



Investigation of Alkaloids in Opium Poppy (*Papaver somniferum* L.) Varieties and Hybrids

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ABSTRACT

This study aimed to investigate the proportions of morphine, thebaine, noscapine, codeine, oripavine and papaverine alkaloids in poppy varieties and hybrids. Nine parents and 36 hybrid lines were used in the trial. The trial was carried out in 2016 and 2017 in four replications according to the Randomized Block Trial Design. According to the average results of the two years, in parent and hybrid combinations,

morphine was found to vary between 0.42% and 1.66%, thebaine between 0.01% and 0.53%, noscapine between 0.01% and 0.31%, codeine between 0.03% and 0.17%, oripavine between 0.00% and 0.12% and papaverine between 0.00% and 0.10%. In the study, Ofis NM x Ofis 1, Ofis 1 x TMO T, Ofis 2 x TMO T, Ofis NM x Ofis 1, Ofis NM x TMO T hybrid combinations were identified as superior hybrids compared to the others.

Keywords: Alkaloids; Diallel hybridization; Morphine; Poppy; *Papaver somniferum* L.

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1. Introduction

Papaver somniferum L. species (2n= 22) the opium poppy, is a traditionally cultivated annual cultivar. It is grown in Turkey, India, Australia, Spain, France and Hungary as legal main producer countries under the supervision of the United Nations to obtain opium and opium alkaloids for medicinal purposes in World (TMO 2014). India produces opium gum, whereas other countries produce dried opium capsules. The average legal opium poppy cultivation area in 2014-2020 is 79 thousand ha on the basis of main producers in the World, the average morphine equivalent raw material production was 483 tons (INCB 2020). Average most poppy cultivation has been realized with share of 52% in Turkey and with a share of 15% in Australia.

Poppy cultivation for a long time in Anatolia geography, including Sumerians and many civilizations since dates back to 4000 BC and it used for various purposes (Tan 2008). There are 7 species of poppy family in Turkey. Studies report that there is a total of 58 papaver taxa including 36 species and 22 subspecies and varieties, 15 of which are endemic (Guner et al. 2012).

Opium poppy makes a significant contribution to the country economy in terms of making up both morphine and derivatives export. In Afyon Alkaloids Factory with its 25.000 tons/year dried un-incised poppy capsule processing capacity, which was established to commercialize opium poppy and meet the legal alkaloid requirement of the market, approximately 80-100 tons of morphine is produced annually based on the proportion of morphine in capsules. Morphine and its derivatives are used in domestic pharmaceutical industry and the rest 95 % is exported for medical purposes (TMO 2017).

Opium poppy (*Papaver somniferum* L.) plant has two important products in terms of use. One of the products is capsules and the alkaloids in them, and the other is seeds and oil. Researchers have identified 80 different alkaloids of medical importance in opium poppy capsules, from which a large number of important alkaloids are obtained (Celik 2011; Mishra et al. 2013; Marciano et al. 2018). A large number of alkaloids are obtained from opium poppy (*Papaver somniferum* L.), and morphine, codeine, thebaine, noscapine, oripavine, and papaverine are among the most important ones. These alkaloids are used as active ingredients of many drugs. Yazici et al. (2017) the alkaloid contents of some poppy varieties and genotypes reported that the rate of morphine varied from 0.53% to 0.58%, the codeine 0.02% to 0.08%, the oripavine 0.0005% to 0.005%, the thebaine 0.006% to 0.02%, the noscapine 0.02% to 0.19% and papaverine 0.01% to 0.09% in the varieties. In the genotypes was reported the rate of morphine varied between 0.15% and 0.60%, the codeine 0.001% to 0.21%, the oripavine 0.00% to 0.01%, the thebaine 0.001% to 0.08%, the noscapine 0.005% to 0.20%, and the papaverine 0.004% to 0.21%. Morphine is the most important alkaloid that is found in the maximum amount in the poppy capsule. Arslan et al. (2000)

