Turkish Journal of FIELD CROPS

Turk J
Field Crops
2017, 22(1), 39-46
DOI: 10.17557/tjfc.301829

THE EFFECTS OF AUTUMN AND SPRING SOWING ON YIELD, OIL AND MORPHINE CONTENTS IN THE TURKISH POPPY (*Papaver somniferum* L.) CULTIVARS

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Received: 12.08.2016

ABSTRACT

The poppy is a plant that can be planted in the autumn and spring seasons. The purpose of the research was to investigate the effects of autumn and spring sowing on capsule yield, seed yield, yield components, oil content and morphine content of fifteen poppy cultivars that have been recently registered under Isparta conditions. The experiment was arranged according to the randomized complete-block design with three replicates during the years of 2012/13 and 2013/14. The results of the research showed that the differences among capsule yields, seed yields, yield components and morphine contents of the cultivars were statistically significant in both sowing times and years. The highest and the lowest values of plant height, capsules number, capsule width, capsule length, 1000 seed weight and oil yield of the poppy cultivars varied according to the cultivars, the sowing times and the years. The capsule yield and seed yield of the poppy cultivars in the autumn sowing varied between 416.7-1043.3 kg ha^{-1} and 523.5-1276.3 kg ha^{-1} in the first year, between 465.3-1375.6 kg ha^{-1} and 596.7-1520.4 kg ha^{-1} in the second year, respectively. In the spring sowing, the capsule yield and seed yield of the poppy cultivars varied between 204.3-455.7 kg ha^{-1} and 286.0-573.0 kg ha^{-1} in the first year, between 497.2-830.7 kg ha^{-1} and 614.3-962.7 kg ha^{-1} in the second year, respectively. The highest oil content was determined in the Zaferyolu cultivar in both years and sowing times. The morphine content of the poppy cultivars varied between 0.47-1.00% in the autumn sowing and between 0.45-0.97% in the spring sowing, respectively. The higher values in the autumn sowing were obtained than the spring sowing in all of the characteristics investigated in both years, except for the oil content. Considering the present results, TMO-3, Ofis-4, Ofis-8, Tınaztepe and Zaferyolu cultivars were advised in the autumn sowing and the TMO-1, Ofis-8 and Afyon-95 cultivars in the spring sowing because of their higher capsule, seed and oil yields. In point of the morphine contents, the TMO-3, TMO-T, Ofis-3, Ofis-8 and Bolvadin-95 cultivars were advised.

Key words: Cultivar, morphine content, oil yield, poppy, seed yield

INTRODUCTION

The poppy (*Papaver somniferum* L.) is used in medicine, in food, in cosmetic, and the paint industries because it contains alkaloids of capsules, and for the oil and protein content of the seeds (Gumuscu and Arslan, 2008). The poppy capsules contain thirty different alkaloids, mainly morphine, codeine, thebaine, noscapine and papaverine, and are used to produce semi-synthetic active pharmaceuticals (Skalicky et al., 2014). The poppy mostly cultivated in countries such as India, Japan, China, France, Spain. In Turkey, Kütahya, Afyon, Burdur, Isparta, Balıkesir, Konya, Amasya, Çorum, Tokat, Manisa, Uşak, Denizli and Eskişehir provinces are main poppy production areas (Karabuk, 2012). Most poppy cultivation takes place in Turkey and India. The poppy is cultivated in an area of 101874 hectares in world (FAO, 2015), and it is cultivated on an area of 61591 hectares, with an annual production of 30730 tons and an average yield of 500 kg ha^{-1}in Turkey (TUIK, 2015). More than 50% of the total sowing areas in the world is performed in Turkey according to the data from 2015 year (FAO, 2015). However, the seed yield in per hectare and morphine content of the capsule is low in Turkey when compared to other poppy producer countries. Recently, the ten poppy cultivars with high morphine content were registered by the Soil Products Office. The poppy quality is mainly evaluated with its oil and morphine content. Poppy varieties with high alkaloid contents are used for medicinal purpose, and varieties with low alkaloid contents and high seed yielding are used for food production (Prajapati et al., 2002). Arslan et al. (2000) reported that the morphine and oil contents of the poppy populations in Turkey varied with 0.25-0.89% and 38.65-53.38%, respectively. Erdemoglu et al. (2002) stated that the morphine contents of the poppy capsules obtained from the different provinces in Turkey varied with 0.093-0.263%. Karadavut and Arslan (2006) reported that the

