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Research Article

Pollen morphology of *Astragalus* L. sect. *Onobrychoidei* DC. (Fabaceae) in Turkey

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Abstract: The pollen morphology of 45 specimens of 29 species of the genus *Astragalus* L. of the section *Onobrychoidei* DC. distributed in Turkey was studied with light and electron microscopies. The pollen is generally 3-colporate. Pollen of the section is prolate, subprolate, and prolate-spheroidal. Size varies, with the polar axis ranging from 23.4 to 42.6 µm and the equatorial axis from 14.3 to 36.4 µm. The outline is elliptic or compressed oval in the meridional section, versus trilobulate and sometimes tetralobulate in the polar optical section. Sculpturing is usually microreticulate, rarely reticulate or rugulate in the meridional optical section, and psilate and perforate (with irregular or circular perforations) in the polar optical section.

Key words: Turkey, Fabaceae, *Astragalus*, *Onobrychoidei*, pollen morphology

Türkiye'deki *Astragalus* L. cinsi *Onobrychoidei* DC. (Fabaceae) seksiyonunun polen morfolojisi

Özet: Türkiye'de yayılış gösteren *Astragalus* L. cinsinin *Onobrychoidei* DC. seksiyonunda yer alan 29 türe ait 45 örneğin polen morfolojisi ışık ve elektron mikroskobuyla çalışılmıştır. Polenler genellikle trikolporat aperture sahip, prolat, subprolat veya prolat-sferiodaldir. Polenlerin polar eksenleri 23,4-42,6 µm ve ekvatoral eksenleri 14,3-36,4 µm arasında değişmektedir. Dış görünümler meridional optik bölgede eliptik veya basık oval, polar optik bölgede ise trilobulat bazen tetralobulattır. Polen yüzeyi süslenmesi meridional optik bölgede genellikle mikroretikülat, nadiren retikülat veya rugulat, polar optik bölgede ise psilat ve perforattır.

Anahtar sözcükler: Türkiye, Fabaceae, *Astragalus, Onobrychoidei*, polen morfolojisi

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Introduction

Astragalus L. is the largest genus of the family Fabaceae in Turkey. Of the 2500 species of *Astragalus* worldwide, 218 species are endemic to Turkey. The genus is divided into 62 sections in the *Flora of Turkey* (Chamberlain & Matthews, 1970). In the present study, from among the sections known in Turkey *Onobrychoidei* DC. was selected and examined because it is the section richest in species and it is taxonomically complex.

Chamberlain and Matthews (1970) identified 31 species and 2 varieties of the section in Turkey, 22 of which are endemic. The number of the taxa belonging to the section subsequently increased to 46 between 1999 and 2002 (Podlech, 1999, 2001; Podlech & Sytin, 2002). Results of a study based on morphological investigations, and both chromosomal and DNA analyses show that some of the taxa given in the revision of Podlech are synonymous and that the taxon number was reduced to 29 (Ekici et al., 2008).

As mentioned above, *Onobrychoidei* is a taxonomically complex section with numerous diploid and polyploid species, and few macromorphological characters are available as phylogenetic markers and for delimitation of species and infragenetic taxa. Determination of the micromorphological characters of the taxa may provide additional taxonomic and phylogenetic information about the section and the pollen morphology of the 29 diploid and polyploid Turkish species that were examined in this study. There are few reports about the pollen morphology of *Astragalus.* Perveen and Qasier (1988) studied the Papilionidae pollen flora of Pakistan with light microscopy (LM) and scanning electron microscopy (SEM). Pollen morphology of the section *Alopeuroidei* DC. was studied by Akan et al. (2005), who described in detail the pollen morphology of 18 *Astragalus* species.

The pollen characters of section *Onobrychoidei* have yet to be studied in detail. Our objective was to examine the pollen morphology of section *Onobrychoidei* taxa that are known and to test their taxonomic value. To the best of our knowledge this is the first comprehensive pollen study of this section. Hence, we examined in detail the pollen grains of 29 Turkish *Astragalus* species of the section *Onobrychoidei*.

Materials and Methods

The materials used for the present study were collected from the wild. Plant specimens were deposited at the Gazi University Herbarium (GAZI). Collectors and localities are shown in the Investigated Specimens Appendix.

Pollen slides were prepared using the technique of Wodehouse (1935). LM studies were made using a Nikon E600 microscope. Measurements were based on 20 or more pollen grains for each species. For SEM, dry pollen grains were mounted on stubs and coated with gold. Morphological observations were made with a JSM 5600 electron microscope. In order to determine the variations within the section, 45 populations were examined.

The terminology used is mainly that of Faegri and Iversen (1992), and Punt et al. (1994, 2007). Shape classification follows Erdtman (1969), based on P/E ratios in the Table. The Simpson and Roe graphical test (in Van der Pluym and Hindeus, 1997) was used for statistical calculations.

Investigated Specimens Appendix

The list of investigated species of the *Astragalus* taxa is given below. Different localities of species are also given and are indicated by letters and numbers in brackets.

Section: **Onobrychoidei**

* *Astragalus cicerellus* Boiss. & Balansa Kayseri: 1350 m, 10.7.2001, *M.Ekici* 2535 et al. **(A1)**; Eskişehir: 930 m, 15.6.1993, *M.Nydegger* 47470 **(A11).**
* *A. mesoginatus* Boiss.; Kayseri: 1600 m, 11.7.2001, *M.Ekici* 2545 et al. **(A2)**; İçel: 650 m, 23.5.1993, *M.Nydegger* 47276 **(A21).**
* *A. lycaonicus* Hub.-Mor. & Reese; Konya: 1300 m, 30.05.2003, *M.Ekici* 3248 & *H.Akan* **(A3).**
* *A. setulosus* Boiss. & Balansa; Kayseri: 1350 m, 2.6.2001, *M.Ekici* 2534 et al. **(A4).**
* *A. strigillosus* Bunge; Sivas: 1350 m, 15.6.2001, *M.Ekici* 2521 et al. **(A5).**
* *A. cancellatus* Bunge; Ağrı: 1400 m, 19.7.2001, *M.Ekici* 2593 et al. **(A6)**; Kars: 1700 m, 13.7.2002, *M.Ekici* 3126 et al. **(A61)**; Ağrı: 16.7.2001, *M.Ekici* 2561 et al. **(A62).**

Table. Pollen morphological parameters of *Astragalus* sect. *Onobrychoidei* (values in μm).

