VERSITA

Biologia **63**/1: 53—60, 2008
Section Botany
DOI: 10.2478/s11756-008-0016-0

Pollen morphology of some *Paronychia* species (Caryophyllaceae) from Turkey

Ayşe Kaplan

Department of Biology, Faculty of Art and Sciences,University of Zonguldak, Incivez. 67100, Zonguldak, Turkey; email: a_kaplan007@yahoo.com.

Abstract: The Pollen morphology of 13 taxa 11 of which are endemics belonging to *Paronychia* Miller (Caryophyllaceae) viz., *P. agryloba*, *P. angorensis*, *P. arabica* subsp. *euphratica*, *P. carica*, *P. cataonica*, *P. chinonea*, *P. condensata*, *P. davisii*, *P. dudleyi*, *P. galatica*, *P. kurdica* subsp. *kurdica*, *P. kurdica* subsp. *montis-munzur* and *P. mughlaei* from Turkey has been investigated by light (LM) and scanning electron microscopy (SEM). LM observations show that pollen grains are usually radially symetrical, isopolar, pantoporate, polygonal (6–gonal) or polygonal-spheroidal. Tectum is psilate or punctate. Tectal surface sparsely-densely spinulose. The numbers of pores are between 6 and 12. On the basis of pollen sizes, *P. davisii* was the biggest pollen type (23.45 μm) and *P. kurdica* subsp. *kurdica* (16.2 μm) was the smallest pollen types. According to exine sculpturing, pollen size and spinule numbers per 1 μm^2, three pollen types were distinguished.

Key words: *Paronychia*; Caryophyllaceae; pollen morphology; Turkey

Introduction

The *Paronychia* genus has been placed in Illecebraceae by some authors (Davis 1967; Perveen & Qaiser 2003) and Caryophyllaceae by the others (Wills 1966; Nowicke 1975; Erdtman 1986; Güner et al. 2000). Some authors have regarded Illecebraceae as only a subfamily of the Caryophyllaceae (Subfam. *Paronychioideae*) (Wills 1966). In reclassification of this family, this genus has been replaced in the Caryophyllaceae by Angiosperm Phylogeny Group II (Soltis et al. 2005).

Turkish *Paronychia* is distributed in Irano-Turanien and East-Mediterranian phytogeoraphic region (Davis 1967). This genus is represented by 28 species, 20 of which are endemics (Davis 1967). According to IUCN and Red Data Book of Turkish Plants (Ekim et. al. 2000) the status of endemic *Paronychia* species are as follows: *P. davisii* endangered (EN); *P. angorensis*, *P. arabica* subsp. *euphratica*, *P. carica*, *P. cataonica*, *P. kurdica* subsp. *montis-munzur* and *P. mughlaei* vulnerable (VU); *P. agryloba, P. condensata, P. dudleyi,* and *P. galatica* low risk (LR).

Pollen morphology of the family Caryophyllaceae has been examined by a number of workers such as Erdtman (1952); Buxbaum (1961); Nowicke (1975); Rao & Shukla (1975); Skvarla & Nowicke (1976); Nowicke & Skvarla (1977,1979); Moore & Webb (1978); Erdtman (1986); Perveen & Qaiser (2003).

Pollen morphology of *Paronychia* has received little attention. Nowicke (1975) studied *Paronychia microphylla* under the SEM and made a comparison between pollen morphology of other Caryophyllaceae species. She defined three main pollen types (Type I, Type II, and Type V) for Caryophyllaceae. She placed *P. microphylla* in the Type II pollen grains. *Paronychia argentea* was studied by Erdtman (1986) only using light microscope.

In this study, pollen morphology of 13 taxa 11 of which are endemics belonging to Turkish *Paronychia* Miller were investigated by using light microscope (LM) and scanning electron microscope (SEM). The different and similar characteristics of the species were determined.

Material and methods

Pollen samples were obtained from Gazi University Herbarium (GAZI) and Hacettepe University Herbarium (HUB). The list of voucher specimens is given in Table 1. The pollen grains were prepared for light microscopy (LM) by the standard methods described by Erdtman (1989). For light microscopy, the pollen grains were mounted in unstained glycerine jelly and observations were made with a Nikon Type E-200 microscope under (640, 0.65) and oil immersion (E100, 1.25), using 20 × eye piece. For SEM studies, pollen grains suspended in a drop of water were directly transferred with a fine pipette to a metallic stub using double sided cellotape and coated with gold in a sputtering chamber (Polaron SC500). Coating was restricted to 30 mA for 4 minutes. The S.E.M examination was carried out on a Jeol microscope JSM-5600.

The measurements were based on 30 readings from each specimen. Pollen diameter, pore diameter and exine thickness were also measured (see Table 2). Spinules were visible only on SEM photographs. Therefore, spinules were counted on SEM photographs and converted to per 1 μm^2.

Table 1. Herbarium specimens investigated.