plant height, capsule number, capsule yield, seed yield and morphine content of the poppy cultivars varied between 22.21-99.71 cm, 1.01-6.17 capsules, 0.30-6.48 g plant^{-1}, 0.26-11.66 g plant^{-1} and 0.22-1.225%, respectively. Gumuscu et al. (2008) determined that the morphine contents of the different poppy lines which were autumn cultivated varied between 0.110-1.140%. Koc et al. (2014) reported that the capsule yield, seed yield and morphine content of the autumn poppy cultivars varied with 420-980 kg ha^{-1}, 720.0-1170.0 kg ha^{-1} and 0.45–1.30%, respectively. Boydak and Kavurmaci (2015) stated that the capsule number, capsule yield, seed yield, capsule width, capsule size and morphine rate of poppy cultivars varied with 3.03-4.47 capsules, 92.9-140.5 kg ha^{-1}, 577.4-1046.4 kg ha^{-1}, 4.33-4.44 mm, 3.38-3.91 mm and 0.23-0.83%, respectively. The poppy is a plant that can be planted in the autumn and spring seasons. The poppy can be planted as a spring sowing when there is no moisture in the soil or due to some reasons. The yield and quality characteristics of the poppy are affected by agronomic practices, soil and climatic conditions (Jaszberenyi and Nemeth, 2012; Skalicky et al., 2014). Isparta is an area, authorized for poppy cultivation by the Soil Products Office in Turkey. Although the poppy is cultivated by a considerable number of producers in Isparta, there is no comprehensive study regarding the adaptation of the new poppy cultivars in the region. To author's knowledge, besides, there is no data on the characteristics of poppy cultivars, adopted by region producers. Therefore, the aim of the research was to determine Turkish poppy cultivars with high-capsule/seed yielding, containing high oil and morphine at different sowing times under Isparta conditions.

MATERIALS AND METHOD

The field experiment was set up in a randomized complete block design in triplicates as the autumn and spring sowing in 2012/13 and 2013/14 growing seasons in Isparta ecological conditions (37° 45'*N* latitude, 30° 33'*E* longitude and 1050 m altitude). The Isparta province shows typical continental climate with cold and snowy winters and dry and mild-temperate summer in the Southwestern Anatolia Region. In the research, fifteen registered poppy cultivars were obtained from the Afyonkarahisar-Bolvadin Poppy Alkaloid Office and the Eskişehir Western Transitional Zone Agricultural Research Institute (Table 1). Generally, the cultivars used in the research are new varieties that have been recently registered in Turkey.

Table 1. The cultivars used in experiments and their obtained office / Institute

Cultivars	Office / Institute
TMO-1	Afyonkarahisar-Bolvadin Poppy and Alkaloid Office
TMO-2	
TMO-3	
TMO-T	
Ofis-3	
Ofis-4	
Ofis-8	
Ofis-95	
Ofis-96	
Afyon-95	
Bolvadin-95	
Tınaztepe	Eskişehir Western Transitional Zone Agricultural Research Institute
Anayurt	
Kemerkaya	
Zaferyolu	

The sowing times: i) Autumn sowing was sown on the 5 and 9 October in the first and the second growing years, respectively. ii) Spring sowing was sown on the 1 and 6 of March in the first and the second years, respectively. The spacing used was 0.45 x 0.15 m and the plot length was 5 m (5x 2.7=13.5 m^2) with 6 rows. The seeds were sown at about a 0.5-1 cm depth using a dibbler. After the emergence of the poppy seeds, the weeds were hand-hoed as appeared and one seedling was left.

All the necessary cultural practices were applied identically to all the cultivars in both years and sowing times. The experiments were not irrigated at any growing stage. 100 kg N ha^{-1} nitrogen and 30 kg P_2O_5 ha^{-1} fertilizers were applied made from ammonium sulfate (21%) and triple super phosphate (43-46%), respectively. Nitrogen was applied in two equal portions at sowing and at plant height 10-15 cm stages, respectively whereas the phosphorous fertilization was made at the sowing (Koc et al., 2012).

Climatic data of the experimental area

The climatic data for the 2012/13 and 2013/14 growing periods are shown in Table 1. During the vegetation period (from October to end of August) in 2012/13 and in 2013/14, there was a total precipitation of 555.0 and 579.9 mm, an average temperature of 12.8 and 12.1 ^{0}C, and an average humidity of 58.8 and 58.3% (Table 2), respectively.

