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YIELD AND QUALITY CHARACTERISTICS OF SUNFLOWER (*Helianthus annuus* L.) CULTIVARS BY DIFFERENT SOWING DATES

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ABSTRACT. A field trial was initiated to ascertain the optimal sowing date for five distinct sunflower cultivars in Turkey's Mardin Province. The trial scrutinised various parameters including plant height, head diameter, seed yield, protein content, oil content and oil yield. The first sowing produced the highest seed yields (3484 kg ha^{-1}), with the Şems (3255 kg ha^{-1}) and Zuhat (3157 kg ha^{-1}) cultivars producing the highest values. The highest overall oil content was achieved in the second sowing (31.7%) and in the Zuhat cultivar (34.6%). The highest mean oil yields were observed in the Zuhat cultivar (1096 kg ha^{-1}) and in the first sowing (1084 kg ha^{-1}). There was a general decrease in yield as the sowing date was delayed. Winter sowing is suggested for the Zuhat cultivar. If possible, the second sunflower crop should be sown shortly following the harvest of the main crop.

Keywords: cultivar; oil content; protein content; sunflower; sowing date; yield.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is Turkey's most critical oilseed plant due to its high oil quality. Since sunflower is not affected by photoperiod (day length) (Goyne and Hammer, 1982) and has drought and low-temperature resistance, it easily adapts to many different environments and can be grown in almost every soil type and ecology. These features give the plant an advantage over other oil plants. In sunflower production, the ideal daytime air temperature is 21–24°C. Pollination is harmed, particularly in second crop sowing at temperatures

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above 36–40°C. Furthermore, at high temperatures, the oil content decreases while the protein content rises. In irrigated agricultural areas, the most suitable date for sowing the second crop is between May and June (Kolsarıcı and Bayraktar, 1987).

Oilseed agricultural production, primarily sunflower, is increasing to meet the increasing oil deficit in Turkey and the world. Among oilseed plants in Turkey, sunflower comprises 74% of the oil used for nutrition (Taşkaya and Uçurum, 2012). Turkey is among the top 10 countries for sunflower cultivation area and production in the world. Turkey consumes approximately 1.5 million tonnes of edible oil each year. Approximately 10,000 tonnes of this are met by animal fats, with the remainder being met by vegetable oils. Sunflower oil has the highest share of all vegetable oils, with an average of 1 million tonnes (Anonymous, 2019b). In addition to studies on other oilseed crops (İzgi, 2023a, 2023b) that will help fill the edible oil gap, there is a need for new studies on sunflower.

Various studies on irrigation, fertiliser, salt stress, sowing forms, and dates in sunflower have been conducted. One study found that some hybrid varieties had high yield stability and little genotype–environment interaction (Göksoy, 1999). However, additional research should be conducted on early and late hybrid cultivars that are highly productive in different regions at different dates, resistant to diseases and plant pests, and adapted to the ecology with cultivation experiments in the ecology's environmental conditions (Güvercin *et al.*, 2002; Karaaslan, 2001; Önder *et al.*, 2001).

Sunflower is primarily cultivated in Thrace, Marmara, Central Anatolia, Aegean, Mediterranean, and Black Sea regions of Turkey, with very few agricultural areas in the eastern and southeastern ecosystems. The Marmara region serves as the primary hub for sunflower production within Turkey, particularly in the Thrace region (Turhan *et al.*, 2005), and expanding sunflower cultivation areas outside of this region is critical to closing the current oil deficit in Turkey.

Therefore, it is critical to identify appropriate cultivars and sowing dates for different ecologies for sunflower agriculture to become widespread. There is a need to identify cultivars with high seed and oil yields that can adapt to the lowland ecological conditions of Mardin Province. The purpose of this study was to investigate the growth and yield characteristics of sunflower (*H. annuus*) cultivars grown for the first time in Mardin, a new province for sunflower cultivation in Turkey, at different sowing times. Under this objective, the scope of this study was to identify high-quality and high-yielding hybrid sunflower cultivars and suitable sowing dates compatible with the plain conditions of Mardin Province.

MATERIALS AND METHODS

For two years (2018–2019), a field experiment was carried out in the lowland climate of Mardin Province, Turkey, at an altitude of 400 m, latitude 37.131131N, and longitude 40.940215E, during the vegetation periods of 2018 and 2019. Sunflower (*H. annuus*) cultivars Baron, Betoli, LG-5542, Şems, and Zuhat were used, and they were patented in Turkey.

The vegetation periods for these cultivars are as follows: Şems and Zuhat are early; Baron, Betoli, and LG-5542 are mid-early commercial hybrid cultivars.

