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Chemotaxonomic review of the genus *Papaver*

Chemotaxonomický přehled rodu *Papaver*

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Novák J.[1]) et Prvininger V.[2]) (1987): Chemotaxonomic review of the genus *Papaver*. — Preslia, Praha, 59 : 1—13.

In plants of particular sections of the genus *Papaver* L., the composition of alkaloid spectra was studied and results in the form of phytochemical characteristics of sections and chemotaxonomic evaluation were obtained. The sections are characterized by the presence of typical alkaloid groups, or of particular alkaloids and by chromosome numbers. Important findings of alkaloids in particular species are also presented, especially with respect to chemotaxonomic relations within the scope of each section, as well as between different sections. The study is based on generally valid taxonomic treatment of the genus. It represents an overall phytochemical evaluation with conclusions for the systematics based on the isolation and identification of alkaloids present in all species, which are chemotaxonomically significant and specific for the section of the genus *Papaver* L. and certain species.

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The genus *Papaver* L. is characterized by a variety of alkaloids, which may be considered as a constant property; other substances were studied very rarely. Out of about 120 species, approximately 70 were studied for the content of alkaloids achieving the isolation of some 145 alkaloids, which belong to isoquinoline alkaloids and variants derived from them biogenetically. According to the basic skeleton the alkaloids belong to several groups (Tab. 1).

The evaluation and taxonomic classification of species of the genus *Papaver* L. into sections was still accomplished particularly on the bases of morphological and phytogeographical studies. The composition of alkaloid spectra with a phytochemical delimitation of sections is the purpose of the chemotaxonomic study, as one of the methods of systematic botany regardless of the social and economic importance of certain alkaloids, particularly of plant species producing these alkaloids. From the chemical standpoint the genus *Papaver* L. was first treated comprehensively by Hegnauer (1969), with respect to a botanical classification of the genus.

MATERIAL AND METHODS

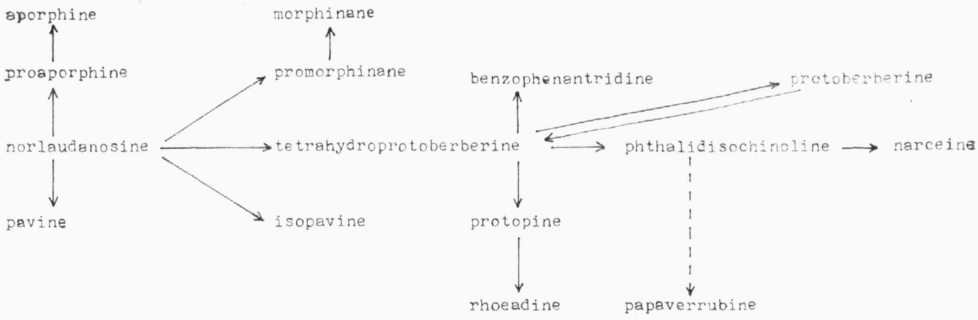
Results are treated of the research performed between 1959 and 1985. The material was stepwise received from 78 producers from 37 countries, including some natural localities, and plants were grown under our conditions. In addition to species of the Czechoslovak flora, in eight cases plants collected at original localities were evaluated.

Methods of botanical systematics used for the taxonomic evaluation of material were after Novák (1979), Novák et Preininger (1981); nomenclature of sections from Kubát (1983) and Kiger (1985). Data from the literature were used, concerning chromosome numbers (Kawatani et Ohno 1965, Fedorov et al. 1969), besides our own findings (e.g. Novák et Preininger 1980, 1981 etc.).

1126/88/p

Tab. 1. — Types of alkaloids, alkaloids chemotaxonomically important, and chromosome numbers found in sections of the genus *Papaver* (+!! = chemotaxonomically important types).