morphine proportions were found between 0.25% and 0.89% in 353 samples collected from various regions. Kara (2017) stated that the morphine content of fifteen poppy cultivars varied between 0.47% and 1.00% in the autumn sowing and between 0.45% and 0.97% in the spring sowing, respectively. Morphine is a strong analgesic (pain killer), utilized to relieve severe pains and to prepare the patient for surgery. Codeine is a very good antitussive (cough controller) as it eliminates the cough response. Thebaine is the most poisonous opium alkaloid. It is not used as a drug; it has a stimulant effect on the central nervous system. Noscapine is the second most common alkaloid after morphine in opium, and it is cough sedative. Papaverine has a pronounced antispasmodic effect on striated and especially non-striated muscles. Oripavine, on the other hand, is used in the treatment of cocaine addiction (Tanker & Tanker 1990; Baser & Arslan 2014; Inal 2015; UNODC 2018). This study aimed at examining the proportions of morphine, thebaine, noscapine, codeine, oripavine, and papaverine alkaloids in opium poppy varieties and hybrids.

2. Material and Methods

In the study, nine different opium poppy varieties (Ofis 96, TMO 1, Huseyinbey, Celikoglu, Ofis NM, Ofis 1, Bolvadin 95, Ofis 2, and TMO T) were used for half diallel crosses (Table 1). The genetic material of the study consisted of nine parents and 36 hybrids obtained through half diallel hybridization method [$n \cdot (n-1) / 2$]. Nine opium poppy cultivars used as parents were sown in the trial field of the Directorate of Middle Black Sea Transition Zone Agricultural Research Institute under Tokat-Kazova conditions on 27 February 2015 to obtain the hybrid seeds to be used as the study material. The varieties used in the trial were planted as three replications in two rows of 3 m length and 45 cm row spacing. 10 cm plant spacing was obtained with later thinning, and 1 m space was left between varieties for the ease of performing hybridization and inbreeding operations. To ensure that the blooming dates of the varieties to be used as fathers and mothers coincide, all varieties were sown again in two rows one month later. F1 hybrid seeds obtained through hybridization and inbred parents were divided into two groups, and they were sown in the trial field of the Directorate of Agricultural Research Institute in 2015-2016 and 2016-2017 vegetation periods in four replications according to the randomized block trial design. The experiment was carried out in two rows of 3 m length and 45 cm row spacing, and 10 cm plant spacing with later thinning. In the study, adequate amount of samples were extracted from capsule shells of each combination, they were ground to powder, and then their alkaloid (morphine, thebaine, noscapine, codeine, oripavine and papaverine) ratios were determined using HPLC analysis method (Kucuk 1996).

Table 1- Parents used in the trial and 9x9 half diallel hybridization combinations

<i>Parents</i>			
<i>Item No</i>		<i>Item No</i>	
1	Ofis 96	6	Ofis 1
2	TMO 1	7	Bolvadin 95
3	Huseyinbey	8	Ofis 2
4	Celikoglu	9	TMO T
5	Ofis NM		
<i>Hybridization combinations</i>			
1x2	Ofis 96 x TMO 1	3x7	Huseyinbey x Bolvadin 95
1x3	Ofis 96 x Huseyinbey	3x8	Huseyinbey x Ofis 2
1x4	Ofis 96 x Celikoglu	3x9	Huseyinbey x TMO T
1x5	Ofis 96 x Ofis NM	4x5	Celikoglu x Ofis NM
1x6	Ofis 96 x Ofis 1	4x6	Celikoglu x Ofis 1
1x7	Ofis 96 x Bolvadin 95	4x7	Celikoglu x Bolvadin 95
1x8	Ofis 96 x Ofis 2	4x8	Celikoglu x Ofis 2
1x9	Ofis 96 x TMO T	4x9	Celikoglu x TMO T
2x3	TMO 1 x Huseyinbey	5x6	Ofis NM x Ofis 1
2x4	TMO 1 x Celikoglu	5x7	Ofis NM x Bolvadin 95
2x5	TMO 1 x Ofis NM	5x8	Ofis NM x Ofis 2
2x6	TMO 1 x Ofis 1	5x9	Ofis NM x TMO T
2x7	TMO 1 x Bolvadin 95	6x7	Ofis 1 x Bolvadin 95
2x8	TMO 1 x Ofis 2	6x8	Ofis 1 x Ofis 2
2x9	TMO 1 x TMO T	6x9	Ofis 1 x TMO T
3x4	Huseyinbey x Celikoglu	7x8	Bolvadin 95 x Ofis 2
3x5	Huseyinbey x Ofis NM	7x9	Bolvadin 95 x TMO T
3x6	Huseyinbey x Ofis1	8x9	Ofis 2 x TMO T

3. Results and Discussion

Genetic diversity is important in plant breeding. Presence of genetic variability is the basic requirement for developing high alkaloid content and better yield varieties in opium poppy. The results of the variance analysis showed that were significant ($P \leq 0.01$) differences among the parents and their F1 progenies in traits studied except for noscapine in the first year (Table 2).

