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COMPARISON OF POLLEN MORPHOLOGICAL STRUCTURES OF SOME TAXA BELONGING TO *ASPARAGUS* L. AND *FRITILLARIA* L. (LILIACEAE) FROM TURKEY

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Abstract

Pollen grains of 20 taxa from two genera of the Liliaceae were examined and compared by LM (light microscope), SEM (scanning electron microscope) and pollens of four taxa were also examined with TEM (transmission electron microscope). Pollen grains shed as monads. They are monosulcate and ellipsoidal. *Fritillaria crassifolia* subsp. *crassifolia* Freyn & Smt. sometimes sheds the pollen as dyads. Exine is semitectate and the tectum is perforate. Columellae are simplicolumellate. Ectexine is thicker than endexine. Exine sculpture (ornamentation) is reticulate, reticulate-rugulate, rugulate and retipilate in *Asparagus* pollens and reticulate, suprareticulate, rugulate-reticulate and striate-reticulate in *Fritillaria* pollens. Sulcus extends from distal to proximal in some pollens of *Asparagus* and *Fritillaria*.

Introduction

The Liliaceae contains approximately 250 genera and 3500 species. There are approximately 400 Liliaceous species in Turkey and it is one of the richest families. According to recent studies, 49 taxa of *Fritillaria* and 13 taxa of *Asparagus* are available in Turkey. The endemism ratio is 36.53% in *Fritillaria* and 23% in *Asparagus*. These genera have economic and pharmaceutical importance (Davis *et al*. 1984, 1988, Seçmen *et al*. 1998, Güvenç 1996, Guner *et al*. 2000). No detailed palynological studies have been found concerning these genera except for the LM studies by Radulescu (1973) and Schulze (1980, 1982); by Gori (1982), El-Ghazali (1993), Kosenko (1991a, 1991b, 1992, 1999) and SEM and TEM studies. Among monocotyledones plants, the Liliaceae family is a difficult group due to taxonomical and systematic reasons. Some authors explained that the comparative study of pollen morphology of the whole Liliaceae by SEM and TEM hasn't been studied in detail yet (Zavada 1983, Doyle and Hotton 1991, Kosenko 1999a). In order to obtain more morphological data to solve some of these problems, the pollen grains of 20 taxa were comparatively examined in detail for the first time.

Materials and Methods

The pollen materials were obtained from the Faculty of Pharmacy of Ankara University, the Faculty of Science of Hacettepe University and the Faculty of Arts and Science, Gazi University herbariums. For the light microscopy (LM) investigations, pollen grains of 20 taxa, taken from herbarium materials, were prepared according to the methods of Wodehouse (1935) and Erdtman (1960). Pollen dimensions of all species were measured in such amounts that the resulting data followed Gaussian curves. These measurements are shown in Table1. For scanning electron microscopy (SEM) investigations, the pollen grains were put on stubs, sputter-coated with gold plate and examined under a Jeol JSM-840A scanning electron microscope. For transmission electron microscopy (TEM) studies, acetolyzed pollen grains were stained with 2 % OsO_4 and with uranyl acetate, dehydrated and embedded in epon-araldite according to the method described by Skvarla and Turner (1966). Ultrathin sections of the pollen grains were obtained with a glass knife in a

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Reichert Supernova microtome. Post staining was performed with lead citrate for 5 minutes (Reynold 1963) and the sections were examined under a Zeiss EM9. The pollen morphological terminologies by Walker (1974 a, b), Faegri and Iversen (1989) and Punt *et al*. (1994) were used.

Specimens investigated: Asparagus acutifolius L. C3 Antalya: Akseki, Çaltılıçukur-Değirmenler road, 650m, 22.7. 1995; A. Duran 3074 GAZI. *A. verticillatus* L. A5 Sinop: Boyabat, Ilıca village, gardenside, 4.6.1993, A. Guvenç 18173 AEF. *A. officinalis* L. B5 Kayseri: Yılanlı mountain, 1200m, 23.5.1993, M. Koyuncu 18232 AEF. *A.lycicus* P.H. Davis C3 Antalya: Between Elmalı-Korkuteli, out going of Elmalı, inside of farm, 1100 m, 11.6.1992, A. Guvenç,16663 AEF. *A. coodei* P.H. Davis C4 Karaman: Between Mut-Ermenek, 10km before Ermenek, *Q. cocciferae* forest, brushwood side, 1150m, 24.5.1992, A. & U. Güvenç 16939 AEF. *A. lycaonicus* P. H. Davis B4 Konya: Cihanbeyli, Boluk lake, 1010m, the back of Alkim factory, salty and with sodium carbonate slopes, 11.7.1992 A. & U. Guvenç 16654 AEF. *A. persicus* Baker: B4 Ankara: Polatlı Sazılar village, the side of Porsuk brook, 19.6.1993, A. & U.Guvenç 18426 AEF. *A. palaestinus* Baker C5 Mersin: Tarsus Çayboyu village, pass the village after 5km, sandy land 50 m, 19.6.1994 A. & U. Guvenç 18603 AEF. *F. aurea* Schott C6 K. Maraş: Goksun-Değirmendere, püren passageway, M. Ekici 1275 GAZI. *F. acmopetala* subsp. *wendelboi* Rix C4 Antalya: Gazipaşa, Cimbiti wold, H. Sumbul 1285 AEF. *F. whittallii* Baker C3 Antalya: Akseki, Guzelsu, Salamut wold, M. Koyuncu 18225 AEF. *F. crassifolia* subsp. *crassifolia* Freyn & Smt. B8: Erzurum: Kapıkaya place, N. Tanker & K. Baykal 2860 AEF. *F. alburyana* Rix B9 Erzurum: Hınıs, Bingol Mountain, alpinic steppe, M. Koyuncu *et al.* 10106 AEF. *F. bithynica* Baker C2: Muğla: The east of Yılanlı Mountain, A. Guner & B. Yıldız, 34967 HUB. *F. fleisheriana* Steudel & Hochst ex Schultes & Schultes A3 Ankara: 5km before Beypazarı, gypsed steppe, Z. Aytaç *et al*. 5703 GAZI. *F. sibthorpiana* (Sm) Baker C2 Muğla: Koyceğiz, Candır village, A. Guner *et al.* 35031 HUB. *F. minima* Rix B9 Van: Gevas, Artos Mountain north with stone slopes, M. Koyuncu & N. Demirkus, 11736 VAN. *F. armena* Boiss A8 Erzurum: Between Bayburt-Askale, Kop Mountain passageway, alpinic steppe, Ca. 2400m, 13.6.1981 T. Baytop & R. Çetik, 10049 AEF. *F. elwesii* Boiss C3 Antalya: Around Alanya, Bademtas village, M. Koyuncu, 19631 AEF.