1. *P. agryloba* Stapf	H.Sümbül	C4 Antalya, GAZİ 1124, HUB 1124
	M.Vural	C4 Konya, GAZİ 1298
2. *P. angorensis* Chaudri	R.D.Reeves & U.Kramer	Balıkesir, GAZİ 1606
3. *P. arabica* (L.) DC. subsp. *euphratica* Chaudri	H.Peşmen & A.Güner	B7 Erzincan, HUB 2237
4. *P. carica* Chaudri	Z.Aytaç & N.Adıgüzel 1996	C5 Konya Ereğli, GAZİ 7171
5. *P. cataonica* Chaudri	H.Duman & Z.Aytaç	B6 Kayseri, GAZİ 51976
6. *P. condensata* Chaudri	M.Vural, Ü. Kol, N.Adıgüzel	B5 Nevşehir, GAZİ 4876
	Z.Aytaç & N.Adıgüzel	C5 Mersin, GAZİ 6960
	M.Vural ve ark. 1989	B5 Nevşehir, GAZİ 5231
7. *P. chinonea* Boiss	H.Duman, 1984	C6 Kahramanmaraş, GAZİ 1765
8. *P. davisii* Chaudri	H.Özçelik, 1995	Isparta, GAZİ 7107
9. *P. dudleyi* Chaudri	Z.Aytaç & H.Duman, 1994	B6 Kayseri, GAZİ 5197a
	H.Duman & Z.Aytaç	A4 Ankara, GAZİ A.1915
10. *P. galatica* Chaudri	E.Hamzaoğlu, 1992	B6 Sivas, GAZİ EH-477
11. *P. kurdica* Boiss subsp. *kurdica*	Ü.Güler, 1993	Kırıkkale, GAZİ 1157
	H.Duman	C6 Kahramanmaraş, GAZİ 4153
	H.Duman	B7 Elazığ, GAZİ 7830
	H.Duman	C6 Kahramanmaraş, GAZİ 3116
	T.Ekim	B7 Elazığ, GAZİ 7122
12. *P. kurdica* Boiss subsp. *montis-munzur* Chaudri	Ş.Yıldırımlı	B7 Tunceli, HUB 3492
13. *P. mughlaei* Chaudri	H.Peşmen & A.Güner	C3 Burdur, HUB 1686

Table 2. Measurements and exine characteristics of pollen grains of *Paronychia* Miller.

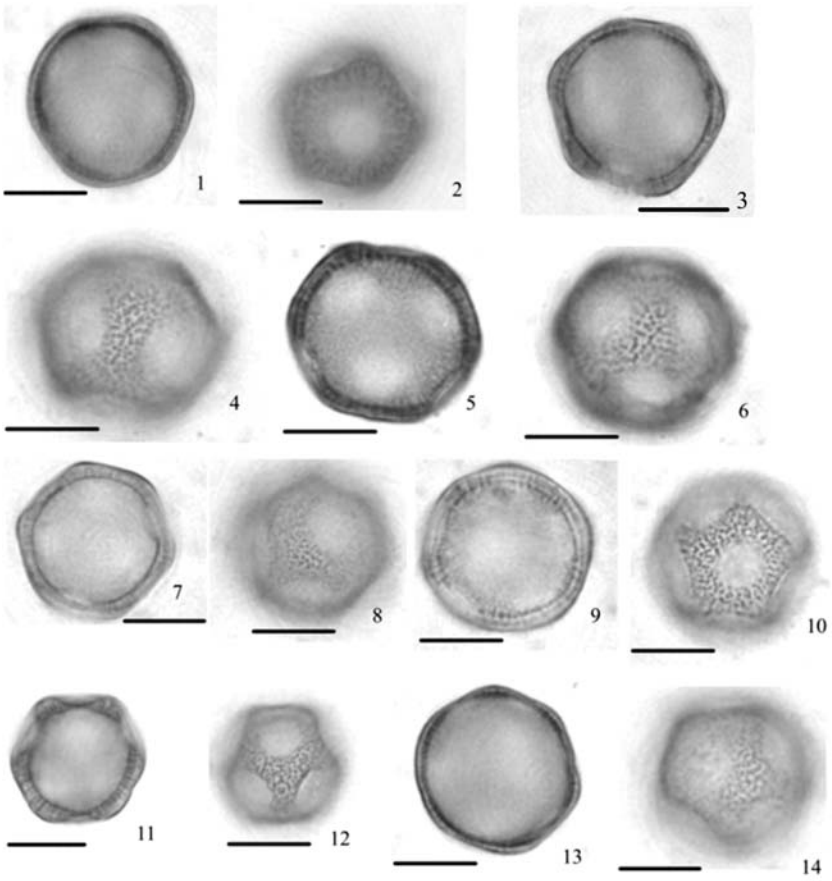
TAXA	Pollen type	P (mean±SD)	E (mean±SD)	Shape	Exine (mean±SD)	Es	Sp (1 μm^2) (mean±SD)	Pd (mean±SD)	Al	Pl
1. *Paronychia agryloba*	8–10 porate	20.20±1.14 (18–22)	20.90±1.52 (18–23)	poly-sp	1.85±0.27	2	2.29±0.47	6.1±0.99	s-ex	sc-v
2. *P. angorensis*	6–12 porate	20.80±1.00 (17–22)	20.70±1.9 (18–24)	poly	1.88±0.21	2	2.95±0.62	5.7±1.66	u-ex	sc
3. *P. arabica* subsp. *euphratica*	8–10 porate	18.50±1.46 (16–20)	17.85±1.73 (15–21)	poly	1.84±0.17	2	2.50±0.64	4.7±0.95	u-ex	sc
4. *P. carica*	12 porate	18.50±0.74 (17.5–20)	19.24±0.88 (18–21)	poly	2.06±0.13	3	3.08±0.76	5.5±0.53	u-ex	sc-v
5. *P. cataonica*	12 porate	20.30±0.86 (19.5–21)	19.55±0.87 (18.5–20.5)	poly	1.92±0.18	3	3.95±1.18	4.7±0.21	u-ex	sc
6. *P. chinonea*	6–12 porate	19.70±1.70 (18–23)	20.05±1.85 (16–22)	poly-sp	1.91±0.19	2	2.24±0.83	5.3±0.67	u-ex	sc
7. *P. condensata*	10–12 porate	21.48±1.27 (20–23.5)	22.23±1.12 (20.5–24)	poly-sp	2.00±0.21	3	3.36±0.74	5.4±0.52	s-ex	sc
8. *P. davisii*	12 porate	23.46±0.73 (22–24)	19.77±0.74 (18–22)	poly	1.55±0.83	1	1.21±0.43	6.7±0.47	u-ex	sc
9. *P. dudleyi*	12 porate	22.59±0.98 (21–23.75)	23.40±0.52 (23–24)	poly	2.00±0.00	3	2.64±0.66	6.2±0.42	s-ex	sc
10. *P. galatica*	12 porate	19.80±1.00 (19–21)	20.50±1.00 (19.5–22)	poly	1.94±0.14	3	3.89±1.05	4.8±0.41	s-ex	sc
11. *P. kurdica* subsp. *kurdica*	6–12 porate	16.20±2.94 (12–21)	16.45±2.7 (13–22)	poly-sp	2.23±0.22	2	2.40±1.00	4.1±1.60	u-ex	sc
12. *P. kurdica* subsp. *montis-munzur*	6–12 porate	16.45±0.95 (14.5–18)	17.15±0.88 (15–18)	poly-sp	2.02±0.08	3	2.50±0.53	4.4±0.69	s-ex	sc
13. *P. muglaei*	6–12 porate	20.19±1.28 (19–22)	20.25±1.01 (19–22)	poly-sp	1.65±0.14	2	2.92±0.93	4.5±0.82	u-ex	sc

