

## EVALUATION OF SELECTED POPPY (*Papaver somniferum* L.) CULTIVARS: INDUSTRIAL ASPECT

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### ABSTRACT

Fifty-six genotypes (usually cultivars) of various origins, from twelve countries, were analysed for morphine production and significant characteristics of the capsule. The Saaty's method was used to analyse the aspect of morphine production and significant characteristics of the capsule, comparing those values representing significant indicators for that production and the content of morphine in poppy straw. This covered the relation to ideotype ('ideotype cultivar') of poppy, with 100% values in the monitored indicators. In the case of white-seed poppies, generally with a lower content of morphine, in three cultivars ('Pulawski bialy', 'Bělosemenný', 'Bulharský slepák bílý') the value of the industrial indicator was determined over 50% and the content of morphine over 0.50% in the poppy straw. In the set of blue-seed cultivars with three production levels, four cultivars were found with values exceeding 80% of the industrial indicator and morphine in poppy straw over 0.90%. In the set of grey-seed cultivars, four production levels were identified based on the values of morphine and the industrial indicator, while the first two showed good values for production - at least 0.52% of morphine in poppy straw and 50% of the industrial indicator (for example 'Soproni tef', 'Šarišský').

**Key words:** blue-seed, capsule characteristics, grey-seed, morphine, pharmaceutical aspect, white-seed

### INTRODUCTION

The current issue of phytochemical research is undoubtedly studying the production of secondary plant metabolites (essential oils, alkaloids, glycosides, etc.) for various taxa including cultivars (for example Inan et al., 2014; Kara and Baydar, 2013; Kizil et al., 2010). The efforts to intensively use *Papaver somniferum* L., its economic effectiveness, medicinal purposes as well as its abuse in drug addiction led to the specific cultivation of this crop to obtain cultivars of specific production types - industrial (specifically pharmaceutical) and food (specifically the seed types). Food poppies are represented by cultivars with low to negligible alkaloid content and high seed yield, typically blue to blue-grey or white colour. As industrial poppies are considered those containing in poppy straw approximately 1% of morphine (usually more), together with minority alkaloids (codeine, thebaine, narcotine, papaverine, and others); cultivars with dominant production of thebaine, codeine or another alkaloid were also bred. The alkaloids of the *P. somniferum* plant belong to a group of benzylisochinoline alkaloids, while from over 100 species of the *Papaver* genus, the presence of morphinan alkaloids (in the sequence of thebaine, codeine, morphine) is characteristic

only for plants of the species *P. somniferum* and *P. setigerum* (Lee et al., 2013; Preininger et al., 1981; Ziegler et al., 2009).

Only plants of these taxa show the presence of enzymatic systems with the specific ability of demethylation of methoxy groups of A and D cycles, leading to the creation of codeine and morphine (Novak and Preininger, 1987). Another opportunity here for the creation of morphine is the biosynthetic path leading from thebaine through oripavine to morphinone (for example Balazova and Psenak, 1998). In this regard, Bajpai et al. (2001) evaluated the mutual relation of the morphine and codeine content in some Indian genotypes. Morphine is first created in the root, then in cotyledons and true leaves and finally in the stem and capsule. The capsules contain most alkaloids at the state of opium ripeness approximately 10-12 days prior to full ripeness (Proksa et al., 1979). The overall yield of morphine from the surface unit depends on the yield of poppy straw and the content of alkaloids in the poppy straw. The main factors influencing the content of morphine are the cultivar, nitrogen nutrition and water regime, then, for example, post-harvest treatment of the poppy straw, presence of diseases and pests, etc. In the case of winter poppy

cultivars, connection of frost tolerance and alkaloid accumulation is important (Jaszberenyi and Nemeth, 2012). In the case of small-seed by poppies, we cannot omit stress factors, particularly the influence of water stress (Szabo et al., 2008; Mahdavi-Damghani et al., 2010). Given that the water regime depends on the course of the season and nitrogen fertilizers only influence the morphine content within the genetic capabilities of the cultivar, the content of morphine can be significantly influenced by selection of the cultivars (Bernath and Tetenyi, 1982). Regional studies also usually solve issues of local cultivars (for example Azcan et al., 2004) from the point of seed production and oil content. Undoubtedly there are studies regarding the genetic variability of the poppy in terms of production and its alkaloid composition of opium, including their mutual relations (Yadav et al., 2006).