Section	Polar axes (P)			Equatorial axes (E)			P/E ratio and shape	Aperture type	Ornamentation	Colpus(Cl)		Pore (Pl)		Exine thickness	Intine thickness
Onobrychoidei	Min.	Mean.	Max.	Min.	Mean.	Max.				Clg	Clt	Plg	Plt		
A. cicerellus (A1)	27.1	30.8	34.3	23.9	25.2	30.2	1.22 Prolate	Trizonocolporate	Microreticulate	3.1	27.1	8.3	6.3	1.6	0.4
A. cicerellus (A11)	26	30.5	33.3	21.8	25.6	28.1	1.19 Prolate	Trizonocolporate	Microreticulate	4.2	25	7.3	6.2	1.3	0.3
A. mesogitanus (A2)	29.1	34.4	40.6	18.7	25.4	30.2	1.35 Prolate	Trizonocolporate	Microreticulate	3.1	25	8.9	7.1	1.9	0.4
A. mesogitanus (A21)	33.3	35.9	38.5	23.9	27.1	30.2	1.32 Prolate	Trizonocolporate	Microreticulate	5.2	30.2	8.3	6.2	1.4	0.3
A. lycaonicus (A3)	30.3	32.6	41.6	23.9	30.4	36.4	1.07 Prolate -Spheroid	30% Tetrazonocolporate 70% Trizonocolporate	Microreticulate	3.1	30.7	9	4.5	1.5	0.3
A. setulosus (A4)	27.3	35.4	42.1	20.3	24.3	30.7	1.46 Subprolate	60% Trizonocolporate 40% Spiraperturate	Microreticulate	3.1	30.5	6.3	6.3	2	0.4
A. strigillosus (A5)	34.3	37.4	40.6	21.8	26.2	31.2	1.43 Subprolate	Trizonocolporate	Microreticulate	3.1	32.2	10.4	6	2.8	0.3
A. cancellatus (A6)	29.1	33.1	37.4	21.8	25.3	30.2	1.31 Prolate	Trizonocolporate	Reticulate	2.6	28.6	8.9	4.2	1.8	0.4
A. cancellatus (A61)	34.3	37.9	41.6	22.9	26.1	30.2	1.45 Subprolate	20% Trizonocolporate 80% Abnormal pollen	Microreticulate	3.1	22.9	-	-	0.87	0.3
A. cancellatus (A62)	32.2	34.4	42.6	20.8	26.4	34.3	1.3 Prolate	Trizonocolporate	Microreticulate	3.1	32.8	6.2	4.2	1.3	0.3
A. eliasianus (A7)	31.2	36.8	39.5	20.8	24.5	20.8	1.5 Subprolate	Trizonocolporate	Microreticulate	4.2	31.2	12.5	4.2	1.3	0.3
A. adunciformis (A8)	28.4	30.2	35.3	19.2	21.2	24.3	1.42 Subprolate	Trizonocolporate	Microreticulate	2.1	26.1	6	3.1	1.5	0.3
A. demirizii (A9)	26	29.6	34.3	20.8	24.7	31.2	1.2 Prolate	Trizonocolporate	Microreticulate	3.1	22.9	9.4	9.4	1.5	0.3
A. cadmicus (A10)	21.5	24.4	27.2	17.4	20.2	23.7	1.21 Prolate	Trizonocolporate	Microreticulate	2.3	20	4.2	4.2	1.6	0.4
A. psoraloides (A11)	29.1	33	37.5	20.8	23.9	27.1	1.38 Subprolate	25% Trizonocolporate 75% Tetrapantocolporate	Microreticulate	5.2	28.1	9.4	5.2	1.2	0.3
A. psoraloides (A111)	29.1	38.3	41.6	23.9	28.6	33.3	1.34 Subprolate	30% Paratrizonocolporate 70% Trizonocolporate	Microreticulate	6.2	32.8	11.4	8.8	1.5	0.3
A. psoraloides (A112)	33.4	38.4	41.2	22.4	29.1	32.3	1.32 Subprolate	10% Tripantocolporate 90% Trizonocolporate	Microreticulate	5.1	35	7.2	5.5	1.4	0.4
A. asciocalyx (A12)	19.4	30.2	35.7	17.5	22.1	26.1	1.37 Subprolate	Trizonocolporate	Microreticulate	3.4	28.3	5.2	4.3	1.5	0.3
A. asciocalyx (A121)	20.3	30.5	36.7	17.3	21.2	29.6	1.44 Subprolate	Trizonocolporate	Microreticulate	2.1	28.3	9.4	5.3	1.5	0.3
A. heldreichii (A13)	27.4	30	33.2	18.9	20.5	22.4	1.46 Subprolate	Trizonocolporate	Microreticulate	3.2	27.4	6.4	5.3	1.4	0.3
A. karamasicus (A14)	29.1	30.1	39.5	23.9	26.1	28.1	1.25 Prolate	Trizonocolporate	Microreticulate	3.1	28.1	10.4	8.3	1.6	0.5
A. karamasicus (A141)	26	27.4	31.2	20.8	23.8	26	1.15 Prolate	Trizonocolporate	Microreticulate	3.1	26	10.4	6.1	1.6	0.3

Table. (Continued)

Section	Polar axes (P)			Equatorial axes (E)			P/E ratio and shape	Aperture type	Ornamentation	Colpus(Cl)		Pore (Pl)		Exine thickness	Intine thickness
Onobrychoidei	Min.	Mean.	Max.	Min.	Mean.	Max.				Clg	Clt	Plg	Plt		
A. lycius (A15)	30.2	32.9	37.5	24.9	25.1	31.2	1.01 Prolate	Trizonocolporate	Microreticulate	4.2	29.2	8.3	6.2	1.4	0.3
A. lycius (A151)	31.4	34.6	42.6	20.8	26.8	34.3	1.29 Prolate	Trizonocolporate	Microreticulate	3.2	32.8	8.2	7.1	1.6	0.3
A. fumosus (A16)	26	27.8	31.2	18.7	20.9	22.9	1.33 Prolate	Trizonocolporate	Microreticulate	3.1	25.7	8.3	7.3	2.1	0.5
A. aduncus (A17)	29.1	33.6	38.5	23.9	26.7	31.2	1.26 Prolate	Trizonocolporate	Microreticulate	5.2	29.1	8.3	6.3	1.3	0.3
A. xylobasis (A18)	29.1	36.5	43.7	22.9	31.2	37.4	1.17Prolate	10% Spiraperturate 40% Trizonocolporate 50% Tetrapontocolparate	Microreticulate	3.1	26	8.3	7.1	1.6	0.3
A. xylobasis (A181)	30.2	33.8	37.4	20.8	24.7	26	1.36 Prolate	Trizonocolparate	Microreticulate	2.6	30.2			1.8	0.3
A. kochakii (A19)	36.4	40.6	42.6	21.9	24.6	26	1.65 Subprolate	Trizonocolparate	Microreticulate	3.4	31.2	7.3	4.2	2.3	0.4
A. onobrychis (A20)	27.1	33.8	41.6	21.8	27.3	31.2	1.24 Prolate	10% Spiraperture 40% Tetrapantocolporate 50% Trizonocolporate	Microreticulate	4.2	24.3	6.5	4.1	2.1	0.3
A. onobrychis (A201)	34.3	37.1	39.5	26	28.6	31.2	1.3 Prolate	10% Spiraperturate 90% Trizonocolporate	Microreticulate	3.1	28.1	7.3	7.3	1.6	0.5
A. onobrychis (A202)	29.1	35.2	42.6	20.8	26.5	31.2	1.33 Prolate	Trizonocolparate	Microreticulate	4.2	30.2	9.4	6.2	1.3	0.3
A. onobrychis (A203)	31.2	36	40.6	21.8	33.3	29.4	1.08 Prolate -Spheroid	Trizonocolparate	Microreticulate	4.2	30.2	6.2	4.2	1.3	0.3
A. onobrychis (A204)	33.3	38.3	42.6	29.1	33.1	37.4	1.16 Prolate	Trizonocolparate	Microreticulate	4.2	31.2	9.4	8.3	1.8	0.3
A. onobrychis (A205)	27.1	30.9	34.3	22.9	26.8	31.2	1.15 Prolate	Trizonocolparate	Microreticulate	3.1	27.2	7.3	6.2	1.3	0.3
A. onobrychioides (A21)	20.1	23.4	28.3	14.3	17.8	21.2	1.31 Prolate	Trizonocolparate	Microreticulate	2.4	20.3	5.4	5.4	1.3	0.3
A. kadschorensis (A22)	20.1	29.2	38.9	19.9	27.7	37.3	1.05 Prolate-Spheroid	Trizonocolparate	Rugulate	8.3	27	10.4	7.3	1.5	0.3
A. trachytrichus (A23)	28.4	30.2	33.7	18.7	20.2	25.2	1.5 Subprolate	Trizonocolparate	Microreticulate	2.4	23.7	6.3	4.1	1.6	0.4
A. eubrychioides (A24)	27.1	31.4	35.4	20.3	22.1	28.4	1.42 Subprolate	Trizonocolparate	Microreticulate	2.1	27.4	4.2	4.3	2	0.3
A. arguricus (A25)	31.2	38.6	44.7	20.8	28.1	34.3	1.3 Subprolate	Trizonocolparate	Microreticulate	6.2	30.2	9.4	7.3	2.1	0.3
A. trabzonicus (A26)	33.3	35.1	38.5	23.9	26.8	30.2	1.3 Prolate	Trizonocolparate	Microreticulate	2.1	27.1	9.4	7.3	1.6	0.3
A. adzharicus (A27)	30.2	33.6	36.4	20.8	24.1	27.1	1.39 Subprolate	Trizonocolparate	Microreticulate	5.2	32.2	8.3	5.2	1.6	0.3
A. xerophilus (A28)	29.1	32.8	35.4	21.8	24.3	28.2	1.35 Subprolate	Trizonocolparate	Microreticulate	4.2	27.1	9.4	6.2	1.3	0.3
A. melitenensis (A29)	26	27.8	34.3	20.8	22.1	34.3	1.35 Subprolate	25% Tricolpodiporate 75% Trizonocolporate	Microreticulate	5.2	25	8.3	7.3	1.4	0.3