Section	Alkaloid types												Chemotaxonomically important alkaloids	Chromosome numbers
	isoquinoline and benzylisoquinoline	proaporphine	aporphine	promorphinane	morphinane	isopavine	protoberberine	protopine	phthalidisoquinoline	narceine	rhoeadine papaverrubine	benzophenantridine		
Rhoeadium /annual plants/	+	+	+!!	+	+	–	+	+!!	–	+	+!!	+	rhoeadine, protopine, isorhoeadine, papaverrubines	x=7 2n=14/28/42
Argemonidium /annual pl./	–	–	–	–	–	–	+	+!!	–	–	+!!	+	rhoeadine, protopine, papaverrubines	x=6/7 2n=12/14/42
Carinatae /annual pl./	+	–	–	–	–	–	–	+!!	–	–	+!!	+	macrostomine, dehydronormacrostomine, sevenine	x=7 2n=14
Papaver /annual pl./	+	–	+	+	+!!	–	+	+	+!!	+	+	+	codeine, morphine, narcotine, narcotoline	x=11 2n=22/44
Glauca /annual pl./	–	–	–	–	–	–	+	+	–	–	+!!	+	rhoeadine, oxysanguinarine, glaucamine, glaudine	x=7 2n14/28
Meconidium /biennial pl./	+!!	+!!	+	+	+!!	–	+	+	+	+	+!!	+	mecambrine, armepavine, protopine	x=6/7 2n=12/14
Pilosa /perennial pl./	+	+	+!!	+!!	+	–	+	+!!	–	–	+!!	+	laterioine, amurine	x=6/7 2n=12/14/28
Macrantha /perennial pl./	+	+	+!!	+	+!!	–	+!!	+	–	–	+	+	isothebaine, thebaine, orientalidine	x=7 2n=14/28/42
Meconella /perennial pl./	–	+	–	+	–	+!!	+	+!!	–	–	+!!	+	amurine, amurensine, amurensinine, alpinine, alpinigenine	x=7 2n=14/28/42/56/70/84



Schematic diagram 1. — Biogenesis of isoquinoline alkaloids derived from norlaudanosine.

ISOLATION AND IDENTIFICATION OF ALKALOIDS

Alkaloids were isolated by extracting the dried ground drugs with methanol (PREININGER et al. 1967, PREININGER et ŠANTAVÝ 1970, PREININGER et al. 1971). The methanolic extract was thickened in vacuum, diluted with 1M acetic acid and extracted with petrolether to remove impurities. Aqueous residue was then first alkalinized with sodium carbonate to a pH of about 8 and ether was used to extract a portion of quaternary protoberberine alkaloids. The obtained mixture of alkaloids was then divided by column chromatography on alumina or silica gel. The isolated alkaloids were identified on the basis of the melting point, by thin layer chromatography, $(\alpha)_D$, UV-, UR-, mass and ^1H nuclear magnetic resonance spectra.

RESULTS AND DISCUSSION

A long term phytochemical research of particular species made it possible to obtain the evaluation and conclusions at the level of sections, on the basis of generally present, chemotaxonomically important alkaloids and types of alkaloids, as well as specific alkaloids, which differ from one species to another or which are biochemically beyond the scope of particular sections.

For the genus *Papaver*, alkaloids are typical, derived from isoquinoline. Some of them — protopine/rhoeadine and benzophenantridine ones — may be found in all the sections of the genus, the remaining ones were found only in some of them. Phytochemical results and conclusions may be used for the chemotaxonomic evaluation of the genus.

Sect. *Rhoeadium* SPACH 1839

The remarkable chemotaxonomic characteristic of the section *Rhoeadium* (basic chromosome number x = 7) is the presence of rhoeadine and protopine as main alkaloids, side alkaloids being in almost all the species represented by isorhoeadine and papaverrubines.

Not quite unambiguous are findings of alkaloids in *P. dubium* agg. (taxonomic classification by KUBÁT 1983), differing in mutual ratios of rhoeadine or proaporphine (mecambrine) and aporphine (aporheine) alkaloids. In *P. dubium* L. (2n=42) there are particularly rhoeadine alkaloids, in *P. albiflorum* PAČ. subsp. *austromoravicum* KUBÁT, aporphine and rhoeadine alkaloids are remarkably represented, whereas in *P. albiflorum* PAČ. subsp. *albiflorum*, there are only aporphine ones (tetraploid species 2n=28); lastly *P. lecogii*

Lamotte (2n=28) contains remarkable amounts of rhoeadine, aporphine as well as proaporphine alkaloids, together with the detection of berberine (e. g. Slavík 1964), which supports the validity of the species.

Similarly in *P. commutatum* Fisch. et Mey., alkaloids of either rhoeadine or aporphine type (isocorydine, corytuberine) and papaverine were found, or possibly all together. These differences may be explained e. g. by different growth stages of the individuals analyzed (the plant may produce or accumulate more types of alkaloids in quantitatively different representations at different stages) in different soil and climatic conditions or from different origin of plants investigated, etc.