(P) Polar axis, (E) Equatorial diameter, (Exine) Exine thickness, (Shape) Pollen grain shape: (poly) polygonal. Exine sculpture (Es): (1) Sparsely scabrate-punctate, (2) Densely scabrate-punctate, (3) Densely scabrate-spinulose. (Sp) Spinule number per 1 μm^2, (Pd) Pore diameter. (Al) Aperture level: (u-ex) pores under the exine surface (sunken), (s-ex), pores at the same level with exine. (Pl) Pore plate: (sc-v) Scabrate-verrucate, (sc) Scabrate. All measurements in μm.

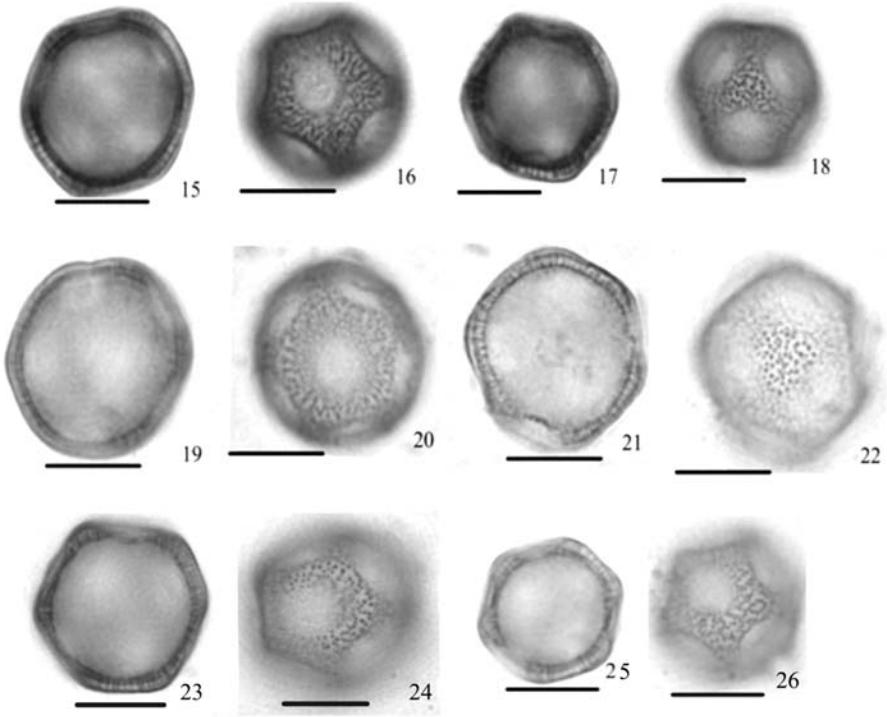
The terminology used is in accordance with Kremp (1965); Walker & Doyle (1976); Erdtman (1986); Faegri & Iversen (1989). For calculating the mean and standard deviation values, ANNOVA test in SPSS 13.0 for Windows was used. A cluster analysis was performed with Winstat for Excel using average taxonomic distance (UPGMA). Palynological characteristics used for cluster analysis are given in Table 2.

