.5 e-l	21.3 f-k	35.4 d-k	36.3 e-l	35.9 g-o
Sidwill	56.8 c-i	58.5 b-j	57.7 c-g	11.5 b	11.1 b-c	11.3 b	10.7 f-m	13.4 l-m	12.1 j-p	21.2 c-j	20.9 h-l	21.1 g-l	32.5 g-k	35.3 g-l	33.9 j-q
San Jose-89	59.5 c-g	65.4 b-c	62.5 bc	6.6 h-q	9.2 c-i	7.9 e-l	9.9 g-n	20.1 b-f	15.0 d-i	21.2 c-j	24.5 a-f	22.9 a-g	35.2 d-k	39.6 b-i	37.4 d-n
Royal	52.5 f-m	63.4 b-d	58.0 c-f	7.8 f-m	7.7 e-m	7.7 f-m	10.7 f-m	12.6 i-n	11.6 l-p	20.6 e-k	25.6 a	23.1 a-f	37.4 b-h	39.1 b-i	38.2 d-i
Gila	42.6 o-p	60.0 b-i	51.3 g-o	5.4 n-q	10.2 b-e	7.8 f-m	8.0 m-n	12.6 i-n	10.3 n-r	21.9 a-h	24.5 a-f	23.2 a-e	36.1 d-k	37.4 e-k	36.8 e-o
Yuyao	43.2 n-p	60.6 b-g	51.9 f-o	6.0 j-q	7.4 f-m	6.7 j-p	11.5 d-l	18.7 c-h	15.1 d-i	20.2 g-m	22.6 a-j	21.4 e-k	42.3 b-c	45.5 a-b	43.9 ab
Shufu	74.8 b	82.4 a	78.6 a	5.8 k-q	7.1 h-m	6.5 l-p	14.6 b-d	20.6 b-e	17.6 cd	19.0 k-o	18.6 l	18.8 n-o	35.9 d-k	35.1 g-l	35.5 g-p
Huaxian	52.1 g-n	52.8 e-o	52.5 f-n	6.1 j-q	6.8 l-m	6.4 l-p	8.3 l-n	8.3 n	8.3 r	20.4 f-l	21.2 f-l	20.8 h-m	34.3 d-k	33.9 h-l	34.1 i-q
FO-2	52.9 e-k	56.1 c-l	54.5 e-l	7.9 d-k	6.7 j-m	7.3 h-n	14.3 b-e	14.1 h-n	14.2 e-l	22.0 a-g	24.6 a-e	23.3 a-e	39.2 b-e	38.7 c-i	39.0 c-g
Gifford	61.4 c-p	60.8 b-f	61.1 b-d	8.0 d-i	8.9 c-j	8.5 d-i	12.6 d-h	11.1 j-n	11.9 k-p	22.9 a-c	23.2 a-i	23.1 a-f	38.9 b-f	44.1 a-d	41.5 b-d

Means with identical letters in the same column are not statistically significant at the level of $p<0.01$.

The number of branches per plant ranged from 4.7 to 14.7 in the study. While the highest number of branches was observed in Rinconado (14.1 in 2011 and 14.7 in 2012) and for the both years, the lowest number of branches was detected in Ole (4.7) in 2011. For combined years, there was no difference between Ole and Finch (Table 4). Weiss (2000) emphasized that 6 to 8 branches should be available in the plant for economic safflower production. However, some researchers reported that the number of branches might increase up to 50 in safflower (Deokar and Patil, 1980; Reddy et al., 2004; Omidi et al., 2009). Our results were found within the limits reported by these researchers. Singh et al. (2008) reported that the additive genes had an effect on the inheritance of the number of branches. Our results ranged from 5.5 to 14.4 according to the average of both years, which suggest that there is genetic variation present for the branch number among the studied genotypes.

