Feddes Repertorium **121** (2010) 3–4, 97–111 DOI: 10.1002/fedr.201000004 Weinheim, September 2010

[1] Umm Al-Qura University, Faculty of Science, Biology Department, Mecca, Saudi Arabia
[2] Sohag University, Faculty of Science, Botany Department, Sohag, Egypt

KADRY ABDEL KHALIK[1,2]

A palynological study of the family Dipsacaceae in Egypt and its taxonomic significance

With one Figure, 2 Tables and 6 Plates

Keywords: Dipsacaceae, pollen morphology, systematic

Abstract

Pollen morphology of nine species belonging to four genera: *Cephalaria*, *Pterocephalus*, *Scabiosa*, and *Lomelosia* of Dipsacaceae in Egypt has been investigated by light microscope (LM) and scanning electron microscopy (SEM). Pollen shape, size, exine ornamentation, number and characters of apertures present powerful characters for distinguishing between species. The pollen grains were tricolpate and triporate. Their shapes vary from spheroidal to oblate-spheroidal. Regarding the position of apertures, three types can be recognized viz., circumaperturate, angulaperturate, and planaperturate. Concerning sculpturing of the exine in proximal face, two different pollen types can be distinguished viz., spinulate and gemmate types. The exine ornamentation was found useful to distinguish between closely related genera such as *Scabiosa* and *Lomelosia.* A diagnostic key is given for all studied taxa based on palynomorphological characters.

Introduction

Dipsacaceae is a small old world family composed of 12–13 genera and including 250–350 species (EHRENDORFER 1965; VERLÀQUE 1977a) of annual to perennial herbs and shrubs. Its distribution is mainly circum-Mediterranean, with extensions to the Middle and Far East (mainly China and Japan), and Africa (VERLÀQUE 1984a; CAPUTO & COZZOLINO 1994). The family Dipsacaceae is a derived member of the order Dipsacales, where it is a sister group of Valerianaceae (BACKLUND & BREMER 1997). Delimitation of taxa within the family has always been subject to argument; consequently, circumscription of genera and tribes has repeatedly changed over time, because of the overall morphological similarity among the taxa in the family and of their diversity in structural detail, particularly, the classical concepts of *Scabiosa* L. and *Pterocephalus* (VAILL.) ADANS. DE CANDOLLE (1830) divided this family into two tribes: Morineae, with the single genus *Morina,* and Scabioseae, including *Dipsacus*, *Cephalaria*, *Knautia*, *Pterocephalus*, and *Scabiosa*. He also placed *Triplostegia* into a monogeneric tribe within Valerianaceae. VERLÀQUE (1984a) divided this family into three tribes with nine genera. CAPUTO & COZZOLINO (1994) presented a cladistic study of 13 genera of the family Dipsacaceae based on morphological and palynological characters, and they divided Dipsacaceae into two major clades, one includes *Dipsacus* and *Cephalaria*, the other including the remaining genera. CAPUTO et al. (2004) presented phylogenetic relationships among 17 species of Dipsacaceae, based on nucleotide sequence of *ITS* and *trnL*, and they divided Dipsacaceae into two major clades: one including *Lomelosia* and *Pycnocomon*, both in a sister group relationship with a clade containing *Pterocephalus*, *Scabiosa* and *Sixalix*, and the other including *Pseudoscabiosa*, *Succisa* and *Succisella* as sister group to *Knautia, Pterocephalidium*, *Dipsacus* and

 0014-8962/10/3-409-0097

Cephalaria. AVINO et al. (2009) studied 35 species from the Dipsacaceae based on sequence data from chloroplast (*trnL intron, trnL–trnF* intergenic spacer, *psbB–psbH* gene complex) and nuclear genomes (*ITS1* and *ITS2*), and they show that Dipsacaceae is a monophyletic group. The topology in the tribe Scabioseae is similar to that from other recent studies, except for the position of *Pycnocomon*, which is nested in *Lomelosia*. Among the authors that have attempted an outline of the phylogeny of Dipsacaceae at the generic and infrageneric levels (EHRENDORFER 1964a, b, 1965; VERLÀQUE 1977a, b, 1984a, b, 1985a, b, 1986a, b; DEVESA 1984; GREUTER & BURDET 1985; GREUTER et al. 1986; MAYER & EHRENDORFER 1999, 2000).

ERDTMANN (1952) studied pollen morphology of 35 species from ten genera of the family Dipsacaceae, and he investigated two types of pollen apertures: porate and colpate, and the sexine usually thicker than nexine. Moreover, he suggested that the pollen of the Dipsacacae (except *Morina*) is more similar to the family Valeraniacaeae. CLARKE & JONES (1981) also studied the pollen morphology of the Dipsacaceae, and they showed that the exine ornamentation consists of processes of two sizes, echinate (over 1 µm in height) and micro-echinate (less than 1 µm in height), and they distinguished two types of apertures, pori and colpi.

In Egypt Dipsacaceae is represented by eleven species belonging to three genera distributed mainly in the Nile region, Mediterranean coastal region and Sinai (TÄCKHOLM 1974; EL HADIDI & FAYED 1994/1995), but recently BOULUS (2000) recorded twelve species.

The aim of the present work is to illustrate the range of variability in pollen characters of the family Dipsacaceae in Egypt in order to establish their availability for future taxonomic work.

Materials and methods

Pollen of each studied species were collected from herbarium specimens or fresh material from the field. The list of voucher specimens is given in Table 1. All investigations were carried out on acetolysed pollen grains according to MOORE et al. (1991). For light microscopy (LM), the pollen grains were examined using Olympus type BH-2. Photomicrographs were taken with Olympus photomicroscope. The measurements are based on 20 readings per slide. The polar axis (*P*), equatorial diameter (*E*) and *P*/*E* ratio, aperture size, exine and nexine thickness were measured (Table 2). For scanning electron microscopy (SEM), acetolysed pollen grains were dehydrated in ethanol series and mounted on a metallic stub in a few drops of ethanol. The specimens were coated with gold in Apolaron E1100 ion sputtering Device, then viewed at 25–30 kv in a JOEL JSM 5300 scanning electron microscope SEM) of Central Laboratory, Faculty of Science, Sohag University, Egypt. The terminology and main morphological concepts are based on ERDTMANN (1952) and PUNT et al. (2007).

Results

Pollen grains in the family Dipsacaceae have a tectum with a complex structure. The palynological data of the investigated taxa were summarized in Table 2.