Results and discussion

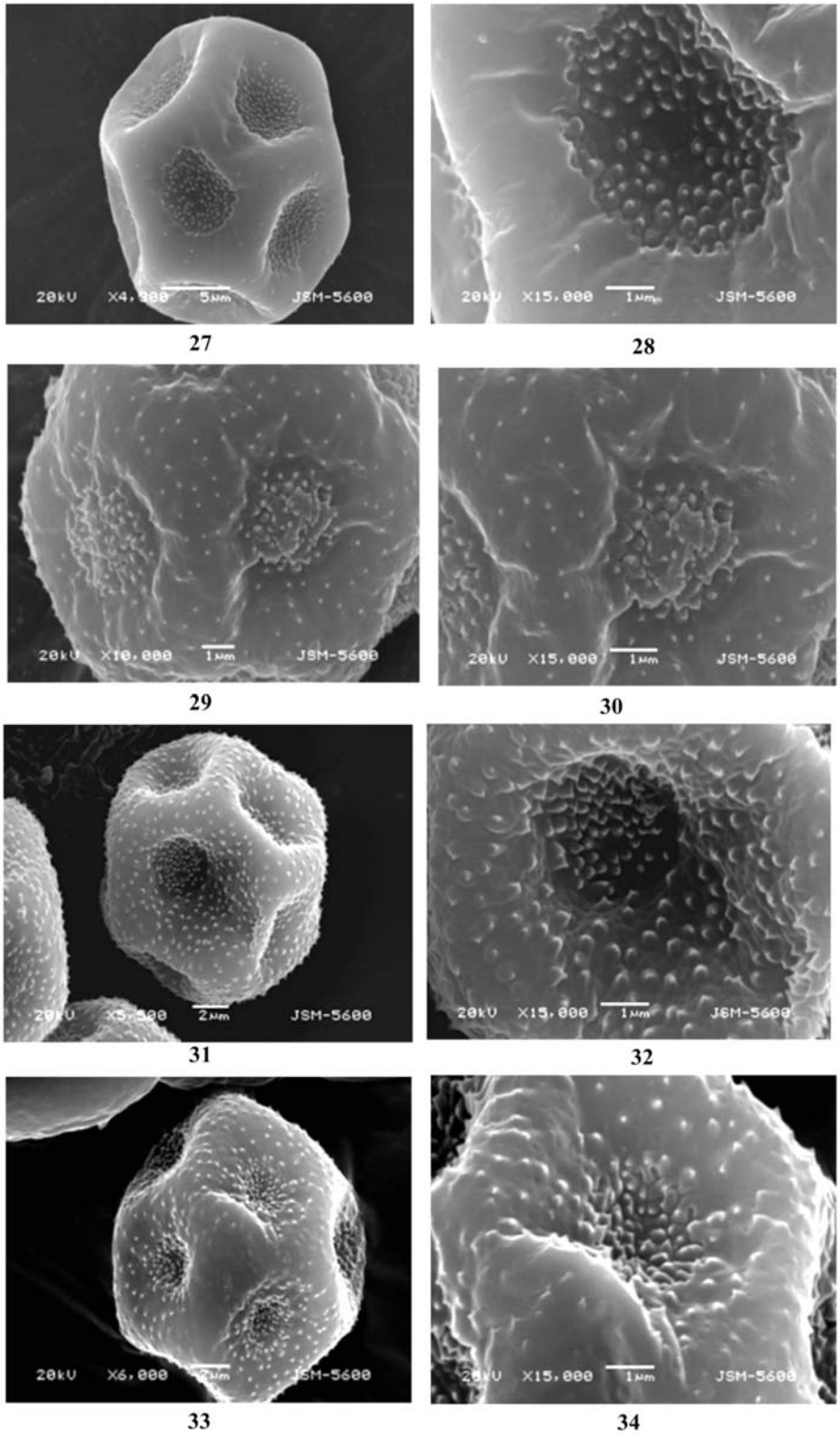
Pollen grains are isopolar, radially symmetrical, polygonal (6-gonal) or polygonal-spheroidal. Amb shape is hexagonal or interhexagonal. Regarding size, the studied *Paronychia* pollen grains have mean values of 19.82 μm (P) and 20.32 μm (E). The size of grains varies from



Figs 1–14. LM photographs of the pollen type I (*P. davisii*-type) and pollen type II.
1, 2 – *P. davisii*, equatorial views showing exine and very sparsely minute spinulose ornamentation. 3, 4 – *P. agryloba*, polar views showing exine and densely spinulose- punctate ornamentation. 5, 6 – *P. angorensis*, polar views showing exine and densely scabrate-punctate ornamentation. 7, 8 – *P. arabica* subsp. *euphratica*, polar views, showing exine and sparsely spinulose ornamentation. 9, 10 – *P. chinonea*, equatorial views. 11, 12 – *P. kurdica* subsp. *kurdica*. 13, 14 – *P. mughlaei*. Scale bars are 10 μm.



Figs 15–26. LM photographs of the pollen grains of Pollen type III. 15, 16 – *P. carica*, exine and subpolar views. 17, 18 – *P. cataonica*, polar views showing exine and densely scabrate spinulose exine sculpture. 19, 20 – *P. condensata,* equatorial views. 21, 22 – *P. dudleyi*, polar views. 23, 24 – *P. galatica*, polar views. 25, 26 – *P. kurdica* subsp. *montis-munzur*, polar views showing exine and densely scabrate-spinulose exine ornamentation.