Table 2. Some climate data of the experiment area in growing seasons*

Climatic factors	Years	Months											Total or Average
		October	Novem.	Decem.	Janu.	Februa.	March	April	May	June	July	August	
Average Temperature (°C)	2012-13	14.4	8.9	4.5	2.8	4.9	7.3	12.1	18.0	21.0	23.5	24.1	12.8
	2013-14	10.7	8.7	1.0	3.7	5.2	7.3	11.7	15.1	20.0	24.5	24.9	12.1
	Long terms	12.9	7.4	3.5	1.9	2.9	6.2	10.7	15.6	20.2	23.6	23.2	11.6
Precipitation (mm)	2012-13	38.8	25.9	60.3	58.6	91.9	25.1	49.9	66.5	34.4	88.2	15.4	555.0
	2013-14	104.0	67.6	29.4	61.3	23.4	78.6	54.8	107.0	42.8	0.8	10.2	579.9
	Long terms	38.0	46.3	84.9	72.2	64.7	54.2	56.0	51.4	29.8	14.6	10.5	522.6
Relative humidity (%)	2012-13	65.1	70.6	74.3	72.5	70.6	59.7	56.5	50.4	47.4	41.5	39.1	58.8
	2013-14	54.0	65.5	64.2	76.7	60.8	63.3	59.5	60.3	49.8	43.5	44.2	58.3
	Long terms	62.0	68.5	74.7	73.2	70.2	65.4	61.3	57.4	51.1	45.4	46.3	61.4

*Isparta Meteorology Office Records

Soil structure

In the years 2012/13 and 2013/14, soil at a depth of 60 cm was low in organic matter (1.80% and 1.66%, respectively), alkaline (pH 7.5 and 7.8, respectively) limey (9.67% and 9.89% $CaCO_3$, respectively), and clay-loamy.

Yield and its components

The capsules from 4 rows in the center of each plot in the full ripeness period according to the maturity stage of the cultivars were manually harvested. The capsule yield (kg ha^{-1}), seed yield (kg ha^{-1}), plant height (cm), capsule number (capsule), capsule width (mm), capsule length (mm) and 1000 seed weight (g) were determined as described by Karabuk (2012). The capsule yield and seed yield were calculated by multiplying by 10000/plot sizes (m^2).

Crude oil content analysis

The poppy seeds were dried for 24 hours at 70 °C and 5 g of powdered poppy samples from each cultivar were extracted with *n*-hexan for 6 hours using the soxhlet apparatus (Buchi Universal Extraction System B-811, Germany) for determining the fixed oil content (%).

Morphine content analysis

The capsule of the poppy was dried for 24 hours at 70 °C, and the capsules were powered by grinding. The morphine content was analyzed according to the spectrophotometric method of the Afyonkarahisar-Bolvadin Poppy and Alkaloid Office.

Statistical analysis

The analysis of the variance (ANOVA) of the obtained data was analyzed by using the Jump 5.0 statistics package program. The significant differences between the means were compared according to the DUNCAN multiple range test.

RESULTS

Mean values of capsule yield, seed yield, some yield components, oil content, oil yield and morphine content of the poppy cultivars tested according to the sowing times and years were shown in Tables 3, 4 and 5. In the research, the differences between the years (except for 1000-seed weight and oil content), cultivars (except for the plant height of the spring sowing in both years) and the sowing times (except for the capsule length in the first years, and the oil content in the both years) were found to be statistically significant for both years (Table 3, 4, and 5).

Capsule yield, seed yield and their components

The capsule and seed yields of the poppy cultivars varied with years, sowing times and varieties. The mean capsule and seed yield in the second year (786.7 kg ha^{-1} and 933.8 kg ha^{-1}, respectively) was higher than the yield in the first year (531.6 kg ha^{-1} and 655.8 kg ha^{-1}, respectively). These differences resulted from the higher rainfall in the spring season of the plant in the second year according to the first year (Table 2).

In comparison to the sowing times, the mean capsule and seed yield in the autumn sowing was significantly higher than the spring sowing in both years. In the autumn and spring sowing, capsule yield of poppy cultivars varied between 1045.6 kg ha^{-1} (Tınaztepe)-416.7 kg ha^{-1} (Bolvadin-95) and 455.7 kg ha^{-1} (Ofis-8)- 204.3 kg ha^{-1} (TMO-2) in the first year, 1375.6 kg ha^{-1} (Ofis-8)-465.3 kg ha^{-1} (Anayurt) and 830.7 kg ha^{-1} (Ofis-8)- 501.6 kg ha^{-1} (Ofis-96) in the second year (Table 4), respectively. In the autumn and spring sowing, the seed yield of the poppy cultivars varied between 1276.3 kg ha^{-1} (Ofis-4)-523.5 kg ha^{-1} (Bolvadin-95) and 573.0 kg ha^{-1} (Ofis-8)-286.0 kg ha^{-1} (TMO-2) in the first year, 1520.4 kg ha^{-1} (Ofis-8)-596.7 kg ha^{-1} (Anayurt) and 962.7 kg ha^{-1} (Ofis-8)-614.3 kg ha^{-1} (Ofis-96) in the second year (Table 4), respectively. The highest and lowest values of the yield components including the plant height, capsule number, capsule width, capsule length and 1000 seed weight of the poppy cultivars varied according to the varieties, the sowing times, and the years (Table 3).

