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Article

POLLEN MORPHOLOGY OF SOME TURKISH *Salvia* L. (LAMIACEAE: MENTHEAE) SPECIES

Morfologia de Pólen de Algumas Espécies Turcas de ***Salvia*** *L. (Lamiaceae: Mentheae)*

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ABSTRACT - In this presented work, the pollen morphologies of twenty-one taxa, nine of them endemic from Turkey, belonging to the genus *Salvia* (Lamiaceae: sub-family Nepetoideae: tribe Mentheae: sub-tribe Salviinae), *S. aethiopis* L., *S. argentea* L., *S. aytachii* Vural & Adigüzel, *S. blepharochlaena* Hedge & Hub.-Mor., *S. cadmica* Boiss., *S. ceratophylla* L., *S. cryptantha* Montbret & Aucher, *S. frigida* Boiss., *S. fructicosa* Miller, *S. halophile* Hedge, *S. napifolia* Jacq., *S. microstegia* Boiss. & Bal., *S. recognita* Fisch. & Mey. *S. sclarea* L., *S. smyrnaea* Boiss. *S. suffruticosa* Montbret & Aucher, *S. tchihatcheffii* (Fisch. & Mey.) Boiss., *S. tometosa* Bertol, *S. verbenaca* L., *S. viridis* L., and *S. wiedemanni* Boiss. and collected throughout the Turkey, have been intensively studied by using light (LM) and a scanning electron (SEM) microscopy. The objectives of this study are to investigate the pollen morphologies of twenty-one taxa of Turkish *Salvia* (nine of which are endemic) and to present similar and different characteristics of the taxa. The investigated whole pollen grains had a structure of both isopolar and radial symmetry. Overall, types of aperture were mostly hexacolpate, but it was also determined that the aperture type of *S. viridis* was both hexacolpate and octacolpate. The pollen grains had characteristic shapes of spheroidal, suboblate, prolate and subprolate. The exine ornamentation was bireticulate and reticulate-perforate. It was determined by the results of palynological studies that pollen morphology changed amongst these studied taxa. As a conclusion, the results of the present study show that palynological characters such as pollen shape, polar axis length (P), equatorial axis length (E), aperture numbers and types and exine ornamentation, exhibit remarkable differences amongst the studied taxa.

Keywords: exine ornamentation, Lamiaceae, palynology, *Salvia*, Turkey.

RESUMO - Neste trabalho, as morfologias polínicas de 21 táxons, nove delas endêmicas da Turquia, pertencentes ao gênero Salvia *(Lamiaceae: subfamília Nepetoideae: tribo Mentheae: subtribo Salviinae):* ***S. aethiopis*** *L.,* ***S. argentea*** *L.,* ***S. aytachii*** *Vural & Adigüzel,* ***S. blepharochlaena*** *Hedge & Hub.-Mor.,* ***S. cadmica*** *Boiss.,* ***S. ceratophylla*** *L.,* ***S. cryptantha*** *Montbret & Aucher,* ***S. frigida*** *Boiss.,* ***S. fructicosa*** *Miller,* ***S. halophile*** *Hedge,* ***S. napifolia*** *Jacq.,* ***S. microstegia*** *Boiss. & Bal.,* ***S. recognita*** *Fisch. & Mey.* ***S. sclarea*** *L.,* ***S. smyrnaea*** *Boiss.,* ***S. suffruticosa*** *Montbret & Aucher,* ***S. tchihatcheffii*** *(Fisch. & Mey.) Boiss.,* ***S. tometosa*** *Bertol,* ***S. verbenaca*** *L.,* ***S. viridis*** *L. e* ***S. wiedemanni*** *Boiss., coletados em toda a Turquia, foram intensamente estudadas usando luz (LM) e uma microscopia eletrônica de varredura (MEV). Os objetivos deste estudo foram investigar as morfologias polínicas de 21 táxons da sálvia turca (nove dos quais são endêmicos) e apresentar características semelhantes e diferentes dos táxons. Os grãos de pólen inteiros*

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investigados tinham uma estrutura de simetria tanto isopolar como radial. No geral, os tipos de abertura foram principalmente hexacolpato, mas também foi determinado que o tipo de abertura de ***S. viridis*** *era hexacolpato e octacolpato. Os grãos de pólen tinham formas características de esferoide, suboblato, prolato e subprolato. A ornamentação exina era birreticulada e reticulado-perfurada. Foi determinado pelos resultados de estudos palinológicos que a morfologia do pólen mudou entre os táxons estudados. Como conclusão, os resultados do presente estudo mostram que caracteres palinológicos, como formato do pólen, comprimento do eixo polar (P), comprimento do eixo equatorial (E), números de abertura e tipos e ornamentação exótica, exibem diferenças notáveis entre os táxons estudados.*

Palavras-chave: ornamentação exina, Lamiaceae, palinologia, *Salvia*, Turquia.

INTRODUCTION

Salvia L. is the largest genus of the Lamiaceae family and comprises of nearly 1000 species with various cosmopolitan assemblages of this family (Walker et al., 2004; Walker and Sytsma, 2007). This genus consists of nearly 500 spp. in Central and South America, 250 spp. in Central Asia and the Mediterranean and 90 spp. in Eastern Asia (Walker et al., 2004). In Asia, Turkey is one of the main centres for diversity for *Salvia* (Vural and Adigüzel, 1996). After the most recent reviews, four new species have been discovered, identifying the genus in Turkey and thus the total number for this species has now reached 90. Forty-seven of these *Salvia* species grow as an endemic in Turkey (Hedge, 1982; Davis et al., 1988; Duman, 2000; Dönmez, 2001; Hamzaoğlu et al., 2005).

In this work, nine of the twenty-one taxa investigated here are endemic to Turkey.

Pollen morphologies for the family Lamiaceae have been investigated by several workers, such as Erdtman (1945), Cantino et al. (1992), Harley et al. (1992), Abu-Asab and Cantino (1993, 1994), Perveen and Qaiser (2003), Celenk et al. (2008), Moon et al. (2008a,b), Salmaki et al. (2008), Hassan et al. (2009) and Doaigey et al. (2018). Although studies on pollen morphology in *Salvia* have been conducted by many researchers worldwide (Henderson et al., 1968; Hassan et al., 2009; Kahraman et al., 2009,2010; Özler et al., 2011,2013), there are still shortcomings and unstudied taxa in Turkey.

Henderson et al. (1968) described the pollen morphologies of 59 Salvia taxa. Twenty of these 59 taxa grow locally in Turkey and researchers demonstrated here that the pollen grains were hexacolpate, prolate to spheroidal and reticulate in shape. Moon et al. (2008b) studied the subtribe Nepetinae of the tribe Mentheae and examined the pollen morphologies; however, these researchers did not work with any taxa of *Salvia.*

Özler et al. (2011) also examined the 30 *Salvia* taxa distributed in Turkey and investigated the pollen morphologies of *S. fruticosa*, *S. halophila, S. recognita*, *S. suffruticosa*, *S. tchihatcheffii, S. tomentosa*, *S. viridis* and *S. wiedemannii*. The same group (Özler et al., 2013) also studied another 30 *Salvia* taxa, which grew in Turkey and examined pollen morphologies of *S. aethiopis*, *S. argentea*, *S. blepharochlaena*, *S. cadmica, S. ceratophylla*, *S. frigida*, *S. microstegia*, *S. sclarea* and *S. smyrnaea*.

This presented study aims to investigate the pollen morphologies of twenty-one taxa of Turkish *Salvia* (nine of which are endemic) and to present similar and different characteristics of the taxa.

MATERIALS AND METHODS

Plant material

In the present study, twenty-one different taxa of *Salvia* were gathered from different localities in Turkey (Table 1). Plant material was dried, prepared as herbarium material and identified with the help of previous literature (Hedge, 1982). Collected specimens are kept in Manisa Celal Bayar University, Faculty of Art and Science, Herbarium of Department of Biology.

Table 1 - Collection details of studied *Salvia* taxa

Name of the plant	Voucher information
S. aethiopis	Amasya: Merzifon, Tavsan Mountain, 950 m, 28.vi.1998, Ozkan 1032
S. argentea	Manisa: between Demirci and Soma, roadside, 4 km before Soma, 650 m, 26.v.2009, Aktas 3001
S. aytachii (E)	Ankara: between Ankara and Polatlı, roadside, 90 km, 850 m, 05.vi.2004, Özkan 4029
S. blepharochlaena (E)	Kırşehir: Cicekdagı, Ahmet Veli Tumba, 1500 m, 28.v.2004, Ozkan 4024
S. cadmica (E)	Ankara: Bala, Beynam national park, under forest, 1200 m, 14.vi.2004, Ozkan 4034
S. ceratophylla	Kastamonu: Tosya, roadside, 700 m, 25.v. 1998, Ozkan 1014
S. cryptantha (E)	Kırşehir: Cicekdagı, 50 km, rock hills, 1150 m, 06.vi.2005, Ozkan 5020
S. frigida	Antalya: Elmalı cedar research forest entry, 1000 m, 15.vii.2009, Aktas 3050
S. fruticosa	Manisa: between Manisa and İzmir, 18 km, 300 m, 13.vi.2009, Aktas 3024
S. halophila (E)	Ankara: Eskisehir road, 70 km, riverside, 1000 m, 27.vii.2004, Ozkan 4074
S. napifolia	Manisa: Salihli – Gölmarmara road, roadside 100 m, 01.iv.2009, Aktas 2885
S. microstegia	Sivas: Su sehri entry, roadside, 1400 m, 01.viii.2004, Ozkan 4084
S. recognita (E)	Ankara: Bala, Beynam national park, under forest, 1200 m, 28.vii.2004, Ozkan 4075
S. sclarea	Manisa: Demirci entry, roadside, 1000 m, 24.vii.2009, Aktas 3060
S. smyrnaea (E)	Izmir: Kemalpasa, Nif Mountain, 1500 m, 01.vii.2009, Aktas 3040
S. suffruticosa	Ankara: Bala, Beynam national park, under forest, 1200 m, 14.vi.2004, Ozkan 4038
S. tchihatcheffii (E)	Ankara: between Ankara and Polatlı, roadside, 50 km, rocky slopes 1000 m, 05.vi.2004, Özkan 4028
S. tomentosa	Hatay: Samandag entry, roadside, under forest, 200 m, 12.viii.2003, Aktas 1900
S. verbenaca	Manisa: Manisa: Demirci, roadside, 900 m, 11.iv.2009, Aktas 2990
S. viridis	Manisa: Salihli-Gölmarmara road, roadside, 100 m, 23.v.2009, Aktas 2997
S. wiedemannii (E)	Ankara: Bala, Beynam national park, under forest, 1200 m, 14.vi.2004, Ozkan 4035

E = endemic.