The symbols AEF, GAZI, HUB and VAN stand for herbarium sheets from the Faculty of Pharmacy of Ankara University, the Faculty of Science and Arts of Gazi University, the Faculty of Science Hacettepe University and the Faculty of Educational Yüzüncü Yıl University, respectively.

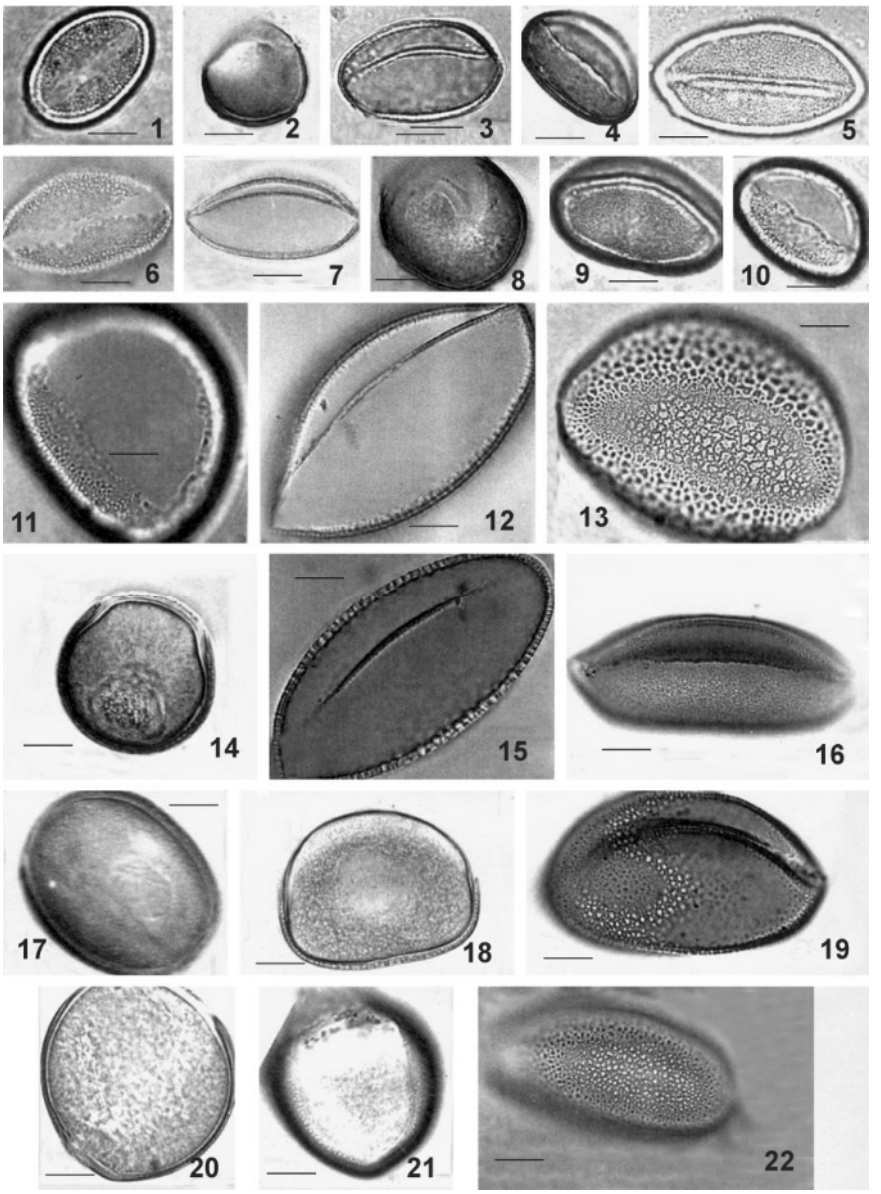
Results and Discussion

General remarks to the genus: *Asparagus*

Pollen grains of 8 *Asparagus* species, 3 of which are endemic, are monads monosulcate, ellipsoidal. Exine is semitectate and the tectum is perforate. Exine sculpture is reticulate, reticulate-rugulate, rugulate or retipilate. Sulcus extends from distal to proximal in the examined seven taxa with the exception of *A. coodei*. Sulcus membrane is granulate, rugulate or psilate. Sulcus ends are rounded in all investigated taxa. Sulcus becomes narrow at the equator, widens at the poles.The number of the lumina in 1 μm^2 is 1-12, the diameter of lumina is approximately 0.10-0.55 µm, the number of perforation in 1 μm^2 is 2-6 at the sulcus side or at the lateral surface. The diameter of a perforation is approximately 0.08-0.18µm and the thickness of a murus is on average 0.09-0.25 µm. Ectexine is thicker than endexine in TEM micrographs in *A. verticillatus* and *A. lycaonicus*. Ectexine is thicker in *A. verticillatus* than in *A. lycaonicus*. Endexine is rather thin in both species. Columellae are simplicolumellate (Figs. 1-10, 23-36, 59, 60).

Fritillaria

Pollen grains of 12 endemic taxa were shed as dyads in *F. crassifolia* subsp. *crassifolia* (5 %) and the other species were monosulcate, and ellipsoidal. Exine was semitectate and the tectum was perforate. Exine sculpture was reticulate, suprareticulate, rugulate-reticulate or striate-reticulate.



Figs. 1-22: LM microphotographs. 1. *Asparagus acutifolius* Pollen grain in distal view (E). 2. *A. verticillatus* Pollen grain in equatorial view in optical section (W). 3. *A. officinalis* Pollen grain in oblique view (E). 4-5. *A. lycicus* Pollen grain in oblique view (W) (4). Pollen grain in distal view with ornamentation (E) (5). 6. *A. coodei* Pollen grain in distal view with ornamentation (E). 7. *A. lycaonicus* Pollen grain in oblique view (E). 8-9. *A. persicus* Pollen grain in equatorial view in optical section (W). (8) Pollen grain in oblique view with ornamentation (W) (9). 10. *A. palaestinus* Pollen grain in distal view (E). 11. *Fritillaria aurea* Pollen grain in optical section in distal view (E). 12. *F. acmopetala* subsp. *wendelboi* Pollen grain in oblique view (E). 13. *F.whitallii* Ornamentation on proximal side (E). 14. *F. michailovskyi* Pollen grain in equatorial view (W). 15. *F. alburyana* Pollen grain in oblique view (E). 16. *F. bithynica* Pollen grain in oblique view with ornamentation (E). 17. *F. crassifolia* subsp. *crassifolia* Pollen grain in distal view (W). 18. *F. sibthorpiana* Pollen grain in oblique view (W). 19. *Fritillaria minima* Pollen grain in oblique view with ornamentation (E). 20. *F. fleischeriana* Pollen grain in equatorial view (W). 21. *F. armena* Pollen grain in optical section in equatorial view (W). 22. *F. elwesii* Ornamentation on proximal side (E). (LM × 1000, Scale =10 µm in all figures); (E: Acetolyzed W: Non acetolyzed pollen grains).

Sulcus extended from distal to proximal in *F. aurea*, *F. bithynica* and *F. sibthorpiana*. Sulcus membrane is gemmate or granulate. The number of granule in 2 μm^2 on sulcus membrane was approximately 2-9, the number of gemmae in 2 μm^2 was approximately two in *F. elwesii*. Sulcus end were rounded or sharp. At the lateral surface or at the edge of the sulcus the number of lumina in 1 μm^2 was 1-4, the diameter of lumina was approximately 0.17-0.97 µm, the number of perforation in 1 μm^2 was 3-7. The diameter of a perforation was approximately 0.12-0.25 µm and the thickness of a murus was on an average 0.20-0.74 µm. In the ultrathin sections of *F. armena* and *F. whittalli*, ectexine was thicker than endexine. Ectexine was thicker in *F. whittalli* than in *F. armena*. Endexine was very thin (Figs. 11-22, 37-58, 61,62).

