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Pollen Morphology of Egyptian Malvaceae: An Assessment of Taxonomic Value

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Abstract: The pollen morphological characteristics of 21 species of Egyptian *Malvaceae* belonging to 10 genera: *Abelmoschus* Medik., *Hibiscus* L., *Gossypium* L., *Lagunaria* L., *Abutilon* Mill., *Sida* L., *Malva* L., *Lavatera* L., *Alcea* L. and *Malvaviscus* Cav., were investigated by light and scanning electron microscopy. The pollens were examined and described in each genus. The results demonstrated that pollen morphological characteristics, principally pollen shape, size, aperture characters and exine sculpture and structure, are taxonomically important. The pollen results are discussed with reference to current systematic treatments of *Malvaceae*.

Introduction

The *Malvaceae* are a worldwide family of herbs, shrubs and small trees with a primary concentration of genera in the tropical regions. This family comprises some 110 genera and over 2000 species, divided into five or six tribes: *Malopeae, Malveae, Hibiscieae, Abutilieae, Ureneae* and *Decaschistieae* (Hutchinson, 1967; Bates, 1968; Fryxell, 1975 & 1988; La Duke & Doebley, 1995; Krebs, 1994, a & b). Owing to the high economic value of some genera of the *Malvaceae*, several studies, from different perspectives, have been carried out on this family. Especially noteworthy are those by Edlin, 1935; Bates & Blanchard, 1970; La Duke & Doebley, 1995; Ray, 1995 & 1998; El Hadidi et al., 1999; El Naggar, 1996 & 2001).

The circumscription and classification of *Malvaceae*, particularly at the generic and tribal levels, are frequently disputed (Bates, 1968; Fryxell, 1968, 1975 & 1988; Alverson et al., 1998 & 1999; Judd & Manchester, 1997).

The pollen morphology of this family or some of its representatives has been included in many studies, for example Lang (1937); Erdtman (1952); Saad (1960); and more recently those of Surova & Velieve (1984); Christensen (1986 a & b); Culhane & Blackmore (1988) and Hosni & Araffa (1999).

Saad (1960) studied the pollen morphology of 35 species of *Malvaceae*. He emphasised the importance of the aperture and spine characteristics, as well as exine stratification, to distinguish between different taxa. Christensen (1986) studied the pollen of 120 species of *Malvaceae* using both light (LM) and scanning electron microscopy (SEM). She gave an account of the taxonomic and phylogenetic value of pollen characteristics in this family. Hosni & Araffa (1999) studied the pollen of 22 indigenous taxa of *Malvaceae* in Egypt with LM. They used pollen characteristics in combination with other morphological characteristics to differentiate between certain taxa.

In Egypt *Malvaceae* are represented by 26 species belonging to 10-11 genera (Täckholm, 1974; El Hadidi et al., 1999; Boulos, 2000).

The main objective of the present work is to investigate and describe the pollen of some of the taxa of wild and cultivated *Malvaceae* growing in Egypt, and to discuss the results obtained with recent classifications of the family.

Material and Methods

The study is based on the pollen morphology of 21 species of wild and cultivated Egyptian representatives of *Malvaceae*. Samples of pollen of each species were collected from living material or herbarium specimens (Table 1). Voucher specimens for each species studied are held in the herbarium of Cairo University (CAI) and in the

Table 1. A list of the studied species and their origin and collectors.

No	Taxon	Localities and Collectors.
1-	*Abelmoschus esculentus* (L.) Moench.	Assiut, Egypt, *El Naggar*, 1998, (AST).
		Maghagha, El Menia, Egypt, *El Naggar*, 1998, (AST).
2-	*Hibiscus trionum* L.	Maghagha, El Menia, Egypt, *El Naggar*, 1998, (AST)
		Assiut University campus, 20.40.2000, *El Naggar*, (AST)
3-	*H. micranthus* L.f.	Gebl Elba, Egypt, *El Naggar*, 1998, (AST)
4-	*H. sabdariffa* L.	Qina, Egypt, *El Naggar*, 1997, (AST)
5-	*H. rosa-sinensis* L.	Assiut University campus, 2001, *El Naggar*, (AST)
6-	*Hibiscus* sp.	Assiut University campus, 2000, *El Naggar*, (AST)
7-	*Gossypium barbadense* L.	Assiut, Egypt, *El Naggar*, 1999, (AST)
8-	*G. hirsutum* L.	Geda, Saudi Arabia, *A. Fayed*, 1999, (AST)
9-	*Lagunaria patersonii* G.Don	Burg el Arab, Guest House of Alexandria University, April, 2001, *El Naggar*, (AST)
10-	*Malva aegyptia* L.	Wadi El Kuf, Gebel Akhdar, Libya, *El Naggar*, 1993, (CAI, AST).
		Wadi El Khatamia, Ben hazi, Libya *El Naggar*, 1995, (CAI, AST)
11-	*M. parviflora* L.	Assiut, Egypt, *El Naggar*, 1998, (CAI, AST). Wadi El Kuf, Gebel Akhdar,
		Libya, *El Naggar*, 1993, (CAI, AST)
12-	*M. neglecta* Wallr.	Wadi Al Arbeen, S. Sinai, Egypt, *El Naggar*, 1997, (CAI, AST)
13-	*M. nicaeensis* All.	El Beida, Gebel Akhdar, Libya, *El Naggar*, 1992, (AST)
14-	*M. sylvestris* L.	El Beida, Gebel Akhdar, Libya, *El Naggar*,1992, (AST)
15-	*Lavatera cretica* L.	El Beida, Gebel Akhdar, Libya, *El Naggar*, 1992, (AST);
		Alexandria, Egypt, 5.4.2000. *El Naggar*, (AST)
16-	*L. bryoniifolia* Mill.	Tulmita, north-east of Benghazi, Libya, *El Naggar*, 1995, (AST)
17-	*Alcea rosea* L.	Assiut, Egypt, *El Naggar*, 1999, (AST)
18-	*Abutilon theophrasti* Medik.	Maghagha, El Menia, Egypt, *El Naggar*, 1998, (AST)
19-	*A. pannosum* (G.Forst.) Schledt.	Gebl Elba, Egypt, *El Naggar*, 1998, (AST)
20-	*Sida alba* L.	Assiut, Egypt, *El Naggar*, 1998, (AST)
21-	*Malvaviscus arboreus* Cav.	Assiut University campus, 2001, *El Naggar*, (AST)

herbarium of the Botany Department, faculty of Science, Assiut University (AST, proposed abbreviation).