Pollen analysis

Pollen descriptions are carried out based on the LM and SEM findings. For light LM studies, the pollen grains were prepared by the standard method based on the Erdtman procedure (Erdtman, 1960). For this purpose, the pollen grains were first mounted in clear glycerine jelly. Observations and measurements were carried out by a Hunt type binocular microscope with oil immersion using 16x eyepiece. The glycerine jelly photographs (LM) were taken by using an Olympus trinocular microscope equipped with a Nikon camera. The light microscope (with a magnification of 1000x) was preferred to measure the polar length (P), the equatorial length (E), the colpus length (Clg), colpus width (Clt) and the exine thickness for 30 pollen grains. The P/E ratios were calculated by using these measurements. For SEM analysis, pollen grains were first covered with a thin film of gold by a Polaron SC7620 sputter coater and SEM pictures were taken at magnifications of 2000x and 10000x with the help of the JEOL JSM-6060 SEM. SEM observations were used to determine the exine sculpturing of the individual pollen. These prepared slides are stored at Manisa Celal Bayar University, Faculty of Art and Science, Department of Biology.

The terminology used is in accordance with Henderson et al. (1968), Faegri and Iversen (1989), Punt et al. (2007) and Özler et al. (2011, 2013) and pollen shape classification follows that of Erdtman (1969) based on the ratio of polar axis/equatorial diameter (Table 2).

RESULTS AND DISCUSSION

Tables 2 and 3 summarise the main characteristics of the pollens, which were investigated for this presented study. Figures 1, 2, 3, 4, 5, and 6 demonstrate the SEM micrographs of the pollen grains. Below, the main pollen features such as size and shape, apertures and exine sculpturing are described.

Table 2 - Summary of pollen morphological data for the *Salvia* taxa examined

No:	Taxa name	P (µm)				E (µm)				Clg (µm)				Clt (µm)				Exine (µm)			
		Min	Max	M	S(±)	Min	Max	M	S(±)	Min	Max	M	S(±)	Min	Max	M	S(±)	Min	Max	M	S(±)
1	*S. aethiopis*	37.90	40,01	38.74	0.97	40.01	41.06	40.64	0.54	29.48	31.59	30.53	0.99	2.10	3.15	2.47	0.43	2.10	2.63	2.21	0.22
2	*S. argentea*	34.74	41.06	36.50	2.43	38.96	47.38	42.00	2.24	26.32	28.43	27.37	0.99	2.63	3.15	2.84	0.27	2.10	3.15	2.36	0.37
3	*S. aytachii*	32.00	34.28	33.76	0.87	29.48	31.59	30.64	0.60	30.00	31.40	31.16	0.21	1.40	1.57	1.43	0.07	1.05	1.57	1.36	0.27
4	*S. blepharochlaena*	61.00	62.01	61.77	0.41	42.01	44.06	43.61	0.59	58.00	59.50	58.72	0.73	0.20	0.50	0.35	0.13	1.05	1.57	1.15	0.22
5	*S. cadmica*	42.12	43.17	42.54	0.54	34.74	37.90	36.85	1.40	29.48	31.59	30.74	0.97	1.05	1.57	1.15	0.22	1.57	2.10	1.99	0.22
6	*S. ceratophylla*	36.85	50.54	41.90	3.50	32.64	51.59	37.30	6.08	31.59	36.85	32.30	1.72	1.05	2.10	1.89	0.37	2.10	3.15	2.36	0.45
7	*S. cryptantha*	33.69	43.17	39.90	3.18	27.37	37.90	31.30	3.06	26.32	33.69	30.04	2.78	1.05	1.57	1.26	0.27	1.05	2.10	1.36	0.37
8	*S. frigida*	44.80	45.02	44.92	0.16	34.20	35.33	35.08	0.47	35.33	36.66	36.32	0.55	3.60	4.01	3.82	0.21	2.10	2.90	2.58	0.20
9	*S. fruticosa*	30.05	31.55	31.20	0.67	39.05	40.05	39.25	0.41	25.01	29.00	27.12	1.36	4.50	5.01	4.60	0.22	1.00	1.05	1.04	0.22
10	*S. halophila*	47.50	49.05	48.32	0.42	35.05	36.05	35.35	0.48	40.85	42.85	42.45	0.64	1.05	1.10	1.07	0.02	1.25	1.70	1.57	0.19
11	*S. napifolia*	42.12	44.12	43.38	0.96	27.37	28.43	27.69	0.51	24.21	25.27	24.85	0.74	1.57	2.10	1.89	0.27	1.05	2.10	1.47	0.41
12	*S. microstegia*	30.05	33.55	31.60	0.96	38.05	41.05	39.35	0.82	25.01	29.00	26.92	1.51	4.35	5.01	4.64	0.26	1.00	1.10	1.05	0.05
13	*S. recognita*	46.40	59.65	53.90	4.94	44.05	45.10	44.63	0.45	50.75	55.31	53.50	1.99	1.70	2.50	2.20	0.31	1.05	1.57	1.10	0.16
14	*S. sclarea*	34.50	37.80	35.07	1.02	39.70	40.05	39.90	0.17	29.50	30.25	29.92	0.27	7.57	9.02	8.40	0.52	1.05	2.02	1.56	0.23
15	*S. smyrnaea*	38.96	60.00	43.50	6.20	32.64	43.17	37.50	3.41	30.53	54.16	33.50	7.30	1.05	1.57	1.10	0.16	1.57	2.10	1.62	0.17
16	*S. suffruticosa*	31.59	56.25	37.10	6.89	24.21	30.53	28.80	1.83	22.11	50.00	27.30	8.41	1.57	3.15	2.36	0.45	1.57	2.10	1.68	0.22
17	*S. tchihatcheffii*	43.50	46.64	45.70	0.97	34.64	35.50	34.72	0.28	39.50	42.89	41.54	1.56	1.05	2.01	1.51	0.23	1.02	1.05	1.02	0.01
18	*S. tomentosa*	30.80	35.70	32.30	1.34	21.70	23.70	22.24	0.69	24.75	25.06	24.99	0.12	1.05	2.20	1.58	0.50	1.57	1.80	1.62	0.08
19	*S. verbenaca*	44.50	45.75	45.16	0.30	32.41	32.50	32.44	0.05	38.25	39.65	39.27	0.59	1.02	1.57	1.52	0.17	1.02	2.02	1.51	0.29
20	*S. viridis* L.	31.59	41.06	38.20	3.10	30.53	44.22	36.40	5.96	25.27	35.80	31.40	3.09	1.05	1.57	1.36	0.27	1.05	2.10	1.94	0.35
21	*S. wiedemanni* Boiss	31.59	32.64	31.90	0.51	25.27	31.59	29.30	1.70	24.21	26.32	25.06	0.83	1.57	2.10	1.68	0.22	1.05	2.63	1.52	0.58

* P = polar axis, E = equatorial axis, Clg = colpus length, Clt = colpus width, Exine = exine thickness, Min. = minimum, Max. = maximum; M = mean, S = standard deviation.