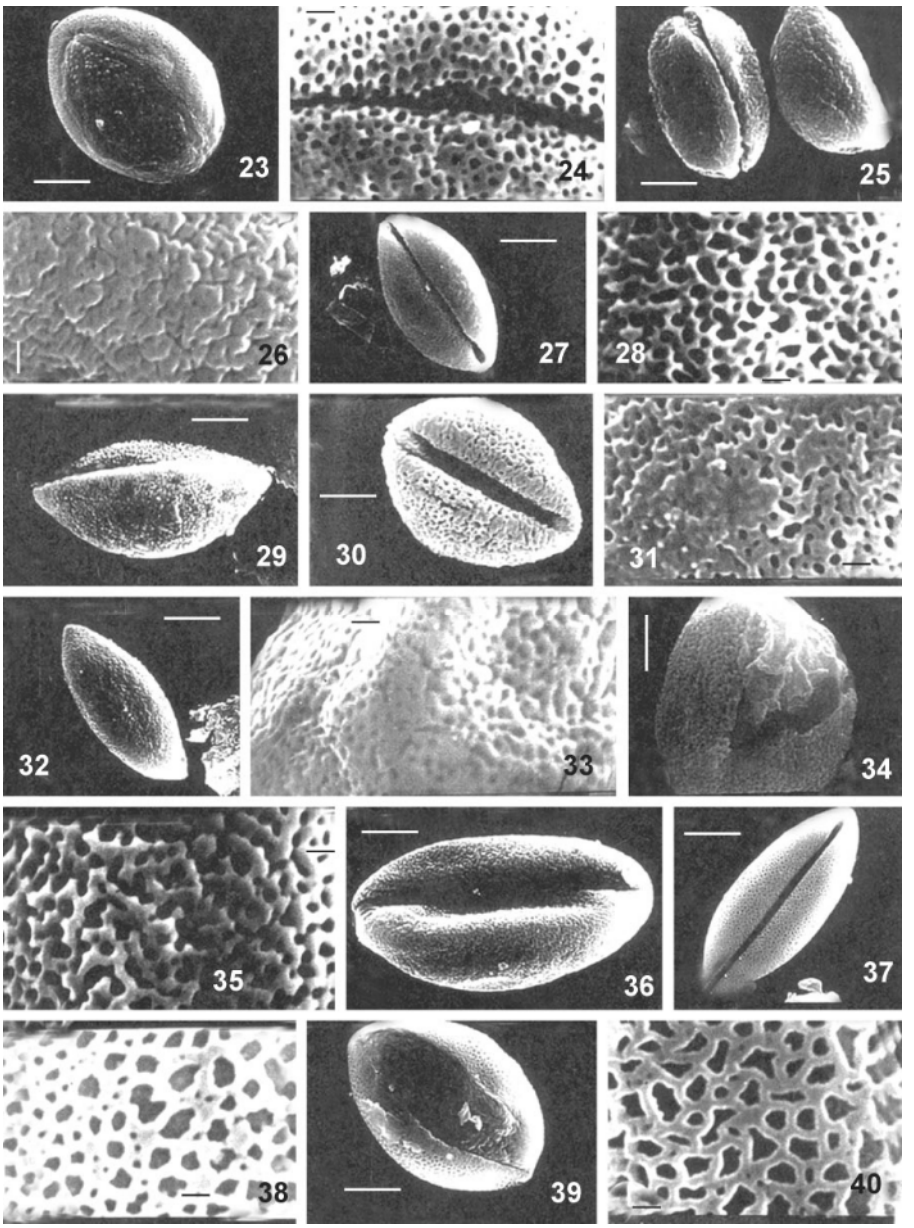
In this study, a comparative pollen morphological study of 20 entomogamous taxa, 15 of which are endemic, were done using LM, SEM. Four taxa belonging to *Asparagus* and *Fritillaria* were also examined with TEM in addition to LM and SEM. The common characteristic of the pollen grains of the investigated taxa is that their pollen apertures are monad monosulcate. It was observed that only a small amount of dyad pollen was found in *F. crassifolia* subsp. *crassifolia*. Kosenko (1991a) found that *F. eduardii* had dyad and tetrad pollens. The predominance of monosulcate aperture in monocotyledons, as in Asparagales and Liliales, is emphasized by Harley and Zavada (2000). Liliaceae and overwhelming majority of Lilialean complex have monosulcate pollens. The evolution of distal sulcate pollen may have occurred in Mezosoic geological periods. Typically, monoaperturate *Asparagus* and *Fritillaria* pollens are shed as ellipsoidal monads. Monosulcate aperture may be strong palynological evidence for the common origin of monocotyledon and dicotyledons. Sulcate, colpate, colporate pollen apertures are the most common in biotically pollinated families and sulcate pollen has a much older pollen record than those of both porate and colpate pollen (Kuprianova 1969, 1979, Sporne 1972, Zavada 1983, Linder 2000).

During the present study, some remarkable differences in the measurement of dimensions were observed between taxa. Among the examined genera, the biggest pollen size was found in *F. sibthorpiana* and *A. persicus* (Table 1). *F. armena* species studied by Kosenko (1991a), is discussed under *F. pinardii* Boiss in Turkish flora (Davis *et al.* 1988).

