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Palynological observations on the genus *Scorzonera* L. (Asteraceae) from north-east Anatolia (Turkey)

Zafer TÜRKMEN[1], Serdar MAKBUL[2], Kamil COŞKUNÇELEBİ[3,*], Osman BEYAZOĞLU[3]

[1]Giresun University, Faculty of Arts & Sciences, Department of Biology, 28049 Giresun - TURKEY

[2]Rize University, Faculty of Arts & Sciences, Department of Biology, 53100 Rize - TURKEY

[3]Karadeniz Technical University, Faculty of Arts & Sciences, Department of Biology, 61080 Trabzon - TURKEY

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Abstract: Pollen morphology of the 13 taxa of *Scorzonera* L. (Asteraceae) from Turkey was investigated by using light (LM) and scanning electron microscopy (SEM). As a result of LM and SEM observations, it was found that the pollen types are generally isopolar, radially symmetric, triangular in polar view, and lophate, with lophae ornamentations that are echinate-perforate and an exine thickness ranging from 6.99 to 11.82 µm. The present study found that the lacunae ornamentation of *S. laciniata* subsp. *laciniata* and *S. tomentosa* is perforate-microrugulate, that of *S. suberosa* and *S. cinerea* is perforate-microreticulate, that of *S. pseudolanata* is perforate-psilate, and that of the others is perforate. Prolate-spheroidal pollen shapes were observed in *S. insica*, and oblate-spheroidal shapes were observed in the rest of the examined taxa, e.g. *S. tomentosa*, *S. pseudolanata*, and *S. sericea*. Spine length ranged between 1.3 and 4.63 µm among the examined taxa. *S. tomentosa* (4.63 µm) showed the highest value. *S. insica* (1.3 µm) showed the lowest value. PCA analysis based on the 16 palynological traits showed that polar axis, equatorial diameter, pollen diameter, colpus length, colpus width, and exine and spine length were the most important characters in explaining total variation among the examined taxa. The results also indicated that pollen characters would be useful in separating the examined taxa.

Key words: Light microscopy, *Scorzonera*, palynology, principal component analysis, SEM

Kuzey Doğu Anadolu (Türkiye) *Scorzonera* L. (Asteraceae) taksonları üzerine palinolojik gözlemler

Özet: Türkiye'de yayılış gösteren 13 *Scorzonera* L. (Asteraceae) taksonunun polen morfolojisi ışık mikroskobu (LM) ve taramalı elektron mikroskobu (SEM) kullanılarak incelendi. LM ve SEM gözlemlerinin sonucu olarak, polar görünüşte polen tipinin genellikle izopolar, radyal simetrik, lophat, triangular, lopha yüzeyi süslemesi ekinat-perforat ve ekzin kalınlığının 6,99-11,82 µm arasında değiştiği bulundu. Bu çalışma *S. laciniata* subsp. *laciniata* ve *S. tomentosa*'nın lakün yüzeyi süslemesi perforat-mikrorugulat, *S. suberosa* ve *S. cinerea*'nın perforat-mikroretikülat, *S. psedolanata*'nın perforat-psilat diğerlerinin ise perforat olduğu belirlendi. Prolat-siferoid polen *S. insica*'da gözlendi. İncelenen taksonların diğerlerinde (*S. tomentosa, S. pseudolanata* ve *S. sericea*) ise polen şeklinin oblat-siferoid olduğu tespit edildi. Spin uzunluğu incelenen taksonlarda 1,3 µm ile 4,63 µm arasında değişir. *S. tomentosa* (4,63 µm) en yüksek spin uzunluğuna

* E-mail: kamil@ktu.edu.tr

sahiptir. *S. insica* (1,3 µm) ise spin uzunluğu yönünden en düşük değeri almıştır. On altı palinolojik karakter üzerinde uygulanan PCA analizi polar aksis, ekvatoral çap, polen çapı, kolpus uzunluğu, kolpus genişliği, ekzin ve spin uzunluğu gibi karakterlerin çalışılan taksonlar arasında toplam varyasyonu açıklamada en önemli karakterler olduğunu göstermiştir. Bu sonuçlar ayrıca çalışılan taksonların ayrımında polen karakterlerinin yararlı olabileceğini göstermiştir.

Anahtar sözcükler: Işık mikroskobu, *Scorzonera*, palinoloji, temel bileşenler analizi, SEM

Introduction

The genus *Scorzonera* L. (Asteraceae) includes about 175 species distributed all over Europe, Asia, and Africa (Bremer, 1994; Nazarova, 1997). This genus appears simple at first sight; however, phenetic similarities, inadequate traits, and the consequent lack of detailed knowledge about its systematic status have resulted in its being ignored by taxonomists (Lipschitz, 1935, 1939; Chamberlain, 1975). Therefore, many questions about the genus remain controversial today (Nazarova, 1997). In recent years, karyological (Guardia & Blanca, 1987; Nazarova, 1997), ethnobotanical (Ertuğ, 2000; Rivera et al., 2006), chemical (Magiatis et al., 2001; Zidorn et al., 2003), phenetic (Mavrodiev et al., 2004), and taxonomic (Chu, 1993) studies have been carried out on the genus. Leaves and roots of many *Scorzonera* species have been used as folk medicine, as cooked vegetables, and in salads (New Zealand Institute for Crop and Food Research, 2001). *Scorzonera* is represented by 46 species in the Turkish flora (Dinç & Bağcı, 2009; Özhatay et al., 2009), and most of them were investigated in terms of anatomy and numerical taxonomy by Makbul et al. (2010). However, there are not many studies on Turkish *Scorzonera* representatives in terms of palynological aspects. The pollen morphology of *S. ketzkhovelii* Grosh. was given by Hamzaoğlu et al. (2010). Pollen morphology may provide informative data to address such questions. The tribe Lactuceae contains 2 basic pollen types (echinolophate and echinate), and most taxa have echinolophate, tricolporate pollen (Tomb, 1975). It is well known that palynological studies performed by LM and SEM have great value in plant taxonomy (Skvarla et al., 1977), specifically for the taxonomy of the family Asteraceae (Wodehouse, 1926; Tomsovic, 1997). The pollen morphology of Cichorieae has since been investigated by many authors using light microscopy, scanning electron microscopy, and transmission electron microscopy (e.g. Askerova, 1970; Blackmore, 1981, 1982, 1984; Blackmore & Jarvis, 1986). Sunderland et al. (1984) indicated that SEM studies provide useful data for the delimitation of *Scorzonera* taxa, but there are not enough palynological data related to the Turkish *Scorzonera*. Thus, the main aim of this study was to explore the palynological properties of the *Scorzonera* species distributed in north-east Anatolia by LM and SEM and elucidate their taxonomical value.

Materials and methods

Specimens: Plants were collected from north-east Anatolia in 2003-2006 and dried according to standard herbarium techniques. The vouchers are stored in the herbarium of Karadeniz Technical University, Department of Biology (KTUB). The collection data of the examined taxa are given in Table 1.

Palynological study: Pollen materials (buds or anthers) were removed from living specimens in the field or from herbarium specimens in the laboratories. LM observations were made on pollen grains prepared according to the Erdtman (1952) acetolysed methods and photographed with Olympus BX51. Data on size were based on the measurements of 30 pollen grains. Characters such as polar axis (P), equatorial diameter (E), P/E ratio, exine thickness, shape in polar view, shape in equatorial view, spine length, spine base, and colpi and aperture type were examined. After pollen grains were coated with a thin layer of gold/palladium for 3 min with an EMITECH K550 sputter coater, they were examined with a JSM-6060LV SEM at the Department of Biology of Gazi University, Ankara, Turkey. Pollen terminology mainly follows Blackmore (1984), Blackmore and Persson (1996), and Punt et al. (2007, 2009), and the terminology of Blackmore and Jarvis (1986) was used for the lacunar types.

Table 1. Locality information of the examined *Scorzonera* taxa.

No.	Taxon	Locality
1	*S. laciniata* subsp. *laciniata*	A9 Artvin: Yusufeli-Yokuşlu, 815 m, *Makbul* 074 (KTUB)
2	*S. cana* var. *cana*	A8 Rize: Cimil, Başköy, 2300 m, *Makbul* 058 (KTUB)
3	*S. armeniaca*	A7 Bayburt: Bayburt Castle, 1650 m, *Makbul* 067 (KTUB)
4	*S. suberosa*	A7 Bayburt: Bayburt to Gümüşhane, Çerçi village, 1710 m, *Makbul* 069 (KTUB)
5	*S. mollis* subsp. *mollis*	A7 Gümüşhane: Mount Tersun, 2040 m, *Makbul* 051 (KTUB)
6	*S. inaequiscapa*	A7 Giresun: from Alucra to Şiran, 15 km, 1670 m, *Makbul* 079 (KTUB)
7	*S. insica*	A7 Bayburt: Mount Kop, 2150 m, *Makbul* 047 (KTUB)
8	*S. eriophora*	A7 Gümüşhane: Tersun Mount, 2040 m, *Makbul* 050 (KTUB)
9	*S. cinerea*	A7 Bayburt: Bayburt to Yusufeli, Mount Kop, 2150 m, *Makbul* 087 (KTUB)
10	*S. sericea*	A7 Bayburt: Mount Kop, 2450 m, *Makbul* 089 (KTUB)
11	*S. pseudolanata*	A7 Gümüşhane: Mount Köse, 1650 m, *Makbul* 040 (KTUB)
12	*S. sosnowskyi*	A8 Erzurum: İspir-Moryayla, 2400 m, *Makbul* 091 (KTUB)
13	*S. tomentosa*	A7 Giresun: Alucra, 1400 m, *Makbul* 010 (KTUB)

Numerical analysis: The 13 *Scorzonera* taxa were assessed based on the 16 palynological characters given in Table 2. Two multivariate analyses were performed using SYN-TAX PC 5.0 (Podani, 1993): cluster analysis (CA) and principal components analysis (PCA). For the CA, a pair-wise matrix of resemblance values was calculated from a standardised data matrix, using Gower's coefficient as the coefficient of resemblance designed for mixed data sets (Sneath & Sokal, 1973), and 3 eigenvectors were extracted, providing 3 axes onto which the standardised data were projected to give a 2-dimensional plot of the OTUs. A dendrogram was generated by the unweighted pair-group method using arithmetic averages (UPGMA). For PCA, the standardised data were used to create a covariance matrix, and 3 eigenvectors were extracted.

