agronomy

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Evaluation of Agronomic and Oil Characteristics of Selected Turkish Poppy Genotypes under Ankara's Climate Conditions

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Abstract: Poppy is a minor agronomic field crop that is cultivated under a UN license. It is known for its alkaloids and seeds, and, rarely, for the latter's use in ethnomedicine. Changing climate conditions could lead to the need for alternate areas for poppy cultivation in Türkiye. This experiment was conducted in Ankara, which is not a poppy production area. The morphological characteristics and oil characteristics of 19 Turkish poppy genotypes were determined over two years. According to the results, the emergence time was between 10 and 22 days, the flowering time ranged from 197 to 214 days, while the harvest maturation time was between 250 and 269 days. The plant height varied from 75.8 to 97.5 cm, the weight of 1000 seeds ranged from 305.0 to 428.0 mg, and the weight of the seeds per plant was between 2.95 and 5.78 g. Furthermore, the yield ranged from 100.7 to 202.3 kg da^{-1}, the fat content was between 38.8 and 44.1%, and the protein content ranged from 15.9 to 18.4%. The linoleic acid content ranged from 66.77% to 75.60%, the oleic acid content ranged from 10.78% to 19.46%, and the palmitic acid content ranged from 8.38% to 9.90%. The highest yield in Ankara was obtained from the Çelikoğlu cultivar.

Keywords: *Papaver somniferum*; growth parameters; oil content; fatty acids; yield

Citation: Kahraman-Yanardağ, Y.; Day, S.; Bayraktar, N.; Özgen, Y. Evaluation of Agronomic and Oil Characteristics of Selected Turkish Poppy Genotypes under Ankara's Climate Conditions. *Agronomy* **2024**, *14*, 957. https://doi.org/10.3390/agronomy14050957

Academic Editors: Wenqing Zhao, Wei Hu and Zhiguo Zhou

Received: 30 March 2024
Revised: 25 April 2024
Accepted: 29 April 2024
Published: 2 May 2024

1. Introduction

Türkiye is the most significant opium-exporting country in the world. It is important for countries that are interested in producing poppies to consider the UN Convention on Narcotics, which was signed in 1988. This convention requires these countries to not only monitor their cultivation methods and patrol cultivation areas, but also to create a new strategy for developing special varieties of poppies. Türkiye has been recognized by the UN as a traditional poppy-producing country, similarly to India. Poppy production takes place in fifteen provinces of Türkiye. The legal poppy producers globally are Türkiye, India, Hungary, Spain, France, the Czech Republic, China and Australia.

The Papaver genus has around 100 taxa worldwide, with 51 of those being present in Türkiye, including 15 endemic taxa. Poppies are grown in Türkiye during both winter and summer, but winter planting is preferred due to the higher yields this generates. Winter planting typically occurs in October, while summer planting occurs in February–March. Poppies have multipurpose uses for several industries. Poppy seeds contain high-quality edible oil, which can also be used in the production of paints, varnishes, and soaps. Poppy capsules are rich in alkaloids, while the seeds are valuable for oil. The oil extracted from poppy seeds is typically cold-pressed and has traditional significance in cooking and baking [1]. Poppies are generally cultivated in a very limited area compared to other oilseed crops; their cultivation area in Türkiye exceeds 26,501 ha and the seed production is around 12,240 tons [2]. Poppy seeds have varying oil contents based on their colour; white and yellow seeds have a higher oil content and the seed oil ranges from 28% to 53%, which is related to the cultivar and environmental conditions [3,4]. Linoleic acids and oleic acids are the major unsaturated oils, and palmitic and stearic acids are the major saturated fatty acids found in oilseed crops [5]. The demand for alkaloids worldwide has resulted in a rise in poppy cultivation, which in turn has led to an increase in seed production. The changing climate conditions in Türkiye could lead to the cultivation of poppy crops in other provinces that are not currently taking part in poppy production, and the observation of crops under field conditions is gaining importance for these new areas which do not commonly cultivate poppy crops. Poppies face many abiotic stress factors threatening their crop cycle and are cultivated under rainfed conditions.

With the changing environmental conditions due to global warming, the search for new areas to cultivate poppy crops and the evaluation of genotypes under new environments is important. This study was conducted to assess the diversity of the morphology, yield, and oil composition of poppy genotypes under the environmental conditions in Ankara, which is not a poppy cultivation area.

2. Materials and Methods

2.1. Plant Material

The seeds of *Papaver somniferum* genotypes used in this experiment were Ofis 1, Ofis 2, Ofis 3, Ofis 4, Ofis 8, Ofis-NP, Ofis-NM, Ofis 95, Ofis 96, TMO 1, TMO 2, TMO 3, Afyon 95, Hüseyinbey, Seyitgazi, Çelikoğlu, Line 8, Line 15, and Line 21.

2.2. Experimental Sites and Design

The poppy genotypes were cultivated during the 2019–2020 and 2020–2021 seasons at the experimental fields of the Department of Field Crops, Faculty of Agriculture, at Ankara University (Figure 1). They are located at an altitude of 860 m above sea level, between 30°53′ north latitude and 32°45′ west longitude.

Figure 1. A view of experiment site in 2020.

The experiment was designed as a randomised complete block with four replications. The sowing time for 2019 was October 26th and for 2020 it was October 27th. The first year's harvest was on 27 July 2020, and the second year's was on 12 July 2021.

This study was carried out on a plot area of 2.4 (2 m × 1.2 m) square meters, which was divided into 4 rows with a gap of 30 cm between them. The space between plants was maintained at 10 cm. Standard agricultural practices were followed throughout in both cropping seasons. DAP (Diammonium phosphate) was applied before sowing to sustain a level of 4 kg da^{-1} N. The first round of hand weeding took place in March; thinning, the second round of hand weeding, and the earthing up process was carried out in April. After sowing, irrigation was carried out for seedling emergence and no further irrigation was performed. Hand weeding was carried out in all plots.

2.3. Characteristics of Morphology and Quality

The capsules were harvested manually when they had reached their full maturity stage, taking into account the varying maturity levels of the different genotypes. Before the harvest, plant height (cm) was measured in the field. After the harvest, various morphological properties such as 1000 seed weight (mg), seed weight per plant (g), and seed yield (kg da^{-1}) were determined. In each plot, plant height and seed weight per plant (g plant^{-1}) were measured in 10 randomly selected poppy plants. Each genotype plot in the experiment, for both years, consisted of 84 poppy plants.

