

Determination of Some Agronomic Characteristics and Fatty Acid Compositions of Anatolian Safflower (*Carthamus tinctorius* L.) Genotypes

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Research Article

Keywords: Safflower, Gene Bank, Seed Yield, Oil Quality, Oil Yield, Oil Ratio

Posted Date: March 6th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9019610/v1>

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Additional Declarations: No competing interests reported.

Abstract

This study aimed to evaluate the agronomic, yield, and quality traits of 16 Anatolian safflower (*Carthamus tinctorius* L.) genotypes and five local safflower cultivars under the winter ecological conditions of Menemen, İzmir, which is characterized by the climatic features of the coastal Mediterranean region. The field experiment was carried out in the 2019–2020 and 2020–2021 growing seasons under field conditions, with 4 replications, using a Randomized Complete Block Design. The results revealed that seed yield ranged from 982 to 2379 kg ha⁻¹, the maturation period spanned 214 to 229 days, oil content ranged from 28.32% to 34.47%, and oil yield ranged from 322,8 to 793,6 kg ha⁻¹. Fatty acid composition included linoleic acid (38.99–76.94%), oleic acid (12.71–51.17%), palmitic acid (5.87–7.93%), and stearic acid (1.91–3.31%). In addition to these findings, it was determined that all safflower genotypes evaluated in the experiment exhibited lodging resistance. Among the genotypes, TR 42670 exhibited high seed and oil yields, TR 50118 demonstrated superior oil content, and TR 49117 was distinguished by its elevated linoleic acid content, indicating they are promising genotypes for varietal development. Among the cultivars, 'Linas' was notable for its high seed yield and linoleic acid content; 'Olas' excelled in seed yield, oil yield, and oleic acid content, 'Balci' showed superior oil content, and 'Asol' was characterized by its high oleic acid content. These cultivars are particularly recommended for the coastal Mediterranean climate during the winter season under natural rainfall conditions and high yield and high oil quality can be obtained.

1. Introduction

Challenges such as climate change, drought, the diversion of agricultural land for non-agricultural purposes, and population growth are exerting increasing pressure on agricultural production systems. Compounding these issues, the unexpected Covid-19 pandemic has led to a dramatic surge in food and vegetable oil prices, with increases exceeding 100% for certain vegetable oils (USDA 2022). Globally, leading producers of oilseed crops including Brazil, the USA, China, Argentina, India, Russia, and Ukraine account for approximately 576 million tons of production across 260 million hectares. In contrast, Turkey contributes only 0.56% to global production, with an annual oilseed output of approximately 3.4 million tons (USDA 2022).

In the future, cultivating plant species and varieties tolerant to increasingly adverse conditions will become crucial. Safflower is known for its resilience to drought, salinity, and weeds, as well as to arid environments (Francois and Bernstein 1964). Its deep root system enables the plant to access moisture and nutrients, particularly nitrogen, from soil layers beyond the rooting depth of most other crops (Yau and Ryan 2010). Additionally, safflower oil, rich in linoleic acid, iodine, and tocopherol, offers potential therapeutic applications for modern health conditions (Koyama et al. 2009). Safflower is a versatile alternative oilseed crop, suitable for both dryland and irrigated agriculture, with minimal climate and soil requirements and limited pest vulnerability (Cosge et al. 2007; Majidi et al. 2011). Its cultivation requires no specialized mechanization, as standard tools used in cereal farming are sufficient (Babaoglu 2011). Globally, approximately 653 thousand tons of safflower seeds are produced on 817 thousand hectares, yielding 77 thousand tons of oil annually (FAO 2022). As of 2022, Kazakhstan, Russia, India, the USA, and Mexico rank as the top five countries in safflower cultivation area, while Turkey holds the sixth position with 30,000 hectares of cultivation (FAO 2024).

Knowles (1969) identified the origin of safflower as stemming from two wild species: *Carthamus flavescentis*, native to Turkey, Syria, and Lebanon, and *Carthamus palaestinus*, originating from Eastern Iraq and Southern Israel. He also noted that one of the seven centers of diversity for similar types is a region extending from Turkey to Afghanistan. Chapman et al. (2010) further reported that safflower (*C. tinctorius* L.), an oilseed crop, is believed to have been domesticated in the Fertile Crescent and is classified into five distinct genetic clusters: 1) Europe, 2) Turkey, Iran, Iraq, Afghanistan, 3) Israel, Jordan, Syria, 4) Egypt, Ethiopia, and 5) the Far East, including India and Pakistan. Anatolia is recognized as one of the genetic centers of safflower, with wild safflower species still found in Turkey (Davis 1975).

Ojaq et al. (2020) emphasized the need for new superior safflower cultivars to address two primary challenges: low seed yield and a long vegetation period. Similarly, La Bella et al. (2019), in a study conducted in Sicily, Italy, with 16 safflower genotypes and one registered variety, concluded that the limited expansion of safflower cultivation in central-southern Italy is due to the extended vegetation period, lasting approximately 240 days as a winter crop (November to July) and 145 days as a spring crop (February to July), coupled with low seed yield. Ahmed et al. (2019), using 27 mutant safflower lines and their parents over six seasons in Egypt, also identified the long vegetation period (180–190 days), along with low seed and oil yields, as reasons for the decline in safflower cultivation in Egypt, underscoring the importance of breeding early-maturing and spineless lines.

Uslu et al. (2001) reported that safflower varieties require 1680–1900°C (272–284 days) to mature under winter sowing conditions and 1580–1770°C (104–114 days) under summer sowing. According to Weiss (2000), the ideal safflower variety should mature within 130–150 days. Plants with shorter vegetation periods are less vulnerable to early fall and late spring frosts and are better able to avoid the effects of the dry summer period (Kilic 2010). Koutroubas and Papakosta (2005) noted that early maturity in safflower can improve yield by enabling plants to escape drought stress during seed filling, thereby enhancing seed set and overall productivity.

This study aimed to evaluate the agronomic, yield, and quality characteristics of safflower genotypes collected from various regions of Anatolia and preserved in the gene bank, specifically for winter planting under Mediterranean climate conditions. The study sought to identify genotypes with potential as variety candidates and to highlight their unique traits, thereby providing valuable genetic resources for plant breeders. Additionally, this research represents the first study conducted with Anatolian-origin safflower genotypes to assess their suitability as a winter intermediate crop in the İzmir Menemen Plain, a region representative of the coastal Mediterranean climate, and to identify genotypes adapted to these conditions.