In the study, Quiriego-88 and AC Sunset were found to have the largest number of heads per plant in 2011, in 2012, and according to the average of both years. Besides, Lesaf (26.3 and 21.9) and AC Sunset (22.2 and 21.1) in 2012 and according to the average of both years also gave high values for number of heads per plant. Finch and Huaxian had the fewest number of heads per plant for 2011, 2012 and combined years. The number of heads for Dincer 5-118, Yenice 5-38 and Remzibey-05 were determined as 16.7, 12.9, and 13.9 according to the average of both years, respectively (Table 4). Even though the number of heads is a characteristic which may vary by the environmental and cultural conditions (particularly by the sowing density) in safflower, it is one of the selection criteria with a direct effect on the high seed yield in early generations in a breeding program (Knowles, 1982). It was also reported that there is a high heritability for the number of heads in safflower and that the variation likely to occur is due to the environmental factors (Pahlavani et al., 2007; Parameshwar, 2009; Safavi et al., 2011). Weiss (2000) stated that although the number of heads ranged from 5 to 50 in safflower, 14 to 16 heads which displayed good development were enough for an economic yield. The variation determined in terms of the number of heads in this study is between the values stated in the other studies performed on the subject (Reddy et al., 2004; Safavi et al., 2011).

In both study years, head diameter significantly varied by year and genotype. Dincer 5-118, Yenice 5-38, Gifford, Oleic Leed, PCA, Leed, 4022, Ole, FO-2, Hartman, UC-1 and Gila in the first year of the study and Royal, Dincer 5-118, PCA, Leed, UC-1, Yenice 5-38, FO-2, San Jose-89, Gila, Ole, Montola 2000, Gifford, Sahuaripa-88, Quiriego-88, Ziyang, Yuyao, 4022, Frio and Remzibey-05 in the second year statistically belonged to the same group. According to the average of both years, the maximum head diameter was recorded in Dincer 5-118, Yenice 5-38, PCA, Leed, UC-1, FO-2, Ole, Gila, Royal and Gifford, San Jose-89, and Montola 2000. AC Sunset was detected to be the genotype with the minimum head diameter in 2011, Shufu in 2012, and Centennial according to the average of both years (Table 4). In the second growing season, bigger heads were obtained because of a higher total amount of rainfall and its best monthly distribution. It was reported that the head diameter could range from 10.0 to 35.0 mm in safflower (Weiss, 2000; Kizil et al., 2008) and that head diameter might vary by location, genotype, and climate (Safavi et al., 2011).

Another essential selection criterion that determines seed yield in safflower is the 1000 seed weight. The 1000 seed weight of the genotypes was in the range of 22.6-49.1 g in 2011, in the range of 26.8-46.6 g in 2012, and among 24.7-47.8 g according to the average of both years. In the study, the highest 1000 seed weight was determined in Ziyang, followed by Yuyao (45.5 g), NO 55-663 (44.7 g), Gifford (44.1 g), Sahuaripa-88 (42.8 g), US-10 (42.4 g), UC-1 (42.2 g), Dincer 5-118 (41.9 g), and PCA (41.4 g) in 2012 (Table 4). Ziyang and Yuyao had the highest values for 1000 seed weight and Oker had the lowest value for 1000 seed weight for combined years. The 1000 seed weight demonstrated that variations existed among the genotypes. Weiss (2000) reported that the high 1000 seed weight up to 50 g in safflower might increase the seed and/or oil yield. Detection of higher 1000 seed weights in 2012 might have contributed to high seed and oil yields observed in the second year of the study. Nevertheless, no genotype with a 1000 seed weight greater than 50 g was detected in either experimental year. The reported results were within the previously reported limits (Reddy et al., 2004; Alizadeh, 2005; Camas and Esendal, 2006; Safavi et al., 2011).

The harvest indexes of the genotypes ranged from 8.5 to 31.5% (Shufu-Gifford) and from 4.1 to 30.8% (Oker-Remzibey-05) in 2011 and 2012, respectively. The highest harvest index according to the average of both years was recorded from Gifford and Remzibey-05, followed by US-10, Dincer 5-118, San Jose-89, Gila, and Ziyang (Table 5). The effects of environmental factors are important on the realized harvest index in safflower. The high precipitation (126.6 mm) in May and June, bolting and budding periods of the plants, in 2012 should have contributed higher value of harvest index by directly increasing head diameter and 1000 seed weights of the genotypes. The results obtained in our study were found to be in agreement with the previous studies (Lakshmi Prayaga et al., 2003; Eslam, 2010). However, higher harvest index (>35%) value was reported among different safflower genotypes (Parameshwar, 2009; Emami et al., 2011).