## MATERIALS AND METHODS

### *Plant material and design*

Seeds of 56 cultivars of *Papaver somniferum* L. were provided by the gene bank of the Research Institute of Oilseed (Opava, Czech Republic; [http://genbank.vurv.cz/genetic/resources/asp2/evg\\_d3\\_a.asp?kodp=O08](http://genbank.vurv.cz/genetic/resources/asp2/evg_d3_a.asp?kodp=O08)), including currently cultivated as well as older cultivars.

**Table 1.** Results of the evaluation of the selected cultivars of *Papaver somniferum* for industrial aspect – characters (indicators) and point scale

Characteristic and its significance (scoring)	Morphological characteristics			Industrial characteristics		
	plant height (20%)	capsule shape* (40%)	capsule size (40%)	Morphine content in poppy straw % (60%)	Weight of dry, empty capsule g (20%)	No. of capsule per plant (20%)
1	very small very high	other	very small very large	< 0.24	0.2	> 3
2		narrow-elliptical		0.25-0.3	0.21-0.5	
3		reniform		0.31-0.4	0.51-0.8	
4		elliptical		0.41-0.5	0.81-1.1	
5	high small	cylindrical	small large	0.51-0.75	1.11-1.4	2-3
6		pear-shaped		0.76-0.8	1.41-1.7	
7		cordiform		0.81-0.9	1.71-2.0	
8		widely elliptical		0.91-1.0	2.1-2.3	
9	medium high	oval ball-shaped	medium-sized	> 1.0	> 2.3	1-2

\* see Fig. 1

The experimental field of CULS Prague - 'Červený Újezd' (50°04' N 14°10' E) has an altitude up to 420 m above sea level, an average annual temperature 7.9°C, normal 526 mm per year precipitation, a moisture area according to Seljaninov 1.3 - moderately dry; climatic area - moderately warm; climatic district - moderately dry; soil group - brown soil; soil type - clay soil; C<sub>ox</sub> content 3%; pH 6.99 (neutral).

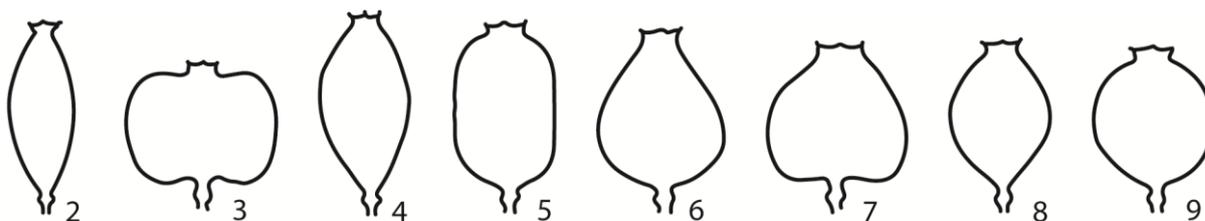
Thus, a total of 56 treatments (selected cultivars, Tables 2-4) were grown in the RCBD (randomized complete block design), with 3 replications at the experimental field of the Czech University of Life Sciences Prague (CULS Prague), Czech Republic, during the three consecutive years 2009, 2010 and 2011.

The planting was done in the 3-m long rows with row-to-row and plant-to-plant distances of 25 and 12.5 cm, respectively (manual seeding at the depth of 0.5 cm in the period from 4th to 14th April; 1.2 kg.ha<sup>-1</sup> seeding rate; fertilized 80 kg N.ha<sup>-1</sup> in LAD; singling at stage 3 and 4 of true leaves). Each genotype was represented by 4 rows (as experimental rows) and 2 rows as non-experimental rows, grown as the border rows in each replication in order to minimize competition from nutritional uptake.

Planting technology was in line with large-area production and the methodology of the study of genetic resources (Dotlacil et al., 2004). In the phase of full maturity, 20 competitive capsules per treatment/replication were randomly selected for chemical analysis of their morphine content (%). Each year, 20 plants were removed from each plot in the phase of full ripeness for the purpose of data collection (evaluation of characters, see Table 1 and Figure 1), from which the three-year average values were calculated.

### *Determination of morphine in poppy straw - high-performance liquid chromatography, with mass detection (HPLC)*

The morphine content in poppy straw was quantified through high performance liquid chromatography analysis (Matyasova et al., 2011). The poppy straw (dried and grinded) was extracted with 5% acetic acid under sonication.