Table 2. List of characters used in this study.

Symbol	Characters
X_1	Polar axis (μm)
X_2	Equatorial diameter (μm)
X_3	Porus width (μm) (plt)
X_4	Porus length (μm) (plg)
X_5	Colpus width (μm) (clt)
X_6	Colpus length (μm) (clg)
X_7	Pollen diameter (μm) (amb)
X_8	Apocolpium (μm)
X_9	Exine (μm)
X_{10}	Muri (μm)
X_{11}	Lumina (μm)
X_{12}	Spine length (μm)
X_{13}	Spine base (μm)
X_{14}	P/E ratio (μm)
X_{15}	Pollen shape: prolate-spheroidal, 1; oblate-spheroidal, 0
X_{16}	Lacunar type: Type B, 0; Type C, 1

Results

Scorzonera laciniata* L. subsp. *laciniata (Figure 1)

Pollen grains are isopolar, radially symmetric, tricolporate, oblate-spheroidal. Polar view triangular, amb 39.23 ± 2.44 μm (34.3-43.12 μm). Polar axis 38.57 ± 1.82 μm (34.3-42.14 μm), equatorial diameter 40.4 ± 1.75 μm (37.24-44.1 μm). P/E ratio is 0.95 μm. Apocolpium quite broad, 20.28 ± 1.48 μm (16.66-22.54 μm); colpi prolonged, distinct line colpus length 19.53 ± 1.47 μm (16.66-21.56 μm), colpus width 4.54 ± 0.87 μm (2.94-5.88 μm), porus length 5.97 ± 0.64 μm (4.9-6.86 μm), porus width 4.21 ± 0.81 μm (2.94-5.88 μm).

Exine 8.62 ± 1.33 μm (5.88-10.78 μm), pollen type is lophate, lophae ornamentation echinate-perforate, lacunae ornamentation perforate-microrugulate,

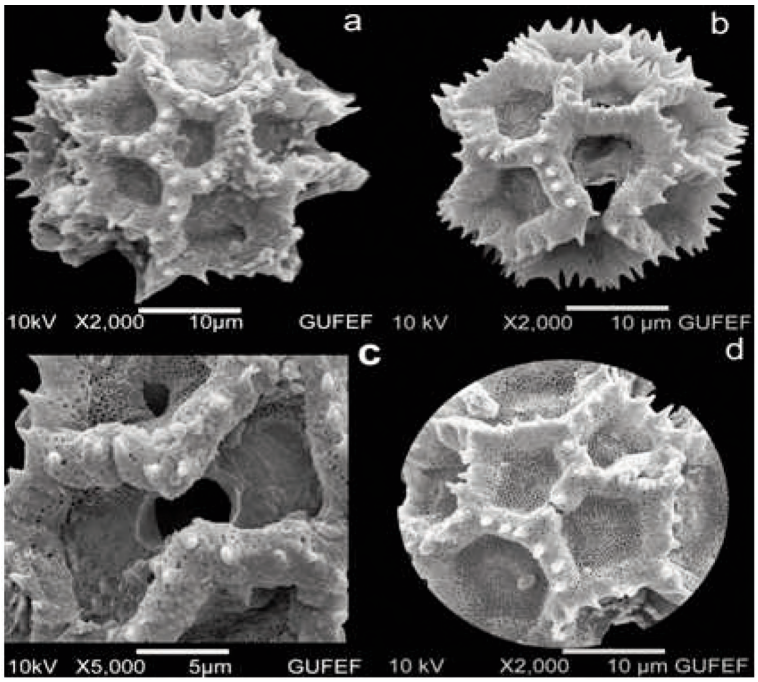

Figure 1. *S. laciniata* subsp. *laciniata*; a - polar view, b - equatorial view, c - aperture, d - ornamentation.

sexine 7.25 µm, nexine 1.37 µm. Thickening in porus zone hexagonal, spines concave-conic, 2.28 ± 0.47 µm (1.96-2.94 µm), spine basis 1.3 ± 0.47 µm (0.98-1.96 µm), singular line on muri. Muri 2.74 ± 0.4 µm (1.96-2.94 µm), lacunae width 8.55 ± 1.19 µm (5.88-9.8 µm), lacunae ornamentation perforate-microrugulate. Lacunar system is type B.

Scorzonera cana* (C.A.Mey.) Hoffm. var. *cana (Figure 2)

Pollen grains are isopolar, radially symmetric, tricolporate, oblate-spheroidal. Polar view triangular, amb 38.25 ± 1.89 µm (34.3-42.14 µm). Polar axis 37.92 ± 1.48 µm (35.28-41.16 µm), equatorial diameter 39.33 ± 1.22 µm (37.24-42.14 µm). P/E ratio is 0.96 µm. Apocolpium quite broad, 17.77 ± 1.93 µm (13.72-20.58 µm); colpi prolonged, distinct line colpus length 19.4 ± 1.41 µm (16.66-22.54 µm), colpus width 3.52 ± 0.7 µm (1.96-4.9 µm), porus length 4.96 ± 0.85 µm (3.92-6.86 µm), porus width 3.26 ± 0.93 µm (1.96-5.88 µm).

Exine 8.75 ± 1.07 µm (6.86-10.78 µm), pollen type is lophate, lophae ornamentation echinate-perforate, sexine 7.05 µm, nexine 1.69 µm. Thickening in porus zone hexagonal, spines concave-conic, 3.26 ± 0.47 µm (2.94-3.92 µm), spine basis 1.96 ± 0.52 µm (0.98-2.94 µm), singular line on muri. Muri 3.46 ± 0.5 µm (2.94-3.92 µm), lacunae width 7.84 ± 0.64 µm (6.86-8.82 µm), lacunae ornamentation perforate. Lacunar system is type B.

***Scorzonera armeniaca* (Boiss. & A.Huet) Boiss.** (Figure 3)

Pollen grains are isopolar, radially symmetric, tricolporate, oblate-spheroidal. Polar view triangular, amb 41.25 ± 2.55 µm (36.26-45.08 µm). Polar axis 44.16 ± 2.53 µm (40.18-49 µm), equatorial diameter 47.79 ± 3.45 µm (41.16-54.88 µm). P/E ratio is 0.92 µm. Apocolpium quite broad, 25.18 ± 2.74 µm (19.6-29.4 µm); colpi prolonged, distinct line colpus length 24.04 ± 1.22 µm (21.56-25.48 µm), colpus width 8.03 ± 1.49 µm (4.9-9.8 µm), porus length 9.53 ± 2.49 µm (4.9-12.74 µm), porus width 5.55 ± 1.46 µm (2.94-7.84 µm).

Exine 6.99 ± 0.97 µm (5.88-8.82 µm), pollen type is lophate, lophae ornamentation echinate-perforate, sexine 6.01 µm, nexine 0.98 µm. Thickening in porus zone hexagonal, spines conic, 1.63 ± 0.47 µm (0.98-1.96 µm), spine basis 1.24 ± 0.44 µm (0.98-1.96 µm),

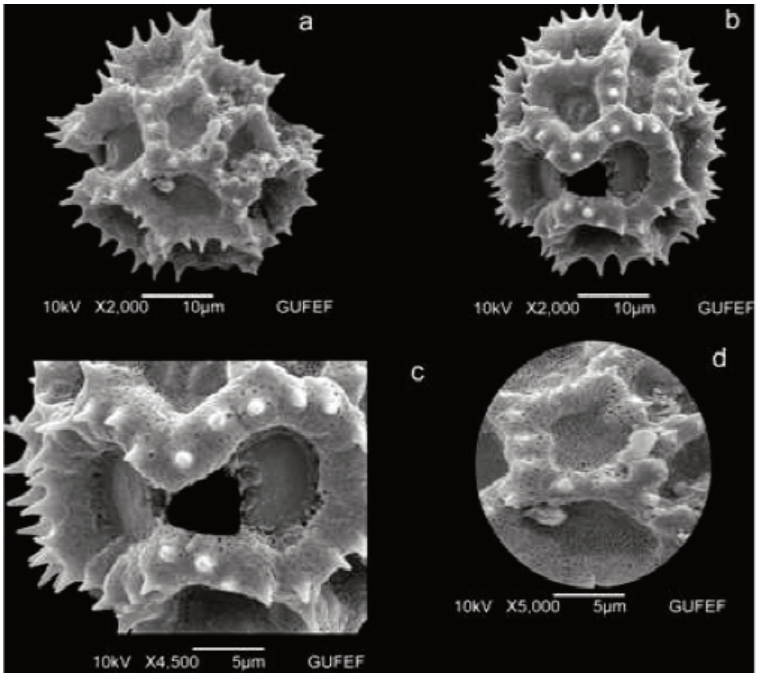

Figure 2. *S. cana* var. *cana*; a - polar view, b - equatorial view, c - aperture, d -ornamentation.