Table 5. Agronomic and quality characteristics of domestic and foreign safflower genotypes

Genotypes	Harvest index (%)			Hull content (%)			Seed yield (kg da^{-1})			Oil content (%)			Oil yield (kg da^{-1})		
	2011	**2012**	**Mean**	**2011**	**2012**	**Mean**	**2011**	**2012**	**Mean**	**2011**	**2012**	**Mean**	**2011**	**2012**	**Mean**
Quiriego-88	22.6 c-g	21.2 c-i	21.9 e-k	47.7 d-l	49.0 d-k	48.3 d-h	114.1 d-g	116.6 d-k	115.3 d-j	29.5 e-k	26.4 g-m	28.0 g-o	33.6 d-f	30.8 f-m	32.2 e-j
Oker	17.7 g-l	4.1 l	10.9 pq	35.1 o	46.5 h-m	40.8 n-o	29.0 p-r	19.5 o-p	24.2 t-u	32.6 a-e	28.4 c-k	30.5 c-g	9.5 m-o	5.5 p-q	7.5 q-r
AC Sunset	16.7 h-l	17.6 g-j	17.2 m-o	50.7 b-f	52.2 a-f	51.5 a-d	83.1f-m	112.2 d-l	97.7 h-m	25.0 m-p	26.1 h-m	25.6 o-q	20.8 h-m	29.2 f-n	25.0 i-n
Enana	15.1 i-l	17.4 h-j	16.3 no	41.3 m-n	44.4 k-m	42.8 l-n	25.6 q-r	63.3 m-o	44.4 s-u	32.2 a-f	30.8 a-g	31.5 a-d	8.2 n-o	19.5 j-o	13.9 p-r
Sahuaripa-88	19.6 e-j	21.9 c-i	20.7 g-m	45.5 g-m	47.7 f-l	46.6 g-k	109.4 e-h	123.5 d-i	116.4 d-i	31.4 b-g	30.1 a-i	30.7 b-g	34.4 d-f	37.2 c-g	35.8 d-f
Montola-2000	18.5 g-k	20.7 d-j	19.6 g-n	43.2 j-n	42.0 m-n	42.6 m-n	157.0 b-c	156.9 b-e	157.0 bc	31.0 b-h	29.5 b-j	30.3 c-h	48.7 b	46.4 b-e	47.5 b-c
AC Stirling	19.1 f-k	19.3 e-j	19.2 h-n	48.2 c-j	53.0 a-e	50.6 c-f	53.5 l-r	85.1 g-n	69.3 m-s	28.2 h-m	24.9 j-m	26.6 m-p	15.0 k-o	21.2 i-o	18.1 m-p
4022	17.7 g-l	20.2 e-j	19.0 j-n	50.8 b-f	51.2 b-h	51.0 b-e	68.6 j-o	130.5 d-h	99.6 g-l	26.3 l-o	26.5 f-m	26.4 m-p	18.1i-n	34.8 d-i	26.4 g-m
PCA	13.9 k-n	23.3 c-i	18.6 k-n	43.2 j-n	47.0 g-m	45.1 h-m	74.6 h-n	116.7 d-k	95.7 h-n	28.8 g-l	30.8 a-h	29.8 c-g	21.5 g-l	35.9 c-h	28.7 f-k
Frio	17.6 g-l	25.9 a-e	21.7 e-l	43.8i-n	46.2 h-m	45.0 h-m	74.9 h-n	118.3 d-j	96.6 h-m	31.0 b-h	30.1 a-i	30.6 b-g	23.2 f-l	35.7 c-h	29.4 e-k
Oleic Leed	22.5 c-g	24.2 a-h	23.3 c-i	42.7 l-n	46.1 h-m	44.4 j-m	76.7 g-n	80.4 i-n	78.6 l-r	34.0 a-b	33.5 ab	33.8 a	26.1 e-k	26.8 g-n	26.4 g-m