The low-lying areas of Turkey's Mardin Province, where the research took place, experience arid, hot summers and mild, rainy winters. Analysis of climate data spanning the years encompassing the field trials and longer periods revealed a notable uptick in temperature and humidity readings during March, April, and May of the second year. However, overall temperature and humidity levels remained consistent between the two years under scrutiny. This region has a warm and temperate climate. Mardin Province is located in a region that receives significantly more precipitation in the winter than in the summer. In August, there is usually no precipitation in Mardin (*Table 1*). The total rainfall amounts in Mardin Province for 2018 and 2019 were 967.7 and 779.3 mm, respectively (Anonymous, 2019a). The station from which climate data was obtained was the Kızıltepe Automatic Meteorological Observation Station in Mardin, Türkiye. The distance to the area where field trials were conducted was approximately 20 km.

The soil in the trial area has a clay-loam structure and is low in organic matter (1.17%). The soil has an extremely high lime content (38.77%), is alkaline (pH = 8.08), and has no salinity issues (0.010%). Phosphorus (29 kg ha^{-1}) suitable for soil uptake is low, and the soil is potassium rich (100.27 mg kg^{-1}) (*Table 2*). The experimental design was established according to a split plot in a randomised block design. There were four sowing dates: two for the main crop in the main plots and two for the second crop. Sunflower cultivars were included in the subplots. In both years of the trial, the sowing dates were as follows: 1^{st} sowing date, 01 March; 2^{nd} sowing, 10 March; 3^{rd} sowing, 11 June; and 4^{th} sowing, 25 June.

This study examined plant height, head diameter, seed yield, protein content, oil content, and oil yield values. Sowing dates were allocated to the main plots, while the subplots were assigned to sunflower cultivars. The experimental design included three replications, with each plot spanning 6 m in length and comprising four rows spaced 70 cm apart. Within each row, seeds were spaced 30 cm apart, resulting in a total plot area of 16.80 m^2. A 2-m gap separated individual plots, and a 3-m gap separated blocks. Sowing was conducted at a seed rate of 5 kg ha^{-1}, with seeds buried at an average depth of 4–5 cm. Fertilisation was achieved using NPK (20–20–20) composite fertiliser, applying 100 kg ha^{-1} of nitrogen, phosphorus, and potassium nutrients. At sowing, this fertiliser was applied to the seedbed's bottom at a depth of 10 cm. Sprinkler irrigation was used until the plants reached a length of 40–50 cm and then furrow irrigation was done. When they reached a length of 10–12 cm, the plants were uprooted to improve their development, and when they reached 30–35 cm in height, the soil was piled on both sides of the plants to keep them from breaking and falling. Weeding was performed manually and by hoeing. No pesticides for fungi, insects, or weeds were applied during the trial.

A total of 10 sunflower heads were manually harvested. Plants 30 cm from the start and end of each row, as well as one row at the start, were excluded. They were left to dry for about 15 days in the open air before being placed in individually numbered sacks for each parcel.

Oil and protein analyses of sunflower seeds were carried out in the Eastern Mediterranean Agricultural Research Institute Quality Laboratory in Adana, Türkiye. The crude protein content (calculated as N × 5.30) was determined on sunflower samples using the standard Kjeldahl procedure (AOAC, 2005). Crude oil was extracted with petroleum ether using a Soxhlet apparatus for 4 h (AOCS, 2005). The data were analysed using the JMP statistical programme (SAS software programme). The results were calculated using a combined analysis of variance (ANOVA). Based on the ANOVA results, the LSD test was used to compare significantly different means (*Table 3*).

RESULTS AND DISCUSSION

The experiment was carried out by sowing five sunflower cultivars on four different dates in the lowland conditions of Mardin Province.

Table 1 – Main climatic data from the growing season in Mardin Province (multiannual average values and from the 2018–2019 agricultural year)

Month	Precipitation (mm)			Temperature (ºC)			Humidity (%)		
	2000-2019	2018	2019	2000-2019	2018	2019	2000-2019	2018	2019
February	33.5	94.3	27.4	8.8	10.2	8.8	56.6	70.9	71.3
March	59.7	7.2	95.8	12.4	14.3	10.7	59.3	64.1	75.1
April	35.1	32.5	79.7	15.9	17.7	13.9	53.8	53	70.9
May	34.7	26.6	49.2	21.7	21.8	22.7	40.5	60.8	29.1
June	3	28.5	16.3	28.4	28.1	29.5	24.5	33.9	24
July	0.9	0	1.7	32.4	30.9	30.8	21	31.3	21.8
August	0.3	0	0.1	30.9	30.2	31.7	27.8	38.3	20.7
September	1.3	0.1	0.3	26.6	27	26.3	29.8	35.3	24.3
October	21.5	115.3	32.7	20.7	19.8	22.3	36.7	44	30.4
November	30.50	128.4	11.8	13.4	11.1	13.5	50	73.1	41.6
Total/Mean	220.5	432.9	320.7	15.0	15.9	14.4	38.6	60.4	59.8