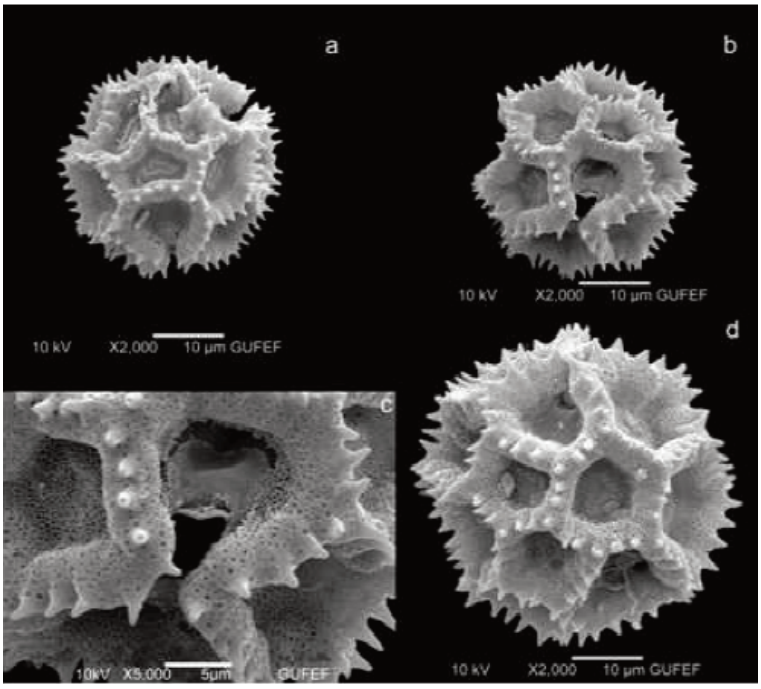

Figure 3. *S. armeniaca*; a - polar view, b - equatorial view, c - aperture, d - ornamentation.

singular line on muri. Muri 3.72 ± 0.66 µm (2.94-4.9 µm), lacunae width 4.96 ± 0.86 µm (3.92-6.86 µm), lacunae ornamentation perforate. Lacunar system is type B.

***Scorzonera suberosa* K.Koch.** (Figure 4)

Pollen grains are isopolar, radially symmetric, tricolporate, oblate-spheroidal. Polar view triangular, amb 48.51 ± 1.66 µm (46.06-51.94 µm). Polar axis 52.78 ± 1.42 µm (50.96-55.86 µm), equatorial diameter 54.32 ± 1.42 µm (52.92-56.84 µm). P/E ratio is 0.97 µm. Apocolpium quite broad, 24.1 ± 2.58 µm (19.6-27.44 µm); colpi prolonged, distinct line colpus length 25.41 ± 0.68 µm (24.5-26.46 µm), colpus width 9.6 ± 0.75 µm (8.82-10.78 µm), porus length 8.23 ± 1.09 µm (5.88-8.82 µm), porus width 4.63 ± 1.35 µm (2.94-6.86 µm).

Exine 10.12 ± 1.09 µm (8.82-11.76 µm), pollen type is lophate, lophae ornamentation echinate-perforate, sexine 8.82 µm, nexine 1.37 µm. Thickening in porus zone hexagonal, spines concave-conic, 3.52 ± 0.72 µm (2.94-4.9 µm), spine basis 1.76 ± 1.76 µm (0.98-2.94 µm), singular line on muri. Muri 4.63 ± 0.68 µm (3.92-5.88 µm), lacunae width 12.34 ± 0.89 µm (10.78-13.72 µm), lacunae ornamentation perforate-microreticulate. Lacunar system is type B.

***Scorzonera mollis* subsp. *mollis* M.Bieb.** (Figure 5)

Pollen grains are isopolar, radially symmetric, tricolporate, oblate-spheroidal. Polar view triangular, amb 49.19 ± 2.61 µm (46.06-53.9 µm). Polar axis 56.02 ± 3.06 µm (50.96-59.78 µm), equatorial diameter 58.96 ± 2.85 µm (53.9-62.72 µm). P/E ratio is 0.95 µm. Apocolpium quite broad, 24.17 ± 2.67 µm (19.6-28.42 µm); colpi prolonged, distinct line colpus length 28.48 ± 1.3 µm (26.46-30.38 µm), colpus width 10.64 ± 1.27 µm (8.82-12.74 µm), porus length 8.49 ± 1.31 µm (5.88-9.8 µm), porus width 4.63 ± 1.35 µm (2.94-6.86 µm).

Exine 10.12 ± 1.09 µm (8.82-11.76 µm), pollen type is lophate, lophae ornamentation echinate-perforate, sexine 8.42 µm, nexine 1.69 µm. Thickening

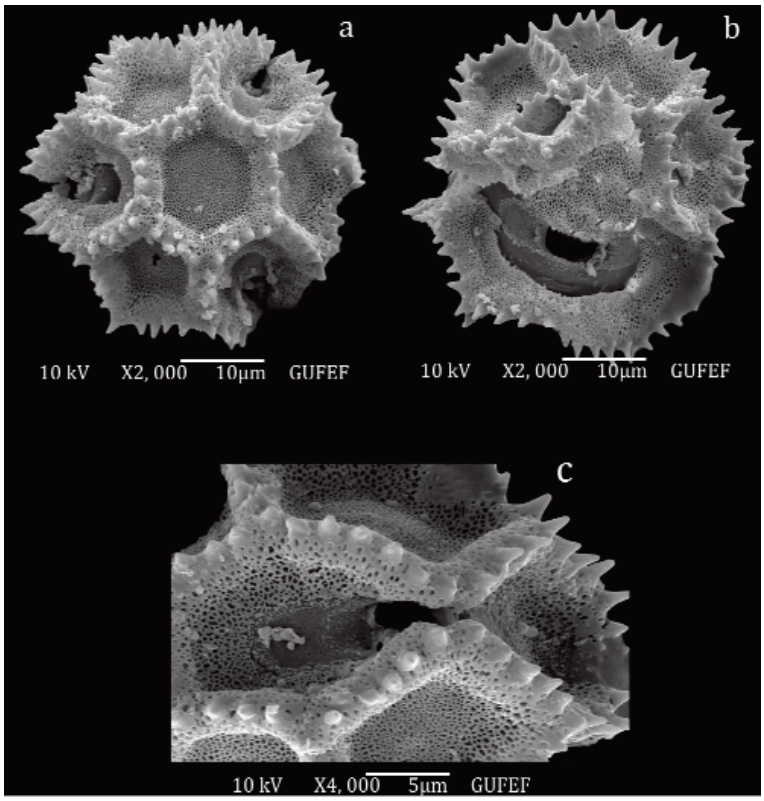

Figure 4. *S. suberosa*; a - polar view, b - equatorial view, c - aperture.

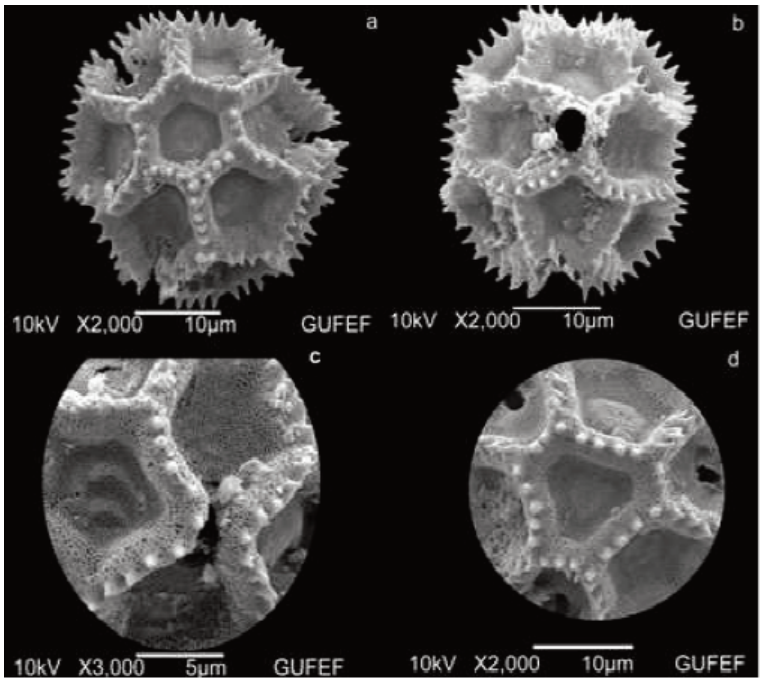

Figure 5. *S. mollis* subsp. *mollis*; a - polar view, b -equatorial view, c - aperture, d - ornamentation.

in porus zone hexagonal, spines concave-conic, 3.92 ± 0.52 µm (2.94-4.9 µm), spine basis 1.96 ± 0.52 µm (0.98-2.94 µm), singular line on muri. Muri 4.83 ± 0.58 µm (3.92-5.88 µm), lacunae width 13.19 ± 1.16 µm (10.78-14.7 µm), lacunae ornamentation perforate. Lacunar system is type B.

***Scorzonera inaequiscapa* Boiss.** (Figure 6)

Pollen grains are isopolar, radially symmetric, tricolporate, oblate-spheroidal. Polar view triangular, amb 52.69 ± 3.0 µm (49.0-58.8 µm). Polar axis 55.99 ± 3.83 µm (49.0-61.74 µm), equatorial diameter 57.39 ± 4.24 µm (49.98-63.7 µm). P/E ratio is 0.98 µm. Apocolpium quite broad, 28.7 ± 4.48 µm (19.6-34.3 µm); colpi prolonged, distinct line colpus length 32.58 ± 2.41 µm (29.4-36.26 µm), colpus width 9.12 ± 1.81 µm (5.88-11.76 µm), porus length 10.04 ± 1.1 µm (7.84-12.74 µm), porus width 5.56 ± 2.75 µm (0.98-11.7 µm).