Field emergence (day) was determined by measuring the number of days from sowing to emergence. Inflorescence time (day) was calculated as the number of days from sowing to the day when 50% of the poppy plants in the plot were in bloom. Harvest maturity (day) was determined by measuring the number of days from sowing to the day when the capsules were dry.

Oil and protein contents were determined by the hexane-based method and the Kjeldahl method, respectively. The process involved the extraction of oil from 2 g of poppy seeds using a homogenized solution of 3 parts hexane and 2 parts isopropanol (v/v). The extraction was carried out three times to ensure accuracy. The oil samples were then converted to fatty acid methyl esters (FAMEs) using the method outlined by Tammekivi et al. [6].

The fatty acid methyl esters (0.5 µL) were analysed using a Hewlett-Packard 6890 series gas chromatograph (Perkin Elmer Auto System XL, Waltham, MA, USA) that was equipped with a flame ionizing detector (FID) and a fused silica capillary column (MN FFAP [50 m $\times$ 0.32 mm i.d.; film thickness = 0.25 µm]). The instrument was operated under the following conditions:

The oven temperature was programmed to start at 120 °C for a duration of 1 min, then raised to 240 °C at a rate of 6 °C per minute and kept constant for 15 min. The injector and detector temperatures were set to 250 °C and 260 °C, respectively. Helium was used as the carrier gas at a flow rate of 40 mL per minute, with a split rate of 1/20 mL per minute. Peak identification was carried out by comparing the relative retention times with those of a commercial standard mixture of FAMEs. The composition of linoleic (C18:2), oleic (C18:1), palmitic (C16:0), stearic (C18:0), linolenic (C18:3), and palmitoleic acid (16:1) and other fatty acids in the oil was determined using a computing integrator. Hexadecane (Sigma-Aldrich, St. Louis, MO, USA, purity $\geq$ 99%) was used as the internal standard in GC analysis [6]. The peaks of fatty acid methyl esters were identified with the help of authentic standards of a C4-C24 fatty acid methyl ester mixture (Supelco, Bellefonte, PA, USA) and were evaluated using ChemStation 10.1 (Agilent Technologies, Santa Clara, CA, USA). The degree of fatty acid unsaturation (IU) was calculated in D/mole using the following equation: IU = [1 (% monoene) + 2 (% diene) + 3 (% triene)]/100 [7]. This study analysed the effects of independent variables on the oil content, and the percentage concentrations of these acids in the oil. These analyses were carried out at the Turkish Grain Board Laboratory.

2.4. Soil Analysis

The physicochemical properties of the soil of the experimental site were investigated at "the Soil Quality and Fertility Analysis Laboratory" of the Central Forestry Soil, Fertilizer and Water Resources Research Institute, Ankara, Türkiye. The soil samples were taken from depths of 0–30 cm.

2.5. Statistical Analysis

The data obtained from experiment were subjected to analysis of variance using randomised complete block design. Data given in percentages were subjected to arcsine transformation before statistical analysis. The post hoc tests were performed with Duncan's Multiple Range Test (MSTAT-C software, version 2.1, Michigan State University, East Lansing, MI, USA, 1991).

3. Results

3.1. Soil and Climate Properties

The texture of the soil at the experimental site was clay and clay loam. The soil showed alkaline characteristics, containing low organic matter and nitrogen. The content of the lime ($CaCO_3$) was 5.15% and 7.27% in 2019–2020 and 2020–2021, respectively. The available phosphorus (P_2O_5) content was determined as 3.04 kg da^{-1} and 5.53 kg da^{-1}. The concentration of available potassium (K_2O) was measured as 117.82 and 128.08 in the respective periods (Table 1).

Table 1. Physical and chemical properties of the experimental fields.

Soil Properties (0–30 cm)	2019–2020	2020–2021
Organic composition (%)	0.61	0.45
CaCO3 (%)	5.15	7.27
Available P_2O_5 (kg da^{-1})	3.04	5.53
Available K_2O (kg da^{-1})	117.82	128.08
pH	7.88	8.08
Total N (%)	0.093	0.059
Salinity (%)	0.0679	0.0347
Soil texture	Clay	Clay-loam
EC (dS m^{-1})	1.33	0.81

Soil quality and fertility analysis completed at the laboratory of the Central Forestry Soil, Fertilizer and Water Resources Research Institute Ankara.

The experimental land at Ankara University, Faculty of Agriculture, Department of Field Crops has an altitude up to 860 m above sea level, an average humidity in the long term of 60.4%, a long-term average temperature of 11.9 °C, and a precipitation average per year of 395.1 mm (Directorate General of Meteorology, 2022). The average temperature, relative humidity, and precipitation of the vegetation period and the long-term average of the meteorological data are given in Table 2.

Table 2. Meteorological data of the experimental site.

Months	Precipitation (mm)			Temperature (°C)			Relative Humidity (%)		
	2019–2020	2020–2021	Average 1929–2022	2019–2020	2020–2021	Average 1929–2022	2019–2020	2020–2021	Average 1929–2022
October	7.5	29.6	27.6	16.4	17.7	13.2	48.2	45.3	58.5
November	21.0	5.9	31.7	10.3	6.8	7.2	58.3	60.2	69.8
December	66.2	17.7	44.6	4.2	6.0	2.5	80.3	71.1	77.6
January	22.4	65.8	41.2	1.4	3.5	0.2	72.8	74.1	77.3
February	70.4	16.8	35.7	4.2	4.5	1.9	66,2	60.5	72.7
March	23.2	69.5	40.0	9.3	5.1	5.8	56.4	62.7	64.4
April	23.4	29.3	43.0	11.7	12.3	11.2	47.4	54.9	58.6
May	69.4	13.7	51.3	17.0	19.1	16.0	48.9	39.7	57.0
June	108.7	41.2	35.9	20.7	19.0	20.0	50.9	57.4	52.1
July	5.1	1.9	14.2	25.9	25.5	23.4	37.4	37.2	44.4

Directorate General of Meteorology, Ankara, Türkiye 2022.

