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EFFECT OF SOWING DATES ON SEED YIELD, YIELD TRAITS AND OIL CONTENT OF SAFFLOWER IN NORTHWEST TURKEY

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ABSTRACT

The aim of this research was to evaluate the effect of different sowing dates on some yield and quality traits of safflower varieties. The field experiments of this study were carried out in spring season of 2017 and 2018 under ecological conditions of the Suleymanpasa and Malkara districts of Tekirdag. Plots of the two safflower varieties (Dincer 5-18-1 and Balci) and four sowing dates (20 February, 5 March, 20 March and 5 April) were arranged in a Randomized Complete Block Design with three replications in both locations. Results showed that variation in sowing dates had a significant effect on seed yield, oil content and oil yield of safflower variety. While the highest seed yield was obtained from the 1st (20 February) sowing date (1442.67 kg ha^{-1}), the lowest seed yield was obtained from the 4th (5 April) sowing date (961.13 kg ha^{-1}). The seed yield was significantly affected by the sowing dates and it seriously decreased as sowing date was delayed (481 kg ha^{-1} higher in 20 February compared to 5 April over the average of two years). As a result, because of sowing dates is a crucial factor for seed and oil yield of safflower, sowing should be done as early as possible in the spring.

Key words: *Carthamus tinctorius* L., Location, Oilseed, Yield components

INTRODUCTION

Global climate change directly or indirectly affects the sowing dates of many cultivated crops. By the end of the 21st century, it is estimated that the global average surface temperature will increase by 0.3-4.8 ºC (Stocker, 2013). This situation causes the sowing dates of cultivated crops to be reviewed for sustainable agricultural production.

Safflower (*Carthamus tinctorius* L., Asteraceae) is an annual oil crop that is adapted to droughty climatic conditions (Li and Mundel, 1996). It is one of the valuable oil crops in the world and it contains 25-45% oil in its seeds, has two different types as linoleic (ω-6) and oleic (ω-9), has high quality vegetable oil (Culpan and Arslan, 2022). About 631.051 tons of safflower seeds are produced in an area of 850.431 ha worldwide (Anonymous, 2021). Location, climatic conditions, variety and production techniques are critical for successful and economic agricultural production. Among the agronomic factors affecting the crop growth and development, sowing date has an expressing influence and determining the suitable sowing date is one of the most critical factors for high seed yield of safflower. Delays in sowing decreased seriously seed yield potential by shortening the period of vegetative fill and flowering and seed fill into late spring, which often coincides with higher temperatures and the decreasing chance of rainfall (Yau, 2007; Koutroubas et al., 2009; GRDC, 2017; El Bey et al., 2021).

Many researchers have emphasized that sowing dates had a significant effect on seed yield, oil content and oil yield of safflower (Keles and Ozturk, 2012; Al-Doori, 2017; Thakare et al., 2018). Samanci and Ozkaynak (2003) reported that seed yield and oil content were decreased with the delay in sowing date in Mediterranean regions. Nikabadi et al. (2008) indicated that 1000 seed weight, number of seeds per head and the seed yield decreased as the sowing date was delayed. El Bey et al. (2021) indicated that late sowing could have adverse effects on yield and yield traits of safflower cultivars. Ahadi et al. (2011) reported that delay in sowing caused a shortening of the vegetation period and consequently a decrease in seed yield.

The aim of the present study was to evaluate the influence of safflower variety, location, sowing dates and year of production on some yield and quality traits of safflower in northwest Turkey.

MATERIALS AND METHODS

Soil and climate characteristics of experimental area

The field experiments of this study were carried out in spring season of 2017 and 2018 under ecological conditions of the Suleymanpasa (40°59'25.1"N 27°34'49.1"E, 10 meters above sea level) and Malkara (40°53'33.6"N 26°53'00.6"E, 250 meters above sea level) districts of Tekirdag (Figure 1). The distance between the two experiment locations is about 69 kilometers. The soil characteristics of the experimental area in Suleymanpasa were clay (C), slightly alkaline and had sufficient phosphorus, rich in potassium but low in organic matter. The soil characteristics of Malkara location were sandy clay (SC), slightly alkaline, rich in potassium and phosphorus and had partially sufficient in organic matter (Table 1).