For *P. rhoeas* L., a high content of rhoeadine/papaverrubine alkaloids is characteristic, aporphine alkaloids being also present besides others.

There is an interesting finding of alkaloide-glycoside latericine in *P. californicum* A. Gray (Šantavý et al. 1960), which is considered as characteristic for the section *Pilosa*.

Unique and not checked in this section are findings of morphinane alkaloid thebaine (*P. rhoeas*, *P. strigosum*) and alkaloids of the promorphinane type (*P. rhoeas*, *P. albiflorum* — both subspecies).

Note: Kubát (1983) proposed provisionally the name *P. maculosum* Schur instead of *P. albiflorum* Pač., which is used here with respect to its frequent and general use and thus suitability from a practical standpoint.

Sect. *Argemonidium* Spach 1839

The plants of the section *Argemonidium* have been studied and analyzed to a small extent so far, e. g. *P. argemone* L., *P. hybridum L.*, *P. pavonium* Fisch. et Mey. The alkaloid spectrum of these species is undoubtedly very poor. Similarly as in the section *Rhoeadium*, alkaloids of the rhoeadine/papaverrubine and protopine type were found, but in lower amounts (Šantavý 1970, 1979).

The basic chromosome number of the section *Argemonidium* is x=6, 7; the section contains mostly diploid species; however, in *P. argemone* 2n=12, 42 were reported, in *P. hybridum* 2n=14 (Kawatani et Ohno 1965, Fedorov et al. 1969).

Sect. *Carinatae* Fedde in Engler 1909

Only the species *P. macrostomum* Boiss. et Huet was investigated biochemically. In plants grown under our conditions rhoeadine/papaverrubine and protopine alkaloids were demonstrated — similarly as in species of the sections *Rhoeadium* and *Argemonidium* (Preininger et al. 1962). Plants collected in the vicinity of the lake Sevan (Armenian SSR) contained as major alkaloids macrostomine- benzylisoquinoline alkaloid of the papaverine type, dehydronormacrostomine and sevanine from the same group. In this material neither rhoeadine nor papaverrubine alkaloids were present (Mnatsakanyan et al. 1977).

In material (root tips of germinated seeds) from the botanic garden of the Academy of Science of the USSR in Moscow we found 2n=14.

Sect. *Papaver*

The phytochemical, cytological and morphological heterogeneity of the original section *Papaver* was the reason for dividing it (Novák et Preininger

1980). According to this classification the species *P. somniferum* L. and *P. setigerum* DC. belong in the section *Papaver*.

Karyologically, the section is characterized by the basic chromosome number x=11, both species mostly diploid (2n=22, reportedly also 2n=20 — Fedorov et al. 1969). Tetraploid forms of *P. setigerum* were found only rarely. Hammer et Fritsch (1977) consider both species of the section *Papaver* as subspecies of *P. somniferum* L. ssp. *somniferum* and *P. somniferum* L. ssp. *setigerum* (DC.) Corb. When studying the origin of cultural papaver, we found *P. somniferum* ssp. *setigerum* to be prevalently tetraploid, rarely occurring diploid forms are considered as those preceding *P. somniferum* ssp. *somniferum*. Fritsch (1979) reports *P. somniferum* ssp. *somniferum* to exert a remarkable variability and to include characteristics of both levels of ploidy of *P. somniferum* ssp. *setigerum*.

The species of the section *P. somniferum* and *P. setigerum* are distinctively different in certain morphological characteristics (Novák et Preininger 1980, 1981); besides a considerably higher alkaloid content, in *P. somniferum*, in contrast to *P. setigerum* i.a. alkaloids of the aporphine (corytuberine) and promorphinane (salutaridine) type were found (Preininger et al. 1981).

For plants of the section *Papaver*, morphinane alkaloids, thebaine, codeine, morphine, are typically present. For a review of the morphinane alkaloid biosynthesis see Theuns (1984). The occurrence of codeine and morphine may be considered as an unambiguous chemotaxonomic characteristic of the section. Thebaine was also found in certain species of different sections, and phenolic oxidation, leading to thebaine production is a more general phenomenon. Enzymatic systems, making demethylation of methoxyl groups of rings A and D possible (which leads to production of codeine and morphine) are, however, present only in *P. somniferum* and *P. setigerum*. Unique findings of codeine in *P. bracteatum* (Küpers et al. 1976) and morphine in *P. decaisnei* (Slavík 1980) should be considered cautiously because of insufficient characterization of experimental material. On the other hand, La Valva et al. (1985) found no morphinane alkaloids in populations of *P. setigerum* from five French and Italian localities. Nyman et Hanson (1979) demonstrated in dry latex of *P. setigerum* (2n=44) from the Canary Islands very low amounts of morphine and of codeine and papaverine.