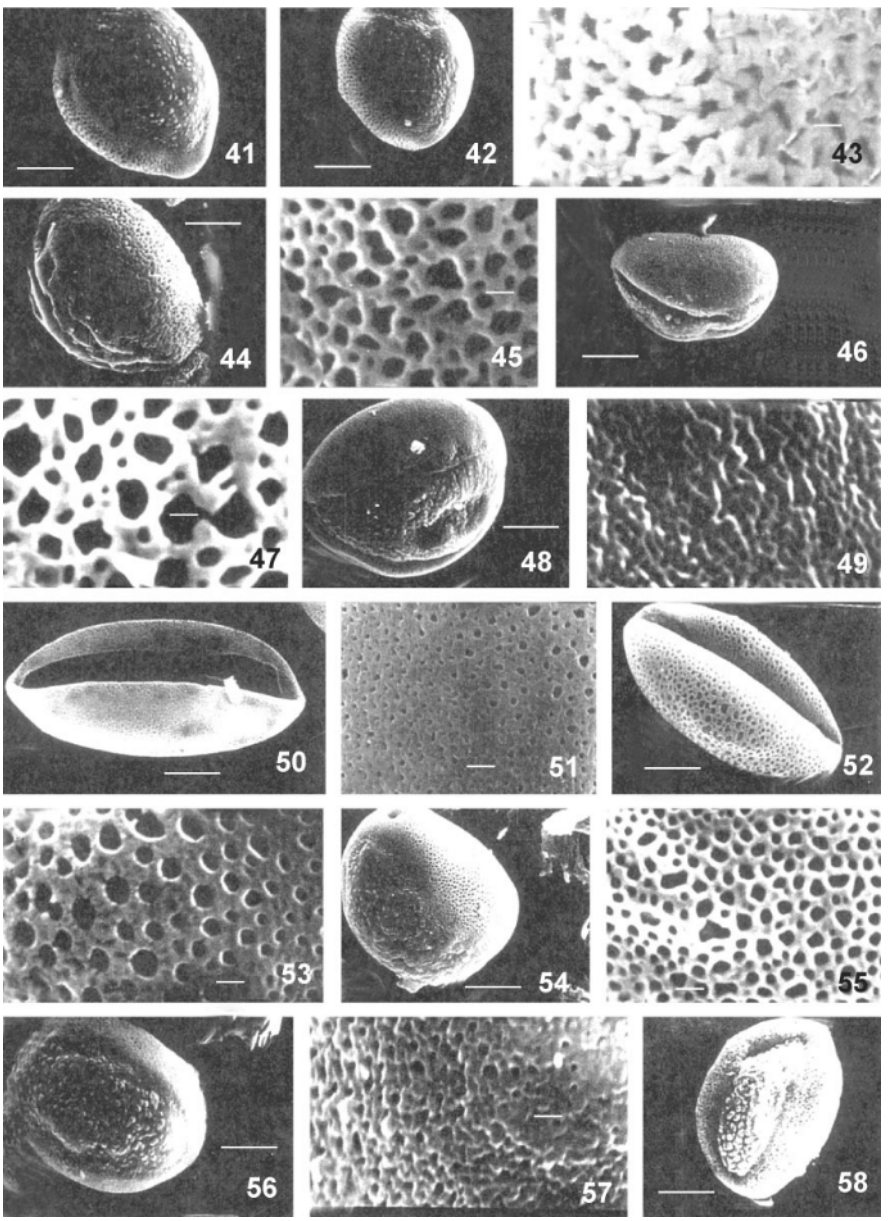
No data about sulcus extention to proximal and sulcus ends have been observed in any work other than those by Schulze (1980), Pehlivan and Ozler (2003) and Guler and Pehlivan (2006). Chanda *et al.* (1979) explained that extended sulcate type of aperture were not common and that were occasionally found in both dicotyledones and monocotyledones. The sulcus ends are rounded in all investigated *Asparagus* pollens and in *Fritillaria* pollen grains except for *F. aurea* and *F. bithynica* (Figs.1-20, 23-58). The longest length of the sulcus (Slg) was seen in *F. aurea*, the shortest was in *A. coodei*. In comparison to *Asparagus*, the widest sulcus was measured in *Fritillaria* pollens (Table 1). Some researchers have shown that the sulcus features may be a taxonomic characteristic in some families (Schulze 1980, 1982, Faegri and Iversen 1989, Kosenko 1991a, 1991b, 1992, 1999, Halbritter and Hesse 1993, Friis *et al.* 1997).

No other previous studies related to these genera provided data about the sulcus membrane characteristics except for the research on *Fritillaria* species by Kosenko (1991a, 1992, 1999). According to Kosenko (1991a, 1999) sulcus membrane surface in *Fritillaria* species were granular or plicate granular and sulcus membrane surface were good characteristics for classification of *Fritillaria* and its subspecies. It was found that sulcus membrane is gemmate in *F. elwesii* and granulate in other *Fritillaria* species pollens. Sulcus membrane of *Asparagus* pollen grains are granulate and psilate. The edges of the sulcus are irregular in investigated taxa (Table 1, Figs.1-21, 23-58).

Semitectate, tectum perforate exine and thin exine in the examined taxa are primitive characteristics in monocotyledones and are observed in the early stages of angiosperm evolution (Radulescu 1973, Schulze 1980, 1982, El-Ghazali 1993, Kosenko 1991a, 1991b, 1999, Furness



Figs. 23-40 SEM microphotographs. 23-24. *Asparagus acutifolius* (× 1800). Pollen grain in distal view with granulate sulcus membrane (23). Reticulate ornamentation on sulcus side (× 10000) (24). 25-26. *A. verticillatus* Pollen grain in distal view on the left and in oblique view on the right (× 3000) (25). Rugulate ornamentation (× 10000) (26). 27-28. *A. officinalis* (× 2200) Pollen grain in distal view (27). Reticulate-rugulate ornamentation (× 10000) (28). 29. *A. lycicus* Pollen grain in distal view with reticulate-rugulate ornamentation (× 3000). 30-31. *A. coodei* Pollen grain in distal view (× 3000) (30). Reticulate-rugulate ornamentation (× 9000) (31). 32-33. *A. palaestinus* Pollen grain in proximal view (× 2000) (32). Reticulate-rugulate ornamentation (× 10000) (33). 34-35. *A. lycaonicus* Pollen grain in equatorial view with granulate sulcus membrane (× 5000) (34). Retipilate ornamentation (× 15000) (35). 36. *A. persicus* Pollen grain in distal view with rugulate ornamentation (× 3500). 37. *Fritillaria aurea* Pollen grain in distal view (× 1300). 38. *Fritillaria aurea* with suprareticulate ornamentation (× 8000). 39-40. *F. acmopetala* subsp. *wendelboi* Pollen grain in distal view with granulate sulcus membrane (× 1800) (39). Suprareticulate ornamentation (× 8000) (40). (Scale = 10 µm Figs. 23, 25, 27, 29, 30, 32, 34, 36, 37, 39 and rest 1µm).