Pollen morphological characters

Pollen size

The size of pollen grains varies considerably among the examined taxa (Fig. 1), the largest pollen in *Cephalaria syriaca* has a polar axis of 100 µm and an equatorial diameter of 97 µm (Plates I, IV, Fig. 1a, b), and the smallest grains have an average $P \times E$ value ranging from 67×66 µm in *Pterocephalus sanctus* to 68×62 µm in *Pterocephalus plumosus* (Plates II, V, Figs. 5a, b; 6a, b), while the rest of the species have slightly larger grains of 85–70×75–62 µm (see Table 2).

Pollen shape

The ratio between the mean polar axis (*P*) and the mean equatorial diameter (*E*) can be used to assign the pollen grains to shape classes as follows PUNT et al. (1994).

P/E = 0.75–0.875 suboblate
P/E = 0.875–1 oblate spheroidal
P/E = 1 spheroidal
P/E = 11–14 prolate spheroidal
P/E = 1.14–1.33 subprolate
P/E = 1.33–2 prolate

Table 1
Species used to study pollen morphology, information on vouchers, geographical origin of plant material, and synopsis of the infrafamilial taxa of Dipsacaceae according to GREUTER & BURDET (1985) and MAYER & EHRENDORFER (1999, 2000)

Tribe	Genus	Sections	Species	Voucher information
Dipsaceae	*Cephalaria* SCHRAD.	Subg. *Cephalaria* Sect. Echinocephalae LANGE	*Cephalaria syriaca* (L.) ROEM. & SCHULT.	Irael, Jerusalem, Mt. Scopus, I. Amdursky 187 (WAG)
Scabioseae	*Lomelosia* RAFIN.	Sect. Olivierianae (RECH. F.) MAYER & EHRENDORFER	*Lomelosia olivieri* (COULT.) J. SOJÁK	Egypt, Boiss. 1831 (L)
			Lomelosia palestina (L.) RAFIN.	Palestine, Jerusalem, rocky places, Fred Meyers & E. Dinsmore (L).
			Lomelosia prolifera (L.) GREUTER & BURDET	Egypt, without location (WAG & L)
	Pterocephalus (VAILL.) ADANS.		*Pterocephalus plumosus* (L.) COULT.	Egypt, without location (WAG)
			Pterocephalus sanctus DECNE.	Egypt, south Sinai, Jabal Musa, 1800 m, Abdel Khalik s.n. (SHG)
	Scabiosa L.	Sect. Cyrtostemma MERT. & KOCH	*Scabiosa arenaria* FORSSK.	Algeria, Saida, near Ain Skrouna, L. Faurel 5671 (L)
			Scabiosa aucheri BOISS.	Palestine, Jerusalem, rocky places, Jericho road, E. Dinsmore 6545 (L).
			Scabiosa tenuis SPRUNER	Europe, De Heldreich 2465 (L).

The shape of the pollen grains in equatorial view ranges from spheroid to prolate-spheroidal (*P/E* = 1–1.14) (Plates I–VI; Table 2). However, the pollen shape in polar view (Amb) varies from triangulate in *Lomelosia palestina* and *Lomelosia prolifera* (Plates I, IV, Figs. 3a, b, 4a, b), circular-triangulate in *Lomelosia olivieri* (Plates I, IV, Fig. 2a, b) to circular in the rest of the species.

Apertures

There are two basic types of pollen grain apertures. It varies from triporate in *Lomelosia* to tricolpate in *Cephalaria, Pterocephalus* and *Scabiosa.*

Regarding the position of apertures, three types can be recognized:

Type 1. Circumaperturate

Pollen grain with equatorial apertures that are regularly arranged around a circular outline, including *Cephalaria syriaca* (Plates I, IV, Fig. 1a, b).

Type 2. Angulaperturate

The apertures situated at the angles of the outline in polar view, including all species of the genus *Lomelosia* (Plates I, IV).

Type 3. Planaperturate

The apertures are situated in the middle of the sides in polar view, including all species of *Pterocephalus* and *Scabiosa*.

Table 2
Measurements of pollen-morphological character

N	Species	Pollen type	Polar axis (*P* µm)		Equatorial diameter (*E* µm)		*P/E*	Pollen shape (Ps)	AMB	Exine ornamentation
			Range	Mean	Range	Mean				
1	*Cephalaria syriaca* (L.) ROEM. & SCHULT.	Tricolpate	(110–92)	100	(105–88)	97	1	Spheroidal (Equiaxial)	Circular	Spinulose, dimorphic (few long and numerous small; conical)
2	*Lomelosia olivieri* (COULT.) J. SOJÁK	Triporate	(95–76)	85	(85–66)	74	1.1	Prolate spheroidal (Equiaxial)	Circular-triangulate	Gemmate, dimorphic (few wart like pegs and numerous small spinuloid)
3	*Lomelosia palestina* (L.) RAFIN.	Triporate	(80–65)	73	(75–60)	65	1.12	Prolate spheroidal (Equiaxial)	Triangulate	Gemmate, dimorphic(few wart like pegs and numerous small spinuloid)
4	*Lomelosia prolifera* GREUTER & BURDET	Triporate	(80–73)	76	(80–72)	75	1	Spheroidal (Equiaxial)	Triangulate	Spinulose, dimorphic (few long and numerous small; conical)
5	*Pterocephalus plumosus* (L.) COULT.	Tricolpate"	(75–57)	68	(70–50)	62	1.1	Prolate spheroidal (Longiaxial)	Circular	Spinulose, dimorphic (few long and numerous small; conical)
6	*Pterocephalus sanctus* DECNE.	Tricolpate	(75–62)	67	(74–63)	66	1	Spheroidal (Equiaxial)	Circular	Spinulose, dimorphic (few long and numerous small; conical)
7	*Scabiosa arenaria* FORSSK.	Tricolpate	(90–75)	85	(75–63)	75	1.13	Prolate spheroidal (Longiaxial)	Circular	Spinulose, dimorphic (few long and numerous small; conical)
8	*Scabiosa aucheri* BOISS.	Tricolpate	(75–64)	72	(65–58)	63	1.14	Prolate spheroidal (Longiaxial)	Circular	Spinulose, dimorphic (few long and numerous small; conical)
9	*Scabiosa tenuis* SPRUNER	Tricolpate	(72–65)	70	(64–55)	63	1.1	Prolate spheroidal (Longiaxial)	Circular	Spinulose, dimorphic (few long and numerous small; conical)

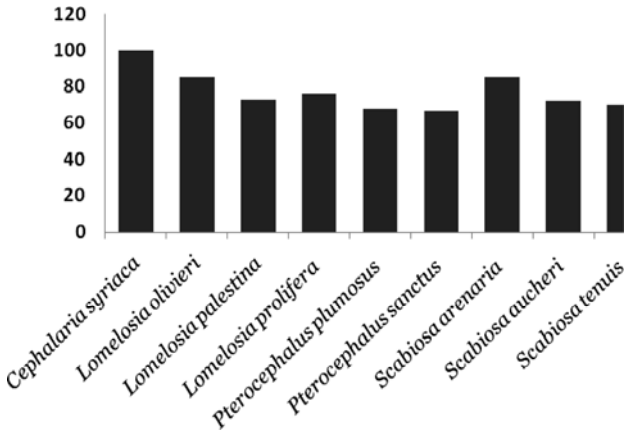

Fig. 1
Average size of polar axis of family Dipsacaceae

On the basis of the apertures sculpturing, all colpate pollens have apertural membranes, and all porate pollens have operculum.

