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Pollen morphology of the genus *Seseli* L. (Umbelliferae) in Turkey

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Abstract: Morphological features of pollen of 11 Turkish taxa belonging to the complex genus *Seseli* L. were examined using light and scanning electron microscopy. On the basis of exine sculpturing, 3 main types were recognised in *Seseli*: Type 1, rugulate at equator, psilate-perforate at pole; Type 2, striate-reticulate at equator, rugulate at pole; and Type 3, rugulate at equator, striate at pole. The study revealed that palynological characters display taxonomic significance in the genus.

Key words: *Seseli*, Umbelliferae, pollen, SEM

Türkiye *Seseli* L. (Umbelliferae) cinsinin polen morfolojisi

Özet: Sistematik açıdan karmaşık bir cins olan *Seseli* L. cinsinin Türkiye'de bulunan 11 taksonunun polen morfolojik özellikleri ışık ve taramalı elektron mikroskoplarında incelenmiştir. *Seseli* cinsinde ekzin ornamentasyon özelliklerinde üç tip fark edilmiştir (Tip 1: ekvatorda rugulat, kutupda psilat-perforat, Tip 2: ekvatorda striat-retikulat, kutupda rugulat, Tip 3: ekvatorda rugulat, kutupda striat). Bu çalışmada palinolojik karakterlerin cinsde taksonomik önem taşıdığı açıklanmıştır.

Anahtar sözcükler: *Seseli*, Umbelliferae, polen, SEM

Introduction

The genus *Seseli* L. (Umbelliferae) contains herbaceous plants distributed in the Irano-Turanian, Euro-Siberian, and East Mediterranean phytogeographic regions (Hedge & Lamond, 1972; Davis et al., 1988). The total number of *Seseli* taxa is about 125-140 in the world (Pimenov & Leonov, 2004).

The genus *Seseli* is represented by 11 species and 1 subspecies in the flora of Turkey (Hedge & Lamond, 1972; Davis et al., 1988; Duman, 2000; Özhatay et al., 2009). *Libanotis transcaucasica* Schischk. was given as synonymous for *Seseli libanotis* (L.) W.Koch in the fourth volume of *Flora of Turkey* (Hedge & Lamond, 1972). In discussion of the *S. libanotis* description, it had been stated that specimens from Van and Hakkari

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provinces were seen to be *Libanotis transcaucasica*. However, *L. transcaucasica* was named *Seseli transcaucasica* by Pimenov and Sdobnina (1975). This species exists in Turkey, but is not given in *Flora of Turkey*. A comprehensive revision of the Turkish genus *Seseli* was finished recently by E. Doğan Güner and H. Duman in Turkey. As Pimenov and Sdobnina's work has been accepted, it was added to the list at the end of the revision study. However, 2 species, *S. grandivittatum* (Sommier & Levier) Schischk. and *S. foliosum* (Sommier & Levier) Manden., could not be found by the authors in Turkey. As a result of the revision study, the number of species was determined as 10 species and 1 subspecies. The study revealed that 37% of the 11 taxa are endemic to Turkey.

The genus has economic importance in Turkey, and also throughout the world. Dried base leaves are used in animal feed. The plant is also used for ornamental purposes in gardens and parks throughout Europe. As in all Umbelliferae genera, the chemicals found in *Seseli* are used for medicinal purposes (Amanturdiyev, 1989; Hu et al., 1990; Meena et al., 1989).

Umbelliferae pollen characters have been mentioned by several authors in general pollen keys (Erdtman, 1963; Faegri & Iversen, 1975; Moore & Webb, 1978; Punt, 1984; Perveen & Qiser, 2006). Cerceau-Larrival (1962, 1972, & 1982) divided pollen into 5 groups by phylogeny. She studied *Seseli libanotis*, *S. montanum* L., *S. hippomarathrum* Jacq., *S. gracile* Waldst. et Kit., and *S. tortuosum* L. Meanwhile, Van Zeith et al. (1977) described the following pollen types from Iran: *Anisosciadium*, *Bunium*, *Eryngium*, *Ferula*, *Malabaila*, *Pimpinella*, *Sium erectum*, and *Turgenia* types. They mentioned *S. libanotis* pollen as being *Pimpinella*-type. Punt (1984) divided family Umbelliferae into 50 pollen types and studied the pollen morphologies of *Seseli annuum* L., *S. hippomarathrum*, *S. libanotis*, and *S. montanum* by using light microscopy (LM) and scanning electron microscopy (SEM).