**Figure 1.** Capsule shape by 'Descriptor List *Papaver somniferum* L.'; No. 2 – 9 see Table 1

The resulting suspension was centrifuged (3000 G) and the supernatant was purified by solid-phase extraction cartridges (Oasis MCX; Waters, USA). The eluate was evaporated to dryness, using a rotary vacuum evaporator. The residue was dissolved in 50% aqueous methanol, filtered through a membrane PVDF filter (0.45  $\mu$ m) and analysed by HPLC-MS/MS. Reverse phase chromatography was employed (HyPURITY AQUASTAR column; Thermo, USA) using gradient elution with A: (0.1% formic acid in methanol, v/v) and B: (0.1% formic acid in deionized water, v/v) as a mobile phase. The detection was carried out using the 3200 QTRAP detector (AB Sciex, USA) with electrospray ionization in positive ion mode.

#### Statistical analyses

A mixed-model procedure with a repeated statement for cultivars was used to analyse the content of morphine and characters in the poppy plants. The evaluation of the individual characteristics in the scales correspond to the 'Descriptor List *Papaver somniferum* L.' - Gene bank of the Research Institute of Oilseed, in relation to the ideotype of the poppy and assigning significance (%) based on Saaty's comparison method (Hosseini et al., 2012; see Table 1). The method dealt with consistency of the pairwise comparison matrix. Data from each part of the plants was tested separately. The graphic representation compares the groups of values representing the indicators of morphological characteristics ( $x$  axis) and industrial characteristics ( $y$  axis) – explained Table 1. The third variable is the indicator of morphine content in the poppy straw, which is expressed by the diameter of the ring, characterizing the specific cultivar. Values of morphological and industrial characteristics are specified in Tables 2-4. The diagrams specify groups of these three values compared to the theoretical 'ideotype cultivar', achieving 100 % evaluation in all three indicators (morphological and industrial indicator, morphine content – see Table 1) in compliance with the 'Descriptor List *Papaver somniferum* L.'. All statistical tests presented in this study were performed using the Statistica 10.0 (StatSoft Inc., Tulsa, OK, U.S.A.) software package.

## RESULTS AND DISCUSSION

So far, the systematic classification of *P. somniferum* cultivars has not been satisfactorily resolved and, although significant works using morphological, chemical and other characteristics undoubtedly exist, they are usually of an older date, for example Veselovskaja (1975), in overview Tetenyi (1997). The primary reason is the multidirectional reticular blending of various characteristics and their