Dincer 5-118	28.8 a-b	27.7 a-d	28.2 ab	51.8 a-e	49.6 d-j	50.7 b-f	165.7 b	183.3 a-c	174.5 b	28.8 g-l	26.4 g-m	27.6 h-o	47.7 b-c	48.3 b-d	48.0 b-c
Yenice 5-38	18.2 g-l	16.9 i-j	17.5 l-o	52.3 a-d	56.1 ab	54.2 a-b	130.5 b-e	131.4 d-g	130.9 c-f	24.7 n-p	24.2 k-m	24.4 q-r	32.2 d-h	31.8 f-k	32.0 e-j
Remzibey-05	28.7 a-b	30.8 a	29.7 a	49.4 b-h	51.9 a-g	50.7 b-f	107.7 e-i	116.7 d-k	112.2 e-j	30.5 c-i	28.3 d-k	29.4 d-l	32.9 d-g	33.0 e-j	32.9 e-i
Centennial	19.0 f-k	8.3 k-l	13.7 op	38.7 n-o	38.9 n	38.8 o	50.1 m-r	50.4 n-p	50.3 r-t	35.0 a	32.6 a-d	33.8 a	17.6 i-o	16.4 n-q	17.0 n-p
S-517	22.2 c-h	21.7 c-i	21.9 e-k	42.9 k-n	45.1 j-m	44.0 k-n	65.5 j-p	51.7 n-p	58.6 o-s	30.0 d-j	33.6 ab	31.8 a-d	19.6 i-n	17.4 l-q	18.5 l-p
Lesaf	20.0 d-i	25.5 a-f	22.7 c-k	46.0 f-m	47.2 f-m	46.6 g-k	84.0 f-m	126.0 d-i	105.0 f-l	30.6 c-i	26.8 e-m	28.7 e-m	25.7 e-k	33.7 e-i	29.7 e-k
Saffire	19.0 f-k	25.0 a-f	22.0 e-k	52.1 a-d	49.0 d-k	50.5 c-f	33.3 o-r	74.3 j-n	53.8 q-t	28.0 h-m	24.9 j-m	26.4 m-p	9.3 m-o	18.5 k-q	13.9 p-r
Rehbein	13.9 k-n	23.6 b-i	18.7 k-n	44.9 h-l	47.0 g-m	45.9 h-m	62.7 k-q	61.1 m-o	61.9 o-s	29.2 f-l	27.7 e-k	28.4 f-n	18.2 i-n	16.9 m-q	17.6 m-p
Finch	19.6 e-j	25.2 a-f	22.4 d-k	43.9 i-l	43.7 l-n	43.8 k-n	48.7 m-r	83.7 h-n	66.2 n-s	33.5 a-c	33.1 a-c	33.3 ab	16.4 j-o	27.7 f-n	22.0 k-p
Leed	14.3 j-m	22.6 c-i	18.4 k-n	43.7 i-n	45.3 i-m	44.5l-m	83.0 f-m	90.3 f-n	86.7 i-o	31.6 b-g	31.2 a-f	31.4 a-e	26.4 e-k	28.2 f-n	27.3 f-l
Arizona SC III	9.6 m-n	7.4 k-l	8.5 q	25.0 p	26.7 o	25.9 p	17.0 r	13.5 p	15.2 u	33.5 a-c	34.2 a	33.8 a	5.7 o	4.6 q	5.1 r
NO 55-633	14.8 i-m	19.8 e-j	17.3 m-o	48.4 b-i	47.2 f-m	47.8e-j	42.6 n-r	69.3 k-n	56.0 p-s	28.0 h-m	26.9 e-m	27.4 i-o	12.0 l-o	18.7 k-p	15.4 o-q
Hartman	22.6 c-g	22.3 d-i	22.4 d-k	46.6 e-l	48.1 e-l	47.4f-k	75.4 g-n	112.1 e-f	93.7 h-n	27.3 j-n	26.1 i-m	26.7 l-p	20.6 h-m	29.2 f-n	24.9 i-n
Ziyang	24.4 b-f	27.7 a-c	26.1 a-e	56.1 a	53.7 a-d	54.9a	117.3 d-f	118.0 d-j	117.7 d-h	24.1 o-p	22.9 l-m	23.5 q-r	28.2 e-j	27.1 g-n	27.7 f-k