Table 2 – Main soil physicochemical indicators at 0–20 cm depth

Parameters	Value
Texture class	Clay-loamy
pH	8.08
Organic matter content, %	1.17%
Lime ($CaCO_3$), %	38.77%
Total salt, %	0.010%
Available P, kg P_2O_5 ha^{-1}	29.0 kg ha^{-1}
Available K, mg kg^{-1}	100.27 mg kg^{-1}

Table 3 – Variance analysis results of vegetative characteristics of sunflower cultivars sown on different dates

Variation sources		F value					
		Plant height	Head diameter	Seed yield	Protein content	Oil content	Oil yield
Year (Y)	1	530.5**	13.1*	0.74ns	44.21**	2.39ns	0.32ns
Cultivar (C)	4	45.9**	16.1**	45.2**	281.3**	94.2**	64.8**
Y × C	4	0.64**	2.3ns	28.6**	139.2**	5.58**	33.0**
Sowing date (S)	3	31.9**	5.5**	142.7**	1.6ns	2.4ns	8.9**
Y × S	3	1.4 ns	9.8**	3.0*	2.3ns	3.6*	2.9*
C × S	12	6.3**	3.0**	1.3ns	9.1**	6.3**	2.3*
Y × C × S	12	3.0**	3.5**	2.9**	1.7ns	4.0**	19.3**
CV		5.39	6.89	8.51	4.98	4.61	9.73

*statistically significant at 5% (P<0.05), **statistically significant at 1% (P<0.01), ns: not significant, Y: Year, C: Cultivar, S: Sowing Date, DF: Degrees of Freedom

Plant height, head diameter, seed yield, protein content, oil content, and oil yield were examined, and significant differences were determined separately for each of the analysed properties.

Plant height

For plant height, all sources of variation (year (Y), cultivar (C), Y × C, sowing date (S), Y × S, C × S, Y × C × S) were significant at the 1% level (*Table 3*). *Table 4* presents the average plant height of the sunflower cultivars. In the first year, the average plant height was higher than in the second year. Among the cultivars, LG-5542 had the highest plant height (193.0 cm), while Şems had the lowest height (81.9 cm). Plant height was significantly influenced by the sowing date. A decrease was observed as the sowing date was delayed. The plant height values varied depending on the sowing date. The highest value was recorded for the first sowing date (146.9 cm), while the lowest values were observed for the third and fourth sowing dates (132.8 and 129.8 cm, respectively). Regarding the Y × C interaction, LG-5542 had the highest average (122.2 cm in the first year), while Betoli had the lowest (99.5 cm in the second year). The highest plant height for the C × S interaction was observed for the Zuhat cultivar at the first planting date (157.1 cm). The Şems cultivar had the lowest plant height (101.2 cm) when planted on the fourth date. *Table 4* indicates that for the Y × S interaction, the maximum value of plant height occurred at the first sowing date of the first year (180.9 cm), while the minimum value was recorded at the fourth sowing date of the second year (98.1 cm) (*Table 4*).

The sowing date and cultivars affected plant height, agreeing with the results of two previous studies (Çil *et al.*, 2016; Yılmaz and Kınay, 2015). Excessive elongation of plant height is considered undesirable. In this study, there were no instances of breaking or plant detachment. The regulation of plant height is determined by the interplay of genetic and environmental factors (Singh *et al.*, 2019).

Head diameter

The Y × C interaction was statistically insignificant for head diameter; however, the Year factor was significant at the 5% level. C, S, Y × S, C × S, and Y × C × S were significant at the

1% level (*Table 3*). Şems had the largest head diameter at 25.0 cm, while LG-5542 had the smallest at 21.4 cm. Şems had the highest value (26.1 cm) in the second year. Baron, Betoli, and LG-5542 cultivars had the lowest values (21.5, 22.0, and 21.4 cm) in the first year, and LG-5542 (21.3 cm) had the lowest in the second year, based on the Y × C interaction. The Şems cultivar had the highest value (26.6 cm) at the second sowing date, based on the C × S interaction. However, the LG-5542 cultivar had the lowest value at the third sowing date. Additionally, in the second year, Şems had the highest value (30.5 cm) at the second sowing date, based on the Y × S × C interaction. At the first sowing date of the first year, the Betoli cultivar showed minimum values of 19.8 and 19.9 cm, as shown in *Table 5*. Saleem et al. (2008) found that early sowing date had a positive effect on sunflower head diameter. Genetics, environmental conditions, cultural practices, soil structure, and irrigated/dry cultivation all play a role in sunflower head diameter (Singh, 2019). Numerous studies have shown that head diameter has a direct effect on 1000-seed weight, grain yield, and oil yield (Çil *et al.*, 2016; Sefaoglu and Kaya, 2018; Yılmaz and Kınay, 2015).