Table 1. Physical and chemical properties of the soil in the experimental areas

Location		Texture	pH	EC (µS/cm)	Organic Matter (%)	$CaCO_3$ (%)	K_2O (kg ha^{-1})	P_2O_5 (kg ha^{-1})
Suleymanpasa	**2017**	Clay	7.35	203	1.22	1.99	1002.4	107.5
	2018	Clay	7.17	168	1.15	2.07	887.4	82.6
Malkara	**2017**	Sandy Clay	6.54	190	2.20	1.18	1051.8	145.0
	2018	Sandy Clay	6.60	185	1.95	1.50	1011.2	125.4

Figure 1. Geographic location of experiment areas (Anonymous, 2011)

The total rainfall at growing season of safflower (February to August) in Suleymanpasa was 228.5 and 366.5 mm in 2017 and 2018, respectively. Also, the mean temperature was 16.4 and 17.6 ºC in 2017 and 2018, respectively. The total rainfall in Malkara was 344.3 and 341.2 mm in 2017 and 2018, respectively. The mean temperature values of Malkara were similar to Suleymanpasa in both years. The climate and soil traits of the research locations are sufficient and appropriate for safflower cultivation. The climate data of Suleymanpasa and Malkara were given in Table 2.

Table 2. Climatical data of the experimental areas*

	Suleymanpasa								
Month	Mean temperature (ºC)			Total rainfall (mm)			Mean humidity (%)		
	2017	**2018**	**Long-term**	**2017**	**2018**	**Long-term**	**2017**	**2018**	**Long-term**
February	6.5	7.2	5.4	38.8	93.6	54.4	82.8	86.2	80.7
March	9.1	9.9	7.3	32.2	76.8	54.0	82.5	86.0	79.7
April	11.2	14.0	11.7	51.8	10.6	40.8	77.6	76.3	77.0
May	16.8	18.5	16.7	16.7	27.4	36.6	76.5	78.7	76.3
June	22.0	22.3	21.1	36.8	75.4	37.9	77.8	72.4	72.3
July	24.1	25.1	23.6	52.2	82.7	24.2	70.0	69.3	68.7
August	25.0	26.0	23.8	0.0	0.0	15.4	66.7	62.1	69.2
Mean/Total	**16.4**	**17.6**	**15.6**	**228.5**	**366.5**	**263.3**	**76.3**	**75.8**	**74.8**
	Malkara								
Month	Mean temperature (ºC)			Total rainfall (mm)			Mean humidity (%)		
	2017	**2018**	**Long-term**	**2017**	**2018**	**Long-term**	**2017**	**2018**	**Long-term**
February	6.2	5.8	4.8	37.0	123.8	66.4	82.9	91.0	78.6
March	9.7	10.1	7.6	47.1	104.0	65.5	77.3	83.7	75.2
April	12.3	15.8	11.9	51.8	7.8	41.8	65.5	64.7	71.0
May	16.9	18.8	17.1	69.6	36.2	43.9	70.5	72.8	68.8
June	22.7	22.2	21.7	30.0	50.8	59.0	67.6	68.3	65.6
July	24.4	25.1	24.1	108.0	18.6	25.1	61.3	67.0	61.7
August	24.4	25.2	24.3	0.8	0.0	12.9	60.6	64.6	61.7
Mean/Total	**16.6**	**17.6**	**15.9**	**344.3**	**341.2**	**314.6**	**69.4**	**73.1**	**68.9**

* Tekirdag Meteorological Station Data

Experimental design and measurements

In this study, seeds of Dincer 5-18-1 and Balci varieties obtained from the Transitional Zone Agricultural Research Institute (Eskisehir) were used as material. Plots of the two safflower varieties (Dincer 5-18-1 and Balci) and four sowing dates (20 February, 5 March, 20 March and 5 April) were arranged in a split plot with randomized complete block design in three replications in both locations (Suleymanpasa and Malkara) during 2017 and 2018 spring growing seasons, respectively.