Ole	22.0 c-h	21.6 c-i	21.8 e-l	46.5 f-l	50.3 c-l	48.4d-h	104.0 e-j	113.4 d-k	108.7 f-k	33.0 a-d	31.5 a-e	32.2 a-c	34.3 d-f	35.6 c-h	35.0 d-g
UC-1	24.8 b-e	24.6 a-g	24.7 b-f	47.7 d-l	47.9 e-l	47.8e-j	208.8 a	223.0 a	215.9 a	30.5 c-i	29.8 a-i	30.2 c-i	63.7 a	66.6 a	65.1 a
US-10	28.8 a-b	30.4 a-b	29.6 a	46.8 e-l	47.9 e-l	47.4f-k	119.2 c-f	159.8 b-d	139.5 c-e	30.0 d-j	30.8 a-h	30.4 c-g	35.9 c-e	49.2 bc	42.6 c-d
Rinconada	18.1 g-l	18.7 f-j	18.4 k-n	43.4 i-n	46.0 i-m	44.7i-m	70.7 h-o	100.6 f-m	85.7 j-p	29.5 e-k	30.8 a-h	30.2 c-i	20.9 h-m	31.0 f-l	25.9 h-n
CH-353	18.3 g-l	22.8 c-i	20.6 g-n	45.2 h-l	48.5 e-l	46.9g-k	70.2 i-o	91.2 f-n	80.7 k-q	29.4 f-l	29.6 a-j	29.5 c-k	20.6 h-m	27.0 g-n	23.8 j-o
Sidwill	15.6 i-l	22.6 c-i	19.1 i-n	46.8 e-l	48.8 d-l	47.8e-j	71.2 h-o	81.6 i-n	76.4 l-r	27.5 i-n	27.1 e-l	27.3 j-o	19.7 i-n	22.2 h-o	21.0 k-p
San Jose-89	26.1 a-c	27.8 a-c	26.9 a-c	45.2 g-m	47.3 f-l	46.3h-l	89.6 f-l	136.5 c-f	113.1 d-j	31.6 b-g	30.3 a-i	31.0 b-f	28.3 e-i	41.3 c-f	34.8 d-h
Royal	22.3 c-g	24.6 a-g	23.5 c-h	45.2 g-m	47.7 f-l	46.5g-k	77.9 g-n	125.5 d-i	101.7 f-l	30.4 c-j	30.5 a-i	30.5 c-g	23.8 f-l	38.3 c-g	31.0 e-j
Gila	25.4 b-d	27.8 a-c	26.6 a-d	47.9 c-k	48.2 e-l	48.1f-i	168.9 b	192.0 ab	180.5 b	29.5 e-l	29.8 a-i	29.6 c-j	49.8 b	57.1 ab	53.5 b
Yuyao	19.4 e-j	28.1 a-c	23.7 c-g	52.9 a-c	49.8 c-j	51.4b-d	95.9 e-k	127.5 d-i	111.7 e-j	26.4 k-o	27.0 e-m	26.7 k-p	25.2 e-k	34.5 d-i	29.9 e-k
Shufu	8.5 n	8.0 k-l	8.2 q	52.0 a-d	55.6 ab	53.8a-c	66.3 j-p	57.6 m-o	62.0 o-s	22.8 p	22.3 m	22.6 r	15.1 k-o	12.8 o-q	14.0 p-r
Huaxian	12.9 l-n	13.8 j-k	13.4 o-p	50.3 b-g	49.7 d-j	50.0d-g	46.8 m-r	64.9 l-o	55.9 p-s	26.6 k-o	24.7 k-m	25.7 n-q	12.4 l-o	16.0 n-q	14.2 p-q
FO-2	19.1 f-k	27.5 a-d	23.3 c-j	51.7 a-e	56.4 a	54.1a-c	100.7 e-k	154.7 b-e	127.7 c-g	26.7 k-o	25.0 j-m	25.9 n-q	26.9 e-k	38.5 c-g	32.7 e-j
Gifford	31.5 a	27.4 a-d	29.5 a	53.5 a-b	54.9 a-c	54.2ab	150.0 b-d	135.3 d-f	142.7 c-d	29.2 f-l	23.7 k-m	26.4 m-p	43.7 b-d	32.0 f-k	37.9 d-e