The colpi are narrow; short or long; often slightly sunken; margin a distinct, smooth to echinate. The ends of the colpi were acute. The porus are circular; margin are distinctly echinate in *Lomelosia prolifera* or granulate in *Lomelosia olivieri* and *Lomelosia palestina* (Plates I, III, IV).

Exine sculpture

The exine ornamentation has a complex structure. The LM and SEM show that the outer surface of the tectum is a solid layer which is covered by many very small spinules. Generally, sexine usually thicker than nexine. Concerning the exine sculpturing, two types of the sexine pattern were observed:

Type I. Spinulate

In ERDTMANN'S (1952) definition spines were defined as more than 3 μm long as spinate, but spinulate if the protruding parts were shorter than 3 μm long. All species of *Cephalaria*, *Pterocephalus*, *Scabiosa*, and *Lomelosia prolifera* (Plates I–VI) show similar ornamentation pattern: the tectum is spinulate and densely beset with numerous similar small conical spinules. The sexine is very thick, twice or up to four times as thick as nexine. The width of the sexine layer including spinules may vary between species (Table 2), the largest sexine layer in *Lomelosia prolifera* have a thickness of 8 μm, and the smallest exine layer measures 4 μm in *Cephalaria syriaca*, while the rest of the species have a slightly larger exine layer of 4.5–7 μm.

Type 2. Gemmate

Exine surface with gemmae (wartlike pegs) irregularly strewn on the sexine surface. Gemmae are constricted at its base, higher than 1 μm, and that has approximately the same width as its height, between the gemmae are numerous low regularly spaced spinuloid.

This type is only present in *Lomelosia olivieri* and *Lomelosia palestina*. The tectum is gemmate and densely beset with numerous similar small spinules. The sexine is very thick, three or four times as thick as the nexine. It varies from exine layer in *Lomelosia palestina* with a thickness of 8 μm to exine layer in *Lomelosia olivieri* 6 μm thick.

Key to the pollen types

1a. Pollen grains triporate 2
1b. Pollen grains tricolpate 4
2a. Exine ornamentation gemmate, pollen grain prolate spheroid 3
2b. Exine ornamentation spinulate, pollen grain spheroid . . . . . *Lomelosia prolifera*
3a. AMB view circular- triangulate, pollen size ($P \times E$) 85 × 74 μm . . . . . *Lomelosia olivieri*

3b. AMB view triangulate, pollen size ($P \times E$) 73 × 65 µm . . . . . *Lomelosia palestina*
4a. Pollen size 100 × 97 µm, apertures position circumaperturate . . . . . *Cephalaria syriaca*
4b. Pollen size 85–68 × 75–62 µm, apertures position planaperturate 5
5a. Pollen grain spheroid . . . . . *Pterocephalus sanctus*
5b. Pollen grain prolate spheroid 6
6a. Pollen size 68 × 62 µm, sexine thickness 7 µm . . . . . *Pterocephalus plumosus*
6b. Pollen size 85–70 × 75–63 µm, sexine thickness 4.5–6.5 µm 7
7a. Pollen size 85 × 75 µm, colpus short, 16 µm . . . . . *Scabiosa arenaria*
7b. Pollen size 72–70 × 63 µm, colpus long, 24 µm 8
8a. Sexine thickness 6.5 µm, colpus membrane smooth . . . . . *Scabiosa aucheri*
8b. Sexine thickness 4.5 µm, colpus membrane echinate . . . . . *Scabiosa tenuis*

Discussion

The taxonomy of the family Dipsacaceae is very difficult due to several problems. Delimitation of taxa has always been subject to argument; therefore, circumscription of genera and tribes has repeatedly changed over time, because of the overall morphological similarity among the taxa in the family and of their diversity in structural detail.

MAYER & EHRENDORFER (1999, 2000) suggested a basal haploid chromosome number $x = 9$ as synapomorphy for Scabioseae but AVINO et al. (2009) show that it is a plesiomorphic character.

The present study shows a large morphological and structural polymorphism within the family Dipsacaceae. Generally, the interspecific differences within the genera studied are often trivial, but there are remarkable differences between the various genera.

Pollen grains in Dipsacaceae are heterogenous and eurypalynous, hence it can be divided into several groups. In general, these groups are in congruence with the formerly supposed groupings within the Dipsacaceae based on macromorphological and phylogenetic characters.

Cephalaria group (subg. *Cephalaria* sect. Echinocephalae LANGE)

This group is represented only by *Cephalaria syriaca*. VERLÀQUE (1985b) investigated the pollen and chromosome morphology of *Cephalaria syriaca*, and showed that it has tricolpate pollen and a dysploidy ($2n = 10$), although the majority of the annuals species of the whole genus has ($2n = 18$). In cladistic and molecular studies (CAPUTO & COZZOLINO 1994; CAPUTO et al. 2004; AVINO et al. 2009), *Cephalaria* forms a clade with *Knautia*, *Pterocephalidium* and *Dipsacus.*

The pollen morphology confirms this division, because *Cephalaria syriaca* can be differentiated by its relatively larger grains (*P* 110–92 µm, *E* 105–88 µm); spheroidal and circular pollen shape; tricolpate; spinulate exine sculpture; smallest exine layer (4 µm), and circumaperturate position. Generally these results are congruent with those of VERLÀQUE (1985b), CAPUTO & COZZOLINO (1994), CAPUTO et al. (2004) and AVINO et al. (2009).