Material for LM was acetolysed according to Erdtman (1960). Before acetolysis the pollens were boiled in 10% KOH for about 8 min, causing the apertures to open or bulge and making them easier to study (Reitsma, 1969). The acetolysed pollens were mounted in glycerine jelly onto glass slides. The pollen was examined using a Leitz Laborlux D microscope fitted with a 100 x oil immersion objective. A Leitz Vorio-orthorat Code No. 933138 automatic photomicrograph attachment was used for photomicrography.

Material for SEM was prepared by mounting acetolysed pollen onto clean stubs covered with double-sided cellotape. Untreated dry pollen was mounted directly onto the cleaned stub surface. Some acetolysed pollen was mounted onto clean stubs and a clean cover slip was pressed down on to the pollen grains to fracture them, so that the wall intra structure could be studied. Other pollens were immersed in liquid nitrogen to freeze them, and then fractured with a hammer. All stubs were coated with gold using a JEOL JFC 1100 E ion sputtering device. The pollen grains were then examined in a JEOL JSM 5400LV scanning electron microscope, operated at an accelerating voltage of 15 kV. The work was carried out in the Electron Microscope Unit, Assiut University. Treated pollen grains generally grow in size, and therefore all measurements of pollen size, spine length and aperture size were taken from untreated dry pollen. Exine thickness was measured from acetolysed pollen.

The terminology used here for pollen description follows Erdtman (1952); Reitsma (1970) and Punt et al. (1994).

Results

Pollen grains in *Malvaceae* are usually spheroidal or globular in outline and, colporate or porate with an echinate sculpture. Pollen exine always consists of sexine and nexine; the latter is usually thicker than the former. Spines are always evenly distributed over the surface of the grain and vary in length, shape and density (Plates 1-7).

Pollen description

1- Abelmoschus Medik. (Plate 1, Fig. 1; Plate 7, Fig.1).

Pollen grains 128-130 µm, spheroidal, polypantoporate; pore number 22-45; pore large, 6-9 µm in diameter, costate (annulate). Exine thick, 3.2-4.3 µm, sexine as thick as or thicker than nexine. Columellae rod-like, elongated near and beneath the bases of spines. Tectum verrucate, micro-reticulate to punctate. Spines long, straight, blunt apices, bulbous or on basal cushions, sparsely distributed.

2- Hibiscus L. (Plate 1, Figs. 2, 3 & 4; Plate 3, Figs. 3 & 4; Plate 4, Figs. 3, 4 & 5; Plate 5, Figs. 1 & 5).

Pollen grains 88-130 µm, spheroidal, colporate or polypantoporate: aperture number 22-45, in spiral pattern, 3-6 µm in diameter, costate (*H. trionum*) or not. Exine 1.5-5.7 µm thick; nexine as thick as or thicker than sexine (about twice as thick as sexine). Columellae rod-like, elongated near or beneath the bases of spines. Tectum verrucate, punctate. Spines long, straight, slender, tapering or blunt apices or with broader or globular lower part, branched spines sometimes present, sparsely distributed.

3- Gossypium L. (Plate 1, Fig. 5; Plate 4, Fig. 6; Plate 6, Fig. 4).

Pollen grains 68-88 µm, spheroidal, colporate; aperture number 22-45, usually in distinct spiral pattern, 6.3-7 µm length, costate. Exine 3-4.5 µm thick; sexine as thick as nexine or slightly thicker. Columellae long, rod-like, thicker in lower part elongated near and beneath the bases of spines. Tectum rugulose microreticulate to punctate. Spines long, pointed apices, lower part globular, bulbous or on basal cushions, sparsely distributed.

4- Lagunaria L. (Plate 1, Fig. 6).

Pollen grains 45-50 µm, spheroidal, colporate; aperture number 22-45, usually in distinct spiral pattern, 6-7.5 µm length. Exine 3-4 µm thick; sexine as thick as nexine or slightly thicker. Columellae long, rod-like. Tectum rugulose microreticulate to punctate. Spines long, straight or curved, pointed or blunt apices, broader lower part, bulbous or on basal cushions, sparsely distributed.

5- Abutilon Mill. (Plate 2, Fig. 1; Plate 4, Fig. 1; Plate 6; Figs. 1 & 6).

Pollen grains 37-45 µm, suboblate-spheroidal, colporate or porate; aperture number 8-15, spindle-shaped with pointed apices, 5.8-13.0 µm length, 4.6-6.4 µm width. Endoaperture porus, circular or lalongate, costate. Exine 1.6-2.0 µm; sexine usually slightly thinner than nexine. Columellae distinct, rod-like, elongated near and beneath the bases of spines. Tectum micro-verrucate or micro-granulate to punctate. Spines short, pointed or tapering apices, usually bulbous or on basal cushions, sparsely distributed.

6- Sida L. (Plate 5, Figs. 3 & 6; Plate 6, Fig. 2).

Pollen grains 43-46 µm, spheroidal, colporate or porate; aperture number 6-9, varying in position from zonal to a distinct spiral pattern, when colporate, colpus length varies from 10-13 µm, diameter 6.5-7.5 µm, costate. Exine 2-2.6 µm thick: nexine 1-2 times as thick as sexine. Columellae thick and densely crowded, elongated near and at the bases of spines. Tectum rugulose to micro-verrucate. Spines short, pointed almost drop-shaped with basal cushions, sparsely distributed.

7- Malva L. (Plate 2, Figs. 2 & 3; Plate 3, Fig. 1; Plate 5, Fig. 4; Plate 6, Figs. 3 & 5; Plate 7, Fig. 2).

Pollen grains 51-75 µm, spheroidal, polypantoporate; pores numerous, ± in spiral pattern; 2-5 µm in diameter. Exine 3-6 µm thick: nexine 3-5 times as thick as sexine. Columellae similar, rounded, rod-like, thicker in at base, elongated beneath the bases of spines. Tectum rugulose to micro-verrucate or micro-reticulate and punctate. Spines monomorphic but variable in length or clearly dimorphic, all studied species with long, slender and pointed spines (3-8 µm) and/or short pointed spines (1-2 µm), regularly and densely distributed.

