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Agronomska svojstva inozemnih sorata i domaćih populacija uljanoga maka

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Poljoprivreda/Agriculture

ISSN: 1848-8080 (Online)
ISSN: 1330-7142 (Print)

http://dx.doi.org/10.18047/poljo.22.2.4

Poljoprivredni fakultet u Osijeku, Poljoprivredni institut Osijek

Faculty of Agriculture in Osijek, Agricultural Institute Osijek

ISSN: 1330-7142
UDK: 633.854.54
DOI: 10.18047/poljo.22.2.4

THE AGRONOMIC TRAITS OF FOREIGN CULTIVARS AND DOMESTIC POPULATIONS OF OILSEED POPPY

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Original scientific paper
Izvorni znanstveni članak

SUMMARY

For the past few years, a rising interest for the production of oil poppy (Papaver somniferum L.) on bigger areas in the Republic of Croatia has been noticed. The aim of this study was to determine seed yield and other agronomic traits of foreign cultivars and domestic populations of oilseed poppy in the environmental conditions of northwestern Croatia and select the best varieties for this area, considering the obtained results. The research was conducted in 2013 and 2015 at the experimental field of University of Zagreb, Faculty of Agriculture. The research involved four foreign cultivars (Opal, Lazur, Major, and Matis) and two domestic populations of oilseed poppy named after locations where they had been collected: Gornji Bogićevci (IND00042) and Beli Manastir (IND00043). According to the obtained results, it can be concluded that the examined cultivars and domestic populations of oilseed poppy differed significantly in seed yield, capsule number per plant, seed weight per capsule, seed weight per plant, and thousand seed weight only in the year of 2013. On average, cultivars/populations with the highest yield were Opal (847 kg/ha), Beli Manastir (834 kg/ha), and Major (816 kg/ha). Oil content in poppy seed ranged from 42.5% (Lazur) to 46.3% (Opal). Linoleic, oleic, and palmitic acids prevailed in examined cultivars and populations.

Key-words: Papaver somniferum L., seed yield, yield components, fatty acids composition

INTRODUCTION

In Croatia oilseed poppy is cultivated for its seed, mostly in gardens for household needs. The need for oilseed poppy in Croatia, however, is far greater and is satisfied through import. Oilseed poppy with dark blue and grey coloured seed is particularly esteemed. It is worth noting that in the last few years in Croatia the interest for cultivation of oilseed poppy on larger areas is growing. Poppy cultivars differ in seed yield, oil content, alkaloids content, etc.

Seed yield is a complex trait that is determined by other yield components. The basic components of oilseed poppy yield are seed weight per capsule and capsule number per unit area (Pospišil and Pospišil, 2013). Shukla and Khanna (1987) found a positive correlation between poppy seed yield and its components. Poppy cultivars differ in basic yield components and their impact on yield, and correlation between the yield and its components stems from genetic basis (Wójtowicz, 2011). Apart from genetic yield potential, poppy seed yield is significantly affected by applied management practices and particularly environmental conditions (Cihlář et al., 2003; Wójtowicz, 2007).

The oil content of poppy varies from 40 and 55%, whereas linoleic (C18: 2 n-6; 60-75%), oleic (C18: 1 n-9; 12-22%), and palmitic fatty acids (C16: 1; 10-12%) prevail (Bernáth and Németh, 2009).

The aim of this study was to determine poppy seed yield and other agronomic traits of foreign cultivars and domestic populations in environmental conditions of northwestern Croatia and, considering the obtained results, select the best varieties for this area.

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MATERIAL AND METHODS

The research was conducted on the experimental field of Faculty of Agriculture, University of Zagreb in 2013 and 2015. The study involved four foreign cultivars (Opal, Major, Matis and Lazur) and two domestic populations of oilseed poppy named after locations where they had been collected: Beli Manastir (receipt number IND00042) and Gornji Bogićevci (receipt number IND00043). The seeds of these populations are stored at the National Bank of Plant Genes, whereas their passport data can be found in Croatian Plant Genetic Resources Database (http://cpgrd.hcphs.hr/). The experiment was set up using randomized block design in five replications. Plot size was 6.6 m^2 (5.5 m x 6 rows x 20 cm). Sowing was performed on April 4, 2013 and March 24, 2015, respectively by "Wintersteiger" plot seeder with 1.5 kg ha^{-1} seed. At the stage of 4 leaves, plant stand was corrected to the final plant population of 60 plants m^{-2}. Standard crop management was used for oilseed poppy cultivation.