Seed yield

The Y factor and C × S interaction were insignificant, but the Y × S interaction was significant at the 5% level. C, Y × C, S, and Y × C × S were statistically significant at the 1% level (Table 3). Based on the calculated mean values for cultivars, it Şems and Zuhat demonstrated the most substantial seed yield (3255 and 3157 kg ha^{-1}, respectively). The lowest value was observed in LG–5542 (2404 kg). The highest yield was obtained at the first sowing date (3484 kg). Based on the Y × C averages, the highest average amount was obtained in the Zuhat cultivar (3554 kg) in the second year, and the lowest amount was obtained for the LG-5542 cultivar in the second year.

Based on the interaction between Y × S, the highest value was obtained at the first sowing date of the first year (3610 kg), and the lowest value was obtained at the fourth sowing date of the second year (2614 kg). The Şems cultivar had the highest value (4340 kg) at the first sowing date of the first year, while cultivars LG-5542 and Betoli recorded the lowest values (1679 and 1742 kg, respectively) at the fourth sowing date of the second year, according to the Y × S × C interaction (*Table 6*).

Early sowing allows plants to complete root development more quickly, resulting in more aboveground growth. Each cultivar is best adapted to a specific region's climatic conditions. Sefaoglu and Kaya (2018) found that seed yield values ranged from 1469 to 2798 kg ha^{-1}. In studies on different hybrid cultivars, sowing dates, and irrigation regimes, early sowing increased seed yield compared to late sowing (Baghdadi *et al.*, 2014; Barros *et al.*, 2004; Flagella *et al.*, 2002; Jones, 1984; Saleem *et al.*, 2008). High temperatures also reduced seed yield during the flowering and seed filling periods. Seed yield is well known to be proportional to head diameter (Çil *et al.*, 2016; Yılmaz and Kınay, 2015).

Table 4 – Plant height data acquired at four different sowing dates for sunflower cultivars in two years (cm)*

Cultivar	Year × Sowing Date × Cultivar								Year × Cultivar		Cultivar × Sowing Date				Mean (Cultivar)
	2018				2019										
	1	2	3	4	1	2	3	4	2018	2019	1	2	3	4	
Baron	187.9^{ab}	172.8^{de}	160.8^{ef}	151.5^{f}	100.6^{l-n}	118.4^{h-k}	107.0^{k-m}	100.5^{l-n}	168.2^{C}	106.6^{F}	144.2^{cd}	145.6^{cd}	133.9^{e-g}	126.0^{g}	137.4^{B}
Betoli	185.2^{a-c}	176.4^{b-d}	172.4^{de}	175.2^{cd}	111.5^{J-l}	101.6^{l-n}	96.9^{m-o}	88^{op}	177.3^{B}	99.5^{G}	148.4^{bc}	139.0^{d-f}	134.7^{ef}	131.6^{e-g}	138.4^{B}
LG–5542	193.0^{a}	185.0^{bc}	176.6^{b-d}	185.4^{bc}	115.2^{i-k}	108.4^{j-m}	93.6^{n-p}	93.6^{n-p}	185.0^{A}	102.7^{FG}	154.1^{ab}	146.7^{b-d}	135.1^{ef}	139.5^{de}	143.9^{A}
Şems	153.2^{f}	150.3^{f}	130.8^{g}	120.4 ^{gi}	108.5^{j-m}	115.8^{i-k}	101.1^{l-n}	81.9^{p}	138.7^{D}	101.8^{FG}	130.9^{fg}	133.1^{e-g}	115.9^{h}	101.2^{i}	120.3^{C}
Zuhat	185.3^{bc}	167.1^{de}	177.1^{cd}	176.1^{b}	128.8^{gh}	101.5^{l-n}	111.4^{j-l}	126.6^{g-i}	176.1^{B}	117.1^{E}	157.1^{a}	134.3^{e-g}	144.3^{cd}	150.7^{a-c}	146.6^{A}
	Year × Sowing Date								Year		Sowing Date				
Mean	180.9	170.3	163.5	161.5	112.9	109.2	102.0	98.1	169.1^{A}	105.5^{B}	146.9^{A}	139.7^{B}	132.8^{C}	129.8^{C}	

*Different lowercase letters within a column indicate significant differences between values, according to Tukey's test ($p \leq 0.05$).
There is no statistically significant difference between values with the same lowercase letters.
1: 1st sowing date, 01 March; 2: 2nd sowing, 10 March; 3: 3rd sowing, 11 June; and 4: 4th sowing, 25 June.