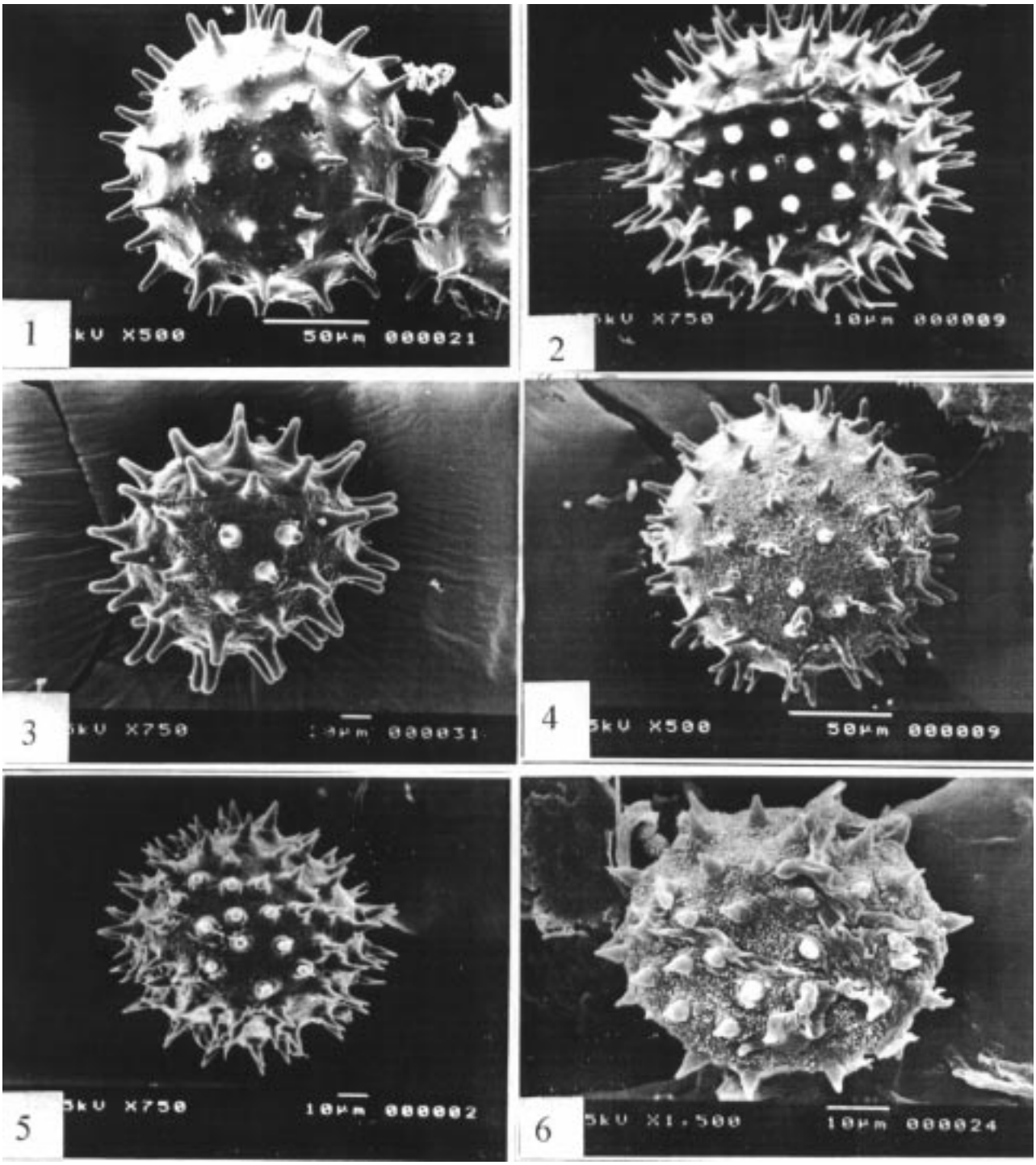

Plate 1. Pollen morphology of the studied taxa of Malvaceae

1- *Abelmoschus esculentus*	x 500	2- *Hibiscus trionum*	x 750
3- *Hibiscus rosa-sinensis*	x 750	4- *Hibiscus* sp.	x 500
5- *Gossypium barbadence*	x 750	6- *Lagunaria patersonii*	x 1500

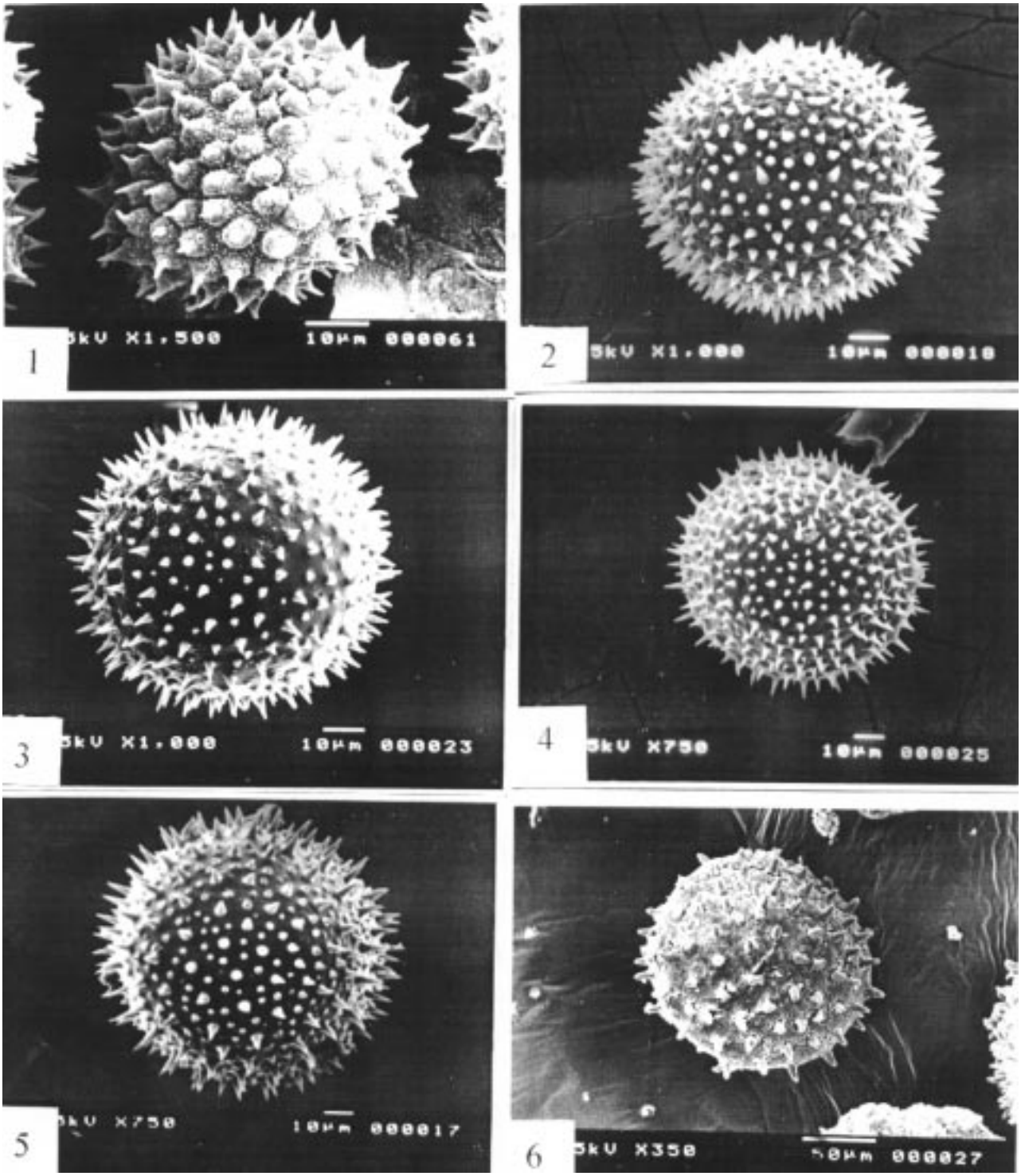

Plate 2. Pollen morphology of the studied taxa of Malvaceae

1- *Abutilon pannosum*	x 1500	2- *Malva aegyptia*	x 1000
3- *Malva neglecta*	x 1000	4- *Lavatera cretica*	x 750
5- *Alcea rosea*	x 750	6- *Malvaviscus arboreus*	x 350