Fertilization was carried out with a total of 55 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5 and 120 kg ha^{-1} K_2O. Oilseed poppy was manually harvested at the stage of technological maturity (August 1, 2013 and July 22, 2015). The seed yield was adjusted for 9% moisture. The oil content was determined in the Laboratory for Oil and Fat Technology at the Faculty of Food Technology and Biotechnology, University of Zagreb, on an average sample of five repetitions according to standard method HRN EN ISO 659:2010 (method according Soxhlet). 5-10 g of grounded unclean poppy seeds was weighed in cellulose extraction. With the help of petroleum solvents, extraction was carried out for eight hours in the Soxhlet apparatus. After extraction had been completed, the solvent evaporated, and the residue was dried for 60 minutes at 103±2° C, then cooled and weighed. Drying was continued for 30 minutes until constant weight. Mass proportion of oil was calculated according to the equation:

$$Oil\ (\%) = \frac{m_1}{m_0}\ x\ 100$$

Where m_0= seed weight, m_1= total weight of extracted oil

Fatty acid composition was determined by gas chromatography according to the method HRN EN ISO 5508:1999, only in 2015. Fatty acids were determined by their methyl esters (HRN EN ISO 5509:2004) using a gas chromatograph (ATI Unicam 610, Cambridge, England) on capillary column TR-FAME (Thermo) (30 m x 0.22 mm thickness the film of 0.25 m; stationary phase: 70% cyanopropyl-polisilfenilen siloxane) and FID detector (constant flow rate of 0.7 ml min^{-1}, helium carrier gas, injector temperature 250°C, split: 1: 75, detector temperature: 280°C, the amount of sample injected: 1.0 ml) with the programmed column temperature 120°C to 160°C - 4°C min^{-1}, 160°C to 190°C - 10°C min^{-1} at 190°C was maintained for 10 min. Identification of individual fatty acids was carried out by comparing the retention time of methyl esters of certain fatty acids with the retention times of standard mixture of methyl esters of fatty acids 18 (F.A.M.E.) of known composition.

Computer-selected method of normalization of areas was used to calculate the quantitative composition of fatty acids. Thus, along with retention time and area under the peaks, percentage share of each fatty acid was also recorded in the chromatogram.

Yield components (capsule number per plant, seed weight per capsule and seed weight per plant) were determined on average samples of 10 plants taken from two central rows of each plot. The obtained data were statistically analyzed through variance analysis using DSAASTAT (Onofri, 2007). Average value of determined indicators was tested by Duncan's multiple range tests at the level of 5%.

Weather conditions and soil characteristics

Mean decade and monthly air temperatures and precipitation from March to July (during the growing season of poppy) in the years of research and a long-term average (1981 – 2010) for Zagreb – Maksimir are given in Table 1. In 2013, due to the large amount of precipitations in March (121.7 mm), poppy was sowed a little later than was optimal.

Table 1. Mean decade and monthly air temperature and precipitation during the period from March to July in years of research and long-term average (Zagreb – Maksimir)

Tablica 1. Srednje dekadne i mjesečne temperature zraka i količine oborina od ožujka do srpnja u godinama istraživanja i višegodišnji prosjek za meteorološku postaju Zagreb – Maksimir

Month *Mjesec*	Decades *Dekada*	Air temperature, ^{0}C *Temperatura zraka, ^{0}C*			Precipitations, mm *Količina oborina, mm*		
		2013	2015	Long-term average *Višegodišnji prosjek* 1981-2010	2013	2015	Long-term average *Višegodišnji prosjek* 1981-2010
March *Ožujak*	III	2.6	10.5	6.8	75.2	26.2	54.1
	Average/Total ***Prosjek/Ukupno***	**4.8**	**7.8**		**121.7**	**35.1**	
April *Travanj*	I	6.4	7.3	11.4	42.3	6.7	59.5
	II	14.9	13.6		7.1	8.8	
	III	17.7	14.8		6.7	6.7	
	Average/Total ***Prosjek/Ukupno***	**13.0**	**11.9**		**56.1**	**22.2**	
May *Svibanj*	I	19.0	19.0	16.5	29.6	8.1	68.6
	II	16.2	18.5		24.3	32.9	
	III	14.1	15.3		40.1	97.0	
	Average / Total ***Prosjek/Ukupno***	**16.4**	**17.5**		**94.0**	**138.0**	
June *Lipanj*	I	17.0	23.0	19.6	18.8	0.0	97.4
	II	23.3	21.0		7.4	27.8	
	III	19.9	18.3		22.5	47.4	
	Average / Total ***Prosjek/Ukupno***	**20.0**	**20.8**		**48.7**	**75.2**	
July *Srpanj*	I	22.5	24.1	21.5	28.9	10.0	71.4
	II	21.7	26.2		1.2	2.0	
	III	25.3	22.1		3.1	96.0	
	Average / Total ***Prosjek/Ukupno***	**23.2**	24.1		33.2	108.0	
Mean / Total: March – July ***Prosjek/Ukupno: Ožujak – Srpanj***		15.5	16.4	15.2	353.7	378.5	351.0