Table 2- Mean squares of variance analysis regarding alkaloid ratios of F1 hybrid combinations and their parents

<i>Variation Sources</i>	<i>DF</i>	<i>Morphine</i>	<i>Thebaine</i>	<i>Noscapine</i>	<i>Codeine</i>	<i>Oripavine</i>	<i>Papaverine</i>
2016							
Repeats	3	0.018	0.018**	0.009**	0.007**	0.0001	0.0005
Genotypes	44	0.288**	0.034**	0.002	0.002**	0.0007**	0.0014**
Error	132	0.033	0.003	0.002	0.0006	0.0000	0.0004
CV (%)		23.97	64.81	98.98	42.65	110.78	117.7
2017							
<i>Variation Sources</i>	<i>DF</i>	<i>Morphine</i>	<i>Thebaine</i>	<i>Noscapine</i>	<i>Codeine</i>	<i>Oripavine</i>	<i>Papaverine</i>
Repeats	3	0.120	0.034*	0.010	0.005	0.0008	0.002
Genotypes	44	0.832**	0.092**	0.086**	0.007**	0.0048**	0.004**
Error	132	0.050	0.011	0.010	0.003	0.0010	0.002
CV (%)		20.66	82.44	52.57	60.43	206.66	157.14

*, **, Significant at $P < 0.05$ and $P < 0.01$ probability levels, respectively

3.1. Morphine ratio

The morphine ratio in the parents was found to vary between 0.35% and 1.30% in the first year, and it was determined to be 0.67% on average. In the second year, the ratio was determined between 0.40% and 1.85%, and the average was 0.92%. According to the average results of two years, the highest morphine ratio in the parents was found in Ofis 2 and Ofis 1 cultivars, while the lowest proportions were in Bolvadin 95 and Huseyinbey cultivars. The proportion of morphine in F1 hybrid combinations ranged between 0.42% and 1.40% in the first year with average of 0.78%, while it was between 0.46% and 2.03%, and with average of 1.12% in the second year. The highest morphine ratio in hybrid combinations was determined in Ofis NM x Ofis 1 and Ofis 1 x TMO T hybrids, whereas the lowest ratios were in Ofis 96 x Huseyinbey and TMO 1 x Huseyinbey hybrid combinations (Table 3 and 4). Harvest et al. (2009) demonstrated that morphine content correlated with capsule mass and total latex mass. Yadav et al. (2007) stated that positive correlations were determined between the morphine content with the size of the capsule and their weight. Thus, in hybrid combinations, varieties for both high capsule yield and morphine content can be developed. Dubedout (1993) reported that no correlation between the agromorphological characteristics and the content of the morphine. Moreover, the morphine content is often average between the parents values in hybrids. According to the work of Khanna & Shukla (1989) maternal effects had observed for earliness, seed weight, morphine content, plant height, flowering period and number of capsules. Danos (1968) who reported that the quantity of morphine alkaloids in the capsule increases under hot and dry cultivation conditions, while rainy weather after flowering and seed setting reduces the alkaloid content. In this study, it was thought that the precipitation in the first year was higher than the second year and it had a negative effect on the decrease in morphine content. According to the average findings of the two years, morphine content of F1 hybrid combinations (0.95%) was higher than either of the parents (0.80%). Hybrid combinations are higher than their parents shows that has an effect of hybrid vigour.