3.2. Morphologic and Quality Characteristic Observation

The year × genotype interaction was found to be statistically significant in terms of the emergence time ($p < 0.01$). The results indicate that all the genotypes displayed an earlier emergence during the second year of the experiment compared to the first year. The temperature difference between the Octobers of the two years was 1.3 °C, with the second year being warmer (Table 2). Additionally, the second year's October witnessed higher precipitation levels (29.6 mm). During the experiment, it was observed that all the genotypes emerged earlier in the second year compared to the first year. Additionally, the precipitation in the October of the second year was higher, at 29.6 mm. It was evident that Ofis-8 (22 days), Ofis-NP (20 days), TMO-2 (20 days), Hüseyinbey (20 days), Line-15 (20 days), and Line-21 (20 days) were affected by the lower temperature during germination and emergence in the first year, causing a delay in emergence (Figure 2). The emergence time for the first year was 18.2 days, and for the second year it was 13.2 days ($p < 0.01$).

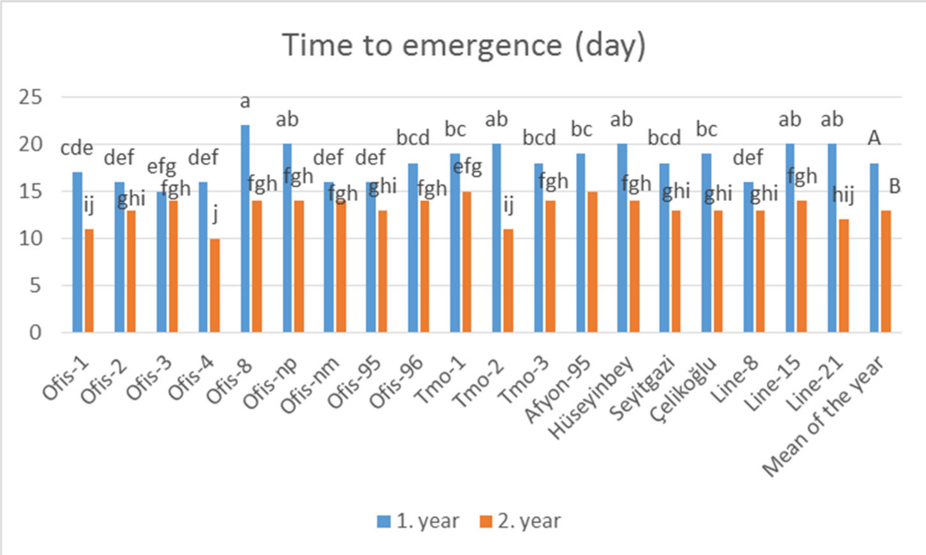

Figure 2. Time to the emergence of poppy genotypes. Different letters indicate significant differences ($p < 0.01$).

The inflorescence time of the poppy genotypes was statistically affected by the year × genotype interaction ($p < 0.01$) and by the year ($p < 0.01$). The time to flowering ranged from 197.0 to 214 days (Figure 3). The average temperature in April 2020 was lower than that in 2021 (Table 2), which caused a delay in flowering.

The harvest maturity time of the poppy genotypes was statistically influenced by the year × genotype interaction ($p < 0.01$) and by the year ($p < 0.01$). The precipitation in the May and June of 2020 exceeded the long-term average (Table 2) and resulted in a longer maturation period, which was not observed in 2021. The time to maturity ranged from 250 to 269 days among the genotypes (Figure 4).

The plant heights of the poppy genotypes were not affected statistically by the year × genotype interaction, genotype, or year ($p > 0.01$ and $p > 0.05$). The plant height values varied between 75.8 and 97.5 cm (Table 3). The maximum and the minimum mean plant heights over the two years were observed in the Ofis-NM (96.3 cm) and Ofis-3 (81.0 cm) cultivars.

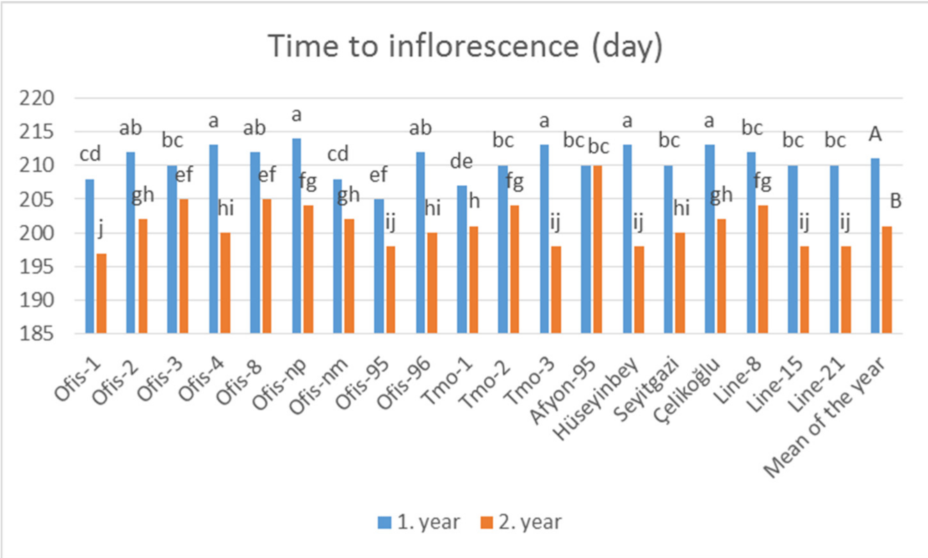

Figure 3. Time to the inflorescence of poppy genotypes. Different letters indicate significant differences ($p < 0.01$).

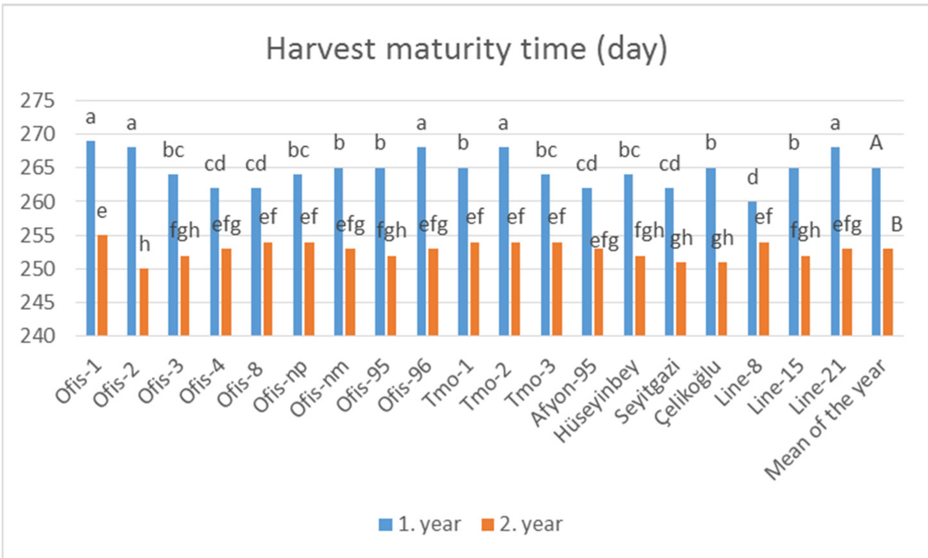

Figure 4. Harvest maturity time of poppy genotypes. Different letters indicate significant differences ($p < 0.01$).

