TÜBİTAK

Research Article

Turk J Bot
35 (2011) 631-642

doi:10.3906/bot-1010-119

Pollen morphology of sections *Siphonomorpha* and *Lasiostemones* of the genus *Silene* from Turkey

Kemal YILDIZ[1,*], Mehmet Yaşar DADANDI[2], Ersin MİNARECİ[1], Ali ÇIRPICI[3]

[1]Celal Bayar University, Faculty of Science and Arts, Department of Biology, Muradiye, Manisa - TURKEY

[2]Erciyes University, Faculty of Science, Department of Biology, Kayseri - TURKEY

[3]Marmara University, Faculty of Science and Arts, Department of Biology, Göztepe, İstanbul - TURKEY

Received: 27.10.2010
Accepted: 27.03.2011

Abstract: The pollen morphology of 16 taxa belonging to the sections *Siphonomorpha* Otth and *Lasiostemones* Boiss. from the genus *Silene* L. (Caryophyllaceae) was examined via scanning electron microscopy (SEM). Pollen types among all of the examined taxa were spheroidal, ornamentations were generally microechinate-microperforate (punctate), but perforate in *Silene viridiflora* L., structures were mostly tectate but were observed to be semitectate only in *S. viridiflora*, the highest pore numbers were found in *S. fruticosa* L. and *S. viridiflora*, the lowest pore numbers were those of *S. gigantea* L. subsp. *rhodopea* (Janka) Greuter and *S. marschallii* C.A.Mey., and interpore distance was greatest in *S. gigantea* subsp. *rhodopea* and smallest in *S. amana* Boiss. The widest perforation was observed in *S. Viridiflora*, whereas the lowest value was observed in *S. olympica* Boiss. As a result of these detailed examinations, some *Silene* species with significant taxonomic problems were reviewed in terms of palynology, and suggestions are provided about their positions. *S. viridiflora* was determined to be the taxon with the most different pollen morphology according to general characters. According to pore number and perforation, the most advanced taxon was *S. Viridiflora*, while the most primitive taxa were found to be *S. olympica*, *S. gigantea* subsp. *rhodopea*, and *S. olympica*.

Key words: *Lasiostemones*, palynology, SEM, *Silene*, *Siphonomorpha*, systematic evaluation

Türkiye'de yayılış gösteren *Silene* cinsi *Siphonomorpha* ve *Lasiostemones* seksiyonlarının polen morfolojisi

Özet: *Silene* L. (Caryophyllaceae) cinsinin *Siphonomorpha* Otth, *Lasiostemones* Boiss., seksiyonlarında yer alan 16 taksonunun polen morfolojisi taramalı elektron mikroskobu (SEM) ile incelenmiştir. İncelenen taksonların tamamında polen tipi sferoidal, ornemantasyon çoğunlukla mikroekinat-mikroperforat (punktat), fakat *Silene viridiflora* L. türünde perforat, strüktür tektat, sadece *S. viridiflora*'da semitektat, en fazla por sayısı *S. fruticosa* L. ve *S. viridiflora*'da, en az por sayısı *S. gigantea* L. subsp. *rhodopea* (Janka) Greuter ve *S. marschallii* C.A.Mey.'de, porlar arası uzaklık en fazla *S. gigantea* subsp. *rhodopea*'da, en az *S. amana* Boiss. türündedir. Perforat genişliği en çok *S. viridiflora*'da, en dar *S. olympica* Boiss.'da olduğu tespit edilmiştir. Bu ayrıntılı incelemeler sonucu, önemli taksonomik sorunları olan, bazı *Silene* türlerinin taksonomik durumları palinolojik bakımdan gözden geçirilmiş ve bunlara ait öneriler getirilmiştir. Genel karekterler gore, en farklı polen yapısına sahip taksonun *S. viridiflora* olduğu görülür. Por sayısı ve perforasyon durumuna gore en primitif taksonlar *S. olympica*, *S. gigantea* subsp. *rhodopea* ve *S. olympica,* en gelişmiş taksonun ise *S. viridiflora* olduğu gözlemlenmiştir.

Anahtar sözcükler: *Lasiostemones*, palinoloji, SEM, *Silene*, *Siphonomorpha*, sistematik değerlendirme

* E-mail: kemalyi@gmail.com

Introduction

The genus *Silene* L., which has about 700 species in 44 sections worldwide (Greuter, 1997), is represented by 165 taxa and 31 sections in Turkey (Coode & Cullen, 1967, Aytaç, 1998, Davis et al., 1988, Tan & Vural, 2000, Vural & Dönmez, 2002, Duran & Menemen, 2003, Aytaç & Duman, 2004, Deniz & Düşen, 2004, Özgökçe et al., 2005, Bağcı et al., 2007, Genç et al., 2007, Aksoy et al., 2008, Bağcı, 2008, Tugay & Ertuğrul, 2008, Aksoy et al., 2009, Kandemir et al., 2009, Yıldız & Dadandı, 2009, Hamzaoğlu et al., 2010, Yıldız & Erik, 2010, Yıldız et al., 2010a). The present study is a palynological examination of 16 taxa in sections *Siphonomorpha* Otth and *Lasiostemones* Boiss., belonging to the genus *Silene*. There have been a number of significant palynological studies in the past on some genera of the family Caryophyllaceae and on *Silene*. The pollen morphology in these studies was observed to be significant, although not as important as morphological and seed micromorphological characters for the clarification of systematic states of the taxa. Melzheimer (1977) biosystematically revised the *Silene* taxa distributed in the Balkans in a study supporting this view. He compared the seed and pollen specifications and the calyx and petal characters, and he stated that while pollen characters were significant, they were not as accurate as other parameters for establishing the systematics of *Silene*. Prentice (1987) determined the variations and significant specifications of *Silene latifolia* Poir. pollens in his palynological study. Skvarla and Nowicke (1976) conducted a palynological study on species belonging to 11 families in the order Centrospermae. The palynological characters of some species belonging to *Silene* were also determined in that study. Nowicke and Skvarla (1977) later carried out further palynological studies on 12 families, including Caryophyllaceae, from the order Centrospermae. The taxonomic position of families and genera were discussed according to the results obtained from that study. Ghazanfar (1984) examined the species *S. italica* (L.) Pers., *S. splendens* Boiss., *S. gigantea* L., *S. fruticosa* L., and *S. viridiflora* L. from *Siphonomorpha* in her palynological study of 44 taxa belonging to sections *Siphonomorpha* and *Auriculatae* (Boiss.) Schischk. of the genus *Silene*. Arkan and İnceoğlu (1992) investigated 18 taxa of the genus *Saponaria* L. (Caryophyllaceae). The pollens of 16 taxa were examined by light microscopy (LM), and the pollens of 15 taxa were examined by scanning electron microscopy (SEM) and transmission electron microscopy (TEM). In their studies on 12 genera and 38 species of Caryophyllaceae distributed throughout Canada, Parent and Richard (1993) indicated that 2 species of *Spergula* L. are colpate while 36 species of *Arenaria* L., *Cerastium* L., *Stellaria* L., *Lychnis* L., *Melandrium* Röhl., *Minuartia* L., *Moehringia* Ehrh., *Sagina* L., and *Silene* are polyporate. Yıldız (1996, 2001a, 2001b, 2005, 2006), on the other hand, examined the taxa of *S. italica*, *S. viridiflora*, and *S. gigantea* var. *gigantea* from section *Siphonomorpha*, *S. marschallii* C.A.Mey., *S. olympica* Boiss., and *S. lasiantha* Koch from section *Lasiostemones*, *S. chlorifolia* Sm. and *S. bupleuroides* L. subsp. *bupleroides* from section *Sclerocalycinae* Boiss., *S. paphlagonica* Bornm. from section *Chloranthae* Rohrb., and *S. otites* (L.) Wibel from section *Otites* (Adams) Otth. The pollen characters of *Silene* were determined to be tectate, semitectate, spinulate, spinulate-microperforate, and semireticulate in those studies. Perveen (2000) discussed the pollen morphology and evolutionary positions of some taxa in the flora of Karachi, Pakistan. Some *Silene* taxa were used in this study to determine the systematic positions.