The seeds were sown by hand on the planned sowing dates with the rate of 60 kg ha^{-1} in plots. Each plot consisted of 6 rows of 5 m length with spacing of 20 cm within the rows. Nitrogen and phosphorous were applied at the rate of 120 kg N (urea) and 60 kg P (diammonium phosphate) per hectare, respectively. All phosphorus and half of the nitrogen were applied prior to seed sowing and the remaining nitrogen was applied in stem elongation stage. Ten plants per plot were selected randomly for observation yield and quality characters. These characters were plant height (cm), head number, number of seeds per head, head diameter (cm), 1000 seed weight (g), seed yield (kg ha^{-1}), oil content (%) and oil yield (kg ha^{-1}). The plants were harvested by hand in both years when the seeds of the head were physiologically mature. For the seeds of each plot, the oil content (as percentage) was measured by reading in the Nuclear Magnetic Resonance (NMR) device. The oil yield was calculated by multiplying seed yield by oil content of seeds (Abou Chehade et al., 2022).

Statistical analysis

The combined analysis of variance was carried out over two years for the values of all traits. The data obtained were analyzed according to the Randomized Complete Block Design (RCBD) design. The means were compared by using the LSD test at the 0.05 and 0.01 levels as described by Steel and Torrie (1980) with MSTAT-C statistical software (MSTAT, 1989).

RESULTS AND DISCUSSION

Plant height

Years, locations, varieties, sowing dates, year × location interactions and year × sowing date interactions had significant effects on plant height ($p<0.01$) (Table 3). When sowing dates were examined, plant height shortened as planting delayed and the highest plant height was obtained from the 1st sowing date (100.57 cm). In year × sowing date interactions, the highest plant height was obtained in 2017 with the 1st sowing date (118.27 cm) (Table 5). The plant height was higher in 2017 probably because the distribution of rainfall over the growing season of safflower (February to August) was more regular in both locations. Clay particles have the ability to physically and chemically hold water molecules to the particle more tightly than sands or silts. Therefore, plant height was probably higher in Suleymanpasa location. In many studies, it has been reported that the plant height of safflower varies significantly according to environment conditions, variety, planting density and seed rates (Kose and Bilir, 2017; Gursoy et al., 2018). Hatipoglu et al. (2012) and Abou Chehade et al. (2022) reported that plant height decreases significantly with the delay of sowing date.

Head number

Years, locations, varieties, sowing dates, location × variety, location × sowing date and variety × sowing date interactions had significant effects on head number ($p<0.01$) (Table 3). In terms of sowing dates, head number decreased significantly as sowing delayed and the lowest head number was obtained from the 3rd (20 March) and 4th (5 April) sowing dates (8.07 and 7.47, respectively). It can be said that the reason for this is the short vegetation period in late sowing. In location × sowing date interactions, the highest head number was obtained from the 1st sowing date in Suleymanpasa location (17.26), in variety × sowing date interactions, the highest head number was obtained from the 1st sowing date in Dincer 5-18-1 variety (14.59) (Table 5). Differences in the head number values of the years may be due to the fact that the first year had lower rainfall during the vegetative growth period compared to the second year, which caused water stress in the plant and reduced growth. Knowles (1982) emphasized that head number is a selection criterion that directly affects seed yield. Atam (2010), Aslantas and Akinerdem (2019) and Kumar Barla et al. (2020) reported that head number was significantly affected by delayed sowing dates. These results confirm our results.