Source: Croatian Meteorological and Hydrological Service, 2015

Deficiency of precipitations occurred during second decades in June (7.4 mm) and in July (33.2 mm) of 2013 when poppy was in sensitive stage of flowering and seed development. In addition to lack of precipitation, the temperature in July was 1.7^{0}C higher than average.

In 2015, the precipitations from March to July were higher by only 24.8 mm compared to 2013, but distribution of precipitation during the poppy growing season was unfavourable. The deficiency of precipitations was noted in March (35.1 mm) and April (22.2 mm), which affected the germination of plants. In 2015, unfavourable distribution of precipitation and high temperatures were also recorded during the stage of flowering and ripening of seeds. The first decade in June, the stage of beginning of flowering, was marked by the average air temperature of 23.0^{0}C and the lack of precipitation (0 mm). During decades I and II in July (until harvest) only 12 mm of precipitations were recorded, while the air temperature was high (24.1°C in the first and 26.2°C in the second decade of July).

The experiments were conducted on anthropogenic, eutric-brown soil. The upper layer of soil has neutral reaction (pH in 1 M KCl = 7.14), with low humus content (1.77% humus) and well supplied with nitrogen (0.11%). It is also well supplied with phosphorus (P_2O_5 = 35.54 mg/100 g soil) and potassium (K_2O = 25.00 mg/100 g soil).

RESULTS AND DISCUSSION

In 2013, the average seed yield was 847 kg ha^{-1} (Table 2). Analysis of variance revealed significant differences in seed yield between the poppy cultivars and populations. Using Duncan's test, cultivars and populations were classified into three ranks (a-c) according to seed yield. The highest seed yield was achieved by cultivars Matis (953 kg ha^{-1}), Opal (880 kg ha^{-1}), Beli Manastir (876 kg ha^{-1}), and Major (864 kg ha^{-1}). In 2013, the average oil content was 44.4%, but it varied from 43.0% (Matis and Gornji Bogićevci) to 47.9% (Opal).

Table 2. Seed yield and oil content of oilseed poppy cultivars and populations, 2013 year

Tablica 2. Prinos sjemena i udio ulja u sjemenu istraživanih sorti i populacija maka u 2013. godini

Cultivar / population *Sorta / populacija*	Seed yield, kg ha^{-1} *Prinos sjemena, kg ha^{-1}*	Oil content, % a.d.m. *Udio ulja, % na s. t.*
Opal	880 ab	47.9
Lazur	810 bc	44.4
Major	864 ab	43.8
Matis	953 a	43.0
Gornji Bogićevci	695 c	43.0
Beli Manastir	876 ab	44.0
Average / *Prosjek*	847	44.4

In 2013, obtained plant population at harvest varied from 55-60 plants m^{-2} (Table 3). Researched cultivars and populations differed in the capsule number per plant, seed weight per capsule, seed weight per plant and 1000 seed weight. Significantly highest capsule number per plant was achieved by cultivars Matis (2.22) and Lazur (1.92). According to seed weight per capsule, first rank (a) encompasses two cultivars (Opal and Major) and both populations (Gornji Bogićevci and Beli Manastir). Although no significant difference exists among these cultivars and populations, in the first rank (a) maximum seed weight per plant was achieved by population Beli Manastir (1.97 g) and cultivar Major (1.78 g). According to the seed weight per plant, there are no big differences among the researched cultivars and populations, and all of them belong to the first rank (a). Evaluated poppy cultivars and population significantly differed in 1000 seed weight and were classified into 4 ranks (a-d). The highest 1000 seed weight was significantly obtained in cultivars Major (0.52 g) and Opal (0.51 g).

