

MICROMORPHOLOGICAL AND TAXONOMICAL STUDY OF THE GENUS PAPAVER SECT. MECONIDIUM (PAPAVERACEAE) IN IRAN

Z. Tavakkoli

Received 07.03.2012. Accepted for publication 09.05.2012.

Tavakkoli, Z. 2012 12 31: Micromorphological and taxonomical study of the genus *Papaver* sect. *Meconidium* (Papaveraceae) in Iran. –*Iran. J. Bot.* 18 (2): 270-283. Tehran.

Pollen grains and seed morphology of nine taxa from *Papaver* L. genus belonging to section *Meconidium* were examined by using light and scanning electron microscopy and their taxonomic significance evaluated. The basic shape of pollen grains in most studied taxa is prolate – spheroidal, but suboblate and oblate – spheroidal pollen grains also have been seen. The grains are tricolpate and their surface is microechinate. Seeds are reniform; the shape of epidermal cells is polygonal or rectangular and anticlinal walls of epidermal cells are mostly sinuate, rarely straight. Our results revealed that palynological data are not of much taxonomic significance in separation of taxa, whereas differences in seed characteristics among the taxa are valuable in separating taxa at specific and infraspecific levels in the section. Also, during taxonomical studies of the genus, we found a new variety which is described as *P. persicum* subsp. *persicum* var. *glabrum*. *P. persicum* subsp. *microcarpum* (Boiss.) Kadereit is recorded here for the first time from W. Iran. Moreover, two new hybrids are recognized in Iran: 1) *P. persicum* × *P. armeniacum*, 2) *P. armeniacum* subsp. *armeniaceum* × subsp. *pilgerianum*. For these taxa, taxonomical characteristics, localities, identification key and geographical distributions are given.

Zahra Tavakkoli <zataavakkoli6@gmail.com> Faculty of Biological Science, Kharazmi University, Tehran, Iran.

Key words. *Papaver*, Taxonomy, Pollen, Seed, micromorphology, Iran.

مطالعه میکرومورفولوژیکی و تاکسونومیکی جنس *Papaver* از سکسیون *Meconidium* در ایران

زهرا توکلی، مربی پژوهش گروه زیست‌شناسی دانشگاه خوارزمی.

در این مطالعه ۹ تاکسون از جنس *Papaver* (sect. *Meconidium*) مورد مطالعه و بررسی قرار گرفت. تاکسون *P. persicum* subsp. *persicum* var. *glabrum* به عنوان یک وارسته جدید معرفی می‌گردد. تاکسونهای *P. armeniacum* subsp. *armeniaceum* × subsp. *pilgerianum* و *P. persicum* × *P. armeniacum* به عنوان دو رگه دو والدی معرفی می‌گردند. زیرگونه *P. persicum* subsp. *microcarpum* برای اولین بار از غرب ایران گزارش می‌شود. مورفولوژی دانه گرده و بذر گونه‌های مورد مطالعه با استفاده از میکروسکپ نوری و الکترونی شرح داده شده و با یکدیگر مقایسه شدند. همچنین ویژگیهای تاکسونومیکی، رویشگاه، کلید شناسایی و پراکنش جغرافیایی گونه‌ها ارائه گردیده است.

INTRODUCTION

The genus *Papaver* comprises approximately 80 species in Europe and 27 species in Asia and S. Africa (Mabberley 2008). The nomenclature and typification of sections of the genus *Papaver* were reviewed by Kiger (1985) who reported 9 sections, but the latest taxonomic revision of *Papaver* (Kadereit 1988) recognized 11 sections (*Argemonidium* Spach; *Carinatae* Fedde; *Californicum* Kadereit; *Horrida* Elk.; *Oxytona* Bernth.; *Meconidium* Bernth.; *Meconella* Spach; *Papaver* L.; *Pilosa* Prantl; *Pseudopilosa* Gunther and *Rhoeadium* Bernth.) that six of them naming *Carinatae*, *Oxytona*, *Meconidium*, *Argemonidium*, *Papaver* and *Rhoeadium* were reported

from Iran (Cullen 1965).

This genus includes 14 species and 10 varieties in sect. *Meconidium* (Fedde 1909), while Boissier (1867) recognized seven species and three varieties in this section. Cullen (1966) described 5 species naming *P. fugax* Poir., *P. armeniacum* (L.) DC., *P. cylidricum* Cullen, *P. persicum* Lindl. and *P. acrochaetum* Bornm. from sect. *Meconidium* in Iran. According to Kadereit (1993), the sect. *Meconidium* has four species and eight subspecies that only one species naming *P. armeniacum* with its three subspecies (subsp. *pilgerianum* (Fedde) Kadereit, subsp. *microstigmum* (Boiss.) Kadereit and subsp. *armeniaceum*) were recognized from Zagros and Elburz mountains and NW Iran.

Table 1. Voucher *Papaver* specimens used in seed study.

Speceis	Locality
<i>P. armeniacum</i> subsp. <i>armeniacum</i>	Azerbaijan: S. slope of Bozgosh chain mountain, Blucan village, 2000 m, 8 9.1981, Mozaffarian & Mohammadi 37440 - TARI; Tabriz to Marand, 3 km after Tabriz, Mishu dagh mountain, 1900 – 1960 m, 2.8.1994, Khatamsaz & Farzaneh 73038 – TARI.
<i>P. armeniacum</i> subsp. <i>microstigmum</i>	Tehran: Lar valley, 2450 – 2550 m, 2.7.1974, Wendelbo & Assadi 13271 – TARI.
<i>P. armeniacum</i> subsp. <i>pilgerianum</i>	Kohkilouyeh – Boirahmad: Sisakht, Gardaneh Bijan, 2600 m, 28.8.994, Assadi 72434 - TARI. Esfahan: ca. 15 km from Semirum to Shahreza, 4150 m, 7.9.1986, Mozaffarian 58214 – TARI.
<i>P. armeniacum</i> subsp. <i>armeniacum</i> × subsp. <i>pilgerianum</i>	Chaharmahal- e Bakhtiari, N. slope rochy Mnt. of Kallar, S. Khederabad, 2600 – 3200 m, 18.8.1986, Mozaffarian 58152 – TARI. Kohkilouyeh – Boirahmad: Sisakht, Gardaneh Bijan, 3200 m, 28 8.1994, Assadi 72459 – TARI.
<i>P. persicum</i> subsp. <i>persicum</i> var. <i>persicum</i> <i>P. persicum</i> subsp. <i>persicum</i> var. <i>glabrum</i>	Azerbaijan: ca. 18 km N W of Khoy on the road to Shiruk, 1700 – 2000 m, 28.7. 1990, Assadi & Olfat 68623 – TARI. Azerbaijan: ca. 70 km W. of Khoy, mountains above the village Razi, 2000 – 2250 m, 26.7.1990, Assadi & Olfat 68914 – TARI; Salavat, Goli daragh village, 1500 – 1850 m, 24.6.1980, Mozaffarian & Noroozi 34983 – TARI.
<i>P. persicum</i> subsp. <i>microcarpum</i>	Kermanshah: Paveh, mountains above the village Shemshir, base of Kuh-e Shahu, 1700 – 1900 m, 18.6.1987, Assadi 60754 – TARI.
<i>P. persicum</i> × <i>P. armeniacum</i>	Kordestan: 11 km to Kamiaran from Sanandaj, 1800 – 2000 m, 15.6.1987, Assadi 60669 – TARI; Azerbaijan: 22 Km to Germe from Ardebil, 1450 m, 27.8.1987, Mozaffarian 64253- TARI.

Table 2. Voucher *Papaver* specimens used in palynology study.