2. Materials and Methods

In this study, 16 different safflower (*C. tinctorius* L.) genotypes originating from Anatolia, obtained from the Izmir Menemen Aegean Agricultural Research Institute (AARI) Gene Bank, and 5 local safflower varieties were used (Tables 1 and 2).

The field experiment was carried out in the experimental fields of İzmir Ege University Faculty of Agriculture Menemen Research and Application Farm (38°34'45.4 "N, 27°01'23.4 "E) in the 2019–2020 and 2020–2021 growing seasons under field conditions with 4 replications according to the Randomized Complete Block Design.

Table 1
Safflower genotypes of Anatolian origin used as material in the study

Genotype	Origin (Province)	District	Altitude (m)
TR 42942	Balikesir	Balya	300
TR 51504	Bolu	Goyunuk	540
TR 50118	Bursa	Harmancik	780
TR 50120	Bursa	Harmancik	780
TR 49116	Isparta	Gelendost	850
TR 49117	Isparta	Gelendost	850
TR 49118	Isparta	Gelendost	860
TR 42630	Edirne	Havsa	40
TR 42631	Edirne	Havsa	40
TR 42642	Kirklareli	Imampazari	40
TR 42646	Edirne	Uzunkopru	40
TR 42660	Kirklareli	Vize	90
TR 42666	Kirklareli	Vize	160
TR 42667	Kirklareli	Vize	160
TR 42670	Tekirdag	Saray	240
TR 73821	Eskisehir	Gunyuzu	991

Table 2
Safflower varieties used as material in the study

Variety	Registrant Institution/Organization
Asol	Sanliurfa Southeastern Anatolia Agricultural Research Institute
Balci	Eskisehir Anatolian Agricultural Research Institute
Olas	Edirne Trakya Agricultural Research Institute
Linas	Edirne Trakya Agricultural Research Institute
Safir	Edirne Trakya Agricultural Research Institute

In the study area, where the typical Mediterranean climate prevails, the long-term average annual precipitation is 546.70 mm and the average annual temperature is 17.01 °C (AARI 2022). In 2020, the first year of the research, during the week of May 14–21, 2020, the temperature exceeded seasonal normals (May average long years 20.10 °C) and reached 38 °C, and as of May 21, temperatures dropped rapidly to 16 °C on May 27. In June 2020, rainfall (34.20 mm) was much higher than the long-term rainfall average (9.79 mm). For this reason, June 2020 was quite humid (60.14%), above the long-term humidity average (49.65%). The months of October and November of 2020 were very dry before the 2021 sowing, the second year of the research (long-term average 112.65 mm, rainfall 28.40 mm). After sowing in the second year of the experiment, December 2020 received 172.80 mm of precipitation, well above the long-term average of 104.04 mm (65.60 mm in December of the previous year). Similarly, January 2021 received 164 mm of rainfall, which is above the long-term average (97.99 mm) and higher than January 2020 (47.20 mm). May 2021 was very dry (long-term average 27.27 mm, rainfall 0.20 mm). The total precipitation in 2019, 2020 and 2021 was 740 mm, 518.60 mm and 406.40 mm, respectively. Considering the long years average precipitation (546.70 mm), it can be said that 2019 was wetter and 2021 was drier.

Table 3
Experimental period and long years climate data of the experimental area (AARI 2022)

Months	Climate Data Of The Trial Years (December 2018 to January 2022)									LONG YEARS CLIMATE DATA (1954–2019)		
	Average			Total			Average			Average	Total	Average
	Temperature (C°)			Precipitation (mm)			Humidity (%)			Temperature (C°)	Precipitation (mm)	Humidity (%)
2019	2020	2021	2019	2020	2021	2019	2020	2021				
January	8.16	7.55	10.50	310.20	47.20	164.00	76.28	64.85	73.31	7.83	97.99	66.95
February	9.28	9.90	10.70	105.00	72.80	62.60	70.42	69.12	66.26	8.95	73.86	64.29
Mart	12.28	12.71	10.36	33.60	62.40	129.60	62.04	67.39	65.19	11.17	62.29	62.43
April	15.14	15.18	15.78	57.60	52.20	33.20	61.32	59.87	63.21	15.12	41.22	59.26
May	20.51	20.74	21.61	3.60	48.60	0.20	59.23	58.79	56.57	20.10	27.27	55.80
June	26.34	24.06	24.87	27.60	34.20	16.80	55.01	60.14	55.14	24.74	9.79	49.65
July	27.02	28.45	29.30	20.60	0.00	0.00	51.35	50.25	47.30	27.06	2.58	47.44
August	28.55	27.79	28.60	0.00	0.00	0.00	47.81	50.28	48.50	26.57	2.51	49.23
September	23.28	25.62	23.60	28.00	0.00	2.80	58.18	57.03	50.65	22.40	12.49	55.11
October	19.69	20.16	17.90	29.40	25.40	62.20	72.17	68.56	63.50	17.51	38.76	61.07
November	16.55	13.70	15.69	59.20	3.00	54.00	74.12	57.67	71.20	13.04	73.89	65.24
December	10.35	12.44	10.80	65.60	172.80	54.00	75.53	74.76	74.19	9.62	104.04	68.12
Mean	18.10	18.19	17.59	61.70	43.22	67.73	63.62	61.56	63.28	17.01	45.56	58.72
Total	217.15	218.32	123.12	740.40	518.60	406.40	763.45	738.71	379.69	204.10	546.70	704.58

The soil of the research area has a sandy-loamy texture and a low salt content. While the upper and middle layers are slightly alkaline, the soil becomes strongly alkaline as it goes deeper. While the top layer is calcareous, the lime rate increases as the soil deepens. Organic matter is low in the upper and middle layers, and it gradually decreases as the soil deepens. The soil phosphorus is insufficient, and it decreases with depth. The amount of potassium is sufficient (Gucdemir 2006). In the experiment established for the research, each plot was 3 meters long and 5 rows, the distance between the rows was 20 cm and the distance above the row was 8 cm. The length of each block was 21 meters and the area was 63 m². A gap of 2.5 m was left between the blocks. In the plots, the 1st and 5th rows were bordered and the plants in the middle three rows (1.8 m²) in each plot were harvested. Sowing was done on November 12, 2019 in the first year and on November 17, 2020 in the second year. In both years of the experiment, 30 kg of pure nitrogen, 30 kg of phosphorus and 30 kg of potassium per hectare were applied as base fertilizer before sowing and 42 kg of pure nitrogen per hectare was applied as top fertilizer before the second hoeing. Thinning, hoeing, and disease and pest control were carried out as needed. Harvesting was carried out between 03–09 July 2020 in the first year and 05–10 July 2021 in the second year.