Number of seeds per head

Varieties and sowing dates had significant effects on number of seeds per head ($p<0.01$), and location, year × location interactions and variety × sowing date interactions had significant effects on number of seeds per head ($p<0.05$) (Table 3). According to the results of the research, the lowest number of seeds per head was observed in the 4th (5 April) sowing date (22.42). In variety × sowing date interactions, the lowest number of seeds per head was obtained from the 4th (5 April) sowing date in Balci variety (20.21) (Table 5). As the sowing date was delayed, the head diameter decreased and therefore the number of seeds per head decreased (Table 4). Adisarwanto and Knight (1997) suggested that early sowing under suitable environmental conditions significantly increases the number of seeds per head. Nikabadi et al. (2008) reported that the sowing date of April 6 and June 6 with 28.6 and 19.2 produced the highest and the least number of seeds per head, respectively. Kumar Barla et al. (2020) reported that there was no significant difference between combination of sowing dates and safflower cultivar for number of seeds per head. Gholami Baseri et al. (2022) emphasized that late sowing can reduce the number of seeds per head in safflower.

Head diameter

Location, varieties, sowing dates, location × sowing date and variety × sowing date interactions had significant effects on head diameter ($p<0.01$), and year and year × sowing date interactions had significant effects on head diameter ($p<0.05$) (Table 3). The highest head diameter was obtained from the 1st (20 February) sowing date with 2.34 cm (Table 4). In terms of Y × SD interactions, the highest head diameter was obtained from the 1st sowing date in 2018 (2.37 cm). In location × sowing date interactions, the highest head diameter was obtained from the 1st sowing date in Suleymanpasa location (2.40 cm), in variety × sowing date interactions, the highest head diameter was obtained from the 1st sowing date in Dincer 5-18-1 variety (2.36 cm) (Table 5). Eslam (2018) reported that delayed sowing led to significant decrease in head diameter. Hatipoglu et al. (2012) reported that the head diameter of safflower decreased as the sowing date was delayed and the lowest head diameter was obtained from sowing on April 5 (1.63 cm). In addition, Camas et al. (2005) indicated that seed yield, number of seeds per head, 1000 seed weight and oil content positively and significantly correlated with head diameter. For this reason, it is necessary to avoid agricultural practices such as late sowing that may cause a decrease in head diameter.

Table 3. Combined analysis of variance for yield and quality traits

SV	DF	Plant height	Head number	Number of seeds per head	Head diameter	1000 seed weight	Seed yield	Oil content	Oil yield
Year (Y)	1	**	**	ns	*	ns	*	**	ns
Location (L)	1	**	**	*	**	**	**	**	**
Y × L	1	**	**	*	**	*	**	*	**
Rep. × (Y × L)	8	ns	**	ns	ns	ns	ns	*	ns
Variety (V)	1	**	**	**	**	*	**	**	ns
Y × V	1	ns	ns	ns	ns	ns	ns	ns	ns
L × V	1	ns	**	ns	ns	**	ns	**	ns
Y × L × V	1	ns	*	ns	ns	ns	ns	**	*
$Error_1$	8								
Sowing Date (SD)	3	**	**	**	**	**	**	**	**
Y × SD	3	**	ns	ns	*	**	**	ns	ns
L × SD	3	ns	**	ns	**	ns	ns	ns	*
Y × L × SD	3	**	**	ns	ns	ns	ns	ns	ns
V × SD	3	ns	**	*	**	ns	ns	ns	ns
Y × V × SD	3	ns	ns	ns	*	ns	ns	**	ns
L × V × SD	3	ns	**	ns	ns	ns	ns	ns	ns
Y × L × V × SD	3	ns	ns	ns	ns	ns	ns	ns	ns
Error	48								
Total	95	--	--	--	--	--	--	--	--
CV (%)		20.42	41.04	19.12	6.13	4.88	27.29	11.89	30.14

SV: source of variation; DF: degree of freedom; CV: coefficient of variation; ns: not significant; *, ** significant at 5% and 1% levels, respectively

Table 4. Simple effects of year, location, variety and sowing dates on assessed traits of safflower