Species	Locality
<i>P. armeniacum</i> subsp. <i>armeniacum</i>	Lorestan: Dorud, Oshtorankuh, Gahar lake, 2000 – 2200 m, 10.7.1997, Jamzad et al. 76839 – TARI.
<i>P. armeniacum</i> subsp. <i>microstigmum</i>	Tehran: Lar valley, 2450 – 2550, 2.7.1994, Wendelbo & Assadi, 13271 – TARI; ca. 25 km S. of Ramsar, between Tanoorehkasht and Janat Rudbar, 3000 m, Assadi & Maasoumi 51349 – TARI. Azerbaijan: Arasbaran protected area, Saigran dagh mountain, 1300 m, 14.7.1977, Assadi & Sardabi 24245 - TARI; Lisar, Subatan protected area, 2076 m, 25 7.2008, Bidar1075 – FAR.
<i>P. armeniacum</i> subsp. <i>pilgerianum</i>	Kohkilouyeh – Boirahmad: Sisakht, Gardaneh Bijan, 2600 m, 28.8.1994, Assadi 72434 – TARI; Khafr, Kuh- e Dena, 3100 m, 16 8.1972, Riazi 7688 – TARI. Chaharmahal- e Bakhtiari: on the road from Shahr- e Kurd to Naghan, N. of Sulegan, Kuh- e Shahpur – Naz, 2100 m, 5.7.1986, Mozaffarian 57443 – TARI.
<i>P. armeniacum</i> subsp. <i>armeniacum</i> × subsp. <i>pilgerianum</i>	Lorestan: ca. 60 km from Aligoodarz toward Shulabad, 2950 m, 16 6.1996, Azadi & Nikchehreh 75958 – TARI; ca. 55 km from Aligoodarz to Shulabad, 2500 m, Assadi & Karimi 43483 – TARI; Aligoodarz., Shulabad, Ghali kuh, 2200 – 3500 m, 20.8.1982, Mozaffarian & Sardabi 42547–TARI. Chaharmahal-e Bakhtiari: N. slope rocky Mnt. Kallar, S. of Khederabad, 2600 – 3200 m, 18.8.1986, Mozaffarian 58152 – TARI. Kohkilouyeh – Boirahmad: Sisakht, Gardaneh Bijan, 3200 m, 28.8. 1994, Assadi 72459 –TARI.
<i>P. persicum</i> subsp. <i>persicum</i> var. <i>persicum</i>	Azerbaijan: Arasbaran protected area, Doghrun mountain, 2500 – 2800m, 3.7.1977, Assadi & Sardabi 23993 – TARI.
<i>P. persicum</i> subsp. <i>persicum</i> var. <i>glabrum</i>	Azerbaijan: ca. 70 km W. of Khoy, mountains above the village Razi, 2000 – 2250 m, 26.7.1990, Assadi & Olfat 68914 – TARI; Urumieh, Pesan, Marmishu valley, 1737 m, 15. 6.2005, Mozaffarian 87227 – TARI.
<i>P. persicum</i> subsp. <i>microcarpum</i>	Kermanshah: Paveh, mountains above the village Shemshir, base of Kuh- e Shahu, 1700 – 1900 m, 18.6.1987, Assadi 60754 – TARI.
<i>P. acrochaetum</i>	Kordestan: 32 km. from Mariwan to Paveh (Tangh Dezli), 1330-1400 m, 30.5.1978, Runemark & Mozaffarian 29373.
<i>P. persicum</i> × <i>P. armeniacum</i>	Azerbaijan: Between Nir and Sarab, Gardaneh Saeen, near Daylan village, Ghesser dagh, 2350 m, 24.6.1980, Mozaffarian & Noroozi 35178 – TARI.

The SEM studies of the seed features have been studied among annual species of *Papaver* from sects. *Rhoeadium* and *Argemonidium* (Kadereit 1986, 1988). However, morphological features of pollen grains and seeds surfaces of biennial species of *Papaver* and their taxonomical significance have not been investigated.

This work was initiated with the aim of using morphological characters of seed and pollen grains of biennial *Papaver* species of Iran as a tool in taxonomy and understanding relationships of taxa.

MATERIALS AND METHODS

This study is mostly based on herbarium specimens of TARI, IRAN, FAR and KARAJ. The pollen grains and seeds were obtained from mature buds and capsules of herbarium specimens (Tables 1, 2). For scanning electron microscopy, pollen grains and seeds were transferred to stubs and coated with gold for 5-6 minutes using the XL - 30 SEM. 20 - 30 measurements of each character were made at a magnification $\times 2000$, $\times 3000$, $\times 4000$, $\times 30000$ (for pollen grains) and $\times 70$, $\times 250$, $\times 4000$ (for seeds). For preparing light microscopy, pollen grains were acetolyzed according to method of Erdtman (1986), then transferred to slide and mounted with glycerin jelly. Thirty measurements of each character were made at a magnification $\times 100$, and three characters were measured: P (polar length), E (equatorial diameter) and the P/E ratio. The morphological characters of seeds such as size, shape and colour were observed and measured by the stereo microscope Zeiss, Stemi SV6 using an ocular micrometer based on 30 reading for each sample. The descriptive terminology of Erdtman (1986), Moore et al. (1991), Simpson (2006) and Bojnansky and Fargasova (2007) are used in this paper. Also, at least 2 - 5 individuals of each species were subjected to morphological studies of pollen grains and seeds. Flora Iranica (Gillen 1966), Flora of Turkey (Cullen 1965), Flora of the USSR (Popov 1937), Flora Orientalis (Boissier 1867) and Kadereit (1993) were used for identification and morphological studies.

RESULTS

Based on LM and SEM observations, pollen grains are single, radially symmetrical, isopolar and tricolpate (Figs. 1- 42). Furrows are long and tapering toward the tips. The exine sculpturing is densely or loosely microechinate. Spinuli are wide at the base and obtuse at the tip. The mean of polar axis (Table 3) varies from 17.06 μm in *P. acrochaetum* to 26.3 μm in *P. armeniacum* subsp. *microstigmum*, but the equatorial axis ranges from 20.06 μm in *P. acrochaetum* to 25.5 μm in *P. persicum* var. *persicum*. The shape of pollen grains (Table 3; Figs. 1- 42) ranges from suboblate

(P/E= 0.89), oblate – spheroidal (P/E= 0.99) to prolate – spheroidal (P/E= 1.003 – 1.03). The length, the base, density and distance between spinuli on the exine surface show variation among studied taxa (Table 3).

The results presented in Table 4 and Figs. 43 – 57 show that seeds are light brown, dark brown, reniform and at the apex narrower than the bottom, with convex dorsal side and concave ventral side. The average length of the investigated seeds is 0.67 – 0.88 mm, whereas the average width is 0.49 – 0.76 mm. The shape of epidermal cells is polygonal and rectangular. The seeds of studied taxa have straight, sinuate, slightly sinuate, rather sinuate or visible sinuate anticlinal walls. The thickness of anticlinal walls ranges from 4.58 to 31.46 μm among the taxa, while seed sculpturing is reticulate in all.

Morphological features of the investigated species are summarized in Table 5.

Papaver L. sect. **Meconidium** Spach, Hist. Nat. Veg. Phan. 7: 21 (1839).

Biennial herbs, mostly glaucous, with indumentum of weakly to very stiff setae or glabrous. Stems paniculately and loosely branched. Basal and lower leaves 1 – 4 pinnate and petiolate; upper leaves trifid or squamose and sessile. Inflorescences mostly many flowered. Buds and pedicels setose or glabrous. Petals orange – pale red. Stamens many; filaments filiform, white to yellowish; anthers yellow or sometimes blue. Capsules narrowly to broadly ellipsoid, cylindrical, obovate or globose, glabrous or with scanty to densely and patent -adpressed setae, valvately dehiscent; stigmatic disc narrower than capsule diameter, pyramidal, cylindrical or umbonate.

Key to the species

- 1 – Mature capsules mostly more than twice as long as broad
 1. **P. armeniacum**
 - Mature capsules mostly less than twice as long as broad
 - 2
 - 2 – Plants glabrous
 2. **P. acrochaetum**
 - Plants setose
 3. **P. persicum**

1. P. armeniacum (L.) DC., Syst. Nat. 2: 83 (1821).

Plants ca. 10 – 85 cm high, mostly erect. Stems with patent indumentum of setae or very stiff setae. Leaves up to 11 cm long, with scanty to densely setae or with long and very stiff setae, 1 – 3 pinnate or trifid to squamose above. Pedicels glabrous or with adpressed setae. Buds 3 – 12 \times 3 – 11 mm, glabrous or setose. Capsules 8 – 18 \times 3 – 7 mm, cylindrical, narrowly elliptic or obovate, mostly attenuate at base, glabrous; stigmatic disc with 3 – 6 rays, weakly to strongly or not emarginate between rays, light or dark.

Key to subspecies

- 1 – Stigmatic disc weakly or not emarginate between rays, light subsp. **pilgerianum**
 – Stigmatic disc emarginate or strongly emarginate between rays, light or dark .2
 2 – Stems loosely branched. Stigmatic disc emarginate between rays, dark subsp. **microstigmum**
 – Stems densely branched. Stigmatic disc strongly emarginate between rays, light or dark subsp. **armeniicum**

-subsp. armeniicum

Syn.: *Argemone armeniicum* L., Sp. Pl. 509 (1753); *P. fugax* Poir., in Lam., Encycl. Meth. 5: 118 (1804); *P. fugax* Poir. var. *platydiscus* Cullen, Notes Roy. Bot. Gard. Edinburg 25: 42(1963); *P. caucasicum* M. Bieb., Fl. Taur. Cauc. 2: 5(1808); *P. floribundum* Desf., Choix Pl.: 62, Pl. 46(1808); *P. hyoscyamifolium* Boiss., Fl. Or. 1: 110 (1867); *P. triniifolium* Boiss., Fl. Or. 1: 110 (1867); *P. cylindricum* Cullen, Notes Roy. Bot. Gard. Edinburg 25: 42 91963).