Exine 11.82 ± 1.71 µm (8.82-14.7 µm), pollen type is lophate, lophae ornamentation echinate-perforate, sexine 9.21 µm, nexine 2.61 µm. Thickening in porus zone hexagonal, spines concave-conic, 3.2 ± 0.44 µm (2.94-3.92 µm), spine basis 1.63 ± 0.47 µm (0.98-1.96 µm), singular line on muri. Muri 4.44 ± 0.72 µm (2.94-4.9 µm), lacunae width 8.16 ± 2.08 µm (4.9-9.8 µm), lacunae ornamentation perforate. Lacunar system is type B.

***Scorzonera insica* DC.** (Figure 7)

Pollen grains are isopolar, radially symmetric, tricolporate, prolate-spheroidal. Polar view triangular, amb 40.08 ± 2.97 µm (42.14-52.92 µm). Polar axis 55.1 ± 2.59 µm (50.96-59.78 µm), equatorial diameter 54.45 ± 3.2 µm (49.0-58.8 µm). P/E ratio is 1.01 µm. Apocolpium quite broad, 28.22 ± 3.37 µm (23.52-34.3 µm); colpi prolonged, distinct line colpus length 27.76 ± 4.36 µm (19.6-35.28 µm), colpus width 7.25 ± 1.37 µm (4.9-9.8 µm), porus length 9.53 ± 1.01 µm (6.86-10.78 µm), porus width 8.1 ± 1.59 µm (5.88-9.8 µm).

Exine 9.08 ± 1.54 µm (6.86-11.76 µm), pollen type is lophate, lophae ornamentation echinate-perforate, sexine 7.7 µm, nexine 1.37 µm. Thickening in porus zone hexagonal, spines concave-conic, 1.3 ± 0.47 µm (0.98-1.96 µm), spine basis 1.43 ± 0.5 µm (0.98-1.96 µm), singular line on muri. Muri 5.16 ± 1.07 µm (3.92-6.86 µm), lacunae width 6.01 ± 1.16 µm (4.9-8.82 µm), lacunae ornamentation perforate. Lacunar system is type C.

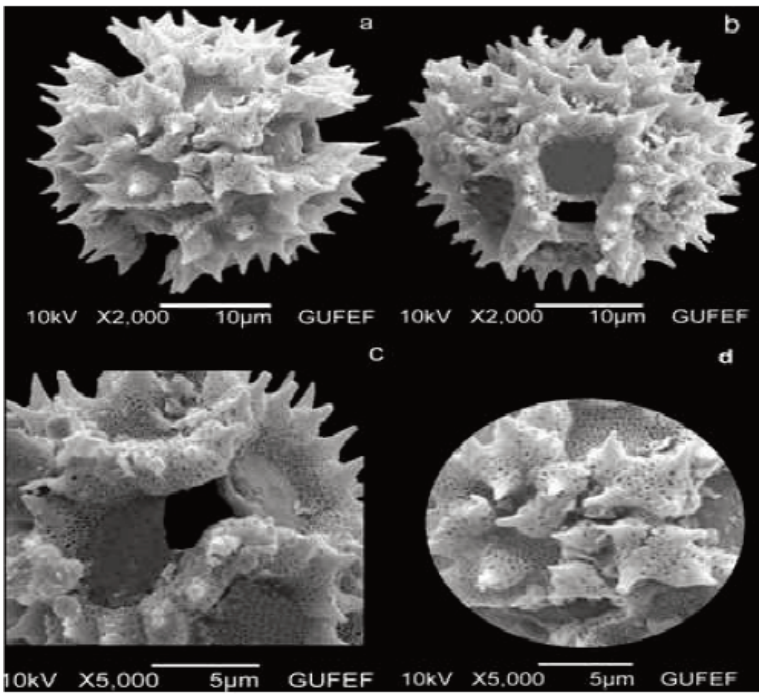

Figure 6. *S. inaequiscapa*; a - polar view, b - equatorial view, c - aperture, d - ornamentation.

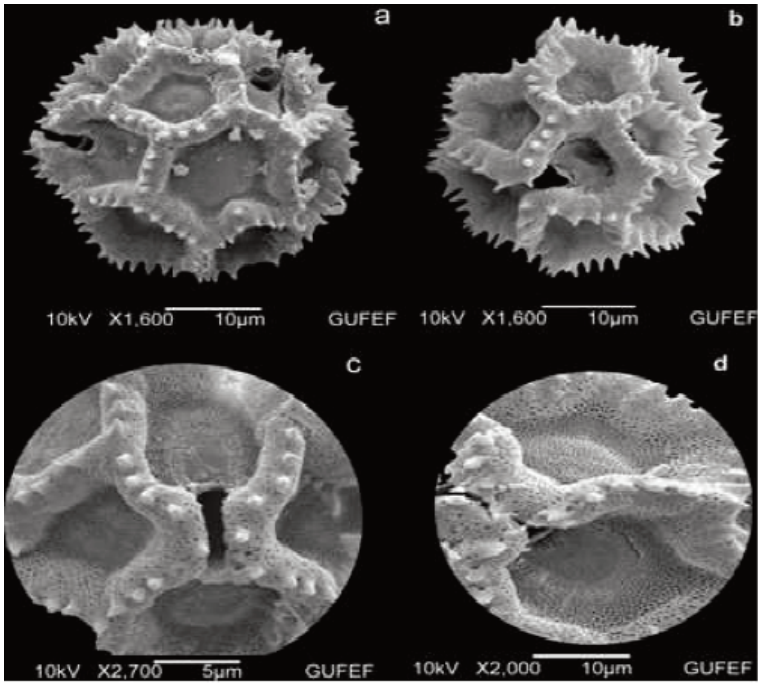

Figure 7. *S. insica*; a - polar view, b - equatorial view, c - aperture, d - ornamentation.

***Scorzonera eriophora* DC.** (Figure 8)

Pollen grains are isopolar, radially symmetric, tricolporate, oblate-spheroidal. Polar view triangular, amb 41.65 ± 1.92 µm (39.2-45.08 µm). Polar axis 40.08 ± 2.99 µm (35.28-45.08 µm), equatorial diameter 41.09 ± 3.0 µm (37.24-47.04 µm). P/E ratio is 0.97 µm. Apocolpium quite broad, 15.81 ± 1.19 µm (14.7-18.62 µm); colpi prolonged, distinct line colpus length 21.29 ± 1.45 µm (19.6-23.52 µm), colpus width 3.52 ± 0.89 µm (1.96-4.9 µm), porus length 6.53 ± 1.02 µm (4.9-7.84 µm), porus width 5.03 ± 0.97 µm (3.92-6.86 µm).

Exine 7.84 ± 1.28 µm (6.86-10.78 µm), pollen type is lophate, lophae ornamentation echinate-perforate, sexine 6.27 µm, nexine 1.56 µm. Thickening in porus zone hexagonal, spines concave-conic, 3.13 ± 0.4 µm (2.94-3.92 µm), spine basis 1.69 ± 0.44 µm (0.98-1.96 µm), singular line on muri. Muri 3.2 ± 0.44 µm (2.94-3.92 µm), lacunae width 5.88 ± 0.74 µm (4.9-6.86 µm), lacunae ornamentation perforate. Lacunar system is type A.

***Scorzonera cinerea* Boiss.** (Figure 9)

Pollen grains are isopolar, radially symmetric, tricolporate, oblate-spheroidal. Polar view triangular, amb 37.53 ± 0.85 µm (36.26-39.2 µm). Polar axis 41.91 ± 1.14 µm (40.18-44.1 µm), equatorial diameter 42.89 ± 1.32 µm (41.16-45.08 µm). P/E ratio is 0.97 µm. Apocolpium quite broad, 25.18 ± 1.74 µm (19.6-29.4 µm); colpi prolonged, distinct line colpus length 23.97 ± 1.32 µm (21.56-25.48 µm), colpus width 4.9 ± 1.49 µm (4.9-9.8 µm), porus length 6.27 ± 1.47 µm (4.9-8.82 µm), porus width 4.57 ± 0.8 µm (2.94-5.88 µm).

Exine 7.12 ± 1.01 µm (5.88-8.82 µm), pollen type is lophate, lophae ornamentation echinate-perforate, sexine 6.14 µm, nexine 0.98 µm. Thickening in porus zone hexagonal, spines concave-conic, 1.37 ± 0.49 µm (0.98-1.96 µm), spine basis 1.43 ± 0.5 µm (0.98-1.96 µm), singular line on muri. Muri 3.72 ± 0.66 µm (2.94-4.9 µm), lacunae width 5.09 ± 0.75 µm (3.92-6.86 µm), lacunae ornamentation perforate-microreticulate. Lacunar system is type B.