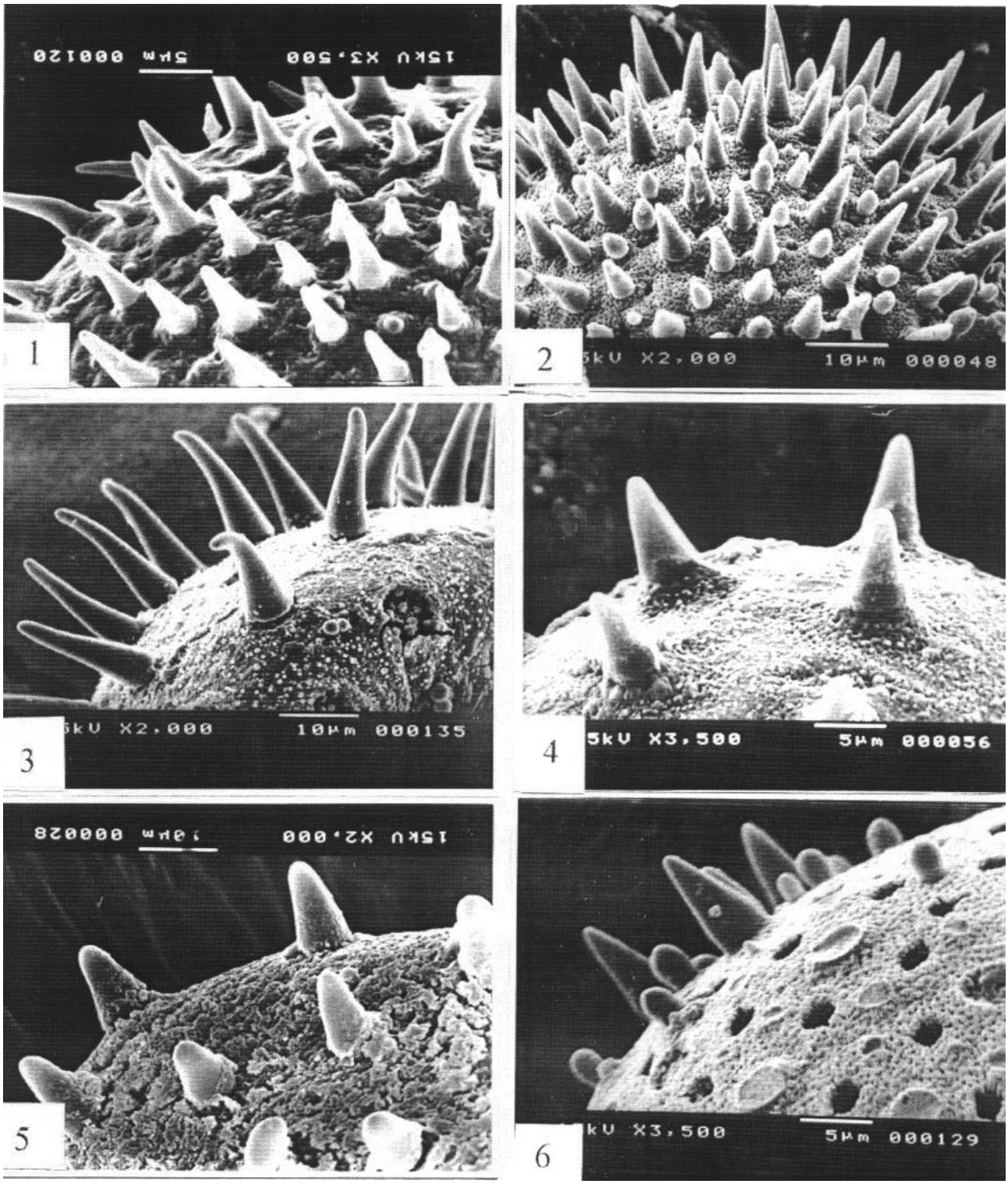

Plate 3. Spine morphology on pollen surface of the studied taxa of Malvaceae

1- *Malva aegyptia*	x 3500	2- *Alcea rosea*	x 2000
3- *Hibiscus sabdariffa*	x 2000	4- *Hibiscus micranthus*	x 3500
5- *Malvaviscus arboreus*	x 2000	6- *Alcea rosea*	x 3500