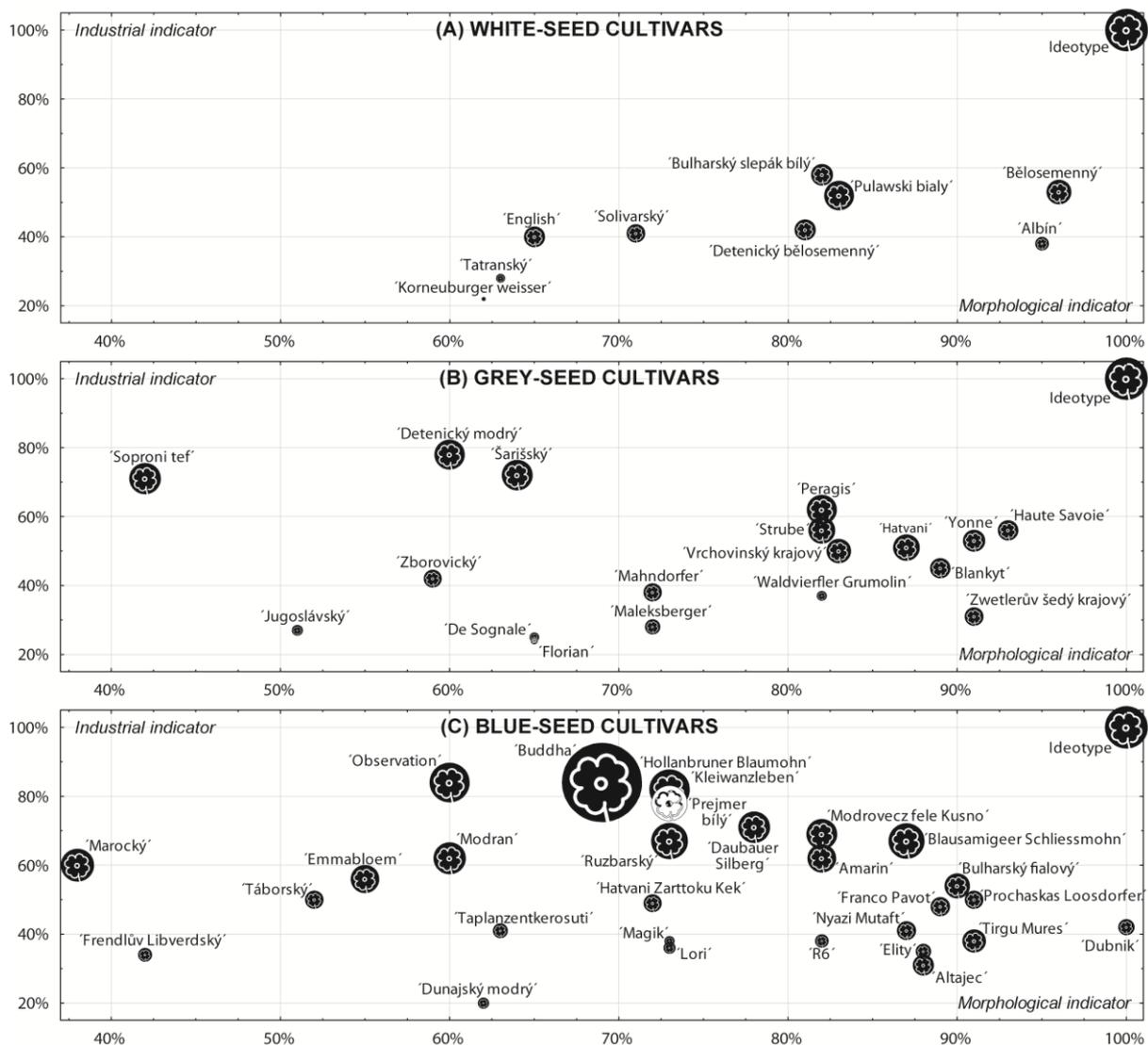
values as a consequence of considerable breeding with a large number of cultivars of different origins. The study presented primarily focus on evaluating those characteristics of the capsule that immediately relate to the production of morphine, including the number of capsules per plant.

The results are presented in three sets, depending on seed colour and with respect to the simplicity of graphic display (Figure 2), although seed colour is the most important from the food production point of view, more than industrial (pharmaceutical). The capsule characteristics have a specific significance for the overall production of poppy (morphine and seed) - for example, positive correlations between content of morphine and the size of the capsule and their weight per thousand seeds were determined (Yadav et al., 2007), while there is no evident correlation between the colour of the seed and the content of morphine.

Among the most significant characteristics that influence morphine production are capsule weight after seed removal, capsule size, number of capsules per plant in a particular plant spacing, (among others the influence of uneven ripening) etc. Sristava and Sharma (1987) and Singh et al. (2003) confirm this with results on certain selected characteristics (Tables 2-4). Harvest et al. (2009) demonstrated that morphine content correlated with capsule mass and total latex mass, but there was no similar correlation between latex capacity and morphine yield. Studies of genetic character are significant from the long-term perspective (for example Kumar and Patra, 2010). The subject of alkaloid production was studied by Nemeth-Zambori et al. (2011) in hybrid generations of five genotypes, representing various chemotypes. Marculescu and Bobit (2001) monitored the content of morphine and the dynamics of its creation over the course of growth and development of the capsule. No significant deviations from usual values were found.

#### White-seed cultivars

White-seed cultivars are generally considered to have lower performance in terms of seed production and morphine (for example Vlk et al., 2009), as well as lower resistance against unfavourable influences (drought, diseases, pests, etc.). Table 2 and Figure 2a show a significantly lower morphine content and, particularly, the industrial indicator in white-seed cultivars (in three levels of the given set), compared to blue-seed and grey-seed cultivars. Generally 0.40% morphine in dry capsules is considered a suitable yield level for the pharmaceutical processing of white-seed cultivars.