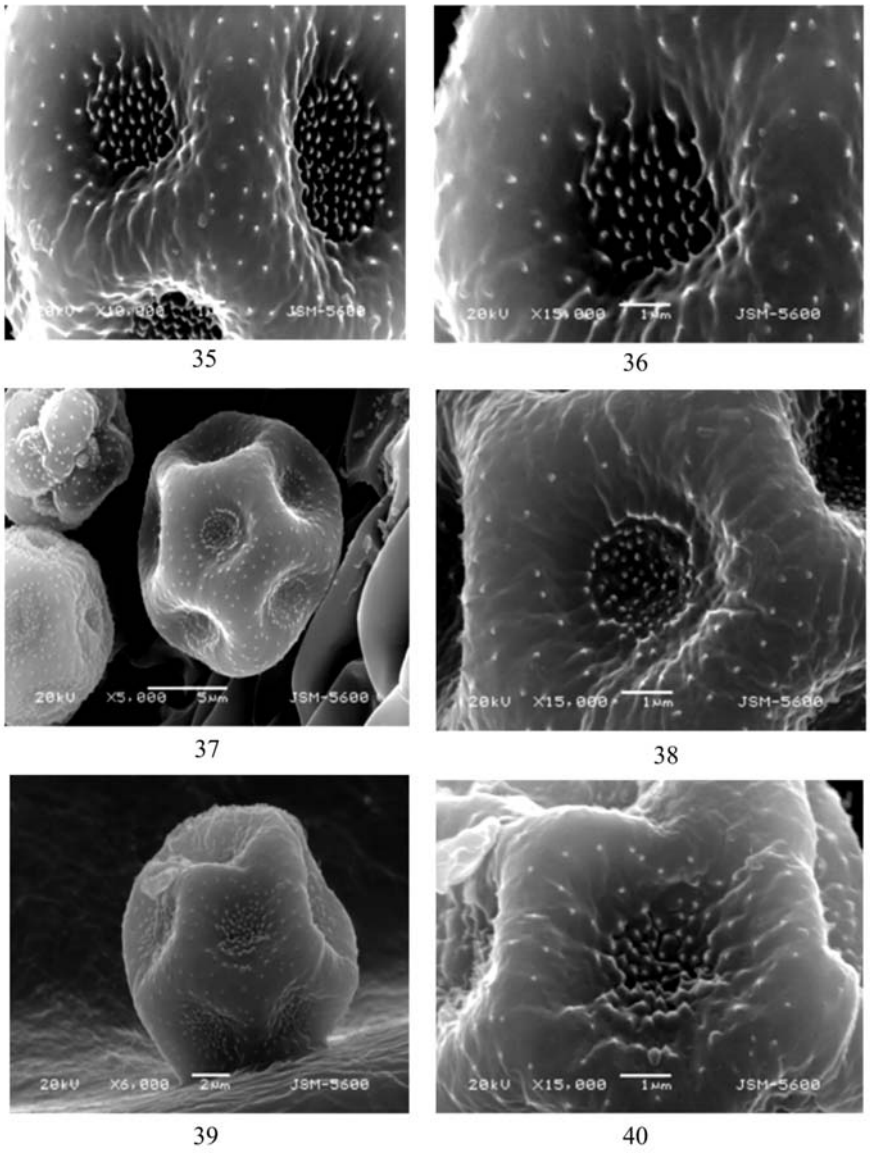


Figs 27–34. SEM photographs of the pollen type I and II. 27, 28 – *P. davisii*. 29, 30 – *P. agryloba*. 31, 32 – *P. angorensis*. 33, 34 – *P. arabica* subsp. *euphratica*.

16.20 (P) × 16.45 (E) μm in *P. kurdica* subsp. *kurdica* to 23.46 (P) × 19.8 (E) μm in *P. davisii* (Table 2).

Pollen grains are pantoporate, generally 6–12 porate. Pores ± circular and under the exine level (sunken) or at the same level with exine surface. Aperture plate present instead of operculum. Pore plate scabrate or scabrate-verrucate (Table 2). Exine thickness varies between 1.55 and 2.23 μm (Table 2). Tectum is psilate or punctate, intertectum is collumellate.

According to these results, pollen grains of examined species are uniform in the fundamental characteristics of symmetry (radially symmetrical), polarity (isopolar), aperture type (pantoporate, 6–12 porate), amb form (hexagonal or interhexagonal). Apart from



Figs 35–40. SEM photographs of the pollen type II. 35, 36 – *P. chinonea*. 37, 38 – *P. kurdica* subsp. *kurdica*. 39, 40 – *P. mughlaei*.

these conformities, some differences could be distinguished in exine sculpturing, spinule number per 100 μm^2 and grain size. Therefore, three pollen types were described.

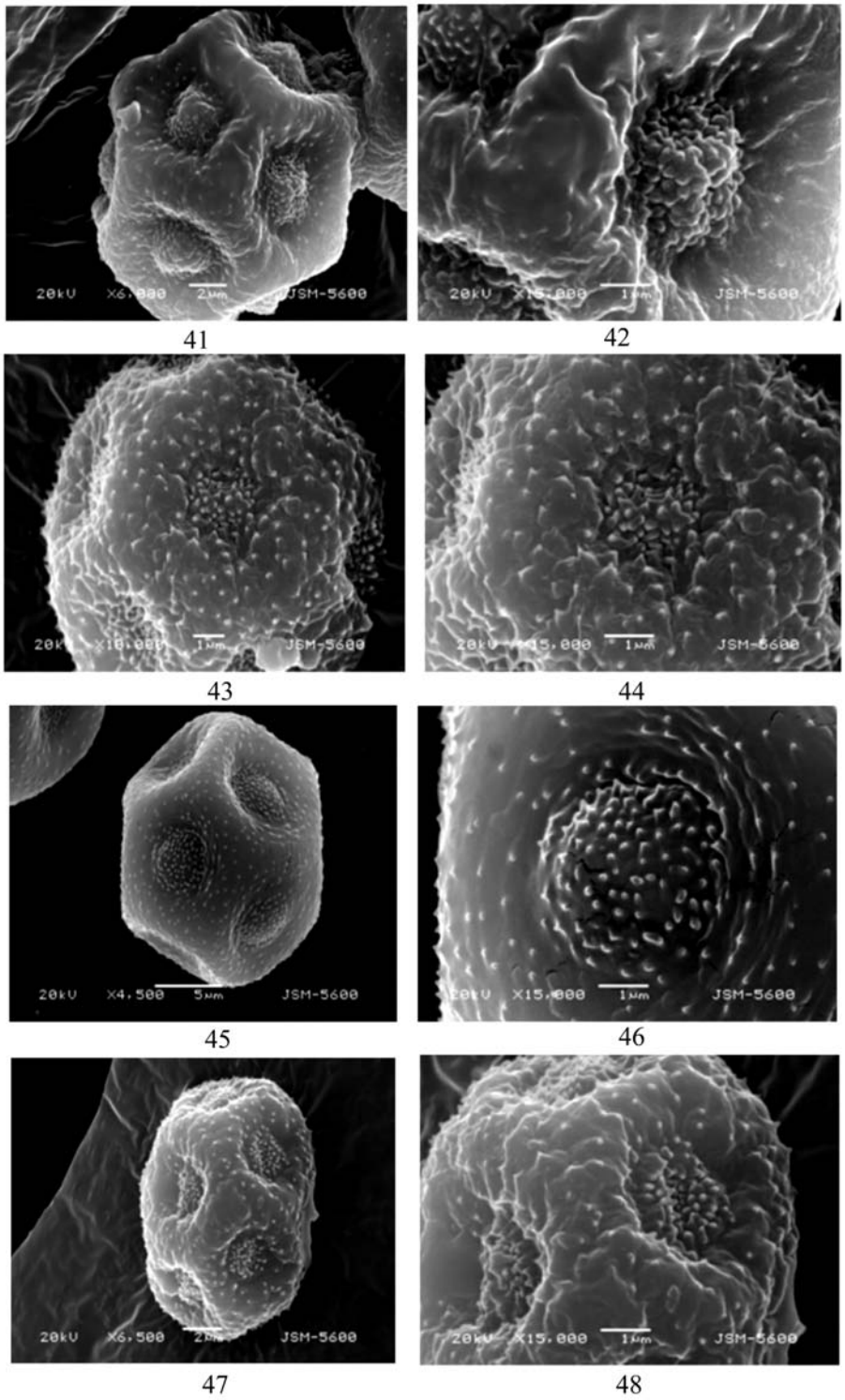
Pollen type I (P. davisii type): This type includes the biggest pollen grains represented by only one species, *P. davisii*. Exine ornamentation is sparsely-spinulose (1.21 ± 0.43 spinules per 1 μm^2) and punctate only around pores. The spinule length is 0.05μm. Pollen grains have also the thinnest exine and the longest pore diameter of all examined species. Pores are under the exine level (sunken), pollen shape is polygonal (6-gonal) (Figs. 1–2, 27–28).