*Clg: Colpus width; Plg: pore width. *Clt: Colpus length; Plt: pore length.

* *A. eliasianus* Kit Tan & Sorger; Kars: 2000 m, 21.7.2001, *M.Ekici* 2611 et al. **(A7).**

* *A. adunciformis* Boiss.; Kayseri: 1150 m, 2.6.2001, *M.Ekici* 2210 & *H.Akan* **(A8).**

* *A. demirizii* R.Kramer & Podlech; Ankara: 950 m, 5.6.2001, *M.Ekici* 2977 & *Aytaç* **(A9).**

* *A. cadmicus* Boiss.; Denizli: 1000 m, 3.7.2002, *M.Ekici* 2998 **(A10).**

* *A. psoraloides* Lam.; Bayburt: 1500-1600 m, 13.6.2001, *M.Ekici* 2486, *H.Akan* & *FAK* **(A11);** Erzurum: 2100 m, 12.6.2001, *M.Ekici* 2451, *H.Akan* & *FAK* **(A111);** Ağrı: 2350-2400 m, 18.7.2001, *M.Ekici* 2582 et al. **(A112).**

* *A. asciocalyx* Bunge; Elazığ: 1475 m, 3.6.2001, *M.Ekici* 2228 et al. **(A12)**; Van: 2000 m, 7.6.2001, *M.Ekici* 2335 et al. **(A121).**

* *A. heldreichii* Boiss.; Isparta: 1830 m, 3.7.2002, *M.Ekici* 2996 et al. **(A13).**

* *A. karamasicus* (Boiss. & Balansa) Kuntze; Konya: 1050 m, 17.5.2001, *M.Ekici* 2196 **(A14);** Sivas: 1450 m, 15.6.2001, *M.Ekici* et al. **(A141).**

* *A. lycius* Boiss.; Kayseri: 1750 m, 2.6.2001, *M.Ekici* 2536 et al. **(A15);** Ankara: 900 m, 16.6.2003, *M.Ekici* 3538 & *M.E.Uzunhisarcıklı* **(A151).**

* *A. fumosus* Boiss.; Van: 2050 m, 6.6.2001, *M.Ekici* 2293 et al. **(A16).**

* *A. aduncus* Willd.; Van: 2100 m, 6.6.2001, *M.Ekici* 2291 et al. **(A17).**

* *A. xylobasis* Freyn & Bournm.; Hakkari: 1800 m, 6.6.2002, *M.Ekici* 2271 & *H.Akan*, *FAK* **(A18)**; Bilecik: 300-400 m, 30.5.1929, *Bornmüller* 14107 **(A181).**

* *A. kochakii* Aytaç & Duman; Ankara: 900 m, 19.6.2002, *M.Ekici* 2995 et al. **(A19).**

* *A. onobrychis* L.; Erzurum: 1800 m, 12.6.2001, *M.Ekici* 2461 et al. **(A20)**; Ağrı: 1700 m, *M.Ekici* 2404 et al. **(A201)**; Erzurum: 2000 m, 13.6.2001, *M.Ekici* 2471 et al. **(A202)**; Van: 2200 m, 8.6.2001, *M.Ekici* 2383, *H.Akan* & *FAK* **(A203)**; Erzurum: 2150 m, 22.7.2001, *M.Ekici* 2626 et al. **(A204);** Sivas: 1600 m, 10.7.2002, *M.Ekici* 3041 et al. **(A205).**

* *A. onobrychioides* M.Bieb.; Ağrı: 1700 m, 9.6.2001, *M.Ekici* 2403 et al. **(A21).**

* *A. kadschorensis* Bunge; Van: 1700-1800 m, 8.6.2001, *M.Ekici* 2352 et al. **(A22).**

* *A. trachytrichus* Bunge; Erzurum: 1800 m, 13.6.2001, *M.Ekici* 2468 et al. **(A23).**

* *A. eubrychioides* Boiss; Erzurum: 1800 m, 13.6.2001, *M.Ekici* 2467 & *H.Akan*, *FAK* **(A24).**

* *A. arguricus* Bunge; Ağrı: 1700 m, 9.6.2001, *M.Ekici* 2409 & *H.Akan* **(A25).**

* *A. trabzonicus* M.Ekici, Aytaç & H.Akan; Trabzon: 2300 m, 10.7.2002, *M.Ekici* 3046, *Z.Aytaç* & *H.Akan* **(A26).**

* *A. adzharicus* Popov; Kars: 180 m, 11.6.2001, *M.Ekici* 2442, *H.Akan* **(A27).**

* *A. xerophilus* Ledeb.; Kars: 2400 m, 20.7.2001, *M.Ekici* 2609 et al. **(A28).**

* *A. melitenensis* Boiss.; Malatya: 850 m, 12.7.2001, *M.Ekici* 2552 et al. **(A29).**

Results

The main palynological features of the Turkish section *Onobrychoidei* specimens that were examined are summarised in the Table and are shown in Figure 1.

Symmetry and shape

The pollen grains of section *Onobrychoidei* are radially symmetrical and isopolar. Pollen of the section is prolate, subprolate, and prolate-spheroidal. Size varies, with the polar axis ranging from 23.4 to 42.6 µm and the equatorial axis from 14.3 to 36.4 µm. (Table, Figure 1). The outline is elliptic or compressed oval in the meridional section and trilobulate, sometimes tetralobulate in the polar optical section (Figures 2-7).