Perveen and Qaiser (2006) worked on the pollen morphology of the Caryophyllaceae taxa distributed in Pakistan and determined the specifications of 10 species belonging to *Silene*. In a later study, Sahreen et al. (2008) studied the pollen morphology of 16 species belonging to the genus *Silene* from Pakistan. They found pollen grains to be polypantoporate or periporate, regarding the polar view. Ataşlar et al. (2009) examined the pollen morphology of 12 taxa belonging to the genus *Gypsophila* L. distributed in Turkey.

Materials and methods

For our study, *Silene* pollen was taken from specimens of 16 taxa found throughout Turkey and from 1 taxon (*S. fruticosa*) taken from Northern Cyprus. Samples were collected between 2005

and 2007 and were later provided as herbarium ((MUFE) specimens. For SEM, pollen samples were mounted on stubs using double-sided adhesive tape and were then coated with gold using a Polaron SC7620 sputter coater. These coated pollens were examined and photographed with a LEO 440 scanning electron microscope at Erciyes University's Technology Research and Development Centre. Pollen measurements were taken by examining 30 pollen grains from each taxon using preparations set up according to the method described by Wodehouse (1935). The GraphPad Prism for Windows software package and Minitab (Version 15) were used for statistical analyses. Multivariate analysis of variance (MANOVA) was used to determine whether the palynological data indicated significant differences between taxa (Rosenberg, 2001). Examinations were performed using a triocular Olympus light microscope LM with 100× oil immersion objective and 10× ocular power. Morphological specifications were evaluated according to the methods of Moore et al. (1997) and Punt et al (2007). The SEM images (Figures 1-3) are provided along with the specifications of pollens belonging to each taxon (Tables 1-2).

Results

Section *Siphonomorpha*

a. Ornamentation: *S. viridiflora* had the highest perforation width value in the section, measured at 0.5-1.0 µm. Microechinae length was the longest in *S. gigantea* L. subsp. *rhodopea* (Janka) Greuter, at 0.5-0.85 µm, and the shortest in *S. Viridiflora*, at 0.22-0.25 µm. Microechinae base width values were the highest in *S. gigantea* subsp. *gigantea*, with measurements of 0.53-0.87 µm, and the lowest in *S. viridiflora*, with measurements of 0.27-0.39 µm.

b. Pollen diameter: The biggest pollen grains were contained in *S. italica* subsp. *italica* (43.56 ± 1.32 µm) and the smallest were contained in *S. phrygia* Boiss. (29.58 ± 2.13 µm). The pollen sizes of the subspecies of *S. gigantea* were very close to each other.

c. Pore diameter: The biggest pores were found in *S. gigantea* subsp. *gigantea*, with an average size of 7.83 ± 0.63 µm, *S. phrygia* had the smallest pores, with an average of 5.34 ± 0.52 µm.

d. Interpore distance: The widest distances between pores were determined in *S. gigantea* subsp. *rhodopea* at 9.76 ± 1.78 µm and the shortest in *S. phrygia* at 4.95 ± 0.64 µm.

e. Pore number: *S. fruticosa* and *S. viridiflora* had the most pores with 41 (range: 37-44) and 40 (range: 35-43), respectively, *S. gigantea* subsp. *rhodopea* had the least with 19 (range: 16-20).

f. Microechinae number on operculum: *S. phrygia* had the largest number of microechinae on the operculum, ranging between 25-34, *S. gigantea* subsp. *rhodopea* had the smallest numbers, at 7-13.

Section *Lasiostemones*

a. Ornamentation: *S. saxatilis* Sims and *S. isaurica* Contandr. & Quézel had the highest and lowest perforation width values of the section, with 0.30-0.50 µm and 0.13-0.051 µm, respectively. Microechinae lengths were the longest in *S. saxatilis*, at 0.5-0.85 µm, and the shortest in *S. capitellata* Boiss., at 0.28-0.42 µm. Microechinae base width values were the highest in *S. longipetala* Vent. (0.52-0.84 µm), and the lowest in *S. olympica* (0.33-0.43 µm) and *S. capitellata* (0.13-0.30 µm).

b. Pollen diameter: The largest pollen grains were found in *S. manissadjianii* Freyn, with an average diameter of 41.47 ± 2.67 µm, the smallest grains were contained in *S. isaurica*, with an average of 28.65 ± 2.51 µm.

c. Pore diameter: At 6.75 ± 0.93 µm, the largest pores belonged to *S. marschallii*, *S. lasiantha* had the smallest pores at 4.34 ± 0.43 µm.

d. Interpore distance: The distance between pores was determined to be the widest in *S. marschallii*, with measurements of 7.78 ± 1.29 µm, and the shortest in *S. isaurica*, with measurements of 5.33 ± 0.47 µm.

e. Pore number: *S. manissadjianii* had the most pores, at 33 (range: 24-38), *S. marschallii* had the fewest, at 20 (range: 18-22).

f. Microechinae number on operculum: *S. marschallii* had the highest number of microechinae on the operculum, ranging from 10 to 35, while *S. saxatilis* had the fewest microechinae, with a range of 2-11.