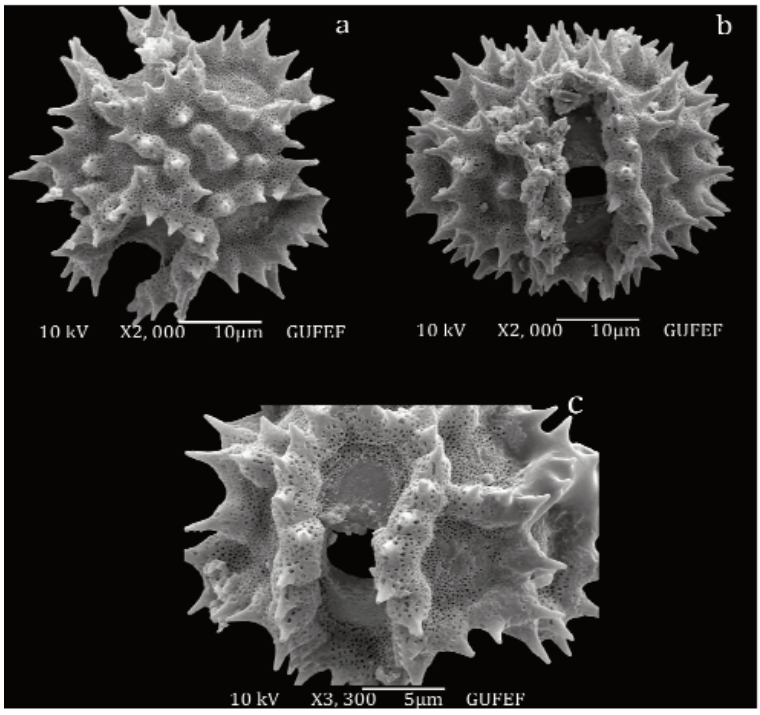

Figure 8. *S. eriophora*; a - polar view, b - equatorial view, c - aperture.

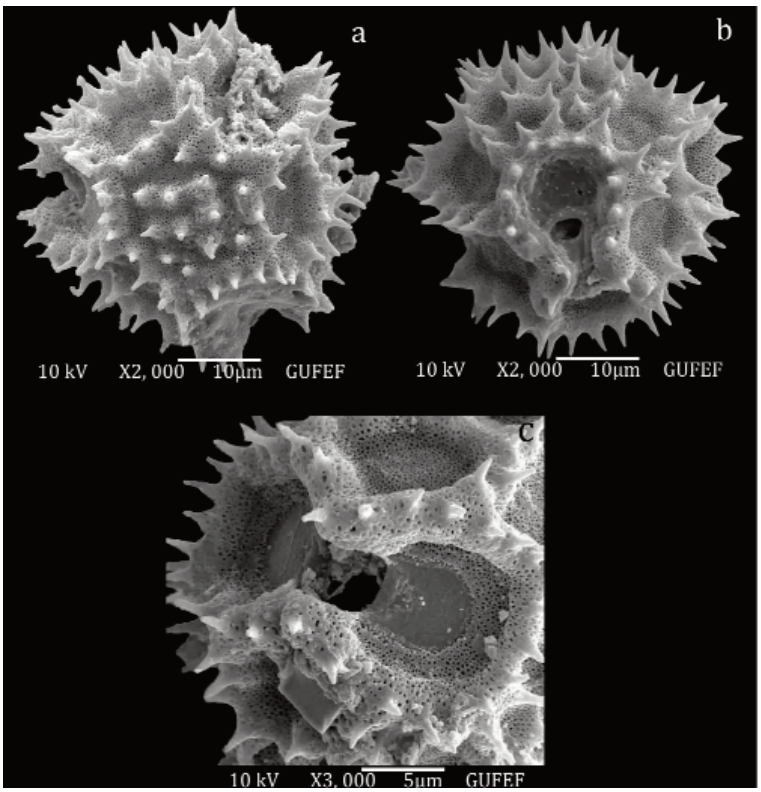

Figure 9. *S. cinerea*; a - polar view, b - equatorial view, c - aperture.

***Scorzonera sericea* DC.** (Figure 10)

Pollen grains are isopolar, radially symmetric, tricolporate, oblate-spheroidal. Polar view triangular, amb 34.26 ± 3.36 µm (28.42-40.18 µm). Polar axis 39.13 ± 2.74 µm (34.3-44.1 µm), equatorial diameter 41.97 ± 3.13 µm (36.26-47.04 µm). P/E ratio is 0.93 µm. Apocolpium quite broad, 18.22 ± 3.08 µm (12.74-22.54 µm); colpi prolonged, distinct line colpus length 22.86 ± 3.37 µm (16.66-29.4 µm), colpus width 6.2 ± 1.41 µm (3.92-8.82 µm), porus length 5.94 ± 1.35 µm (3.92-8.82 µm), porus width 4.76 ± 1.04 µm (2.94-6.86 µm).

Exine 7.51 ± 1.83 µm (3.92-10.78 µm), pollen type is lophate, lophae ornamentation echinate-perforate, sexine 6.01 µm, nexine 1.5 µm. Thickening in porus zone hexagonal, spines concave-conic, 3.26 ± 0.88 µm (1.96-4.9 µm), spine basis 1.89 ± 0.68 µm (0.98-2.94 µm), singular line on muri. Muri 3.2 ± 1.01 µm (1.96-4.9 µm), lacunae width 4.5 ± 1.15 µm (2.94-6.86 µm), lacunae ornamentation perforate. Lacunar system is type B.

***Scorzonera pseudolanata* Grossh.** (Figure 11)

Pollen grains are isopolar, radially symmetric, tricolporate, oblate-spheroidal. Polar view triangular, amb 36.44 ± 2.71 µm (32.34-41.16 µm). Polar axis 39.49 ± 3.07 µm (34.3-46.06 µm), equatorial diameter 40.6 ± 1.97 µm (37.24-44.1 µm). P/E ratio is 0.97 µm. Apocolpium quite broad, 15.05 ± 2.5 µm (9.8-20.58 µm); colpi prolonged, distinct line colpus length 22.73 ± 1.62 µm (19.6-24.5 µm), colpus width 7.44 ± 0.81 µm (5.88-8.82 µm), porus length 5.94 ± 1.54 µm (3.92-8.82 µm), porus width 4.5 ± 1.47 µm (1.96-6.86 µm).

Exine 7.7 ± 0.81 µm (6.86-9.8 µm), pollen type is lophate, lophae ornamentation echinate-perforate, sexine 6.4 µm, nexine 1.3 µm. Thickening in porus zone hexagonal, spines concave-conic, 3.26 ± 0.47 µm (2.94-3.92 µm), spine basis 1.82 ± 0.62 µm (0.98-2.94 µm), singular line on muri. Muri 3.39 ± 0.97 µm (1.96-4.9 µm), lacunae width 6.66 ± 2.1 µm (2.94-9.8 µm), lacunae ornamentation perforate-psilate. Lacunar system is type B.

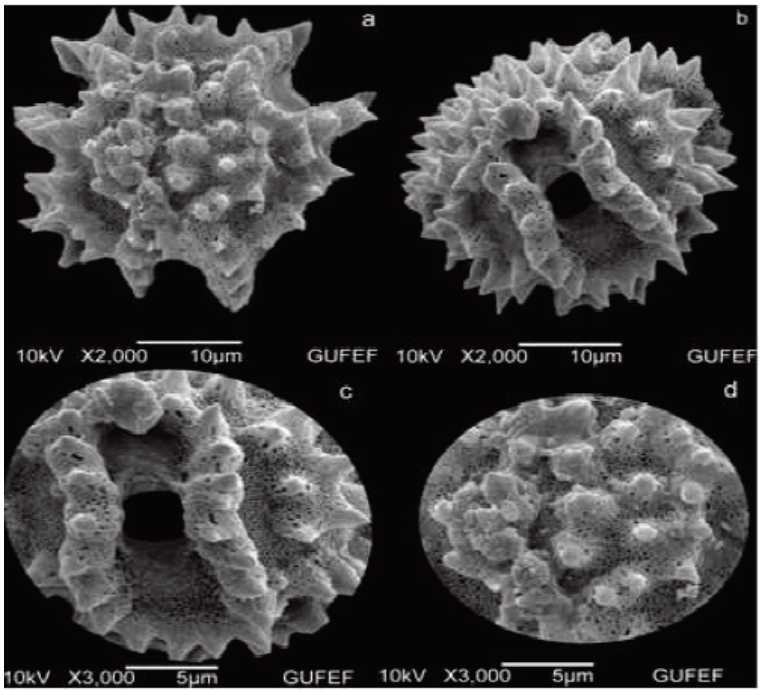

Figure 10. *S. sericea*; a - polar view, b - equatorial view, c - aperture, d - ornamentation.

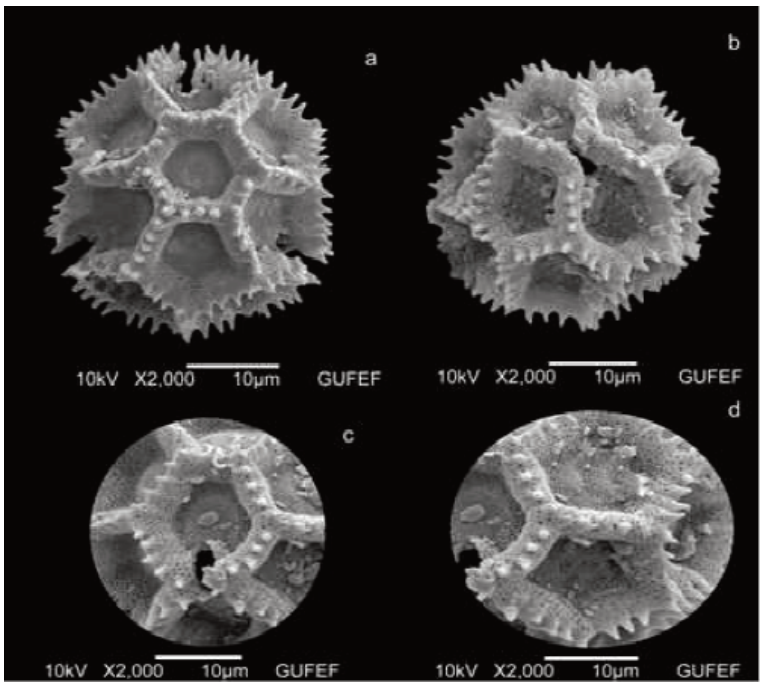

Figure 11. *S. pseudolanata*; a - polar view, b - equatorial view, c - aperture, d - ornamentation.