Pollen type II: This type is characterized by densely scabrate-punctate exine sculpturing and 2.24 ± 0.95 spinule numbers per 1 μm^2. Pollen shape is polygonal or polygonal-spheroidal, exine thickness 1.65–2.23 μm, pore diameter 4.1–6.1 μm. This group includes medium and small sized pollen grains. This type is represented by *P. agryloba*, *P. arabica* subsp. *euphratica*, *P. chinonea*, *P. kurdica* subsp. *kurdica*, *P. angorensis* and *P. mughlaei*.

P. kurdica subsp. *kurdica* has the smallest pollen grains out of the 13 species. Pores at the same level with exine surface in *P. agryloba*, sunken in other species. Pore plate is scabrate-verrucate in *P. agryloba*, scabrate in the others (Figs 3–14, 29–34).

Pollen type III: This group is represented by *P. carica*, *P. cataonica*, *P. condensata*, *P. dudleyi*, *P. galatica* and *P. kurdica* subsp. *montis-munzur* (Figs 15–26, 35–51). Exine ornamentation is densely scabrate-spinulose, spinule numbers per 1 μm^2 are varying from 2.50 ± 0.95. Pollen shape is polygonal or polygonal-spheroidal, exine thickness 1.88–2.02 μm, pore diameter 4.4–6.7 μm. This type includes middle and small sized pollen grains. Pores are sunken in *P. cataonica* and *P. galatica*, but located at the same level with exine surface in the others. Pore plate is scabrate-verrucate in *P. carica*, scabrate in other species.

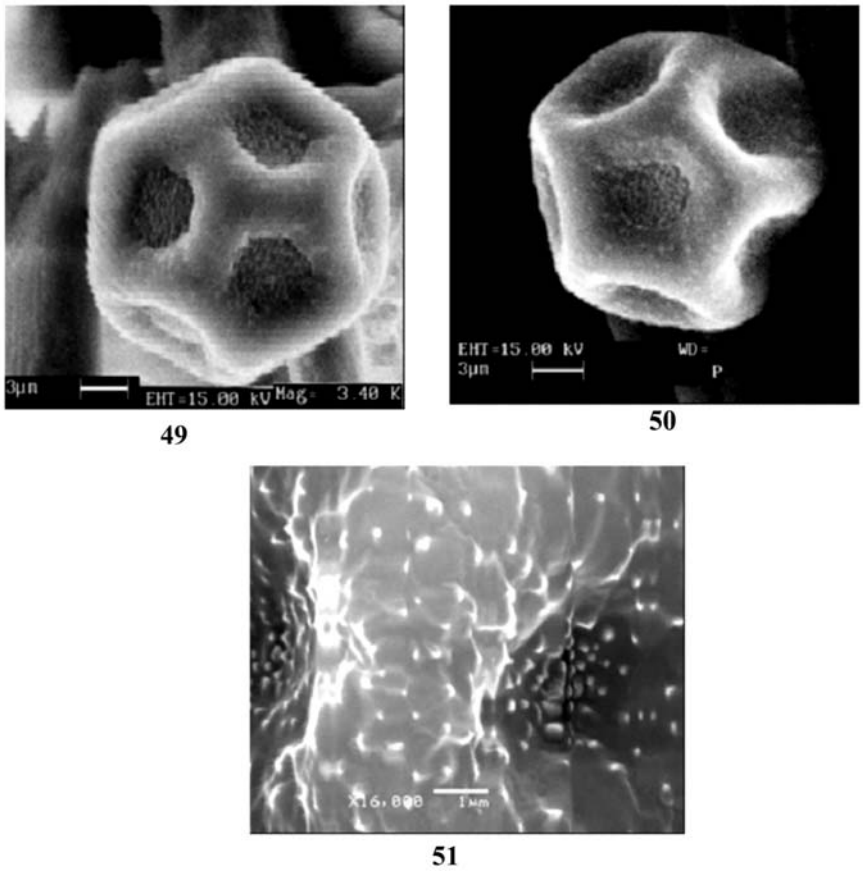
Pollen morphology of Caryophyllaceae family has



Figs. 41–48. SEM photographs of the pollen type III. 41, 42 – *P. carica*. 43, 44 – *P. condensata*. 45, 46 – *P. dudleyi*. 47, 48 – *P. kurdica* subsp. *montis-munzur*.

been studied by Nowicke (1975), Skvarla & Nowicke (1976), Yıldız (2001b) using SEM and TEM. Punt & Hoen (1999) established the pollen key for Caryophyllaceae except for *Paronychia*.