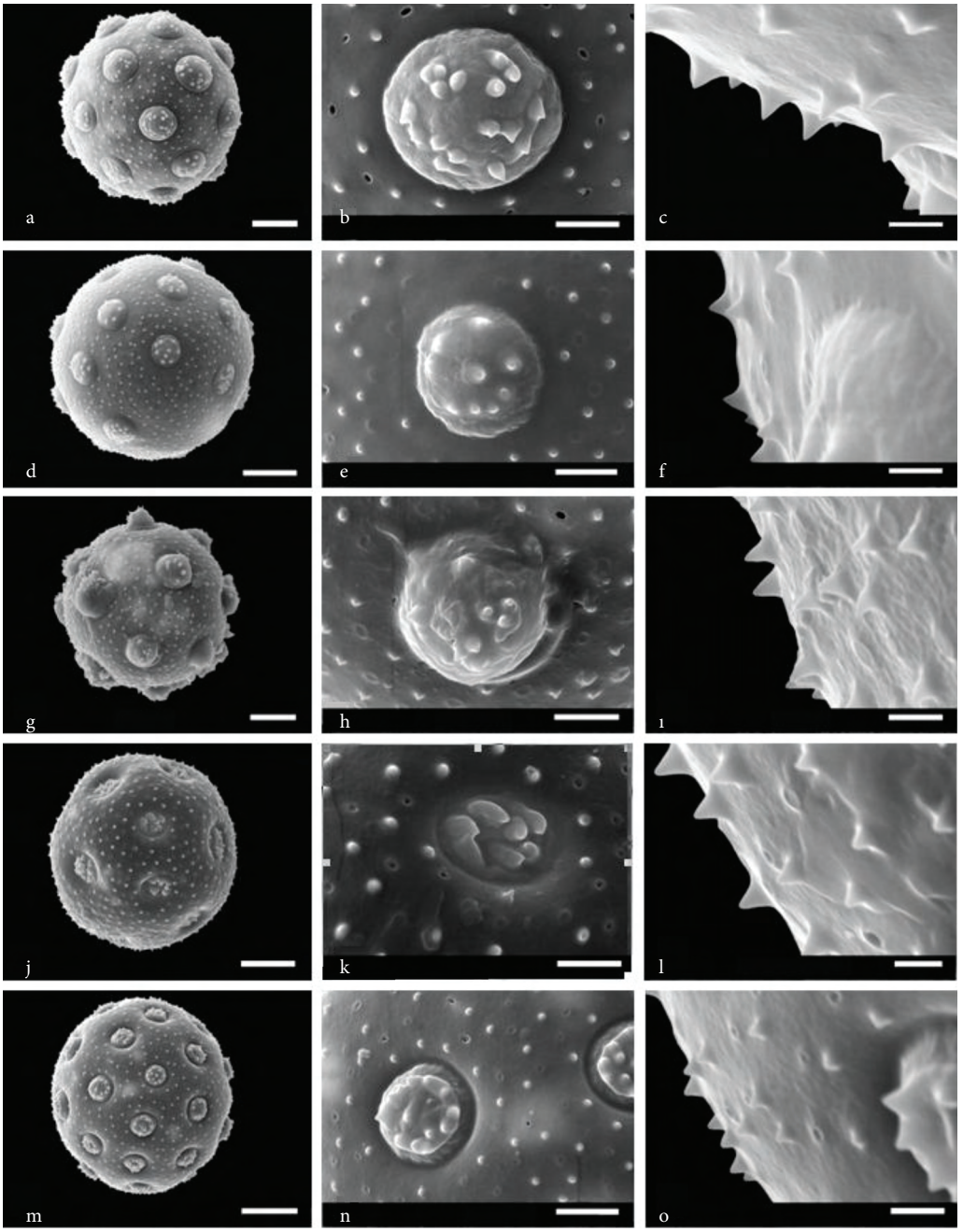

Figure 1. a-c: *Silene italica* subsp. *italica* ((MUFE 12428), d-f: *S. splendens* ((MUFE 12076), g-ı: *S. gigantea* subsp. *gigantea* ((MUFE 12220), j-l: *S. gigantea* subsp. *rhodopea* ((MUFE 12058), m-o: *S. fruticosa* ((MUFE 12390). a, d, g, j, m: scale bar, 10 µm, b, e, h, k, n: scale bar, 3 µm, c, f, i, l, o: scale bar, 1 µm.

Discussion

It was observed that the pollen types of all taxa were spheroidal and that their aperture specifications were polyporate. Ornamentation was perforate in *S. viridiflora* (Figure 2), whereas it was microechinate-microperforate (punctate) for all of the other taxa. Structures were generally tectate, but semitectate structures were seen in *S. viridiflora* (Figure 2). The biggest grains of pollen were obtained from *S. italica* subsp. *italica* (Table 1), while the smallest grains were