Plants 32 – 65 cm high. Leaves with scanty to rather dense indumentum of not very stiff setae. Inflorescence paniculate and dense. Pedicels shorter than stem axis, glabrous, rarely setose. Stigmatic disc strongly emarginate between rays, light or dark.

Selected specimens. Azerbaijan: ca. 20 km E. Jolfa, beginning of the road to Gheshlagh village, 1400 m, 20.6.1988, Assadi & Shahsavari 65818; Kuh e Sahand, between Lighvan and Isperekhan, 2200 – 2600 m, 2.7.1978, Assadi & Mozaffarian 30586; Marand, 1400 m, 6. 6. 1971, Iranshahr 34166. Kordestan: Ghorveh, Asef abad, Kuh- e Kan Barzeh, 2400 – 3100 m, 1.8.1995, Assadi 75379. Lorestan: Dorud, Gahar lake, 2250 – 2900 m, 15.8.1982, Mozaffarian & Sardabi 42265.

-subsp. **microstigmum** (Boiss.) Kadereit, Edinb. J. Bot. 50 (2): 131 (1993).

Syn.: *P. caucasicum* M. Bieb. var. *microstigmum* Boiss. Fl. Or. 1: 110 (1867).

Plants ca. 10 – 50 cm high, mostly erect. Leaves with scanty to rather dense indumentum of setae. Inflorescence loosely paniculate. Pedicels mostly longer than stem axis, glabrous or setose. Stigmatic disc emarginate between rays, dark.

Selected specimens. Mazandaran: ca. 30 km. S. of Ramsar, Shah- e Sefidkuh mountains, 3100 – 3400 m, 12.7.1984, Assadi & Maasoumi 51261. Tehran: near Damavand, Havir, 2500 m, 25.7.1979, Assadi & Mozaffarian 33251. Semnan: ca. 20 km. N. W. of Shahrud, above Nekarman, Kuh e Shahvar, 3000 –

3700 m, 1.8.1982, Mozaffarian & Assadi 40838. Azerbaijan: Arasbaran protected area, Saigram dagh, 1300 m, 14.7.1997, Assadi & Sardabi 24245.

-subsp. **pilgerianum** (Fedde) Kadereit, Edinb. J. Bot. 50 (2): 133 (1993).

Syn.: *P. armeniicum* (L.) DC. var. *pilgerianum* Fedde, Engler, Pflanzenr. 4, 104: 352(1909).

Plants ca. 42 – 82 cm high, erect. Leaves with indumentum of very stiff setae. Inflorescence paniculate and dense. Pedicels glabrous. Stigmatic disc weakly or not emarginate between rays, light.

Selected specimens. Kohkiluyeh – Boirahmad: between Iasuj and Dehdasht, near Sadat, 2300 m, 20.7.1983, Assadi & Abuhamez 46458. Chaharmahal- e Bakhtiari: Lordegan, between Munj and Chahartagh, Tang- e Zendan, 1850 – 2100 m, 13.6.1987, Mozaffarian 62088. Lorestan: Dorud, Oshtorankuh, 2400 – 2700 m, 9.8.1991, Assadi 70750. Fars: 5 km. from Ardekan on the road to Iasuj, 2200 m, 30.7.1978, Assadi & Mozaffarian 31099.

2 . P. acrochaetum Bornm., Mitt. Thur. Bot. Ver. N. F., 7: 6 (1895).

Herb, distinctly glaucous, glabrous, sometimes stems with very scanty indumentums of setae below. Leaves up to 10 cm long; lower leaves pinnatisect – pinnatipartite and petiolate; upper leaves trifid, with broadly segments and obtuse, sessile. Buds 6 – 8 × 6 – 7 mm, elliptic or ovate. Capsules 9 - 11 × 4 - 6 mm, ellipsoid to subglobose, rounded at base; stigmatic disc with 4 rays, strongly emarginate between rays.

Specimen seen. Kordestan: 32 km. from Marivan to Paveh (Tangeh Dezli), 1330 – 1400 m, 30.5.1978, Runemark & Mozaffarian 29373.

3. P. persicum Lindl., Bot. Reg. 1570 (1833).

Plants 15 – 65 cm high. Stems paniculately branched, with rather densely and patent setae to glabrous above. Leaves up to 16 cm long, with scanty to rather dense indumentum of setae, 1–3 pinnate to trifid and squamose above. Pedicels glabrous or with patent setae. Buds 5 – 12 × 4 – 10 mm, with dense and white to brownish setae or glabrous. Petals orange – pale red. Stamens many; filaments and anthers yellow. Capsules 8 – 15 × 6 – 8 mm, broadly ellipsoid to subglobose, rounded at base; glabrous or with white to brownish and patent – adpressed setae; stigmatic disc pyramidal or umbonate, sometimes nearly flat, with 5 – 6 rays, strongly or weakly emarginate between rays, light or dark.

Table 3. Pollen morphological data of the examined species of *Papaver* (P = polar length, E = equatorial length).

Taxa	μm	E (μm)	P/E	Shape	Spinule length (nm)	Spinule base (nm)	Distance between spinuli (nm)	The number of spinuli per 9μm ² exine surface
<i>P. armeniacum</i> subsp. <i>armeniaceum</i>	20 (20.76) 23	18 (20.9) 22	0.99	Oblate-spheroidal	214.43 (284.54) 387.52	418.59 (558.83) 696.37	150.99 (243.44) 432.33	36 (40.37) 45
<i>P. armeniacum</i> subsp. <i>microstigmum</i>	23 (26.3) 30	20 (25.12) 30	1.007	Prolate-spheroidal	197.83 (278.66) 413.37	296.51 (409.8) 744.56	71.42 (305.99) 670.16	16 (27.92) 45
<i>P. armeniacum</i> subsp. <i>pilgerianum</i>	20 (22.35) 35	19 (22.23) 24	1.005	Prolate-spheroidal	130.47 (210.66) 361.19	197.42 (352.29) 635.48	128.2 (282.29) 756.72	19 (35.88) 55
<i>P. armeniacum</i> subsp. <i>armeniaceum</i> × subsp. <i>pilgerianum</i>	20 (22.99) 30	16 (22.14) 27	1.03	Prolate-spheroidal	125.11 (235.12) 357.14	213.76 (328.4) 852.33	94.84 (288.93) 881.36	18 (36.42) 57
<i>P. persicum</i> subsp. <i>persicum</i> var. <i>persicum</i>	21 (25.6) 29	20 (25.5) 30	1.003	Prolate-spheroidal	267.23 (342.8) 428.18	308.15 (419.52) 717.1	126.92 204.45) 351.78	17 (21.28) 28
<i>persicum</i> subsp. <i>persicum</i> var. <i>glabrum</i>	27 (23.78) 20	27 (23.25) 17	1.02	Prolate-spheroidal	128.26 (220.98) 314.64	157.42 (326.36) 606.03	110.43 (253.69) 566.85	17 (31.68) 36
<i>P. persicum</i> subsp. <i>microcarpum</i>	24 (25.3) 29	22 (24.35) 26	1.03	Prolate-spheroidal	97.02 (254.51) 400.01	279.59 (405.13) 710.52	100.15 (279.36) 624.19	19 (28) 40
<i>P. acrochaetum</i>	14 (17.06) 19	17 (20.06) 21	0.85	Suboblate	160 (242.16) 353	196 (323.65) 593.43	68.84 (195.02) 300.57	28 (43.25) 60
<i>P. persicum</i> × <i>P. armeniacum</i>	21 (23.96) 26	20 (23.56) 26	1.01	Prolate-spheroidal	175.57 (239.9) 329.72	533.43 (403.76) 254.25	130.6 (255.12) 709.45	25 (29.71) 34

Table 4. Seed morphological data of the examined species of *Papaver* (L = seed length, W = seed width).