**Figure 2.** Characteristics of the 56 selected *Papaver somniferum* cultivars, representing the indicators of morphological characteristics (x axis) and industrial characteristics (y axis) – see Table 1. The third variable is the indicator of morphine content in the poppy straw, which is expressed by the diameter of the ring

**Table 2.** White-seed cultivars of *Papaver somniferum*: values of monitored characteristics (A – content of morphine in the deseeded capsule in % | B – weight of the deseeded capsule in g | C – number of capsules per 1 plant in pcs | D – morphological indicator in % | E – industrial indicator in %)

Cultivars	Co.	A	B	C	D	E	
'Pulawski biały'	POL	0.697	1.42	3.07	83	52	
'Bělosemenný'	CSK	0.580	0.77	1.90	96	53	I.
'Bulharský slepák bílý'	BGR	0.512	1.14	1.72	82	58	
'English'	NM	0.491	1.12	3.08	65	40	
'Detenický bělosemenný'	CSK	0.495	1.22	2.43	81	42	II.
'Solivarský'	SVK	0.434	0.86	2.12	71	41	
'Albín'	CSK	0.320	1.50	1.58	95	38	
'Tatranský'	SVK	0.211	1.01	2.29	63	28	III.
'Korneuburger weisser'	AUT	0.097	0.73	2.35	62	22	

Co.: country of origin, abbreviations according to ISO 3166-1 | NM: non-mentioned.

I. Cultivars with the content of morphine in the dry mass of deseeded capsules over 0.50% and the industrial indicator over 50%. | II. Cultivars with the content of morphine in the dry mass of deseeded capsules 0.40 – 0.50% and the industrial indicator 40 – 50%. | III. Cultivars with the content of morphine in the dry mass of deseeded capsules under 0.40% and the industrial indicator under 40%.

In the 'Pulawski biały' cultivar, the negative impact of stem branching was evident (specifically the number of capsules per plant), which, based on the 'Descriptor List *Papaver somniferum* L.' (Havel et al., 2001) significantly reduced the value of the industrial indicator, despite this cultivar being one of relatively high morphine content (on average 0.7%) as well as capsule weight (1.42 g), representing good usability as a genetic source of poppy with white seeds. 'Bulharský slepák bílý' and 'Bělosemenný' cultivars could be comparable in terms of the industrial indicator, with the value of this indicator also exceeding 50% and morphine content of at least 0.50% in ripe capsules with seeds removed. The 'English', 'Detenický bělosemenný' and 'Solivarský' cultivars, with average amounts of capsule morphine (0.45%), reached lower values in other characteristics that immediately influence alkaloid production (similar results were stated by Strakova and Novak, 1993). 'Albín', 'Tatarský' and 'Koneuburger weisser' cultivars might be considered less beneficial from both a production point of view and as

donors of monitored characteristics. Matyasova et al. (2011) also demonstrated an evaluation of 'Albín', 'Solivarský' and 'Tatarský' cultivars, with analogous results.

#### Grey-seed cultivars

Within the set there are four apparent levels of morphine content in poppy straw (Table 3), of which the first two can be considered very well from the point of view of pharmaceutical use. In cultivars with high morphine content (0.5% and more, Table 3, group I) there were also higher average values of the industrial indicator, including capsule weight. Costes et al. (1976) examined some selected identical cultivars ('Soproni tef' and 'Peragis') as regards to mineral nutrition a morphine production and their results (morphine content) were analogous. In the 'Detenický modrý' cultivar there was an apparent influence of stem branching, allowing a larger number of capsules per plant (among the same number of plants grown per 1 m<sup>2</sup>).

**Table 3.** Grey-seed cultivars of *Papaver somniferum*: values of monitored characteristics (A – content of morphine in the deseeded capsule in % | B – weight of the deseeded capsule in g | C – number of capsules per 1 plant in pcs | D – morphological indicator in % | E – industrial indicator in %)

Cultivars	Co.	A	B	C	D	E	
'Soproni tef'	HUN	0.739	1.38	1.21	42	71	I.
'Šarišský'	SVK	0.721	1.37	1.69	64	72	
'Detenický modrý'	CSK	0.710	1.12	4.02	60	78	
'Peragis'	NLD	0.703	0.81	1.73	82	62	
'Strube'	DDR	0.629	1.35	2.38	82	56	II.
'Hatvani'	HUN	0.624	0.96	2.08	87	51	
'Vrchovinský krajový'	CSK	0.575	1.32	2.23	83	50	
'Yonne'	FRA	0.520	0.71	1.67	91	53	
'Haute Savoie'	HUN	0.479	0.82	2.17	93	56	III.
'Blankyt'	CSK	0.477	0.90	1.63	89	45	
'Zwetlerův šedý krajový'	CSK	0.438	1.35	3.83	91	31	
'Mahndorfer'	DEU	0.429	0.79	2.71	72	38	
'Zborovický'	CSK	0.421	0.81	1.74	59	42	IV.
'Maleksberger'	DEU	0.359	1.04	1.68	72	28	
'Jugoslávský'	NM	0.257	1.05	2.15	51	27	
'De Sognale'	FRA	0.227	0.78	2.48	65	25	
'Waldvierfler Grumolin'	AUT	0.233	1.02	1.87	82	37	
'Florian'	AUT	0.167	0.72	2.53	65	24	

Co.: country of origin, abbreviations according to ISO 3166-1 | NM: non-mentioned.