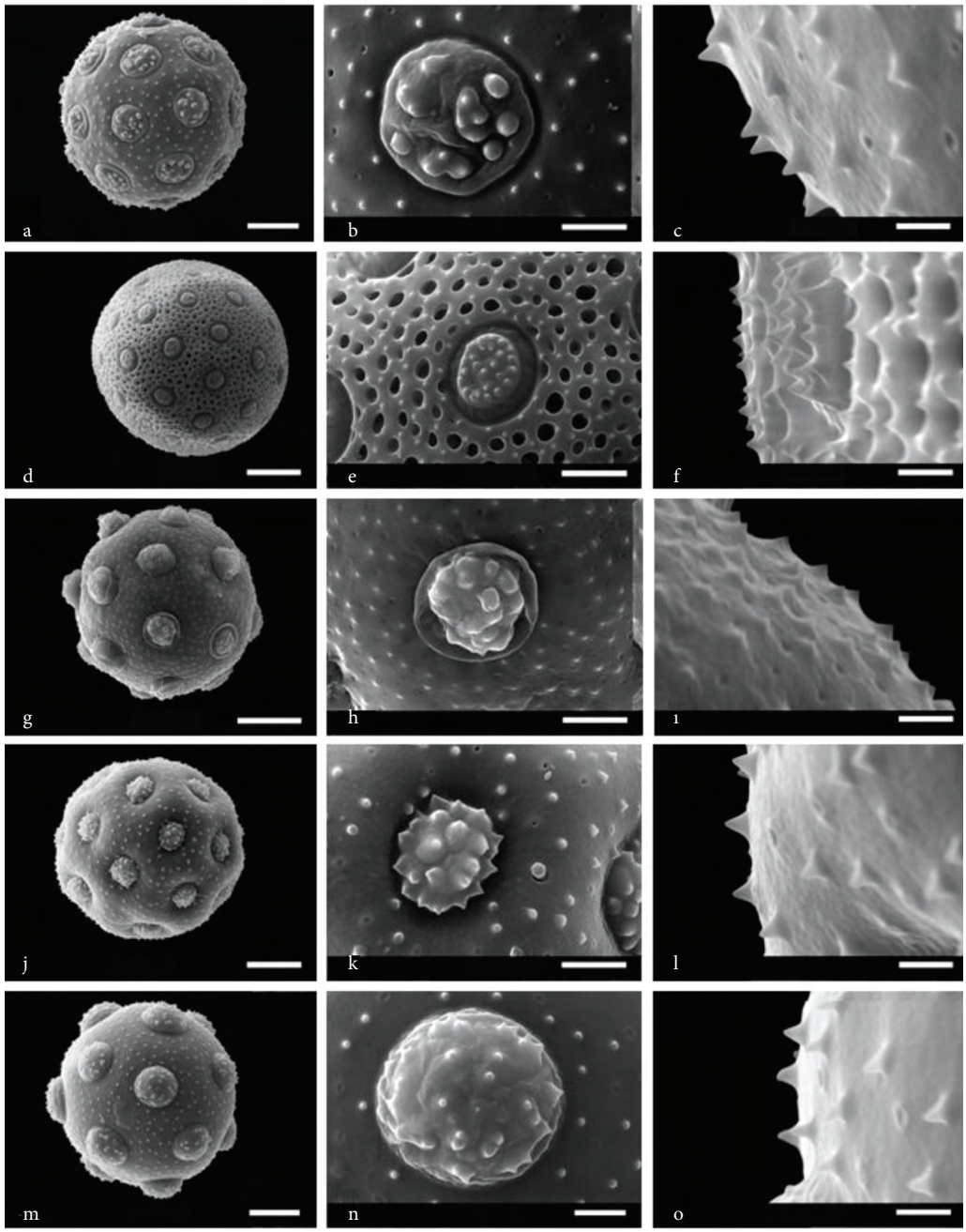

Figure 2. a-c: *Silene amana* ((MUFE 12297), d-f: *S. viridiflora* ((MUFE 12092), g-i: *S. phrygia* ((MUFE 12406), j-l: *S. longipetala* ((MUFE 12037), m-o: *S. marschallii* ((MUFE 12122). a, d, g, j, m: scale bar, 10 µm, b, e, h, k, n: scale bar, 3 µm, c, f, i, l, o: scale bar, 1 µm.

observed in *S. phrygia* and *S. isaurica* (Tables 1 and 2). The highest pore numbers were in *S. fruticosa* and *S. viridiflora* (Table 1), the lowest pore numbers were in *S. gigantea* subsp. *rhodopea* and *S. marschallii* (Tables 1 and 2). Interpore distance was the highest in *S. gigantea* subsp. *rhodopea* and the lowest in *S. amana* Boiss. (Table 1). The longest and shortest microechinae lengths were observed in *S. gigantea* subsp. *rhodopea* and *S. viridiflora*, respectively (Table 1). The widest perforation was also seen in *S. viridiflora* (Table 1), whereas the lowest value was observed in *S. olympica* (Table 2). According to these specifications, the taxon with the most varied pollen morphology was found to be *S. viridiflora*. The pollen of the genus *Silene* was determined to be medium in diameter (28.65-43.56 µm), as shown in Tables 1 and 2, along with all other findings.

Comparison with previous studies

Previous studies on the pollen morphology of Caryophyllaceae have demonstrated that the pollen is usually of medium size, ranging from 25 to 50 µm (Skvarla, 1975, Skvarla & Nowicke, 1976, Nowicke & Skvarla, 1977, Ghazanfar, 1984, Arkan & İnceoğlu, 1992, Yıldız, 1996a, 1996b, 2001b, Perveen & Qaiser, 2006, Ataşlar et al., 2009, Yıldız et al., 2010b). The findings of the present study are in agreement with those results. The pollens of the 16 species examined here were of medium size.

Ataşlar et al. (2009) examined the pollen morphology of 12 taxa belonging to the genus *Gypsophila* L., which is distributed in Turkey. Their results showed that the pollens of all 12 *Gypsophila* taxa were polyporate and spheroidal. The exine sculptures of the remaining *Gypsophila* taxa were tectate with granulate-microechinate-microperforate ornamentation, similar to the findings of the present report.

In his biosystematic revision study, Melzheimer (1977) stated that there were some differences in the pollen characters of the *Silene* taxa, but he also emphasised that those differences were not sufficient for systematic evaluations. Palynological data, however, have been used in other studies to determine the systematic states of the family Caryophyllaceae (Skvarla & Nowicke, 1976, Nowicke & Skvarla, 1977, Parent & Richard, 1993, Perveen, 2000, Yıldız, 2001b, Perveen & Qaiser, 2006, Yıldız et al, 2010b). Parent and Richard (1993), in their studies on 12 genera and 38 species of Caryophyllaceae distributed in Canada, indicated that 2 species of *Spergula* are colpate while 36 species of *Arenaria*, *Cerastium*, *Stellaria*, *Lychnis*, *Melandrium*, *Minuartia*, *Moehringia*, *Sagina*, and *Silene* are polyporate, findings that are similar to those of our present report.

The pollen of *S. italica* has been previously examined by Ghazanfar (1984) and Yıldız (1996), these studies found the pollen diameter to be 38-45 and 40.47 ± 1.97 µm, pore diameter to be 5-7 and 7.93 ± 0.52 µm, and interpore distance to be 7.5-10 and 6.40 ± 1.32 µm, respectively. The findings of our study comply with the figures presented in those studies (Table 1). Findings with different characters are provided in the comparisons below, since there were similar findings in examinations of other taxa. When compared with the findings on *S. viridiflora*, there was a significant difference only in the number of pores. In our study, the pore number was found to be 35-43, noticeably higher than the 29-34 and 25-32 pores counted in the studies of Ghazanfar (1984) and Yıldız (1996), respectively.

In her 1984 examination of *S. fruticosa*, Ghazanfar found the pollen diameter to range between 38 and 44 µm, with an interpore distance of 5-8 µm and a pore number of 25-30. The same characters were observed in the present study, the average pollen diameter was determined to be 32.16 ± 2.21 (30.5-36.67) µm, interpore distance averaged 6.72 ± 1.78 (3.25-9.50) µm, and the pore count was 37-44 (Table 1, Figure 1). Despite the fact that the samples used for these studies were both from Cyprus, differences can be seen in the results.

Pore diameter in *S. marschallii* was measured at 9.20 ± 1.87 by Yıldız (2001a), whereas it was 6.75 ± 0.93 (5.30-8.45) in this study, the number of operculum granules was 8-15 in that study while our count ranged from 10-35 (Table 2, Figure 2). Similarly, Yıldız reported an interpore distance of 8.87 ± 1.7 in *S. lasiantha* (2001b), while it was found to be 6.73 ± 1.54 (5.13-7.25) in this study (Table 2, Figure 3).

Table 1. Variations in the pollen characters of *Silene* section *Siphonomorpha*.