Lomelosia group (sect. Olivierianae (RECH. F.) MAYER & EHRENDORFER)

This group comprises three species, *Lomelosia palestina*, *Lomelosia prolifera* and *Lomelosia olivieri*. MAYER & EHRENDORFER (1999) separated all species of *Scabiosa* section *Trochocephalus* into *Lomelosia*, including *Tremastelma* and *Scabiopsis*, and characterized by free involucral bracts, an epicalyx morphology with deep foveoles and with a second sclerenchyma ring in its anatomy structure (VERLÀQUE 1986a), triporate breviaxial to subequiaxial angulaperturate and operculate pollen, they also share chromosome base number ($x = 9$ or $x = 8$ in few annual species).

Recently, CAPUTO et al. (2004) and AVINO et al. (2009) presented phylogenetic relationships among species of Dipsacaceae, and they separated *Lomelosia* and *Pycnocomon* in one clade, both in a sister group with a clade containing *Pterocephalus*, *Scabiosa* and *Sixalix*, and the rest of taxa in the other clade.

The pollen morphology verifies this group, because *Lomelosia* have pollen shape in polar view (Amb) varies from triangulate in *Lomelo-*

sia palestina and *Lomelosia prolifera* to circular-triangulate in *Lomelosia olivieri* while it is circular in the rest of the species; triporate; gemmate exine sculpture; sexine very thick, three or four times as thick as nexine; angulaperturate and operculate apertures sculpture. However, the pollen studies did provide distinctive characters for some taxonomically difficult species, since *Lomelosia palestina*, *Lomelosia prolifera* and *Lomelosia olivieri* were previously placed in the genus *Scabiosa* based on the calyx which usually has five scabrous awns (TÄCKHOLM 1974; RECHINGER 1989; BOULOS 2000). In general these results agree with those of MAYER & EHRENDORFER (1999), CAPUTO et al. (2004) and AVINO et al. (2009).

***Pterocephalus* group**

This group includes *Pterocephalus plumosus* and *P. sanctus*. MAYER & EHRENDORFER (2000), presented details study of 30 species of the genus *Pterocephalus* based on morphology, anatomy and karyology, and divided *Pterocephalus* into five groups, and they placed *Pterocephalus sanctus* with other species in one group, and *Pterocephalus plumosus* in another group.

Pollen grains support this classification, because *Pterocephalus sanctus* has spheroid, equiaxal pollen grain but *Pterocephalus plumosus* has prolate spheroidal, longiaxial pollen grain. Moreover, both *Pterocephalus plumosus* and *P. sanctus* have circular pollen shape in polar view (Amb); tricolpate; spinulate exine sculpture; angulaperturate and membranous apertures sculpture and these results are congruent with those of MAYER & EHRENDORFER (2000), CAPUTO et al. (2004) and AVINO et al. (2009).

***Scabiosa* group (sect. *Cyrtostemma* MERT. & KOCH)**

This group consists of *Scabiosa arenaria*, *Scabiosa aucheri* and *Scabiosa tenuis*. DEVESA (1984), GREUTER & RAUS (1985), GREUTER et al. (1986), and MAYER & EHRENDORFER (1999), divided *Scabiosa* based on the account of differences in epicalyx structure into *Lomelosia*, *Scabiosa*, *Sixalix*, *Pseudoscabiosa* and *Pycnocomon*, and they traditionally divided into five sections: *Trochocephalus, Sclerostemma, Cyrtostemma, Asterothrix* and *Pycnocomon* respectively.

Furthermore, MAYER & EHRENDORFER (1999), said sect. *Cyrtostemma* as most closely related to sect. *Scabiosa* because the two sections share the same chromosome number $x = 8$ instead of $x = 9$ in *Lomelosia,* and tricolpate, longiaxial and non-operculate pollen grains, similarities pointed out by VERLÀQUE (1986a). Pollen grain evidence agrees to maintain this group, because all species of *Scabiosa* have prolate-spheroidal longiaxial, circular pollen shape; triporate; spinulate, angulaperturate and membranous apertures sculpture. These results agree with those of previously classification.

Conclusions

In conclusion, Dipsacaceae is a heterogenous and an eurypalynous family. The interspecific differences within the genera studied are often trivial, but there are remarkable differences between the various genera. Investigation of pollen grains shows that, no morphological synapomorphy may be found for the tribe Scabioseae, since it has more than one pollen type: triporate, gemmate pollen in *Lomelosia* and tricolpate, spinulate one in the rest of the studied species. Although there are only few reliable molecular systematic study on Dipsacaceae (CAPUTO et al. 2004; AVINO et al. 2009) including few species distributed in Egypt, these are excellent works providing strong support for evolution of pollen characters in Dipsacaceae, which can be considered phylogenetically informative characters. Moreover, pollen morphology offers evidence for excluding some species such as *Lomelosia palestina*, *Lomelosia prolifera* and *Lomelosia olivieri* from the genus *Scabiosa* and which can therefore be maintained in a separate genus.

Acknowledgements

I am grateful to the Director and Curator of Wageningen University Herbarium (WAG) and National Herbarium of the Netherlands, Leiden branch, Leiden, the Netherlands (L). My great thanks are due to Prof. Dr. van der Maesen, Professor of plant taxonomy in Biosystematics group, Plant Science, Wageningen University, the Netherlands for going through the manuscript and making valuable suggestions.

References

AVINO, M.; TORTORIELLE, G. & CAPUTO, P. 2009: A phylogenetic analysis of Dipsacaceae based on four DNA regions. – Plant System. Evol. **279** (1–4): 69–86.

BACKLUND, A. & BREMER., B. 1997: Phylogeny of the Asteridae s.str. based on *rbcL* sequences, with particular reference to the Dipsacales. – Plant System. Evol. **207**: 225–254.

BOULOS, L. 2000: Flora of Egypt, 2. – Cairo.

CAPUTO, P. & COZZOLINO, S. 1994: A cladistic analysis of Dipsacaceae (Dipsacales). – Plant System. Evol. **189**: 41–61.

CAPUTO, P.; COZZOLINO, S. & MORETTI, A. 2004: Molecular phylogenetics of Dipsacaceae reveals parallel trends in seed dispersal syndromes. – Plant System. Evol. **246**: 163–175.

CLARKE, G. C. S. & JONES, M. R. 1981: The Northwest European Pollen Flora, 21. Dipsacaceae. – Rev. Palaeobot. Palynol. **33**(1–2): 1–25.

DE CANDOLLE, A. P. 1830: Prodromus systematis naturalis regni vegetabilis **4**. – Paris.

DEVESA, J. A. 1984: *Pseudoscabiosa*, genere nuevo de Dipsacaceae. – Lagascalia **12**: 213–221.