Means with identical letters in the same column are not statistically significant at the level of $p<0.01$.

Reducing the hull content in safflower is one of the significant goals of breeding programs. In the study, Ziyang, Gifford, FO-2 and Shufu had the highest hull content in 2011 and 2012; and according to the average of both years. Besides, Yuyao and Saffire in 2011 and Yenice 5-38, AC Stirling and AC Sunset in 2012 were the genotypes with high hull content. Arizona SC III had the lowest hull content value in 2011, 2012, and the average of the both years (25.0, 26.7, and 25.9%, respectively) (Table 5). It was reported that the genes controlling the seed hull thickness in safflower, also control the secondary wall thickening in stem cells and anther dehiscence of flowers (structural sterility) by having a pleiotropic effect. Therefore, genotypes with a thin hull have both thin stems with low fertility (Weiss, 2000). Arizona SC III had the lowest hull content and the highest oil content whereas its seed and oil yields were the lowest among the study material. Rudra Naik et al. (2009) reported that the environment may affect the hull content; however, the vast majority of the variation for hull content was due to genetic factors.

The seed yields of the genotypes ranged from 17.0 to 208.8 kg da^{-1} in 2011, from 13.5 to 223.0 kg da^{-1} in 2012, and from 15.2 to 215.9 kg da^{-1} for the average of both years. For combined yields of both years, the highest seed yield was determined in UC-1 but the lowest seed yield in Arizona SC III. Gila and Dincer 5-118 also had high seed yields (192.0 and 183.3 kg da^{-1}, respectively) in 2012. Of the registered cultivars in Turkey, only Dincer 5-118 gave a higher seed yield in both years than Remzibey-05 and Yenice 5-38 (Table 5). The seed yield of a genotype in a given year might vary by light, water, precipitation, temperature, humidity, and nutrient competition (Koutroubas et al., 2004). Additive genes affect the inheritance of the seed yield along with the environmental factors therefore seed yield show low heritability (Ghongade et al., 1993; Reddy et al., 2004; Camas and Esendal, 2006; Erbas, 2012). In the world, 40-170 kg da^{-1} of yield could be obtained from safflower under non-irrigated conditions, but up to 300 kg da^{-1} of yield can be obtained under favorable cultivation conditions (Weiss, 2000). The yield obtained from different safflower genotypes under arid conditions in the studies performed in different ecological regions in Turkey ranged from 113.1 to 316.4 kg da^{-1} under the conditions of Ankara (Kolsarici and Ekiz, 1983), from 45 to 170 kg da^{-1} under the conditions of Antalya (Baydar and Turgut, 1992), from 84.9 to 125.5 kg da^{-1} under the conditions of Kahramanmaras (Atakan, 1992), from 207.7 to 339.7 kg da^{-1} under the conditions of Eskisehir (Celikoglu, 2004), from 77.4 to 167.8 kg da^{-1} under the conditions of Erzurum (Öztürk et al., 2008), and from 45.6 to 298.0 kg da^{-1} under the conditions of Samsun (Camas and Esendal, 2006).

Safflower has lower oil content than the other important oilseed crops (e.g. sunflower, rapeseed, peanut, and sesame). The oil contents of the genotypes varied between 22.6 and 33.8% on average in the study. The highest oil content was determined in Centennial (33.8%), Oleic Leed (33.8%), Arizona SC III (33.8%), followed by Finch (33.3%) Ole (32.2%), S-517 (31.8%), Enana (31.5%) and Leed (31.4%) based on the average of both years. The lowest oil content was recorded in Shufu in both years (Table 5). The oil content is known to vary between 25 and 40% in commercial safflower cultivars (Knowles, 1982). Johnson et al. (1999) reported that the oil content ranged from 13 to 46% among 797 safflower introductions and the mean oil content was 27.0% among 137 introductions originated from Mediterranean basin, encompassing the safflower genotypes of Turkey as well. Fernandez-Martinez et al. (1993) reported that 200 safflower accessions from 37 countries contained 20.1 to 40.0% oil. Besides, safflower lines whose oil content could increase up to 55.0% were developed through intensive breeding research (Rubis, 2001). Oil content is known to change depending on cultivar, soil characteristics, and climate. By evaluating the results of the present study, it can be stated that said results are in accordance with those of previously published reports. The results could also be used to confirm that spiny safflower cultivars contain more oil than spineless cultivars (Weiss, 2000).

The oil yield of the genotypes varied between 5.1 and 65.1 kg da^{-1} for the average of both years. With the highest seed yield, UC-1 had the highest oil yield followed by Gila (53.5 kg da^{-1}). Even though, Arizona SC III had the highest oil content, it had the lowest oil yield due to its low seed yield (Table 5). Omidi (2000) reported that oil yield was significantly and positively correlated with seed yield and oil yield would also increase with increase in seed yield. Ada (2013) reported that the oil yield was in the range of 20.9-57.9 kg da^{-1} on average in the safflower genotypes under Konya conditions, while Beyyavas et al. (2011) reported that oil yield ranged from 24.2 to 54.3 kg da^{-1} on average under Adıyaman conditions. Since the genotypes displayed variations in seed yield and oil content in the present study, they also displayed a large variation in oil yield.