3.2. Thebaine ratio

The proportion of thebaine in the parents was found to range between 0.01% and 0.42% and the average was determined as 0.09% in the first year, the ratio varied between 0.00% and 0.63% and the average ratio was 0.12% in the second year. The highest thebaine ratio in parents was found in TMO T, while the lowest was in TMO 1 varieties. The rate of thebaine in F1 hybrid combinations was determined as 0.02-0.37%, and average was 0.09% in the first year. In the second year, was determined between 0.00 and 0.61%, and with average of 0.13%. The highest ratio of thebaine in hybrids was in Ofis 2 x TMO T, and the lowest was in TMO 1 x Huseyinbey hybrid combinations (Table 3 and 4). Dubedout (1993) reported that morphine content was positively correlated to the thebaine and codeine contents. Selection would be effective to improve these traits simultaneously. No relation was found between the thebaine content and yield in capsules. The highest thebaine was obtained at the start of flowering (Levy et al. 1986; Levy et al. 1988). Saco & Lopez-Belmonte (1988) was found significant negative correlation between precipitation (mm) and thebaine content.

3.3. Noscapine ratio

The proportion of noscapine in the parents was found to vary between 0.00% and 0.09%, and average was 0.04% in the first year, In the second year, the ratio was determined between 0.02% and 0.53% and 0.16% on average. The highest and the

lowest noscapine ratios in parents were found in Ofis 96 and Celikoglu, respectively. The rate of noscapine in F1 hybrid combinations ranged between 0.01 and 0.12% in the first year, and average was 0.05%. In the second year, ranged between 0.05 and 0.58%, and the average was 0.20%. The highest ratio of noscapine in hybrid combinations was found in Ofis NM x Ofis 1, Ofis 1 x TMO T, while the lowest was determined in Ofis 96 x Celikoglu and TMO 1 x Celikoglu hybrid combinations (Table 3 and 4). Ozgen et al. (2017) in a study reported that noscapine ratio ranged between 0.00% and 1.79% in experiment using 22 lines and one standard variety.

Table 3- Mean values of 2016 and 2017 related to the proportion of alkaloids in the parent (%)

*Parents	Morphine (%)			Thebaine (%)			Noscapine (%)		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
(1)	0.39	0.52	0.45	0.03	0.20	0.11	0.03	0.53	0.28
(2)	0.49	0.62	0.55	0.02	0.00	0.01	0.04	0.07	0.05
(3)	0.46	0.40	0.43	0.06	0.07	0.06	0.07	0.09	0.08
(4)	0.49	0.69	0.59	0.04	0.05	0.04	0.00	0.02	0.01
(5)	0.82	0.95	0.88	0.08	0.05	0.06	0.09	0.11	0.10
(6)	1.30	1.85	1.57	0.10	0.02	0.06	0.04	0.22	0.13
(7)	0.35	0.49	0.42	0.01	0.05	0.03	0.06	0.14	0.10
(8)	0.92	1.72	1.32	0.05	0.03	0.04	0.03	0.08	0.05
(9)	0.84	1.07	0.95	0.42	0.63	0.52	0.08	0.24	0.16
Mean	0.67	0.92	0.80	0.09	0.12	0.10	0.04	0.16	0.10
SE	0.05	0.09		0.02	0.03		0.008	0.02	
Range %	0.28-1.53	0.26-2.23		0-0.58	0-0.85		0-0.19	0-0.71	
*Parents	Codeine (%)			Oripavine (%)			Papaverine (%)		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
(1)	0.04	0.12	0.08	0.003	0.000	0.001	0.01	0.02	0.01
(2)	0.04	0.05	0.04	0.001	0.078	0.039	0.01	0.00	0.00
(3)	0.04	0.05	0.04	0.002	0.055	0.028	0.02	0.03	0.02
(4)	0.05	0.08	0.06	0.004	0.000	0.002	0.00	0.00	0.00
(5)	0.08	0.10	0.09	0.009	0.000	0.004	0.03	0.08	0.05
(6)	0.10	0.00	0.05	0.004	0.000	0.002	0.02	0.00	0.01
(7)	0.03	0.08	0.05	0.001	0.019	0.010	0.04	0.03	0.03
(8)	0.07	0.04	0.05	0.001	0.000	0.000	0.01	0.00	0.00
(9)	0.09	0.10	0.09	0.073	0.178	0.125	0.01	0.05	0.03
Mean	0.06	0.06	0.06	0.010	0.036	0.023	0.01	0.02	0.02
SE	0.005	0.01		0.003	0.01		0.004	0.008	
Range %	0-0.15	0-0.21		0-0.08	0-0.35		0-0.12	0-0.26	

*(1); Ofis 96, (2); TMO 1, (3); Huseyinbey, (4); Celikoglu, (5); Ofis NM, (6); Ofis 1, (7); Bolvadin 95, (8); Ofis 2, (9); TMO T, SE; Standard error