Table 4
Soil characteristics of the experimental area (Altitude :5 m, Land Type :Valley,
Relief :Alluvial Plain)

Feature	Horizon and Depth		
	Ap (0–41 cm)	C1 (41–90 cm)	C2 (90–125 cm)
pH	7.55	7.75	8.24
EC (μS/cm)	308	705	123.3
CaCO ₃ (%)	9.67	6.96	6.19
Sand (%)	64	86	84
Mile (%)	23.28	9.28	9.28
Clay (%)	12.72	4.72	6.72
Composition	Sandy loam	Loamy Sand	Loamy Sand
Organic Matter (%)	1.84	1.53	0.88
% Total Nitrogen	0.101	0.067	0.073
P (ppm)	3.12	2.16	1.57
Ca (ppm)	3160	2772	2772
K (ppm)	155.2	67.9	77.6
Na (ppm)	38.4	28.8	28.8
Mg (ppm)	405.7	270.6	285.2
Fe (ppm)	3.14	2.63	2.09
Cu (ppm)	0.37	0.27	0.19
Zn (ppm)	1.62	0.59	0.24
Mn (ppm)	2.19	1.00	0.76

Observations were made on 10 plants randomly selected from each plot. Plant height (cm), number of lateral branches (number), number of heads (number), number of seeds per head (number), head diameter (cm), thousand seed weight (g), 50% flowering days (days), maturation days (days), seed yield (kg ha⁻¹), harvest index (%), oil ratio (%), oil yield (kg ha⁻¹), fatty acid composition (%) (linoleic, oleic, palmitic and stearic acid ratio) were analyzed. Oil content was calculated as percentage (%) by SupNIR-2700 Near Infrared Analyzer of Ege University Faculty of Agriculture, Department of Field Crops Laboratory (Zhao et al. 2020; Keskinoglu 2022). Fatty acid composition was determined by Agilent brand and 7890B model gas chromatograph with the Aocs Ce 1-62-09 method (Ersahin 2018).

The data obtained in the research were subjected to analysis of variance to determine the differences between genotypes using the statistical analysis package program "TOTEMSTAT" (Acikgoz et al. 2004). The average groupings were determined using the Least Significant Difference (LSD) method (Steel and Torrie 1960).

3. Results And Discussion

3.1. Yield and Yield Components

The results of the analysis of variance for yield and some yield components, and the comparison of means according to the LSD (0,05) test, are given in Table 3. Environmental differences between growing seasons significantly influenced the number of heads at the $p < 0.05$ level, while other traits were more strongly affected ($p < 0.01$). All yield and yield components were significantly affected by genotype ($p < 0.01$). In the second year (2021) of the trial, when drier weather conditions prevailed, leading to a decrease in yield and its components, except for the number of seeds per head. This reduction resulted in a significant year $\times$ genotype interaction. Although the interaction's effect on the number of seeds per head was statistically insignificant, it significantly impacted plant height ($p < 0.05$). It showed highly significant effects ($p < 0.01$) on other parameters.

In our study, average plant heights ranged from 110.07 cm (TR 49117) to 135.16 cm (Linan) in 2020, and from 108.36 cm (TR 49117) to 126.23 cm (TR 42630) in 2021. The overall average plant height of the varieties was 126.11 cm in 2020 and 120.90 cm in 2021, while the average height of Anatolian-origin safflower genotypes was 122.40 cm and 115.54 cm for the respective years. Notably, the genotype TR 42630 (125.70 cm) exhibited plant height comparable to the Linan variety, outperforming several other varieties and Anatolian-origin genotypes. Additional genotypes, such as TR 42631 and TR 42666, also showed notable performance in plant height. La Bella et al. (2019) and Licata et al. (2023) reported plant heights similar to those in our study (101.16-149.17 cm and 113–118 cm, respectively) under Sicilian conditions in Italy. Bardhi et al. (2023) under Albania conditions, Houmanat et al. (2017) under Douyet conditions in Morocco, Zanetti et al. (2022) under Toscana and Emilia-Romagna conditions in Italy, Attia et al. (2024) under Cairo conditions

in Egypt, Mazeed et al. (2024) under Sohaq conditions in Egypt, Stavropoulos et al. (2022) under Greece conditions reached different plant height results from our research (105–165 cm, 61.57-107.87 cm, 87–104 cm, 146.87-160.04 cm, 144.5–182 cm, 80.75-104.75 cm, respectively). Safflower genotypes of Anatolian origin appeared to perform better than commercial cultivars under heat stress conditions, particularly in the second year of the study. This aligns with Babaoglu's (2006) findings, which reported that safflower plants typically grow to a height of 80–100 cm. In contrast, Weiss (2000) emphasized that the optimal plant height for safflower, taking into account factors such as mechanized harvesting, improved solar radiation exposure, higher harvest index, and lodging resistance, should range from 60–80 cm. The average plant heights observed in our study were significantly higher than the ideal range reported by previous researchers (Babaoglu 2006; Weiss 2000). For instance, the Linas variety, a modern cultivar, achieved a plant height of 135 cm in the first year of the study. Despite these elevated heights, no lodging issues were observed in either year, indicating that the genotypes used in this research possess high lodging resistance. Researchers such as Bardhi et al. (2023), Attia et al. (2024) and Mazeed et al. (2024) obtained considerably taller plants (105–165 cm, 146.87-160.04 cm, 144.5–182 cm, respectively) compared to our study but did not mention any lodging problem. These findings suggest that safflower genotypes with high lodging resistance can achieve substantial plant heights in regions with elevated groundwater levels. This makes safflower cultivation viable in such areas without concerns regarding lodging, provided that appropriate high-resistance genotypes are selected. The results of the study indicated that the mean number of heads ranged from 6.84 (TR 42667) to 16.27 (Olas) in 2020 and from 7.00 (TR 42666) to 14.23 (Olas) in 2021. The average number of heads for varieties was 12.78 in 2020 and 11.73 in 2021, while for Anatolian-origin safflower genotypes, these averages were 9.37 and 9.26, respectively. The number of heads is one of the three most critical selection criteria influencing seed yield in safflower plants, with values reported to range between 5 and 50 depending on the safflower breeder (Weiss 1983). These findings underscore the importance of genotype selection for optimizing seed yield through traits such as head number. In the second year of the study, May, which marks the transition to the generative period, was exceptionally dry, with precipitation levels nearly negligible at 0.20 mm compared to the long-term average of 27.27 mm. Despite these challenging conditions, the results indicated that the Olas and Safir varieties excelled in terms of head number.