Taxa	L (mm)	W (mm)	L/W	Seed shape	Seed surface	Epidermal cells shape	Epidermal walls of seed length (μm)	Epidermal walls of seed width (μm)	Anticlinal wall	Thicknes of anticlinal wall (nm)	Seed colour
<i>P. armeniacum</i> subsp. <i>armeniaceum</i>	0.7 (0.88) 1.1	0.5 (0.65) 0.8	1.28	Reniform	Reticulate	Polygonal-rectangular	54.29(103.64) 194.15	30.84 (58.99) 117.32	Rather sinuate	5.24 (12.18) 26.68	Dark brown
<i>P. armeniacum</i> subsp. <i>microstigmum</i>	0.8 (0.84) 0.9	0.6 (0.67) 0.8	1.24	Broad reniform	Reticulate	Polygonal-rectangular	49.83 (75.1) 92.78	22.76 (68.37) 118.32	Vosible sinuate	4.58 (12.9) 5.7	Dark brown
<i>P. armeniacum</i> subsp. <i>pilgerianum</i>	0.62 (0.9) 1.2	0.58 (0.68) 0.8	1.33	Reniform	Reticulate	Polygonal-rectangular	57.83 (97.04) 155.21	22. 42 (51.5) 105.89	Slightly sinuate	6.12 (13.03) 25.07	Light brown
<i>P. armeniacum</i> subsp. <i>armeniaceum</i> × subsp. <i>pilgerianum</i>	0.8 (1.01) 1.25	0.6 (0.76) 0.9	1.33	Reniform	Reticulate	Polygonal	42.92 (84.9) 128.12	34.88 (69.74) 144.76	Straight sinuate	8.26 (14.38) 24.54	Dark brown
<i>P. persicum</i> subsp. <i>persicum</i> var. <i>persicum</i>	0.8 (0.91) 1	0.6 (0.7) 0.8	1.28	Reniform	Reticulate	Rectangular-Polygonal	56.18 (103.46) 307.21	28.23 (76.22) 196.37	Sinuate	9.8 (18.2) 31.46	Dark brown
<i>P. persicum</i> subsp. <i>persicum</i> var. <i>glabrum</i>	0.8 (0.83) 0.9	0.6 (0.66) 0.7	1.25	Reniform	Reticulate	Rectangular-Polygonal	42.26 (86.45) 140.22	32.02 (59.94) 106.05	Sinuate	13.17 (20.21) 29.88	Dark brown
<i>P. persicum</i> subsp. <i>microcarpum</i>	0.6 (0.67) 0.7	0.4 (0.49) 0.6	1.36	Reniform	Reticulate	Rectangular-Polygonal	61.69 (95.96) 173.04	33.08 (63.64) 87.21	Straight	7.74 (14.88) 23.4	Dark brown
<i>p. persicum</i> × <i>P. armeniacum</i>	0.7 (083) 0.9	0.5 (.61) 0.8	1.36	Reniform	Reticulate	Polygonal-rectangular	46.5 (120.6) 299.6	36 (62.94) 168.14	Straight sinuate	3.29 (16.56) 45.53	Dark brown

Table 5. Morphological characters of *Papaver* species (sect. *Meconidium*).

Taxa	Leaves	Buds	Pedicels	Capsules	Stigmatic disc
<i>P. armeniacum</i> subsp. <i>armeniaceum</i>	1-3 pinnate; with scanty to rather dense indumentum of not very stiff setae	Obovate elliptic, glabrous or with moderate setae	Shorter than stem axis; glabrous or sometimes hairy	Cylindrical, attenuate at the base, narrowly elliptic, sometimes torulose	Light or dark; strongly emarginate between rays
<i>P. armeniacum</i> subsp. <i>microstigma</i>	1-3 pinnate; with scanty to rather dense indumentum of not very stiff setae	Obovate, ovate or elliptic; with moderate to rather dense setae	As long as to longer than stem axis; mostly hairy	Oblong to elliptic, attenuate at the base, obconical, narrowly elliptic, torulose or not torulose	Dark, strongly emarginated between rays
<i>P. armeniacum</i> subsp. <i>pilgerianum</i>	1-2 pinnate, with indumentum of very stiff setae	Obovate, ovate or broadly elliptic; glabrous	Shorter than stem axis; glabrous	Cylindrical or narrowly elliptic torulose or not torulose; glabrous	Light, weakly or not emarginate between rays
<i>P. armeniacum</i> subsp. <i>armeniaceum</i> × subsp. <i>pilgerianum</i>	Pinnatisect; with scanty setae to glabrous	Globose, obovate; glabrous	Shorter than stem axis; glabrous	Cylindrical or elliptic, mostly torulose; glabrous	Light or dark, strongly or weakly emarginate between rays
<i>P. persicum</i> subsp. <i>persicum</i> var. <i>persicum</i>	1-2 pinnate; with scanty to rather dense setae	Elliptic to ovate, ovate or obovate, with moderate to dense setae	Shorter than stem axis; glabrous or with scanty setae	Broadly elliptic, ovate to elliptic or globose; with moderate to dense setae	Light or dark; strongly or weakly emarginate between rays
<i>P. persicum</i> subsp. <i>persicum</i> var. <i>glabrum</i>	Pinnatisect-pinnatipartit; with scanty to rather dense setae	Broadly elliptic, ovate, obovate or globose; with moderate or dense setae	Shorter than stem axis; glabrous or with scanty setae	Elliptic to almost globose; glabrous	Light or dark; strongly or weakly emarginate between rays
<i>P. persicum</i> subsp. <i>microcarpum</i>	1-2 pinnate; with scanty to rather moderately setae	Globose to obovate; glabrous	Shorter than stem axis; glabrous or with scanty setae	Elliptic to almost globose; glabrous	Dark; weakly emarginate between rays
<i>P. acrochaetum</i>	Pinnatisect-pinnatipartit; glabrous	Elliptic or ovate; glabrous	Shorter than stem axis; glabrous	Elliptic to subglobose; glabrous	Dark, strongly emarginate between rays
<i>P. persicum</i> × <i>P. armeniacum</i>	1-3 pinnate; with scanty setae on veins or with very stiff setae on both sides and sometimes with two kinds of leaves	Globose, elliptic, ovate or obovate; with scanty to dense setae or glabrous	Shorter than axis or sometimes longer than stem axis; glabrous or with scanty setae	Elliptic to oblong, obovate or sometimes rounded at the base; glabrous, hairy or with two kinds of capsules	Dark; emarginate between rays

Key to subspecies

Buds setose. Capsules setose or glabrous

subsp. **persicum**

Buds and capsules glabrous

subsp. **microcarpum****--subsp. persicum**

Buds setose. Capsules glabrous or with patent to adpressed and white to brownish setae.

Capsules setose

var. **persicum**

Capsules glabrous.

var. **glabrum****--var. persicum**Syn.: *P. persicum* Lindl. subsp. *flavum* Kit Tan & Sorger, Pl. Syst. Evol. 154: 111(1986).

Buds and capsules setose.

Selected specimens. Azerbaijan: Mianeh to Tabriz, 1000 m, 1.6.1973, Sabeti 14772; Arasbaran protected area, Dughrum mountain, 2500 – 2800 m, 13.7.1977, Assadi & Sardabi 23993; 60 km from Namin to Khage – Boulagh above Khage – boulagh, Agh Boulagh, 1950 m, 21.6.1980, Mozaffarian & Noroozi 34648.

--var. glabrum Tavakkoli, var. nov.

Differt a varietato typo capsulis glabris (Fig. 60).

Typus. Azerbaijan: ca. 70 km W. of Khoy, mountains above the village Razi, 2000 – 2250 m, 26.7.1990, Assadi & Olfat 68914 (holotypus TARI); Salavat, Goli Daragh village, Goli Daragh mountain, 1500 – 1850 m, 24.6.1980, Mozaffarian & Noroozi 34983; between Marand and Jolfa, Kiamaki Dagh, 1400 – 2000 m, 27.6.1978, Assadi & Mozaffarian 30025; Urumieh, Pesan, Marmishu, 1737 m, 15.6.2005, Mozaffarian 87227.

--subsp. microcarpum (Boiss.) Kadereit, Edinb. J. Bot. 50 (2): 141 (1993).Syn.: *P. tauricum* Boiss. *β. microcarpum* Boiss., Fl. Or. 1: 109 (1867).

Stems setose to glabrous. Pedicels glabrous. Buds globose, glabrous. Capsules elliptic to almost globose, glabrous; stigmatic disc strongly umbonate, dark, emarginate between rays (Fig. 58).

Specimens seen. Bakhtaran: Paveh, mountains above the village Shemshir, base of Kuh e Shahu, 18.6.1987, Assadi 60754; Bivanij, Tamoreh, 24.6.1968, Iranshahr & Dezfoolian, 20231.