3.4. Codeine ratio

Codeine ratio was determined between 0.03% and 0.10% in the first year, 0.06% on average, between 0.00% and 0.12% in the second year, and 0.06% on average in the parents. The highest codeine ratio in parents was found in TMO T, and the lowest was in TMO 1 and Huseyinbey varieties. F1 hybrid combinations, codeine ratio ranged between 0.02 and 0.14%, and 0.06% on average in the first year, In the second year ranged between 0.01 and 0.21%, and 0.10% on average. The highest codeine proportion in hybrids was found in Ofis 1 x TMO T and Celikoglu x Ofis 1 hybrids, while the lowest was in Huseyinbey x Ofis 2 hybrid combinations (Table 3 and 5). *Papaver bracteatum* L. can be used to be a potential alternative for the higher yields of

codeine from unit area in breeding (Bohm 1981). Laughlin (1980) the highest codeine and morphine was obtained about five weeks after full flowers.

Table 4- Mean values of 2016 and 2017 for morphine, thebaine and noscapine ratios in F1 hybrid combinations (%)

*Crosses	Morphine (%)			Thebaine (%)			Noscapine (%)		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
1x2	0.47	0.76	0.61	0.03	0.01	0.02	0.04	0.11	0.07
1x3	0.44	0.46	0.45	0.04	0.01	0.02	0.04	0.08	0.06
1x4	0.58	0.53	0.55	0.03	0.01	0.02	0.04	0.05	0.04
1x5	0.66	0.85	0.75	0.09	0.19	0.14	0.03	0.13	0.08
1x6	1.02	1.41	1.21	0.08	0.16	0.12	0.08	0.45	0.26
1x7	0.53	0.56	0.54	0.05	0.04	0.04	0.04	0.08	0.06
1x8	0.66	1.04	0.85	0.03	0.02	0.02	0.01	0.12	0.06
1x9	0.67	0.99	0.83	0.11	0.26	0.18	0.04	0.15	0.09
2x3	0.42	0.63	0.52	0.02	0.00	0.01	0.04	0.05	0.04
2x4	0.51	0.70	0.60	0.05	0.03	0.04	0.02	0.06	0.04
2x5	0.66	0.95	0.80	0.03	0.07	0.05	0.01	0.11	0.06
2x6	1.04	1.64	1.34	0.02	0.07	0.04	0.05	0.34	0.19
2x7	0.63	0.95	0.79	0.02	0.08	0.05	0.08	0.14	0.11
2x8	0.84	1.48	1.16	0.02	0.11	0.06	0.03	0.24	0.13
2x9	0.84	1.08	0.96	0.05	0.09	0.07	0.03	0.20	0.11
3x4	0.44	0.64	0.54	0.04	0.09	0.06	0.03	0.11	0.07
3x5	0.60	0.84	0.72	0.08	0.19	0.13	0.03	0.14	0.08
3x6	1.00	1.26	1.13	0.06	0.18	0.12	0.07	0.39	0.23
3x7	0.50	0.59	0.54	0.04	0.08	0.06	0.04	0.09	0.06
3x8	0.83	1.03	0.93	0.03	0.02	0.02	0.04	0.10	0.07
3x9	0.93	0.90	0.91	0.14	0.25	0.19	0.04	0.30	0.17
4x5	0.62	0.96	0.79	0.15	0.07	0.11	0.03	0.12	0.07
4x6	1.19	1.52	1.35	0.12	0.25	0.18	0.03	0.32	0.17
4x7	0.49	0.73	0.61	0.04	0.04	0.04	0.08	0.07	0.07
4x8	0.83	1.27	1.05	0.06	0.07	0.06	0.01	0.08	0.04
4x9	0.64	1.03	0.83	0.29	0.48	0.38	0.02	0.14	0.08
5x6	1.40	1.92	1.66	0.09	0.09	0.09	0.12	0.50	0.31
5x7	0.72	1.09	0.90	0.06	0.05	0.05	0.05	0.15	0.10
5x8	1.08	2.03	1.55	0.13	0.14	0.13	0.07	0.31	0.19
5x9	0.88	1.51	1.19	0.37	0.37	0.37	0.04	0.28	0.16
6x7	1.06	1.47	1.26	0.04	0.13	0.08	0.09	0.23	0.16
6x8	1.05	1.68	1.36	0.06	0.06	0.06	0.09	0.37	0.23
6x9	1.23	1.86	1.54	0.29	0.42	0.35	0.05	0.58	0.31
7x8	0.73	1.02	0.87	0.03	0.02	0.02	0.03	0.11	0.07
7x9	0.79	1.01	0.90	0.16	0.09	0.12	0.06	0.10	0.08
8x9	1.14	1.92	1.53	0.23	0.61	0.42	0.06	0.51	0.28
Mean	0.78	1.12	0.95	0.09	0.13	0.11	0.05	0.20	0.12
LSD (0.05)	0.27	0.30		0.07	0.13		0.05	0.13	
SE	0.02	0.03		0.008	0.01		0.004	0.01	