The fatty acid composition of the safflower genotypes is presented in Table 6. There are differences in the fatty acid composition of the genotypes. However, when the genotypes were examined individually, there were no marked changes in the fatty acid compositions for both years. The palmitic acid content was in the range of 9.1-13.7% in 2011 and in the range of 9.2-12.9 in 2012. Stearic acid content ranged between 2.5 to 5.3% in 2011 and between 2.4 to 5.6% in 2012. The highest palmitic acid content was found in FO-2 in both years, whereas the lowest palmitic acid content was detected in Montola 2000 and S-517 (9.1%) in 2011 and in Montola 2000 and Ole (9.2%) in 2012. The lowest stearic acid content was observed in PCA (2.5 and 3.1%) and UC-1 (3.0 and 2.4%) in 2011 and 2012, respectively. The highest stearic acid content was determined in Oker (5.3 and 5.6%). Knowles (1989) reported that there was a recessive gene (*st*) which controlled the synthesis of the stearic acid and that many safflower cultivars with different stearic acid contents were available.

Table 6. Fatty acid composition of safflower genotypes in 2011 and 2012.

	2011				2012			
	$C_{16:0}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{16:0}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$
Quiriego-88	10.9	4.2	18.5	65.7	11.0	4.2	20.1	64.6
Oker	11.8	5.3	14.1	67.9	11.0	5.6	16.5	66.5
AC Sunset	10.1	3.8	12.9	72.7	11.0	3.4	15.2	70.1
Enana	11.0	4.0	24.5	60.1	10.0	3.8	27.3	58.0
Sahuaripa-88	11.3	3.5	17.9	66.8	12.0	3.4	21.0	63.4
Montola-2000	9.1	3.2	60.2	26.9	9.2	3.6	64.2	22.4
AC Stirling	11.0	3.9	25.0	60.0	10.4	3.4	24.9	60.7
4022	10.9	3.3	21.5	63.5	9.8	3.9	22.6	62.9
PCA	10.5	2.5	13.2	73.2	10.2	3.1	15.3	70.8
Frio	12.9	3.9	14.5	67.8	12.6	3.2	14.9	68.7
Oleic Leed	9.2	3.3	46.6	40.3	9.8	3.9	47.9	37.9
Dincer 5-118	13.1	4.3	12.9	68.8	12.7	4.9	13.6	68.2
Yenice 5-38	11.1	4.2	12.3	71.8	10.5	3.9	14.3	71.0
Remzibey-05	12.3	3.3	17.9	68.0	11.5	3.6	18.9	65.7
Centennial	12.8	5.1	15.2	63.5	12.6	5.3	15.7	66.4
S-517	9.1	4.0	68.3	18.0	10.2	3.9	71.6	14.2
Lesaf	10.4	3.8	21.9	63.4	11.0	3.4	22.6	63.0
Saffire	9.7	3.5	20.5	65.6	10.0	2.9	20.6	66.5
Rehbein	9.9	3.8	13.6	72.1	10.3	4.6	14.0	70.4
Finch	11.1	4.5	12.5	71.4	11.4	4.5	12.8	70.8
Leed	9.2	3.1	12.3	74.7	9.5	3.6	13.0	73.9
Arizona SC III	12.1	3.7	13.2	70.5	11.5	3.2	14.0	71.3
NO 55-633	10.4	3.5	65.4	19.6	11.0	2.9	68.1	17.3
Hartman	9.9	4.2	22.5	62.8	10.3	3.1	23.7	62.9
Ziyang	10.5	4.2	18.1	66.7	9.7	3.6	19.0	67.2
Ole	8.6	3.2	62.9	24.7	9.2	3.8	63.9	23.1
UC-1	10.3	3.0	65.3	20.5	11.0	2.4	67.8	18.8
US-10	11.9	3.3	16.8	67.3	11.0	3.6	17.3	67.3
Rinconada	10.6	3.6	17.2	68.0	12.0	3.1	18.1	66.8
CH-353	12.1	4.3	12.8	70.3	11.6	3.5	15.2	69.7
Sidwill	10.9	4.1	14.7	69.8	11.5	4.3	16.4	67.8
San Jose-89	11.4	5.1	15.0	68.0	12.4	4.6	17.2	65.1
Royal	13.7	4.4	13.0	66.9	12.8	4.8	14.1	68.1
Gila	12.8	4.0	14.4	67.9	11.9	3.5	15.0	69.4
Yuyao	12.2	3.7	22.9	60.7	12.0	4.2	23.0	60.8
Shufu	11.6	4.0	11.1	71.4	11.3	4.3	12.0	72.4
Huaxian	12.6	3.9	13.3	69.6	11.4	3.4	13.7	70.9
FO-2	14.6	3.8	12.0	68.9	12.9	4.6	12.9	69.6
Gifford	11.4	4.3	15.5	68.1	11.4	4.5	16.1	67.1