Table 3. The plant height, the number of capsule, capsule width and capsule length of poppy cultivars

Cultivars / sowing times	Plant height (cm)				The number of capsule (capsule)			
	2012-13		2013-14		2012-13		2013-14	
	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring
TMO-1	100.9a-d	66.1	128.2ab	99.2	4.40efg	1.46 de	4.33ef	4.46ab
TMO-2	93.2de	57.9	114.5cd	102.3	4.46d-g	1.96cde	5.13b-e	3.40bcd
TMO-3	90.3 ef	60.1	120.5bc	97.6	5.68bcd	2.10bcd	5.03cde	2.96cd
TMO-T	102.4 a-d	65.0	115.5cd	101.7	5.26b-f	2.13bcd	5.60bcd	3.27bcd
Ofis-3	82.9 f	58.5	102.9 e	96.9	4.06fg	1.90cde	4.50def	2.43 d
Ofis-4	96.2 cde	59.5	136.1 a	99.7	5.96 bc	1.36 e	4.96cde	3.43bcd
Ofis-8	104.4 abc	61.1	118.2 c	98.3	5.60b-e	2.83 a	5.76 b	3.46bcd
Ofis-95	106.1 ab	59.6	116.0 cd	104.2	5.26b-f	1.83cde	4.76c-f	4.00 bc
Ofis-96	98.5 b-e	51.5	117.3 c	99.4	6.26ab	1.93cde	6.30 a	2.56 d
Afyon-95	99.0 b-e	67.3	108.1de	100.1	5.66bcd	2.73 ab	6.13 a	3.53bcd
Bolvadin-95	81.1 f	66.7	79.1 f	100.9	3.46 g	2.86 a	3.70 f	3.26bcd
Tınaztepe	109.4 a	72.2	136.3 a	99.4	7.36a	1.47 de	5.62bcd	5.40a
Anayurt	103.3 abc	71.1	120.5bc	101.4	5.06b-f	1.73cde	3.56 f	2.80cd
Kemerkaya	101.3 a-d	60.5	123.4bc	99.3	4.80c-f	1.86cde	5.15b-e	2.67d
Zaferyolu	101.2a-d	62.1	134.4 a	100.3	5.46b-e	2.33abc	5.40b-e	2.40 d
$Mean_{Sowing\ times}$	98.0 A	63.3B	118.1A	99.72B	5.25 A	2.04 B	5.12 A	3.33 B
Years	**80.6 B**		**108.9 A**		**3.6 B**		**4.2 A**	
$M.square_{Cultivar}$	195.476	61.42	631.39	16.729	2.720	0.735	2.569	1.972
$F\ value_{Cultivar}$	10.68**	1.49^{ns}	39.24	0.74^{ns}	8.71**	8.42**	8.70**	6.46**
C.V (%)	4.36	10.15	3.39	4.76	10.63	4.44	10.59	6.56

Cultivars / sowing times	Capsule width (mm)				Capsule length (mm)			
	2012-13		2013-14		2012-13		2013-14	
	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring
TMO-1	41.30abc	24.39 g	46.75abc	39.06 a	40.66cde	36.17 e	36.12bcd	29.73a-d
TMO-2	40.43abc	27.24d-g	45.38bcd	39.9abc	38.53ef	37.19de	37.54 b	27.76bcd
TMO-3	42.50 a	27.82d-g	47.10ab	39.31 a	43.53abc	39.35cde	43.63 a	29.53a-d
TMO-T	39.03bcd	24.85fg	42.31c-f	33.80 c	39.40ef	41.78bcd	36.69bc	30.96ab
Ofis-3	38.63cd	27.39d-g	40.71ef	39.90abc	39.50ef	38.58de	33.56efg	27.83bcd
Ofis-4	43.33 a	27.38d-g	48.78ab	34.80bc	46.80a	37.53de	43.31 a	28.30a-d
Ofis-8	41.73ab	37.34 a	50.83a	38.75 a	40.03de	49.96 a	44.26 a	31.25ab
Ofis-95	37.16de	29.54c-f	47.80ab	39.40 a	38.36ef	36.29 de	35.97b-e	31.27ab
Ofis-96	40.96abc	25.84efg	47.05ab	37.02abc	34.26 g	40.02b-e	33.89d-g	26.2 d
Afyon-95	40.66abc	36.13ab	46.58abc	39.76 a	36.64fg	44.30bc	31.47 g	30.53abc
Bolvadin-95	40.43 f	27.96d-g	38.73 f	35.06bc	33.90 g	40.67b-e	36.33bcd	31.70 a
Tınaztepe	38.50cd	33.12abc	50.16a	33.73c	44.56ab	38.06de	44.61 a	28.56a-d
Anayurt	35.36 e	28.76c-g	41.56def	37.70ab	36.26fg	41.64b-e	32.47fg	31.36ab
Kemerkaya	38.60cd	31.42bcd	44.94b-e	33.63 c	41.40b-e	38.73de	34.29c-f	27.26cd
Zaferyolu	42.53 a	29.59cde	47.51ab	37.60ab	42.90bcd	45.25 ab	43.92 a	29.26a-d
$Mean_{Sowing\ times}$	39.41A	29.25 B	45.74A	36.90B	40.37	38.78	37.87A	29.43 B
Years	**34.3 B**		**41.32 A**		**39.58 A**		**33.65 B**	
$M.square_{Cultivar}$	32.765	43.305	36.769	14.458	570.81	42.816	67.190	8.958
$F\ value_{Cultivar}$	17.81**	9.85**	8.75**	5.95**	19.43**	7.10**	56.37**	3.43*
C.V (%)	3.44	7.16	4.48	4.22	3.64	6.08	2.88	5.49