Apertures

The grains are usually trizonocolporate. Some recorded species are heteromorphic. For example, tetrapantocolporate-trizonocolporate pollen grains were observed in *A. lycaonicus* and *A. psoraloides*, tricolporate-spiraperturate in *A. setulosus*, trizonocolporate-paratrizonocolporate in *A. canescens* (syn. *A. psoraloides*), trizonocolporate-

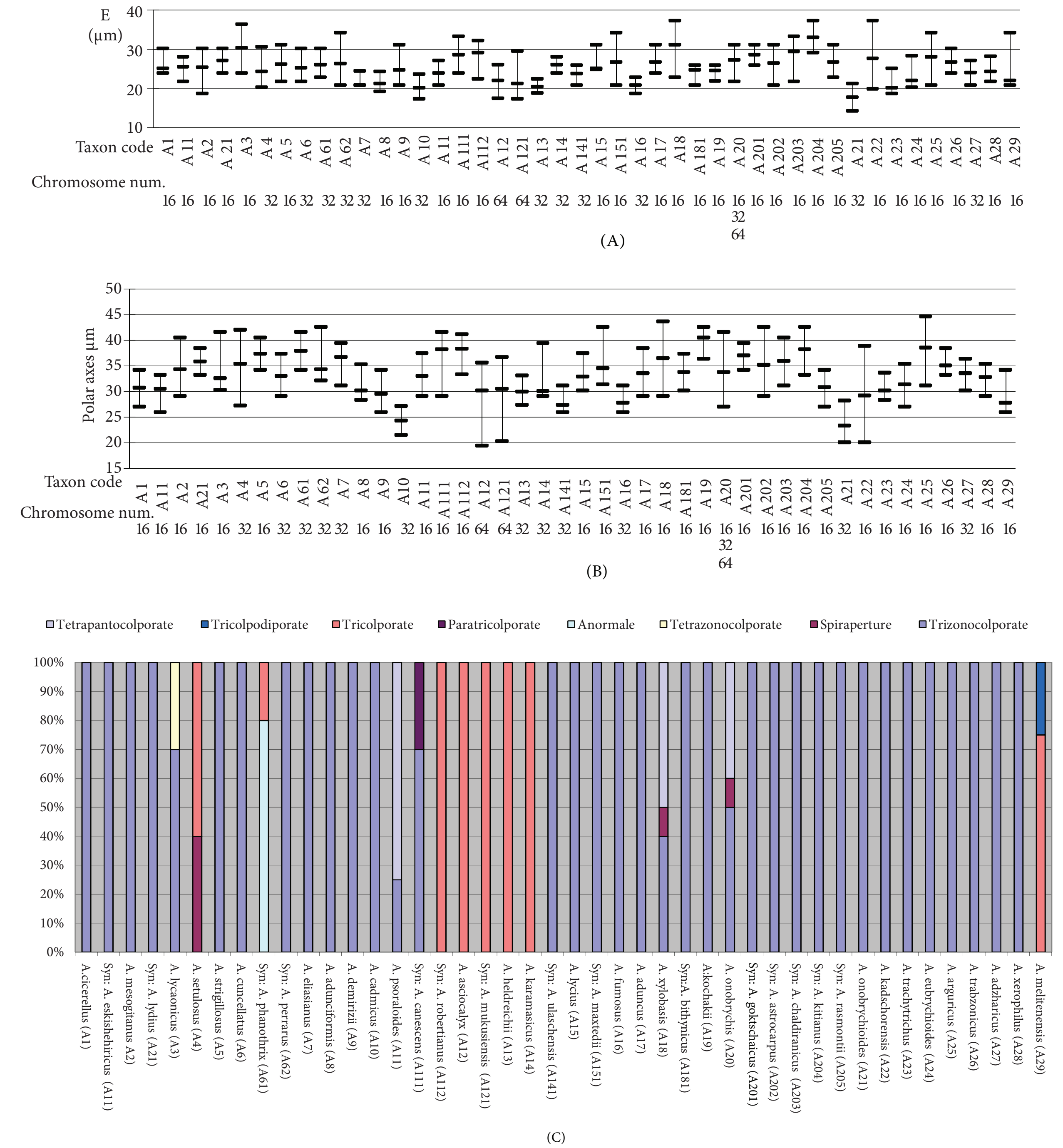

Figure 1. A: Polar axes (P); B: Equatorial axes (E); C: Aperture types.

tetrapantocolporate-spiraperturate in *A. xylobasis* and *A. onobrychis*, and trizonocolporate-tricolpodiporate in *A. melitenensis.* Additionally, in *A. cancellatus* 80% of the pollen grains are abnormal. Colpi are long, subterminal and generally narrow with clear margins (Clt 2.1-8.3 µm, Clg 20.3-35 µm). The aperture membrane is generally psilate or rarely granulate. Pores are lalongate or circular (Plg 3.1-9.4 µm, plt 4.2-12.5 µm). The apocolpium is more or less broad (Figures 2-7).

Exine and intine

The exine is subtectate and 1.2-2.9 µm thick. The ectexine is slightly thicker than the endexine. Sculpturing is usually microreticulate and, rarely, reticulate or rugulate in the meridional optical section, and is psilate and perforate (with irregular or circular perforations) in the polar optical section (Figures 2-7). The intine is 0.3-0.5 µm thick.