Table 3. The comparison of the means of some morphologic components obtained from poppy genotypes.

Genotypes	Plant Height (cm)			1000 Seed Weight (mg)			Seed Weight per Plant (g plant^{-1})		
	1. Year	2. Year	Mean	1. Year	2. Year	Mean	1. Year	2. Year	Mean
Ofis-1	84.5	88.8	86.6	428.0	385.0	406.0 ^{ab} **	3.88	4.15	4.01 $^{c–f}$ **
Ofis-2	82.2	90.0	86.1	395.0	345.0	370.0 ^{abc}	4.58	4.70	4.64 $^{a–d}$
Ofis-3	75.8	86.3	81.0	413.0	390.0	401.0 ^{ab}	5.15	5.30	5.23 ^{abc}
Ofis-4	81.3	88.8	85.0	415.0	412.0	414.0 ^{ab}	4.60	4.45	4.53 $^{a–d}$
Ofis-8	77.3	90.0	83.6	407.0	293.0	350.0 ^{bc}	3.60	3.70	3.65 ^{def}

Table 3. *Cont.*

Genotypes	Plant Height (cm)			1000 Seed Weight (mg)			Seed Weight per Plant (g plant^{-1})		
	1. Year	2. Year	Mean	1. Year	2. Year	Mean	1. Year	2. Year	Mean
Ofis-NP	91.3	95.0	93.1	383.0	417.0	400.0 ^{ab}	2.88	3.15	3.01 ^{f}
Ofis-NM	95.0	97.5	96.3	428.0	427.0	427.0 ^{a}	4.85	4.45	4.65 $^{a–d}$
Ofis-95	86.3	92.5	89.4	407.0	398.0	402.0 ^{ab}	5.40	5.40	5.40 ^{ab}
Ofis-96	88.5	88.8	88.6	338.0	367.0	353.0 ^{bc}	4.73	4.65	4.69 $^{a–d}$
TMO-1	85.0	92.5	88.8	383.0	432.0	407.0 ^{ab}	4.20	4.15	4.18 $^{b–f}$
TMO-2	86.3	91.3	88.8	407.0	400.0	404.0 ^{ab}	4.08	3.90	3.99 $^{c–f}$
TMO-3	88.3	92.5	90.4	402.0	385.0	394.0 ^{ab}	3.43	2.95	3.19 ^{ef}
Afyon-95	89.5	93.8	91.6	350.0	383.0	366.0 ^{abc}	3.90	3.45	3.68 ^{def}
Hüseyinbey	95.0	86.3	90.6	305.0	328.0	316.0 ^{c}	5.23	4.95	5.09 ^{abc}
Seyitgazi	93.8	86.3	90.0	380.0	392.0	386.0 ^{ab}	5.08	3.85	4.46 $^{a–e}$
Çelikoğlu	96.3	85.0	90.6	345.0	412.0	379.0 ^{abc}	5.78	5.45	5.61 ^{a}
Line-8	86.3	87.5	86.9	345.0	347.0	346.0 ^{bc}	5.08	4.70	4.89 $^{a–d}$
Line-15	86.3	87.5	86.9	398.0	352.0	375.0 ^{abc}	5.03	5.25	5.14 ^{abc}
Line-21	88.8	82.5	85.6	392.0	407.0	400.0 ^{ab}	4.55	4.45	4.50 $^{a–d}$
Mean	87.2	89.6		385.0	383.0		4.53	4.37	

** Figures having a similar letter(s) are not statistically and significantly different using Duncan's test at $p < 0.01$.

There were statistical differences ($p < 0.01$) between the average 1000 seed weights of the genotypes over the two years. The highest 1000 seed weight was recorded for Ofis-NM, which was 427.0 mg, while the lowest 1000 seed weight was recorded for Hüseyinbey, which was 316.0 mg (Table 3).

Different effects of the genotypes ($p < 0.01$) were observed in the seed weight per plant (in the range of 3.01–5.61 g plant^{-1}). The maximum value was noted in Çelikoğlu, whereas the minimum value was noted in Ofis-NP (Table 3).

The statistical differences ($p < 0.01$) were determined between the average seed yield values over the two years. The maximum yield was recorded in the Çelikoğlu cultivar (with a yield of 196.6) while the minimum value was recorded in Ofis-NP (with a yield of 105.5). The Duncan Multiple Range Test indicated that the Ofis-2, Ofis-3, Ofis-4, Ofis-NM, Ofis-95, Ofis-96, Hüseyinbey, Seyitgazi, Çelikoğlu, Line-8, Line-15, and Line-21 genotypes were in the same group for the seed yields (Table 4).

The seed oil contents of the poppy genotypes were statistically affected by the year × genotype interaction ($p < 0.01$). The Ofis-8 genotype produced the highest oil content, at 44.1%, in the second year, while the lowest yield of 38.8% was obtained for Ofis-NM in the first year of the experiment. In terms of the average of the two years, it was observed that there was diversity in the seed protein content of the various poppy genotypes ($p < 0.01$). The maximum protein content was recorded for Ofis-NM, at 18.0%, while the minimum protein content was recorded for Ofis-96, at 16.3% (Table 4).

The interaction between the years and genotypes had a significant impact on the linoleic acid levels ($p < 0.01$). The genotypes were found to be rich in linoleic acid. TMO-3 had the highest levels, at 76.12%, in the second year of the experiment. In the first year, the linoleic acid content was 71.49%, while in the second year, it increased to 73.07%. Oleic acid was the second most abundant fatty acid in the genotypes and was the major monounsaturated fatty acid (MUFA). The oleic acid ratios in the poppy genotypes were influenced by the year × genotype interactions and by the year ($p < 0.01$). The first year of the experiment revealed that Ofis-1 had the highest content of oleic acid, at 19.46%, while the lowest was found in TMO-3, at 10.78%, in the second year. The oleic acid content in the first year was 15.21%, decreasing to 13.83% in the second year. Palmitic acid showed differences in terms of the year × genotype interactions ($p < 0.01$) and between the two years ($p < 0.01$). The most common saturated fatty acid found in the genotypes is known as palmitic acid. During the first year of the experiment, the highest and lowest palmitic acid content was observed in TMO-2 and Ofis-95, respectively, at 9.90% and 8.38% (Table 5).