Table 3 - Summary of pollen morphology for the *Salvia* taxa examined

No:	Taxa name	P/E (µm)				Pollen Shape	Number of Colpus	Structure	Ornamentation
		Min	Max	M	S(±)				
1	*S. aethiopis*	0.92	0.97	0.94	0.02	Spheroidal	6	Tectate	Reticulate-perforate
2	*S. argentea*	0.73	1.00	0.87	0.08	Suboblate	6	Tectate	Bireticulate
3	*S. aytachii*	1.04	1.16	1.09	0.40	Spheroidal	6	Tectate	Bireticulate
4	*S. blepharochlaena*	1.40	1.45	1.41	0.01	Prolate	6	Tectate	Bireticulate
5	*S. cadmica*	1.13	1.24	1.18	0.04	Subprolate	6	Tectate	Bireticulate
6	*S. ceratophylla*	0.97	1.35	1.13	0.13	Spheroidal	6	Tectate	Bireticulate
7	*S. cryptantha*	1.06	1.39	1.27	0.13	Subprolate	6	Tectate	Bireticulate
8	*S. frigida*	1.26	1.31	1.27	0.02	Subprolate	6	Tectate	Reticulate-perforate
9	*S. fruticosa*	0.75	0.82	0.78	0.02	Suboblate	6	Tectate	Reticulate-perforate
10	*S. halophila*	1.34	1.38	1.35	0.02	Prolate	6	Tectate	Bireticulate
11	*S. napifolia*	1.48	1.61	1.56	0.05	Prolate	6	Tectate	Bireticulate
12	*S. microstegia*	0.75	0.85	0.79	0.03	Suboblate	6	Tectate	Reticulate-perforate
13	*S. recognita*	1.02	1.33	1.21	0.11	Subprolate	6	Tectate	Bireticulate
14	*S. sclarea*	0.86	0.94	0.87	0.02	Spheroidal	6	Tectate	Bireticulate
15	*S. smyrnaea*	0.92	1.53	1.16	0.18	Subprolate	6	Tectate	Reticulate-perforate
16	*S. suffruticosa*	1.00	2.07	1.28	0.30	Subprolate	6	Tectate	Bireticulate
17	*S. tchihatcheffii*	1.25	1.34	1.31	0.03	Subprolate	6	Tectate	Reticulate-perforate
18	*S. tomentosa*	1.38	1.50	1.44	0.04	Prolate	6	Tectate	Reticulate-perforate
19	*S. verbenaca*	1.36	1.41	1.38	0.01	Prolate	6	Tectate	Bireticulate
20	*S. viridis*	0.87	1.24	1.09	0.13	Spheroidal	6-8	Tectate	Bireticulate
21	*S. wiedemannii*	1.03	1.29	1.09	0.08	Spheroidal	6	Tectate	Reticulate-perforate

P = polar axis, E = equatorial axis, Min. = minimum, Max. = maximum, M = mean, S = standard deviation.

Pollen Size and Shape

The pollen grains are dispersed as monads. The polar axis (P) size of the samples changed between 30.05 µm (*Salvia fructicosa* and *S. microstegia*) and 62.01 µm (*S. blepharochlaena*). The equatorial axis (E) size of the pollen grains was found to be in the range of 21.70 µm (*S. tometosa*)

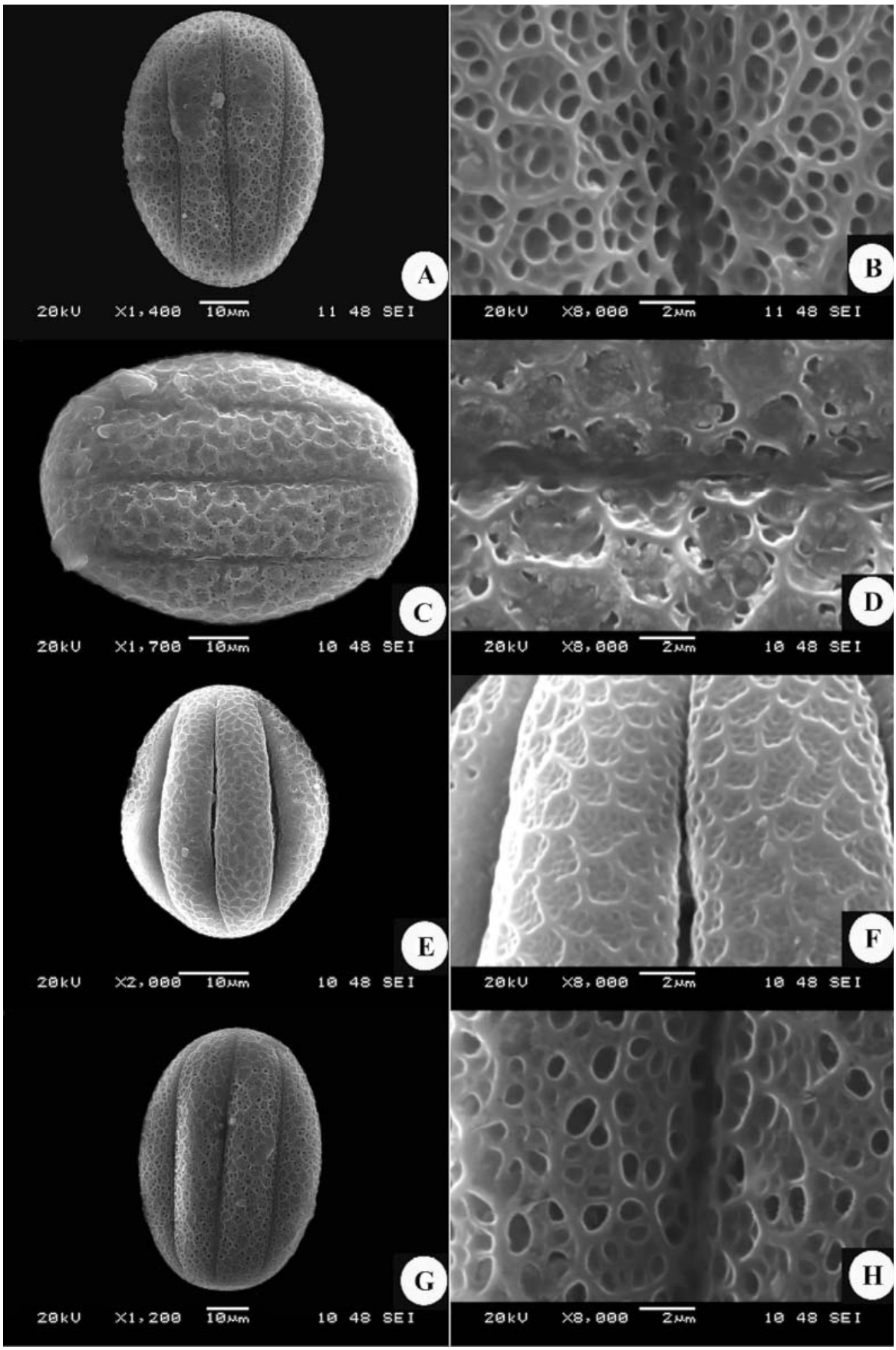

Figure 1 - SEM micrographs of pollen grains in the *Salvia* taxa examined. *S. aethiopis* (A-B), *S. argentea* (C-D), *S. aytachii* (E-F); *S. blepharochlaena* (G-H).

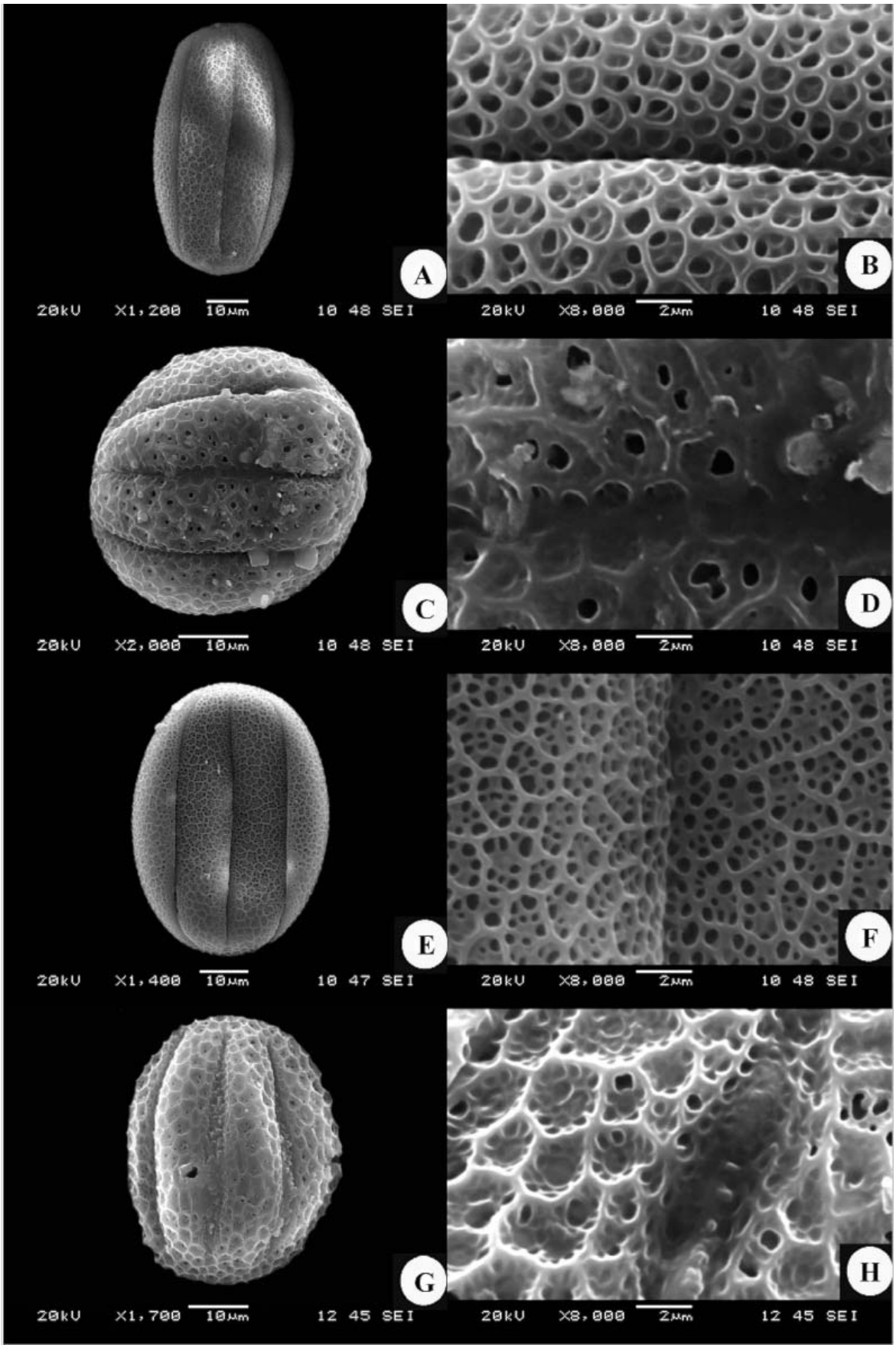

Figure 2 - SEM micrographs of pollen grains in the *Salvia* taxa examined. *S. cadmica* (A-B), *S. ceratophylla* (C-D), *S. cryptantha* (E-F), *S. frigida* (G-H).