***Scorzonera sosnowskyi* Lipschitz** (Figure 12)

Pollen grains are isopolar, radially symmetric, tricolporate, oblate-spheroidal. Polar view triangular, amb 50.07 ± 3.42 µm (44.1-55.86 µm). Polar axis 50.66 ± 3.77 µm (44.1-56.84 µm), equatorial diameter 56.77 ± 2.95 µm (50.96-60.76 µm). P/E ratio is 0.89 µm. Apocolpium quite broad, 26.98 ± 3.39 µm (20.58-33.32 µm); colpi prolonged, distinct line colpus length 20.38 ± 2.67 µm (16.66-24.5 µm), colpus width 5.88 ± 1.57 µm (3.92-8.82 µm), porus length 6.72 ± 1.03 µm (4.9-8.82 µm), porus width 7.38 ± 1.73 µm (4.9-9.8 µm).

Exine 9.4 ± 0.89 µm (7.84-10.78 µm), pollen type is lophate, lophae ornamentation echinate-perforate, sexine 8.16 µm, nexine 1.23 µm. Thickening in porus zone hexagonal, spines concave-conic, 3.33 ± 0.81 µm (1.96-4.9 µm), spine basis 1.96 ± 0.52 µm (0.98-2.94 µm), singular line on muri. Muri 4.44 ± 1.03 µm (2.94-5.88 µm), lacunae width 6.27 ± 1.32 µm (4.9-8.82 µm), lacunae ornamentation perforate. Lacunar system is type B.

***Scorzonera tomentosa* L.** (Figure 13)

Pollen grains are isopolar, radially symmetric, tricolporate, oblate-spheroidal. Polar view triangular, amb 62.98 ± 2.5 µm (57.82-66.64 µm). Polar axis 57.26 ± 4.08 µm (50.96-63.7 µm), equatorial diameter 63.34 ± 3.89 µm (56.84-68.6 µm). P/E ratio is 0.90 µm. Apocolpium quite broad, 21.33 ± 2.28 µm (16.66-25.48 µm); colpi prolonged, distinct line colpus length 30.52 ± 3.02 µm (24.5-34.3 µm), colpus width 5.22 ± 1.72 µm (2.94-7.84 µm), porus length 8.29 ± 1.8 µm (4.9-10.78 µm), porus width 7.31 ± 1.6 µm (4.9-9.8 µm).

Exine 10.58 ± 0.66 µm (9.8-11.76 µm), pollen type is lophate, lophae ornamentation echinate-perforate, sexine 9.47 µm, nexine 1.11 µm. Thickening in porus zone hexagonal, spines concave-conic, 4.63 ± 0.44 µm (3.92-4.9 µm), spine basis 1.96 ± 0.0 µm (1.96-1.96 µm), singular line on muri. Muri 4.96 ± 0.78 µm (3.92-5.88 µm), lacunae width 5.68 ± 0.4 µm (4.9-5.88 µm), lacunae ornamentation perforate-microrugulate. Lacunar system is type B.

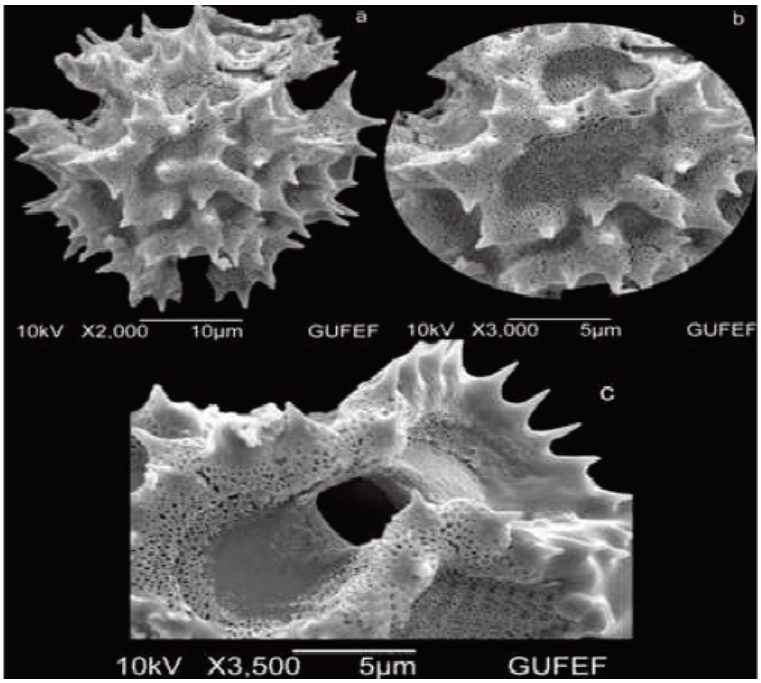

Figure 12. *S. sosnowskyi*; a - polar view, b - equatorial view, c - aperture.

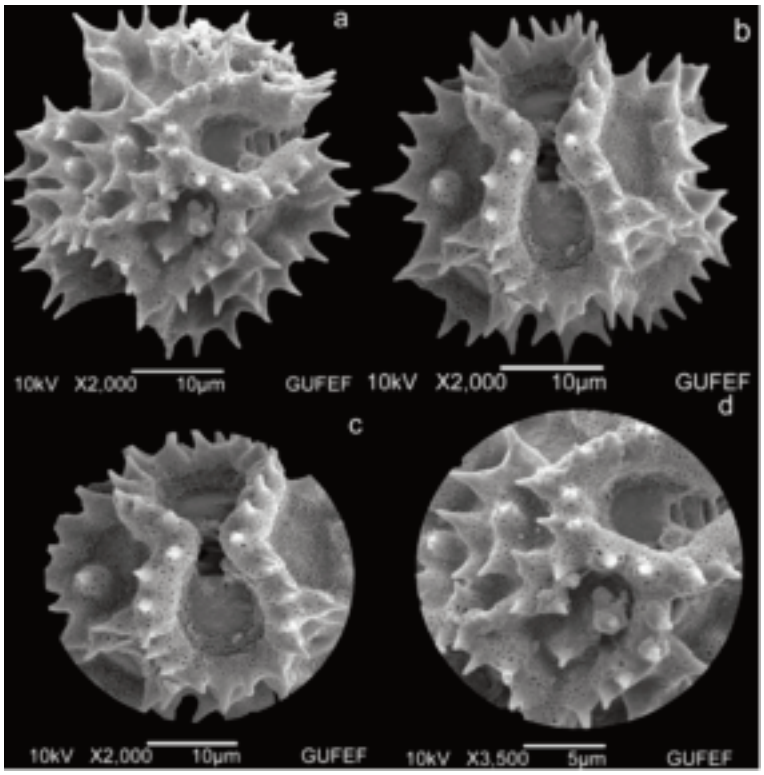

Figure 13. *S. tomentosa*; a - polar view, b - equatorial view, c - aperture, d - ornamentation.

Discussion

The dendrogram resulting from UPGMA based on 16 palynological variables is represented in Figure 14. As seen in Figure 14, all investigated taxa fall into 2 major clusters at 98% dissimilarity levels. One, labelled as "a," consists of 5 caulescent and 2 scapigerous taxa. Cluster "b" includes 3 caulescent and 3 scapigerous taxa. When the dendrogram is carefully examined, it is seen that palynological results from cluster analysis generally support the morphological delimitations reported by Chamberlain (1975) and Makbul et al. (2010), but there are some distinctive differences, to be explained as follows.

Cluster "a" is divided into 2 subgroups (Figure 14). While the first subgroup consists of both scapigerous (*S. sericea* and *S. pseudolanata*) and caulescent (*S. laciniata, S. cana* var. *cana*, and *S. eriophora*) taxa, the second subgroup consists of only caulescent taxa (*S. armeniaca* and *S. cinerea*). *S. armeniaca* and *S. cinerea* are closely related taxa (Chamberlain, 1975; Makbul et al., 2010), and as seen in Figure 14, these 2 taxa are not easily separated by means of palynological traits used in this study. Similarly, *S. laciniata* subsp. *laciniata* and *S. armeniaca*, which are phenetically (Chamberlain, 1975) and anatomically (Makbul et al., 2010) related taxa, are not grouped in the same cluster based on palynological data. This means that palynological traits supply useful information for delimiting the 2 examined taxa, but *S. cana* and *S. laciniata* subsp. *laciniata*, indicated as allied taxa by Chamberlain (1975), are not separated from each other in terms of palynological characters (Figure 14). It is seen that pollen features are not distinctive for the 2 related examined taxa. *S. cinerea* and *S. armeniaca* are linked to each other very closely in contrast to the anatomical and phenetic dissimilarity reported by Makbul et al. (2010).