Table 4. The comparison of the means of some yield components obtained from poppy genotypes.

Genotypes	Seed Yield (kg da^{-1})			Oil Content (%)			Protein Content (%)		
	1. Year	2. Year	Mean	1. Year	2. Year	Mean	1. Year	2. Year	Mean
Ofis-1	135.7	145.4	140.6 $^{c–f}$ **	39.7 ^{efg}	40.5 $^{b–g}$ **	40.1	16.9	17.4	17.1 ^{abc} **
Ofis-2	160.3	164.6	162.4 $^{a–d}$	41.0 $^{b–g}$	43.1 ^{ab}	42.1	17.7	17.1	17.4 ^{abc}
Ofis-3	180.4	185.6	183.0 ^{abc}	40.2 $^{d–g}$	40.5 $^{b–g}$	40.4	16.8	17.5	17.2 ^{abc}
Ofis-4	161.1	155.9	158.5 $^{a–d}$	41.1 $^{b–g}$	43.1 ^{abc}	42.1	16.1	16.7	16.4 ^{bc}
Ofis-8	126.1	129.6	127.8 ^{def}	39.1 ^{fg}	44.1 ^{a}	41.6	16.4	17.1	16.7 ^{abc}
Ofis-NP	100.7	110.3	105.5 ^{f}	40.1 $^{d–g}$	40.1 $^{d–g}$	40.1	17.8	17.6	17.7 ^{ab}
Ofis-NM	169.9	155.9	162.9 $^{a–d}$	38.8 ^{g}	40.2 $^{d–g}$	39.5	17.6	18.4	18.0 ^{a}
Ofis-95	189.2	189.2	189.2 ^{ab}	39.7 $^{d–g}$	40.0 $^{d–g}$	39.9	17.3	17.1	17.2 ^{abc}
Ofis-96	165.5	162.9	164.2 $^{a–d}$	39.5 ^{efg}	42.5 $^{a–d}$	41.0	16.7	15.9	16.3 ^{c}
TMO-1	147.1	145.4	146.2 $^{b–f}$	40.0 $^{d–g}$	41.8 $^{a–f}$	40.9	16.5	16.3	16.4 ^{bc}
TMO-2	142.7	136.6	139.7 $^{c–f}$	41.0 $^{b–g}$	40.7 $^{b–g}$	40.8	17.4	16.8	17.1 ^{abc}
TMO-3	120.0	103.3	111.7 ^{ef}	41.1 $^{b–g}$	42.0 $^{a–e}$	41.6	16.7	16.7	16.7 ^{abc}
Afyon-95	136.6	120.8	128.7 ^{def}	39.1 ^{fg}	40.3 $^{c–g}$	39.7	17.1	17.2	17.1 ^{abc}
Hüseyinbey	183.0	173.4	178.2 ^{abc}	40.6 $^{b–g}$	40.4 $^{c–g}$	40.5	17.6	17.5	17.5 ^{abc}
Seyitgazi	177.8	134.9	156.3 $^{a–e}$	40.3 $^{c–g}$	40.3 $^{c–g}$	40.3	17.1	18.0	17.5 ^{abc}
Çelikoğlu	202.3	190.9	196.6 ^{a}	40.9 $^{b–g}$	41.1 $^{b–g}$	41.0	16.7	17.3	17.0 ^{abc}
Line-8	177.8	164.6	171.2 $^{a–d}$	40.8 $^{b–g}$	42.1 $^{a–e}$	41.4	17.4	17.5	17.4 ^{abc}
Line-15	176.0	183.9	180.0 ^{abc}	41.4 $^{b–g}$	40.6 $^{b–g}$	41.0	17.0	17.3	17.2 ^{abc}
Line-21	159.4	155.9	157.6 $^{a–d}$	40.2 $^{d–g}$	41.2 $^{b–g}$	40.7	17.2	17.5	17.3 ^{abc}
Mean	158.5	153.1		40.2	41.3		17.0	17.2	

** Figures having a similar letter(s) are not statistically and significantly different using Duncan's test at $p < 0.01$.

Table 5. The comparison of the means of linoleic, oleic, and palmitic acids obtained from poppy genotypes.

Genotypes	Linoleic Acid (18:2) (%)			Oleic Acid (18:1) (%)			Palmitic Acid (16:0) (%)		
	1. Year	2. Year	Mean	1. Year	2. Year	Mean	1. Year	2. Year	Mean
Ofis-1	66.77 ^{q}	70.01 ^{n} **	68.39	19.46 ^{a}	16.22 ^{de} **	17.84	9.42 ^{f}	9.25 ^{h} **	9.33
Ofis-2	70.23 ^{n}	73.20 ^{gh}	71.72	16.37 ^{d}	13.53 ^{o}	14.95	9.23 ^{i}	9.12 ^{j}	9.17
Ofis-3	70.92 ^{m}	72.74 ^{ij}	71.83	15.28 ^{g}	13.55 ^{o}	14.41	9.78 ^{b}	9.45 ^{e}	9.62
Ofis-4	72.02 ^{k}	71.75 ^{kl}	71.89	14.83 ^{jk}	15.17 ^{gh}	15.00	8.73 ^{r}	8.41 ^{y}	8.57
Ofis-8	70.23 ^{n}	73.13 ^{gh}	71.68	16.03 ^{e}	14.14 ^{m}	15.09	9.26 ^{h}	9.05 ^{k}	9.15