Besides alkaloids of the morphinane type (morphine, codeine) the section *Papaver* differs from the section *Glauca*, as well as from other sections, by the presence of more alkaloids in the species *P. somniferum* and *P. setigerum*, such as phthalidisoquinoline narcotoline, narcotine being only in certain species of the section *Meconidium*).

Sect. *Glauca* J. Novák et V. Preininger 1980

The section *Glauca* includes species *P. glaucum* Boiss. et Hausskn., *P. gracile* Auch. and *P. decaisnei* Hochst. et Steud. Besides morphological characters they are remarkably different chemotaxonomically from plants of the section *Papaver*. Whereas for plants of the section *Papaver* the presence of morphinane alkaloids is typical, in species of the section Glauca, findings were checked several times of rhoeadine/papaverrubine alkaloids, which may be taken as a chemotaxonomic characteristic of the section (Tab. 2). In *P. somniferum* and *P. setigerum*, rhoeadine/papaverrubine alkaloids were identified only as subsidiary or trace alkaloids. In empty capsules of *P. de-*

Tab. 2. — Types of alkaloids found in plants of the sections Papaver and Glauca: 1 — tetrahydroisoquinoline and benzyltetrahydroisoquinoline, 2 — benzylisoquinoline, 3 — aporphine, 4 — promorphinane, 5 — morphinane, 6 — protoberberine, 7 — protopine, 8 — phthalidisoquinoline, 9 — narceine, 10 — rhoedanine and papaverrubine, 11 — benzophenanthridine; tr. — traces.

Species	Alkaloid types											Chromosome numbers
	1	2	3	4	5	6	7	8	9	10	11	
P. somniferum L.	+	+	+	+	+	+	+	+	+	tr.	+	2n = 22
P. setigerum DC.	+	+	−	−	+	+	+	+	+	tr.	+	2n = 22/44
P. glaucum BOISS. et HAUSSKN.	−	−	−	−	−	+	−	−	−	+	−	2n = 14
P. gracile AUCH.	−	−	−	−	−	−	−	−	−	+	+	2n = 14/28
P. decaisnei HOCHST. et STEUD.	−	−	−	−	−	+	+	−	−	+	−	2n = 14/28

caisnei (plants grown in the botanic garden in Brno), SLAVÍK (1980) found papaverin as the main alkaloid and rhoeadine and morphine as subsidiary alkaloids. By the TLC, he demonstrated the presence of coptisine, narcotine, corytuberine, codeine, papaverrubines, protopine, thebaine and thebaine methoiodide. These findings are quite unique in *P. decaisnei* and without any thorough characteristics of the experimental material, particularly as to the karyological examination; besides this, they were not checked.

Plants of the section *Glauca* and *Papaver* are distinctively different karyologically. For the basic chromosome number of x=7, *P. glaucum* was found to be a diploid species (2n=14), *P. gracile* and *P. decaisnei* as diploid (2n=14) or tetraploid species (2n=28); by contrast to x=11 in the section *Papaver*.

The species of the section *Glauca* are morphologically different from the section *Rhoedium*, though according to certain authors, these sections are very closely related (NOVÁK et PREININGER 1980). In both sections, the basic chromosome number is identical (x=7), the phytochemical similarity being supported by the presence of certain identical rhoeadine alkaloids (glaucamine, glaudine). However, the basic chromosome number x=7 occurs in all the sections of the genus, except for the section *Papaver;* even the presence of certain identical alkaloids in plants of two (or more) sections is not rare.