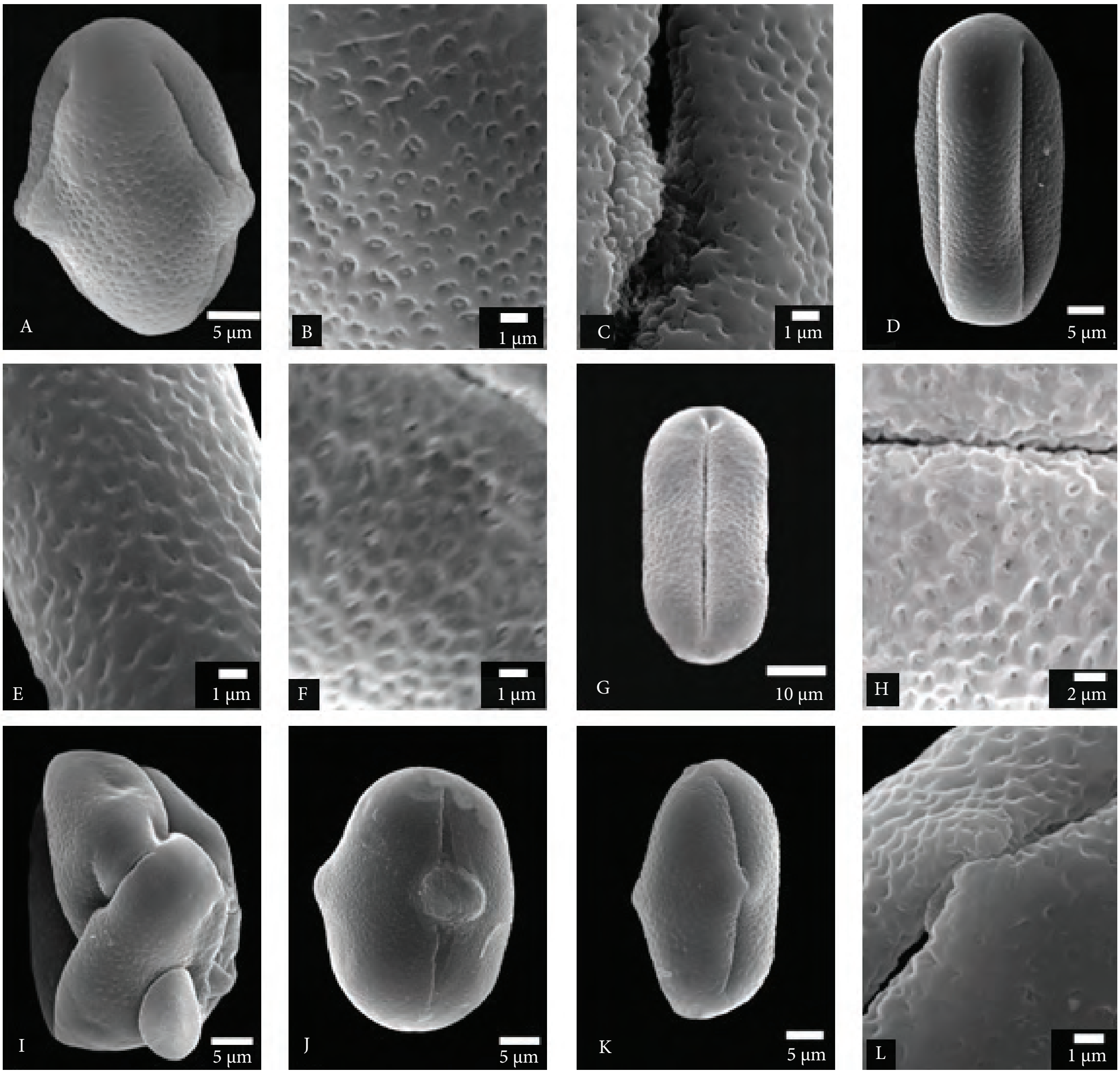

Figure 2. SEM photos of *Astragalus* species of the *Onobrychoidei* section. A-B: *A. cicerellus* (A1). A. Equatorial view and apertures (SEM 4000×). B. Ornamentation (SEM 10,000×). C: *A. cicerellus* (A11) ornamentation and apertures (SEM 10,000×). D-E: *A. mesoginatus* (A2). D. Equatorial view and apertures (SEM 2700×). E. Ornamentation (SEM 10,000×). F: *A. mesoginatus* (A21) ornamentation (SEM 10,000×). G-H: *A. lycaonicus* (A3) G. Equatorial view and apertures (SEM x 2200). H. Ornamentation (SEM 10,000×). I-J: *A. setulosus* (A4). I. Spiraaperture type (SEM 3000×). J. Equatorial view and trizonocolporate (SEM 3000×). K-L: *A. strigillosus* (A5). K. Equatorial view and apertures (SEM 270×). L. Ornamentation (SEM 10,000×).

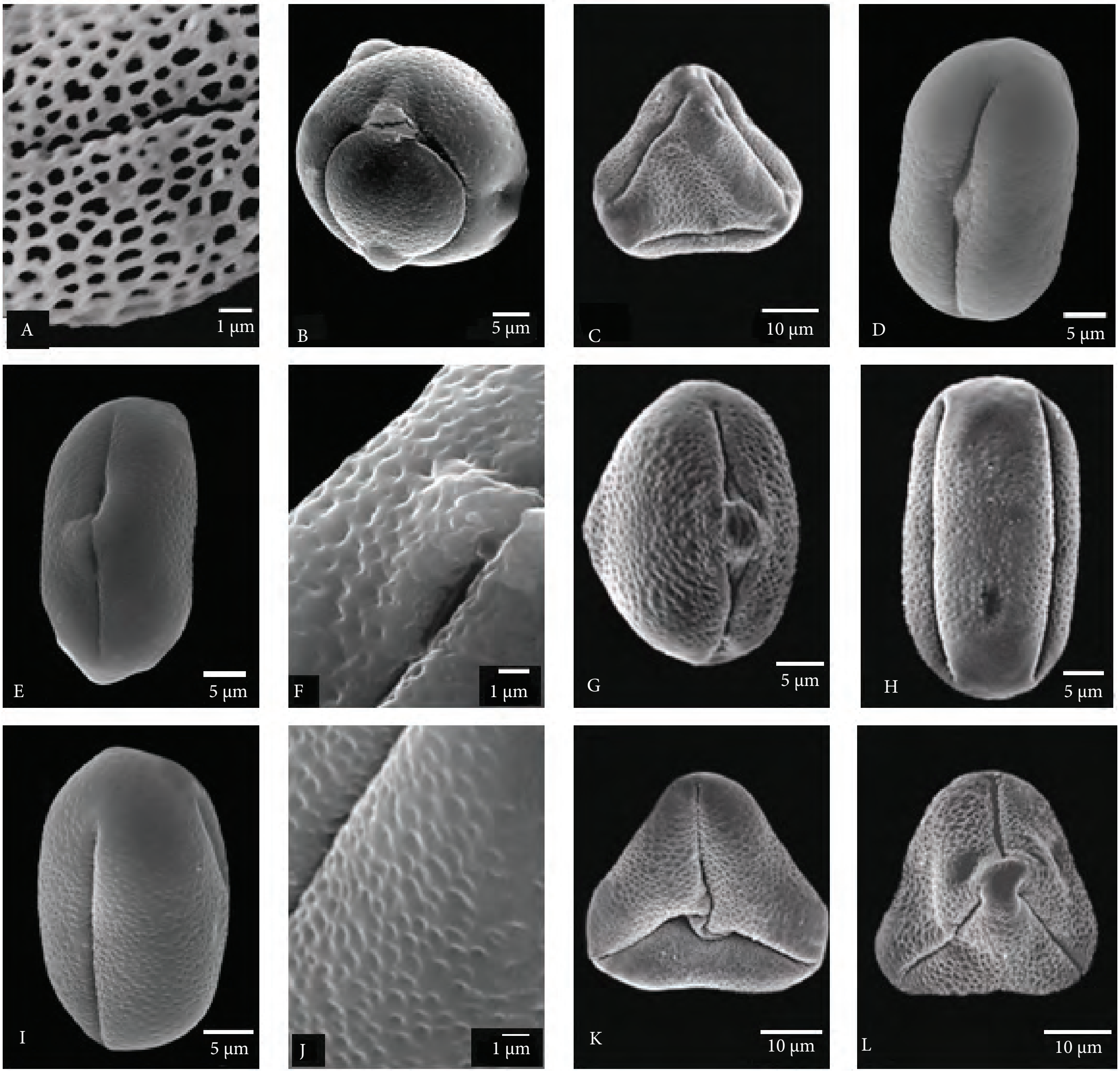

Figure 3. SEM photos of *Astragalus* species of the *Onobrychoidei* section: A: *A. cancellatus* (A6) ornamentation (SEM 10,000×). B: *A. cancellatus* (A61)*;* abnormal pollen (SEM 2700×). C: *A. cancellatus* (A62) polar view and apertures (SEM 2000×). D: *A. eliasianus* (A7) equatorial view and apertures (SEM 3000×). E-F: *A. adunciformis* (A8). E. Equatorial view and apertures (SEM 3000×). F. Ornamentation (SEM 10,000×). G: *A. demirizii* (A9) equatorial view and apertures (SEM 3000×). H: *A. cadmicus* (A10) equatorial view and apertures (SEM 2700×). I-J: *A. psoraloides* (A11). I. Equatorial view and apertures (SEM 3700×). J. Ornamentation (SEM 10,000×). K-L: *A. psoraloides* (A111). K. Paratricolporate aperture type (SEM 2200×). L. Trizonocolporate aperture type (SEM 2300×).