In comparison with other genera in Caryophyllaceae, Turkish *Paronychia* pollen grains seem somewhat similar to *Cerastium*, *Scleranthus and Dryphis* in Nowicke's Type II (Nowicke 1975). They also resemble *Herniaria* type of Perveen & Qaiser's (Perveen & Qaiser 2003). In *Dryphis* and *Scleranthus,* pollen grains are 11–12 porate with operculum and exine sculpturing is spinulate-punctate (Nowicke 1975; Punt & Hoen 1999). In *Cerastium*, pollen grains are usually 12 porate (Nowicke 1975), but more than 12 porate in *C. fontanum*, 12 (10–17) porate in *C. cerastoides* (Punt & Hoen 1999). Exine ornamentation is spinulate-punctate



49 50 51

Figs. 49–51. SEM photographs of the pollen type III. 49 – *P. galatica*. 50, 51 – *P. cataonica*.

(Nowicke 1975; Punt & Hoen 1999). In the present study, pollen types I and II are similar to these genera except for absence of annulus, margo and operculum.

In *Herniaria* type, pollen grains are 12 porate with scabrate-spinulose exine ornamentation (Perveen & Qaiser 2003). Punt & Hoen (1999) reported 4–6 porate (rarely more) pollen grains of *Hernaria glabra*. Type III pollen grains of Turkish *Paronychia* are similar to *Herniaria* type on the basis of exine sculpturing and pore number except for sunken pores and distinctly convex mesoporial exine.

Pollen grains of some genera (*Agrostemma* L., *Cucubalus* L., *Lychnis* L., *Melandirum* Röhl, *Stellaria* L. and *Silene* L.) in Caryophyllaceae have more pore numbers (15–45) than *Paronychia* (Chanda 1962; Nowicke 1975; Skvarla & Nowicke 1976; Iwarsson 1977; Punt & Hoen 1999; Yıldız 2001a).

Nowicke (1975) separated Type II pollen grains into two groups -those with a prominent mesoporial exine and those lacking this development. She supposed that this prominence may have been especially accentuated by SEM preparation techniques. Thus, Turkish *Paronychia* pollen can be located in the former category of Type II.

When the pollen key of Caryophyllaceae (Punt & Hoen 1999) is examined, it can be seen that Turkish *Paronychia* pollen grains are somewhat distinct from caryophyllaceous pollen because of lacking annulus, operculum and margo.

The phenogram resulting from the cluster analysis (average linkage agglomeriation method) is presented in Fig. 52. The palynological relationships of investigated 13 *Paronychia* taxa obtained by UPGMA clustering shown in the dendogram agree with the pollen types, but contradict the traditional relationships of Davis (1967).

In cluster analysis, the dendogram shows two closely related groups. The group of *P. cataonica, P. condensata, P. dudleyi* and *P. galatica* clustered close to each other and visualized at the 12 phenon line. The group of *P. angorensis*, *P. chinonea*, *P. arabica* subsp. *euphratica* and *P. mughlaei* visualized at the 15 phenon line. These groups clustered together at the 16 phenon line. Although exine ornamentations are different, these two groups seem rather homogenous. *P. agryloba* and *P. carica* separated from these two groups at the 22 phenon line since pore plate sculpturing is scabrate-verrucate. They related to each other at the 13 phenon line. *P. kurdica* ssp. *kurdica* and *P. kurdica* ssp. *montis-munzur* separated from the rest of the groups at the 24 phenon line. In this relationship, grain size and pore diameter masked exine sculpturing.

The nearest relationship was visualized at the 5.5 phenon line between *P. cataonica* and *P. galatica*, which are similar to each other in pollen ornamentation and pore plate sculpturing. *P. angorensis* is closely related to *P. chinonea* at the 6 phenon line, *P. condensata* is close to *P. dudleyi* at the 7 phenon line. P. *arabica*

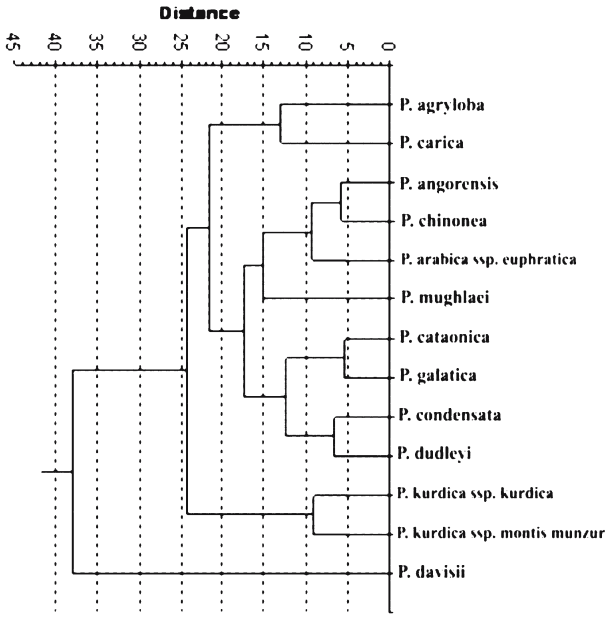


Fig. 52. Phenogram of the 13 studied taxa clustering with (UPGMA) method.

ssp. *euphratica* clustered with *P. angorensis* and *P. chinonea* at the 9 phenon line. *P. kurdica* subsp. *kurdica* is close to *P. kurdica* subsp. *montis-munzur* at the 9 phenon line. In this relationship, pollen size has masked the exine sculpture. *P. davisii* separated from the rest of the species at the 38 phenon line because of its different exine sculpturing, the biggest pollen size and the longest pore diameter.