Means in the same columns followed by the same letters are not significantly different as statistically.
*, **: Significant at P<0.05 and P<0.01 probability levels, respectively, ns: non significant

Table 4. The 1000 seed weight, capsule yield, seed yield, and oil yield of poppy cultivars

Cultivars / sowing times	Capsule yield (kg ha^{-1})				Seed yield (kg ha^{-1})			
	2012/13		2013/14		2012/13		2013/14	
	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring
TMO-1	801.3 c	214.0fg	918.3 d	789.0ab	946.7 b	302.3fg	1084.2cd	910.5 ab
TMO-2	807.3 c	204.3 g	965.0 d	748.2bc	923.3 b	286.0 g	1144.2 c	890.2 abc
TMO-3	1039.4 a	319.3 g	1205.1 b	744.1 c	1242.3 a	438.3 bc	1393.3ab	896.7 abc
TMO-T	707.67 de	260.6 de	829.7 e	673.0 d	835.4 bc	353.7def	995.8cd	788.5 cde
Ofis-3	530.0 g	266.3efg	693.3 f	497.2 g	676.7 de	346.1d-g	828.9 e	630.8 f
Ofis-4	1034.7 a	247.3ef	1137.3 c	546.3 e	1276.3 a	346.6d-g	1344.8 b	695.7ef
Ofis-8	923.2 b	455.7 a	1375. 6 a	830.7 a	1130.7 a	573.0a	1520.4 a	962.7 a
Ofis-95	717.1 de	285.6 cd	945.0 d	740.1 c	825.6bcd	421.6 bc	1099.1cd	817.5 bcd
Ofis-96	752.0 d	311.3 c	921.3 d	501.6 fg	878.4 bc	380.6cd	1066.5cd	614.3 f
Afyon-95	613.3 f	409.0 b	841.7 e	799.6 a	740.3 cd	533.6 a	985.3 d	920.0 ab
Bolvadin-95	416.7 h	292.6 cd	501.0 g	540.3 ef	523.5 e	375.0cde	627.1 f	650.3 f
Tınaztepe	1045.6 a	221.0 fg	1148.3bc	736.3 c	1238.7 a	312.0efg	1352.5b	873.7 abc
Anayurt	449.7 h	210.3 fg	465.3 g	552.6 e	571.8 e	300.2 fg	596.7 f	701.1 def
Kemerkaya	695.3 e	314.7 c	793.0 e	531.0efg	818.2 bcd	408.0bcd	953.7de	629.1 f
Zaferyolu	1043.3 a	379.6 b	1086.0 c	563.3 e	1208.3 a	463.3 b	1333.4 b	708.8 def
Mean$_{Sowing\ times}$	771.7 A	290.1 B	921.7 A	654.0 B	922.3A	389.4 B	1088.4A	779.3 B
Years	**531.6 B**		**786.7 A**		**655.8 B**		**933.8 A**	
M.square$_{Cultivar}$	137427.2	17689.9	189110.4	43434.1	184175.6	21706.06	222489	45792.6
F value $_{Cultivar}$	292.95**	64.80**	229.22**	124.05**	37.93**	27.19**	51.19**	15.75**
C.V (%)	2.80	5.69	3.11	2.87	7.55	7.25	6.05	6.91