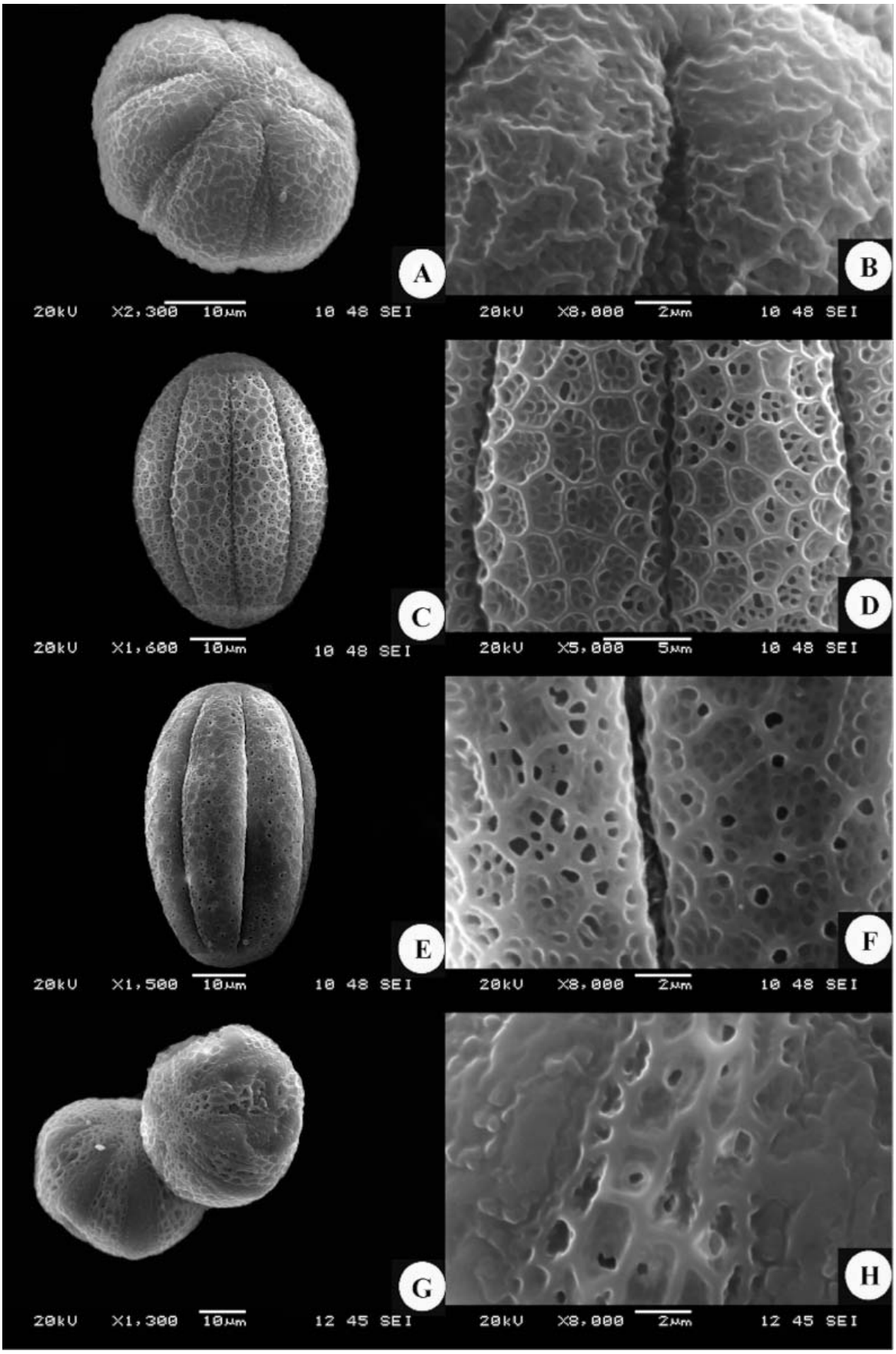

Figure 3 - SEM micrographs of pollen grains in the *Salvia* taxa examined. *S. fruticosa* (A-B), *S. halophila* (C-D), *S. napifolia* (E-F), *S. microstegia* (G-H).

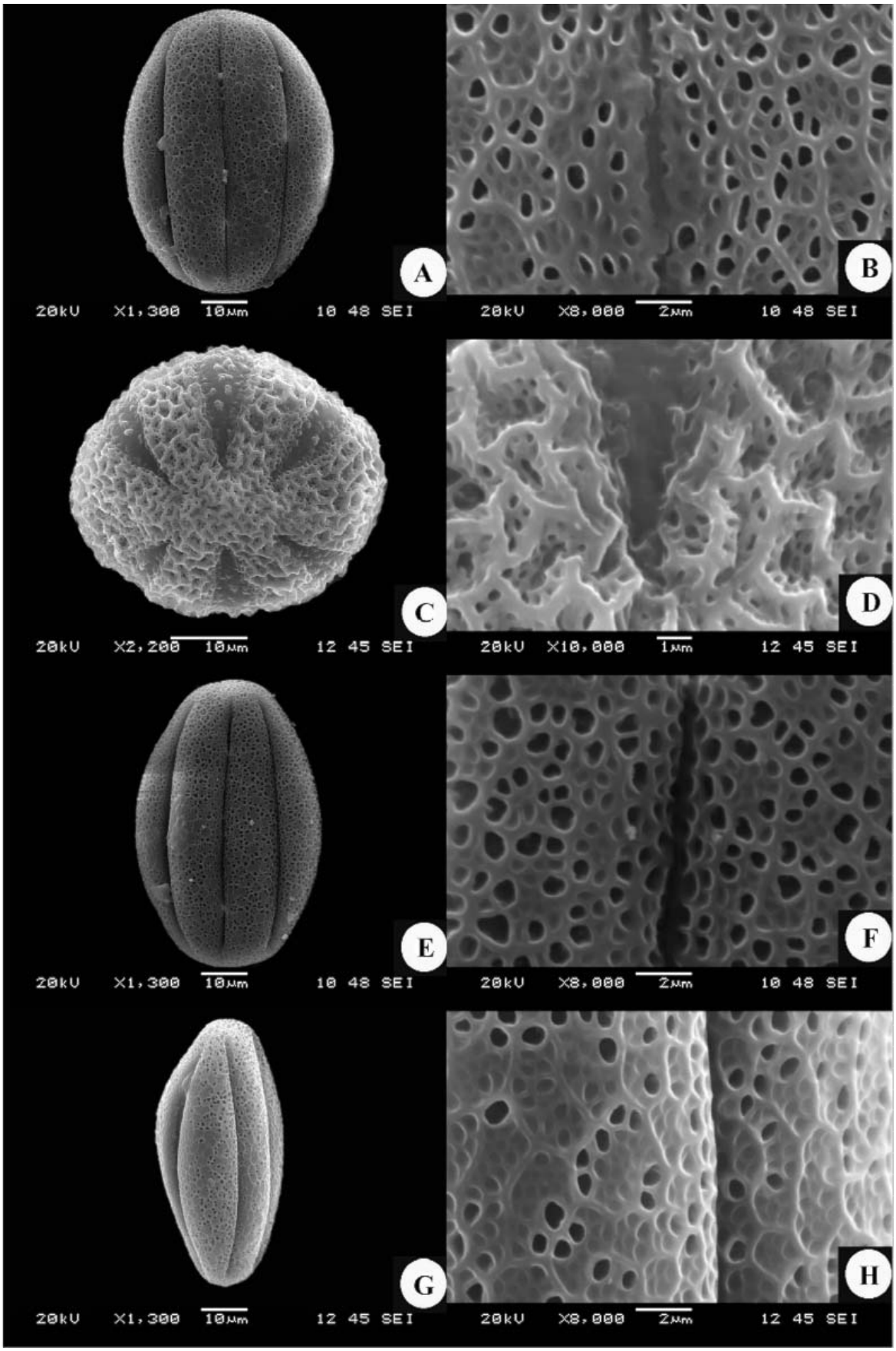

Figure 4 - SEM micrographs of pollen grains in the *Salvia* taxa examined. *S. recognita* (A-B), *S. sclarea* (C-D), *S. smyrnaea* (E-F), *S. suffruticosa* (G-H).