Table 5 – Head diameter data acquired at four different sowing dates for sunflower cultivars in two years (cm)*

Cultivar	Year × Sowing Date × Cultivar								Year × Cultivar		Cultivar × Sowing Date				Mean (Cultivar)
	2018				2019										
	1	2	3	4	1	2	3	4	2018	2019	1	2	3	4	
Baron	23.2^{e-l}	21.4^{i-o}	20.4^{no}	20.9^{l-o}	23.5^{e-k}	24.9^{c-e}	24.6^{d-f}	21.7^{h-o}	21.5^{D}	23.7^{BC}	23.4^{c-e}	23.2^{d-f}	22.5^{e-i}	21.3^{g-i}	22.6^{B}
Betoli	24.8^{de}	23.3^{e-l}	19.8^{o}	19.9^{o}	24.4^{d-g}	23.9^{e-i}	23.8^{e-j}	23.0^{e-m}	22.0^{D}	23.8^{BC}	24.6^{b-d}	23.6^{c-e}	21.8^{e-i}	21.5^{f-i}	22.9^{B}
LG–5542	22.0^{g-o}	21.2^{k-o}	21.0^{k-o}	21.5^{h-o}	20.5^{m-o}	22.5^{e-n}	21.0^{k-o}	21.3^{j-o}	21.4^{D}	21.3^{D}	21.2^{hi}	21.8^{e-i}	21.0^{i}	21.4^{f-i}	21.4^{C}
Şems	27.4^{bc}	22.7^{e-n}	22.4^{e-o}	22.6^{e-n}	24.0^{e-h}	30.5^{a}	27.9^{ab}	22.1^{f-o}	23.8^{BC}	26.1^{A}	25.7^{ab}	26.6^{a}	25.2^{a-c}	22.3^{e-i}	25.0^{A}
Zuhat	22.4^{e-o}	23.1^{e-l}	22.0^{f-o}	22.6^{e-n}	22.6^{e-n}	23.1^{e-l}	23.8^{e-j}	26.6^{b-d}	22.5^{CD}	24.0^{B}	22.5^{e-i}	23.1^{d-g}	22.9^{d-h}	24.6^{b-d}	23.3^{B}
	Year × Sowing Date								Year		Sowing Date				
Mean	24.0^{AB}	22.3^{CD}	21.1^{E}	21.5^{DE}	23.0^{BC}	25.0^{A}	24.2 ^{A}	22.9^{BC}	23.8^{A}	22.2^{B}	23.5^{AB}	23.7^{A}	22.7^{BC}	22.2^{C}	

* Different lowercase letters within a column indicate significant differences between values, according to Tukey's test ($p \leq 0.05$).
There is no statistically significant difference between values with the same lowercase letters.
1: 1st sowing date, 01 March; 2: 2nd sowing, 10 March; 3: 3rd sowing, 11 June; and 4: 4th sowing, 25 June.

The number of seeds and, consequently, the seed yield increase as the diameter of the sunflower head increases. A number of factors affect sunflower seed yield, including environmental, morphological, physiological, and agronomic factors as well as cultivar and genetic structure (Andrei *et al.*, 1992). Sunflower seed yield can decrease (de La Vega and Hall, 2002) or increased (Kızılgeçi and Öztürk, 2018) when the appropriate sowing date is delayed.

Protein content

Y, C, Y × C, and C × S factors and interactions were statistically significant (1%), but S, Y × S, and Y × C × S were statistically insignificant (*Table 3*). Based on the mean values, the Şems cultivar had the highest protein content at 26.6%, whereas the Baron cultivar had the lowest at 17.4%. Examination of the interaction between Y and C indicates showed that the Şems cultivar maintained a consistently high protein content across both years, with negligible variance observed (26.9 and 26.4%, respectively). In the C × S interaction, Şems had the highest protein content.

No statistically significant differences were detected among the various sowing dates, as evidenced by the protein content values of 26.6, 26.9, 26.9, and 26.2 (*Table 7*).

According to Alpman and Sinan (2020), the protein contents of various cultivars and row spacing applications ranged between 20.8 and 22.1%, with this application having a significant effect on the protein content. Gupta *et al.* (1994) found that as the sowing date was delayed, the plant's oil yield increased, while its protein yield declined. Different nitrogen dose applications (Marschner, 2011), agricultural applications, and cultivar genetic factors can affect the protein content in the seed.