Table 3. Yield components of oilseed poppy cultivars and populations, 2013 year

Tablica 3. Komponente prinosa istraživanih sorti i populacija maka u 2013. godini

Cultivar / population *Sorta / populacija*	Plant number m^{-2} *Broj biljaka m^{-2}*	Capsule number per plant *Broj tobolaca / biljci*	Seed weight per capsule, g *Masa sjemena / tobolcu, g*	Seed weight per plant, g *Masa sjemena / biljci, g*	1000 seed weight, g *Masa 1000 sjemenki, g*
Opal	60	1.64 bc	1.65 ab	2.48 ab	0.51 ab
Lazur	57	1.92 ab	1.31 b	2.48 ab	0.48 c
Major	59	1.56 bc	1.78 a	2.49 ab	0.52 a
Matis	55	2.22 a	1.26 b	2.56 ab	0.48 c
Gornji Bogićevci	57	1.54 bc	1.57 ab	2.01 b	0.44 d
Beli Manastir	58	1.64 c	1.97 a	3.00 a	0.49 bc
Average / *Prosjek*	57	1.75	1.59	2.50	0.49

In 2015, the average seed yield of researched poppy cultivars and populations was 729 kg ha^{-1}, and varied from 656 kg ha^{-1} (Lazur) to 813 kg ha $^{-1}$ (Opal) (Table 4). Analysis of variance, among evaluated oilseed poppy cultivars and populations showed no significant differences in seed yield. Average oil content in this year was 43.7% and ranged from 40.6% (Lazur) to 46.4% (Gornji Bogićevci) (Table 4).

Table 4. Seed yield and oil content of oilseed poppy cultivars and populations, 2015 year

Tablica 4. Prinos sjemena i udio ulja u sjemenu istraživanih sorti i populacija maka u 2015. godini

Cultivar / population *Sorta / populacija*	Seed yield, kg ha^{-1} *Prinos sjemena, kg ha^{-1}*	Oil content, % a.d.m. *Udio ulja, % na s. t.*
Opal	813	44.6
Lazur	656	40.6
Major	768	41.4
Matis	642	44.2
Gornji Bogićevci	705	46.4
Beli Manastir	791	45.1
Average / *Prosjek*	729	43.7

When it comes to oil of the researched poppy cultivars and populations, linoleic fatty acid was dominant (C18:2). Content of this fatty acid ranged from 67.5% (Opal) to 71.1% (Gornji Bogićevci) (Table 5). Oleic acid (C18:1) also had a high share in the oil, namely from 16.3% (Gornji Bogićevci) to 21.7% (Lazur). The content of palmitic acid (C16:0) was in the range from 9.1% (Matis and Beli Manastir) to 9.5% (Major). Poppy oil contained low amount of stearic acid, from 2.1% (Matis and Gornji Bogićevci) to 2.7% (Lazur). The content of linolenic acid in this research ranged from 0.8% (Beli Manastir and Gornji Bogićevci) to 1.1% (Lazur).

Table 5. Fatty acids composition of oilseed poppy cultivars and populations, 2015 year

Tablica 5. Dominantne masne kiseline u ulju istraživanih sorti i populacija maka u 2015. godini

Cultivar / population *Sorta / populacija*	Fatty acids (%) / *Masne kiseline* (%)				
	Palmitic *Palmitinska* C16:0	Stearic *Stearinska* C18:0	Oleic *Oleinska* C18:1	Linoleic *Linolna* C18:2	Linolenic *Linolenska* C18:3
Opal	9.2	2.4	19.3	67.5	1.0
Lazur	9.2	2.7	21.7	69.4	1.1
Major	9.5	2.2	18.8	68.3	0.9
Matis	9.1	2.1	20.3	66.4	0.9
Gornji Bogićevci	9.2	2.1	16.3	71.1	0.8
Beli Manastir	9.1	2.2	18.4	69.1	0.8
Average / *Prosjek*	9.2	2.3	19.1	68.6	0.9

In 2015, the achieved plant population at harvest varied from 50 to 56 plants m^{-2} (Table 6). Researched poppy cultivars and populations did not differ in capsule number per plant, seed weight per capsule, seed weight per plant or 1000 seed weight.

Table 6. Yield components of poppy seed cultivars and populations, 2015 year

Tablica 6. Komponente prinosa istraživanih sorti i populacija maka u 2015.

Cultivar / population *Sorta / populacija*	Plant number m^{-2} *Broj biljaka* m^{-2}	Capsule number per plant *Broj tobolaca / biljci*	Seed weight per capsule, g *Masa sjemena / tobolcu, g*	Seed weight per plant, g *Masa sjemena / biljci, g*	1000 seed weight, g *Masa 1000 sjemenki, g*
Opal	56	1.40	1.93	2.64	0.47
Lazur	53	1.27	1.68	2.09	0.50
Major	50	1.47	1.98	2.79	0.49
Matis	55	1.47	1.74	2.30	0.46
Gornji Bogićevci	50	1.13	1.79	1.99	0.46
Beli Manastir	53	1.20	1.6	1.80	0.45
Average / *Prosjek*	53	1.32	1.70	2.30	0.47

Yield of oilseed poppy cultivars Opal and Lazur in this research was similar to the yield of oilseed poppy in the Czech Republic, obtained by using standard management practices (Cihlář et al., 2003). However Cihlář et al. (2005) reported varying seed yield of cultivar Opal from 0.95 to 2.35 t ha^{-1}, depending on the year of cultivation. In Poland seed yields of cultivars Opal and Lazur were also higher, ranging from 1.55 to 2.66 t ha^{-1} and from 1.40 to 2.45 t ha^{-1} (Wójtowicz, 2007).