Table 5
Analysis of variance, mean values and LSD groups for yield and some yield components

Variety / Genotype		Plant Height (cm)		Number of Heads		Number of Seeds Per Head	Thousand Seed Weight (g)		Seed Yield (kg ha ⁻¹)		Maturation Days (day)	
		2020	2021	2020	2021	Mean of 2020 and 2021 years	2020	2021	2020	2021	2020	2021
Asol		120.23 bcd	113.45 c-g	11.70 cd	10.70 cd	25.40 i	36.37 bcd	32.69 d	1638.4 ef	1408.4 efg	222,25 a	215,25 a
Balci		125.30 bc	119.57 a-e	10.34 ef	9.93 def	27.79 gh	35.30 cde	33.30 bcd	1287.0 ij	1282.7 ghi	223,25 abc	215,00 a
Linaz		135.16 a	125.37 a	12.07 c	11.67 bc	25.04 i	41.45 a	36.76 a	2378.6 a	2326.7 a	223,50 abc	215,50 a
Olas		121.93 bc	119.86 a-e	16.27 a	14.23 a	29.64 c-h	35.77 b-e	35.11 abc	2350.0 ab	2281.6 a	222,25 a	215,25 a
Safir		127.90 ab	115.23 b-g	13.50 b	12.15 b	29.52 d-h	36.81 bc	31.79 de	1927.6 c	1665.8 cd	222,75 ab	217,50 b
TR 42630		125.16 bc	126.23 a	10.52 def	11.77 bc	30.85 cd	27.45 ghi	29.91 e	1093.3 k	1151.9 ij	223,25 abc	222,50 efg
TR 42631		117.83 cde	123.06 ab	8.47 ghi	10.13 def	30.06 cde	28.84 fgh	27.34 fg	1149.7 jk	982.1 k	224,50 c	222,25 efg
TR 42642		121.56 bc	119.46 a-f	8.27 hi	9.33 efgh	29.78 c-g	25.81 i	26.42 g	1132.8 k	1110.0 jk	224,25 bc	222,75 fg
TR 42646		122.76 bc	120.46 a-d	8.04 hij	9.50 d-h	30.44 cde	37.91 b	29.68 ef	1418.8 ghi	1512.5 ef	223,50 abc	217,25 b
TR 42660		127.63 ab	120.20 a-e	9.77 fg	8.93 fghi	31.63 c	35.66 b-e	31.50 de	1770.7 de	1522.3 e	222,50 a	214,00 a
TR 42666		123.13 bc	121.30 abc	6.87 j	7.00 j	28.80 e-h	34.43 de	29.60 ef	1320.4 i	1175.5 ij	222,75 ab	214,25 a
TR 42667		127.13 ab	113.43 c-g	6.84 j	8.53 ghi	24.65 i	36.90 bc	32.96 bcd	1666.8 def	1423.5 ef	222,50 a	214,25 a
TR 42670		126.55 b	114.22 c-g	8.83 ghi	7.63 ij	35.15 b	30.77 f	31.73 de	2214.9 b	1898.2 b	223,25 abc	218,50 bc
TR 42942		125.00 bc	115.86 b-g	7.73 ij	9.63 d-g	35.60 ab	25.32 i	22.88 h	1535.6 fg	1382.1 fgh	222,25 a	221,25 def
TR 49116		121.76 bc	112.50 d-g	9.23 fgh	8.60 ghi	37.22 a	25.30 i	27.08 g	1709.6 de	1383.6 fgh	227,50 de	221,00 de
TR 49117		110.07 e	108.36 g	9.60 fg	9.43 d-h	28.67 e-h	33.54 e	30.29 e	1919.7 c	1854.3 b	228,00 def	220,25 d
TR 49118		120.66 bcd	115.60 b-g	11.23 cde	9.92 def	35.48 ab	25.51 i	29.79 e	1310.4 i	1262.5 hi	229,25 f	222,25 efg
TR 50118		113.00 de	112.16 efg	11.60 cde	9.81 d-g	27.98 fgh	26.36 i	25.71 g	1802.8 cd	178,05 bc	226,50 d	222,75 fg
TR 50120		125.13 bc	111.40 fg	11.23 cde	9.29 e-h	31.27 cd	29.66 fg	32.79 cd	1393.7 hi	1236.8 ij	229,00 ef	223,00 g
TR 51504		124.52 bc	111.05 g	12.13 c	10.35 de	29.92 c-f	26.67 hi	25.03 gh	1529.5 fgh	1399.9 e-h	222,75 ab	222,75 fg
TR 73821		126.40 b	114.33 c-g	9.56 fg	8.23 hij	27.65 h	30.90 f	35.17 ab	1555.5 fg	1531.9 de	222,50 a	220,00 cd
Mean (varieties)		126.11	120.90	12.78	11.73	27.48	37.14	33.93	1916.3	1793.1	222,80	215,70
Mean (Anatolian genotypes)		122.40	115.54	9.37	9.26	30.95	30.07	29.24	1532.8	1413.0	224,64	219,94
Mean (all genotypes)		123.28	116.82	10.18	9.85	30.12	31.75	30.36	1624.1	1503.5	224,20	218,93
Source of Variation	Year	**		*		**	**		**		**	
	Genotype	**		**		**	**		**		**	
	Year*Genotype	*		**		ns	**		**		**	

Variety / Genotype	Plant Height (cm)		Number of Heads		Number of Seeds Per Head	Thousand Seed Weight (g)		Seed Yield (kg ha ⁻¹)		Maturation Days (day)	
	2020	2021	2020	2021	Mean of 2020 and 2021 years	2020	2021	2020	2021	2020	2021
LSD _{0.05}	8.148		1.315		2.037	2.360		138.50		1.552	
Coefficient of Variation (%)	4.86		9.39		6.84	5.44		6.34		0.55	

Additionally, certain Anatolian-origin safflower genotypes, such as TR 42630 and TR 51504, demonstrated performance levels comparable to most varieties, with the exception of Olas and Safir. These findings highlight the adaptability and potential of specific genotypes under drought stress during critical developmental stages. Zanetti et al. (2022) in Italy Toscana and Emilia-Romagna conditions, Licata et al. (2023) in Italy Sicily conditions, Stavropoulos et al. (2022) in Greece conditions, La Bella et al. (2019) in Italy Sicily ecological conditions, Abou Chehade et al. (2022) in Italy Pisa conditions reached similar results (Respectively 8.6 pcs, 13 pcs, 6.51–14.25 pcs, 10.65-16.00 pcs, 8.30-19.04 pcs) to our research in terms of the number of heads per plant, while Bardhi et al. (2023) in Albania and Houmanat et al. (2017) in Moroccan Douyet conditions reached different results (Respectively 15–28 pcs, 42.44–69.71 pcs).