The aim of this current study was to illustrate the range of variability in pollen characters of the *Seseli* species found in Turkey in order to establish their availability for future taxonomic work.

Material and methods

The material was collected from wild populations. The collectors and localities are provided below in "Specimens examined" for each taxon. The specimens were deposited in the herbarium of Gazi University.

Pollen slides were prepared using the technique of Wodehouse (1935). LM studies were conducted with a Prior microscope. Measurements were based on 20 or more pollen grains per specimen. For SEM studies, pollen grains and seeds were coated with gold for 4 min in a sputter coater. Morphological observations were made with a JEOL JSM-6060 LV electron microscope.

The pollen terminology was adopted from Faegri and Iversen (1975), Punt (1984), and Punt et al. (2007), and the shape classification followed that of Erdtman (1969), based on the P/E ratio in the Table. The Simpson and Roe graphical test (Van Der Pluym & Hideux, 1997) was used for statistical calculations.

Specimens examined: The order of the species was adapted from Hedge and Lamond (1972): –*Seseli libanotis* (L.) W.Koch; A9 Ardahan: *E.Doğan* 1622. –*S. transcaucasica* (Schischk.) Pimenov & Sdobnina; B9 Van: *M.Armağan* 1867. –*S. petraeum* M.Bieb.; A7 Gümüşhane: *E.Doğan* 1644. –*S. gummiferum* Pall. ex Sm. subsp. *gummiferum*; A4 Ankara: *E.Doğan* 1583. –*S. gummiferum* subsp. *corymbosum* (Boiss. & Heldr.) Davis; C3 Antalya: *E.Doğan* 1584. –*S. resinolum* Freyn & Sint.; A4 Bartın: *E.Doğan* 1607. –*S. peucedanoides* (M.Bieb.) Koso-Pol.; A9 Kars: *M.Vural* 8283 & et al. –*S. tortuosum* L.; A4 Ankara: *E.Doğan* 1652. –*S. campestre* Besser; A2 İstanbul: *E.Doğan* 1656. –*S. andronakii* Woron.; A8 Erzurum: *E.Doğan* 1615. –*S. hartvigii* Parolly & Nordt; C3 Antalya: *E.Doğan* 1585.

Results

Size, symmetry and shape

The pollen grains are radially symmetrical and isopolar. The shape is prolate and perprolate (shape classification follows Erdtman, 1969), with polar axes of 20.3–25.2 µm and equatorial axes of 10.5–12.4 µm (Table, Figure 1). The outline is elliptic in the equatorial optical section and triangular in the

Table. Palynological observations and measurements of the *Seseli* taxa (in μm).