Taxa	Pollen diameter (µm)	Pore diameter (µm)	Interpore distance (µm)	Size of microechinae, height × base (µm)	Micro-perforate diameter (µm)	Pore number	Number of operculum microechinae
	M ± SD (V)	M ± SD (V)	M ± SD (V)	V	V	M (V)	V
S. italica subsp. *italica*	43.56 ± 1.32 (40.28-45.31)	7.15 ± 0.77 (6.50-7.82)	7.08 ± 1.89 (5.30-9.00)	0.43-0.58 × 0.38-0.68	0.2-0.55	28 (21-30)	11-20
S. splendens	38.33 ± 2.39 (35.24-42.33)	6.45 ± 0.57 (5.39-7.33)	6.69 ± 0.41 (5.00-7.63)	0.32-0.41 × 0.42-0.56	0.4-0.5	25 (22-26)	8-13
S. gigantea subsp. *gigantea*	39.56 ± 3.18 (35.20-43.63)	7.83 ± 0.63 (6.19-8.75)	9.47 ± 1.28 (6.28-11.77)	0.46-0.62 × 0.53-0.87	0.3-0.5	20 (16-22)	9-15
S. gigantea subsp. *rhodopea*	39.02 ± 2.37 (33.20-42.24)	5.77 ± 0.85 (4.24-7.28)	9.67 ± 1.78 (6.76-13.77)	0.50-0.85 × 0.53-0.61	0.27-0.7	19 (16-20)	7-13
S. fruticosa	32.16 ± 2.21 (30.50-36.67)	5.45 ± 1.62 (3.75-7.60)	6.72 ± 1.78 (3.25-9.50)	0.31-0.42 × 0.46-0.54	0.31-0.37	41 (37-44)	7-16
S. amana	37.58 ± 3.79 (34.24-41.70)	7.02 ± 1.67 (5.04-8.70)	4.33 ± 1.34 (2.52-5.75)	0.43-0.50 × 0.51-0.57	0.2-0.4	28 (26-31)	14-20
S. viridiflora	40.67 ± 2.73 (36.30-44.02)	5.14 ± 0.52 (4.10-5.88)	6.21 ± 0.44 (4.50-6.80)	0.22-0.25 × 0.27-0.39	0.5-1.0	40 (35-43)	12-23
S. phrygia	29.58 ± 2.13 (24.56-32.14)	5.64 ± 0.77 (4.44-6.88)	4.95 ± 0.64 (4.10-6.16)	0.27-0.30 × 0.38-0.46	0.21-0.32	22 (19-24)	17-24

Abbreviations: **M** - mean value, **SD** - standard deviation, **V** - variation, minimum-maximum values in parentheses.

Table 2. Variations in the pollen characters of *Silene* section *Lasiostemones*.

Taxa	Pollen diameter (µm)	Pore diameter (µm)	Interpore distance (µm)	Size of microechinae height × base (µm)	Micro-perforate diameter (µm)	Pore number	Number of operculum microechinae
	M (V)	M (V)	M (V)	V	V	M (V)	V
S. longipetala	34.49 ± 2.75 (30.2 -37.12)	5.56 ± 0.81 (4.80-6.41)	6.84 ± 2.54 (4.45-10.84)	0.46-0.68 × 0.52-0.84	0.20-0.30	28 (24-30)	16-24
S. marschallii	38.26 ± 2.43 (35.36-41.21)	6.75 ± 0.93 (5.30-8.45)	7.78 ± 1.29 (5.71-9.14)	0.32-0.50 × 0.39-0.58	0.20-0.32	20 (18-22)	10-35
S. saxatilis	37.05 ± 1.65 (33.34-38.96)	4.96 ± 0.55 (4.11-5.71)	6.67 ± 0.78 (4.61-7.77)	0.43-0.77 × 0.50-0.75	0.30-0.50	25 (23-29)	2-11
S. capitellata	36.42 ± 3.27 (28.11-39.42)	6.45 ± 0.79 (3.81-7.5)	6.43 ± 0.65 (5.12-7.18)	0.28-0.42 × 0.40-0.42	0.13-0.30	27 (25-30)	10-21
S. isaurica	28.65 ± 2.51 (23.94-31.81)	4.53 ± 0.84 (3.04-5.35)	5.33 ± 0.47 (4.63-7.75)	0.53-0.58 × 0.52-0.60	0.13-0.51	26 (22-28)	14-20
S. olympica	33.71 ± 2.87 (25.44-38.87)	5.45 ± 0.52 (4.46-5.76)	5.33 ± 0.67 (4.04-6.44)	0.27-0.36 × 0.33-0.43	0.20-0.25	24 (17-28)	10-16
S. lasiantha	30.26 ± 2.97 (26.51-33.39)	4.34 ± 0.43 (3.33-5.42)	6.73 ± 154 (5.13-7.25)	0.33-0.42 × 0.42-0.51	0.20-0.26	25 (22-28)	6-12
S. manissadjianii	41.47 ± 2.67 (38.48-44.01)	5.08 ± 0.33 (3.18-5.82)	7.33 ± 0.96 (6.35-8.56)	0.29-0.40 × 0.35-0.51	0.25-0.66	33 (24-38)	7-12

Abbreviations: **M** - mean value, **SD** - standard deviation, **V** - variation, minimum-maximum values in parentheses.