Figs. 41-58 SEM microphotographs. 41. *F.whitallii* pollen grain in distal view with granulate sulcus membrane (× 1800). 42-43. *F. crassifolia* subsp. *crassifolia* Pollen grain in distal view with granulate sulcus membrane (× 1500) (42). Reticulate ornamentation (× 10000) (43). 44-45. *F. michailovskyi* Pollen grain in distal view (× 1600) (44). Suprareticulate ornamentation (× 9500) (45). 46-47. *F. alburyana* Pollen grain in distal view with granulate sulcus membrane (× 1500) (46). Reticulate ornamentation (× 10000) (47). 48-49. *F. bithynica* Pollen grain in distal view with granulate sulcus membrane (× 2000) (48). Rugulate-reticulate ornamentation (× 10000) (49). 50-51. *F. fleischeriana* Pollen grain in distal view(× 2000) (50). Striate-reticulate ornamentation (× 5500) (51). 52-53. *F. sibthorpiana* Pollen grain in distal view (× 1500) (52). suprareticulate ornamentation (× 6000) (53). 54-55. *Fritillaria minima* Pollen grain in distal view with granulate sulcus membrane (× 1800) (54). Reticulate ornamentation (× 8500) (55). 56-57. *F. armena* Pollen grain in distal view with granulate sulcus membrane (× 2000) (56). Rugulate-reticulate ornamentation (× 10000) (57). 58. *F. elwesii* Pollen grain in distal view with gemmate sulcus membrane (× 1500). (Scale = 10 µm Figs. 41, 42, 44, 46, 48, 50, 52, 54, 56, 58 and rest 1 µm).

Table 1. Pollen morphological parameters of *Asparagus* and *Fritillaria* taxa.

