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A CONTRIBUTION TO THE PALYNOLOGICAL STUDIES OF THE ENDEMIC FLORA OF SINAI, EGYPT

Azza A. Shehata, Wafaa M. Kamel

A.A. Shehata, Department of Botany, Faculty of Science, Alexandria University, Alexandria, Egypt, e-mail: dr_azzashehata@yahoo.com
W.M. Kamel, Department of Botany, Faculty of Science, Suez Canal University, Egypt

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ABSTRACT. The morphology of pollen grains of 12 endemic and near endemic species related to nine families and 12 genera collected from Sinai, Egypt were studied using light and scanning electron microscopy. The pollen grains exhibit a wide range of morphological characters. Their size, mean length of polar (P) and equatorial (E) axis are in the range 8.2-49.1 μm and 6.7-24.6 μm. They are distributed among five shape classes. Nearly all studied species except *Plantago sinica* and *Bufonia multiceps* have isopolar and radially symmetrical pollen grains. The equatorial outline varies from elliptic to wide elliptic while the amb varies from rounded, triangular to oval outline. Pollen grains of *Anarrhinum pubescens*, *Brassica deserti*, *Hypericum sinaicum*, *Ballota kaiseri* and *Phlomis aurea* are tricolpate with either reticulate or micro reticulate surface sculpture. *Primula boveana* and *Zygophyllum dumosum* have tricolporate grains and micro reticulate exine pattern. *Nepeta septemcrenata* has grains with six colpi and reticulate exine pattern. Pollen grains of *Plantago sinica* are pantoporate, scabrate and undulate. Polyzonocolporate (20 colpi) with psilate exine surface are met with *Polygala sinaica*. The present study is a modest contribution to previous studies on the endemic flora of the Sinai Peninsula.

KEY WORDS: endemic, flora, pollen morphology, SEM, Sinai

INTRODUCTION

Endemic taxa are usually rare and restricted to rather small geographical regions, so they deserve special attention for their conservation. They represent an important part of our heritage and may provide us with important food, medicinal or other resources in the future. In general, the percentage of endemic species is highest in insular floras (Carlquist 1974), Peninsulas and mountain chains (Strid 1986). The Sinai endemic vegetation is not evenly distributed. The great majority of plant taxa being in its southern mountainous region; about 53% of the endemic Egyptian species are recorded there (Boulos 1997). Thus, the southern part of Sinai represents a great pool of endemism. Moreover, the Sinai Peninsula consists of sandy desert in the north and rugged mountains in the south, with summits looming more than 2100 m (7000 ft) above the Red Sea. Due to the aforementioned facts; the Sinai Peninsula is one of Egypt's most floristically diverse and phytogeographically interesting regions.

From a phytogeographical point of view, the importance of the Sinai Peninsula has been documented. Being the meeting point of Asia and Africa, its flora combines elements from these two continents, Saharo-Arabian, Irano-Turanian, Mediterranean and Sudanian elements (Danin and Plitmann 1987). In the meantime, Sinai is separated from the phytogeographical regions of Egypt proper by an effective barrier, the Gulf of Suez, and has a special flora of its own (Migahid et al. 1959).

The study of the floristic biodiversity of Sinai was overlooked for many decades due to the fact that the peninsula was for most of the twentieth century era, a more or less closed military zone. Little attention has been paid to the endemic flora of Sinai, most of the studies focused on their identification, biodiversity and gross morphology (El Hadidi 1989, Danin 1993, Ayyad et al. 2000, Moustafa et al. 2002, and others). In the meantime, a very few studies dealt with micro morphological criteria as leaf surface, seed and pollen morphology (El-Naggar and Abdel Hafez 2003). However, these studies included only a small portion of Sinai endemics.

Pollen morphology is an exciting tool for the solutions of problems concerned with the history of our vegetation and evolution of our contemporary environment. Moreover, it has a considerable systematic value at various taxonomic levels (Sivarajan 1980, Blackmore 1981 and others). Some authors as Henrickson (1973), Janssen et al. (1976) and Maguire (1981) pointed to the value of inclusions the palynological data in the floras.

The present study was undertaken to provide a comprehensive account of the pollen morphology of some species endemic to Sinai, Egypt and it was also an attempt to make a preliminary contribution to the previous and further studies on the flora of Sinai.

MATERIAL AND METHODS

Pollen samples of each studied species were collected from herbarium specimens kept in the herbarium of Suez Canal University (Table 1). Identification and plant named followed Täckholm (1974) and Boulos (1999, 2000, 2002). Pollen grains were examined by Light Microscopy (LM) and Scanning Electron Microscopy (SEM). For LM studies, pollen grains were acetolyzed according to Erdtman (1960). For SEM investigation, dried pollen grains were sputtered onto cleaned stubs, coated with gold then examined and imaged with JEOL JSM 5300 SEM which is operated at accelerated voltage of 15 and 25 KV at the Electron Microscopy Unit, Faculty of Science, Alexandria University. The measurements are usually based on at least 20 fully developed grains per specimen. Pollen size was described according to Erdtman (1952). The terminology used here for pollen description followed Erdtman (1952) and Punt et al. (1994).