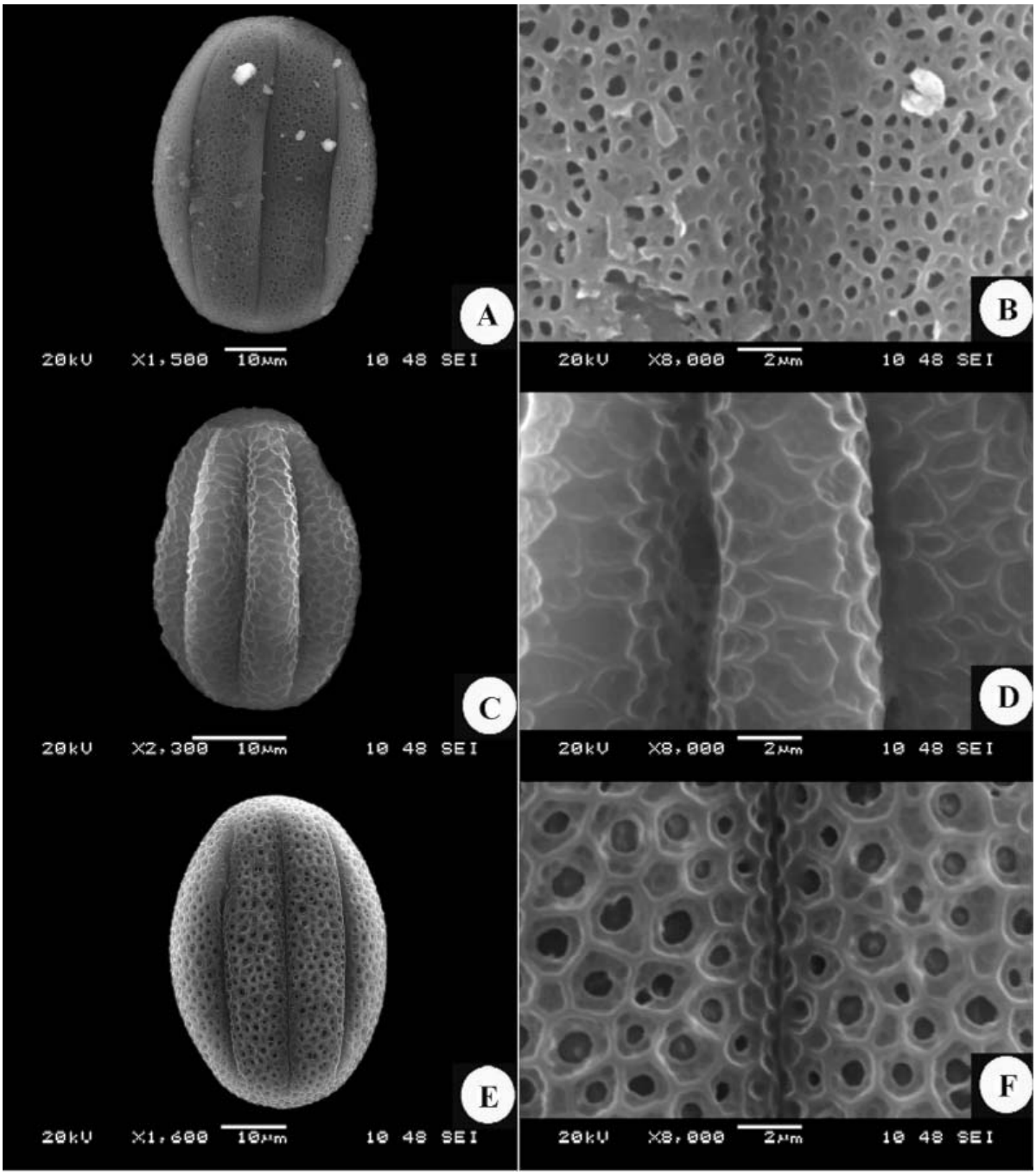

Figure 5 - SEM micrographs of pollen grains in the *Salvia* taxa examined. *S. tchihatcheffii* (A-B), *S. tomentosa* (C-D), *S. verbenaca* (E-F).

to 47.38 µm (*S. argentea*) (Table 2). The pollen grains also had variable shapes such as spheroidal, suboblate, prolate and subprolate (Table 3).

Apertures

The studied whole pollen grains have radial symmetry with isopolar character. The pollen grains mostly have a hexacolpate structure, but some of them are both hexacolpate and octacolpate as in *S. viridis* (Figures 1 and 2). Colpi are observed to be distributed as symmetric. Length of colpus (Clg) changed between 22.11 µm (*S. suffruticosa*) and 58.00 µm (*S. blepharochlaena*). Colpus width (Clt) was found to be in the range of 0.20 µm (*S. aytachii*) to 7.57 µm (*S. sclarea*) (Table 2).

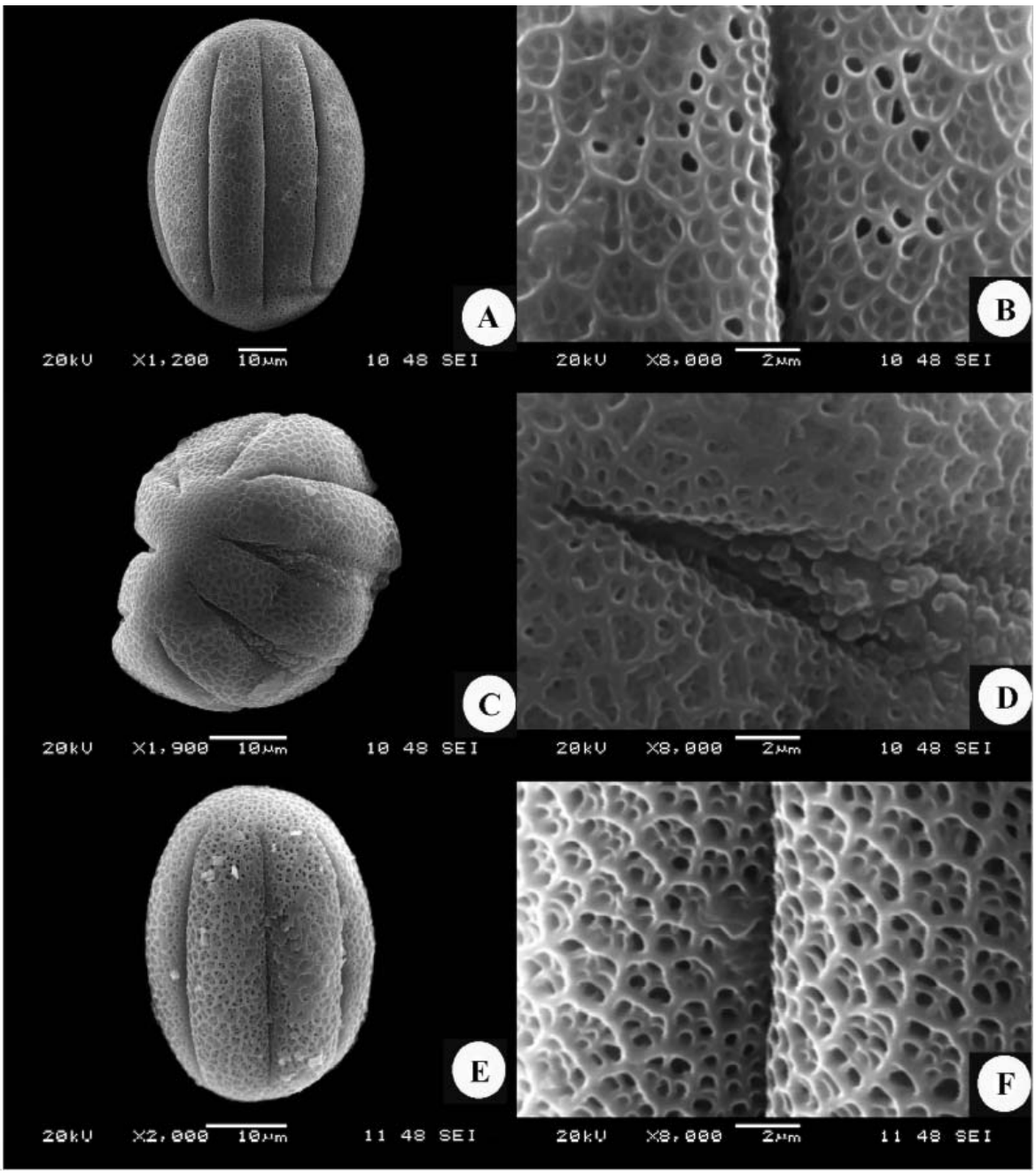

Figure 6 **-** SEM micrographs of pollen grains in the *Salvia* taxa examined. *S. viridis* (A-D), *S. wiedemannii* (E-F).

Exine

Exine shows bireticulate (*S. argentea*, *S. aytachii*, *S. blepharochlaena*, *S. cadmica*, *S. ceratophylla*, *S. cryptantha*, *S. halophila*, *S. napifolia*, *S. recognita*, *S. sclarea*, *S. suffruticosa*, *S. verbenaca*, *S. viridis*) and bireticulate-perforate (*S. aethiopis*, *S. frigida*, *S. fructicosa*, *S. microstegia*, *S. smyrnaea*, *S. tchihatcheffii*, *S. tometosa*, *S. wiedemanni*) ornamentation. The thickness of exine varies between 1.00 µm (*S. fruticosa*) and 3.15 µm (*S. argentea* and *S. ceratophylla*) (Table 2).

This presented study demonstrates that the investigated whole pollen grains are hexacolpate except *S. viridis*. The pollen grain of *S. viridis* has both hexacolpate and octacolpate (Figure 6A-D). These results agree with some previous studies (Perveen and Qaiser, 2003; Özler et al., 2011, 2013).

The pollen sizes of the examined samples are very variable, with small to large characteristics (P = 30.05-61.00 µm, E = 21.70-51.59 µm). The smallest pollen grain occurs in *S. fruticosa*, whereas

the largest is observed in *S. blepharochlaena* (Tables 2 and 3; Figure 1). Similarly, Özler et al. (2011) observed that *S. blepharochlaena* has the largest pollen grain.