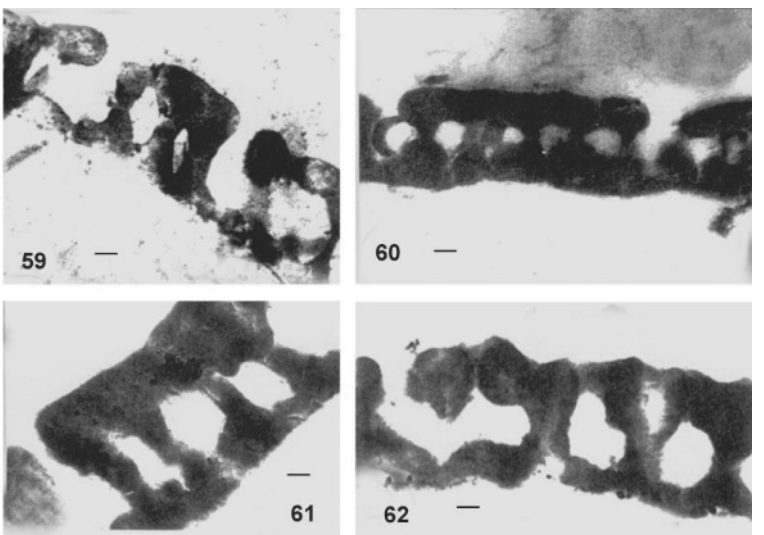
Taxon	A µm	B µm	A/B µm	Slg µm	Slt µm	Exine µm	Intine	Orn	SMO
A. acutifolius (W)	25.29 ± 1.83	18.98 ± 1.27	1.33	29.46 ± 2.16	5.28 ± 1.89	1.02 ± 0.13	0.81 ± 0.47	R	G
A. acutifolius (E)	27.93 ± 2.0	17.25 ± 2.11	1.61	31.15 ± 2.47	3.96 ± 1.17	1.57 ± 0.22			
A. verticillatus (W)	20.91 ± 0.95	17.28 ± 1.20	1.21	26.72 ± 3.01	6.38 ± 1.04	1.07 ± 0.18	0.94 ± 0.20	Rg	Rg
A. *verticillatus* (E)	22.87 ± 1.46	18.15 ± 1.93	1.26	27.70 ± 3.39	7.68 ± 1.85	1.39 ± 0.30			
A. officinalis (W)	27.16 ± 1.62	19.74 ± 1.21	1.37	32.37 ± 2.93	6.33 ± 1.68	1.18 ± 0.32	0.84 ± 0.17	R-Rg	Rg
A. officinalis (E)	31.37 ± 2.91	22.28 ± 2.05	1.40	35.70 ± 2.99	5.44 ± 1.90	1.74 ± 0.22			
A. lycicus (W)	27.28 ± 2.90	19.22 ± 2.85	1.41	34.76 ± 3.29	6.33 ± 1.68	1.18 ± 0.32	0.84 ± 0.17	R-Rg	Rg
A. lycicus (E)	37.92 ± 3.56	21.91 ± 2.81	1.73	43.20 ± 4.30	5.44 ± 1.90	1.74 ± 0.22			
A. coodei (W)	25.40 ± 2.52	17.79 ± 2.40	1.42	21.36 ± 2.90	5.48 ± 2.04	1.00 ± 0.14	0.83 ± 0.09	R-Rg	Rg
A. coodei (E)	31.08 ± 2.01	24.45 ± 1.47	1.27	26.37 ± 3.50	8.83 ± 2.31	1.65 ± 0.22			
A. lycaonicus (W)	24.42 ± 1.51	16.40 ± 1.18	1.48	29.34 ± 1.97	5.04 ± 0.87	1.00 ± 0.17	0.81 ± 0.16	Rt	G
A. lycaonicus (E)	0.66 ± 2.33	19.57 ± 3.95	1.56	35.46 ± 2.99	5.09 ± 1.87	1.50 ± 0.31			
A. persicus (W)	30.80 ± 1.66	21.76 ± 1.43	1.41	35.32 ± 3.16	8.28 ± 2.17	1.17 ± 0.30	0.78 ± 0.13	Rg	G
A. persicus (E)	38.91 ± 3.27	22.72 ± 3.17	1.71	44.80 ± 4.16	6.03 ± 2.12	1.78 ± 0.22			
A. palaestinus (W)	28.97 ± 4.43	20.01 ± 1.43	1.27	32.57 ± 2.37	5.30 ± 1.42	0.99 ± 0.17	0.76 ± 0.19	R-Rg	P
A. palaestinus (E)	36.51 ± 3.51	24.42 ± 1.47	1.49	41.72 ± 3.23	4.45 ± 1.26	1.79 ± 0.22			
F. aurea (W)	48.03 ± 2.58	35.27 ± 2.91	1.36	55.95 ± 3.49	16.48 ± 5.22	1.68 ± 0.38	0.81 ± 0.31	R	G
F. aurea (E)	60.27 ± 3.06	41.22 ± 4.26	1.46	66.91 ± 3.36	20.73 ± 4.47	2.16 ± 0.37			
F. acmopetala sub sp. *wendelboi* (W)	50.37±1.84	34.60 ± 2.12	1.45	45.15 ± 2.67	12.28 ± 3.14	1.93±0.52	0.85 ± 0.24	R	G
F. acmopetala subsp. *wendelboi* (E)	54.95 ± 4.53	40.15 ± 3.21	1.36	48.00 ± 3.67	14.80 ± 4.72	2.08 ± 0.33			