EHRENDORFER, F. 1965: Evolution and karyotype differentiation in a family of flowering plants: Dipsacaceae. – Genetics Today (Proc. XI Internat. Congr. Genetics, The Hague, The Netherlands, 1963) **2**: 399–407.

EHRENDORFER, F. 1964a: Cytologie, Taxonomie und Evolution bei Samenpflanzen: 99–186. – In: W. B. TURRIL (ed.), Vistas in Botany. 4. – New York.

EHRENDORFER, F. 1964b: Über stammesgeschichtliche Differenzierungsmuster bei den Dipsacaceen. – Ber. Dtsch. Bot. Ges. **77**: 83–94.

EL HADIDI, M. N. & FAYED, A. A. 1994/1995: Materials for excursion flora of Egypt (EFE). – Taeckholmia **15**: 1–223.

ERDTMANN, G. 1952: Pollen morphology and plant taxonomy. – Chronica Botanica Co., Massachusettes; Copenhagen.

GREUTER, W. & BURDET, R. 1985: Dipsacaceae. – In: W. GREUTER & T. RAUS (eds), Med-Checklist Notulae 11. – Willdenowia **15**: 71–76.

GREUTER, W.; BURDET, R. & LONG, G. 1986: Med-Checklist. Vol. **2**: 176–198. – Genève.

MAYER, V. & EHRENDORFER, F. 1999: Fruit differentiation, palynology, and systematics in the *Scabiosa* group of genera and *Pseudoscabiosa* (Dipsacaceae). – Plant System. Evol. **216**: 135–166.

MAYER, V. & EHRENDORFER, F. 2000: Fruit differentiation, palynology, and systematics in *Pterocephalus* Adanson and *Pterocephalodes,* gen. nov. (Dipsacaceae). – Bot. J. Linn. Soc. **132**: 47–78.

MOORE, P. D.; WEBB, J. A. & COLLINSON, M. E. 1991: Pollen Analysis. – London.

PUNT, W.; HOEN, P. P.; BLACKMORE, S.; NILSSON, S. & LE THOMAS 2007: Glossary of pollen and spore terminology. – Rev. Palaeobot. Palynol. **143**: 1–81.

RECHINGER, K. H. 1989: *Scabiosa* sect. Olivierianae, sect. nova (Dipsacaceae). – Willdenowia **19**: 137–151.

TÄCKHOLM, V. 1974: Students' Flora of Egypt. – Beirut.

VAN THIEGHEM, P. 1909: Remarques sur les Dipsacees. – Ann. Sci. Nat. Bot., ser. 9, **10**: 148–200.

VERLÀQUE, R. 1977a: Rapports entre les Valerianaceae, les Morinaceae et les Dipsacaceae. – Bull. Soc. Bot. Fr. **124**: 475–482.

VERLÀQUE, R. 1977b: Importance du fruit dans la determination des Dipsacaceae. – Bull. Soc. Bot. Fr. **124**: 515–527.

VERLÀQUE, R. 1984a: A biosystématic and phylogenetic study of the Dipsacaceae: 307–320. – In: R. GRANT (ed.), Plant biosystematics. – Toronto.

VERLÀQUE, R. 1984b: Etude biosystématique et phylogénétique des Dipsacaceae. I – Délimitation des Dipsacaceae à l'intérieur des Dipsacales, rapports avec les autres familles de l'ordre. – Rev. Gén. Bot. **91**: 81–121.

VERLÀQUE, R. 1985a: Etude biosystématique et phylogénétique des Dipsacaceae. II – Caractères généraux des Dipsacaceae. – Rev. Cytol. Biol. Végét. Botaniste **8**: 117–168.

VERLÀQUE, R. 1985b: Etude biosystématique et phylogénétique des Dipsaceae. III – Tribus des Knautieae et des Dipsaceae. – Rev. Cytol. Biol. Végét. Botaniste **8**: 171–243.

VERLÀQUE, R. 1986a: Etude biosystématique et phylogénétique des Dipsacaceae. IV – Tribus des Scabioseae (phylum n 1, 2, 3). – Rev. Cytol. Biol. Végét. Botaniste **9**: 5–72.

VERLÀQUE, R. 1986b: Etude biosystématique et phylogénétique des Dipsacaceae. V – Tribus des Scabioseae (phylum n 4) et conclusion. – Rev. Cytol. Biol. Végét Botaniste **9**: 97–176.

Addresses of the author:

[1] Assoc. Prof. Dr. Kadry Abdel Khalik, Umm Al-Qura University, Faculty of Science, Biology Department, Mecca 673, Saudi Arabia; present address

[2] Sohag University, Faculty of Science, Botany Department, Sohag Herbarium, Sohag 82524, Egypt
e-mail: kadry3000@yahoo.com

Manuscript received: May 31st, 2010.

Explanations to Plates I–III

Scanning electron microscope photographs of pollen grains
a — entire pollen grains; b — enlargement part of pollen grain exine
Bars indicate size

PLATE I

Fig. 1: *Cephalaria syriaca*
Fig. 2: *Lomelosia olivieri*
Fig. 3: *Lomelosia palestina*
Fig. 4: *Lomelosia prolifera*

PLATE II

Fig. 5: *Pterocephalus plumosus*
Fig. 6: *Pterocephalus sanctus*
Fig. 7: *Scabiosa arenaria*
Fig. 8: *Scabiosa aucheri*

PLATE III

Fig. 9: *Scabiosa tenuis*
Fig. 10a: Pollar view of *Lomelosia palestina* showing pore
Fig. 10b: Exine pattern of *Lomelosia olivieri* showing gemma (wartlike pegs)

Explanations to Plates IV–VI

Light microscope photographs of pollen grains
a — entire pollen grains; b — enlargement part of pollen grain exine
Bars indicate size

PLATE IV

Fig. 1: *Cephalaria syriaca*
Fig. 2: *Lomelosia olivieri*
Fig. 3: *Lomelosia palestina*
Fig. 4: *Lomelosia prolifera*

PLATE V

Fig. 5: *Pterocephalus plumosus*
Fig. 6: *Pterocephalus sanctus*
Fig. 7: *Scabiosa arenaria*
Fig. 8: *Scabiosa aucheri*