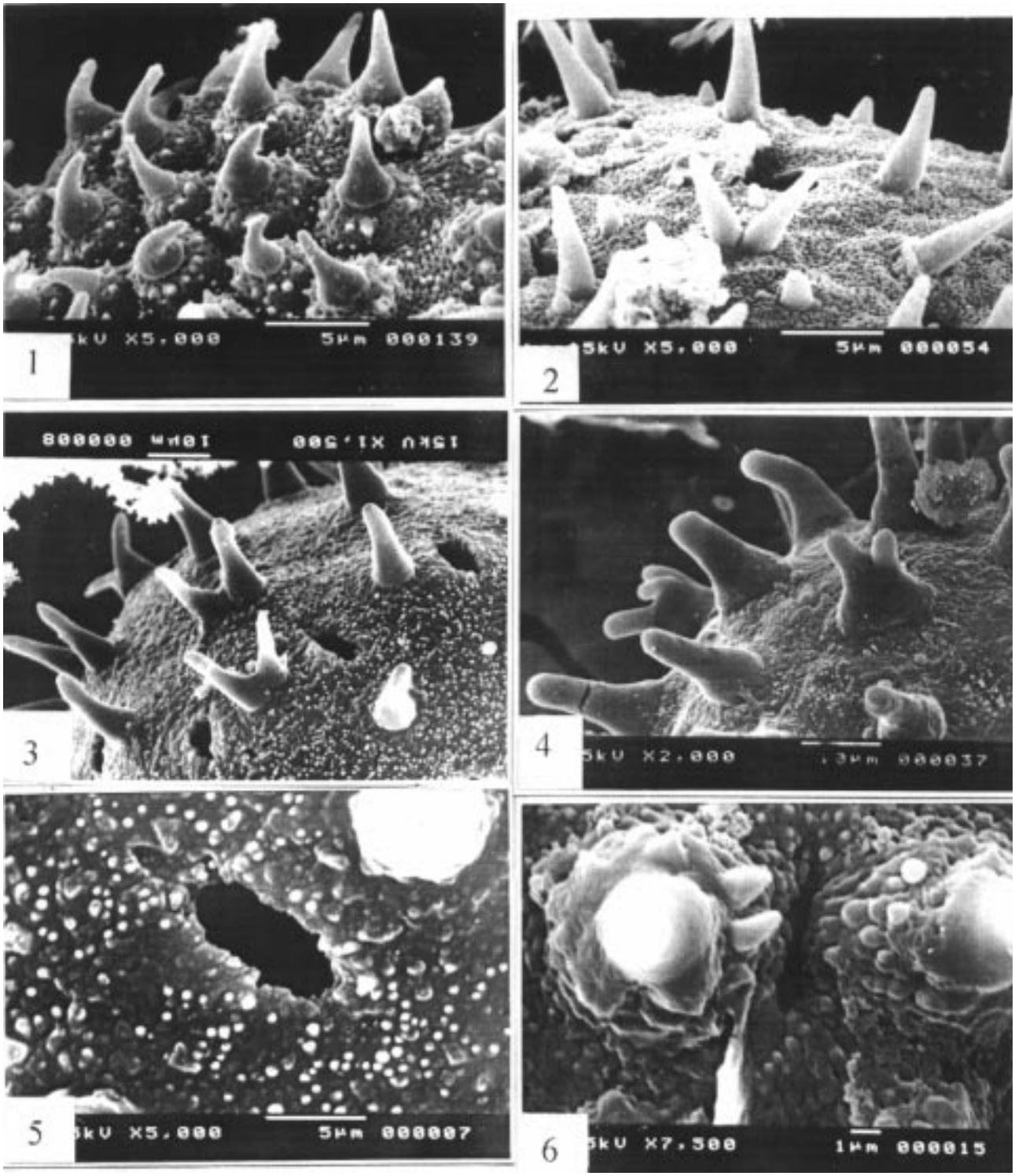

Plate 4. Spine morphology and aperture from outside of the studied taxa of Malvaceae

1- *Abutilon pannosum*	x 5000	2- *Lavatera cretica*	x 5000
3- *Hibiscus sp.*	x 1500	4- *Hibiscus rosa-sinesis*	x 2000
5- *Hibiscus sp.*	x 5000	6- *Gossypium hirsutum*	x 7500

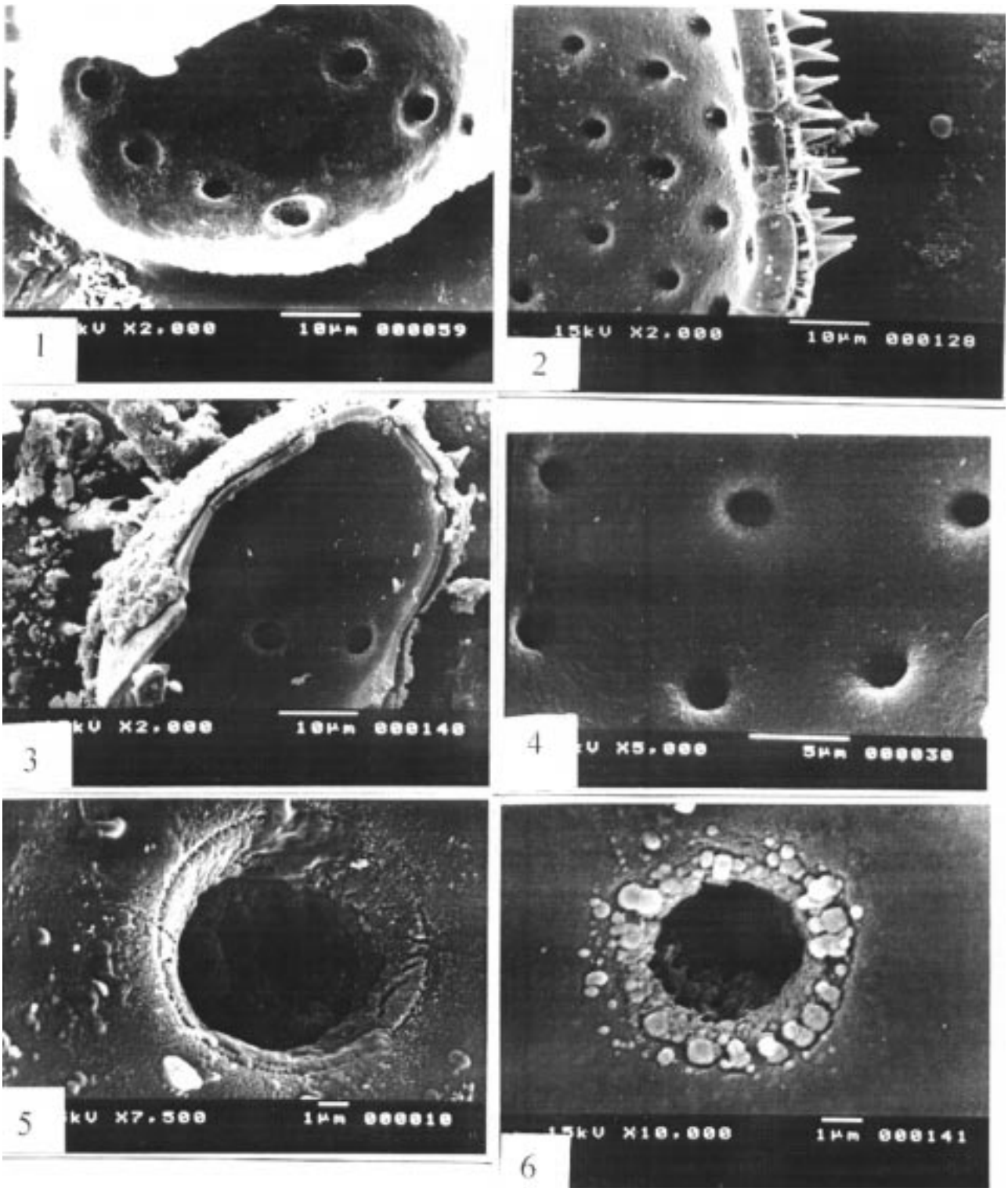

Plate 5. Aperture sculpture from inside of the studied taxa of Malvaceae

1- *Hibiscus micranthus*	x 2000	2- *Lavatera cretica*	x 2000
3- *Sida alba*	x 2000	4- *Malva nicaeensis*	x 5000
5- *Hibiscus sabdariffa*	x 7500	6- *Sida alba*	x 10000