In our research, the year × genotype interaction was found to be insignificant for the number of seeds per head. Based on the two-year averages, the number of seeds per head ranged from 24.65 (TR 42667) to 37.22 (TR 49116). The average number of seeds per head was 27.48 for the registered varieties and 30.95 for the Anatolian-origin safflower genotypes. Previous studies have emphasized that the number of lateral branches and seeds per head are critical factors influencing seed yield. High-yielding lines can be developed by selecting these traits, and ideal safflower varieties typically exhibit 30–40 seeds per head (Saleh and Farag 2016; Weiss 2000). The number of seeds per head is a key selection criterion in safflower breeding. Our findings indicate that Anatolian-origin safflower genotypes produced more seeds per head than the registered varieties. However, the lower thousand-seed weight of these genotypes resulted in reduced overall seed yield. This highlights the importance of targeting high thousand-seed weight as a breeding objective for Anatolian-origin safflower genotypes. Furthermore, the number of seeds per head in safflower is characterized by high heritability and minimal sensitivity to environmental conditions, as reported by Dhruw et al. (2022). This suggests a strong genetic basis for this trait, making it a reliable target in breeding programs. The findings of our study align with this proposition. The results demonstrated that safflower genotypes of Anatolian origin generally produced more seeds per head than the registered varieties. Furthermore, specific genotypes, such as TR 49116, TR 42942, TR 49118, and TR 42670, exhibited high yield potential. This potential could be further enhanced if these genotypes achieve higher thousand-seed weights through targeted breeding efforts. These observations emphasize the importance of incorporating high thousand-seed weight as a key breeding objective to maximize the yield potential of Anatolian-origin safflower genotypes. Ahmed et al. (2019) reached similar results to our study with 19.75–47.75 seeds under Egyptian conditions, while Houmanat et al. (2017) in Moroccan Douyet conditions, Stavropoulos et al. (2022) under Greek conditions obtained lower results in terms of number seeds per head compared to our study (17.07–21.23 seeds per head, 17.24–27.43 seeds per head, respectively).

In our study, the average thousand-seed weight ranged from 25.30 g (TR 49116) to 41.45 g (Linaz) in 2020 and from 22.88 g (TR 42942) to 36.76 g (Linaz) in 2021. The average thousand-seed weight of registered varieties was 37.14 g in 2020 and 33.93 g in 2021, while for Anatolian-origin safflower genotypes, it was 30.04 g and 29.24 g in the respective years. Safflower yield is strongly correlated with thousand-seed weight. Saleh and Farag (2016) reported a positive and significant relationship between seed yield per plant and factors such as the number of lateral branches, number of heads, number of seeds per head, and thousand-seed weight. Weiss (1983) suggested that breeding programs should aim for a thousand-seed weight of 50 g in safflower. Among Anatolian-origin safflower genotypes, TR 42646 and TR 42667 surpassed the thousand-seed weight of some registered varieties in the first year. However, these genotypes exhibited a significant decline under drought stress in the second year. Conversely, the TR 73821 genotype showed an increase in thousand-seed weight during the second year, although this was accompanied by a decrease in the number of seeds per head. This variability in thousand-seed weight among Anatolian-origin genotypes likely reflects low stability under different environmental conditions. Thus, it is essential to evaluate the performance of these genotypes, which in some cases achieved higher thousand-seed weights than most registered varieties (excluding Linaz), in conjunction with other yield-related factors. This holistic evaluation can better understand their potential for breeding and cultivation under varying conditions. Bardhi et al. (2023) under Albania conditions, Houmanat et al. (2017) under Morocco Douyet conditions, Zanetti et al. (2022) under Italy Toscana and Emilia-Romagna conditions, Licata et al. (2023) under Italy Sicily conditions, Attia et al. (2024) under Cairo conditions in Egypt, Mazeed et al. (2024) under Sohaq conditions in Egypt obtained different thousand seed weight results from our study (31–51 g, 40.01 g, 38.2–40.8 g, 39 g, 45.2–50.5 g, 38.1–51.1 g, respectively).

The average seed yields obtained in 2020 ranged from 1093.3 kg ha⁻¹ (TR 42630) to 2378.6 kg ha⁻¹ (Linaz), while in 2021 they ranged from 982.1 kg ha⁻¹ (TR 42631) to 2326.7 kg ha⁻¹ (Linaz and Olas). In 2020, the average seed yield for registered varieties was 1916.3 kg ha⁻¹, compared to 1624.1 kg ha⁻¹ for Anatolian-origin safflower genotypes. In 2021, these averages decreased to 1793 kg ha⁻¹ and 1413 kg ha⁻¹, respectively, reflecting the impact of drought conditions and irregular precipitation distribution. Previous studies have highlighted the significant positive effects of the number of heads, number of lateral branches, number of seeds per head, and thousand-seed weight on seed yield (Saleh and Farag 2016). Weiss (2000) identified the number of heads, the number of seeds per head, and the thousand-seed weight as the three most critical selection criteria influencing safflower seed yield. Additionally, Abou Chehade et al. (2022) associated higher seed yields with greater plant height and the number of heads. La Bella et al. (2019) noted that seed yield performance can vary widely for the same safflower variety under different climatic and soil conditions. Furthermore, Kilic (2010) emphasized that genetic potential alone is insufficient for achieving high yield and quality in safflower; optimal cultivation practices and favorable

environmental conditions are necessary to realize this potential. In both years of our study, the Linas and Olas varieties demonstrated the highest seed yield performance. However, due to drought in 2021, seed yield averages declined significantly, resulting in a notable year $\times$ genotype interaction. Notably, the Anatolian-origin safflower genotypes TR 42670, TR 49117, and TR 50118 exhibited promising performance under drought stress. These genotypes outperformed some registered varieties and showed potential for cultivation in regions with a coastal Mediterranean climate, where drought stress and irregular precipitation patterns are prevalent. Bardhi et al. (2023) in Albania and Zanetti et al. (2022) in Italy, under Toscana and Emilia-Romagna conditions, obtained similar seed yields to our study ($1090\text{--}2210\text{ kg ha}^{-1}$, 1775 kg ha^{-1} , respectively). While Houmanat et al. (2017) reached higher results than our study with 2000 kg ha^{-1} seed yield in their research conducted under Moroccan Douyet conditions, Licata et al. (2023) and La Bella et al. (2019) under Italy Sicily conditions, Stavropoulos et al. (2022) under Greece conditions reached lower results ($1130\text{--}1160\text{ kg ha}^{-1}$, $700.0\text{--}1640.0\text{ kg ha}^{-1}$, $770.2\text{--}1469.4\text{ kg ha}^{-1}$ respectively).