Taxa	P	E	P/E ratio, shape	Exine thickness: ExE, ExK, ExZ	Int.	Ornamentation, equatorial area	Ornamentation, polar area	Clg	Clt	Plg	Plt
<i>S. libanotis</i>	24.1 \pm 1.46	12.2 \pm 0.96	1.98, prolate	1.0 \pm 0.20, 1.0 \pm 0.15, 0.8 \pm 0.16	0.4 \pm 0.04	Rugulate	Psilate-perforate	14.8 \pm 1.64	1.1 \pm 0.32	3.9 \pm 0.81	5.2 \pm 0.80
<i>S. transcaucasica</i>	21.6 \pm 1.18	11.5 \pm 0.86	1.88, prolate	0.9 \pm 0.06, 0.8 \pm 0.08, 0.8 \pm 0.10	0.4 \pm 0.00	Striate- reticulate	Rugulate	13.1 \pm 1.01	0.9 \pm 0.11	2.9 \pm 0.74	3.8 \pm 0.81
<i>S. petraeum</i>	25.0 \pm 0.99	11.5 \pm 0.55	2.17, perprolate	1.0 \pm 0.17, 0.9 \pm 0.06, 0.8 \pm 0.11	0.4 \pm 0.00	Rugulate	Psilate-perforate	14.1 \pm 0.86	0.9 \pm 0.13	4.8 \pm 0.51	5.9 \pm 0.54
<i>S. gummiferum</i> subsp. <i>gummiferum</i>	25.2 \pm 1.06	10.8 \pm 0.49	2.33, perprolate	0.9 \pm 0.04, 0.9 \pm 0.05, 0.7 \pm 0.07	0.4 \pm 0.00	Rugulate	Psilate-perforate	14.1 \pm 1.04	0.9 \pm 0.19	4.1 \pm 0.55	5.1 \pm 0.46
<i>S. gummiferum</i> subsp. <i>corymbosum</i>	24.4 \pm 0.97	10.8 \pm 0.62	2.26, perprolate	0.9 \pm 0.18, 1.0 \pm 0.17, 1.0 \pm 0.21	0.5 \pm 0.08	Rugulate	Striate	12.3 \pm 1.11	0.7 \pm 0.17	4.4 \pm 0.54	5.3 \pm 0.64
<i>S. resinotum</i>	23.2 \pm 0.85	11.4 \pm 0.45	2.04, perprolate	0.9 \pm 0.11, 0.8 \pm 0.06, 0.8 \pm 0.06	0.4 \pm 0.00	Rugulate	Striate	13.1 \pm 1.05	0.9 \pm 0.16	4.0 \pm 0.61	5.2 \pm 0.52
<i>S. peucedanooides</i>	24.2 \pm 1.48	12.4 \pm 1.06	1.95, prolate	0.9 \pm 0.13, 0.9 \pm 0.05, 0.8 \pm 0.10	0.5 \pm 0.12	Rugulate	Striate	15.1 \pm 1.23	0.9 \pm 0.18	4.0 \pm 0.72	4.9 \pm 0.65
<i>S. tortuosum</i>	22.7 \pm 0.60	11.7 \pm 0.59	1.94, prolate	0.9 \pm 0.07, 0.9 \pm 0.06, 0.7 \pm 0.09	0.4 \pm 0.00	Rugulate	Psilate-perforate	13.9 \pm 0.90	1.1 \pm 0.19	3.1 \pm 0.48	4.6 \pm 0.43
<i>S. campestre</i>	21.3 \pm 1.01	11.6 \pm 0.61	1.84, prolate	0.9 \pm 0.07, 0.9 \pm 0.05, 0.8 \pm 0.14	0.4 \pm 0.04	Rugulate	Striate	14.1 \pm 1.13	0.9 \pm 0.28	3.1 \pm 0.63	4.2 \pm 0.44
<i>S. andronakii</i>	20.8 \pm 0.68	10.6 \pm 0.45	1.96, prolate	1.0 \pm 0.12, 0.9 \pm 0.07, 0.7 \pm 0.07	0.5 \pm 0.10	Rugulate- granulate	Striate	12.1 \pm 0.87	0.7 \pm 0.13	3.2 \pm 0.61	4.3 \pm 0.55
<i>S. hartvigii</i>	20.3 \pm 0.81	10.5 \pm 0.63	1.93, prolate	0.9 \pm 0.08, 0.9 \pm 0.05, 0.8 \pm 0.10	0.5 \pm 0.08	Rugulate- granulate	Striate	13.6 \pm 0.97	1.0 \pm 0.13	3.1 \pm 0.74	4.2 \pm 0.85