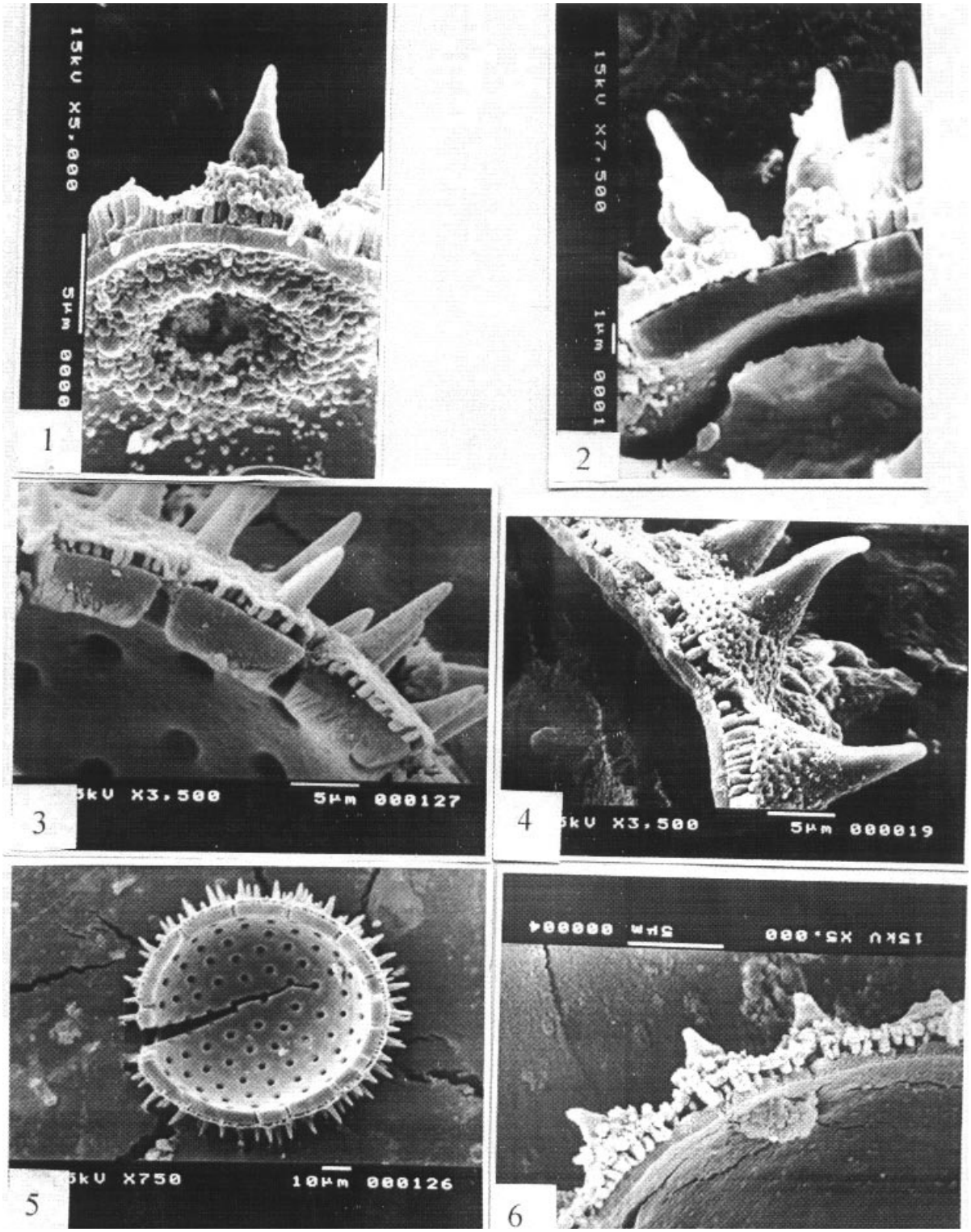

Plate 6. Exine structure and stratification of the studied taxa of Malvaceae

1- *Abutilon pannosum*	x 5000	2- *Sida alba*	x 75000
3- *Malva sylvestris*	x 3500	4- *Gossypium barbadense*	x 3500
5- *Malva sylvestris*	x 750	6- *Abutilon theophrasti*	x 5000

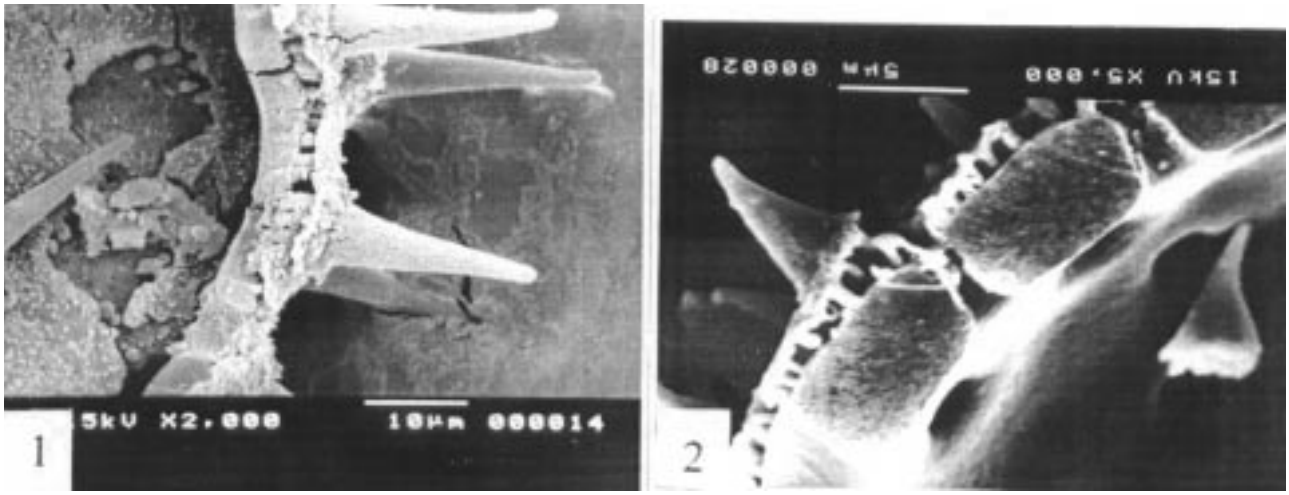

Plate 7. Exine structure and stratification of the studied taxa of Malvaceae
1- *Abelmoschus esculentus* x 2000 *2- Malva nicaeensis* x 5000

8- Lavatera L. (Plate 2, Fig. 4; Plate 4, Fig. 2; Plate 5, Fig. 2).