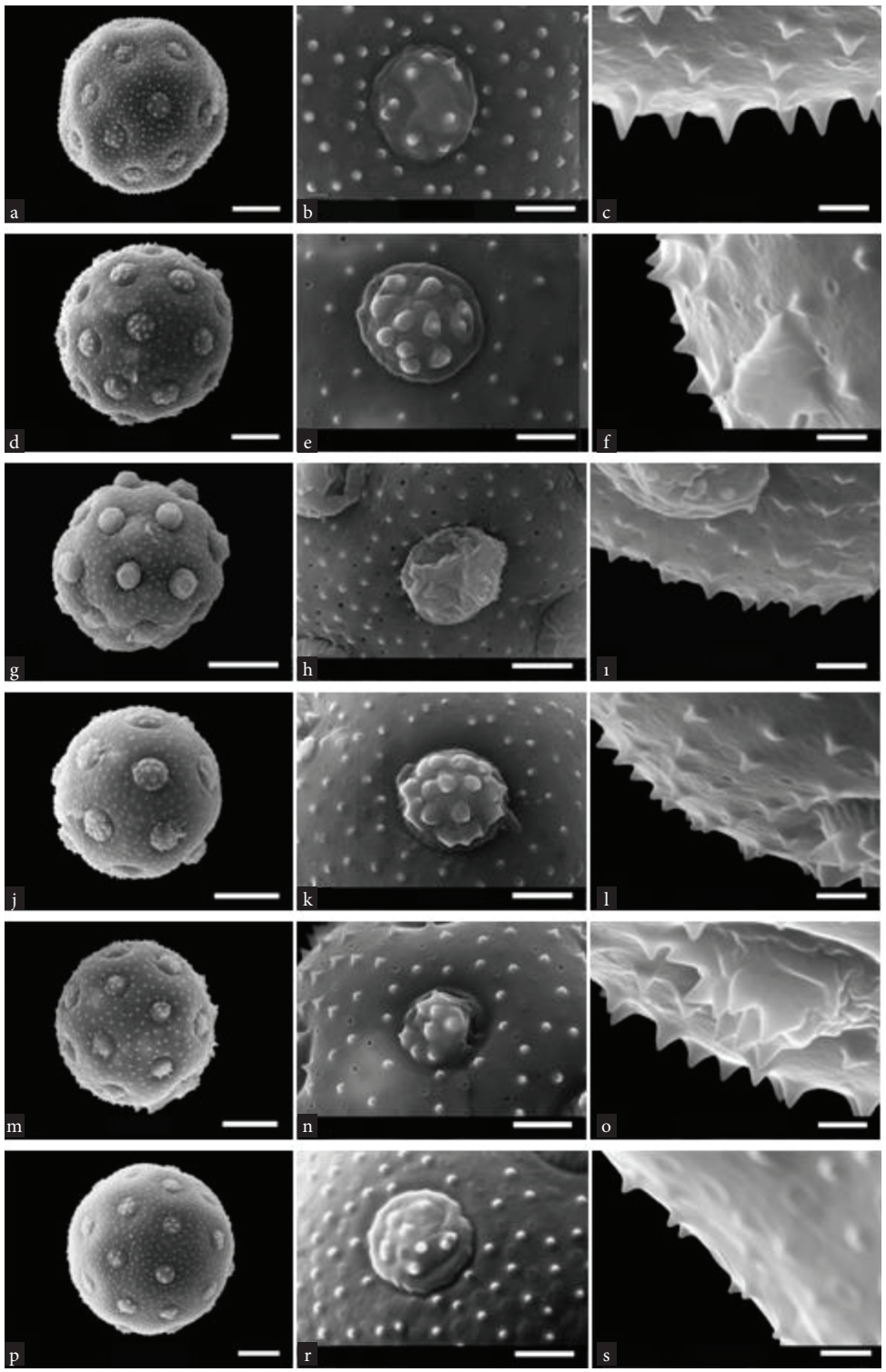

Figure 3. a-c: *Silene saxatilis* ((MUFE 12140), d-f: *S. capitellata* ((MUFE 12027), g-i: *S. isaurica* ((MUFE 12349), j-l: *S. olympica* ((MUFE 12091), m-o: *S. lasiantha* ((MUFE 12107), p-s: *S. manissadjianii* ((MUFE 12102). a, d, g, j, m, p: scale bar, 10 μm, b, e, h, k, n, r: scale bar, 3 μm, c, f, i, l, o, s: scale bar, 1 μm.

Taxonomic evaluations

Section *Siphonomorpha* (Table 1, Figures 1 and 2)

Because of their morphological similarities, *S. italica* subsp. *italica*, *S. splendens*, and *S. amana*, *S. gigantea* subsp. *gigantea* and subsp. *rhodopea*, and *S. amana* and *S. viridiflora* were identified as problematic taxa in terms of the taxonomic observations conducted for this study (Coode & Cullen, 1967). *S. italica* subsp. *italica* shows a significant difference from *S. splendens* regarding pollen specifications. *S. italica* subsp. *italica* has larger pollen diameters and wider microechinae that can be used to distinguish it from *S. splendens* (Table 1, Figure 1). In spite of the taxonomic problems mentioned above (Coode & Cullen, 1967), these 2 taxa can be more or less easily differentiated with a palynological examination.

S. amana samples were seen to be morphologically similar to *S. italica* subsp. *italica* in our observations. The most significant difference regarding pollen specifications was that pollen diameters were bigger and the interpore distances were wider in *S. italica* subsp. *italica* (Table 1, Figures 1 and 2).

S. amana also showed a morphological similarity with *S. viridiflora* (Coode & Cullen, 1967). The difference between *S. amana* and *S. viridiflora* (Figure 2) regarding pollen specifications was that pore diameters were bigger, microechinae were longer, and, most significantly, perforations were narrower in *S. amana*. It was easy to differentiate between these 2 taxa because of these differences in their pollen morphologies (Table 1).

S. gigantea subsp. *gigantea* and *S. gigantea* subsp. *rhodopea*, as 2 subspecies of *S. gigantea*, could be differentiated with morphological specifications but were not observed to be very distinct. *S. gigantea* subsp. *gigantea* demonstrated a wider pore diameter, which indicated its difference from *S. gigantea* subsp. *rhodopea* (Table 1, Figure 1).

Some common palynological specifications of *S. fruticosa* and *S. viridiflora*, both belonging to section *Siphonomorpha*, were determined to be different from the other section members. Their pores most distinctively showed costa ectocolpi (Punt et al., 2007) specifications, although they had significant differences regarding ornamentation, which was perforate in *S. viridiflora* (Figure 2) and microechinate-microperforate (punctate) for *S. fruticosa* and other taxa of the section *Siphonomorpha*.

The major evolutionary trend in exine structure proceeds from tectate-imperforate to tectate-perforate to semitectate to intectate exine (Walker, 1974). A lower number of pores (Van Campo, 1966) and the absence of spinules on the tectum (Takhtajan, 1980) of the pollen are generally accepted as primitive. In addition to the determination of palynological characters, systematic evaluations have been undertaken. According to the evolutionary view of Walker (1974), Van Campo (1966), and Takhtajan (1980), *Siphonomorpha* taxa were ordered, from primitive to advanced, as: *S. phrygia*, *S. gigantea* subsp. *gigantea*, *S. gigantea* subsp. *rhodopea*, *S. splendens*, *S. italica* subsp. *italica*, *S. amana*, *S. viridiflora*, and *S. fruticosa.* As indicated by this ranking, *S. viridiflora* and *S. fruticosa* are seen as the most advanced taxa of the section and may be considered separately. Consequently, these 2 taxa can be transferred to a different section.

Section *Lasiostemones* (Table 2, Figures 2 and 3)

Contandriopoulos and Quézel transformed *S. isaurica* into a new taxon, similar to *S. otites*, in 1976. Therefore, it was transferred to the *Otites* section in *Flora of Turkey*, but *S. isaurica* could also be considered as a member of *Lasiostemones*. For the purpose of the present study, *S. isaurica* was evaluated within *Lasiostemones*.

Further morphological similarities are seen between the taxa of *S. capitellata* and *S. isaurica*, *S. marschallii* and *S. lasiantha*, and *S. olympica* and *S. lasiantha*, *S. capitellata*, *S. isaurica*, *S. marschallii*, and *S. saxatilis* (Coode & Cullen 1967). These taxa could be systematically differentiated from each other by observations of key characters (Figures 2 and 3).

S. lasiantha was indicated as a synonym of *S. marschallii* subsp. *marschallii* in *Flora of Iran* (Melzheimer, 1988). Significant differences were observed in the pollen examinations of this study. *S. marschallii* can be differentiated from *S. lasiantha* due to the former's wider pollen and pore diameters, longer interpore distances, lower pore numbers, and less evident pore opercula (Table 2, Figures 2 and

3). *S. lasiantha* is also morphologically similar to *S. olympica*. There were palynological differences such as narrower pollen and pore diameters and longer interpore distance in *S. lasiantha*, although similarities existed regarding pore numbers and microperforate diameters. Significant palynological differences were observed according to the data obtained in this study (Table 2, Figure 3).