General distribution. Iraq, Turkey and Iran.

This taxon is recorded here for the first time from Iran.

Hybrids

***P. armeniacum* (L.) DC. subsp. *armeniaceum* × subsp. *pilgerianum* (Fedde) Kadereit**

Plants 12 – 34 cm high. Stems glabrous or with very scanty setae below. Leaves with very scanty setae on

the veins to glabrous, pinnatisect, trifid to squamose above. Pedicels glabrous. Filaments yellow or sometimes reddish; anthers yellow. Capsules 7-11 × 2. – 5 mm, cylindrical or elliptic, mostly torulose; stigmatic disc pyramidal, light, weakly or not emarginate between rays. Also, a specimen was observed with two kinds of leaves: leaves with very scanty setae and leaves with indumentum of very stiff setae (Fig. 61).

This hybrid differs from subsp. *armeniaceum* in having stigmatic disc of light and weakly or not emarginate between rays and from subsp. *pilgerianum* in having leaves with scanty indumentum of setae to glabrous.

Specimens seen. Kohkilouyeh – Boirahmad: Sisakht, Gardaneh Bijan, 3200 m, 28.8.1994, Assadi 72459. Chaharmahal- e Bakhtiari: N. slope rocky Mnt. of Kallar. S. Khederabad, 2600 – 3200 m, 18.8.1986, Mozaffarian 58152; Lorestan: ca. 60 km from Aligoodarz toward Shulabad, 2950 m, 16.6.1996, Azadi & Nikchehreh 75958; Aligoodarz, Shulabad, Ghalikuh, 2200 – 3500 m, 20.8.1982, Mozaffarian & Sardabi 42547. Kordestan: Baneh, 2000 – 2200 m, 7.8.1967, Iranshahr & Termeh 32019.

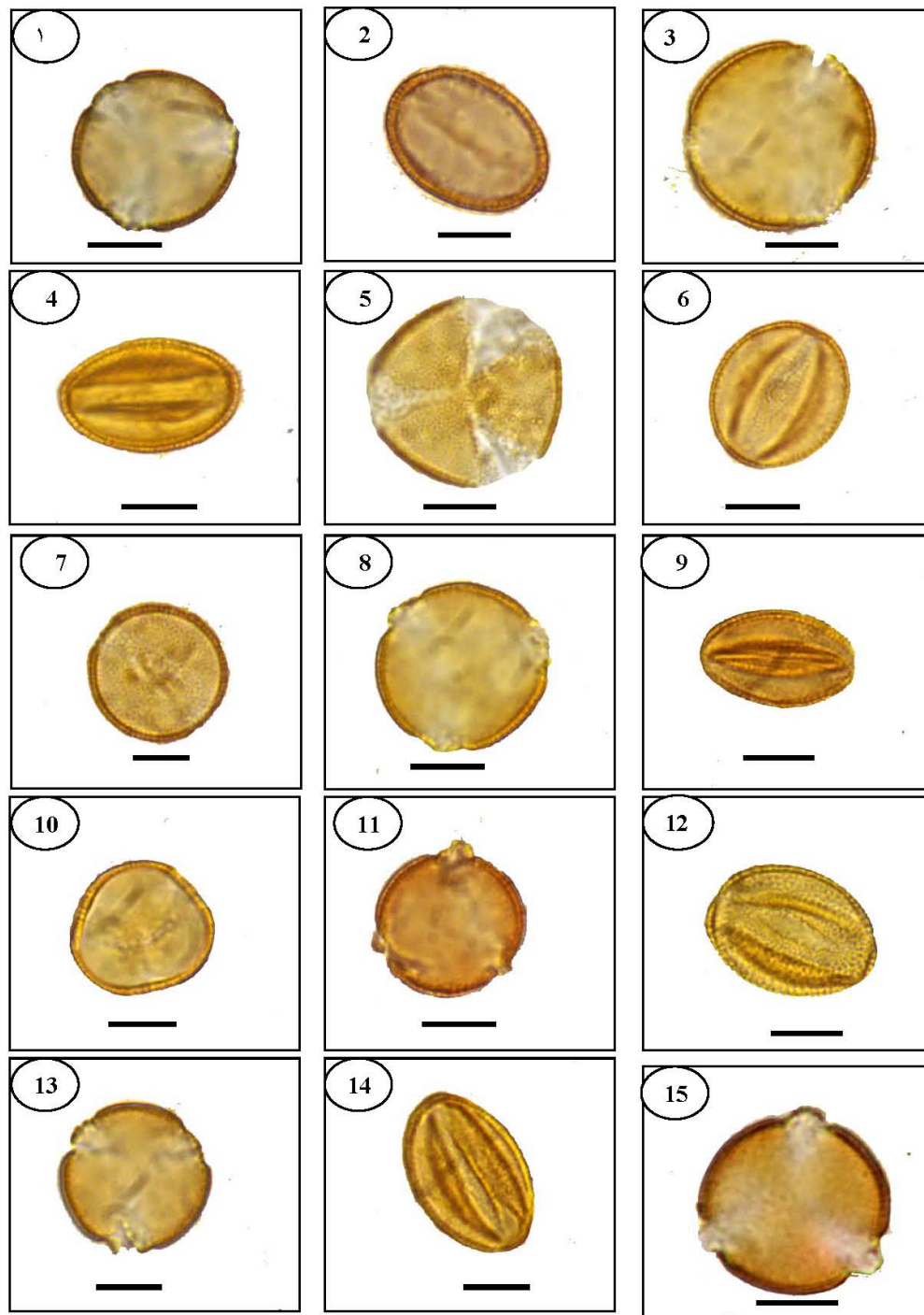
P. armeniacum subsp. *armeniaceum* is mainly found in NW Iran, and subsp. *pilgerianum* is usually missing in NW Iran, but mainly occurring in W Iran. However, localities are from W Iran where both subspecies could be found growing in close vicinity making hybridization possible.

***P. persicum* Lindl. × *P. armeniacum* (L.) DC.**

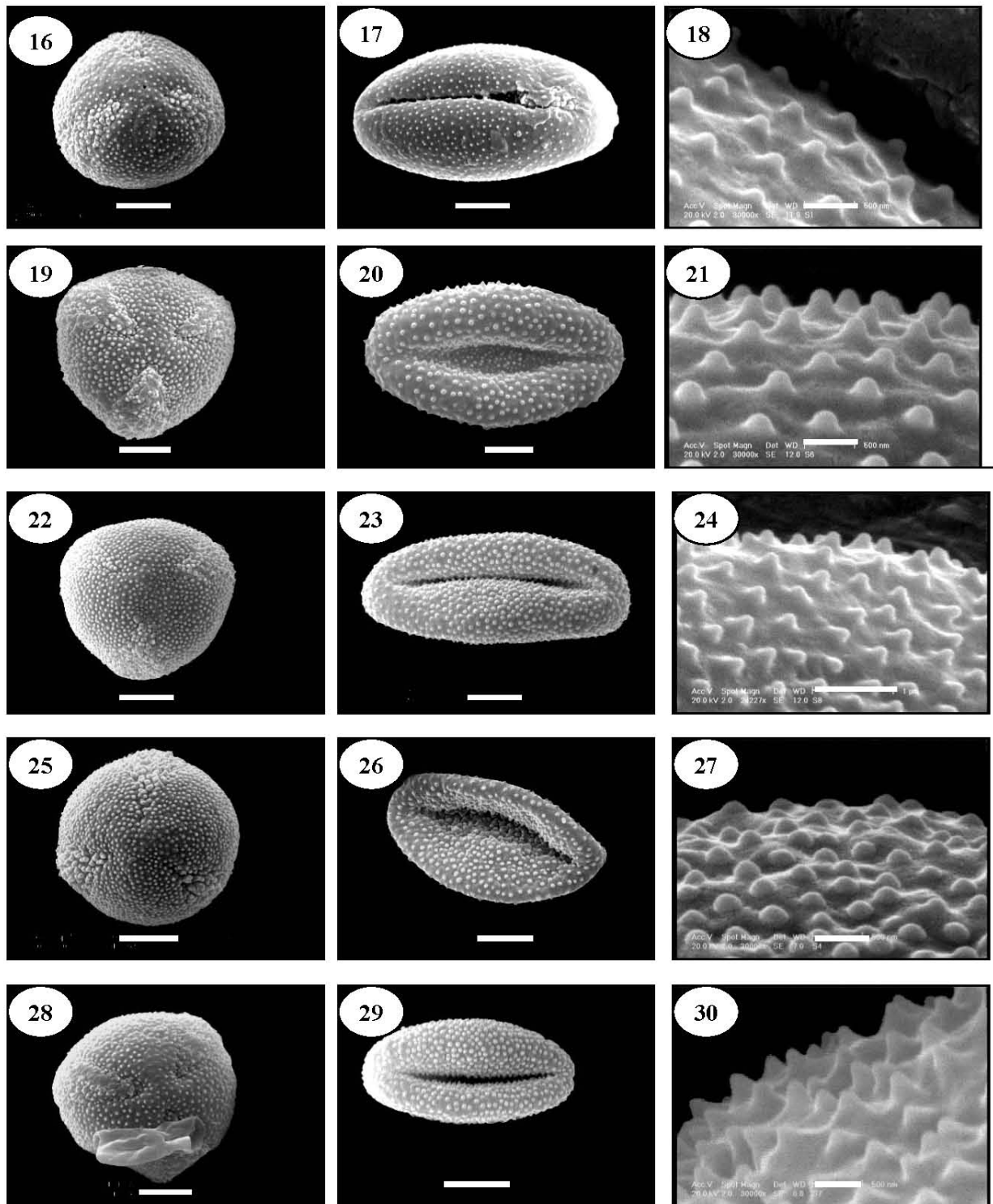
Plants 26 – 62 cm high. Stems glabrous or setose below. Leaves with scanty indumentum of setae on veins or with very stiff setae on both side and sometimes with both kinds of leaves, 1–3 pinnate, trifid to squamose above. Pedicels glabrous or setose. Buds glabrous or with scanty to densely setae. Capsules 9.5 – 16.5 × 5 – 7.5 mm, narrowly elliptic to oblong, obovate or globose, attenuate at base or rounded at base, glabrous or with scanty to densely and adpressed setae; stigmatic disc conical, umbonate, dark, emarginate between rays (Fig. 59).