Cultivars / sowing times	1000 seed weight (%)				Oil yield (kg ha^{-1})			
	2012/13		2013/14		2012/13		2013/14	
	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring
TMO-1	0.37def	0.32de	0.41abc	0.28ab	369.4cd	120.1 f	434.3de	382.5ab
TMO-2	0.34gh	0.36abc	0.42ab	0.24cde	384.8 c	116.5 f	448.6dc	329.2b-e
TMO-3	0.42 ab	0.35a-d	0.42ab	0.27bc	484.9ab	178.8bcd	534.1bc	370.7abc
TMO-T	0.38cde	0.31de	0.39cd	0.28ab	336.7cde	149.7def	411.5def	307.6d-g
Ofis-3	0.38cde	0.32 de	0.38de	0.26bcd	275.4efg	135.1ef	345.4f	227.4 h
Ofis-4	0.43 a	0.38 a	0.43 a	0.25bcd	535.5ab	158.5cde	547.2bc	299.4d-g
Ofis-8	0.40abc	0.39 a	0.43 a	0.31 a	471.7 b	233.5 a	644.0 a	356.7a-d
Ofis-95	0.33 h	0.30ef	0.39bcd	0.27bc	346.7cde	187.0 bc	443.6de	328.9b-e
Ofis-96	0.34fgh	0.34bcd	0.40bcd	0.26bcd	360.3cd	162.3cde	430.2de	251.9gh
Afyon-95	0.36efg	0.37ab	0.39cd	0.22 e	306.0def	226.1 a	387.6ef	392.5 a
Bolvadin-95	0.40bcd	0.33cde	0.39bcd	0.24de	219.66 g	162.7cde	259.1 g	273.0e-h
Tınaztepe	0.39bcd	0.26 f	0.44 a	0.30 a	524.7ab	142.4def	550.2bc	367.0abc
Anayurt	0.34gh	0.34b-e	0.35 e	0.31a	250.7fg	133.0ef	254.8 g	306.5e-h
Kemerkaya	0.39bcd	0.28 f	0.38de	0.24cde	346.2cde	187.7bc	391.3ef	266.8fgh
Zaferyolu	0.41abc	0.37ab	0.42abc	0.25cde	543.7 a	213.1 ab	573.5ab	314.5c-f
Mean$_{Sowing\ times}$	0.38 A	0.34 B	0.40 A	0.27 B	383.7A	167.1 B	446.1 A	318.3B
Years	**0.36**		**0.34**		**275.4 B**		**382.2 A**	
M.square $_{Cultivar}$	0.0414	0.0421	0.0018	0.0021	33134.9	4062.406	37587.5	7378.71
F value $_{Cultivar}$	17.82**	14.79**	8.84**	10.21**	33.01**	15.28**	34.71**	10.66**
C.V (%)	3.38	4.98	3.57	5.42	8.25	9.75	7.37	8.26

Means in the same columns followed by the same letters are not significantly different as statistically.
**: significant at P<0.01 probability levels.

Oil content and oil yield

The mean oil content of the years (41.9% and 40.5%, respectively), autumn and spring sowing times (41.6%-42.7% in the first year and 40.0%-40.9% in the second year) was found to be very close to each other (Table 5). In both years (2012-13 and 2013-14), among the cultivars, the highest oil content was determined from the Zaferyolu cultivar (45.0- 46.3% in the first year and 43.0%-44.3% in the second year) in all the sowing times (Table 4). The highest oil yield was obtained from the Zaferyolu (573.5 kg ha^{-1}), Ofis- 4 (535.5 kg ha^{-1}) Tınaztepe (524.7 kg ha^{-1}), TMO-3 (484.9 kg ha^{-1}) and Ofis 8 (644.0 kg ha^{-1}) cultivar in the autumn sowing, and Ofis-8 (233.5 kg ha^{-1}), Afyon-95 (392.5 kg ha^{-1}), TMO-1 (382.5 kg ha^{-1}) and Tınaztepe (367.0 kg ha^{-1}) cultivars in the spring sowing times (Table 4).

Morphine content

The mean morphine content in the spring sowing (0.77%) was higher than that of the autumn sowing (0.70%). The morphine content of the poppy cultivars ranged from 1.00% (Ofis-3) to 0.47% (Kemerkaya) in the autumn sowing and ranged from 0.97% (TMO-3) to 0.45% (Kemerkaya) in the spring sowing (Table 5).