*(1);Ofis 96, (2); TMO 1, (3);Huseyinbey, (4);Celikoglu, (5);Ofis NM, (6);Ofis 1, (7);Bolvadin 95, (8);Ofis 2, (9);TMO T, SE; Standard error

3.5. Oripavine ratio

The proportion of oripavine in the parents was found between 0.001% and 0.073%, and average was 0.010% in the first year. In the second year the ratio was determined between 0.000% and 0.178%, and with average of 0.036%. The ratio of oripavine in parents was the highest in TMO T, and the lowest was in Ofis 2. The rate of oripavine in F1 hybrid combinations was determined as 0.001-0.044%, and with average of 0.008% in the first year, in the second year 0.000-0.118%, and with average of 0.009%.

The cross Ofis NM x TMO T and Bolvadin 95 x TMO T showed the highest oripavine and the lowest was in Ofis 96 x Bolvadin 95 (Table 3 and 5). Yazici et al. (2017) reported that the rate of oripavine ranged between 0.000% and 0.005%. Yazıcı & Yılmaz (2017), reported that the rate of oripavine varied from 0.01% to 0.02%, in the cultivated as summer and in cultivated as winter; the rate of oripavine varied from 0.0002% to 0.007 %.

3.6. Papaverine ratio

The ratio of papaverine in the parents was found between 0.00% and 0.04%, and average was 0.01% in the first year and in the second year was determined between 0.00% and 0.08% and 0.02% on average. The highest proportion of papaverine in parents

was found in Ofis NM, and the lowest was in Celikoglu. The ratio of papaverine in F1 hybrid combinations ranged between 0.00 and 0.08%, and average was 0.02%, in the first year, in the second year ranged between 0.00 and 0.12%, and 0.03% on the average. The highest ratio of papaverine in hybrids was in Huseyinbey x Ofis 1 and Ofis NM x Ofis 2 hybrid combinations and the lowest was in TMO 1 x Ofis NM (Table 3 and 5). Karabuk (2012) the rate of papaverine between 0.00 and 0.02%, Yazıcı et al. (2017) the rate of papaverine was reported to be 0.01-0.09% in varieties and in genotypes was reported to be 0.00-0.21%. Khanna & Shukla (1991) found a relationship between white latex and papaverine content.

Table 5- Mean values of 2016 and 2017 regarding codeine, oripavine and papaverine ratios in F1 hybrid combinations (%)