This hybrid differs from *P. persicum* in having capsules with length of more than twice as long as broad and attenuate at base and from *P. armeniacum* in having capsules with scanty to densely indumentum of setae. Also, individuals were observed with three kinds of capsules: capsules with length of more than twice as long as broad, with length of less than twice as long as broad and with length of twice as long as broad, glabrous or setose.

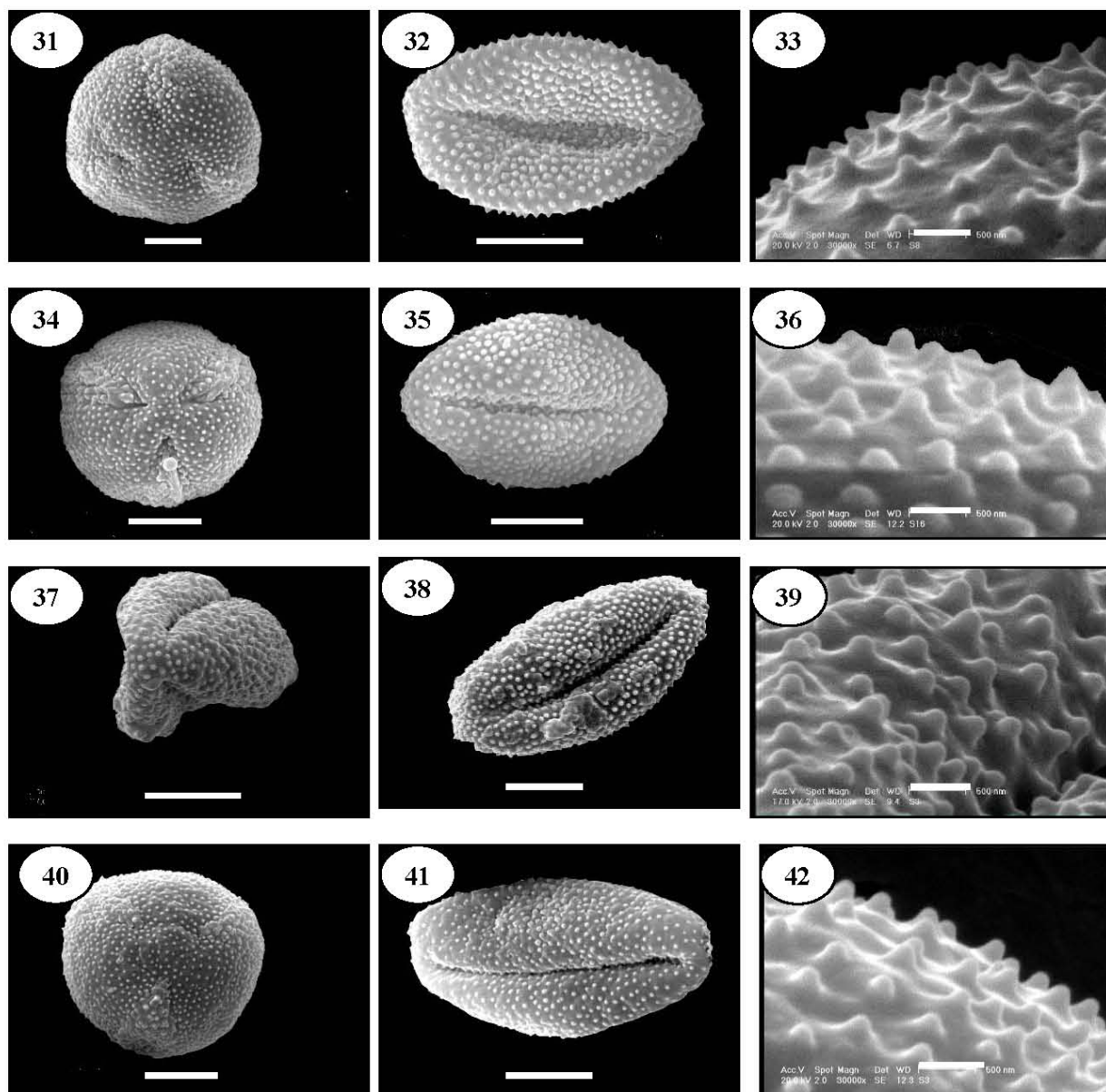
Specimens seen. Azerbaijan: 9 km from diviation of Kivi to Ardebil road, above Meresht village, 2000 m, 18.6.1980, Mozaffarian & Noroozi 34389; Kuh- e