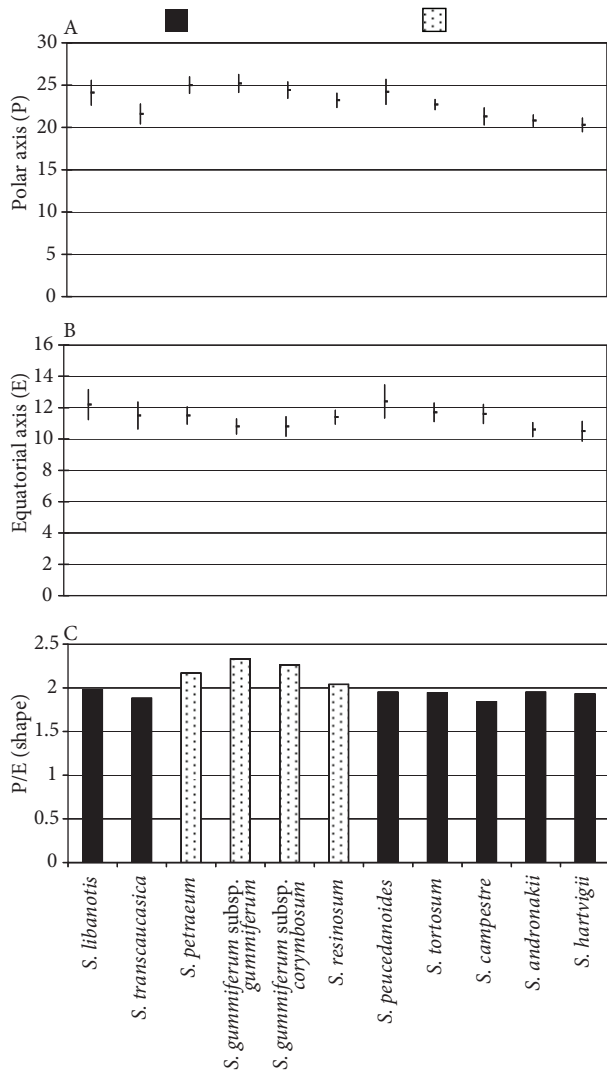


Figure 1. Graphs of palynological measurements of the *Seseli* taxa: A) Polar axis (P), B) Equatorial axis (E), C) P/E ratio and pollen shape.

polar optical section. In the equatorial view, the inner contour of the mesocolpium side is straight, and the outer contour is straight or slightly concave (*S. gummiferum* subsp. *gummiferum*, *S. gummiferum* subsp. *corymbosum*, and *S. resinosum*) (Figure 2).

Aperture

The pollen grains are operculate and tricolporate with costae. Ectoaperture rather long (12.1-15.1 µm) and slit-like; margins distinct, wavy; ends distinct, acute; fastigium absent. Endoaperture elliptic in outline, often with straight margins (Figure 2).

Exine and intine

The exine is subtectate and 0.9-1.0 µm in thickness in the equatorial area, 0.8-1.0 µm in thickness in polar area, 0.7-1.0 µm in shoulders area. Nexine thinner than sexine at poles or about equally thick, always thinner than sexine in equatorial area. Columella short and distinct at poles, longer and distinct at equator. Intine thickness ranges from 0.4 to 0.5 µm (Table).

Various ornamentation types were observed: rugulate in the equatorial area, psilate at the poles (*S. libanotis*, *S. petraeum*, *S. gummiferum* subsp. *gummiferum*, and *S. tortuosum*); striate-reticulate equator, rugulate at poles (*S. transcaucasica*); rugulate at equator, striate at poles (*S. gummiferum* subsp. *corymbosum*, *S. resinosum*, *S. peucedanoides*, *S. campestre*); and rugulate-granulate at equator, striate at poles (*S. andronakii*, *S. hartvigii*).

On the basis of exine sculpturing and shape, 3 types were recognised in *Seseli* (Figure 3).