According to determinations of the section *Lasiostemones* regarding pore perforation specifications and pore number, the evolutionary line-up of taxa in *Siphonomorpha*, from primitive to advanced, is: *S. marschallii*, *S. olympica*, *S. lasiantha*, *S. isaurica*, *S. saxatilis*, *S. longipetala*, *S. capitellata*, and *S. manissadjianii*. Because *S. marschallii* was seen to be the most primitive taxon of the section, it was separated from the other taxa.

Acknowledgements

The study was supported by the Scientific and Technological Research Council of Turkey (TÜBİTAK, Project No. 104T310) and we would like to express our gratitude to the Council for its financial support. We would also like to thank the authorities at the Erciyes University Technology Research and Development Centre, where the pollen SEM images were taken.

Specimens Investigated

Section *Siphonomorpha*

Silene italica subsp. *italica*. Turkey, Manisa: Sipil mountain, At Alanı road, 1100-1200 m, 38°33′091″N, 27°26′224″E, 15.05.2004, *K.Yıldız s.n.* (MUFE 12428).

S. splendens. Turkey, Konya: Kurucuova-Anamas mountain, SW slopes of Küre, forest, 1450-1500 m, 37°41′368″N, 31°20′809″E, 12.07.2005, *K.Yıldız* & *M.Y.Dadandı s.n.* (MUFE 12076).

S. gigantea subsp. *gigantea*. Turkey, Manisa: Sipil mountain, around Seyirtepe, 700-800 m, 38°35′335″N, 27°25′048″E, 26.05.2006, *K.Yıldız s.n.* (MUFE 12220).

S. gigantea subsp. *rhodopea*. Turkey, Karaman: Ermenek-Mut road, 40-45 km, Gezende barrage, roadsides, rocky slopes, 1050 m, 36°32′818″N, 33°12′472″E, 09.07.2005, *K.Yıldız* & *M.Y.Dadandı s.n.* (MUFE 12058).

S. fruticosa. Cyprus, Girne: Mersinlik-Kantara Castle road, rocky and sandy slopes, 10 m, 35°25′457″N, 33°46′382″E, 21.04.2006, *S.Gücel s.n.* (MUFE 12390).

S. amana. Turkey, Osmaniye: Above Zorkun Yaylası, Yörükler disctrict, *Pinus* forest, 1600 m, 36°58′104″N, 36°21′251″E, 09.07.2006, *K.Yıldız* & *M.Y.Dadandı s.n.* (MUFE 12297).

S. viridiflora. Turkey, Zonguldak: Mengen-Devrek road, around Dorukhan subway, roadside, forest, 750-850 m, 41°01′293″N, 32°04′866″E, 15.07.2005, *K.Yıldız* & *M.Y.Dadandı s.n.* (MUFE 12092).

S. phrygia. Turkey, Konya: Derebucak, Cevizli, Kuyucak village, open forest, 1030 m, 37°10′174″N, 31°54′854″E, 06.06.2007, *A.Çırpıcı, K.Yıldız* & *M.Y.Dadandı s.n.* (MUFE 12406).

Section *Lasiostemones*

S. longipetala. Turkey, Kahramanmaraş: Pınarbaşı-Göksun road, 1 km east of Doğankonak village, roadside, rocky places, 1570 m, 38°14′600″N, 36°25′873″E, 06.07.2005, *K.Yıldız* & *M.Y.Dadandı s.n.* (MUFE 12037).

S. marschallii. Turkey, Bayburt: Bayburt-Aşkale (Erzurum) road, Kop pass, SW slopes, 2300-2400 m, 40°02′158″N, 40°29′963″E, 27.07.2005, *K.Yıldız* & *M.Y.Dadandı s.n.* (MUFE 12122).

S. saxatilis. Turkey, Ardahan: Yalnızçam, around ski centre, NE slopes, rocky places, 2045 m, 40°41′305″N, 42°25′157″E, 29.07.2005, *K.Yıldız* & *M.Y.Dadandı s.n.* (MUFE 12140).

S. capitellata. Turkey, Kahramanmaraş: Göksun, Değirmendere village, above Alıklıkaya, NW slopes, 1650-1700 m, 37°53′280″N, 36°27′172″E, 06.07.2005, *K.Yıldız* & *M.Y.Dadandı s.n.* (MUFE 12027).

S. isaurica. Turkey, Antalya: Akseki, Çimi village to Kuyu Yaylası 9th km (2-3 km to Kuyu Yayla), 1550-1570 m, 36°59′848″N, 31°55′624″E, 15.07.2006, *K.Yıldız* & *M.Y.Dadandı s.n.* (MUFE 12349).

S. olympica. Turkey, Bursa: Uludağ, around hotels, rocky places, *Abies* forest, 1870-1950 m, 36°34′694″N, 29°53′028″E, 14.07.2005, *K.Yıldız* & *M.Y.Dadandı s.n.* (MUFE 12091).

S. lasiantha. Turkey, Sivas: Zara, near Şerefiye, open *Pinus nigra* forest, 1520-1550 m, 40°06′485″N, 37°45′782″E, 26.07.2005, *K.Yıldız* & *M.Y.Dadandı s.n.* (MUFE 12107).

S. manissadjianii. Turkey, Tokat: Niksar, Çamiçi, entrance of Özören village, roadside, on rocky surfaces, 1260 m, 40°38′690″N, 37°08′400″E, 25.07.2005, *K.Yıldız* & *M.Y.Dadandı s.n.* (MUFE 12102).

References

Aksoy A, Hamzaoğlu E & Budak Ü (2009). *Silene ozyurtii* (Caryophyllaceae), a new species from Anatolia, Turkey. *Ann Bot Fenn* 46: 431-434.

Aksoy A, Hamzaoğlu E & Kılıç S (2008). A new species of *Silene* L. (Caryophyllaceae) from Turkey. *Bot J Linn Soc* 158: 730-733.

Arkan O & İnceoğlu Ö (1992). Türkiye'nin bazı *Saponaria* L. taksonlarının polen morfolojisi. *Turk J Bot* 16: 253-272.

Ataşlar E, Potoğlu Eİ & Tokur S (2009). Pollen morphology of some *Gypsophila* L. (Caryophyllaceae) species and its taxonomic value. *Turk J Bot* 33: 335-351.

Aytaç Z (1998). A new species of *Silene* L. (Caryophyllaceae) from Anatolia (Turkey). *Thaiszia Journal of Botany* 8: 7-11.

Aytaç Z & Duman H (2004). Six new taxa (Caryophyllaceae) from Turkey. *Ann Bot Fenn* 41: 213-221.

Bağcı Y (2008). A new species of *Silene* L. (Caryophyllaceae) from south Anatolia, Turkey. *Turk J Bot* 32: 11-15.

Bağcı Y, Uysal T, Ertuğrul K & Demirelma K (2007). *Silene kucukodukii* sp. nov. (Caryophyllaceae) from South Anatolia, Turkey. *Nord J Bot* 25: 306-310.

Coode MJE & Cullen J (1967). *Silene* L. In: Davis PH (ed.) *Flora of Turkey and the East Aegean Islands*, Vol. 2, pp. 179-242. Edinburgh: Edinburgh University Press.