Discussion

The results of our investigations show that the pollen morphology of the Turkish representatives of section *Onobryoidei* is comparatively homogeneous. Some taxa of the section have 16n, 32n, and 64n chromosomes (Ekici et al., 2005) (Figure 1). Brochman (1992) reports that pollen grain size strongly correlates with the level of polyploidy, but the data presented here do not show such a correlation (Table, Figure 1). Mean values for P and E in diploid,

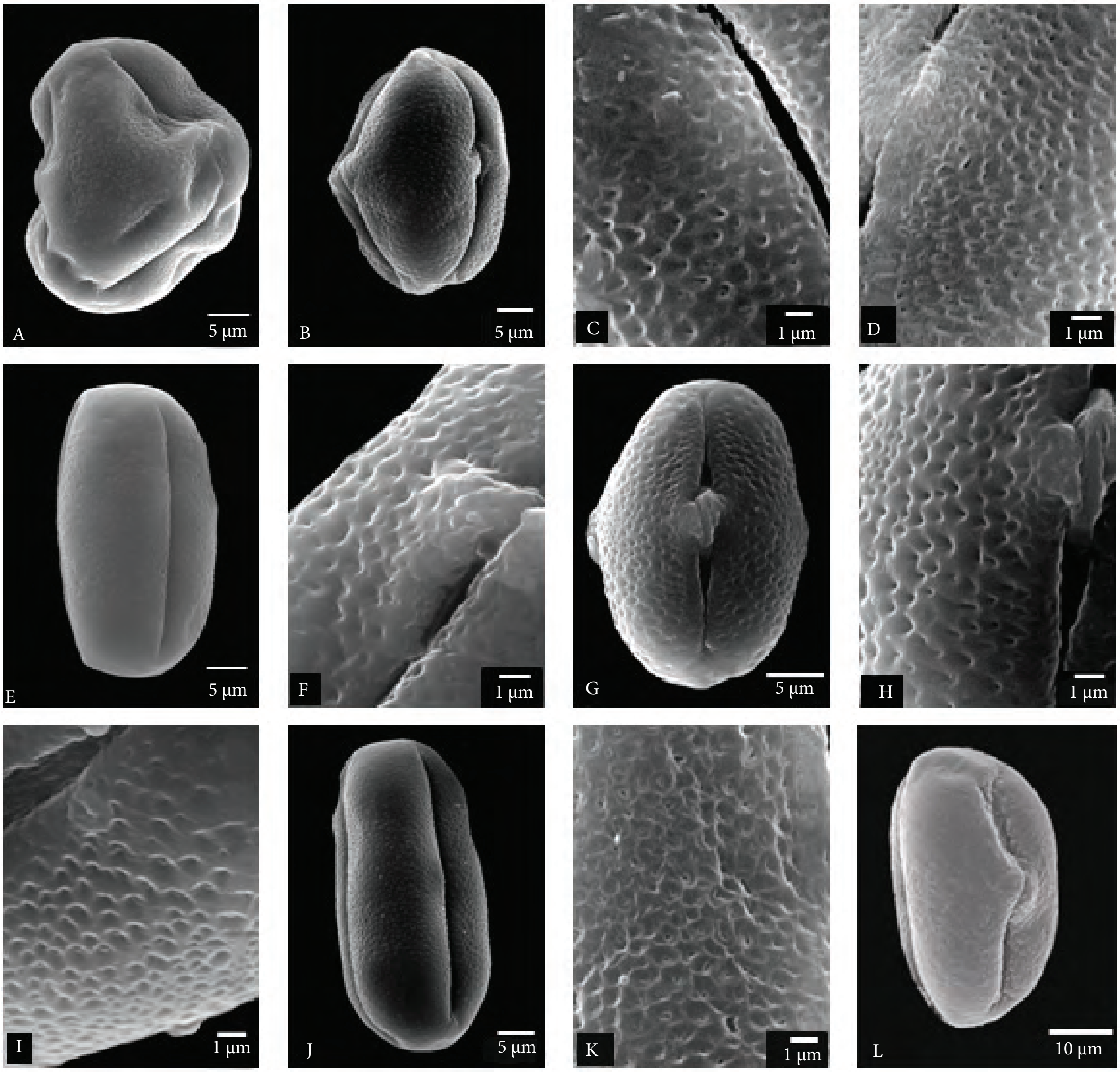

Figure 4. SEM photos of *Astragalus* species of the *Onobrychoidei* section: A: *A. psoraloides* (A112) tripantocolporate aperture type (SEM 3000×). B-C: *A. asciocalyx* (A12). B. Equatorial view and apertures (SEM 2700×). C. Ornamentation (SEM 10,000×). D: *A. asciocalyx* (A121) ornamentation (SEM 10,000×). E-F: *A. heldreichii* (A13). E. Equatorial view and apertures (SEM 3000×). F. Ornamentation (SEM 10,000×). G-H: *A. karamicus* (A14). G. Equatorial view and apertures (SEM 4300×). H. Ornamentation (SEM 10,000×). I: *A. karamicus* (A141) ornamentation (SEM 10,000×). J-K: *A. lycius* (A15). J. Equatorial view and apertures (SEM 2700×). K. Ornamentation (SEM 10,000×). L: *A. lycius* (A151) equatorial view and apertures (SEM 2300×).

triploid, and tetraploid species are very similar; however, greater variation in the maximum and minimum values occurs in the tetraploid species. Similarly, great variations in the maximum and minimum values of P and E have been observed in diploid and natural tetraploid *Trifolium pratense* L. (Fabaceae) species by Pınar et al. (2001), and in triploid, tetraploid, and hexaploid *Arachis* L. (Fabaceae) species by Chatuverdi et al. (1990). The general *Astragalus* aperture form is tricolporate