Oil content

Y and S were insignificant, but C, Y × C, C × S, and Y × C × S were significant for the oil content (1%). The Y × S interaction was significant for the oil content according at the 5% probability level (*Table 3*). Based on the mean values, the Zuhat cultivar demonstrated the highest oil content at 34.6%, whereas the Betoli cultivar exhibited the lowest value at 27.0%. Based on the mean values for the Y × C interaction, the Zuhat cultivar recorded the highest values in the second year (34.9%), while the Betoli cultivar displayed the lowest values in both the first and second years (27.3 and 26.7%, respectively). Based on C × S, Zuhat had the highest oil content in the first sowing (35.9%), and Betoli had the lowest value in the third sowing (26.1%). Based on the averages of the Y × S interaction, the highest values were observed at the third sowing date of the first year and at second sowing date of the second year (32.1 and 32.0%, respectively). The lowest values were observed at the fourth sowing date of the first year (30.7%) and at the first, third, and fourth sowing dates of the second year (30.5, 30.5, and 30.5%, respectively). The Zuhat cultivar had the highest value (37.0%) based on the Y × S × C interaction, specifically on the first sowing date of the second year (*Table 8*). The Betoli cultivar had the lowest value (24.5%) in the third sowing of the second year. Saleem *et al.* (2008) found that the average oil content was higher in late sowing than in early sowing, consistent with our findings. In other studies, seed oil contents were 33.5–44.5% (Yılmaz and Kınay, 2015), 42.85–46.18% (Demir, 2019), and 40.37% (Çil et al., 2016).

Genetic factors, ecologies (Singh *et al.*, 2019), species, cultivars, genotypes, and some agricultural techniques affect the oil content (Çil *et al.*, 2016; Ozer *et al.*, 2004; Yılmaz and Kınay, 2015).

Table 6 – Seed yield data acquired at four different sowing dates for sunflower cultivars in two years (kg ha^{-1})*

Cultivar	Year × Sowing Date × Cultivar								Year × Cultivar		Cultivar × Sowing Date				Mean (Cultivar)
	2018				2019										
	1	2	3	4	1	2	3	4	2018	2019	1	2	3	4	
Baron	3537^{e-f}	3096^{g-m}	2241^{q-s}	2192^{rs}	3206^{f-i}	3158^{f-j}	2758^{k-o}	2492^{n-r}	2767^{EF}	2904^{DE}	3372	3127	2500	2342	2835^{B}
Betoli	3689^{c-e}	3350^{e-h}	2640^{n-q}	2434^{o-r}	3155^{f-k}	3075^{g-m}	2189^{rs}	1742^{t}	3028^{CD}	2540^{G}	3422	3212	2414	2088	2784^{B}
LG–5542	3188^{f-i}	2851^{i-n}	2437^{o-r}	2161^{rs}	2786^{j-o}	2272^{qr}	1859^{s-t}	1679^{t}	2659^{FG}	2149^{H}	2987	2561	2148	1920	2404^{C}
Şems	4340^{a}	3822^{b-d}	2714^{m-p}	2341^{pr}	3523^{c-f}	3449^{d-g}	3117^{g-l}	2737^{l-p}	3304^{B}	3207^{BC}	3931	3636	2915	2539	3255^{A}
Zuhat	3295^{e-h}	2813^{i-o}	2454^{n-r}	2478^{n-r}	4118^{ab}	3911^{bc}	3148^{f-k}	3040^{hm}	2760^{EF}	3554^{A}	3706	3362	2801	2759	3157^{A}
	Year × Sowing Date								Year		Sowing Date				
Mean	3610^{A}	3187^{BC}	2497^{DE}	2321^{E}	3358^{B}	3173^{C}	2614^{D}	2338^{E}	2870	2904	3484^{A}	3180^{B}	2556^{C}	2330^{D}	

* Different lowercase letters within a column indicate significant differences between values, according to Tukey's test ($p \leq 0.05$).
There is no statistically significant difference between values with the same lowercase letters.
1: 1st sowing date, 01 March; 2: 2nd sowing, 10 March; 3: 3rd sowing, 11 June; and 4: 4th sowing, 25 June.

Table 7 – Protein content data acquired at four different sowing dates for sunflower cultivars in two years (%)*