PLATE VI

Fig. 9: *Scabiosa tenuis*

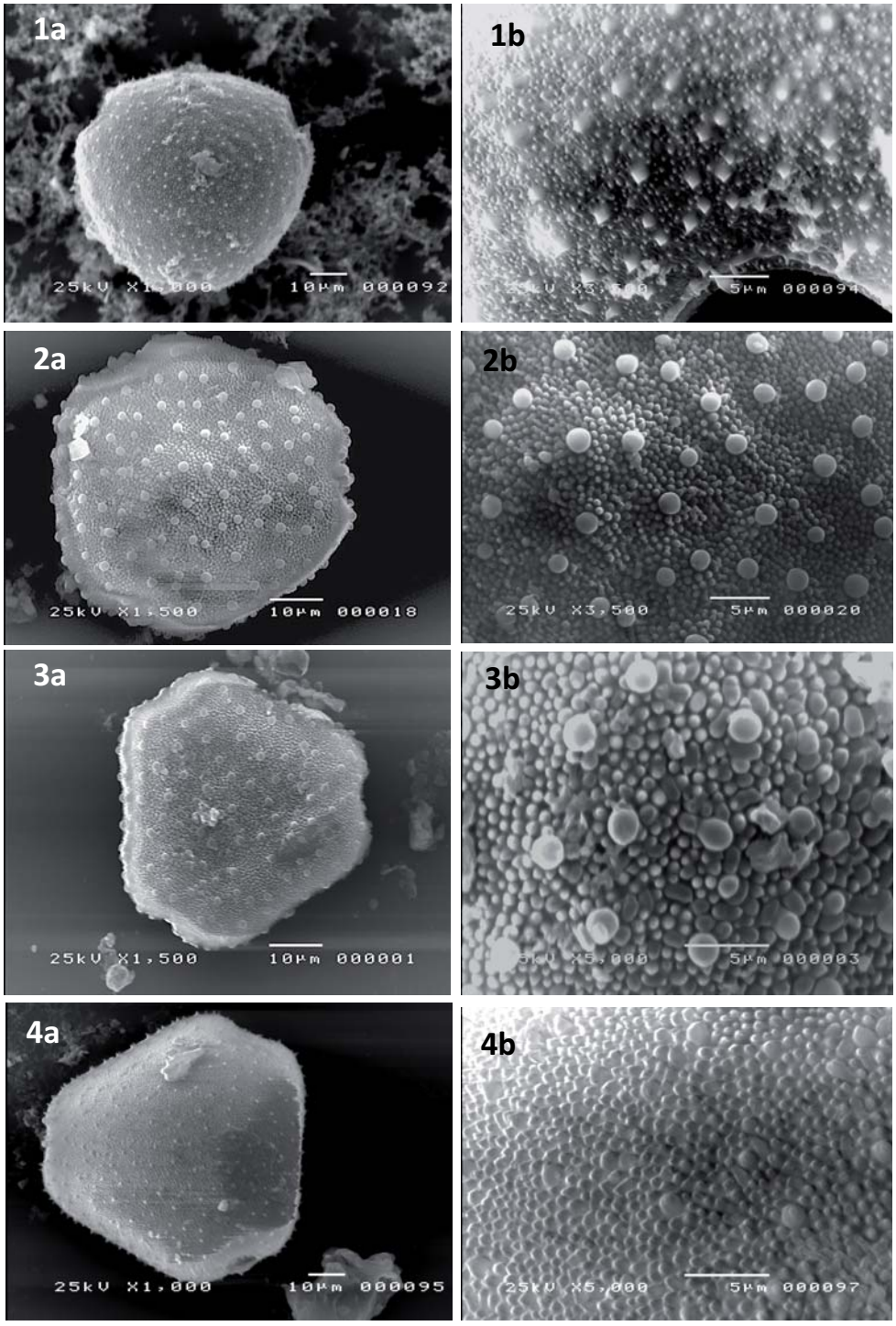

PLATE I

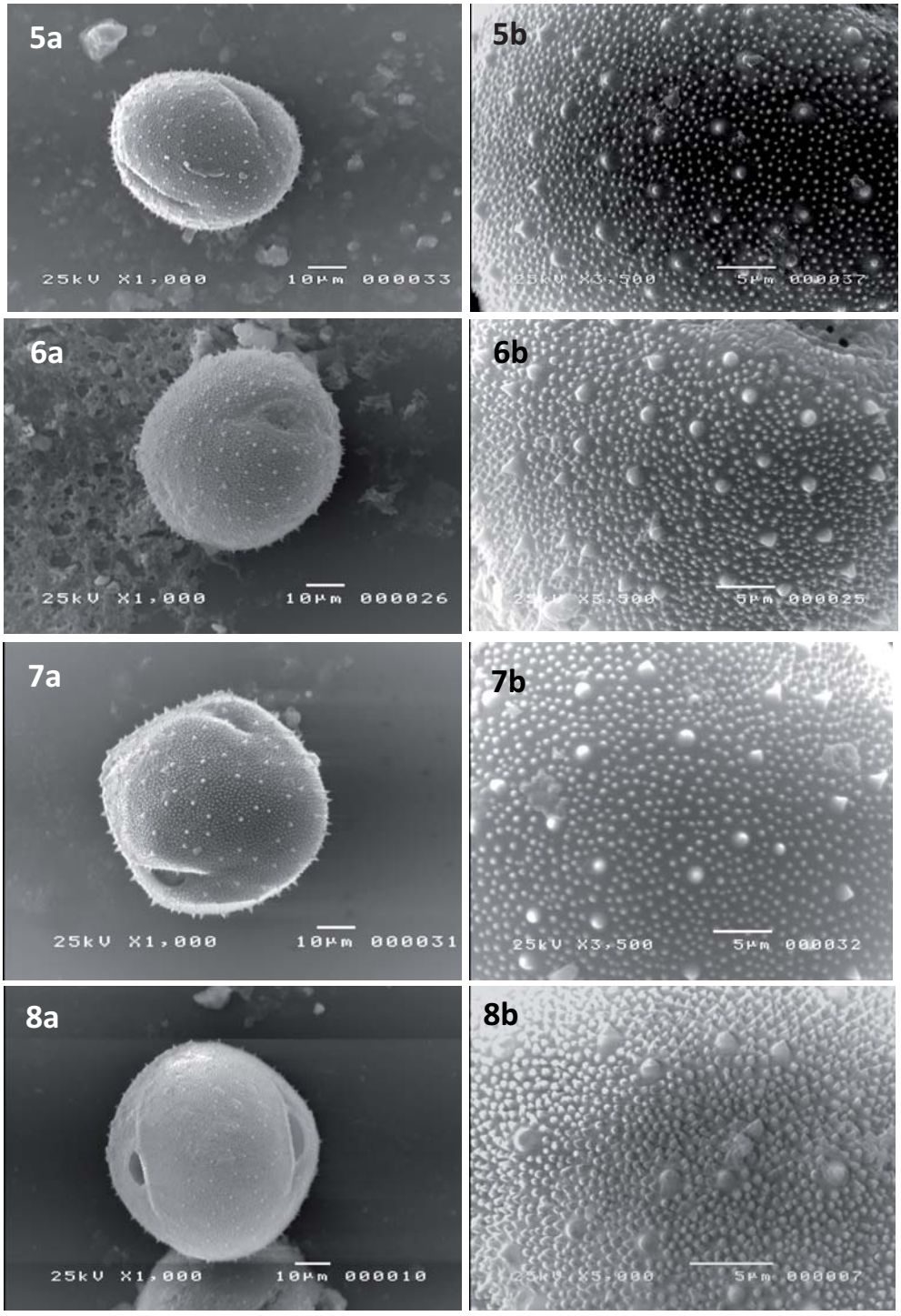