Type 1: The exine sculpturing is rugulate at the equator and psilate-perforate at the pole. Pollen shape is 50% prolate or 50% perprolate (Table, Figures 1-2). Among the species examined, this type includes *S. libanotis*, *S. petraeum*, *S. gummiferum* subsp. *gummiferum*, *S. tortuosum*. Pollen size is 22.7-25.2 µm in polar axis, 10.8-12.2 µm in equatorial axis.

Type 2: The exine sculpturing is striate-reticulate at equator and rugulate at pole. Among the species examined, only *S. transcaucasica* is of this type (Table, Figures 1-2).

Type 3: The pollen grains are rugulate or rugulate-granulate at equator and striate at pole. The shape is 82% prolate or 18% perprolate. Among the Turkish *Seseli* species, *S. gummiferum* subsp. *corymbosum*, *S. resinosum*, *S. peucedanoides*, and *S. campestre* have rugulate sculpturing. Rugulate-granulate sculpturing is present in *S. andronakii* and *S. hartvigii* (Figure 3).

Discussion

The pollen morphologies of the Turkish *Seseli* species have taxonomic significance. We observed variation mainly in pollen shape and ornamentation, and we recognised 3 main types (Table, Figures 1-2), defined by pollen sculpturing.

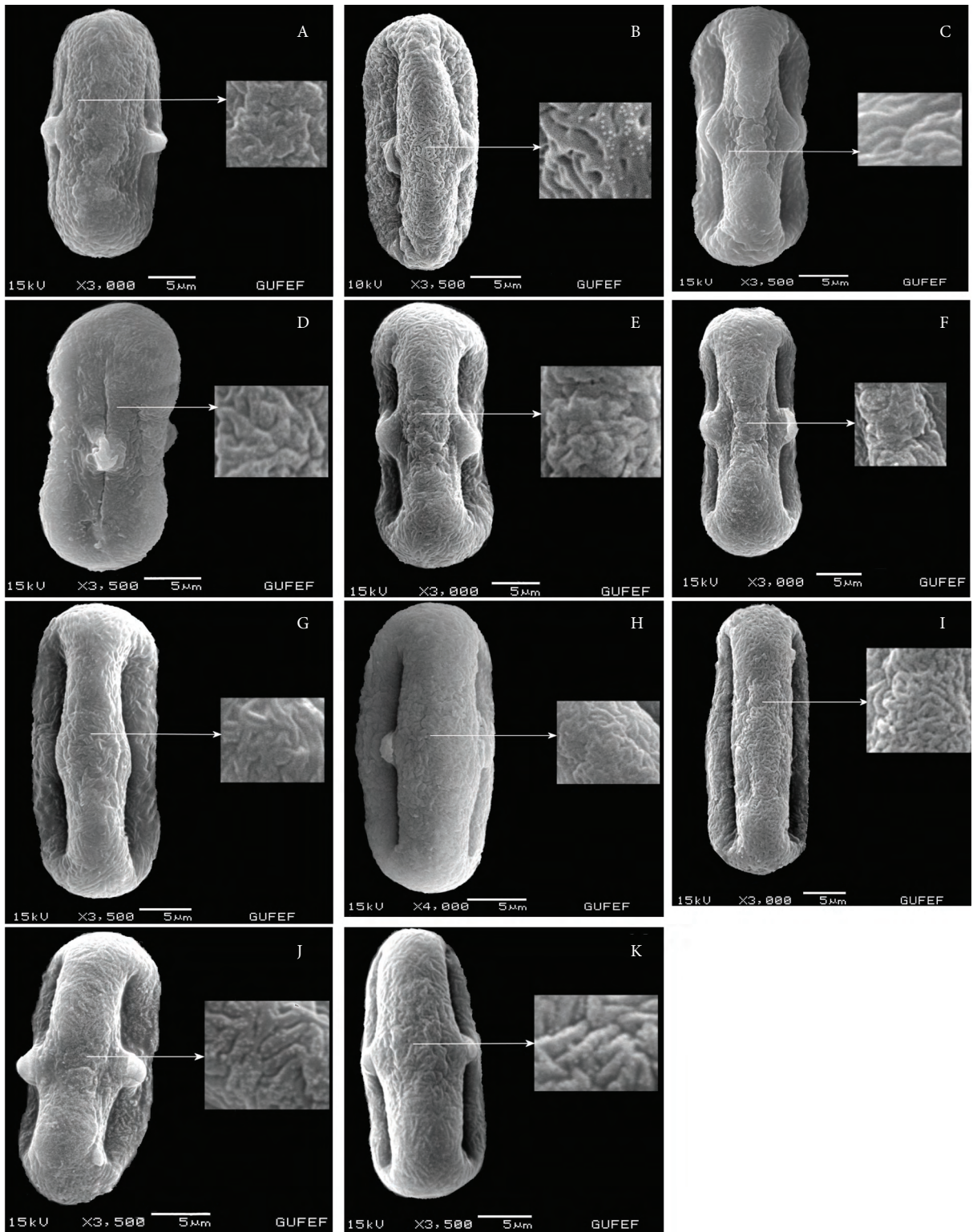