	Plant height (cm)	Head number	Number of seeds per head	Head diameter (cm)	1000 seed weight (g)	Seed yield (kg ha^{-1})	Oil content (%)	Oil yield (kg ha^{-1})
Year (Y)								
2017	108.39 **a**	9.02 **b**	24.37	2.21 **b**	44.25	1164.81 **b**	32.59 **a**	380.69
2018	75.94 **b**	10.47 **a**	25.96	2.25 **a**	44.58	1251.83 **a**	30.73 **b**	398.17
Location (L)								
Suleymanpasa	94.69 **a**	11.46 **a**	26.36 **a**	2.27 **a**	44.94 **a**	1394.03 **a**	32.85 **a**	456.31 **a**
Malkara	89.64 **b**	8.03 **b**	23.98 **b**	2.19 **b**	43.89 **b**	1022.61 **b**	30.47 **b**	322.54 **b**
Variety (V)								
Dincer	94.39 **a**	10.67 **a**	26.65 **a**	2.28 **a**	44.72 **a**	1288.05 **a**	28.52 **b**	381.92
Balci	89.94 **b**	8.82 **b**	23.68 **b**	2.18 **b**	44.11 **b**	1128.59 **b**	34.80 **a**	396.94
Sowing Dates (SD)								
1st (20 Februay)	100.57 **a**	13.18 **a**	27.28 **a**	2.34 **a**	46.56 **a**	1442.67 **a**	31.93 **ab**	459.15 **a**
2nd (5 March)	94.83 **b**	10.25 **b**	26.24 **ab**	2.27 **b**	45.01 **b**	1315.77 **b**	32.34 **a**	429.23 **a**
3rd (20 March)	90.51 **c**	8.07 **c**	24.72 **b**	2.21 **c**	43.84 **c**	1113.71 **c**	31.66 **b**	351.84 **b**
4th (5 April)	82.76 **d**	7.47 **c**	22.42 **c**	2.10 **d**	42.25 **d**	961.13 **d**	30.72 **c**	317.50 **b**
Mean	**92.17**	**9.74**	**25.17**	**2.23**	**44.41**	**1208.32**	**31.66**	**389.43**

1000 seed weight

Location, sowing dates, location × variety and year × sowing date interactions had significant effects on 1000 seed weight ($p<0.01$), and varieties and year × location interactions had significant effects on 1000 seed weight ($p<0.05$) (Table 3). In terms of the sowing dates, the highest 1000 seed weight was observed in the 1st (20 February) sowing date (46.56 g). In location × variety interactions, the highest 1000 seed weight was obtained from Dincer 5-18-

1 variety in Suleymanpasa location (45.82 g). In year × sowing date interactions, the highest 1000 seed weight was obtained from the 1st sowing date in 2018 (47.44 g) (Table 5). Knowles (1959) emphasized that 1000 seed weight depending on seed filling was directly related to climatic conditions at flowering period. When the climatic characteristics of the locations were compared, Suleymanpasa had higher humidity than Malkara during the flowering period (Table 2). Hatipoglu et al. (2012) reported that early sowing is necessary for high seed yield and that the 1000 seed weight may vary according to sowing dates. They determined the 1000 seed weight in spring sowing as 39.49 g in the 20 February, 38.86 g in the 7 March, 38.02 g in the 22 March and 37.33 g in the 5 April over the average of three years. The results of the researchers are similar to our results.

Table 5. Mean comparison the double interaction effects on assessed traits of safflower