According to Davis's (1967) traditional relationships are based on their morphological characters (leaf, gluma, bracte), *P. mughlaei* is close to *P. chinonea*. But in this phenogram, it was far from the group including *P. chinonea* at the 15 phenon line. It seems close to *P. arabica* ssp. *euphratica* at the 6 phenon line due to their similarity in exine sculpturing, pore diameter and pore plate ornamentation. Davis (1967) also established relationships between *P. condensata – P. angorensis, P. carica – P. chinonea, P. angorensis – P. davisii, P. davisii – P. agryloba, P. agryloba – P. davisii.* The dendogram (Fig. 52) obtained by cluster analysis contradicts these traditional treatments. Therefore, much further work on revision of Turkish *Paronychia* such as seed morphology and molecular studies is needed.

In the present study, palynological results show that there are some pollen characters of taxonomic significance in Turkish *Paronychia* such as densely scabrate or sparsely-densely scabrate-punctate exine sculpturing, spinule number, pollen size, pore level (sunken or at the same level with exine) and pore diameter. This study also supports the retention of *Paronychia* in tribe Paronychieae, Caryophyllaceae.

Acknowledgements

I am deeply grateful to Prof. Dr. Mecit Vural from Gazi University, Assoc. Prof. Dr. Ali Dönmez and Prof. Dr. Şinasi Yildirimli from Haccettepe University for his kind help with this research and for allowing me to use herbarium specimens. This work was supported by Turkish Scientific Research Concile (TUBITAK) through the research project (project No. TBAG-106T213-HD/150). I also thank the staff of SEM Laboratory of Kirikkale University for help with the SEM studies.

References

Buxbaum F. 1961. Vorlaufige untersuchungen uber Umfang systematische stellung und Gliderung der Caryophyllales (Centrospermae). Beitrage Biol. Pflanzen **36:** 1–56.

Chanda S. 1962. On the pollen morphology of some Scandinavian Caryophyllaceae. Grana **3:** 67–89.

Davis P.H. 1967. Flora of Turkey and the East Aegean Islands. Volume 2. Edinburgh University Press, Edinburgh, Great Britain, 581 pp.

Ekim T., Koyuncu M., Duman H., Aytaç Z. & Adıgüzel N.2000. Red Data Book of Turkish Plants (Pteridophyta and Spermatophyta). Barışcan Ofset, Ankara.

Erdtman G. 1986. Pollen morphology and plant taxonomy-Angiosperms (An Introduction to Pollen Analysis). E.J.Brill, Leiden, The Netherlands.

Erdtman G. 1952. Pollen Morphology and Plant Taxonomy. Angiosperms. Chronica Botanica Co., Waltham, Massachusettes.

Faegri K., Iversen J., Kaland E.P. & K. Krzywinski.1989. Textbook of Polen Analysis, IV. Edition. The Blackburn Pres, New Jersey, USA.

Güner A., Özhatay N., Ekim T. & Canbaser K.H. 2000. Flora of Turkey and the east Aegean Islands (Suppl. 1). Univ. Press, Edinburg, 656 pp.

Iwarsson M. 1977. Polen morphology of East African Caryophyllaceae. Grana **15:** 51–77.

Kapp R.O., Davis O.K. & King J.E. 2000. Pollen and Spores, Second Edition. AASP Foundation, Texas, USA.

Kremp G.O.W. 1965. Encyclopaedia of Pollen Morphology. Univ. Arizona Press, Tuscon, U.S.A.

Moore P.D. & Webb J.A. 1978. Illustrated Guide to Pollen Analysis. Hodder & Stoughton, London.

Nowicke J.W. 1975. Pollen morphology in the order Centrospermae. Grana **15:** 51–77.

Nowicke J.W. & Skvarla J.J. 1977. Pollen morphology and the relationship of the Plumbaginaceae, Polygonaceae and the Primulaceae to the order Centrospermae. Smithsonian Contrib. Bot. **37:** 1–64.

Nowicke J.W. & Skavarla J.J. 1979. Pollen morphology: The potential influence in higher order systematics. Ann. Mo. Bot. Gard. **66:** 633–699.

Perveen A. & Qaiser M. 2003. Pollen Flora of Pakistan-XII. Illecebraceae. Pak. J. Bot. **35:** 141–144.

Punt W. & Hoen P. 1999. Caryophyllaceae. In The Northwest European Pollen Flora, Volume 7. www.bio.uu.nl/∼palaeo/Research2/NEPF/volume7.htm

Rao A.R. & Shukla P. 1975. Indian pollen and spore Flora S. No 1. 1: Pollen of upper gangetic plane. New Delhi Press.

Skvarla I.J. & Nowicke J.W. 1976. The structure of the exine in the order Centrospermae. Pl. Sys. Evol. **126:** 55–78.

Soltis P., Endress P.K., Chase M.V. & Soltis D.E. 2005. Phlogeny and evolution of Angiosperms. Sinauer Associeties Inc., USA, 370 pp.

Wills J.C. 1966. A dictionary of the flowering plants & ferns. 7. Edition, Cambridge University Pres, London, UK, 1270 pp.

Yıldız K. 2001a. Pollen morphology of some *Silene* L. (Caryophyllaceae) from Turkey. Pak. J. Bot. **33:** 13–25.

Yıldız K. 2001b. Pollen morphology of Caryophyllaceae species from Turkey. Pak J Bot. **34:** 161–171.

Received January 9, 2007
Accepted July 10, 2007