Pollen grains 47-66 µm, spheroidal, polypantoporate; pores numerous, in distinct spiral pattern, 2-3 µm in diameter. Exine 5-6 µm thick: nexine asthick as or twice as thick as sexine. Columellae similar, rounded, rod-like, thicker in lower part and elongated beneath the bases of spines. Tectum rugulose to densely micro-verrucose or micro-reticulate. Spines dimorphic, long or short, slender and more or less pointed, branched spines sometimes present, regularly and densely distributed.

9- Alcea L. (Plate 2, Fig. 5; Plate 3, Fig. 2).

Pollen grains 60-90 µm, spheroidal, polypantoporate; pores numerous, in spiral pattern, 1.7-2 µm in diameter. Exine 3-4.5 µm thick: sexine very much thinner than nexine. Columellae short, hook-like. Tectum rugulose to verrucate or micro-reticulate-punctate. Spines usually dimorphic, either medium to long, pointed and slender or short and rounded ovoid or flask-shaped, densely distributed.

10- Malvaviscus Cav. (Plate 2, Fig. 6).

Pollen grains 100-128 µm, spheroidal, polypantoporate: pores numerous; 5-6 µm in diameter. Exine 5.7-6.5 µm thick, nexine about twice as thick as sexine. Columellae rod-like, elongated near or beneath the bases of spines. Tectum verrucate. Spines long, straight, slender, blunt or rounded apices, sparsely distributed.

Size: Pollen size varies greatly among the different genera as well as among the species of the same genus. It ranges from 37-40 µm in studied taxa of *Abutileae* (*Sida alba*, *Abutilon theophrasti* and *A. pannosum* to 128-130 µm in studied taxa of *Hibiscieae* (*Abelmoschus esculentus*, *Hibiscus trionum*, *H. sabdariffa*, *H. rosa-sinensis*, *Hibiscus* sp., *Gossypium barbadense*, *G. hirsutum* and *Lagunaria patersonii*) (Table, 2). In the tribe Malveae (*Malva aegyptia*, *M. parviflora*, *M. nicaeensis*, *M. neglecta*, *M. sylvestris*, *Lavatera cretica*, *L. bryoiifolia* and *Alcea rosea*) pollen size varies considerably among the taxa studied, from 66 µm in *Lavatera cretica* to 90 µm in *Alcea rosea*. The smallest grains are those of *Abutilon theophrasti* (37 µm) while the largest are those of *Abelmoschus esculentus* (130 µm).

Aperture: Pore numbers vary considerably among the taxa examined: 8-15 in Abutilieae (*Sida alba*, *Abutilon theophrasti*, and *A. pannosum*), 22-45 in Hibiscieae (*Abelmoschus esculentus, Hibiscus trionum, H. sabdariffa H. rosa-sinensis, Hibiscus* sp., *Gossypium barbadense*, *G. hirsutum* and *Lagunaria patersonii*) and more than 45 in the tribe Malveae (*Malva aegyptia, M. parviflora, M. nicaeensis, M. neglecta, M. sylvestris, Lavatera cretica, L. bryoiifolia* and *Alcea rosea*).

Pore diameter varies in the different genera, as in different species for a given genus. This ranges from 1-3 µm as in all studied species of tribe *Malveae* (*Malva*, *Lavateria* & *Alcea*) to 15 µm as in the studied species of Hibisceae. Aperture type in the taxa studied is porate,

Table 2. Summmarises the palynological data of the studied taxa

No.	Taxon	Pollen size (µm)	No.	Diameter	Arrangement	Shape	Inside	Length (µm)	Base	Flask shape	branched	Thicknes (µm)	Sexine (µm)	Nexine (µm)	Tectum sculpture
1.	*Abelmoschus esculentus*	128-130	22-45	6-Eyl	panto	porate	costate	16	bulbous	-	-	3.2-4.3	2.55	1.75	verrucate or microreticulate- puncutate
2.	*Hibiscus trionum*	80-88	22-45	4.6	panto	porate	costate	11	bulbous	-	-	5.7	2.85	2.85	verrucate
3.	*H. micranthus*	62-130	22-45	3	panto	porate	costate	15	bulbous	-	-	1.4	0.6	0.8	verrucate, microreticulate-punctate
4.	*H. sabdariffa*	72-96	22-45	5.1	panto	porate	smooth	14	bulbous	-	-	3.42	0.9	2.57	verrucate
5.	*H. rosa-sinensis*	73-75	22-45	4	panto	colporate	costate	11.5	bulbous	-	present	3.5	1.3	2.2	verrucate
6.	*Hibiscus* sp.	100-120	22-45	3.5	panto	colporate	costate	10	bulbous	-	present	3.8	1.5	2.3	verrucate
7.	*Gossypium barbadense*	66-73	22-45	5	panto	porate	costate	11	bulbous	-	-	3.43	1.71	1.71	rugulose, microreticulate-punctate
8.	*G. hirsutum*	85-88	22-45	4	panto	colporate	costate	7.5	bulbous	-	-	-	-	-	rugulose
9.	*Lagunaria patersonii*	45-50	22-45	7.5	panto	colporate	costate	7.5	bulbous	-	-	-	-	-	rugulose, microreticulate-punctate
10.	*Malva aegyptia*	52-75	numerous	3.6	panto	porate	smooth	4	-	-	-	4.4	1.6	2.8	verrucate
11.	*M. parviflora*	51-53	numerous	2	panto	porate	costate	3	-	-	-	3.2	0.9	2.1	verrucate, microreticulate-punctate
12.	*M. neglecta*	58-63	numerous	2.2	panto	porate	verrucate	6	-	-	-	3.2	1.4	1.8	verrucate, microreticulate-punctate
13.	*M. nicaeensis*	55-60	numerous	2.2	panto	porate	smooth	6	-	-	-	4.4	1.2	3.2	verrucate, microreticulate-punctate
14.	*M. sylvestris*	72-75	numerous	2.6	panto	porate	smooth	8	-	-	-	6	2.6	3.7	verrucate, microreticulate-punctate
15.	*Lavatera cretica*	47-66	numerous	2.7	panto	porate	verrucate	5	-	-	present	5	1.75	3.25	verrucate, microreticulate-punctate
16.	*L. bryoniifolia*	50-65	numerous	2.5	panto	porate	smooth	5	-	-	present	4.8	1.7	3.1	verrucate, microreticulate-punctate
17.	*Alcea rosea*	75-90	numerous	2.6	panto	porate	smooth	8	-	present	-	3.5	0.7	2.8	verrucate, microreticulate-punctate
18.	*Abutilon theophrasti*	37-47	Ağu-15	3.4	zono	porate	costate	5.3	bulbous	-	-	1.5	0.93	0.53	microverrucate, microreticulate-punctate
19.	*A. pannosum*	43-44	Ağu-15	3.2	zono	porate	costate	5	bulbous	-	-	1.4	0.7	0.7	microverrucate, microreticulate-punctate
20.	*Sida alba*	43-47	6-Eyl	3	zono	colporate or porate	costate	5	bulbous	-	-	2.4	1.2	1.2	microerrucate, microreticulate-punctate
21.	*Malvaviscus arboreus*	100-128	numerous	5-Haz	panto	colpate	costate	4	bulbous	-	-	6.5	2.15	4.3	verrucate

colporate, rarely colpate. In some cases, such as *Sida*, *Abutilon* and *Hibiscus*, the apertures are colpate or colporate or due to the verrucate nature of the pollen surface, the aperture is of colpus appearance of different shapes, such as ovate or slit-like (Plate 4).