Sect. *Meconidium* SPACH 1839

The dominating alkaloids in plants of the section *Meconidium* are mecambrine (proaporphine type), armepavine (benzylisoquinoline type) and protopine (protopine type), whose presence is considered as a chemotaxonomic characteristic of the section. By the combination of these three alkaloids the species of the section are distinctively different phytochemically from plants of the remaining sections of the genus. Armepavine was not found in any other section of the genus *Papaver*. Similarly, in plants of this section, pronucipherine (milthantine), roemerine, nuciferine, palmatine and other general alkaloids of the genus are present. This finding resulted from analyses of numerous plants of *P. armeniacum* (L.) DC., *P. fugax* (syn. *P. causacisum* M. B., *P. floribundum* DESF.), *P. persicum* LINDL., *P. polychaetum* SCHOTT et KOTSCHY, *P. triniaefolium* BOISS., and *P. tauricolum* BOISS., grown under our conditions from seeds obtained from botanic gardens of the countries of the original distribution of these species.

In certain species (*P. fugax*, *P. tauricolum*), also morphinane alkaloid thebaine was detected (e. g. PHILLIPSON et al. 1981) in plants collected at original localities in Turkey, Iran, and Armenia. In plants of *P. fugax* grown in England from seeds from Eastern Turkey, thebaine was the main alkaloid, whereas, in other Turkish plants glaudine, glaucamine and rhoeadine were prevalent (PHILLIPSON et al. 1. c.). In *P. cylindricum* CULLEN, other morphinane alkaloids were found — oripavine and papaverine (SARIYAR 1980). These are alkaloids characteristic particularly of *P. bracteatum* (thebaine) and *P. orientale* (oripavine) from the section *Macrantha*, *P. somniferum* and *P. setigerum* (papaverine, thebaine) from the section *Papaver*. In certain collections papaverine was also found in *P. dubium* (section *Rhoeadium*).

It is also possible to consider as chemotaxonomically significant the findings of rhoeadine alkaloids in *P. armeniacum*, *P. tauricolum* and *P. fugax* (SARIYAR et PHILLIPSON 1980, PHILLIPSON et al. 1981), and in a number of cases

identical with findings in *P. rhoeas* (rhoeadine, rhoeagenine, glaucamine, glaudine, synactine). The presence of rhoeadine in *P. fugax* (syn. *P. caucasicum*) as a trace alkaloid was previously demonstrated (PREININGER et al. 1967). So far alkaloids of the rhoeadine type were found as the main alkaloids in plants of sections *Rhoeadium*, *Argemonidium*, *Glauca*, *Meconidium*, *Pilosa*.

The basic chromosome number of the section is x=6, 7, judging from eleven recognized and karyologically examined species (NOVÁK 1982). In *P. acroachetum* CULLEN 2n=12; in remaining species 2n=14 (never 2n=28 as reported in certain communications).

Biennial plants of nearly all the species of the section *Meconidium* are well-defined morphologically and close to each other (some differences occur in *P. polychaetum* and *P. libanoticum*) and the composition of the alkaloid spectra may contribute to solving taxonomic problems at the species level. Different authors have described 8 to 25 species with a number of synonyms.

Sect. *Pilosa* PRANTL in ENGLER et PRANTL 1889

In all the studied species of the section *Pilosa*, rhoeadine or papaverrubine and protopine alkaloids were present. In spite of the fact that this is a rather morphologically and karyologically homogeneous section, there were remarkable differences in the composition of the alkaloid spectra of certain species. In *P. atlanticum* BALL and *P. oreophylum* RUPR. protopine alkaloids were detected with oxygen at C-13. In certain species of the sections *Papaver*, *Argemonidium* and *Meconella*, 13-Oxoprotopine alkaloids were also isolated.

The highest number of alkaloids within the section Pilosa was identified in *P. oreophylum* (VĚŽNÍK, SEDMERA, PREININGER et al. 1981; VĚŽNÍK, TÁBORSKÁ, SLAVÍK 1981). I. a. oreodine and oreogenine occur here, which are closely related to the rhoeadine alkaloids glaudine and glaucamine, found in the sections *Glauca* and *Papaver*. Thebaine, morphinane alkaloid of the species *P. oreophylum*, is present in plants of both species of the section *Papaver* and of certain species of the sections *Macrantha* and *Meconidium*. It should be mentioned that *P. oreophylum*, as to its phytochemical activity, is rather beyond the scope of the section *Pilosa*. The highest number of identical alkaloids are in *P. orientale* and *P. bracteatum* (section *Macrantha*) and *P. fugax* (section *Meconidium*).