Cultivar	Year × Sowing Date × Cultivar								Year × Cultivar		Cultivar × Sowing Date				Mean (Cultivar)
	2018				2019										
	1	2	3	4	1	2	3	4	2018	2019	1	2	3	4	
Baron	16.5	19.7	20.2	17.1	15	17.9	16.5	16.6	18.4^{D}	16.5^{E}	15.8^{h}	18.8^{d-f}	18.4^{ef}	16.8^{gh}	17.4^{E}
Betoli	18.3	15.5	15.9	18	26.8	27.2	26.6	26.8	16.9^{E}	26.9^{A}	22.6^{b}	21.3^{c}	21.2^{c}	22.4^{bc}	21.9^{B}
LG–5542	21.3	18.6	23.3	22.8	17.9	17.7	21.3	21	21.5^{B}	19.5^{C}	19.6^{d}	18.2^{f}	22.3^{bc}	21.9^{bc}	20.5^{C}
Şems	26.8	27.2	26.6	26.8	26.3	26.6	27.1	25.5	26.9^{A}	26.4^{A}	26.6^{a}	26.9^{a}	26.9^{a}	26.2^{a}	26.6^{A}
Zuhat	19.7	18.3	18.2	18.7	19.3	19.2	17.2	17.5	18.7^{CD}	18.3^{D}	19.5^{de}	18.7^{df}	17.7^{fg}	18.1^{f}	18.5^{D}
	Year × Sowing Date								Year		Sowing Date				
Mean	20.5	19.8	20.8	20.7	21.1	21.7	21.8	21.5	20.5^{B}	21.5^{A}	20.8	20.8	21.3	21.1	

* Different lowercase letters within a column indicate significant differences between values, according to Tukey's test ($p \leq 0.05$).
There is no statistically significant difference between values with the same lowercase letters.
1: 1st sowing date, 01 March; 2: 2nd sowing, 10 March; 3: 3rd sowing, 11 June; and 4: 4th sowing, 25 June.

Furthermore, high temperatures during the seed filling period have been shown to reduce the oil content (Ozer *et al.*, 2004).

Oil yield

For oil yield, the Y factor was statistically insignificant, but the Y × S and C × S interactions were significant at the 5% level. At the 1% level, C, Y × C, S and Y × C × S were significant (*Table 3*). Among the evaluated sunflower cultivars, Zuhat had the highest oil yield at 1096 kg ha^{-1}, while Betoli and LG-5542 yielded the lowest at 751 and 772 kg ha^{-1}, respectively. The first sowing period resulted in the highest oil production of 1084 kg ha^{-1}, which was influenced by the sowing date variable. Conversely, the fourth sowing date resulted in the lowest yield of 718 kg ha^{-1}. An examination of the Y × C interaction indicated that Zuhat achieved the highest oil yield (1249 kg ha^{-1}) in the second year, while Betoli and LG-5542 exhibited the lowest yields in the first year (680 and 654 kg ha^{-1}, respectively).

Further investigation into the C × S interaction revealed that Zuhat produced the highest oil yield (1335 kg ha^{-1}) in the first sowing, whereas Betoli yielded the lowest amount of oil (582 kg ha^{-1}) at the fourth sowing date (*Table 9*). The highest oil yields found in among studies were 2690 kg ha^{-1} (Yılmaz and Kınay, 2015), 1413 kg ha^{-1} (Çil *et al.*, 2016), 1119 kg ha^{-1} (Sefaoğlu and Kaya, 2018), and 1180 kg ha^{-1} (Andrei *et al.*, 1992). Head diameter, seed yield, and oil content, as well as different ecologies and agricultural practices, have a direct impact on sunflower oil yield (Flagella *et al.*, 2002; Yılmaz and Bayraktar, 1996).

The oil content and yield of sunflower are influenced by cultivar characteristics, agronomic practices, and environmental conditions (Ashley *et al.*, 2002). Numerous studies have identified oil yield as the primary criterion for economic efficiency in all oil crops.

These studies demonstrate that earlier sowing dates are associated with higher oil yields, whereas later sowing dates result in reduced oil yields (Çil *et al.*, 2016; İzgi, 2023a, 2023b; Saleem *et al.*, 2008; Unger, 1980). It can be concluded that root development is more pronounced during the early sowing period, which positively influences the yield of sunflower plants. Furthermore, the superior yield of the Zuhat cultivar in this region underscores the significant impact of genetic factors, as demonstrated in this study.

CONCLUSIONS

This study's findings showed that the highest oil yield was achieved on the first sowing date (March 1) with the Zuhat cultivar. Delayed sowing exposed the plants' flowering and seed filling periods to extreme temperatures, leading to reductions in head diameter, seed yield, and oil content, which collectively diminished oil yield. However, planting a second sunflower crop immediately after the main crop harvest in regions capable of producing two crops per year will enhance yield. Differences in climate data had no effect on seed yield during the trial years. Future sunflower research in arid and semi-arid conditions is anticipated to significantly contribute to reducing the global edible oil deficit and conserving diminishing groundwater resources.