I. Cultivars with the content of morphine in the dry mass of deseeded capsules over 0.70% and the industrial indicator over 60%. | II.

Cultivars with the content of morphine in the dry mass of deseeded capsules 0.50 – 0.70% and the industrial indicator 50 – 60%. | III.

Cultivars with the content of morphine in the dry mass of deseeded capsules 0.40 – 0.49% and the industrial indicator 30 – 49.9%. | IV.

Cultivars with the content of morphine in the dry mass of deseeded capsules under 0.49% and the industrial indicator under 30%.

Evenness among the cultivars of group II (Table 3) was evident in all monitored parameters, particularly in terms of morphine content, industrial and morphological indicators at a very satisfactory standard. The lower average values of morphological indicator did not significantly impact morphine production (see Table 3 - compare group I to groups II-IV). This could be observed within the whole set of grey-seeded cultivars (Figure 2b); for example the values of the morphological indicator in

some of the group IV cultivars (those with the lowest production of morphine) were higher compared to cultivars showing high morphine content, including group I. Similarly, cultivars of group III (with low morphine content as well as low industrial indicator values) in some cases showed relatively high values among morphological characteristics. It was evident from the results that morphological characteristics had no significant impact on the content of morphine in poppy straw.

### Blue-seed cultivars

The blue-seed *Papaver somniferum* L. cultivars are traditionally used to obtain both seed and morphine and are often bred for this universal purpose. In the evaluated set of blue-seed cultivars there were mostly materials of this universal type, with relatively high morphine content in dry mass capsules (ranged from 0.24 to 0.94%, average of three consecutive years). However, the seed harvest was often primary (this could be due to their eventual use as genotypes as donors of the required characteristics in breeding). The subject of seed production and the morphological diversity of an extensive collection of cultivars was studied by Brezinova et al. (2009), unfortunately without data on alkaloid production. Yet the

amount of morphine determined by us in the stated cultivars was comparable to values in dry mass capsules stated by other authors in a number of genotypes - for example Gumuscu et al. (2008) states 0.110-1.114 % (on selected poppy lines), Matyasova et al. (2011).

Of the analysed materials, only cultivar 'Buddha' could be clearly considered as an industrial high-morphine poppy type (1.8%, see Table 4, group I). From the point of view of breeding goals and use, cultivars with very low (nearly zero) content of morphine were also interesting for the purpose of obtaining cultivars grown exclusively for seed and for limiting the exploitation of *P. somniferum* for drug abuse.

**Table 4.** Blue-seed cultivars of *Papaver somniferum*: values of monitored characteristics (A – content of morphine in the deseeded capsule in % | B – weight of the deseeded capsule in g | C – number of capsules per 1 plant in pcs | D – morphological indicator in % | E – industrial indicator in %)