Davis PH, Mill RR & Tan K (1988). *Flora of Turkey and the East Aegean Islands* (Suppl. 1), Vol. 10, Edinburgh: Edinburgh University Press.

Deniz İG & Düşen OD (2004). *Silene sumbiliana* from SW Anatolia, Turkey. *Ann Bot Fenn* 41: 293-296.

Duran A & Menemen Y (2003). A new species of *Silene* (Caryophyllaceae) from south Anatolia, Turkey. *Bot J Linn Soc* 143: 109-113.

Genç EG, Kandemir A & Genç İ (2007). A new species of *Silene* (Caryophyllaceae) from east Anatolia, Turkey. *Nord J Bot* 25: 58-63.

Ghazanfar SA (1984). Morphology of the genus *Silene* L. (Caryophyllaceae), section *Siphonomorpha* Otth. and *Auriculatae* (Boiss.) Schischk. *New Phytol* 98: 683-690.

Greuter W (1997). *Silene* L. In: Sitrid A & Tan K (eds.) *Flora Hellenica*, Vol. 1, pp. 239-323. Koenigstein: Koeltz Scientific Books.

Hamzaoğlu E, Aksoy E & Budak Ü (2010). A new species of *Silene* (Caryophyllaceae) from Turkey. *Turk J Bot* 34: 47-50.

Kandemir A, Genç GE & Genç İ (2009). *Silene dumanii* (Caryophyllaceae), a new species from East Anatolia. *Ann Bot Fenn* 46: 71-74.

Melzheimer V (1977). Biosystematiche revision einiger *Silene*-Arten (Caryophyllaceae) der Balkanbinsel (Griechenland). *Bot Jahrb Syst* 98: 1-92.

Melzheimer V (1988). *Silene* L. In: Rechinger KH (ed.) *Flora Iranica* 63, pp. 341-508, Akad. Druck-u. Verlangstalt: Graz, Austria.

Moore PD, Webb JA & Collinson ME (1997). *An Illustrated Guide to Pollen Analysis*. London: Blackwell Scientific Publications.

Nowicke JW & Skvarla JJ (1977). Pollen morphology and the relationship of the Plumbaginaceae, Polygonaceae and Primulaceae to the order Centrospermae. *Smithsonian Contributions to Botany* 37: 1-64.

Özgökçe F, Tan K & Stenovic V (2005). A new subsp. of *Silene acualis* (Caryophyllaceae) from East Anatolia, Turkey. *Ann Bot Fenn* 42: 143-149.

Parent J & Richard PJH (1993). Morphologie pollinuque des Caryophyllaceae du Quebec nordique, der territoires adjacents et de l'archipel Arctique canadien. *Can J Bot* 7: 887-905.

Perveen A (2000). Pollen characters and their evolutionary significance with special reference to the flora of Karachi. *Turk J Bot* 24: 365-377.

Perveen A & Qaiser M (2006). Pollen flora of Pakistan-LI -Caryophyllaceae. *Pak J Bot* 38: 901-915.

Prentice HC (1987). Analysis of the clinal variation pattern in *Silene latifolia* (Caryophyllaceae) pollen morphology. *Plant Syst Evol* 156: 5-11.

Punt W, Blackmore S, Nilsson S & Thomas A (2007). Glossary of pollen and spore terminology. *Rev Palaeobot Palyno* 143: 1-81.

Rosenberg MS (2001). *Passage, Pattern Analysis, Spatial Statistics, and Geographic Exegesis*. Tempe, Arizona: Department of Biology, Arizona State University.

Sahreen S, Khan MA, Meo AA & Jabeen A (2008). Pollen morphology of the genus *Silene* (*Sileneae*-Caryophyllaceae) from Pakistan. *Biological Diversity and Conservation* 1: 74-85.

Skvarla JJ (1975). Pollen morphology in the order Centrospermae. *Grana* 15: 51-77.

Skvarla JJ & Nowicke JW (1976). Ultrastructure of pollen of exine Centrospermous families. *Plant Syst Evol* 126: 55-78.

Takhtajan AL (1980). Outline of the classification of flowering plants (Magnoliophyta). *Bot Rev* 46: 225-359.

Tan K & Vural M (2000). *Silene* L. In: Güner A, Özhatay N, Ekim T & Başer KHC (eds.) *Flora of Turkey and the East Aegean Islands*, Vol. 11 (Suppl. 2), pp. 50-53. Edinburgh: Edinburgh University Press.

Tugay O & Ertuğrul K (2008). A new species of *Silene* (Caryophyllaceae) from East Anatolia, Turkey. *Bot J Linn Soc* 156: 463-466.

Van Campo M (1966). Pollen et phylogenie. Les Breviaxes. *Pollen Spores* 8: 57-73.

Vural M & Dönmez AA (2002). Two new taxa of *Silene* (Caryophyllaceae) from Turkey. *Ann Bot Fenn* 39: 153-158.

Wodehouse RP (1935). *Pollen Grains*, New York: McGraw-Hill.

Walker JW (1974). Evolution of exine structure in the pollen of primitive Angiosperms. *Am J Bot* 61: 891-902.

Yıldız K (1996a). Pollen morphology of some *Silene* L. (Caryopyllaceae) taxa of north-west Anatolia. *Turk J Bot* 20: 231-240.

Yıldız K (1996b). Pollen morphology of some endemics *Silene* L. (*S. olympica* Boiss., *S. paphlagonica* Bornm., *S. sangaria* Coode and Cullen) species. *XIII. Ulusal Biyoloji Kongresi*, pp. 637-646.

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* 33: 329-355.

Yıldız K (2005). A palynological investigation on *Silene* L. (Caryophyllaceae) species distributed in North Cyprus and West Anatolia. *Celal Bayar Üniversitesi Fen Bilimleri Dergisi* 1: 61-72.

Yıldız K (2006). Morphological and palynological investigation on *Silene gigantea* L. var. *gigantea* and *Silene behen* L. (Caryophyllaceae) disributed in Western Anatolia and Northern Cyprus. *Turk J Bot* 30: 105-119.

Yıldız K, Çırpıcı A & Dadandı MY (2010a). *Silene demirizii* sp. nov. and *S. marschallii* subsp. *anamasi* subsp. nov (Caryophyllaceae) from Turkey. *Nord J Bot* 28: 332-340.

Yıldız K, Çırpıcı A & Dadandı MY (2010b). Pollen morphology of *Silene* (Caryophyllaceae) in four sections from Turkey. *Phytologia Balcanica* 16: 85-95.

Yıldız K & Dadandı MY (2009). *Silene cirpicii* (Caryophyllaceae), a new species from Turkey. *Ann Bot Fenn* 46: 464-468.

Yıldız K & Erik S (2010) *Silene aydosensis* (Caryophyllaceae) from south Anatolia, Turkey. *Ann Bot Fenn* 47: 151-155.