$C_{16:0}$, palmitic acid; $C_{18:0}$, stearic acid; $C_{18:1}$, oleic acid; $C_{18:2}$, linoleic acid

Likewise, Johnson et al. (1999) reported that the palmitic acid ranged from 3.9 to 6.8% and the stearic acid from 1.1 to 4.5% among 797 safflower introductions. Even though the agriculture of linoleic acid rich safflower cultivars is widely carried out in the world, the interest in the cultivars with high oleic acid content has increased as oil has been displaying high stability in the recent years (Weiss, 2000). The oleic and linoleic acid contents of the genotypes showed wide variation. Variation for oleic acid was between 11.1 and 68.3% in 2011 and between 12.0 and 71.6% in 2012. Linoleic acid content varied between 18.0 and 74.7% in 2011 and between 14.2 and 73.9% in 2012. Montola 2000, Ole, UC-1, NO 55-663 and S-517 were found to contain more than 60% oleic acid. On the other hand, the other genotypes contained more than 60% linoleic acid with the exception of Oleic Leed which contained moderate oleic and linoleic acids (46.6 and 40.3% in 2011 and 47.9 and 37.9% in 2012, respectively) (Table 7). Fernandez-Martinez et al. (1993) reported variation for oleic (3.1-84.2%) and linoleic (9.1-89.2%) acids was large among the 200 safflower accessions. Velasco and Fernandez-Martinez (1999) reported that the 132 accessions examined from the US safflower collection contained 5.8% palmitic acid (3.4-10.2%), 2.2% stearic acid (0.8-9.9%), 26.2% oleic acid (5.6-86.9%), and 65.9% linoleic acid (7.1-88.7%) on average. The oleic acid contents of the genotypes were relatively higher in 2012 than in 2011. Temperatures in the flowering and seed development periods (July-August) were higher in 2012. It is known that temperature fluctuations have significant effects on the fatty acid composition in safflower (Bartholomew, 1971). With the increased temperatures, there is a decrease in the activity of the enzymes catalyzing the synthesis of linoleic and linolenic acids from oleic acid. Therefore linoleic acid synthesis increase when plants grow in a cool climate, but synthesis of oleic acid increase during the hot growing conditions in safflowers (Röbbelen et al., 1989; Broun and Somerville, 1997). This gives rise to highly negative correlations between oleic and linoleic acids (>-0.90**) (Knowles, 1989; Erbas, 2012).

Due to its high tolerance for aridity and moderate tolerance to cold due to the strong root structure, safflower is one of the most likely alternative oilseed crops to be utilized in the arid and semi-arid agricultural lands of Turkey. The most important goals of safflower breeding include seed yield and oil content increase. The oil contents and seed yields of the available cultivars in Turkey are not at the desired level. To reach economic level of yield from safflower, new safflower cultivars should be introduced along with modern cultivation methods. Superior lines may be obtained from the transgressive likely segregation to occur upon the hybridization of genotypes with high oil or seed yield. Large variations in seed yield, oil yield, oil content, and fatty acid composition were observed in the present study, in which the adaptation performances of 39 safflower genotypes were examined in 2011 and 2012. UC-1 was detected to be the genotype with high values in terms of seed and oil yield. For oil content, Arizona SC III, Oleic Leed, Centennial, Finch, Ole, S-517, Enana and Leed were the genotypes with the highest oil content. The available cultivars in Turkey all have high linoleic acid content. Identification of new genotypes with high oleic acid content may allow modifying the fatty acid composition of the available cultivars with the breeding methods. Further studies to assess the adaptability of the genotypes examined in this paper might be necessary for other characters.

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