PLATE II

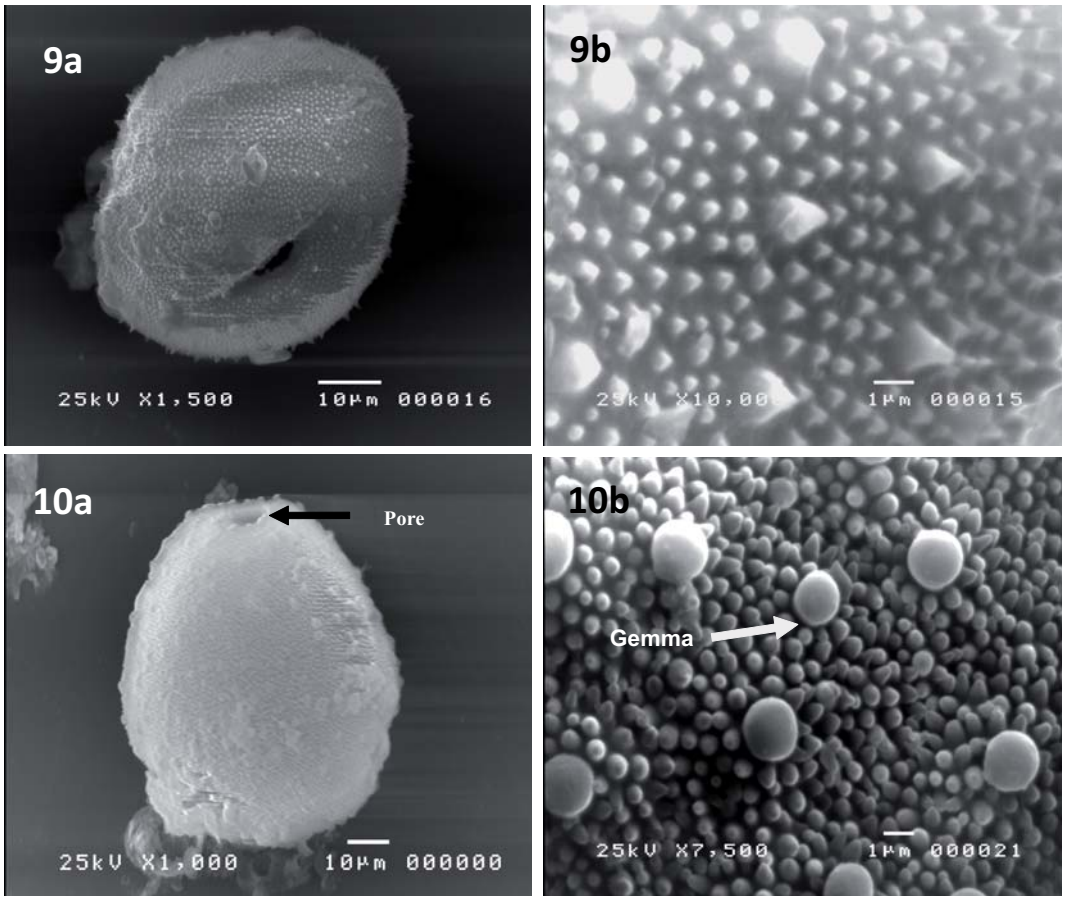

PLATE III

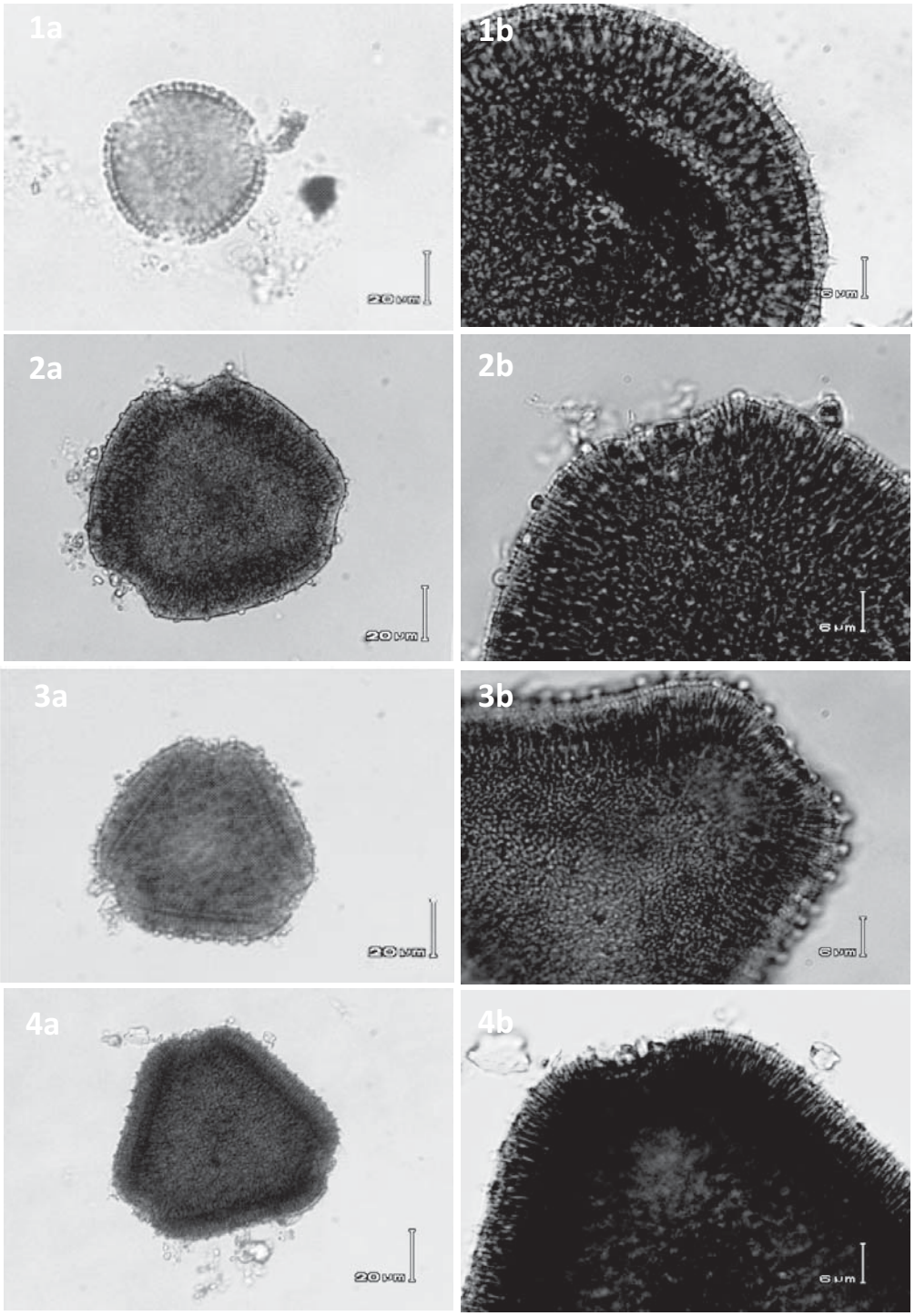