The thickness of the exine changed between 1.00 µm (*S. fruticosa*) and 3.15 µm (*S. argentea* and *S. ceratophylla*). According to our results, the exine ornamentation displays two types: bireticulate and reticulate-perforate. The pollen morphology of some Lamiaceae taxa, including *S. aethiopis, S. fructicosa, S. sclarea* and *S. verbenaca*, have been examined by Moon et al. (2008b). They determined that the exine ornamentation of *S. aethiopis, S. fructicosa, S. sclarea* and *S. verbenaca* is bireticulate (Tables 4 and 5). According to our study, it was shown that exine ornamentation of *S. sclarea* and *S. verbenaca* are bireticulate but exine ornamentation of *S. fructicosa* is reticulate-perforate. Hassan et al. (2009) studied some *Salvia* species distributed in Egypt, including *Salvia sclarea* and *S. verbenaca* and examined the pollen morphology of the samples. They determined the exine ornamentation of *Salvia sclarea* and *S. verbenaca* to be bireticulate. In our presented work, SEM microphotographs demonstrated that the exine ornamentations of *S. sclarea* and *S. verbenaca* are also bireticulate. Özler et al. (2011, 2013) studied some *Salvia* taxa distributed in Turkey, such as *S. aethiopis*, *S. argentea*, *S. blepharochlaena*, *S. cadmica*, *S. ceratophylla*, *S. frigida*, *S. fructicosa*, *S. halophila*, *S. microstegia*, *S. recognita*, *S. sclarea*, *S. smyrnaea*, *S. suffruticosa*, *S. tchihatcheffii*, *S. tometosa*, *S. viridis* and *S. wiedemanni* and a researcher examined the pollen morphology of the whole samples. They determined that the exine ornamentation in *S. argentea*, *S. ceratophylla*, *S. halophila*, *S. microstegia*, *S. recognita*, *S. sclarea*, *S. suffruticosa, S. blepharochlaena* and *S. cadmica* as bireticulate and *S. aethiopis*, *S. frigida*, *S. fructicosa*, *S. smyrnaea*, *S. tchihatcheffii*, *S. tometosa*, *S. viridis* and *S. wiedemanni* was reticulate-perforate (Tables 4 and 5). Our findings also confirm the exine ornamentation results of Özler et al. (2011, 2013).

Table 4 **-** Comparison between pollen morphological data obtained from the present work with some previous studies

		This study					Moon et al. (2008b)					Ozler et al. (2011)					Ozler et al. (2013)				
		P (µm) (Min.-Max.) M S(±)	E (µm) (Min.-Max.) M S(±)	Clg (µm) (Min.-Max.) M S(±)	Clt (µm) (Min.-Max.) M S(±)	Exine (µm) (Min.-Max.) M S(±)	P (µm) (Min.-Max.) M S(±)	E (µm) (Min.-Max.) M S(±)	Clg (µm) (Min.-Max.) M S(±)	Clt (µm) (Min.-Max.) M S(±)	Exine (µm) (Min.-Max.) M S(±)	P (µm) (Min.-Max.) M S(±)	E (µm) (Min.-Max.) M S(±)	Clg (µm) (Min.-Max.) M S(±)	Clt (µm) (Min.-Max.) M S(±)	Exine (µm) (Min.-Max.) M S(±)	P (µm) (Min.-Max.) M S(±)	E (µm) (Min.-Max.) M S(±)	Clg (µm) (Min.-Max.) M S(±)	Clt (µm) (Min.-Max.) M S(±)	Exine (µm) (Min.-Max.) M S(±)
1	*S. aethiopis*	(37.90-40.01) 40.01 ±0.97	(40.01-41.06) 40.64 ±0.54	(29.48-31.59) 30.53 ±0.99	(2.10-3.15) 2.47 ±0.43	(2.10-2.63) 2.21 ±0.22	(38.3-43.2) 41.1	(32.9-44.1) 37.6	(29.2-37.7) 32.6	–	(1.7-2.7) 2.1 Po (1.5-2.3) 1.8 Eq	–	–	–	–	–	(25.0-33.6) 30.7 ±2.4	(35.5-43.2) 39.2 ±2.2	(22.1-28.8) 26.1 ±2.0	(6.2-9.6) 7.7 ±1.0	(1.2-1.7) 1.5 ±0.2
2	*S. argentea*	(34.74-41.06) 36.50 ±2.43	(38.96-47.38) 42.00 ±2.24	(26.32-28.43) 27.37±0.99	(2.63-3.15) 2.84 ±0.27	(2.10-3.15) 2.36 ±0.37	–	–	–	–	–	–	–	–	–	–	(37.4-50.9) 41.5 ±3.2	(43.2-56.6) 48.6 ±3.3	(31.7-47.0) 35.3 ±3.2	(7.7-10.6) 9.2 ±0.8	(1.2-1.9) 1.6 ±0.3
3	*S. aytachii*	(32.00-34.28) 33.76 ±0.87	(29.48-31.59) 30.64 ±0.60	(30.00-31.40) 31.16 ±0.21	(1.40-1.57) 1.43 ±0.07	(1.05-1.57) 1.36 ±0.27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	*S. blepharochlaena*	(61.00-62.01) 71.77 ±0.41	(42.01-44.06) 43.61 ±0.59	(58.00-59.50) 58.72 ±0.73	(0.20-0.50) 0.35 ±0.13	(1.05-1.57) 1.15 ±0.22	–	–	–	–	–	–	–	–	–	–	(49.9-61.4) 57.0 ±2.8	(45.1-65.3) 53.0 ±5.0	(48.0-60.5) 52.9 ±3.2	(5.3-8.2) 6.5 ±0.8	(1.0-1.4) 1.2 ±0.2
5	*S. cadmica*	(42.12-43.17) 42.54 ±0.54	(34.74-37.90) 36.85 ±1.40	(29.48-31.59) 30.74 ±0.97	(1.05-1.57) 1.15 ±0.22	(1.57-2.10) 1.99 ±0.22	–	–	–	–	–	–	–	–	–	–	(43.2-51.8) 47.7 ±2.4	(43.2-54.7) 50.0 ±3.5	(37.4-48.0) 42.6 ±2.4	(4.6-7.7) 5.7 ±0.9	(1.2-1.7) 1.4 ±0.2
6	*S. ceratophylla*	(36.85-50.54) 41.90 ±3.50	(32.64-51.59) 37.30 ±6.08	(31.59-36.85) 32.50 ±1.72	(1.05-2.10) 1.89 ±0.37	(2.10-3.15) 2.36 ±0.45	–	–	–	–	–	–	–	–	–	–	(31.7-43.2) 38.4 ±2.9	(44.2-52.8) 47.5 ±2.5	(25.0-36.5) 32.5 ±3.0	(7.7-10.6) 9.2 ±0.8	(1.4-1.9) 1.6 ±0.2
7	*S. cryptantha*	(33.69-43.17) 39.90 ±3.18	(27.37-37.90) 31.30 ±3.06	(26.32-33.69) 30.04 ±2.78	(1.05-1.57) 1.26 ±0.27	(1.05-2.10) 1.36 ±0.37	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
8	*S. frigida*	(44.80-45.02) 44.92 ±0.16	(34.20-35.33) 35.08 ±0.47	(35.33-36.66) 36.32 ±0.55	(3.60-4.01) 3.82 ±0.21	(2.10-2.90) 2.58 ±0.20	–	–	–	–	–	–	–	–	–	–	(30.7-44.2) 37.3 ±3.1	(37.4-46.1) 42.5 ±2.6	(24.0-37.4) 31.3 ±3.7	(7.2-9.6) 8.2 ±0.7	(1.2-1.7) 1.4 ±0.2
9	*S. fruticosa*	(30.05-31.55) 31.20 ±0.67	(39.05-40.05) 39.25 ±0.41	(25.01-29.00) 27.12 ±1.36	(4.50-5.01) 4.60 ±0.22	(1.00-1.05) 1.04 ±0.22	(39.1-50.6) 48.1	(36.5-43.6) 40.6	(37.8-43.7) 39.9	–	(1.5-2.4) 2.0 Po (1.3-2.1) 1.7 Eq	(30.7-41.3) 35.7 ±2.8	(27.8-43.2) 38.0 ±3.5	(23.0-31.7) 28.9 ±2.5	(2.9-6.7) 4.9 ±4.9	(1.0-1.2) 1.1 ±0.2	–	–	–	–	–
10	*S. halophila*	(47.50-49.05) 48.32 ±0.42	(35.05-36.05) 35.35 ±0.48	(40.85-42.85) 42.45 ±0.64	(1.05-1.10) 1.07 ±0.02	(1.25-1.70) 1.57 ±0.19	–	–	–	–	–	(37.4-53.8) 43.2 ±3.6	(43.2-49.9) 47.5 ±1.7	(32.5-49.9) 38.6 ±3.8	(6.7-11.5) 8.1 ±1.3	(1.2-1.9) 1.6 ±0.3	–	–	–	–	–
11	*S. napifolia*	(42.12-44.12) 43.38 ±0.96	(27.37-28.43) 27.69 ±0.51	(24.21-25.27) 24.85 ±0.74	(1.57-2.10) 1.89 ±0.27	(1.05-2.10) 1.47 ±0.41	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
12	*S. microstegia*	(30.05-33.55) 31.60 ±0.96	(38.05-41.05) 39.35 ±0.82	(25.01-29.00) 26.92 ±1.51	(4.35-5.01) 4.64 ±0.26	(1.00-1.10) 1.05 ±0.05	–	–	–	–	–	–	–	–	–	–	(32.6-50.9) 41.3 ±6.1	(39.4-60.5) 47.7 ±5.5	(26.9-43.2) 34.7 ±5.3	(7.2-9.8) 8.6 ±0.9	(1.2-1.7) 1.4 ±0.2
13	*S. recognita*	(46.40-59.65) 53.90 ±4.94	(44.05-45.10) 44.63 ±0.45	(50.75-55.31) 53.50 ±1.99	(1.70-2.50) 2.20 ±0.31	(1.05-1.57) 1.10 ±0.16	–	–	–	–	–	(40.3-47.0) 43.4 ±2.1	(43.2-49.9) 47.5 ±1.6	(28.8-39.4) 35.9 ±2.4	(6.7-9.6) 8.4 ±0.9	(0.7-1.2) 1.0 ±0.1	–	–	–	–	–
14	*S. sclarea*	(34.50-37.80) 35.05 ±1.02	(39.70-40.05) 39.90 ±0.17	(29.50-30.25) 29.92 ±0.27	(7.57-9.02) 8.40 ±0.52	(1.05-2.02) 1.56 ±0.23	(43.9-55.0) 49.0	(43.0-50.5) 48.0	(37.2-49.3) 42.3	–	(1.5-2.2) 1.9 Po (1.2-2.0) 1.5 Eq	–	–	–	–	–	(38.4-47.0) 42.3 ±2.6	(47.0-59.5) 53.0 ±3.4	(33.6-41.3) 37.2 ±2.5	(7.2-10.6) 8.8 ±0.8	(1.2-1.7) 1.4 ±0.2
15	*S. smyrnaea*	(38.96-60.00) 43.50 ±6.20	(32.64-43.17) 37.50 ±3.41	(30.53-54.16) 33.50 ±7.30	(1.05-1.57) 1.10 ±0.16	(1.57-2.10) 1.62 ±0.17	–	–	–	–	–	–	–	–	–	–	(39.4-49.9) 42.7 ±2.7	(42.2-53.8) 49.1 ±3.1	(34.6-45.6) 38.1 ±2.8	(6.7-9.6) 8.3 ±0.9	(1.2-1.9) 1.6 ±0.2
16	*S. suffruticosa*	(31.59-56.25) 37.10 ±6.89	(24.21-30.53) 28.80 ±1.83	(22.11-50.00) 27.30 ±8.41	(1.57-3.15) 2.36 ±0.45	(1.57-2.10) 1.68 ±0.22	–	–	–	–	–	(34.6-49.0) 41.9 ±4.0	(37.4-49.9) 45.0 ±2.9	(28.8-43.2) 35.0 ±4.1	(3.8-6.7) 5.3 ±0.8	(0.7-1.2) 1.0 ±0.1	–	–	–	–	–
17	*S. tchihatcheffii*	(43.50-46.64) 45.70 ±0.97	(34.64-35.50) 34.72 ±0.28	(39.50-42.89) 41.54 ±1.56	(1.05-2.01) 1.51 ±0.23	(1.02-1.05) 1.02 ±0.01	–	–	–	–	–	(31.7-38.40) 34.7 ±1.7	(31.7-49.9) 39.6 ±3.8	(25.0-35.5) 28.8 ±2.2	(4.8-8.64) 6.5 ±1.2	(1.0-1.7) 1.2 ±0.2	–	–	–	–	–
18	*S. tomentosa*	(30.80-35.70) 32.30 ±1.34	(21.70-23.70) 22.24 ±0.69	(24.75-25.06) 24.99 ±0.12	(1.05-2.20) 1.58 ±0.50	(1.57-1.80) 1.62 ±0.08	–	–	–	–	–	(38.4-43.2) 41.2 ±1.4	(45.1-49.0) 47.2 ±1.2	(33.6-39.4) 37.1 ±1.6	(7.7-9.6) 8.9 ±0.6	(1.4-1.9) 1.7 ±0.2	–	–	–	–	–
19	*S. verbenaca*	(44.50-45.75) 45.16 ±0.30	(32.41-32.50) 32.44 ±0.05	(38.25-39.65) 39.27 ±0.59	(1.02-1.57) 1.52 ±0.17	(1.02-2.02) 1.51 ±0.29	(35.8-46.0) 42.0	(32.8-39.3) 35.6	(30.0-40.0) 35.5	–	(1.6-2.7) 1.9 Po (1.2-1.9) 1.6 Eq	–	–	–	–	–	–	–	–	–	–
20	*S. viridis*	(31.59-41.06) 38.20 ±3.10	(30.53-44.22) 36.40 ±5.96	(25.27-35.80) 31.40 ±3.09	(1.05-1.57) 1.36 ±0.27	(1.05-2.10) 1.94 ±0.35	–	–	–	–	–	(31.7-37.4) 34.1 ±1.6	(37.4-47.0) 42.1 ±2.3	(26.9-34.6) 29.7 ±2.2	(6.7-9.1) 7.7 ±0.7	(1.0-1.4) 1.2 ±0.2	–	–	–	–	–
21	*S. wiedemannii*	(31.59-32.64) 31.90 ±0.51	(25.27-31.59) 29.30 ±1.70	(24.21-26.32) 25.06 ±0.83	(1.57-2.10) 1.68 ±0.22	(1.05-2.63) 1.52 ±0.58	–	–	–	–	–	(34.6-52.8) 40.7 ±3.7	(35.5-58.6) 46.6 ±3.8	(31.7-52.8) 36.3 ±3.6	(4.3-6.2) 5.4 ±0.5	(1.2-1.4) 1.3 ±0.1	–	–	–	–	–