Figure 2. Ornamentation and aperture of pollen by SEM: A) *Seseli libanotis*, B) *S. transcaucasica*, C) *S. petraeum*, D) *S. gummiferum* subsp. *gummiferum*, E) *S. gummiferum* subsp. *corymbosum*, F) *S. resinosum*, G) *S. peucedanoides*, H) *S. tortuosum*, I) *S. campestre*, J) *S. andronakii*, K) *S. hartvigii*.

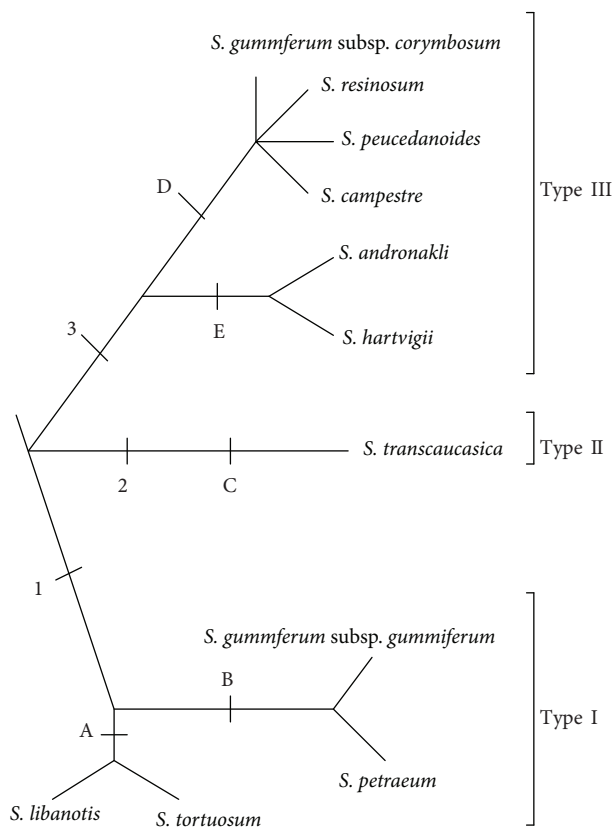


Figure 3. Phylogenetic hypothesis based on the pollen data of the studied *Seseli* species. Synapomorphies: Type 1, rugulate at equator, psilate-perforate at pole, A) prolate shape, B) perprolate shape; Type 2, C) striate-reticulate at equator, rugulate at pole; Type 3, D) rugulate at equator, striate at pole, E) rugulate-granulate equator.

The sculpturing of the pollen exine is useful for ascertaining relationships among species (Brochmann, 1992). They differ in sculpturing from the equatorial area to the poles. In Type 1 species, the sculpturing is rugulate on the equatorial axis and psilate-perforate on the polar axis. The sculpturing is striate-reticulate on the equatorial axis and rugulate on the polar axis in Type 2 species, while in Type 3, it is rugulate and rugulate-granulate on the equatorial axis and striate on the polar axis (Table, Figures 1-3).