Table 5. *Cont.*

Genotypes	Linoleic Acid (18:2) (%)			Oleic Acid (18:1) (%)			Palmitic Acid (16:0) (%)		
	1. Year	2. Year	Mean	1. Year	2. Year	Mean	1. Year	2. Year	Mean
Ofis-NP	68.17 ^{p}	68.63 ^{o}	68.40	18.12 ^{b}	17.34 ^{c}	17.73	9.51 ^{c}	9.34 ^{g}	9.43
Ofis-NM	71.53 ^{l}	73.45 ^{fg}	72.49	14.98 ^{hij}	13.36 ^{op}	14.17	9.45 ^{e}	9.34 ^{g}	9.39
Ofis-95	72.72 ^{ij}	75.60 ^{b}	74.16	14.77 ^{jk}	12.48 ^{s}	13.62	8.38 ^{z}	8.47 ^{w}	8.42
Ofis-96	71.63 ^{l}	74.22 ^{de}	72.93	15.09 ^{ghi}	12.82 ^{qr}	13.95	8.66 ^{t}	8.69 ^{s}	8.67
TMO-1	71.66 ^{l}	73.35 ^{fg}	72.51	15.18 ^{gh}	13.55 ^{o}	14.36	8.76 ^{q}	8.62 ^{u}	8.69
TMO-2	71.06 ^{m}	71.49 ^{l}	71.28	15.32 ^{g}	14.44 ^{l}	14.88	9.90 ^{a}	9.49 ^{d}	9.69
TMO-3	75.07 ^{c}	76.12 ^{a}	75.60	11.70 ^{t}	10.78 ^{u}	11.24	9.49 ^{d}	9.49 ^{d}	9.49
Afyon-95	72.47 ^{j}	74.35 ^{de}	73.41	14.65 ^{kl}	13.18 ^{p}	13.91	8.76 ^{q}	8.85 ^{p}	8.81
Hüseyinbey	72.58 ^{j}	74.15 ^{e}	73.37	14.48 ^{l}	13.47 ^{o}	13.97	8.48 ^{w}	8.44 ^{x}	8.46
Seyitgazi	71.49 ^{l}	71.51 ^{l}	71.50	15.10 ^{ghi}	14.92 ^{ij}	15.01	8.97 ^{m}	8.93 ^{n}	8.95
Çelikoğlu	72.96 ^{hi}	73.58 ^{f}	73.27	13.78 ^{n}	13.55 ^{o}	13.66	8.88 ^{o}	8.88 ^{o}	8.88
Line-8	72.96 ^{hi}	74.47 ^{d}	73.72	14.03 ^{m}	12.94 ^{q}	13.49	8.78 ^{q}	8.70 ^{s}	8.74
Line-15	70.76 ^{m}	71.76 ^{kl}	71.26	15.77 ^{f}	14.75 ^{jk}	15.26	8.98 ^{m}	9.02 ^{l}	9.00
Line-21	73.03 ^{hi}	74.86 ^{c}	73.95	14.14 ^{m}	12.65 ^{rs}	13.39	8.56 ^{v}	8.77 ^{q}	8.66
Mean	71.49 B	73.07 A **	72.28	15.21 A	13.83 B **	14.52	9.05 A	8.96 B **	

** Figures having a similar letter(s) are not statistically and significantly different using Duncan's test at $p < 0.01$.

Statistical differences ($p < 0.01$) were observed in the stearic acid contents in terms of the year × genotype interaction. During the two-year study, Ofis-96 had the highest value (2.49%) and Ofis-3 had the lowest (2.17%) in the first year (Table 6).

Table 6. The comparison of the means of stearic and linolenic acids obtained from poppy genotypes.

Genotypes	Stearic Acid (18:0) (%)			Linolenic Acid (C18:3) (%)			Palmitoleic Acid (C16:1) (%)		
	1. Year	2. Year	Mean	1. Year	2. Year	Mean	1. Year	2. Year	Mean
Ofis-1	2.22 ^{mno}	2.41 ^{cd} **	2.32	0.76 ^{c}	0.76 ^{c} **	0.76	0.33 ^{a}	0.29 ^{cde} **	0.31
Ofis-2	2.24 ^{lmn}	2.18 ^{pq}	2.21	0.78 ^{b}	0.71 ^{gh}	0.75	0.26 ^{fg}	0.25 ^{gh}	0.26
Ofis-3	2.17 ^{q}	2.29 ^{ijk}	2.23	0.59 ^{p}	0.69 ^{i}	0.64	0.15 ^{o}	0.24 ^{hi}	0.20
Ofis-4	2.32 ^{ghi}	2.39 ^{de}	2.36	0.72 ^{fg}	0.70 ^{hi}	0.71	0.27 ^{efg}	0.23 ^{ij}	0.25
Ofis-8	2.24 ^{lmn}	2.21 ^{nop}	2.23	0.75 ^{cd}	0.66 ^{j}	0.71	0.27 ^{efg}	0.15 ^{o}	0.21
Ofis-NP	2.30 ^{hij}	2.46 ^{ab}	2.38	0.60 ^{op}	0.84 ^{a}	0.72	0.19 ^{kl}	0.30 ^{bcd}	0.25
Ofis-NM	2.33 ^{fgh}	2.31 ^{ghi}	2.32	0.62 ^{mn}	0.64 ^{kl}	0.63	0.24 ^{hi}	0.19 ^{kl}	0.22
Ofis-95	2.31 ^{ghi}	2.21 ^{nop}	2.26	0.60 ^{op}	0.51 ^{r}	0.56	0.17 ^{mn}	0.12 ^{p}	0.15
Ofis-96	2.49 ^{a}	2.36 ^{ef}	2.43	0.75 ^{cd}	0.71 ^{gh}	0.73	0.29 ^{cde}	0.27 ^{efg}	0.28
TMO-1	2.43 ^{bc}	2.32 ^{ghi}	2.38	0.73 ^{ef}	0.66 ^{j}	0.70	0.18 ^{lm}	0.20 ^{k}	0.19
TMO-2	2.31 ^{ghi}	2.46 ^{ab}	2.39	0.54 ^{q}	0.72 ^{fg}	0.63	0.19 ^{kl}	0.31 ^{abc}	0.25
TMO-3	2.26 ^{kl}	2.18 ^{pq}	2.22	0.61 ^{no}	0.60 ^{op}	0.61	0.16 ^{no}	0.16 ^{no}	0.16
Afyon-95	2.41 ^{cd}	2.27 ^{jkl}	2.34	0.60 ^{op}	0.53 ^{q}	0.57	0.22 ^{j}	0.13 ^{p}	0.18