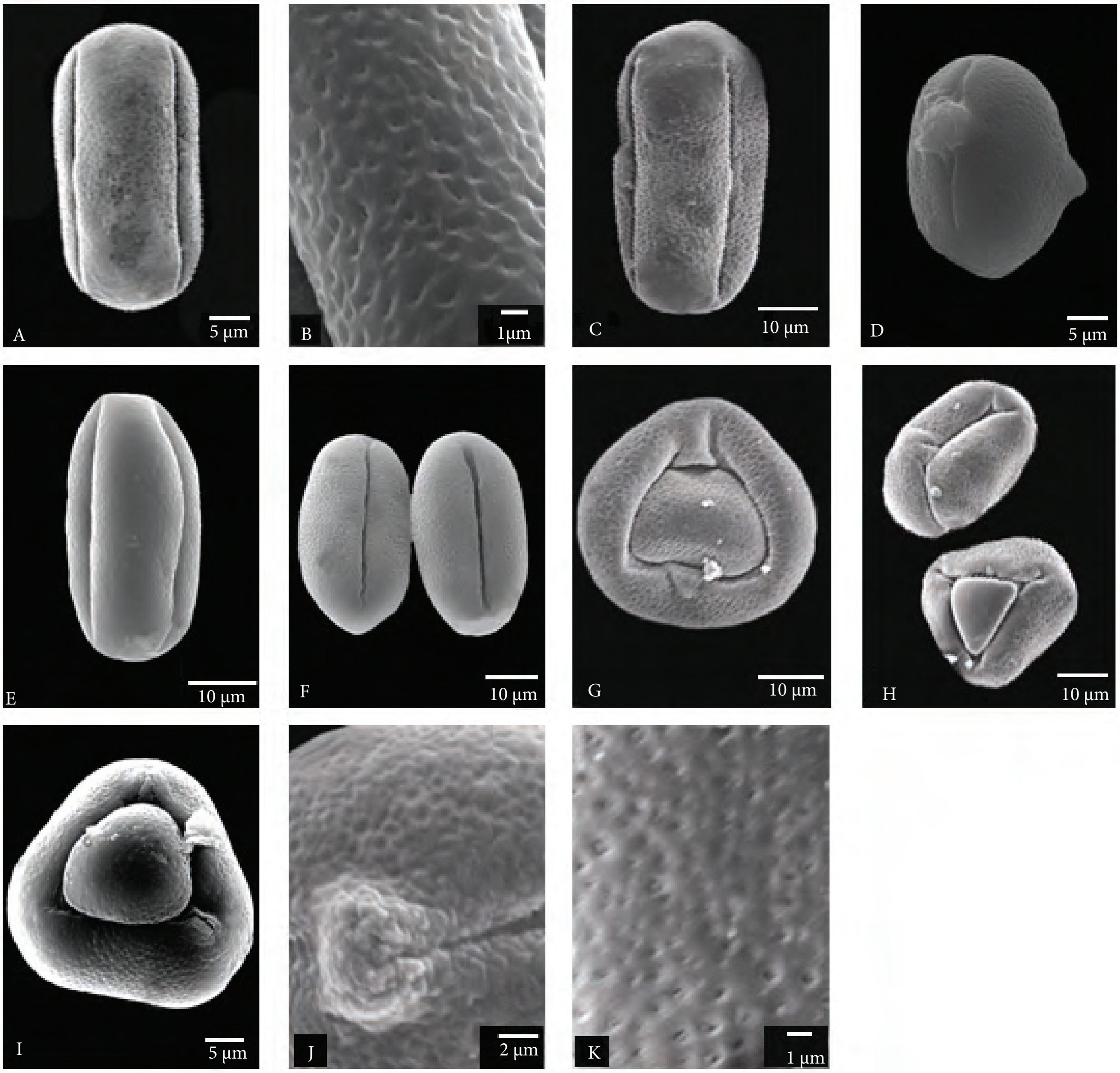

Figure 5. SEM photos of *Astragalus* species of the *Onobrychoidei* section: A-B: *A. fumosus* (A16). A. Equatorial view and apertures (SEM 3000×). B. Ornamentation (SEM 10,000×). C: *A. aduncus* (A17) equatorial view and apertures (SEM 2300×). D: *A. xylobasis* (A18) equatorial view and apertures (SEM 2700×). E: *A. xylobasis* (A181). equatorial view and apertures (SEM 2500×). F: *A. kochakii* (A19) equatorial view and apertures (SEM 2000×). G-H: *A. onobrychis* (A20). G. Spiraperturate type (SEM 2500×). H. Trizonocolporate and tetrapantocolporate aperture type (SEM 1800×). I: *A. onobrychis* (A201) spiraperturate (SEM 2400×). J: *A. onobrychis* (A202) ornamentation and apertures (SEM 6700×). K: *A. onobrychis* (A203) ornamentation (SEM 10,000×).

(Simons & Chinnappa, 2004), but in this section *A. lycaonicus* (70% trizonocolporate, 30% tetrapantpcolporate, 2n = 16), *A. setulosus* (60% trizonocolporate, 40% spiraperturate, 2n = 32), *A. psoraloides* (25% trizonocolporate, 75% tetrapantocolporate, 2n = 16), *A. xylobasis* (40% trizonocolporate, 50% tetrapantocolporate-10% spiraperurate, 2n = 16, 32, 64), and *A. melitenensis* (75% trizonocolporate, 25% tricolpo-diporate, 2n = 16) show considerable aperture type variation (Table,