Table 5. The oil content and morphine contents of Turkish opium poppy cultivars

Cultivars / sowing times	Oil content (%)				Morphine content (%) +		
	2012/13		2013/14		Seed colors	2012/13	
	Autumn	Spring	Autumn	Spring		Autumn	Spring
TMO-1	39.0 d	39.6 cd	40.0def	42.2a-d	L. brown	0.67d-h	0.65 f
TMO-2	41.7 c	40.5 bcd	42.4abc	37.1 e	Blue	0.72b-f	0.56 h
TMO-3	39.2 d	40.7bcd	38.3 f	41.3a-d	White	0.76 b-e	0.97 a
TMO-T	40.3 cd	42.3a-d	41.3a-e	39.0 de	Blue	0.85 b	0.95 a
Ofis-3	40.6 cd	39.0 d	41.6a-d	36.0 e	Blue	1.00 a	0.95 a
Ofis-4	42.5 bc	45.6 a	40.6b-e	43.0abc	L. brown	0.56ghı	0.83 c
Ofis-8	41.6 c	40.6bcd	42.3abc	37.0 e	White	0.84bc	0.95 a
Ofis-95	42.0bc	44.3 ab	40.3c-f	40.3cd	Yellow	0.56ghı	0.76 e
Ofis-96	41.0 cd	42.6a-d	40.4c-f	41.0bcd	Yellow	0.69c-g	0.75 e
Afyon-95	41.3 c	42.2a-d	39.3ef	42.6abc	Yellow	0.58f-ı	0.61 g
Bolvadin-95	42.2 bc	43.4 ab	41.4a-d	42.4a-d	Blue	0.76b-e	0.90 b
Tınaztepe	42.4bc	45.7 a	40.7b-e	42.6abc	Yellow	0.78bcd	0.79 d
Anayurt	44.0 ab	44.3 ab	42.6 ab	43.7ab	Yellow	0.52hı	0.66 f
Kemerkaya	42.3 bc	46.0 a	41.0a-d	42.5abc	Yellow	0.47 ı	0.45 ı
Zaferyolu	45.0 a	46.3 a	43.0 a	44.3 a	White	0.62e-h	0.88 b
$Mean_{Sowing\ times}$	41.6	42.7	40.0	40.9		0.70 B	0.77 A
Years	**41.9**		**40.5**				
M.square $_{Cultivar}$	7.565	17.174	4.926	19.546		0.0620	0.0789
F value $_{Cultivar}$	8.33**	6.22**	5.43**	9.69**		14.44**	767.69**
C.V (%)	2.28	3.87	2.32	3.47		9.43	1.30

Means in the same columns followed by the same letters are not significantly different as statistically.
**: Significant at P<0.01 probability levels. +: The morphine contents were belonging to 2012/13 year

DISCUSSION

The capsule yield, seed yield, oil yield, plant height, capsule number and capsule width in all poppy cultivars tested in the second year were significantly higher than those of the first year in both the autumn and spring sowings. The great yield differences between years were mainly derived from the higher rainfall in the second year according to the first year. The rainfall in the spring months (March, April, and May) is very important for healthy and strong seedling development (Vanova et al., 2006). The spring season precipitations in the second year in particular were higher than in the first year. The poppy cultivars weren't stressed to high temperatures and water deficit during the tillering periods due to high precipitation in the spring sowing of the second year (Svobodova and Misa, 2004). Therefore, capsule yield and seed yield of the autumn and spring sowing in the second year were close to each other.

The capsule yield, seed yield and yield components in all the poppy cultivars in the autumn sowing were significantly higher than the spring sowing in both years. The mean capsule yield in the autumn sowing was higher by approximately 62.4% during 2012/13 and 29.0% during 2013/14, compared to the spring sowing. Similarity, the mean seed yield in the autumn sowing was higher by approximately 57.7% during 2012/13 and 28.4% during 2013/14, compared to the spring sowing. The reason for these differences were significantly higher in the plant characteristics such as plant height, capsule number per plant, capsule width and capsule length in the autumn sowing than in the spring sowing. This increase in the capsule characteristics might be due to longer vegetation periods, more developed roots and the finer development of the plant in the autumn sowing compared to the spring sowing. The first development stage and flowering period in the autumn sowing did not coincide with high temperatures and drought due to the available moisture and nutrient according to the spring sowing. The root system of the poppy is finer and the roots are deeper in a long growing season. In addition, plant growth is better in the long growing period. Yilmaz (1997) reported that capsule yield and seed yield in the autumn sowing was three times higher due to finer development and resistance to diseases compared to the spring sowing. The same authors stated that the fertilization problem and periodically short stress in the spring sowing could be due to dry weather and extreme temperatures. Similarly, Gumuscu (1996) stated that the capsule and seed yield in the autumn sowing was significantly higher according to the spring sowing.