Table 6. *Cont.*

Genotypes	Stearic Acid (18:0) (%)			Linolenic Acid (C18:3) (%)			Palmitoleic Acid (C16:1) (%)		
	1. Year	**2. Year**	**Mean**	**1. Year**	**2. Year**	**Mean**	**1. Year**	**2. Year**	**Mean**
Hüseyinbey	2.33 ^{fgh}	2.29 ^{ijk}	2.31	0.74 ^{de}	0.69 ^{i}	0.72	0.29 ^{cde}	0.17 ^{mn}	0.23
Seyitgazi	2.34 ^{fg}	2.44 ^{bc}	2.39	0.71 ^{gh}	0.69 ^{i}	0.70	0.28 ^{def}	0.33 ^{a}	0.31
Çelikoğlu	2.34 ^{fg}	2.29 ^{ijk}	2.32	0.74 ^{cde}	0.61 ^{no}	0.68	0.26 ^{fg}	0.20 ^{k}	0.23
Line-8	2.26 ^{kl}	2.25 ^{lm}	2.26	0.63 ^{lm}	0.64 ^{kl}	0.64	0.25 ^{gh}	0.18 ^{lm}	0.22
Line-15	2.29 ^{ijk}	2.34 ^{fg}	2.32	0.60 ^{op}	0.69 ^{i}	0.65	0.25 ^{gh}	0.32 ^{ab}	0.29
Line-21	2.27 ^{jkl}	2.19 ^{opq}	2.23	0.65 ^{jk}	0.59 ^{p}	0.62	0.22 ^{j}	0.17 ^{mn}	0.20
Mean	2.31	2.31		0.67 A	0.66 B **		0.24 A	0.22 B **	

** Figures having a similar letter(s) are not statistically and significantly different using Duncan's test at $p < 0.01$.

Linolenic acid was affected by the year × genotype interaction ($p < 0.01$). The maximum and the minimum linolenic acid content was recorded in the second year of the experiment in Ofis-NP, at 0.84%, and Ofis-95, at 0.51%, respectively. The linolenic acid content also showed differences between the years ($p < 0.01$), and its content was found to be 0.67–0.66% in the 2020 and 2021 harvests (Table 6).

Palmitoleic acid was a minor monounsaturated fatty acid found in the genotypes in the experiment, and the palmitoleic acid contents were statistically affected by the year × genotype interaction ($p < 0.01$) and by the year ($p < 0.01$). In the first and second years of the experiment, Ofis-1 and Seyitgazi had the highest values of palmitoleic acid, with both recorded at 0.33% (Table 6).

The results of the correlation analysis, presented in Table 7, indicated that the emergence time displayed a positive correlation with the inflorescence time, harvest maturity time, and oleic acid content, while displaying a negative correlation with the oil content and linoleic acid content. The inflorescence and harvest maturity time displayed a positive correlation with each other and oleic acid, and they displayed a negative correlation with the oil content and linoleic acid content. Furthermore, the plant height showed a positive correlation with the seed yield.

Linoleic acid was found to be negatively correlated with oleic acid, palmitic acid, stearic acid, linolenic acid, and palmitoleic acid. An increase in the amount of linoleic acid led to a decrease in the other fatty acids. On the other hand, oleic acid showed positive correlations with palmitic, stearic, linolenic, and palmitoleic acids. Palmitic acid had a negative correlation with stearic and linolenic acids, and a positive correlation with palmitoleic acid was observed. Additionally, stearic acid and linolenic acid displayed a positive correlation with each other and with palmitoleic acid.

Table 7. Correlation matrix of the studied parameters of poppy genotypes.

	Inflorescence Time	Harvest Maturity Time	Plant Height	1000 Seed Weight	Seed Weight per Plant	Yield	Oil Content	Protein Content	C18:2	C18:1	C16:0	C18:0	C18:3	C16:1
Emergence time	0.714 **	0.719 **	0.015	−0.089	0.028	0.008	−0.227 **	−0.073	−0.269 **	0.281 **	0.077	−0.003	−0.015	0.058
Inflorescence time		0.757 **	0.147	−0.027	−0.030	−0.030	−0.207 *	−0.076	−0.342 **	0.341 **	0.177 *	−0.002	0.043	0.099
Harvest maturity time			−0.097	0.043	0.006	0.006	−0.257 **	−0.098	−0.446 **	0.466 **	0.154	0.031	0.072	0.129
Plant height				−0.062	0.281 **	0.281 **	0.068	0.210 **	0.101	−0.103	−0.047	0.134	−0.002	0.024
1000 seed weight					−0.060	−0.060	−0.130	0.049	−0.156	0.125	0.214 **	−0.017	−0.092	0.005
Seed weight per plant						1.000 **	−0.056	0.035	0.140	−0.107	−0.277 **	−0.056	−0.024	0.065
Yield							−0.056	0.035	0.140	−0.107	−0.277 **	−0.056	−0.024	0.065
Oil content								0.012	0.238 **	−0.243	−0.072	−0.193 *	0.001	−0.095
Protein content									−0.063	0.072	0.090	−0.027	−0.075	−0.029
C18:2										−0.977 **	−0.393 **	−0.309 **	−0.485 **	−0.577 **
C18:1											0.250 **	0.285 **	0.439 **	0.512 **
C16:0												−0.161 *	−0.028	0.071
C18:0													0.433 **	0.512 **
C18:3														0.745 **

*: $p < 0.05$; **: $p < 0.01$.

4. Discussion

Seed germination and seedling emergence are crucial stages for successful crop growth in fields [8]. These stages determine the uniformity of field emergence and the plant density [9]. Poppies should be in the rosette stage before entering winter to enhance their cold resistance. Delayed emergence can make poppies vulnerable to cold temperatures. This study examines the impact of temperature on seedling emergence of poppy genotypes. All the genotypes showed earlier emergence in the second year of the experiment, compared to the first year, due to a 1.3 °C increase in temperature. The delayed emergence in the first year caused a delay in the flowering and harvest maturity time of the genotypes. The delay in harvest maturity is also related to the excessive precipitation during the June of 2020, exceeding the long-term average. According to a study conducted in the Denizli province, one of the poppy cultivation areas in Türkiye, the harvest maturity time for Turkish cultivars sown in October was reported as 225–235 days [10], which is shorter than that in Ankara's conditions.

The plant height determined in this experiment showed similarities to earlier experiments. An initial report indicated that the height of poppy plants ranges from 66.35 cm to 107.55 cm [10,11].

The seed weight per plant plays an indicative role in the seed yield and the mean value recorded for most of Turkish genotypes are found to be higher. The values for the 13 genotypes in this study are higher than those of Indian landraces (mean value 4.20 g plant^{-1}) reported by Bajpai et al. [12].