In our research, the average number of maturation days in 2020 ranged from 222.25 to 229.25 days. The earliest maturation was observed in the Asol variety, while the latest was in the TR 49118 genotype. The average maturation period for registered varieties was 222.80 days, compared with 224.64 days for Anatolian-origin safflower genotypes. In 2021, maturation days ranged from 214.00 (TR 42660) to 223.00 days (TR 50120). The average number of maturation days was 215.70 days for varieties and 219.94 days for Anatolian-origin genotypes. The year $\times$ genotype interaction was significant, as plants matured about one week earlier under the drought stress of 2021. Previous studies have reported that safflower planted as a winter crop has a long vegetation period of 180–190 days, which limits its planting area (La Bella et al. 2019; Ahmed et al. 2019). Zanetti et al. (2022) reported that safflower sown in early January under Toscana and Emilia-Romagna conditions in Italy was harvested in 190 days. Licata et al. (2023) reported that safflower sown on December 20 under Sicily conditions in Italy was harvested 183–201 days later. Stavropoulos et al. (2022) reported that safflower sown with a row spacing of 0.4 m under Greek conditions was harvested after 190 days. Considering the sowing dates and inter-row distances in these studies, the maturation days are similar to those in our study. Our findings are consistent with earlier studies conducted in the same location (Sayilir 2015). One objective of this research was to identify alternative crops for producers in regions such as the study area, where cotton monoculture is predominant, and to evaluate safflower's potential in crop rotation systems.

3.2. Oil Ratio, Oil Yield and Fatty Acid Composition

The results of the analysis of variance for oil ratio, oil yield, and fatty acid composition (including linoleic, oleic, palmitic, and stearic acids), along with the mean comparisons based on the LSD (0.05) test, are presented in Table 4. The analysis revealed that genotype and the year $\times$ genotype interaction had a highly significant effect ($p < 0.01$) on oil ratio, oil yield, and fatty acid composition. These findings highlight the strong influence of genetic and environmental interactions on these key traits.

In our research, the oil ratio ranged from 28.32% (TR 73821) to 34.46% (Balci) in 2020 and from 30.00% (TR 73821) to 33.91% (TR 51504) in 2021. The average oil ratio for registered varieties was 33.41% in 2020 and 31.91% in 2021, while for Anatolian-origin safflower genotypes, it was 30.40% and 31.80%, respectively. The year $\times$ genotype interaction was significant in 2021 due to the differential responses of genotypes to drought and high-temperature stress during the transition to the generative period. Interestingly, in 2021, Anatolian-origin safflower genotypes showed an increase in oil ratio under adverse conditions, while the oil ratio of registered varieties decreased. Among the varieties, Balci and Safir stood out with their high oil ratios, while TR 50118, TR 51504, TR 42942, and TR 42642 genotypes also demonstrated improved oil ratios, making them competitive under challenging environmental conditions. Houmanat et al. (2017) and Ben Moumen et al. (2013) obtained similar results to our study in Moroccan conditions (28.6%, 28.84–35.38%, respectively). Zanetti et al. (2022) in Italy Toscana and Emilia-Romagna conditions and Licata et al. (2023) in Italy Sicily conditions reached higher oil ratios (36.1–40.3%, 40.15%, respectively) compared to our study, while Attia et al. (2024) under Cairo conditions in Egypt, Mazed et al. (2024) under Sohaq conditions in Egypt, Zemour et al. (2021) under Algeria conditions obtained lower oil content values (21.66–22.65%, 18.04–20.21%, 22.8–28.4%, respectively). Commercial safflower seeds typically contain 25–40% oil (Knowles 1982), though Rubis (2001) reported that some genotypes can achieve up to 55% oil content. Studies have shown that larger and fuller seeds tend to increase thousand-seed weight while decreasing the oil ratio (Gonzalez et al. 1994). Erbas (2012) emphasized that the oil ratio is governed by many genes with additive effects, and lines with higher oil ratios can be developed through targeted selection. Environmental factors, particularly inter-annual temperature fluctuations, have a significant impact on oil ratio. Notably, hot growing seasons often lead to considerable reductions in oil ratio (Weiss, 1983; Gonzalez et al. 1994; Ozturk 1994). These findings underline the importance of considering both genetic potential and environmental conditions in safflower breeding programs aimed at improving oil content.

In the study, oil yield averages ranged from 323.1 kg ha^{-1} (TR 42630) to 793.6 kg ha^{-1} (Olas) in 2020 and from 322.7 kg ha^{-1} (TR 42631) to 742.1 kg ha^{-1} (Linas) in 2021. The average oil yield of registered varieties was 638 kg ha^{-1} in 2020 and 572.3 kg ha^{-1} in 2021, while the average oil yield for Anatolian-origin safflower genotypes was 465 kg ha^{-1} and 448.4 kg ha^{-1} , respectively, over the same years. Olas and Linas achieved the highest oil yields among the varieties, with the TR 42670 genotype following closely. Genotypes TR 50118, TR 49117, and TR 42660 also demonstrated oil yields comparable to those of some registered varieties and exceeded those of other Anatolian-origin safflower genotypes. These results highlight their potential as promising breeding candidates for improving oil yield. The findings align with Moghadassi and Omid (2009), who reported a positive correlation between seed and oil yields. This relationship emphasizes the importance of optimizing both traits simultaneously to enhance overall productivity. The performance of certain Anatolian-origin genotypes in this study suggests their adaptability and potential for high oil yield under specific environmental conditions, further supporting their value in breeding and cultivation strategies. Licata et al. (2023) found results similar to ours, with 460 kg ha^{-1} oil yield under Sicilian conditions in Italy.