It has been suggested that reticulate, rugulate, and granulate sculpturing types evolved from psilate ancestors (Abu-Asab & Cantino, 1992; Cantino, 1992; Tekşen et al., 2010). We observed that primitive species have psilate sculpturing in the polar area,

while advanced species have either rugulate or striate sculpturing. The phylogenetic hypothesis outlined above is summarised in Figure 3.

In the analysis of the mean P and E values, the largest grains were found in *S. gummiferum* subsp. *gummiferum* ($25.2 \pm 1.06 \mu\text{m}$), and the smallest P values ($20.3 \pm 0.81 \mu\text{m}$) and smallest E values ($10.5 \pm 0.63 \mu\text{m}$) were found in *S. hartvigii* (Table, Figure 1).

Prolate, perprolate, and tricolporate pollen with costae grains were seen in all species. Cerceau-Larrival (1962) divided the pollen of Umbelliferae into 5 types based on P/E ratio: subrhomboidal (type 1, P/E: 1-1.5), subcircular (type 2, P/E: 1-1.5), oval (type 3, P/E: 1.5-2), subrectangular (type 4, P/E: 2), and equatorially constricted (type 5, P/E: over 2). In the present study, all of the taxa examined belong to all of the pollen types of Cerceau-Larrival, oval-type with a P/E ratio of 1.5-2 to equatorially constricted-type with a P/E ratio greater than 2. The outer contours of *S. gummiferum* subsp. *gummiferum*, *S. gummiferum* subsp. *corymbosum*, and *S. resinosum* are slightly concave. Van Zeist et al. (1977) divided the pollen grains of Umbelliferae into 9 pollen types, *Anisosciadium*, *Bunium*, *Bupleurum*, *Eryngium*, *Ferula*, *Malabaila*, *Pimpinella*, *Sium erectum*, and *Turgenia* types. They mentioned *S. libanotis* pollen as being *Pimpinella*-type, a type mainly characterised by its very long columellae between the shoulders and the equator, ectoaperture short, endoaperture rectangular to quadrangular. On the other hand, Turkish *Seseli* pollen did not show pollen morphology very similar to the *Pimpinella* type. The columellae at the equator view are longer in *Seseli* taxa, with ectoaperture rather long and endoaperture elliptic in outline. According to Punt (1984), pollen grains of Umbelliferae are very distinctive with their characteristic inner and outer slit-like ectocolpi and broad, band-like costae (Perveen & Qaiser, 2006). Punt divided the family into 50 pollen types and mentioned *S. annum*, *S. hippomarathrum*, *S. libanotis*, and *S. montanum* pollen as *S. libanotis*-type. Pollen grains of the *S. libanotis* type have rather long to very long ectoaperture, elliptic endoaperture, short columellae at poles, and long columellae at equator. Ornamentation is psilate or irregularly rugulate-striate. Thus, the Turkish *Seseli* pollen

morphology resembles the *S. libanotis* type in several characteristics. Perveen and Qaiser (2006) recognised 3 pollen types of Umbelliferae in Pakistan on the basis of exine pattern: the *Bupleurum gilesii* type, *Pleurospermum hookeri* type, and *Trachyspermum ammi* type. The tectal surface of the *Pleurospermum hookeri* type is rugulate-striate, which is why, in this study, all examined taxa show ornamentation similar to the *Pleurospermum hookeri* type.

Some *Seseli* species are closely related to each other morphologically, for example, *S. libanotis* and *S. transcaucasica*, *S. gummiferum* subsp. *gummiferum* and *S. gummiferum* subsp. *corymbosum*, and *S. tortuosum* and *S. campestre*. By our analysis, the pollen features of these species quite differ from each other. The results would support classification based on morphology. The pollen characters seem to have the potential for evaluation of infrageneric relationships in the genus *Seseli*.

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