F. whittallii (W)	45.07 ± 2.81	34.71 ± 3.08	1.29	40.32 ± 3.28	21.34 ± 3.44	1.62 ± 0.31	0.81 ± 0.18	R	G
F. whittallii (E)	54.30 ± 2.45	42.84 ± 2.03	1.26	49.82 ± 4.53	22.01 ± 4.89	2.00 ± 0.20			
F. crassifolia subsp. *crassifolia* (W)	44.73 ± 2.5	33.24 ± 1.79	1.34	39.16 ± 3.22	13.06 ± 2.17	1.90 ± 0.26	0.79 ± 0.26	R	G
F. crassifolia subsp. *crassifolia* (E)	55.32 ± 3.10	37.04 ± 3.80	1.49	48.68 ± 3.43	12.26 ± 5.13	1.89 ± 0.14			
F. michailovskyi (W)	45.15 ± 1.68	36.12 ± 1.22	1.25	40.76 ± 1.63	23.47 ± 2.24	1.99 ± 0.30	1.25 ± 0.44	R	G
F. michailovskyi (E)	58.67 ± 3.89	41.67 ± 2.06	1.40	49.01 ± 5.66	16.72 ± 5.51	2.04 ± 0.19			
F. alburyana (W)	49.68 ± 2.25	35.68 ± 1.79	1.39	43.63 ± 3.05	16.05 ± 4.08	2.10 ± 0.28	0.93 ± 0.23	R	G
F. alburyana (E)	60.45 ± 2.17	42.79 ± 3.11	1.41	49.92 ± 3.51	13.99 ± 3.91	2.01 ± 0.78			
F. bithynica (W)	43.22 ± 2.67	32.72 ± 3.71	1.32	47.52 ± 4.61	17.87 ± 4.68	1.96 ± 0.17	0.90 ± 0.16	Rg-R	G
F. bithynica (E)	49.17 ± 8.31	34.98 ± 3.95	1.40	49.44 ± 4.21	15.00 ± 3.76	1.90 ± 0.20			
F. fleisheriana (W)	49.60 ± 3.41	35.41 ± 5.22	1.40	44.66 ± 4.24	15.00 ± 5.18	1.77 ± 0.17	0.86 ± 0.25	St-R	G
F. fleisheriana (E)	58.89 ± 4.77	42.76 ± 3.65	1.37	35.20 ± 3.65	18.52 ± 5.74	1.90 ± 0.01			
F. sibthorpiana (W)	43.76 ± 2.27	30.68 ± 2.82	1.42	47.96 ± 2.40	12.24 ± 3.76	1.84 ± 0.29	0.84 ± 0.09	SR	G
F. sibthorpiana (E)	66.81 ± 2.98	36.17 ± 2.90	1.84	70.40 ± 3.71	11.04 ± 3.10	1.92 ± 0.15			
F. minima (W)	46.27 ± 1.43	37.48 ± 1.91	1.23	41.14 ± 1.87	23.76 ± 2.22	1.85 ± 0.23	1.07 ± 0.27	R	G
F. minima (E)	59.43 ± 3.08	40.98 ± 1.83	1.45	46.13 ± 4.27	14.19 ± 3.26	1.93 ± 0.10			
F.armena (W)	46.27 ± 2.40	33.74 ± 1.38	1.37	41.11 ± 2.64	15.36 ± 4.97	1.90 ± 0.15	0.88 ± 0.18	R	G
F. armena (E)	48.55 ± 4.36	36.20 ± 3.07	1.34	42.86 ± 4.19	13.30 ± 3.09	1.88 ± 0.06			
F. elwesii (W)	42.75 ± 1.83	33.60 ± 1.66	1.27	38.29 ± 2.47	18.53 ± 4.56	1.85 ± 0.27	0.84 ± 0.23	Rg-R	Gm
F. elwesii (E)	54.82 ± 3.81	37.44 ± 3.19	1.46	49.16 ± 3.32	11.52 ± 4.07	1.92 ± 0.08			