Cultivars	Co.	A	B	C	D	E	
'Buddha'	HUN	1.870	1.62	2.60	69	84	I.
'Kleiwanzleben'	DEU	0.944	0.93	1.73	73	82	
'Observation'	AUT	0.937	1.15	1.48	60	84	
'Hollanbruner Blaumohn'	AUT	0.933	1.20	1.77	73	82	
'Ruzbarský'	SVK	0.858	0.98	2.27	73	67	
'Blausamigeer Schliessmohn'	DEU	0.842	0.89	2.50	87	67	II.
'Prejmer bílý'	POL	0.834	1.30	1.28	73	78	
'Marocký'	NM	0.776	1.09	2.21	38	60	
'Modran'	CSK	0.756	1.30	2.43	60	62	
'Daubauer Silberg'	AUT	0.743	1.12	1.33	78	71	
'Modrovecz fele Kusno'	HUN	0.719	0.94	1.98	82	69	
'Amarin'	CSK	0.671	0.95	1.91	82	62	
'Emmabloem'	NLD	0.665	1.17	2.52	55	56	
'Bulharský fialový'	BGR	0.593	0.76	1.49	90	54	
'Tirgu Mures'	HUN	0.550	1.02	3.47	91	38	
'Altajec'	SUN	0.492	0.88	3.67	88	31	III.
'Nyazi Mutaft'	HUN	0.446	1.23	2.17	87	41	
'Franco Pavot'	FRA	0.453	0.64	1.23	89	48	
'Prochaskas Loosdorfer'	AUT	0.433	0.95	1.83	91	50	
'Táborský'	CSK	0.430	1.07	1.85	52	50	
'Hatvani Zarttoku Kek'	HUN	0.422	0.86	1.67	72	49	
'Dubnik'	CSK	0.380	1.01	1.29	100	42	
'Elity'	HUN	0.362	1.07	2.09	88	35	
'Taplanzentkerosuti'	HUN	0.350	0.94	1.67	63	41	
'Trendlův Libverdský'	CSK	0.326	0.98	2.66	42	34	
'R6'	FRA	0.317	1.20	2.04	82	38	
'Lori'	DNK	0.282	0.80	1.72	73	36	
'Dunajský modrý'	CSK	0.263	0.18	3.51	62	20	
'Magik'	CSK	0.238	1.17	1.66	73	38	

Co.: country of origin, abbreviations according to ISO 3166-1 | NM: non-mentioned.

I. Cultivars with the content of morphine in the dry mass of deseeded capsules over 0.90% and the industrial indicator over 80%. | II.

Cultivars with the content of morphine in the dry mass of deseeded capsules 0.60 – 0.90% and the industrial indicator 55 – 80 %. |

III. Cultivars with the content of morphine in the dry mass of deseeded capsules under 0.60% and the industrial indicator under 55%.

We could establish three groups within the set of blue-seed poppies for monitored characteristics - Table 4, Figure 2c. With the exception of the high-morphine 'Buddha' cultivar in the first group, there were universal cultivars with a relatively high morphine content above 0.90% in a ripe empty capsule. They included a high

average (above 80%) industrial indicator value, while the values of the morphological indicator in the cultivars of this group were slightly above average overall.

The second group - cultivars with the morphine content of 0.60-0.90% in the ripe capsule, with values

between 55-80% of the industrial indicator. These poppies of the universal type were usually suitable for pharmaceutical processing and, given the production and seed colour, often also for food purposes. Some (for example 'Amarin', 'Modran') were originally bred primarily for high yields of quality blue seed. The 'Modran' cultivar showed a 0.75% morphine value over the three-year average, while Bernath and Tetenyi (1982) found practically half of morphine here (0.35%). Despite this, morphine content was very favourable from the pharmaceutical point of view, particularly in values over 0.80%.

The third group included cultivars with lower morphine content (under 0.60%) and with lower value of the industrial indicator (less than 55%). Yet in half of these cultivars, over 0.40% morphine was found in the capsules on average, which is an amount still acceptable for pharmaceutical processing in some abundant years. The low average value of industrial indicator was evident (see Table 4, group III) and in some cultivars the higher percentage level of morphological indicator did not show in the production of morphine.

### CONCLUSIONS

The content of morphine in poppy straw, as well as production-significant morphological and industrial indicators were evaluated in a population of 56 *Papaver somniferum* L. cultivars in relation to the 'ideotype cultivar' which represents 100% values in the monitored indicators. In three white-seed cultivars, the production of morphine was over 50% showing very favourably in combination with the values of the industrial (as well as the morphological) indicator, compared to the ideotype and providing a good predisposition for use in breeding.

In the set of 18 grey-seed cultivars, four cultivars group levels were determined in terms of industrial aspect - their content of morphine and industrial significant characteristics. In cultivars with higher morphine content there were, on average, also relatively high values of the industrial indicator; thus the cultivars of the first two levels could be considered suitable in terms of industrial use.

In blue-seed poppies, the most productive cultivars reached values of over 90% morphine content and over 80% of the industrial indicator. The second level also represents cultivars with acceptable morphine content (0.60-0.90%) as well as the industrial indicator (55-80 %). The cultivars with lower morphine levels and industrial indicators were included in the third group of blue-seed poppies of lesser industrial use. In the monitored morphological characteristics, no significant influence on the content of morphine in empty capsule was found, their values compared to the ideotype were also shown graphically. With the exception of the high-morphine 'Buddha' cultivar, these were universal types of poppy, often used for production of both seed and morphine.

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