In both years of research deficiency of precipitations during poppy flowering stage caused a reduction in seed yield. Apart from the cultivar Opal with slightly higher oil content in the seed, the average oil content of researched cultivars and populations was similar to the results of research in Poland where, depending on the cultivar, the oil content varied 40-44% (Walisiewicz-Niedbalska et al., 2000). In Turkey, blue seed poppy contains on average 33.6% oil, what is lower than in our experiment (Azcan et al., 2004).

Oilseed poppy is a good source of unsaturated fatty acids. The fatty acid composition of the oil indicates that poppy is suitable for use in human diet due to the presence of essential fatty acids (linoleic and linolenic) (Singh et al., 1998).

Fatty acid composition of the researched cultivars is comparable to the results of the same cultivars in the Czech Republic, except for a slightly lower content of linoleic acid in our research (Hlinkova et al., 2011). Compared to the composition of fatty acids in the oil of Turkish cultivars, oil of researched poppy cultivars contained less palmitic and stearic acids and more linoleic and linolenic acid (Özcan and Atalay, 2006; Azcan et al., 2004).

CONCLUSION

Based on the obtained results it can be concluded that the researched poppy cultivars and domestic populations significantly differed in seed yield, capsule number per plant, seed weight per capsule, seed weight per plant and 1000 seeds weight only in favorable weather 2013. On average, the best yielding cultivars/ populations were Opal (847 kg ha-1), Beli Manastir (834 kg ha^{-1}) and Major (816 kg ha^{-1}). The oil content ranged from 42.5% (Lazur) to 46.3% (Opal). A higher content of oil in the seed was obtained in 2013, when lower temperatures and less precipitations during the period from flowering to harvest poppies were registered. When it comes to oil composition of researched cultivars and populations, linoleic acid (an essential omega-6 fatty acid), oleic and palmitic fatty acids prevailed. Fatty acid composition of poppy oil indicates that it is a good source of unsaturated fatty acids and is suitable for use in human diet.

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AGRONOMSKA SVOJSTVA INOZEMNIH SORATA I DOMAĆIH POPULACIJA ULJANOGA MAKA

SAŽETAK

Posljednjih nekoliko godina u Republici Hrvatskoj primjetan je interes za uzgoj uljanoga maka (Papaver somniferum L). na većim površinama. Stoga je cilj ovih istraživanja bio utvrditi prinos sjemena i druga agronomska svojstva inozemnih sorata i domaćih populacija uljanoga maka u agroekološkim uvjetima sjeverozapadne Hrvatske te, na temelju dobivenih rezultata, odabrati najbolje sorte za to područje. Istraživanja su provedena kroz sortne pokuse postavljene na pokušalištu Sveučilišta u Zagrebu Agronomskoga fakulteta u 2013. i 2015. godini. U istraživanje bile su uključene četiri inozemne sorte (Opal, Lazur, Major i Matis) i dvije izvorne domaće populacije maka: Gornji Bogićevci (IND00042) i Beli Manastir (IND00043). Pokus je bio postavljen prema slučajnome bloknome rasporedu u pet ponavljanja. Na temelju dobivenih rezultata, može se zaključiti kako su se istraživane sorte i domaće populacije maka značajno međusobno razlikovale po prinosu sjemena, broju tobolaca po biljci, masi sjemena po tobolcu, masi sjemena po biljci i masi 1000 sjemenki samo u 2013. godini. U prosjeku istraživanja najrodnije sorte/populacija bile su Opal (847 kg ha^{-1}), Beli Manastir (834 kg ha^{-1}) i Major (816 kg ha^{-1}). Udjel ulja u sjemenu kretao se od 42,5% (Lazur) do 46,3% (Opal). U sastavu ulja istraživanih sorti i populacija maka prevladavaju linolna, oleinska i palmitinska masna kiselina.

Ključne riječi: Papaver somniferum L., prinos sjemena, komponente prinosa, sastav masnih kiselina

(Received on 1 September 2016; accepted on 24 October 2016 - *Primljeno 1. rujna 2016.; prihvaćeno 24. listopada 2016.*)