		Plant height (cm)	**Head number**	**Number of seeds per head**	**Head diameter (cm)**	**1000 seed weight (g)**	**Seed yield (kg ha^{-1})**	**Oil content (%)**	**Oil yield (kg ha^{-1})**
Y × V									
2017	Dincer	110.313	9.99	25.56	2.25	44.40	1263.44	29.61	376.93
	Balci	106.47	8.05	23.18	2.17	44.10	1066.18	35.58	384.45
2018	Dincer	78.48	11.34	27.74	2.31	45.04	1312.66	27.44	386.92
	Balci	73.41	9.59	24.19	2.19	44.12	1190.99	34.02	409.43
L × V									
Suleymanpasa	Dincer	97.43	12.80 **a**	27.94	2.32	45.82 **a**	1489.69	29.99 **c**	445.96
	Balci	91.95	10.12 **b**	24.78	2.23	44.05 **b**	1298.36	35.71 **a**	466.67
Malkara	Dincer	91.35	8.53 **c**	25.36	2.24	43.62 **b**	1086.41	27.06 **d**	317.88
	Balci	87.93	7.53 **c**	22.59	2.13	44.12 **b**	958.81	33.88 **b**	327.20
Y × SD									
2017	1st	118.27 **a**	12.45	26.97	2.31 **b**	45.68 **b**	1391.89 **a**	32.96	455.61
	2nd	111.82 **b**	9.81	25.65	2.22 **c**	44.60 **cd**	1198.93 **b**	33.36	408.07
	3rd	106.65 **c**	7.19	23.25	2.20 **c**	43.96 **d**	1094.82 **b**	32.72	355.12
	4th	96.83 **d**	6.62	21.60	2.11 **d**	42.76 **e**	973.61 **c**	31.33	303.95
2018	1st	82.87 **e**	13.91	27.60	2.37 **a**	47.44 **a**	1493.44 **a**	30.89	462.70
	2nd	77.84 **f**	10.69	26.83	2.31 **b**	45.42 **bc**	1432.62 **a**	31.31	450.39
	3rd	74.38 **g**	8.96	26.18	2.23 **c**	43.71 **d**	1132.60 **b**	30.59	348.56
	4th	68.69 **h**	8.32	23.42	2.09 **d**	41.74 **f**	948.65 **c**	30.12	331.04
L × SD									
Suleymanpasa	1st	102.24	17.26 **a**	28.30	2.40 **a**	46.78	1651.32	32.88	538.57 **a**
	2nd	97.49	12.34 **b**	26.27	2.27 **b**	45.49	1541.53	33.66	521.49 **a**
	3rd	92.37	8.58 **cd**	26.32	2.25 **b**	44.52	1247.96	32.76	405.33 **b**
	4th	86.67	7.65 **de**	24.54	2.18 **c**	42.96	1135.30	32.09	359.88 **bc**
Malkara	1st	98.90	9.09 **c**	26.28	2.28 **b**	46.34	1234.02	30.97	379.74 **bc**
	2nd	92.17	8.16 **cde**	26.21	2.26 **b**	44.52	1090.01	31.01	336.97 **cd**
	3rd	88.66	7.57 **de**	23.11	2.18 **c**	43.16	979.46	30.55	298.35 **de**
	4th	78.85	7.30 **e**	20.30	2.03 **d**	41.54	786.96	29.36	275.12 **e**
V × SD									
Dincer	1st	102.77	14.59 **a**	28.01 **a**	2.36 **a**	46.87	1547.98	28.76	447.12
	2nd	97.91	11.83 **b**	26.22 **a**	2.30 **ab**	45.25	1404.90	29.47	415.83
	3rd	92.19	8.28 **c**	27.72 **a**	2.27 **bc**	44.23	1185.07	28.24	337.08
	4th	84.70	7.95 **cd**	24.64 **ab**	2.18 **de**	42.54	1014.26	27.63	327.66
Balci	1st	98.37	11.77 **b**	26.56 **a**	2.32 **ab**	46.25	1337.35	35.09	471.19
	2nd	91.75	8.67 **c**	26.26 **a**	2.23 **cd**	44.76	1226.64	35.20	442.62
	3rd	88.84	7.87 **cd**	21.72 **bc**	2.15 **e**	43.44	1042.35	35.07	366.59
	4th	80.82	6.99 **d**	20.21 **c**	2.02 **f**	41.97	908.00	33.82	307.33
Mean		**92.17**	**9.74**	**25.17**	**2.23**	**44.41**	**1208.32**	**31.66**	**389.43**

Values followed by the same letter(s) are not significantly different at the 5% probability level according to LSD