Table 6
Analysis of variance, mean values and LSD groups for oil ratio, oil yield and fatty acid composition

Variety / Genotype		Oil Ratio		Oil Yield (kg ha ⁻¹)		Linoleic Acid Ratio		Oleic Acid Ratio		Palmitic Acid Ratio		Stearic Acid Ratio	
		2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Asol		33.06 c	30.24 k	541.6 de	426.2 def	38.99 j	41.69 j	51.17 a	48.01 a	5.92 a	6.12 a	1.91 a	2.28 a
Balci		34.46 a	32.48 de	443.6 hi	416.7 ef	64.59 h	64.59 h	25.28 c	25.21 c	6.72 cdef	6.62 bcde	2.29 b	2.30 a
Linaz		32.02 d	31.89 ef	761.7 a	742.1 a	74.22 b	76.94 a	14.70 fg	12.72 k	6.65 cde	6.36 abc	2.81 fg	2.91 gh
Olas		33.77 b	31.68 fg	793.6 a	722.9 a	45.31 i	47.58 i	44.86 b	42.25 b	6.19 ab	6.15 a	1.97 a	2.31 a
Safir		33.71 b	33.22 bc	649.6 b	553.3 b	45.63 i	47.15 i	43.99 b	42.24 b	6.16 ab	6.12 a	2.60 b-e	2.67 b-e
TR 42630		29.53 i	31.51 fgh	323.1 k	362.4 gh	74.05 b	74.84 cd	15.90 e	14.89 fgh	6.28 b	6.07 a	2.60 b-e	2.80 efg
TR 42631		31.44 de	32.85 cd	361.3 jk	322.7 h	71.42 f	73.93 def	18.14 d	15.34 fgh	6.25 b	6.39 abc	2.47 bcd	2.74 c-g
TR 42642		30.53 fg	33.28 bc	345.8 k	369.2 g	75.99 a	74.97 cd	13.42 hi	14.31 hij	6.21 ab	6.69 cde	2.74 efg	2.88 fg
TR 42646		30.89 ef	31.42 f-i	438.1 hi	475.4 c	71.71 ef	75.16 c	15.53 ef	13.66 ijk	7.49 fgh	6.43 abc	3.29 k	2.97 h
TR 42660		29.60 hi	30.58 jk	524.0 ef	465.8 cd	71.10 f	70.74 g	18.48 d	18.45 d	6.52 cd	6.45 abc	2.65 c-f	2.79 efg
TR 42666		30.58 fg	31.07 hij	403.1 ij	365.1 gh	73.06 bcd	73.02 f	16.23 e	16.60 e	6.47 cd	6.22 ab	2.69 d-g	2.75 d-g
TR 42667		29.77 hi	30.20 k	496.4 fg	430.1 def	70.89 f	73.36 ef	17.75 d	15.79 ef	6.78 d- g	7.00 e	2.81 fg	2.65 a-d
TR 42670		28.76 j	30.89 ij	636.9 b	586.3 b	71.94 def	74.47 cde	18.20 d	15.43 fg	5.87 a	6.08 a	2.32 bc	2.61 abc
TR 42942		31.08 ef	33.56 ab	477.3 gh	463.7 cd	72.81 cde	74.88 cd	16.36 e	14.42 g-j	6.25 b	6.16 a	2.88 hi	2.73 c-f
TR 49116		30.17 gh	32.29 de	515.8 efg	446.9 cde	69.14 g	73.355 ef	18.92 d	15.32 fgh	7.93 h	6.72 cde	2.99 j	3.05 i
TR 49117		29.92 hi	31.25 ghi	574.5 cd	579.3 b	76.26 a	76.56 ab	13.32 i	12.71 k	6.34 c	6.41 abc	2.74 efg	2.80 efg
TR 49118		30.70 fg	31.58 fgh	402.2 ij	398.5 fg	73.35 bc	73.77 def	14.45 gh	14.84 fgh	6.65 cde	6.27 ab	2.85 gh	2.86 fg
TR 50118		32.83 c	32.81 cd	591.7 c	584.1 b	75.54 a	75.46 bc	14.34ghi	14.93 fgh	6.16 ab	6.14 a	2.67 c-f	2.90 fgh
TR 50120		30.89 ef	31.52 fgh	430.3 i	389.8 fg	71.16 f	73.90 def	16.28 e	14.68 ghi	7.51 fgh	6.48 a-d	3.31 k	2.97 h
TR 51504		31.34 e	33.91 a	479.1 gh	474.8 c	71.69 ef	75.57 bc	15.80 e	13.37 jk	7.56 gh	6.87 de	2.95 ij	2.66 b-e
TR 73821		28.32 j	30.00 k	440.5 hi	459.7cde	71.81 ef	75.56 bc	16.12 e	13.36 jk	7.01efg	6.38 abc	2.85 gh	2.49 ab
Mean (varieties)		33.41	31.91	638.0	572.3	53.75	55.59	36.00	34.08	6.32	6.27	2.31	2.49
Mean (Anatolian genotypes)		30.40	31.80	465.0	448.4	72.52	74.34	16.20	14.88	6.70	6.42	2.80	2.79
Mean (all genotypes)		31.12	31.82	506.2	477.9	68.12	69.88	20.91	19.45	6.61	6.38	2.68	2.72
Source of Variation	Year	**		**		**		**		**		*	
	Genotype	**		**		**		**		**		**	
	Year*Genotype	**		**		**		**		**		**	
	LSD _{0.05}	0.604		43.21		1.221		1.072		0.412		0.161	

Variety / Genotype	Oil Ratio		Oil Yield (kg ha ⁻¹)		Linoleic Acid Ratio		Oleic Acid Ratio		Palmitic Acid Ratio		Stearic Acid Ratio	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Coefficient of Variation (%)	1.37		6.28		0.88		2.63		3.14		2.95	

Zanetti et al. (2022) under Toscana and Emilia-Romagna conditions in Italy and Abou Chehade et al. (2022) under Pisa conditions in Italy found higher oil yield results compared to our study (682 kg ha⁻¹, 276–838 kg ha⁻¹, respectively). La Bella et al. (2019) reached lower results (220–590 kg ha⁻¹) under Sicily conditions in Italy.