*Crosses	Codeine (%)			Oripavine (%)			Papaverine (%)		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
1x2	0.04	0.09	0.06	0.003	0.017	0.010	0.00	0.01	0.00
1x3	0.06	0.06	0.06	0.002	0.000	0.001	0.01	0.03	0.02
1x4	0.04	0.05	0.04	0.003	0.000	0.001	0.01	0.00	0.00
1x5	0.07	0.09	0.08	0.004	0.000	0.002	0.02	0.02	0.02
1x6	0.05	0.16	0.10	0.003	0.012	0.007	0.01	0.00	0.00
1x7	0.05	0.08	0.06	0.001	0.000	0.000	0.00	0.01	0.00
1x8	0.03	0.04	0.03	0.002	0.000	0.001	0.00	0.01	0.00
1x9	0.03	0.11	0.07	0.012	0.000	0.006	0.01	0.06	0.03
2x3	0.04	0.07	0.05	0.002	0.042	0.022	0.03	0.02	0.02
2x4	0.05	0.08	0.06	0.002	0.000	0.001	0.00	0.02	0.01
2x5	0.04	0.08	0.06	0.001	0.003	0.002	0.00	0.05	0.02
2x6	0.04	0.13	0.08	0.003	0.008	0.005	0.00	0.00	0.00
2x7	0.05	0.10	0.07	0.003	0.004	0.003	0.01	0.02	0.01
2x8	0.04	0.09	0.06	0.002	0.000	0.001	0.00	0.06	0.03
2x9	0.07	0.08	0.07	0.003	0.007	0.005	0.01	0.00	0.00
3x4	0.05	0.14	0.09	0.002	0.000	0.001	0.03	0.05	0.04
3x5	0.04	0.11	0.07	0.008	0.007	0.007	0.06	0.09	0.07
3x6	0.08	0.13	0.10	0.002	0.000	0.001	0.08	0.11	0.09
3x7	0.05	0.09	0.07	0.002	0.000	0.001	0.03	0.04	0.03
3x8	0.04	0.01	0.02	0.002	0.029	0.015	0.02	0.00	0.01
3x9	0.11	0.14	0.12	0.014	0.009	0.011	0.05	0.07	0.06
4x5	0.07	0.07	0.07	0.021	0.000	0.010	0.00	0.03	0.01
4x6	0.11	0.17	0.14	0.006	0.000	0.003	0.02	0.06	0.04
4x7	0.06	0.10	0.08	0.004	0.012	0.008	0.01	0.02	0.01
4x8	0.05	0.07	0.06	0.002	0.000	0.001	0.01	0.00	0.00
4x9	0.11	0.09	0.10	0.021	0.000	0.010	0.02	0.00	0.01
5x6	0.08	0.17	0.12	0.002	0.026	0.014	0.07	0.05	0.06
5x7	0.07	0.07	0.07	0.006	0.000	0.003	0.01	0.03	0.02
5x8	0.07	0.13	0.10	0.010	0.000	0.005	0.06	0.12	0.09
5x9	0.14	0.12	0.13	0.044	0.118	0.081	0.00	0.10	0.05
6x7	0.06	0.12	0.09	0.003	0.000	0.001	0.02	0.02	0.02
6x8	0.05	0.03	0.04	0.004	0.000	0.002	0.01	0.02	0.01
6x9	0.12	0.21	0.16	0.029	0.000	0.014	0.02	0.00	0.01
7x8	0.02	0.05	0.03	0.002	0.009	0.005	0.01	0.00	0.00
7x9	0.09	0.07	0.08	0.026	0.073	0.049	0.00	0.01	0.00
8x9	0.09	0.14	0.11	0.033	0.000	0.016	0.01	0.00	0.00
Mean	0.06	0.10	0.08	0.008	0.010	0.009	0.02	0.03	0.02
LSD (0.05)	0.03	0.05		0.01	0.03		0.01	0.05	
SE	0.003	0.005		0.001	0.003		0.002	0.004	

*(1); Ofis 96, (2); TMO 1, (3);Huseyinbey, (4); Celikoglu, (5); Ofis NM, (6); Ofis 1, (7); Bolvadin 95, (8); Ofis 2, (9); TMO T, SE; Standard error

4. Conclusions

In this study, were used nine parents and 36 hybrid combinations. The experiment was conducted in 2016 and 2017, alkaloid ratios were examined and appropriate parents and hybrid combinations were determined according to alkaloid ratios. According to the average findings of the two years, the parents Ofis 1, Ofis 2, Ofis NM and TMO T were identified as the highest cultivars in a result of investigated all traits. Therefore they could be considered as promising parents in further breeding studies. The mean performance of F1 hybrids was found higher than either of the parental for all traits exhibiting the role of hybrid vigour. In this study, 15 hybrid combinations were found to be higher than the hybrid average values of two years for morphine content and 13 for thebaine, 13 for noscapine, 12 for codeine, 6 for oripavine, 12 for papaverine. Particularly, the crosses Ofis NM x Ofis 1, Ofis 1 x TMO T, Ofis 2 x TMO T, Ofis NM x Ofis 1, Ofis NM x TMO T were

identified as superior hybrids compared to the others. Hybrid combinations with high alkaloid ratios can be evaluated as suitable hybrids for breeding studies.

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