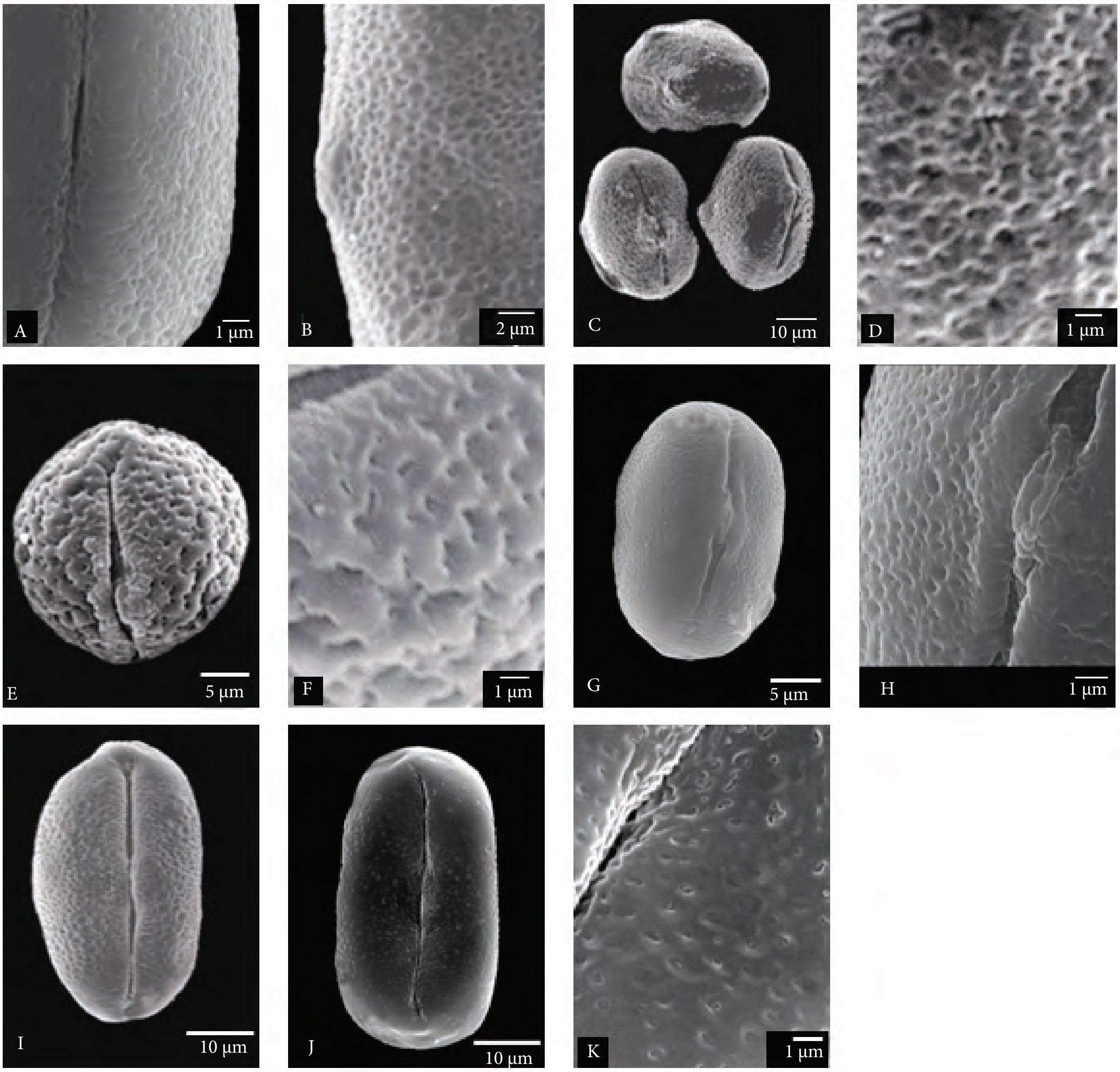

Figure 6. SEM photos of *Astragalus* species of the *Onobrychoidei* section: A: *A. onobrychis* (A204) ornamentation and apertures (SEM 10,000×). B: *A. onobrychis* (A205) ornamentation and apertures (SEM 6500×). C-D: *A. onobrychioides* (A21). C. Equatorial view and apertures (SEM 1600×). D. Ornamentation (SEM 10,000×). E-F: *A. kadschorensis* (A22). E. Equatorial view and apertures (SEM 3500×). F. Ornamentation (SEM 10,000×). G-H: *A. trachytrichus* (A23). G. Equatorial view and apertures (SEM 3700×). H. Ornamentation (SEM 10,000×). I: *A. eubrychioides* (A24) equatorial view and apertures (SEM 2500×). J-K: *A. arguricus* (A25). J. Equatorial view and apertures (SEM 2600×). K. Ornamentation (SEM 10,000×).

Figure 2). Variations in pollen size and aperture type were attributed to heteromorphy in pollen grains by some researchers (Mukherji, 1951; Nair & Kaul, 1965; Sharma, 1967; İnceoğlu, 1973). Heteromorphy is caused by either anomalies in meiosis (Mukherji, 1951) or hybridisation (Matsuda, 1928; Aytuğ et al., 1971). Variation in pollen aperture type is generally related to different levels of ploidy (Borsch & Wilde,

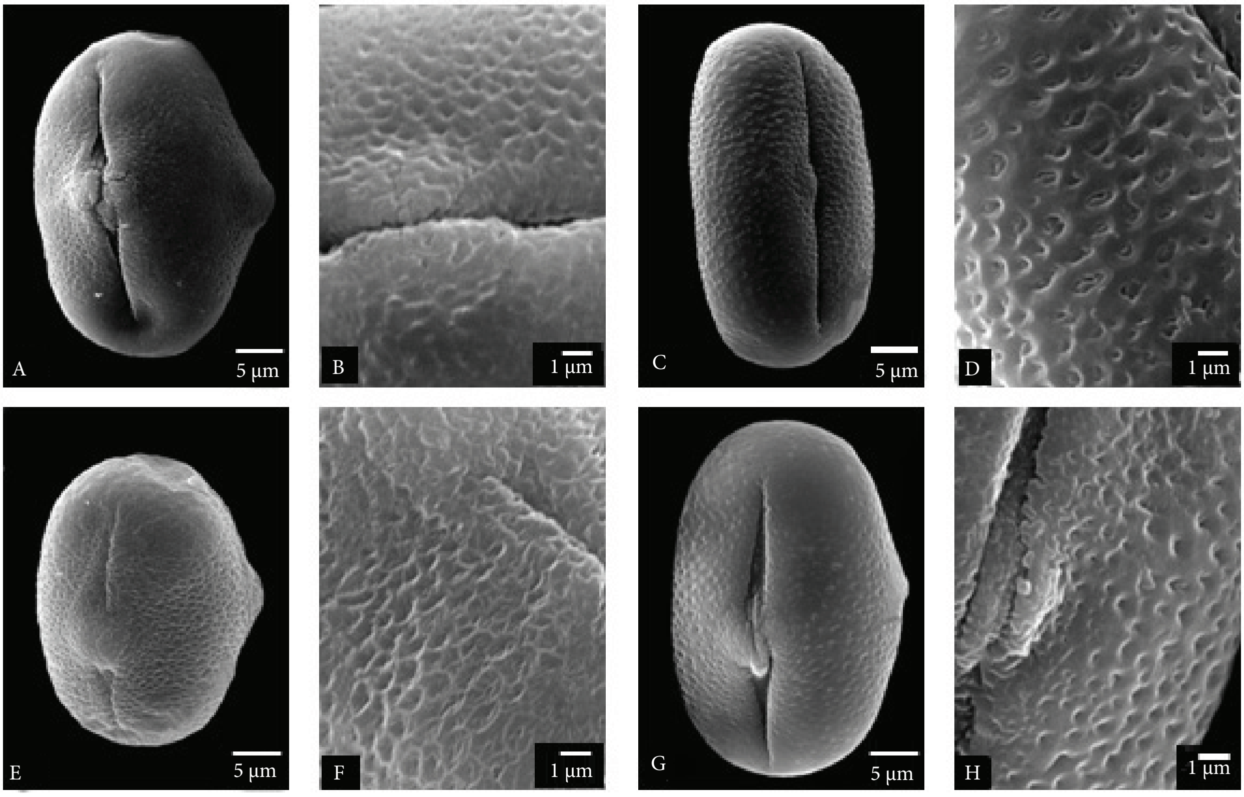

Figure 7. SEM photos of *Astragalus* species of the *Onobrychoidei* section: A-B: *A. trabzonicus* (A26). A. Equatorial view and apertures (SEM 3000×). B. Ornamentation (SEM 10,000×). C-D: *A. adzharicus* (A27). C. Equatorial view and apertures (SEM 3000×). D. Ornamentation (SEM 10,000×). E-F: *A. xerophilus* (A28). E. Equatorial view and apertures (SEM 3300×). F. Ornamentation (SEM 10,000×). G-H: *A. melitenensis* (A29). G. Equatorial view and apertures (SEM 3300×). H. Ornamentation (SEM 10,000×).

2000); however, for the Turkish *Onobrychoidei* section, it is impossible to reach a similar conclusion. The chromosome number 2n = 32 (in *A. Setulosus*) might be the cause of the hybridisation anomalies. Variation in aperture type in species with 2n = 16 chromosomes are likely to be caused by anomalies in meiosis during microsporogenesis.

SEM showed generally 2 types of sculpturing in the taxa—namely rugulate and microreticulate. Rugulate sculpturing was only observed in *A. kadschorensis* (Figure 6). Species of the *Alopecuroidei* section showed microreticulate ornamentations (Akan et al., 2005)

The results of the present palynological study, in general, are similar to those of the taxa of species from different localities (Table, Figure 1). *Onobrychoidei* is not distinguished from other *Astragalus* sections previously studied. General pollen morphological features of the section are similar to those of the *Alopecuroidei* section examined by Akan et al. (2005), in which the pollen type is tricolporate; however, in the *Onobrychoidei* section there are various aperture types, as well as tricolporate pollen grains.

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