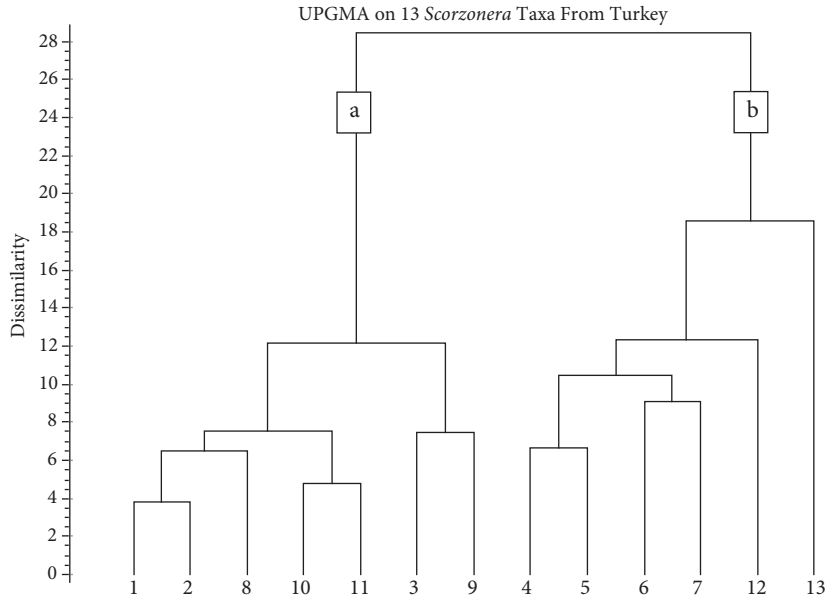

Figure 14. Cluster analysis – UPGMA. 1 - S. *laciniata* subsp. *laciniata*, 2 - *S. cana* var. *cana*, 3 - *S. armeniaca*, 4 - *S. suberosa*, 5 - *S. mollis* subsp. *mollis*, 6 - *S. inaequiscapa*, 7 - *S. insica*, 8 - *S. eriophora*, 9 - *S. cinerea*, 10 - *S. sericea*, 11 - *S. pseudolanata*, 12 - *S. sosnowskyi*, 13 - *S. tomentosa*.

Table 3. Percentage of variance of variables accounted for by first 3 components.

Names of variables	PC-1	PC-2	PC-3
X2	49.176	8.573	73.500
X3	5.345	1.417	2.007
X4	7.418	1.670	2.788
X5	6.862	2.274	5.174
X6	24.528	4.219	17.803
X7	44.590	8.150	66.423
X8	22.308	4.595	21.118
X9	8.879	1.486	2.210
X10	3.982	0.797	0.635
X11	7.269	2.751	7.569
X12	2.923	0.999	0.999
X13	1.688	0.266	0.071
X14	0.951	0.033	0.001
X15	0.076	0.277	0.076
X16	0.153	0.375	0.141
Percentage of variance explained	45.71	21.53	12.20
Cumulative percentages of variance explained	45.71	67.25	79.45

Cluster "b" was also divided into 2 groups, as was cluster "a." The first group consists of scapigerous (*S. suberosa*, *S. mollis* subsp. *mollis*, and *S. inaequiscapa*) and caulescent (*S. insica* and *S. sosnowskyi*) taxa. *S. suberosa*, *S. mollis* subsp. *mollis*, and *S. inaequiscapa*, taxa that are related according to Chamberlain (1975), are grouped in the same small cluster. This means that these taxa are also closely related based on palynological properties, in contrast to the anatomical properties reported by Makbul et al. (2010).

As indicated by Chamberlain (1975) and Makbul et al. (2010) based on phenetic and anatomical properties, respectively, *S. sosnowskyi* and *S. tomentosa* are also closely related species according to our palynological results, and these results show that palynological data are not sufficient for delimiting these 2 related taxa.

According to Chamberlain (1975), *S. pseudolanata* and *S. inaequiscapa* are closely related species in terms of morphological properties, but anatomical results reported by Makbul et al. (2010) and palynological results presented in this study do not support this view. Additionally, *S. cinerea* is very similar to *S.*

tomentosa and *S. sosnowskyi* based on both morphological (Chamberlain, 1975; Makbul et al., 2010) properties, but this view is not confirmed by results from UPGMA based on general palynological traits. This means that palynological traits can also be useful in distinguishing these 2 taxa from *S. cinerea*.

In order to determine which traits are important in explaining the total variation among the examined species, PCA analysis was performed on the standardised data given in Table 2. It was determined that most of the traits among the observed features were important in explaining the total variation. PCA results for the first 2 components are given in Figure 15. The eigenvalues as percentages are given in Table 3. Only the first 3 components were taken into account because of their eigenvalues. The eigen values of the first 3 components as percentages based on 16 palynological traits are 45.71%, 21.53%, and 12.20%, respectively.

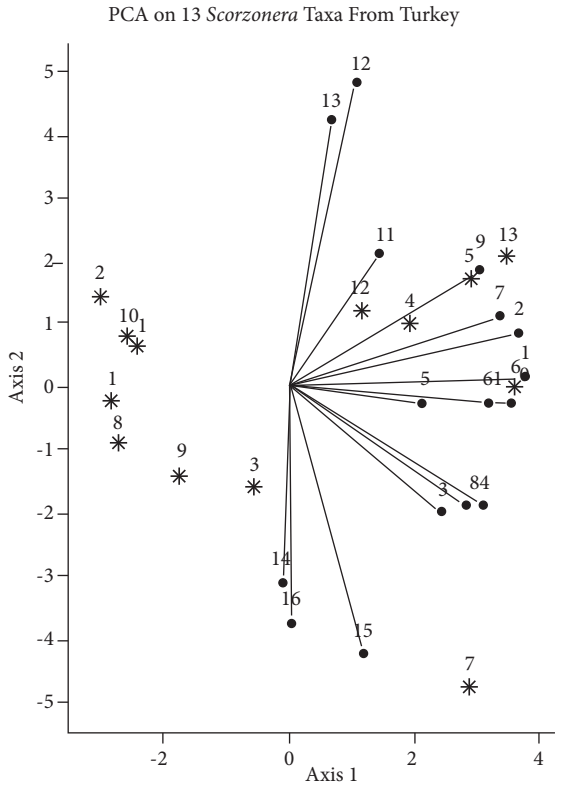

Figure 15. Principal component analysis of 13 taxa and 16 variables projected onto the first 2 axes. For taxa (*) and variable at the end of dashed lines (•) number explanations, see Tables 2 and 3, respectively.

The first 3 components emphasise polar axis (X_1), equatorial diameter (X_2), colpus length (X_6), and pollen diameter (X_7). However, most of weights are under 40% and almost equal. In summary, polar and equatorial diameter, together with pollen diameter, are the most important palynological traits in separating the *Scorzonera* taxa examined in the present study. These characters should be used for separating the examined taxa, together with the morphological trait used in most floras. Our palynological results are generally supported the phenetic similarity found by Chamberlain (1975).

Pollen grains have an important role in the modern issue of plant taxonomy (Bashir & Khan, 2003). Pollen characters were used for the establishment of interspecies relationships among species of Asteraceae by Mbagwu et al. (2008). There is great variation in pollen size among the *Scorzonera* taxa. The dimension of the polar axis ranged from 37.92 µm (*S. cana* var. *cana*) to 57.26 µm (*S. tomentosa*), and the equatorial diameter ranged between 39.33 µm (*S. cana* var. *cana*) and 63.34 µm (*S. tomentosa*). Pollen sizes from 28.0 µm (*Crepis multicaulis* K.Koch, *Picrotheca falconeri*) to 61.0 µm (*Scorzonera divaricata* Turcz.) were reported in 41 species of different genera of tribe Lactuceae by Nair and Lawrence (1985). The pollen size was given as 19-35 × 26-42 µm in 14 Spanish *Sonchus* species by Mejias and Diez (1993). The size of the polar area in pollen morphology is taxonomically useful (El-Ghazaly, 1980).

Scorzonera armeniaca can be distinguished due its P/E ratio of 0.92 (Table 4). A prolate-spheroidal pollen shape is observed in *S. insica*, and oblate-spheroidal in the rest of the examined taxa, e.g. *S. tomentosa*, *S. pseudolanata*, and *S. sericea*. *S. cana* var. *cana* and *S. insica* are similar to *S. hondae* Kitamura, *S. ammophila* Bunge, *S. picridioides* Boiss., and *S. virgata* DC. (Meo & Khan, 2004). It can be concluded that pollen size would play an important role in taxonomy.

There was a wide variation in the exine thickness among the examined taxa. It varied from 6.99 to 11.82 µm. The highest exine value was recorded for *S. inaequiscapa* (11.82 µm) and the lowest value for *S. armeniaca* (6.99 µm). This variation is prominent within this genus and can be used at a specific level (Table 4). Osman (2006) reported thicker sexine than

Table 4. Measurements and exine characteristics of pollen grains of *Scorzonera* taxa.