P = polar axis, E = equatorial axis, Clg = colpus length, Clt = colpus width, Exine = exine thickness, Min. = minimum, Max. = maximum; M = mean, S = standard deviation, Po = pole, Eq = equator.

Table 5 **-** Comparison between pollen morphology obtained from the present work with some previous studies

		This study				Moon et al. (2008b)				Ozler et al. (2011)				Ozler et al. (2013)			
		P/E (µm) (Min.-Max.) M S(±)	Pollen Shape	Number of Colpus	Ornamentation	P/E (µm) (Min.-Max.) M S(±)	Pollen Shape	Number of Colpus	Ornamentation	P/E (µm) (Min.-Max.) M S(±)	Pollen Shape	Number of Colpus	Ornamentation	P/E (µm) (Min.-Max.) M S(±)	Pollen Shape	Number of Colpus	Ornamentation
1	*S. aethiopis*	(0.92-0.97) 0.94 ±0.02	Spheroidal	6	Reticulate-perforate	–	Oblate-spheroidal Prolate-spheroidal Subprolate	6	Bireticulate	–	–	–	–	–	Suboblate Oblate-spheroidal	6	Reticulate-perforate
2	*S. argentea*	(073-1.00) 0.87 ±0.08	Suboblate	6	Bireticulate	–	–	–	–	–	–	–	–	–	Suboblate Prolate-spheroidal	6	Bireticulate
3	*S. aytachii*	(1.04-1.16) 1.09 ±0.40	Spheroidal	6	Bireticulate	–	–	–	–	–	–	–	–	–	–	–	–
4	*S. blepharochlaena*	(1.40-1.45) 1.41 ±0.01	Prolate	6	Bireticulate	–	–	–	–	–	–	–	–		Prolate-spheroidal Spheroidal	6	Bireticulate
5	*S. cadmica*	(1.13-1.24) 1.18 ±0.04	Subprolate	6	Bireticulate	–	–	–	–	–	–	–	–	–	Prolate-spheroidal Spheroidal	6	Bireticulate
6	*S. ceratophylla*	(0.97-1.35) 1.13 ±0.13	Spheroidal	6	Bireticulate	–	–	–	–	–	–	–	–	–	Suboblate Oblate-spheroidal	6	Bireticulate
7	*S. cryptantha*	(1.06-1.39) 1.27 ±0.13	Subprolate	6	Bireticulate	–	–	–	–	–	–	–	–	–	–	–	–
8	*S. frigida*	(1.26-1.31) 1.27 ±0.02	Subprolate	6	Reticulate-perforate	–	–	–	–	–	–	–	–		Suboblate Oblate-spheroidal	6	Reticulate-perforate
9	*S. fruticosa*	(0.75-0.82) 0.78 ±0.02	Suboblate	6	Reticulate-perforate	–	Oblate-spheroidal Prolate-spheroidal Subprolate	6	Bireticulate		Prolate-spheroidal Oblate-spheroidal	6	Reticulate-perforate	–	–	–	–
10	*S. halophila*	(1.34-1.38) 1.35 ±0.02	Prolate	6	Bireticulate	–	–	–	–		Oblate-spheroidal	6	Bireticulate	–	–	–	–
11	*S. napifolia*	(1.48-1.61) 1.56 ±0.05	Prolate	6	Bireticulate	–	–	–	–	–	–	–	–	–	–	–	–
12	*S. microstegia*	(0.75-0.85) 0.79 ±0.03	Suboblate	6	Reticulate-perforate	–	–	–	–	–	–	–	–		Suboblate Oblate-spheroidal	6	Bireticulate
13	*S. recognita*	(1.02-1.33) 1.21 ±0.11	Subprolate	6	Bireticulate	–	–	–	–		Prolate-spheroidal Oblate-spheroidal	6	Bireticulate	–	–	–	–
14	*S. sclarea*	(0.86-0.94) 0.87 ±0.02	Spheroidal	6	Bireticulate	–	Oblate-spheroidal Prolate-spheroidal	6	Bireticulate	–	–	–	–		Suboblate Oblate-spheroidal	6	Bireticulate
15	*S. smyrnaea*	(0.92-1.53) 1.16 ±0.18	Subprolate	6	Reticulate-perforate	–	–	–	–	–	–	–	–	–	Suboblate	6	Reticulate-perforate
16	*S. suffruticosa*	(1.00-2.07) 1.28 ±0.30	Subprolate	6	Bireticulate	–	–	–	–	–	Prolate-spheroidal Oblate-spheroidal	6	Bireticulate		–	–	–
17	*S. tchihatcheffii*	(1.25-1.34) 1.31 ±0.03	Subprolate	6	Reticulate-perforate	–	–	–	–	–	Suboblate Oblate-spheroidal Prolate-spheroidal	6	Reticulate-perforate	–	–	–	–
18	*S. tomentosa*	(1.38-1.50) 1.44 ±0.04	Prolate	6	Reticulate-perforate	–	–	–	–		Suboblate Oblate-spheroidal	6	Reticulate-perforate		–	–	–
19	*S. verbenaca*	(1.36-1.41) 1.38 ±0.01	Prolate	6	Bireticulate	–	Prolate-spheroidal Subprolate	6	Bireticulate	–	–	–	–	–	–	–	–
20	*S. viridis*	(0.87-1.24) 1.09 ±0.13	Spheroidal	6,8	Bireticulate	–	–	–	–		Suboblate Oblate-spheroidal Prolate-spheroidal	6	Bireticulate	–	–	–	–
21	*S. wiedemannii*	(1.03-1.29) 1.09 ±0.08	Spheroidal	6	Reticulate-perforate	–	–	–	–		Suboblate Oblate-spheroidal Prolate-spheroidal	6	Reticulate-perforate	–	–	–	–