A: Long axis of pollen grains, B: Short axis of pollen grains, Slg: Length of the sulcus , Slt: Width of the sulcus, (W): Non acetolyzed pollen grains (LM), (E): Acetolyzed pollen grains (LM), Orn (Ornamentation): Sculpture of pollen wall , SMO: Sulcus membrane ornamentation R: Reticulate, Rg: Rugulate, SR: Suprareticulate, St : Striate, Rt: Retipilate, G: Granulate, Gm: Gemmate

and Rudall 2000, Simpson 1983, 1985, 1987**,** Takahashi 1987, Zavada 1983, 1984, Walker 1974 a, 1974 b, Crane 1989, Hughes and Audrey 1994, Pehlivan and Ozler 2003, Guler and Pehlivan 2006).

As a result of TEM examinations, we also observed that endexine is very thin in all examined taxa (Figs. 59-62). Ectexine is thicker in *Fritillaria* pollen grain in comparison to

Asparagus pollen grains. While endexine is very thin and uninterrupted in *A. verticillatus* it is interrupted in *A. palaestinus*, *F. whitallii* and *F. armena*. The perforation number is observed to be the greatest in *A. lycicus* and in *F. armena*. In the investigated taxa, exine sculpture is reticulate, reticulate-rugulate, striate-reticulate, retipilate and suprareticulate (Figs. 23-58). El-Ghazali (1993) explained that *Asparagus flagellaris* pollen had psilate exine sculpture. However, we haven't observed such an exine sculpture in *Asparagus* pollens. Reticulate, microreticulate, macroreticulate, faveolate-plicate, and tuberculate exine structure were mentioned in previous studies of *Fritillaria* pollen grains (Radulescu 1973, Schulze 1980, Kosenko 1991a, 1999). In this study it is detected that reticula are rather big in *Fritillaria* pollens in comparison with the *Asparagus* taxa (Figs.23-36). According to Kosenko (1991a, 1992) small reticulae are more plesiomorphic characteristics than big ones. Kosenko (1991a) and Radulescu (1973) had grouped *Fritilaria* pollen grains according to the density of reticula. Schulze (1982) found out that the diameter of the lumina was under 1µm or approximately 2µm in *Asparagus*. During the present study it was found that the diameter of lumina was 0.10-0.55µm in *Asparagus* pollens. Schulze (1980, 1982) stated that the diameter of reticula were 1-4 µm in *Fritillaria*. In the present study, it was observed that the diameter of lumina is approximately 0.17-0.97 µm in *Fritillaria* pollens.



Figs. 59-62. TEM microphotographs of exine structure (× 30000). 59. *A. verticillatus*, 60. *A. palaestinus.* 61. *F.whitallii*, 62. *F. armena*. Scale = 0.23 µm.

Ornamentational characteristics of pollen grains of the investigated taxa as observed in SEM micrographs have been used for their diagnostic features and accordingly both *Asparagus* and *Fritillaria* are proposed to be divided into four types as shown below:

Index

Asparagus

Type I: Ornamentation is reticulate: *A. acutifolius*

Type II: Ornamentation is rugulate: *A. verticillatus* and *A. persicus.*

Type III: Ornamentation is retipilate: *A. lycaonicus*

Type IV: Ornamentation is reticulate-rugulate: *A. officinalis*, *A. lycicus*, *A. coodei*, and *A. palaestinus*

Fritillaria:

Type I: Ornamentation is suprareticulate: *F. sibthorpiana*, *F. aurea*, *F. acmopetala* subsp. *wendelboi* and *F. michailovskyi*.

Type II: Ornamentation is reticulate: *F. whittallii*, *F. crassifolia* subsp. *crassifolia*, *F. alburyana*, *F.minima* and *F. elwessii*.

Type III: Ornamentation is rugulate-reticulate: *F. bithynica* and *F. armena*.

Type IV: Ornamentation is striate-reticulate: *F. flesheriana*.

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