Taxon	Pl. Sh.	P/E	P (µm)			E (µm)			Plt (µm)			Plg (µm)			Clt (µm)			Clg (µm)		
			M	S	Var.	M	S	Var.	M	S	Var.	M	S	Var.	M	S	Var.	M	S	Var.
1	Obl.-sph.	0.95	38.57	±1.82	34.3-42.14	40.4	±1.75	37.24-44.1	4.21	±0.81	2.94-5.88	5.97	±0.64	4.9-6.86	4.54	±0.87	2.94-5.88	19.53	±1.47	16.66-21.56
2	Obl.-sph.	0.96	37.92	±1.48	35.28-41.16	39.33	±1.22	37.24-42.14	3.26	±0.93	1.96-5.88	4.96	±0.85	3.92-6.86	3.52	±0.7	1.96-4.9	19.4	±1.41	16.66-22.54
3	Obl.-sph.	0.92	44.16	±2.53	40.18-49	47.79	±3.45	41.16-54.88	5.55	±1.46	2.94-7.84	9.53	±2.49	4.9-12.74	8.03	±1.49	4.9-9.8	24.04	±1.22	21.56-25.48
4	Obl.-sph.	0.97	52.78	±1.42	50.96-55.86	54.32	±1.42	52.92-56.84	4.63	±1.35	2.94-6.86	8.23	±1.09	5.88-8.82	9.6	±0.75	8.82-10.78	25.41	±0.68	24.5-26.46
5	Obl.-sph.	0.95	56.02	±3.06	50.96-59.78	58.96	±2.85	53.9-62.72	4.63	±1.35	2.94-6.86	8.49	±1.31	5.88-9.8	10.64	±1.27	8.82-12.74	28.48	±1.3	26.46-30.38
6	Obl.-sph.	0.98	55.99	±3.83	49-61.74	57.39	±4.24	49.98-63.7	5.56	±2.75	0.98-11.7	10.04	±1.1	7.84-12.74	9.12	±1.81	5.88-11.76	32.58	±2.41	29.4-36.26
7	Prl.-sph.	1.01	55.1	±2.59	50.96-59.78	54.45	±3.2	49-58.8	8.1	±1.59	5.88-9.8	9.53	±1.01	6.86-10.78	7.25	±1.37	4.9-9.8	27.76	±4.36	19.6-35.28
8	Obl.-sph	0.97	40.08	±2.99	35.28-45.08	41.09	±3.00	37.24-47.04	5.03	±0.97	3.92-6.86	6.53	±1.02	4.9-7.84	3.52	±0.89	1.96-4.9	21.29	±1.45	19.6-23.52
9	Obl.-sph.	0.97	41.91	±1.14	40.18-44.1	42.89	±1.32	41.16-45.08	4.57	±0.8	2.94-5.88	6.27	±1.47	4.9-8.82	4.9	±1.49	4.9-9.8	23.97	±1.32	21.56-25.48
10	Obl.-sph.	0.93	39.13	±2.74	34.3-44.1	41.97	±3.13	36.26-47.04	4.76	±1.03	2.94-6.86	5.94	±1.35	3.92-8.82	6.2	±1.41	3.92-8.82	22.86	±3.37	16.66-29.4
11	Obl.-sph.	0.97	39.49	±3.07	34.3-46.06	40.6	±1.97	37.24-44.1	4.5	±1.47	1.96-6.86	5.94	±1.54	3.92-8.82	7.44	±0.81	5.88-8.82	22.73	±1.62	19.6-24.5
12	Obl.-sph.	0.89	50.66	±3.77	44.1-56.84	56.77	±2.95	60.76-50.96	7.38	±1.73	4.9-9.8	6.72	±1.03	4.9-8.82	5.88	±1.57	3.92-8.82	20.38	±2.67	16.66-24.5
13	Obl.-sph.	0.90	57.26	±4.08	50.96-63.7	63.34	±3.89	56.84-68.6	7.31	±1.6	4.9-9.8	8.29	±1.8	4.9-10.78	5.22	±1.72	2.94-7.84	30.52	±3.02	24.5-34.3

(Pl. Sh.) Pollen Shape, (P) Polar axis, (E) Equatorial diameter, (Plt) Porus width, (Plg) Porus length, (Clt) Colpus width, (Clg) Colpus length. 1 - S. *laciniata* subsp. *laciniata*, 2 - *S. cana* var. *cana*, 3 - *S. armeniaca*, 4 - *S. suberosa*, 5 - *S. mollis* subsp. *mollis*, 6 - *S. inaequiscapa*, 7 - *S. insica*, 8 - *S. eriophora*, 9 - *S. cinerea*, 10 - *S. sericea*, 11- *S. pseudolanata*, 12 - *S. sosnowskyi*, 13 - *S. tomentosa*.

Table 4. Continued.

Taxon	Amb (µm)			Apocolpium (µm)			Ex. (µm)			Muri (µm)			Lum. (µm)			Sp. lg (µm)			Sp. bs. (µm)		
	M	S	Var.	M	S	Var.	M	S	Var.	M	S	Var.	M	S	Var.	M	S	Var.	M	S	Var.
1	39.23	±2.44	34.3-43.12	20.28	±1.48	16.66-22.54	8.62	±1.33	5.88-10.78	2.74	±0.4	1.96-2.94	8.55	±1.19	5.88-9.8	2.28	±0.47	1.96-2.94	1.3	±0.47	0.98-1.96
2	38.25	±1.89	34.3-42.14	17.77	±1.93	13.72-20.58	8.75	±1.07	6.86-10.78	3.46	±0.5	2.94-3.92	7.84	±0.64	6.86-8.82	3.26	±0.47	2.94-3.92	1.96	±0.52	0.98-2.94
3	41.25	±2.55	36.26-45.08	25.18	±2.74	19.6-29.4	6.99	±0.97	5.88-8.82	3.72	±0.66	2.94-4.9	4.96	±0.86	3.92-6.86	1.63	±0.47	0.98-1.96	1.24	±0.44	0.98-1.96
4	48.51	±1.66	46.06-51.94	24.1	±2.58	19.6-27.44	10.12	±1.09	8.82-11.76	4.63	±0.68	3.92-5.88	12.34	±0.89	10.78-13.72	3.52	±0.72	2.94-4.9	1.76	±1.76	0.98-2.94
5	49.19	±2.61	46.06-53.9	24.17	±2.67	19.6-28.42	10.12	±1.09	8.82-11.76	4.83	±0.58	3.92-5.88	13.19	±1.16	10.78-14.7	3.92	±0.52	2.94-4.9	1.96	±0.52	0.98-2.94
6	52.69	±3.0	49-58.8	28.7	±4.48	19.6-34.3	11.82	±1.71	8.82-14.7	4.44	±0.72	2.94-4.9	8.16	±2.08	4.9-9.8	3.2	±0.44	2.94-3.92	1.63	±0.47	0.98-1.96
7	48.08	±2.97	42.14-52.92	28.22	±3.37	23.52-34.3	9.08	±1.54	6.86-11.76	5.16	±1.07	3.92-6.86	6.01	±1.16	4.9-8.82	1.3	±0.47	0.98-1.96	1.43	±0.5	0.98-1.96
8	41.65	±1.92	39.2-45.08	15.81	±1.19	14.7-18.62	7.84	±1.28	6.86-10.78	3.2	±0.44	2.94-3.92	5.88	±0.74	4.9-6.86	3.13	±0.4	2.94-3.92	1.69	±0.44	0.98-1.96
9	37.53	±0.85	36.26-39.2	25.18	±1.74	19.6-29.4	7.12	±1.01	5.88-8.82	3.72	±0.66	2.94-4.9	5.09	±0.75	3.92-6.86	1.37	±0.49	0.98-1.96	1.43	±0.5	0.98-1.96
10	34.26	±3.36	28.42-40.18	18.22	±3.08	12.74-22.54	7.51	±1.83	3.92-10.78	3.2	±1.01	1.96-4.9	4.5	±1.15	2.94-6.86	3.26	±0.88	1.96-4.9	1.89	±0.68	0.98-2.94
11	36.44	±2.71	32.34-41.16	15.05	±2.5	9.8-20.58	7.7	±0.81	6.86-9.8	3.39	±0.97	1.96-4.9	6.66	±2.1	2.94-9.8	3.26	±0.47	2.94-3.92	1.82	±0.62	0.98-2.94
12	50.07	±3.42	44.1-55.86	26.98	±3.39	20.58-33.32	9.4	±0.89	7.84-10.78	4.44	±1.03	2.94-5.88	6.27	±1.32	4.9-8.82	3.33	±0.81	1.96-4.9	1.96	±0.52	0.98-2.94
13	62.98	±2.5	57.82-66.64	21.33	±2.28	16.66-25.48	10.58	±0.66	9.8-11.76	4.96	±0.78	3.92-5.88	5.68	±0.4	4.9-5.88	4.63	±0.44	3.92-4.9	1.96	±0.0	1.96-1.96

(Ex.) Exine, (Lum.) Lumina, (Sp. lg.) Spine length, (Sp. bs.) Spine base.

1 - S. *laciniata* subsp. *laciniata*, 2 - *S. cana* var. *cana*, 3 - *S. armeniaca*, 4 - *S. suberosa*, 5 - *S. mollis* subsp. *mollis*, 6 - *S. inaequiscapa*, 7 - *S. insica*, 8 - *S. eriophora*, 9 - *S. cinerea*, 10 - *S. sericea*, 11 - *S. pseudolanata*, 12 - *S. sosnowskyi*, 13 - *S. tomentosa*.

nexine in some Egyptian *Scorzonera* taxa (*S. alexandrina* Boiss., *S. mollis*).

The present study found that the lacunae ornamentation of *S. laciniata* subsp. *laciniata* and *S. tomentosa* is perforate-microrugulate, that of *S. suberosa* and *S. cinerea* perforate-microreticulate, that of *S. pseudolanata* perforate-psilate, and that of the others perforate.

Pinar and Dönmez (2000) mentioned that the spine cavities of pollen exine can be regarded as diagnostic characters in the genera of Compositae. Clark et al. (1980) distinguished some taxonomic groups in Compositae by utilising the number of spine rows and spine length. Similarly, spine length has been used as an important diagnostic character in Lactuceae by Tomb et al. (1974) and Tomb (1975). There was a wide variation in spine length among the examined taxa. The highest value was observed in *S. tomentosa* (4.63 µm) and the lowest was observed in *S. insica* (1.3 µm). Additionally, the spines were generally concave-conic, except for *S. armeniaca* and *S. cana* var. *cana*. According to Meo and Khan (2004), *S. hondae* has the highest spine length (4.8 µm) and *S. laciniata* can be distinguished due to its lowest spine length of 2.5 µm. These results are more or less similar to our findings. It can be concluded that the character of spines have great potential in the distinguishing of further taxonomic groups in this genus for further taxonomic studies of *Scorzonera*.

Pollen grains of the examined taxa usually consist of colpi with a round ends. While the longest colpi were observed in *S. inaequiscapa* and *S. tomentosa*, the shortest colpi were observed in *S. laciniata* subsp. *laciniata* and *S. cana* var. *cana*. According to Meo and Khan (2004), pollen characters such as size, shape, colpi, exine thickness, and aperture type are considerably important, but our findings, obtained from numerical analysis, do not fully support the importance of those characters.

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