PLATE IV

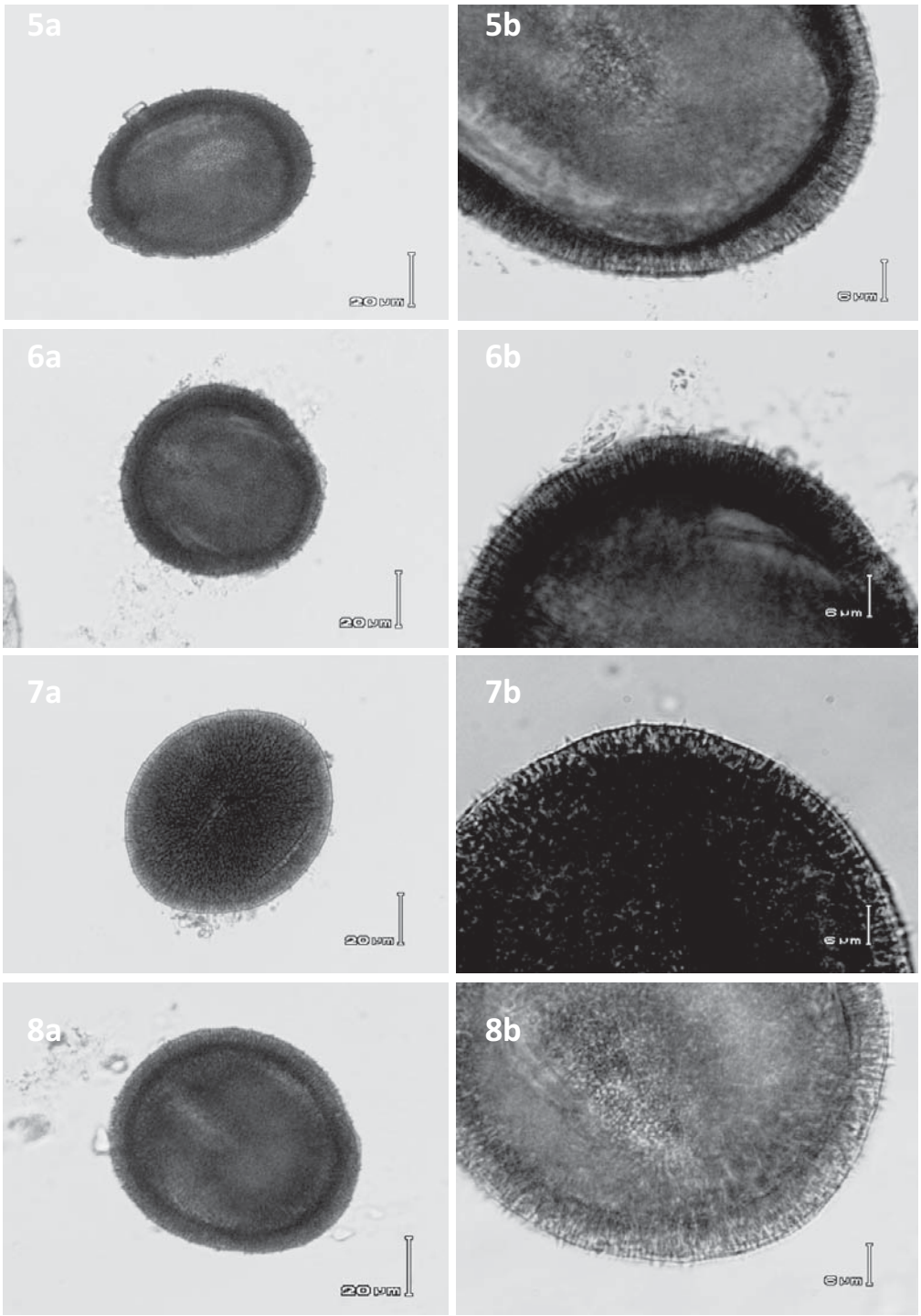

PLATE V

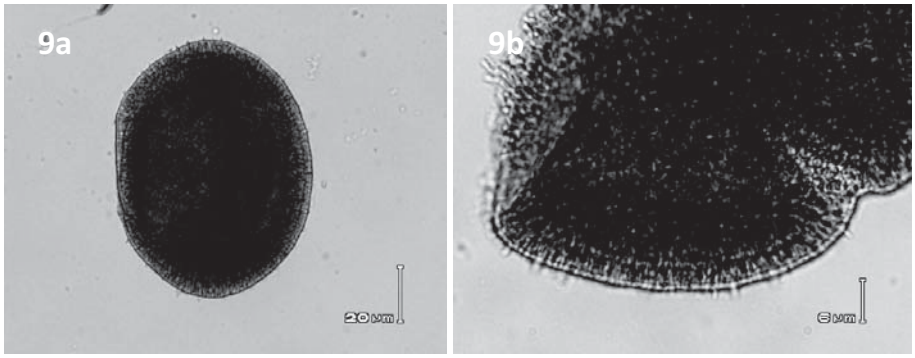

PLATE VI