P = polar axis, E = equatorial axis, Min. = minimum; Max. = maximum; M = mean, S = standard deviation.

Systematic implications of pollen morphology

Hedge (1982), "Flora of Turkey and the East Aegean Islands", reports that *S. argentea* and *S. microstegia* show very similar morphological characteristics. In our presented study, it was determined that the pollen morphology of these two species was different even for same exine ornamentation. According to our results, the pollen of *S. argentea* showed the characteristics of P = 36.50 µm, E = 42.00 µm, Clg = 27.37 µm, Clt = 2.84 µm and Exine thickness = 2.36 with the pollen shape of *S. argentea* being determined as suboblate (P/E = 0.87); the characteristics of the pollen of *S. microstegia* were; P = 44.92 µm, E = 35.08 µm, Clg = 36.32 µm, Clt = 3.82 µm and Exine thickness = 2.58 µm with the pollen shape of *S. microstegia* determined as subprolate (P/E = 1.27).

S. cadmica and *S. smyrnaea* are also stated as morphologically very similar in "Flora of Turkey and the East Aegean Islands", but they have not been recognised according to palynological data. We determined that the pollen size and pollen shape of these two species were also quite similar. Their exine ornamentation is, however, of a different type. We determined the exine ornamentation in *S. cadmica* as bireticulate and in *S. smyrnaea* as reticulate perforate. According to our results, the pollen of *S. cadmica* had characteristics of; P = 42.54 µm, E = 36.85 µm, Clg = 30.74 µm, Clt = 1.15 µm and Exine thickness = 1.99 µm with the pollen shape of *S. cadmica* determined as subprolate (P/E = 1.18); whereas the pollen of *S. smyrnaea* had characteristics of; P = 43.50 µm, E = 37.50 µm, Clg = 33.50 µm, Clt = 1.10 µm and Exine thickness = 1.62 µm with the pollen shape of *S. smyrnaea* determined as subprolate (P/E = 1.16).

As a conclusion, the results of the present study show that palynological characters such as pollen shape, polar axis length (P), equatorial axis length (E), aperture numbers and types and exine ornamentation, exhibit remarkable differences amongst the studied taxa, as already reported in previous studies.

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REFERENCES

Abu-Asab MS, Cantino PD. Phylogenetic implications of pollen morphology in tribe Ajugeae (Labiatae). Syst Bot. 1993;18:100-22.

Abu-Asab MS, Cantino PD. Systematic implications of pollen morphology in subfamilies Lamioideae and Pogostemonoideae (Labiatae). Ann Miss Bot Garden. 1994;81:653-86.

Cantino PD, Harley RM, Wagstaff SJ. Genera of Labiatae: Status classification. In: Harley RM, Reynolds T, editors. Advances in Labiatae Science. Kew: Royal Botanical Gardens; 1992. p.27-37.

Celenk S, Dirmenci T, Malyer H, Bicakci A. A palynological study of the genus *Nepeta* L. (Lamiaceae). Plant Syst Evol. 2008;276:105-23.

Davis PH, Mill RR, Tan K. Flora of Turkey and the East Aegean Islands. Edinburgh: Edinburgh University Press; 1988. v.10.

Doaigey AR, El-Zaidy MA, Alfarhan AE, Milagy S, Jacob T. Pollen morphology of certain species of the family Lamiaceae in Saudi Arabia. Saudi J Biol Sci. 2018;25:354-60.

Dönmez AA. A new Turkish species of *Salvia* L. (Lamiaceae). Bot J Linnean Soc. 2001;137:413-6.

Duman H. *Salvia* L. In: Güner A., Özhatay N., Ekim T., Baser K.H.C., editors. Flora of Turkey and the east Aegean islands. Edinburgh: Edinburgh University Press, 2000. v.11. p.197-209.

Erdtman G. Pollen morphology and plant taxonomy. IV. Labiatae, Verbanaceae and Avicenniaceae. Sven Bot Tidskrift. 1945;39:279-85.

Erdtman G. The acetolysis method: revised description. Sven Bot Tidskrift 1960;54:561-4.

Erdtman G. Handbook of palynology morphology, taxonomy, ecology. An introduction to the study of pollen grains and spores. New York: Hafner Publication; 1969. 486p.

Faegri K, Iversen J. Textbook of pollen analysis. 4th. ed. New York: John Wiley & Sons, 1989. 328p.

Hamzaoğlu E, Duran A, Pinar NM. *Salvia anatolica* (Lamiaceae), a new species from East Anatolia, Turkey. Ann Bot Fennici. 2005;42:215-20.

Harley MM, Paton A, Harley RM, Cade PG. Pollen morphological studies in tribe Ocimeae (Nepetoideae: Labiatae): I. *Ocimum* L. Grana Palynol. 1992;31:161-176.

Hassan N, Osman AK, El Garf IA. Pollen types of the Egyptian species of the genus *Salvia* (Lamiaceae). Feddes Repert. 2009;120:394-404.

Hedge IC. *Salvia* L. In: Davis PH, Mill RR, Tan K, editors. Flora of Turkey and the East Aegean Islands. Edinburgh: Edinburgh University Press; 1982. v.7. p.400–61.

Henderson DM, Prentice H, Hedge IC. Pollen morphology of *Salvia* and some related taxa. Grana Palynol. 1968;8:70-85.

Kahraman A, Celep F, Dogan M. Morphology, anatomy and palynology of *Salvia indica* L. (Labiatae). World Appl Sci J. 2009;6:289-96.

Kahraman A, Celep F, Dogan M, Anatomy, trichome morphology and palynology of *Salvia chrysophylla* Stapf (Lamiaceae). South Afr J Bot. 2010;76:187-95.

Moon HK, Vinckier S, Smets E, Huysmans S. Palynological evolutionary trends within the tribe Mentheae with special emphasis on subtribe Menthinae (Nepetoideae: Lamiaceae). Plant Syst Evol. 2008a;275:93-108.

Moon HK, Vinckier S, Walker JB, Smets E, Huysmans S.A search for phlogenetically informative pollen characters in the subtribe Salviinae (Mentheae: Lamiaceae). Int J Plant Sci. 2008b;169:455-71.

Özler H, Pehlivan S, Kahraman A, Dogan M, Celep F, Baser B, et al. Pollen morphology of the genus *Salvia* L. (Lamiaceae) in Turkey. Flora. 2011;206:316-27.

Özler H, Pehlivan S, Celep F, Dogan M, Kahraman A, Yavru Fiþne A, et al. Pollen morphology of *Hymenosphace* and *Aethiops* section of the genus *Salvia* L. (Lamiaceae) in Turkey. Turk J Bot. 2013;37:1070-84.

Perveen A, Qaiser M. Pollen morphology of the family Labiatae from Pakistan. Pak J Bot. 2003;35:671-93.

Punt W, Hoen PP, Blackmore S, Nilsson S, Le Thomas A. Glossary of pollen and spore terminology. Rev Palaeobot Palynol. 2007;143:1-81.

Salmaki Y, Jamzad Z, Zarre S, Bräuchler C. Pollen morphology of *Stachy*s (Lamiaceae) in Iran and its systematic implication. Flora. 2008;203:627-39.

Vural A, Adiguzel N. A new species from Central Anatolia: *Salvia aytachii* M. Vural et N. Adiguzel (Labiatae). Turk J Bot. 1996;20:531-4.

Walker JB, Sytsma KJ, Treutlein J, Wink M. *Salvia* (Lamiaceae) is not monophyletic: implications for the systematics, radiation, and ecological specializations of *Salvia* and tribe Mentheae. Am J Bot. 2004;91:1115-25.

Walker JB, Sytsma KJ. Staminal evolution in the genus *Salvia* (Lamiaceae): Molecular phylogenetic evidence for multiple origins of the staminal lever. Ann Bot. 2007;100:375-91.