There are large variations in the yields and yield components of the poppy cultivars. In the autumn sowing, while in both capsule yield and seed yield the highest were determined in TMO-3, Ofis-4, Ofis-8, Tınaztepe and

Zaferyolu cultivars, TMO-1, Ofis-8 and Afyon-95 cultivars in the spring sowing were identified as high yielding cultivars. These differences among the poppy cultivars are due to the genetic potential, the plant characteristics, the root structures and the nutrient uptake capacities of the varieties as reported by previous authors (Gumuscu and Arslan, 1999; Karadavut and Arslan, 2006; Gumuscu et al., 2008; Ipek, 2011). In addition, generally, plant height, capsule number, capsule width, capsule length and 1000 seed weight of the high-yielding cultivars (TMO-3, TMO-T, Ofis-3, Ofis-4, Ofis-8, Afyon-95, Tınaztepe and Zaferyolu) were higher than those of the low-yielding cultivars (Table 3 and 4). The previous researchers reported that the capsule yield and seed yield of the poppy cultivars varied between 61.4-697.2 kg ha-^{1} and 82.2-767.5 kg ha^{-1} (Gumuscu and Arslan, 1999), 450.3-1331.0 and 512.0-1511.0 kg ha^{-1} (Gumuscu and Arslan, 2008), 2029.7-2781.5 kg ha^{-1} and 1088.0-1550.0 kg ha^{-1} (Ipek, 2011) 1200.0 kg ha^{-1} and 1500.0 kg ha^{-1} (Kosar et al., 2012), 92.9-140.5 kg ha^{-1} and 577.4-1046.4 kg ha^{-1} (Boydak and Kavurmacı, 2015). The differences in capsule/seed yield could be the result of climatic and soil conditions, sowing times, agronomic practices and genotypes.

The mean oil content in the years and sowing times (autumn and spring sowing) were found to be very close to each other; however, among the cultivars at the point of the oil content significant differences were observed in both years and sowing times. The differences among the cultivars might be due to the variety of characteristics such as efficiency in the production of the secondary metabolites of the poppy. In the present study, the oil content varied between 36.0% and 46.3%. Previous studies reported that the oil content of the poppy varied between 40.4-44.7% (Katar and Yilmaz, 1997), 38.8-53.3% (Arslan et al., 2000) and 32.4-45.5% (Ozcan and Atalay, 2006). At the point of the oil yield, the highest oil yield was detected in TMO-1, TMO-3, Ofis-4, Ofis-8, Tınaztepe, Zaferyolu and Afyon-95 cultivars in both years and sowing times (Table 4). At the same time, these cultivars were high-yielding varieties. A significant and positive correlation between the seed yield with oil yield was reported by Sethi et al. (1990).

The main component of the poppy's alkaloids was morphine, and its ratio varied between 0.45% and 1.00% depending on the cultivars and sowing times. The morphine content of the industrial poppies was approximately 1% (Skalicky et al., 2014). In the present research, the morphine contents of TMO-3, Ofis-3, TMO-T, Ofis-8 and Bolvadin-95 cultivars in the spring sowing were determined as 0.97%, 0.95%, 0.95%, 0.95%, and 0.90%, respectively. At the same time, the morphine contents in the autumn sowing of these cultivars were higher than that of other cultivars. These cultivars could be used for industrial purposes. The mean morphine content in the spring sowed cultivars was higher compared to the autumn sowed ones. The reasons for these differences could be higher synthesize rate of the secondary metabolites due to stress factors such as low moisture and high temperature in the spring sowing. At the same time, among the morphine content of the cultivars significantly differences were found due to the capsule characteristic and genetic structures of the varieties. Yadav et al. (2007) stated that positive correlations were determined between the morphine content with the capsule size, the capsule weight, and the number of capsules per plant. Marculescu and Bobit (2001) and Harvest et al. (2009) confirm that the morphine content correlated with the capsule mass, the growth, and the development of the capsule. Many factors affecting the morphine accumulation during the vegetation periods were noted by Jaszberenyi and Nemeth (2012) and Skalicky et al. (2014). Many researchers determined that the morphine content in the poppy can be affected by the genetic capabilities of the cultivar, the nitrogen nutrition, the water regime, diseases and pests (Marculescu and Bobit, 2001; Harvest et al., 2009; Jaszberenyi and Nemeth, 2012; Skalicky et al., 2014).

CONCLUSION

The results obtained from the present study indicated that the capsule yield, seed yield, examined yield components, oil content, oil yield and morphine content of the poppy cultivars varied according to years, sowing times and varieties.

As a result, under Isparta's ecological conditions: i) The capsule yield, seed yield and oil yield of the autumn sowing was significantly higher than in the spring sowing.

ii) It could be suggested that TMO-3, Ofis-4, Ofis-8, Tınaztepe and Zaferyolu cultivars in the autumn sowing and the TMO-1, Ofis-8 and Afyon-95 cultivars in the spring sowing because of their higher capsule, seed and oil yields.

iii) The TMO-3, TMO-T, Ofis-3, Ofis-8 and Bolvadin-95 cultivars could be used for industrial purposes due to their higher morphine contents.

ACKNOWLEDGEMENTS

The author thanks the Afyonkarahisar-Bolvadin Poppy Alkaloid Office for providing the poppy cultivars and contributions to the morphine analysis.

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