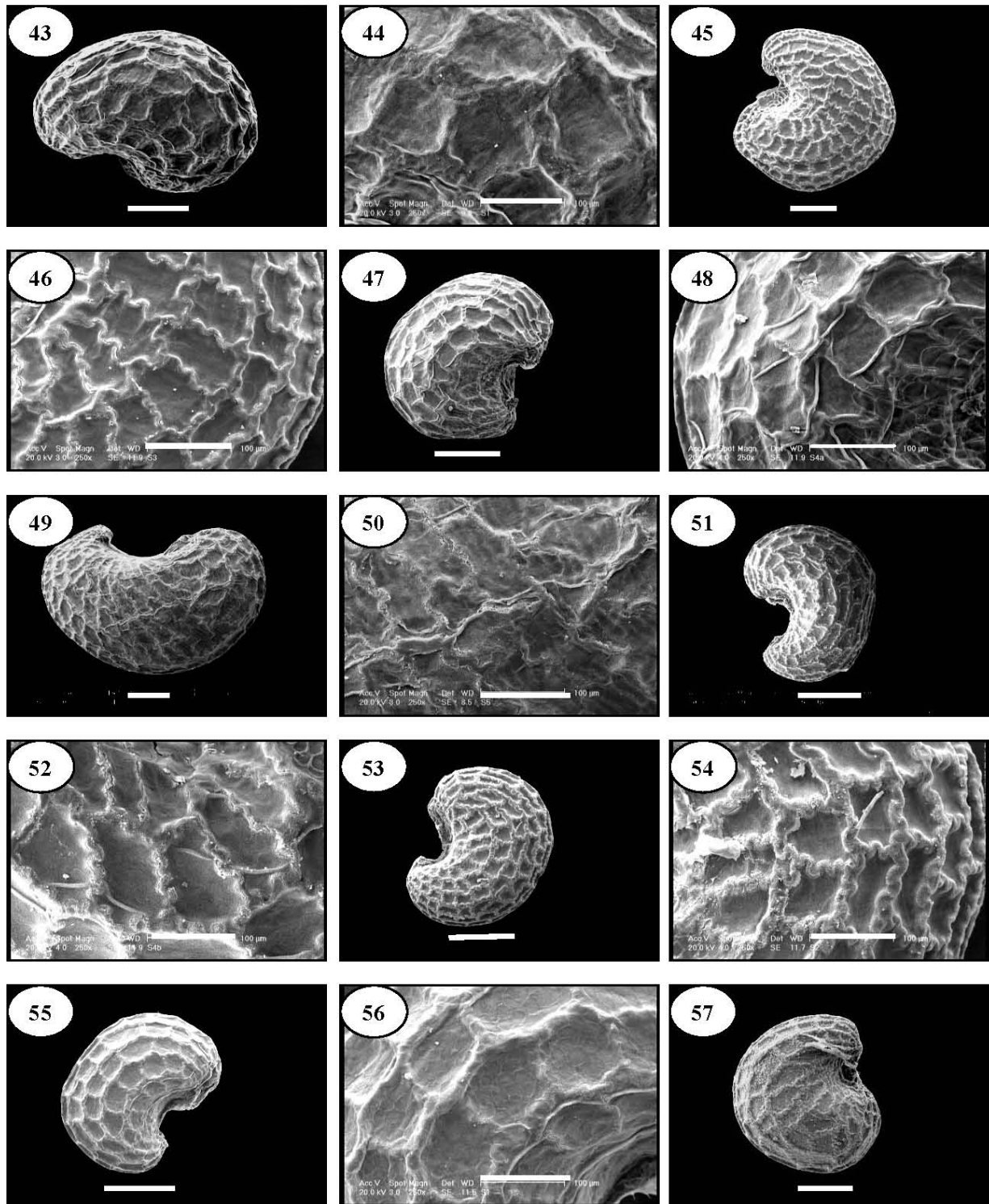
Figs. 1-15. LM micrographs of pollen grains in *Papaver* species sect. *Meconidium*. scale bars =10 μ m. 1-2: *P. armeniacum* subsp. *armeniaceum*, 1) polar view, 2) equatorial view; 3-4: *P. armeniacum* subsp. *microstigmum*, 3) polar view, 4) equatorial view; 5-6: *P. armeniacum* subsp. *pilgerianum*, 5) polar view, 6) equatorial view; 7: *P. armeniacum* subsp. *armeniaceum* \times subsp. *pilgerianum* (polar view); 8-9: *P. persicum* subsp. *persicum* var *persicum*, 8) polar view, 9) equatorial view; 10: *P. persicum* subsp. *persicum* var. *glabrum* (polar view); 11-12: *P. persicum* subsp. *microcarpum*, 11) polar view, 12) equatorial view; 13-14: *P. acrochaetum*, 13) polar view, 14) equatorial view; 15: *P. persicum* \times *P. armeniacum* (polar view).



Figs. 16-30. SEM micrographs of pollen grains in *Papaver* species sect. *Meconidium*. 16-18) *P. armeniacum* subsp. *armeniaceum*; 19-21) *P. armeniacum* subsp. *microstigmum*; 22-24) *P. armeniacum* subsp. *pilgerianum*; 25-27) *P. armeniacum* subsp. *armeniaceum* × subsp. *pilgerianum*; 28-30) *P. persicum* subsp. *persicum* var. *persicum*; (16, 17, 19, 20, 22, 23, 25, 26, 28, 29) scale bars=5 μm; (18, 21, 24, 27, 30) scale bars=500 nm.



Figs. 31-42. SEM micrographs of pollen grains in *Papaver* species sect. *Meconidium*. 31-33) *P. persicum* subsp. *persicum* var. *glabrum*; 34-36) *P. persicum* subsp. *microcarpum*; 37-39) *P. acrochaetum*; (40-42) *P. persicum* × *P. armeniacum*; (31, 32, 34, 35, 37, 38, 40, 41) scale bars=5μm; (33, 36, 39, 42) scale bars=50nm.



Figs. 43-57. SEM micrographs of seeds in *Papaver* species sect. *Meconidium* 43-44) *P. armeniacum* subsp. *armeniacum*; 45-46) *P. armeniacum* subsp. *microstigma*; 47-48) *P. armeniacum* subsp. *pilgerianum*; 49-50) *P. armeniacum* subsp. *armeniacum* × subsp. *pilgerianum*; 51-52) *P. persicum* subsp. *persicum* var. *persicum*; 53-54) *P. persicum* subsp. *persicum* var. *glabrum* 55-56) *P. persicum* subsp. *microcarpum*; 57) *P. persicum* × *P. armeniacum*; (43, 45, 47, 49, 51, 53, 55, 57) scale bars=200μm; (44, 46, 48, 50, 52, 54, 56) scale bars=100μm.

Sabalan, 2800 m, 27.7. 1972, Foroughi 7691-B; 40 km. from Razi to Germi, 1700 m, 22.6.1980, Mozaffarian & Noroozi 34816. Ardebil: 42 km to W Nohour, Lisar protected area, 2540 m, 23.7.1974, Foroughi & Assadi 13821. Kordestan: just east of Bijar, 1920 m, 5.6.1974, Wendelbo & Assadi 12269.

The provinces of Azerbaijan and Kordestan are localities where both species could be found in close vicinity.

DISCUSSION

Papaver L. sect. *Meconidium* includes five species in Iran (Cullen 1966) and they have been recognized based on the absence of hairy indumentum in *P. acrochaetum*; pinnatisect leaves and narrowly elliptic or narrowly obovate and attenuate at base capsules in *P. cylindricum* and *P. fugax* respectively; 2 – 3 pinnatisect leaves and narrowly elliptic to oblong and torulose capsules in *P. armeniacum*. In addition, *P. persicum* has been introduced by having ovate – globose, rounded base and hairy capsules (Cullen 1966). Our observations indicated that three species of *P. armeniacum*, *P. cylindricum* and *P. fugax* were morphologically close to each other, so that their separation is difficult. On the other hand, many intermediate forms were observed as follows: the members with leaves of 2 – 3 pinnatisect but with the capsules of narrowly elliptic or obovate and attenuate at base and the forms with pinnatisect leaves and with the capsules of narrowly elliptic – oblong and not torulose. Hence, our study confirms the systematic treatments of Kadereit (1993) in which *P. armeniacum* and *P. persicum* were separated based on their capsules shape and size; *P. cylindricum* and *P. fugax* reduced to the synonymies of *P. armeniacum*.

Papaver acrochaetum differs from *P. persicum* in being glaucous and glabrous and rarely stems with scanty setae below (Cullen 1966). Our morphological observations confirms Cullen hypothesis in separation of *P. acrochaetum* from *P. persicum*.

Based on pollen morphology, all taxa of this section have tricolpate pollen grains and show the microechinate sculpturing of exine. In the analysis of the mean P and E values, the smallest grains are found in *P. acrochaetum* (Table 3 and Figs. 13 – 14; 37 – 39). The shape of pollen grains is suboblate in *P. acrochaetum* and oboblate – spheroidal in *P. armeniacum* subsp. *armeniaceum*, whereas the rest of taxa are prolate – spheroidal. Differences in the length, the base, density and distance between spinuli are not particularly significant in the separation of species. It seems that pollen morphological characters don't support the separation of *P. armeniacum* from *P. persicum*.

P. acrochaetum show differences from *P. persicum* in pollen size and ratio P/E (Table 3), therefore pollen grains micromorphological evidences support treatment of Cullen and *P. acrochaetum* should be a distinct species from *P. persicum*.

Our observations show that variation in seed testa characters have taxonomic value and can be divided into main types: type I with thicker anticlinal walls (more than 14 nm) is found in the species of *P. persicum* (Table 4; Figs. 51 – 56), whereas type II with slender anticlinal walls (less than 14 nm) is found in the species of *P. armeniacum* (Table 4; 43 – 48). This character is useful in separation of the species *P. armeniacum* from *P. persicum*. Hence, these data confirm the systematic treatments of Kadereit (1993).

The other characters of seed such as shape, size, colour, sculpturing of seed surface and anticlinal wall shape are not correlated with morphological characters in species level.