In our study, the linoleic acid content ranged from 38.99% (Asol) to 76.26% (TR 49117) in 2020 and from 41.69% (Asol) to 76.94% (Linaz) in 2021. The average linoleic acid content of the varieties was 53.75% in 2020 and 55.59% in 2021, while the average for Anatolian-origin safflower genotypes was higher, at 72.52% and 74.34%, respectively. The TR 49117 genotype and Linaz variety exhibited the highest linoleic acid ratios, followed by TR 50118, TR 42642, and TR 42630 genotypes, which also displayed favorable linoleic acid characteristics compared to some other varieties and genotypes. Zemour et al. (2021) under Algerian conditions and Ben Moumen et al. (2013) under Moroccan conditions found higher linoleic acid ratios than our study (75–79.3%, 77.94–79.49%, respectively). Bardhi et al. (2023) in Albania, Licata et al. (2023) and La Bella et al. (2019) in Sicily, Italy and Abu Chehade et al. (2022) in Pisa, Italy found lower linoleic acid ratios compared to our study (48.21–70.06%, 25.10%, 19.02–73.88%, 17.04–80.32%, respectively). In terms of oleic acid, the TR 49117 genotype consistently had the lowest ratio (13.32% in 2020 and 12.71% in 2021), while the Asol variety had the highest (51.17% in 2020 and 48.01% in 2021). Along with Asol, the Olas and Safir varieties also demonstrated high oleic acid content. In contrast, lower oleic acid ratios generally characterized Anatolian-origin safflower genotypes. Bardhi et al. (2023) under Albanian conditions, Licata et al. (2023) and La Bella et al. (2019) under Sicily conditions in Italy, Abu Chehade et al. (2022) under Pisa conditions in Italy found results above the average oleic acid ratios reached in our research (19.17–41.52%, 66.2%, 17.13–72.00%, 28.32%, respectively). Zemour et al. (2021), under Algerian conditions, and Ben Moumen et al. (2013), under Moroccan conditions, found lower oleic acid ratios than our study (10.2–14.7%, 9.50–11.29%, respectively). For palmitic acid, the ratios ranged from 5.87% (TR 42670) to 7.93% (TR 49116) in 2020 and from 6.12% (Asol and Safir) to 7.00% (TR 42667) in 2021. The TR 42670 genotype, along with the Asol and Safir varieties, stood out with relatively higher palmitic acid ratios, followed closely by the TR 50118 genotype. Zemour et al. (2021) in Algeria and Licata et al. (2023) in Sicily, Italy obtained similar results to the palmitic acid ratios obtained in our study (6.6–7.15%, 6%, respectively). Bardhi et al. (2023) under Albanian conditions and Ben Moumen et al. (2013) under Moroccan conditions obtained higher (8.11–9.50%, 7.20–8.60%, respectively), La Bella et al. (2019) under Italian Sicily conditions and Abu Chehade et al. (2022) under Italian Pisa conditions obtained lower (5.26–5.96%, 4.74–6.20%, respectively) palmitic acid ratios compared to our research. These findings emphasize the distinct fatty acid profiles of safflower genotypes and varieties, with Anatolian-origin genotypes showing a preference for higher linoleic acid content and lower oleic acid ratios. This differentiation is crucial for breeding programs targeting specific oil quality traits, as linoleic acid is desirable for nutritional and industrial applications, while oleic acid offers advantages in stability and shelf life. In our study, stearic acid ratios ranged from 1.91% (Asol) to 3.31% (TR 50120) in 2020 and from 2.28% (Asol) to 3.05% (TR 49116) in 2021. The varieties Asol, Olas, and Balci stood out for their favorable stearic acid ratios, followed by the TR 42670 and TR 42631 genotypes, which performed better than some other varieties and Anatolian-origin safflower genotypes. While Abu Chehade et al. (2022) reached similar results to our study with 1.98–3.20% stearic acid ratio under Pisa conditions in Italy, Bardhi et al. (2023) under Albanian conditions, Licata et al. (2023) and La Bella et al. (2019) under Sicily conditions in Italy, Ben Moumen et al. (2013) under Moroccan conditions obtained lower stearic acid ratios compared to our research (0.025–1.60%, 2.1%, 2.26–2.30%, 2.00–2.39%, respectively). Research has demonstrated that safflower plants do not consistently exhibit the same fatty acid composition, as this is influenced by genotype and environmental factors, as well as cultural practices (La Bella et al. 2019). While genotype significantly affects fatty acid synthesis, particularly oleic and linoleic acid ratios during seed oil formation, environmental factors such as temperature and moisture during seed maturation also play a critical role in determining the oleic/linoleic acid ratio (La Bella et al. 2019). The typical fatty acid composition of standard safflower seed oil includes 71–75% linoleic acid, 16–20% oleic acid, 6–8% palmitic acid, and 2–4% stearic acid (Velasco and Fernandez 2005). Nazari et al. (2017) observed that drought stress in high-linoleic safflower genotypes led to a 1–2.6% increase in oleic acid and a 1.7% decrease in linoleic acid. Similarly, Baydar (2000) noted that higher temperatures in southern latitudes promote a shift toward greater oleic acid synthesis and reduced linoleic acid content. Changes in oil composition under drought stress, characterized by a decrease in the proportion of unsaturated fatty acids, may be attributed to restricted synthesis and conversion activities of polyunsaturated fatty acids into more complex structures (Ashrafi et al. 2010). In their study conducted under Algerian conditions, Zemmour et al. (2021) reported that low rainfall and high temperatures maintained the oil content in the seed at a relatively high level, and that the ratio of saturated to unsaturated fatty acids was 9/91. Roche et al. (2019), in their study in Southwestern France, found that the total of unsaturated fatty acids was 87%, delays in sowing caused high temperature and water stress, this resulted in an increase in saturated fatty acids and a decrease in unsaturated fatty acids, and delayed sowing reported a negative correlation between the two main unsaturated fatty acids, in contrast to sunflower. These findings highlight the dynamic nature of safflower oil composition and the importance of both genotype selection and environmental management in optimizing oil quality for specific applications.

4. Conclusion

Research findings revealed that TR 42670 (high seed and oil yield), TR 50118 (high oil content) and TR 49117 (high linoleic acid content) of Anatolian origin Safflower genotypes obtained from the Gene Bank stood out as promising genotypes, leaving behind many registered varieties and other Anatolian origin genotypes. Among the varieties studied, Linaz stood out for its high seed yield and linoleic acid ratio, Olas for its high seed and oil yield as well as high oleic acid ratio, Balci for its high oil ratio, and Asol for its high oleic acid ratio, highlighting their potential for targeted breeding and cultivation strategies. In addition to these findings, it was determined that all safflower genotypes evaluated in the experiment exhibited lodging resistance, further

supporting their suitability for cultivation under varying environmental conditions. These cultivars are particularly recommended for the coastal Mediterranean climate during the winter season under natural rainfall conditions, and high yield and high oil quality can be obtained.

Declarations

Acknowledgement

This study was carried out by Celal SAYILIR for his doctoral thesis at Ege University, Institute of Science, Department of Field Crops, under the supervision of Prof. Dr. Emre Ilker.

Author Contributions

All authors contributed equally to the study.

Funding

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Data Availability No datasets were generated or analysed during the current study.

Competing interests The authors declare no competing interests.

Ethics Approval and Consent to Participate

All experimental studies and experimental materials involved in this research are in full compliance with relevant institutional, national, and international guidelines and legislation.

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