Exine: In *Malvaceae* the pollen exine varies considerably in thickness and structure. Thick exine occurs in *Malveae* (3.5-6 µm) and thin exine in pollen of *Abutilieae* (1.4-2.4 µm), while in the tribe *Hibiscieae* pollen exine thickness varies among the species studied. It is thin (1.4 µm) in *Hibiscus micranthus* and thick (5.7 µm) in *H. trionum* (Table 2). The exine in *Malvaceae* pollen usually consists of sexine and nexine. In most of the studied taxa the nexine is usually thicker than the sexine; however, in *Abutilon pannosum, Hibiscus trionum* and *Gossypium barbadense* the sexine and nexine are about the same thickness, although the sexine in *Abutilon theophrasti* and *Abelmoschus esculentus* is thicker than the nexine (Plates 5, 6 & 7).

Discussion

Variation in pollen size, aperture and spine characteristics, as well as exine stratification, are all of taxonomic value.

Pollen size is useful as a taxonomic characteristic, particularly at the tribal level: for example, it is large in all studied taxa of the tribe Hibiscieae and small in the tribe *Abutilieae*. Saad (1960) reported that there is a correlation between pollen size and chromosome number. Christensen (1986, a) agrees with Saad, and considers small size to be relatively underived in comparison to large size in terms of pollen evolution within the *Malvaceae*.

Therefore, the number of apertures is also useful as a taxonomic character at tribal level. The results agree with those of Saad (1960), Erdtman (1962) and Christensen (1986, a).

The appearance of pores on the inner surface of the acetolysed pollen has proved to have reliable taxonomic characteristics as well: in *Abutilon*, *Hibiscus* and *Sida* there is a distinct costate ring surrounding the pore, but not in *Malva*, *Lavatera* and *Alcea*. The pores in *Malva aegyptia, M. nicaeensis, M. sylvestris*, *Lavatera cretica* and *Alcea rosea* are smooth and featureless while in *M. neglecta, Sida alba, Abutilon theophrasti* and *A. pannosum* (Plate 5) they are verrucate.

The pore sculpture of the inner exine surface in *Malvaceae* is used as a taxonomic characteristic for the first time in the present work. Neither Saad (1960) nor Hosni & Araffa (1999) recorded this feature. Christensen (1986, a) commented on the feature but not did use it as a taxonomic characteristic in her investigation. Moreover, she considered the presence of the inner ring-like costae less derived than the non-costate state.

The results showed that the sexine is variable in thickness in the studied taxa, thus disagreeing with the conclusion of Christensen (1986, b) who states that the sexine is usually of constant thickness in *Malvaceae* while the nexine is variable. The nexine is usually thicker than the sexine in the tribe *Malveae*. The nexine in *Abutilieae* and *Hibiscieae* may be thinner or thicker or as thick as the sexine. The variation in exine thickness is obviously related to both nexine and sexine thickness and not to nexine thickness as Christensen (1986, a) stated. Columellae in *Malvaceae* are always similar, rod-shaped or with a broad lower part; they vary in length in the studied taxa, which reflects the difference in sexine thickness. However, columella length differs in the same grain because the length of the columella increases near, or at the bases of spines and this increase is responsible for the cushion shape in the pollen spines of *Sida*, *Abutilon*, *Abelmoschus* and *Gossypium*. Pollen exine in *Malvaceae* is usually tectate and of more or less the same thickness among all taxa. The tectum is the upper layer of the sexine. This surface pattern of the tectum varies from microreticulate or punctate, as in *Malva aegyptia*, *M. sylvesteris, Alcea rosea*, *Abutilon pannosum* and *Gossypium barbadense* to rugulate, granulate or verrucate (Plate 1, 2, 3 & 4).

Spines (echinae): Pollen grains of the *Malvaceae* are characterised by a spiny tectum. The spines show reliable variations in size, shape and surface distribution. The variations are of value at different taxonomic levels, because they may occur not only between genera but also between species of the same genus. Spine length may be similar on pollen grains (monomorphic) as in most species of tribe *Hibiscieae, Abutileae* and *Ureneae*, or it may vary on the same grain, giving a dimorphic pattern as in species of tribe *Malveae* (Plates 3 & 4). Results show that the longest spines are recorded in *Hibiscus micranthus* (16 µm) and the smallest in *Malva parviflora* (2.5-3 µm).

Spine shape: The spines are conical with straight sides in most of the investigated taxa. Curved or crooked spines are sometimes found in species of *Abutilon* and in *Sida alba, Malva aegyptia* and *Abelmoschus esculentus*. Spines are either conical and taper into an acuminate or pointed tip like those in the pollen of *Malva sylvestris, M. aegyptia, Lavatera cretica* and *Alcea rosea*, or conical with pointed ends such as those in the pollen of *Malva parviflora* (Plate 3). Spines with blunt or rounded apices occur only in pollens of some species of *Hibiscieae* or, together with spines which have tapering apices, in pollen of some species of *Malveae*. Globular or flask-shaped spines are found only in *Alcea rosea*. In *Sida alba*, *Abutilon* and *Gossypium* the spines are raised on rounded bases which are formed by an increase in the length of the columellae. In most species of *Hibiscus*, *Abelmoschus* and *Gossypium* (*Abutilieae*), spines are conical with blunt and rounded ends. In *Lavatera cretica* and *Hibiscus rosa-sinensis* spines may be branched from the bases or from above (Plate 4). The distribution of spines on the surface of the grain is fairly constant in the same species but varies between different species and genera. They are always evenly distributed. The spine distances, i.e. the distance between two neighbouring spines, differ between species. In pollen of *Hibiscus*, *Gossypium* and *Abelmoschus* it ranges from 10 to 15 µm, and is small and narrow in *Malva*, *Alcea* and *Lavatera*.

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