Table 8 – Oil content data acquired at four different sowing dates for sunflower cultivars in two years (%)*

Cultivar	Year × Sowing Date × Cultivar								Year × Cultivar		Cultivar × Sowing Date				Mean (Cultivar)
	2018				2019										
	1	2	3	4	1	2	3	4	2018	2019	1	2	3	4	
Baron	32.3^{f-h}	33.8^{b-f}	34.6^{b-e}	29.1^{i-k}	33.6^{b-g}	32.7^{d-h}	31.1^{hi}	31.1^{hi}	32.5^{CD}	32.1^{D}	32.9^{cd}	33.3^{b-d}	32.9^{cd}	30.1^{fg}	32.3^{B}
Betoli	28.7^{jk}	24.7^{m}	27.7^{kl}	28.1^{k-l}	25.9^{lm}	28.3^{k}	24.5^{m}	28.1^{kl}	27.3^{F}	26.7^{F}	27.3^{h-j}	26.5^{ij}	26.1^{j}	28.1^{hi}	27.0^{D}
LG–5542	32.4^{e-h}	33.6^{b-g}	35.6^{ab}	32.8^{d-h}	27.6^{kl}	30.9^{h-j}	31.4^{gi}	33.2^{c-h}	33.6^{BC}	30.8^{E}	30.0^{fg}	32.2^{de}	33.5^{b-d}	33.0^{cd}	32.2^{E}
Şems	29.3^{i-k}	31.1^{hi}	29.6^{i-k}	29.2^{i-k}	28.4^{kl}	32.7^{d-h}	32.3^{fh}	27.3^{kl}	29.8^{E}	30.2^{E}	28.9^{gh}	31.9^{de}	31.0^{ef}	28.2^{h}	30.0^{C}
Zuhat	34.8^{a-d}	34.1^{b-f}	33.2^{c-h}	34.6^{b-f}	37.0^{a}	35.3^{a-c}	33.1^{c-h}	34.4^{b-f}	34.2^{AB}	34.9^{A}	35.9^{a}	34.7^{ab}	33.1^{b-d}	34.5^{a-c}	34.6^{A}
	Year × Sowing Date								Year		Sowing Date				
Mean	31.5^{AB}	31.5^{AB}	32.1^{A}	30.7^{B}	30.5^{B}	32.0^{A}	30.5^{B}	30.5^{B}	31.5	30.9	31.0	31.7	31.3	30.8	

* Different lowercase letters within a column indicate significant differences between values, according to Tukey's test ($p \leq 0.05$).
There is no statistically significant difference between values with the same lowercase letters.
1: 1st sowing date, 01 March; 2: 2nd sowing, 10 March; 3: 3rd sowing, 11 June; and 4: 4th sowing, 25 June.

Table 9 – Oil yield data acquired at four different sowing dates for sunflower cultivars in two years (kg ha^{-1})*

Cultivar	Year × Sowing Date × Cultivar								Year × Cultivar		Cultivar × Sowing Date				Mean (Cultivar)
	2018				2019										
	1	2	3	4	1	2	3	4	2018	2019	1	2	3	4	
Baron	1144^{cf}	1049^{d-g}	776^{l-o}	639^{o-q}	1077^{dg}	1033^{e-g}	860^{i-l}	775^{l-o}	902^{CD}	936^{B-D}	1110^{bc}	1040^{cd}	32.9^{cd}	818^{hi}	919^{C}
Betoli	1056^{d-g}	827^{j-m}	731^{l-o}	677^{n-q}	818^{j-n}	870^{h-l}	542^{q}	489^{r}	822^{E}	680^{F}	937^{ef}	848^{fg}	635^{jk}	582^{k}	751^{D}
LG–5542	1034^{e-g}	957^{g-k}	867^{hl}	708^{m-p}	771^{l-o}	702^{m-p}	583^{p-r}	558^{qr}	891^{DE}	654^{F}	902^{e-h}	829^{gh}	724^{ij}	725^{ij}	772^{D}
Şems	1273^{bc}	1190^{cd}	804^{l-n}	683^{n-q}	1002^{f-i}	1127^{d-f}	1008^{e-h}	747^{l-o}	987^{BD}	971^{BC}	28.9^{gh}	1158^{b}	31.0^{ef}	906^{e-h}	979^{B}
Zuhat	1147^{c-e}	958^{g-j}	814^{k-n}	856^{j-l}	1523^{a}	1380^{ab}	1043^{e-g}	1048^{d-g}	944^{BD}	1249^{A}	1335^{a}	1168^{b}	928^{e-g}	929^{eg}	1096^{A}
	Year × Sowing Date								Year		Sowing Date				
Mean	1131^{A}	996^{B}	798^{C}	712^{D}	1038^{B}	1022^{B}	807^{C}	723^{D}	90.9	89.8	1084^{A}	1009^{B}	802^{C}	718^{D}	

* Different lowercase letters within a column indicate significant differences between values, according to Tukey's test ($p \leq 0.05$).
There is no statistically significant difference between values with the same lowercase letters.
1: 1st sowing date, 01 March; 2: 2nd sowing, 10 March; 3: 3rd sowing, 11 June; and 4: 4th sowing, 25 June.

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