Seed yield

In the study, year ($p<0.05$), locations, varieties, sowing dates and year × sowing date interactions were found to be statistically significant ($p<0.01$) (Table 3) for seed yield. The second year had higher seed yield (1251.83 kg ha^{-1}) than the first year (1164.81 kg ha^{-1}). While the highest seed yield was obtained from the 1st (20 February) sowing date (1442.67 kg ha^{-1}), the lowest seed yield was obtained from the 4th (5 April) sowing date (961.13 kg ha^{-1}). In terms of the year x sowing date interactions, the highest seed yield was observed at the 1st sowing date in the first year (1391.89 kg ha^{-1}) and at the 1st (1493.44 kg ha^{-1}) and 2nd sowing dates (1432.62 kg ha^{-1}) in the second year (Table 5). According to the climatic characteristics of experiment areas given in Table 2, more precipitation fell in March 2018 than March 2017 in both locations. Therefore, seed yield values may have been in the same group at 1st and 2nd sowing dates in 2018. Many researchers agreed that the seed yield and some of its components decreases significantly with the delay of sowing dates (Omidi and Sharifmogadas, 2010; Keles and Ozturk, 2012; Eslam, 2018; El Bey et al., 2021). Samanci and Ozkaynak (2003) reported that seed yield decreased with delay in sowing date and seed yields of 1875 (25 April), 1637 (15 May) and 1176 (25 May) kg ha^{-1} were obtained from the first, second and third sowing date, respectively. Arslan and Culpan (2018) reported that the seed yield in safflower genotypes obtained from USDA collection ranged from 147.90 to 2349.90 kg ha^{-1} in Suleymanpasa ecological conditions. Erbas et al. (2016) reported that seed yields of safflower ranged from 152.00 to 2159.00 kg ha^{-1}. The results were found within the limits reported by these researchers.

Oil content

Years, locations, varieties, sowing dates, location × variety interactions had significant effects on oil content ($p<0.01$). In addition, the triple interactions of Y × L × V and Y × V × SD were found to be statistically significant at level 1% (Table 3). The average oil content was determined as 31.66% (Table 4). In terms of the sowing dates, the highest oil content was obtained from the 1st (31.93%) and 2nd (32.34%) sowing dates, while the lowest oil content was obtained from the 4th sowing date (30.72%). In location × variety interactions, the highest oil content was obtained from Balci variety in Suleymanpasa location with 35.71% (Table 5). Omidi et al. (2012) has obtained similar results in previous studies and they reported that oil content was significantly affected by variety. Many researchers reported that there are many factors affecting the oil content (Omidi et al., 2012; Mirshekari et al., 2013). Contrary to the fact that Emami et al. (2011) found that late sowing decreased oil content, Keles and Ozturk (2012) reported that oil content was not affected by sowing date.

Oil yield

In the study, locations, sowing dates and year × location interactions were found to be statistically significant at level 1% and location × sowing date interactions at level 5% for oil yield (Table 3). The highest oil yield was obtained from the 1st and 2nd sowing dates (459.15 and 429.23 kg ha^{-1}, respectively) (Table 4). In location × sowing date interactions, the highest oil yield was obtained from the 1st and 2nd sowing dates (538.57 and 521.49 kg ha^{-1}, respectively) in Suleymanpasa location (Table 5). As seen in the research findings, oil yield decreased as the sowing date was delayed depending on the seed yield. Eslam et al. (2010) reported that since late sowing reduces the seed filling stage in spring safflower genotypes, oil yield decreases. Omidi Tabrizi (2006) evaluated safflower genotypes under three different ecological conditions (Karaj, Isfahan, and Darab in Iran) and indicated significant differences among genotypes for oil yield. In addition, La Bella et al. (2019) emphasized that the oil yield in safflower may vary according to production years.

CONCLUSIONS

This study showed that late sowing significantly reduces seed yield and oil yield in safflower, which limits sustainable safflower cultivation. The environmental and climatic conditions, locations and production year influenced yield components and oil content depending on the varieties used. In general, early sowing in suitable ecological conditions seemed to be appropriate for safflower. Especially in Suleymanpasa location, it is seen that both varieties are suitable for seed and oil yield. When the results of this study are evaluated as a whole, because of sowing date is an important factor for seed and oil yield of safflower, sowing should be done as early as possible depending on soil temperature in the spring season in northwest Turkey.

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