In certain species of the section, aporphine (*P. oreophylum*, *P. rupifragum* BOISS. et REUT., *P. heldreichii* BOISS.) and promorphinane alkaloids (*P. heldreichii*, *P. oreophylum*, *P. pilosum*, *P. spicatum*, *P. strictum*) were demonstrated.

For the basic chromosome number of x=6, 7 all the species for which the seeding material was available, were diploid; the only of, *P. rupifragum*, has 2n=12, in the remaining 5 species 2n=14; but 2n=28 has never been demonstrated (NOVÁK 1983).

Sect. *Macrantha* ELKAN 1839

With respect to a rather high content of the morphinane alkaloid thebaine in *P. bracteatum* LINDL., plants of the section *Macrantha* have been studied intensively since the beginning of the seventies. Thus, a possibility was presented of producing codeine by a partially synthetic method from thebaine with favourable economic and sociologic results (decrease in *P. somniferum* narcomania).

After the analysis of characteristics for taxonomic differentiation on the morphologic, cytologic, anatomic and palynologic basis, a taxonomic revision of the section was performed (GOLDBLATT 1974, NOVÁK 1979, NOVÁK et VOLF 1979, etc.) with detailed characteristics of three species. This made it possible to perform phytochemical analyses of precisely identified plants. A complete review of the chemistry of hitherto isolated alkaloids in particular species of the section was prepared by THEUNS (1984) on the basis of his own research and evaluation of an extensive, practically complete review of data from literature, including biogenetic relationships between alkaloids of the section *Macrantha* and biosynthesis of alkaloids of the morphinane type. Earlier communications about the alkaloid content of plants of the section *Macrantha* should be considered cautiously, particularly when a description of the experimental material is missing with respect to numerous changes in various species.

The section as a whole, as well as particular species are chemotaxonomically well defined. As a remarkable chemotaxonomic property of the section *Macrantha* it is possible to consider the presence of the aporphine alkaloid isothebaine, tetrahydroprotoberberine alkaloid orientalidine, and morphinane alkaloid thebaine. Isothebaine and orientalidine have not been found in any other section of the genus *Papaver*, yet. Numerous chemical studies demonstrated the presence of these alkaloids in each species of the section *Macrantha*. The basic chromosome number of the section is x=7.

In *P. bracteatum* LINDL. (diploid, 2n=14) thebaine was found as a dominant alkaloid. In certain plants from Iran there was alpinigenine in high concentrations, and in unique cases of material of Turkish provenience, salutaridine (THEUNS 1984, SARIYAR 1975, SARIYAR et BAYTOP 1979, NOVÁK et PREININGER 1981). Up to the present time, in reliably determined material (of different origin) of *P. bracteatum*, five major alkaloids (thebaine, alpinigenine, 14β-hydroxycodeine, salutaridine, macrantaline) and about 14 minor alkaloids belonging to 10 alkaloid types have been found.

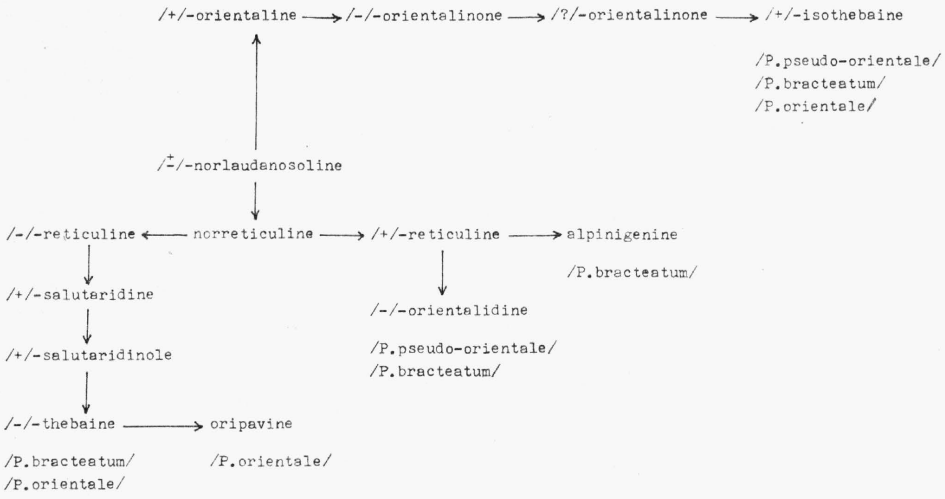
Upon analyses of capsules of correctly determined specimens *P. orientale* L. (tetraploid, 2n=28), coming from original localities, five different chemotypes of the same species were discovered (SHAFIEE et al. 1975): 1. oripavine, (2) oripavino-thebaine, (3) oripavino-isothebaine, (4) oripavino-alpinigenine and (5) oripavino-thebaino-alpinigenine. In all the chemotypes oripavine is the dominant alkaloid, thebaine, isothebaine and alpinigenine being major alkaloids; and, in unique cases, mecambridine and salutaridine were found as major alkaloids. In plants of *P. orientale* of different origin, eight minor alkaloids were identified.