Turkish poppy cultivars have a seed yield values ranging from 44.93 to 228.20 kg da^{-1} in reported studies [10]. Most of the genotypes displayed a higher seed yield under Ankara's environmental conditions and their cultivation in Ankara did not lead to a decrease in the seed yield.

There was a slight increase or no change in the oil content of the genotypes according to the Duncan Multiple Range Test in the second year of the experiment compared to the first year. During the seed filling period (May and June), the precipitation in the first year of the experiment was higher than that in the second year and the average long-term precipitation. This excessive rain during seed filling might cause a reduction in the rate of photosynthesis and lead to nutrient leaching into the deeper soil layers [13]. As a result, certain genotypes displayed a noticeable or minor rise in their oil content. Most of the Turkish cultivars had an oil ratio value ranging from 32.4% to 53.39% [14,15], and the results of the oil ratio revealed that the genotypes and their responses under different environmental conditions are variable.

The analysis of the protein content revealed that the diversity in proteins is highly related to the poppy genotypes.

The quality of fat is determined by the amount of free acids present in it. The fatty acids that were determined with a content of ≥99 % are linoleic acid (C18:2), oleic acid (C18:1), palmitic acid (C16:0), stearic acid (C18:0), linolenic acid (C18:3), and palmitoleic acid (C16:1). The data related to these fatty acids were analysed using variance analysis, while disregarding the fatty acids present in minor quantities. The composition of fatty acids is influenced by the cultivars and prevailing climatic conditions during their crop cycle. The fatty acid composition of the poppy genotypes revealed that linoleic acid was the major polyunsaturated fatty acid (PUFA). In general, especially for the 2021 harvest, the seeds of most of the genotypes contained more linoleic acid, which could be one of the consequences of climatic changes, especially the decreased precipitation during May and June, the high temperature in May 2021 (2.1 °C higher than in May 2020), and the decreased temperature during June 2021. Decreased temperature leading to high linoleic acid in oilseed crops is observed in poppies [16] and sunflowers [17]. The composition of the fatty acids in poppy seed oils is similar to that of many other crop seed oils, with more linoleic acid and less oleic acid. However, poppy seed oils contain more linoleic acid than some of the other crop oils. Therefore, poppy seed oil is a good source of essential fatty acids, particularly linoleic acid, which makes it a healthy option compared to other types of edible oilseeds. The linoleic acid content of some genotypes was found to be higher or close to that reported by Rahimi et al. [3] in Ankara (71.40%) and Bolvadin (73.23%).

Most of the genotypes had high oleic acid in the 2020 harvest, which could be attributed to the high precipitation and high temperature in June. High precipitation leading to high oleic acid was reported by Day et al. [18] in black cumin.

Poppy seeds are rich in linoleic acid, which makes them ideal for high-linoleic-acid crop development. The quality of oil and its intended use is determined by the proportion of oleic and linoleic acid present in it [18]. However, oils with high amounts of linolenic acid are not suitable for food products due to their instability and reversion of flavour caused by autoxidation. Fortunately, poppy seeds contain very low levels of linolenic acid and high levels of linoleic acid, making them an ideal oilseed crop for the food industry [19].

The genotypes exhibited varying palmitoleic acid levels between the two years, at 0.24% and 0.22%, respectively. These results are in line with those of Rahimi et al. [20] and Satranský et al. [21].

All the genotypes evaluated during the two-year experiment had trace levels of linolenic acid. The other fatty acids in the poppy seeds which were determined in trace amounts were arachidic acid (C20:0), eicosenoic acid (C20:1), myristic acid (C14:0), margaric acid (17:0), behenic acid (C22:0), nervonic acid (C 24:1, lauric acid (C12:0), and caproic acid (C6:0). Similar findings were reported by Hlinková et al. [7].

It is worth mentioning that previous studies have reported a negative correlation between linoleic acid and oleic acid in poppy seed oil [16,21] and sunflower seed oil [22]. The findings of this study are in line with those earlier findings.

The poppy genotypes evaluated in this experiment are mainly developed for the alkaloid content in their capsules. The poppy is good for crop rotation. The seeds remaining are mainly used for traditional cooking and baking. The genotypes are a good source of protein and valuable edible oil due to their fatty acid contents and richness in monounsaturated and polyunsaturated fatty acids (between 87.08 and 88.71%), which makes their oil valuable as a nutrient source.

All the genotypes exhibited a longer harvest maturity time due to the heavy precipitation during seed filling. The importance of the climate is very clear for harvest maturity. Among the genotypes, Çelikoğlu gave the highest seed yield, directly leading to an increase in oil yield. All the genotypes assessed in this study were found to be high in linoleic and oleic acid, indicating their superior edible quality.

5. Conclusions

The diversity among all the genotypes were evaluated in Ankara's environmental conditions and represented by this study. It is very clear that all the genotypes have the capability of adapt to Ankara and their yields were satisfactory. Furthermore, crop development and the oil fatty acid composition are related to different temperature variables (the daily mean or minimum night temperature, respectively), which are expected to be differently affected by global warming. The cultivars displaying a high seed yield, apart from Çelikoğlu, were Ofis-2, Ofis-3, Ofis-4, Ofis-NM, Ofis-95, Ofis-96, Hüseyinbey, Seyitgazi, Line-8, Line-15, and Line-21.

Author Contributions: Conceptualization, Y.K.-Y., S.D. and N.B.; data curation, Y.K.-Y., S.D., N.B. and Y.Ö.; formal analysis, Y.K.-Y., S.D. and N.B.; funding acquisition, Y.K.-Y., S.D. and N.B.; investigation, Y.K.-Y., S.D. and N.B.; methodology, Y.K.-Y., S.D. and N.B.; resources, Y.Ö.; writing—original draft, Y.K.-Y., S.D., N.B. and Y.Ö.; writing—review and editing, S.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research received help with the analysis of the fatty acids from the Turkish Grain Office—Toprak Mahsulleri Ofisi (TMO).

Data Availability Statement: Data will be made available upon request.

Acknowledgments: This article is part of the Ph.D. thesis of Yağmur Kahraman-Yanardağ. The cultivation of poppies in the experiment field was performed under the permission of the Turkish Grain Office, which is responsible for legal poppy cultivation in Türkiye.

Conflicts of Interest: The authors declare no conflicts of interest.

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