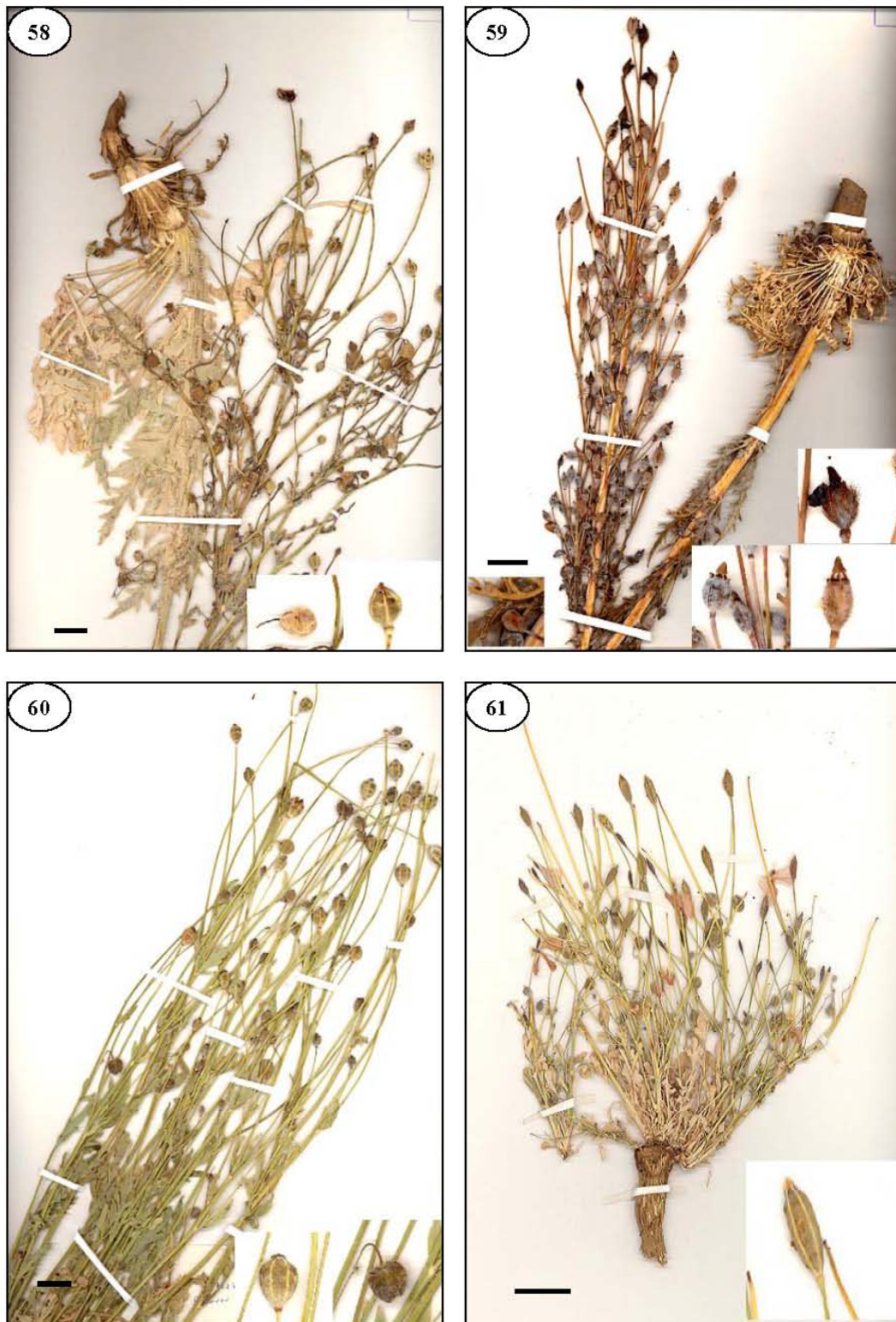
According to Kadereit (1993), division of *P. armeniacum* into three subspecies is based on hairy indumentum of leaves, the length of stem axis, inflorescence branches, density of flowers, stigmatic disc colour and weakly or strongly emarginate between rays. Our results show that those three subspecies are different from each other in some seed and pollen morphological characters such as: pollen grains size and shape, the length and density of spinuli of exine surface; size, color and anticlinal wall shape of seed (Tables 3, 4; Figs. 1-6; 16-24; 43-48).

Mostly *P. armeniacum* subsp. *armeniaceum* is distributed in NW Iran; subsp. *microstigmum* in Alborz mountains and subsp. *pilgerianum* in Zagros Mountains.

Two subspecies and two varieties of *P. persicum* are different from each other in presence or absence of hairy indumentum on the capsule and bud and there are not distinctive palynological characters for separating of these taxa from each other.

Seed morphological characters support the distinction of *P. persicum* subsp. *persicum* from subsp. *microcarpum*. The shape and thickness of anticlinal walls and seed size are characters that show variation in these two subspecies (Table 4; Figs. 51- 56). The two taxa are also different in geographical distribution. *P. persicum* subsp. *persicum* is distributed in NW Iran and subsp. *microcarpum* is distributed in W Iran. Thus these taxa according to Kadereit hypothesis (1993) should be given a subspecies rank.

In hybrid species, micromorphological characters are intermediate between their parents (Tables 3, 4; Figs. 25-27; 40- 42; 49, 50, 57), proving their different origins. Hence, seed and pollen morphological



Figs. 58-62. Photographs of some species of the genus *Papaver* sect. *Meconidium*, 58) *P. persicum* subsp. *microcarpum*; 59) *P. persicum* × *P. armeniacum*; 60) *P. persicum* subsp. *persicum* var. *glabrum*; 61) *P. armeniacum* subsp. *armeniacum* × subsp. *pilgerianum*. Scale bars=15mm.

characters haven't taxonomic value in distinguishing hybrid species from the other taxa of this section.

CONCLUSION

Our study on Iranian species of the genus *Papaver* sect. *Meconidium* shows that in some cases, pollen and seed morphological characters can be of taxonomical value.

In this section, although two species of *P. armeniacum* and *P. persicum* well characterized, they can be separated from each other based on seed morphology. But pollen morphology is not useful for their separation.

There has been a debate that whether the species *P. acrochaetum* should be taxonomically treated as independent species or a taxon of the species *P. persicum*. Our results show that pollen size and spinule length on exine surface well demonstrate its difference from *P. persicum*. Also these two characters are important indicators for distinguishing infraspecies taxa in *P. armeniacum* and *P. persicum*.

Seed size and color, the shape and thickness of anticlinal walls are valuable for identification of infraspecies taxa. For example, the separation of *P. persicum* subsp. *microcarpum* from another subspecies by seed size, the shape and thickness of anticlinal walls; *P. armeniacum* subsp. *microstigmum* by having anticlinal wall of visible sinuate and *P. armeniacum* subsp. *pilgerianum* by seed size and color.

In sect. *Meconidium*, hybrid species are morphological easy to be distinguished. However, they are not separated from the other taxa based on pollen and seed morphology.

REFERENCES

- Boissier, E., 1867: *Papaver*. In: Boissier, E. (ed.), *Flora orientalis*, vol. 1: 105-119. -Geneva & Basileae.
- Bonjanansky, V. & Fargasova, A., 2007: *Atlas of seeds and fruits of Central and East European Flora*. -

Springer.

- Cullen J., 1965: *Papaver*. In: Davis, P.H. (ed.), *Flora of Turkey and the East Aegean Islands*, vol. 1: 219 - 236. -Edinburgh University Press.
- Cullen J., 1966: *Papaver*. In: Rechinger K. H. (ed.), *Flora Iranica*, no 34: 10 - 22 -Akademische Druck- und Verlagsanstalt, Graz.
- Erdtman, G., 1989: *Pollen morphology and Plant taxonomy – Angiosperms*. E. J. Brill, Leiden, The Netherlands.
- Fedde, F., 1909: *Papaveraceae – Hypecoideae et Papaveraceae – Papaveroideae*. In Engler, A., (ed.), *Das Pflanzenreich*, vol. 4 (104): 1 - 430 -Wilhelm Engelmann, Leipzig.
- Kadereit, J. W., 1986: A revision of *Papaver* section *Argemonidium*. -Notes from the Royal Botanic Garden Edinburgh 44 (1): 25 - 43.
- Kadereit, J. W., 1988: Sectional affinities and geographical distributio in the genus *Papaver* L. (*Papaveraceae*). -Beitr. Biol. Pflanzen 63: 139 – 156.
- Kadereit, J. W., 1993: A revision of *Papaver* sect. *Meconidium*. -Edinburgh Journal of Botany 50 (2): 125 - 148.
- Kiger, R. W., 1985: Revised sectional nomenclature in *Papaver* L. -Taxon 34: 150 – 152.
- Mabberley, D. J., 2008: *Mabberley's plant book: a Portable Dictionary of the Vascular Plants*, third edition. -Cambridge University Press, Cambridge, UK.
- Moore, P. D., Webb, J. A. & Couirson, M. E., 1991: *Pollen analysis*. -Black well scientific publications, Oxford.
- Popoy M. G., 1937: *Papaver*. In: Komarov, V. L. (ed.), *Flora of the U. S. S. R.*, vol. 7.: 456 – 494. - Moskva & Leningrad.
- Simpson, M. G., 2006: *Plant Systematics*. -Elsevier Academic Press, Canada.