Plants of *P. pseudo-orientale* (FEDDE) MEDW. (hexaploid, 2n=42) contain isothebaine as the dominant alkaloid, mecambridine, orientalidine, exceptionally salutaridine and macrantaline as major alkaloids. In various amounts about 25 alkaloids were found in plants of different origin. *P. pseudo-orientale* is a species rather variable from the standpoint of the alkaloid composition, and also of morphologic characteristics; therefore, the existence of different chemotypes cannot be precluded.

The considered biosynthesis of the main alkaloids of section *Macrantha* is presented in Scheme 2. In the biosynthetic pathway in the direction from norreticuline to alpinigenine, which is present in some forms of *P. bracteatum*, (+)-reticuline is being formed. It is a precursor of orientalidine (present in

P. pseudo-orientale and *P. bracteatum*). In the direction of the biosynthesis of prom orphinane and morphinane alkaloids the first product is (—)-reticuline; in this direction thebaine and other alkaloids are being formed. Thebaine is the do minant alkaloid of *P. bracteatum*.

Wit h respect to practical significance and attemps to introduce *P. bracteatum* and use the drug for pharmaceutical treatment, the taxonomic deter-



Schematic diagram 2. — Biosynthesis of main alcaloids of the section *Macrantha* (minor alkaloids for the species in brackets).

mination of the species *P. bracteatum* is of importance: The plant is about 1.1 m high, with 5 to 7 leaves evenly distributed on the stem, the last of them always in the upper third of the stem, leaf emarginations uniform as to shape and size, close to each other and regularly dentate along the margin; trichomes on buds decumbent; 3 to 8 bracts below the blossom up to 60 mm long; dark red petals with permanent pigments (darkening on drying) and a black, elongate spot at the base.

Results of extensive experiments with very numerous introductions of *P. bracteatum* in California, particularly with respect to their growth, productions of dry matter and to the thebaine content in the capsules was reviewed by DAVIS (1982). In a four-year period of 1976 to 1979, in mature capsules he determined 0.4 to 4.2 % of thebaine. In our experiments (1982 to 1985) seeding material was available from three sources and the thebaine concentration in mature capsules ranged between 0.82 and 1.45 %. From the economy standpoint the production of thebaine, composition and content of oil in seeds of *P. bracteatum* (SEDDIGH et al. 1982) including a comparison with *P. somniferum*, are of importance.

P. orientale may be considered from the phytochemical standpoint, as intermediate due to the presence of thebaine (dominant alkaloid of *P. bracteatum*) and isothebaine (dominant alkaloid of *P. pseudo-orientale*) as major alkaloids.

Sect. *Meconella* SPACH 1839

The section *Meconella* includes arcto-alpine, boreally montane species, occupying extensive areas of Euroasia and North America. In the taxonomic treatment of the section, 43 taxa of specific rank divided into nine series were evaluated (NOVÁK 1978) on the basis of morphological-geographic method with respect to karyological data: *Nudicauliatae*, *Radicatae*, *Canesciatae*, *Stubendorfiatae*, *Anomaliatae*, *Walpoliatae*, *Microcarpoiatae*, *Rhaeticatae*, *Lisoiatae*.

Chemotaxonomically, the section is characterized by the presence of alkaloids of the isopavine, protopine and rhoeadine/papaverrubine type. Findings that may also be considered as important are isopavine alkaloids amurensine and amurensinine and the promorphinane alkaloid amurine, which was, besides this section, found only in certain species of the section *Pilosa*. Rhoeadine occurs only in several species, e.g. in *P. rubro-aurantiacum* (FISCH.) LÜNDSTR., *P. anomalum* FEDDE, *P. leiocarpum* TURCZ. and *P. pseudocanescens* M. POP. Out of the remaining rhoeadine alkaloids, alpinine and alpinigenine were identified (e.g. *P. rhaeticum* LERESCHE, *P. kerneri* HAYEK, *P. sendtneri* A. KERNER), but found only in *P. bracteatum* (section *Macrantha*) and *P. fugax* (section *Meconidium*) so far.

On the other hand, in no species of the section *Meconella* were aporphine alkaloids found, which occur generally in other sections of the genus *Papaver*. In a number of species, no rhoeadine alkaloids were demonstrated except for papaverrubine ones. No findings were checked of morphinane alkaloids in the section *Meconella*, as reported by GRECHOVA (1950) and SOKOLOV (1952).

The basic chromosome number of the section *Meconella* is x=7. On the basis of data from literature and our own karyological studies in 12 species of the section, the somatic numbers of chromosomes occur in a wide interval of 2n=14, 28, 42, 56, 70, 84. In some of these polyploid taxa, various chromosome numbers were found (out of the above-mentioned), probably in plants from different localities. However, it is also impossible to preclude incorrect identification of plants. Variability of data about the degree of the ploidy in certain species complicates to a larger or lesser extent their use in the taxonomic classification.

SUMMARY

In species of the genus *Papaver* L., the occurrence and amounts of alkaloids of particular types were studied with the aim of determining the phytochemical characteristics of the sections and to arrive at chemotaxonomic conclusions. In general, in all the sections there are protopine, rhoeadine and benzophenantridine alkaloids. The section *Rhoeadium* may be characterized particularly by the presence of aporphine, protopine and rhoeadine/papaverrubine alkaloids. *Argemonidium* and *Glauca* plants are poor in the content of alkaloids mainly protopine and rhoeadine/papaverrubine alkaloids. In plants of the only analyzed species of the section *Carinatae*, protopine alkaloids were found, in some cases also rhoeadine/papaverrubine alkaloids.

The section *Papaver* is characterized by the presence of morphinane (codeine, morphine) and phthalidisoquinoline (narcotine, narcotoline) alkaloids. In all the species of the section *Pilosa*, protopine and rhoeadine/papaverrubine alkaloids are constantly present. In some species there are aporphine, promorphinane alkaloids and the alkaloid-glycoside latericine. Plants of the section *Macrantha* are chemotaxonomically unambiguously defined by the dominance of one of the three alkaloids, representing the chemotaxonomic characteristic of the section, i.e. aporphine type isothebaine, tetrahydroberberine type orientalidine and morphinane type thebaine. For the section *Meconella* the presence of alkaloids of the isopavine, protopine and rhoeadine/papaverrubine types is chemotaxonomically characteristic.

SOUHRN

V druzích rodu *Papaver* L. bylo sledováno zastoupení alkaloidů jednotlivých typů s cílem stanovení fytochemických charakteristik sekcí a chemotaxonomických závěrů. Obecně se ve všech sekcích vyskytují alkaloidy protopinové, rhoeadinové a benzofenantridinové. Sekci *Rhoeadium* lze charakterizovat zejména přítomností aporfinových, protopinových a rhoeadinových/papaverrubinových alkaloidů. Alkaloidním obsahem chudé rostliny sekcí *Argemonidium* a *Glauca* obsahují rovněž hlavně protopinové a rhoeadinové/papaverrubinové alkaloidy. V rostlinách jediného analyzovaného druhu sekce *Carinatae* byly prokázány protopinové alkaloidy, v některých případech také rhoeadinové/papaverrubinové. Sekce *Papaver* je charakteristická přítomností morfinanových (kodein, morfin) a ftalidisochinolinových (narkotin, narkotolin alkaloidů. Ve všech druzích sekce *Pilosa* jsou konstantně přítomny protopinové a rhoeadinové) papaverrubinové alkaloidy, v některých druzích alkaloidy aporfinové, promorfinanové a alkaloid/glykosid latericin. Rostliny sekce *Macrantha* jsou chemotaxonomicky jednoznačně definovány dominancí jednoho ze tří alkaloidů, představujících v souhrnu chemotaxonomickou charakteristiku sekce, a to aporfinovým isothebainem, tetrahydroberberinovým orientalidinem a morfinanovým thebainem. Pro sekci *Meconella* je chemotaxonomicky příznačná přítomnost alkaloidů isopavinového, protopinového a rhoeadinového/papaverrubinového typu.

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