RESULTS

Table 2 summarized the main palynological features of the studied taxa.

Pollen morphological characters:

1. *Anarrhinum pubescens* Fresen. (Plate I, Figs 1, 2)

Pollen grains are isopolar, radially symmetrical, prolate, tricolpate and small in size. Elliptic in equatorial view; rounded triangular in polar view, the amb is convex and triangulaperturate. Polar axis (P) – 19.4 µm, equatorial axis (E) – 11.52 µm, P/E ratio – 1.68. Colpi 15.7

Table 1. The collection data of the investigated species and their habitat

No.	Species	Family	Localities and collectors	Date of collection	Habitat
1	*Anarrhinum pubescens* Fresen.	Scrophulariceae	Saint Catherine area, West El--Arbaie'en, near Gebel Musa; W. Kamel	28.04.1994	crevices of smooth-faced granite and near springs in rock type
2	*Ballota kaiseri* Täckh.	Labiatae	Saint Catherine area, West El-Arbaie'en, Kahf El-Ghola; S. Zaghloul	4.06.1997	large outcrops of smooth--faced rocks
3	*Brassica deserti* Danin & Hedge	Cruciferae	North Sinai, El-Arish; R. Abdel-Wahab	2.02.2005	chalky slops and wadis
4	*Bufonia multiceps* Decne.	Caryophyllaceae	Saint Catherine area, West El-Fara'a; W. Kamel	4.05.2004	steppes on stony and rocky slops and crevices of rock outcrops
5	*Hypericum sinaicum* Boiss.	Guttiferae	El-Arish, Hagar El-Bardi; Gamal El-Din	28.04.1991	crevices of smooth-faced granite and near fresh water springs
6	*Nepeta septemcrenata* Benth.*	Labiatae	Saint Catherine area, West El-Arbaie'en; W. Kamel	3.05.2004	crevices of smooth-faced outcrops of hard granite and metamorphic rocks, at the foot of such rocks and in wadis draining smooth rocks
7	*Phagnalon nitidum* Fresen.	Compositae	Saint Catherine area, West El-Deir; W. Kamel	3.05.2004	crevices of smooth-faced outcrops of hard rocks
8	*Phlomis aurea* Decne.	Labiatae	Saint Catherine area, West El--Arbaie'en; A. Moustafa	3.05.2004	crevices of smooth-faced outcrops of hard granite and metamorphic rocks, at the foot of such rocks and in wadis draining smooth rocks
9	*Plantago sinaica* (Barn.) Decne.	Plantaginaceae	Saint Catherine area, West El-Fara'a; W. Kamel	4.05.2004	crevices of smooth-faced granite and narrow wadis in these rock outcrops
10	*Polygala sinaica* Botsch.	Polygalaceae	Saint Catherine area, West Batharan; A. Moustafa	6.04.1995	crevices of smooth-faced granite hard rocks on slopes and wadis
11	*Primula boveana* Decne. ex Duby	Primulaceae	Saint Catherine area, E. slopes of J. Katherine; A. Moustafa	3.07.1988	granite rocks and little sandy areas
12	*Zygophyllum dumosum* Boiss.*	Zygophyllaceae	North Sinai, El-Arish; R. Abdel-Wahab	2.02.2005	coastal and inland saline sandy soils

* Near endemic taxa, according to Boulos (2000, 2002).

µm long with tapering ends. Sexine sculpture reticulate, muri straight and smooth. Lumina smooth vary in shape and are reduced in size at the colpus margin.

2. *Ballota kaiseri* Täckh. (Plate I, Figs 3, 4)

Pollen grains are isopolar, radially symmetrical, oblate-spheroidal, tricolpate and small in size; wide elliptic in equatorial, rounded in polar view. Polar axis (P) – 22.2 µm, equatorial diameter (E) – 22.9 µm, P/E ratio – 0.97. Colpi converge close to the polar ends, colpi 21 µm long with tapering ends. The colpus membrane is mainly endexinous material with granules of probable ecktexinous origin on the surface. Sexine sculpture is microreticulate, muri sinuous in outline. Lumina variable in shape and reduced in size along the colpi margins and apocolpia.

3. *Brassica deserti* Danin & Hedge (Plate I, Figs 5, 6)

Grains of *Brassica deserti* are isopolar, radially symmetrical, prolate, tricolpate and medium in size. The equatorial outline is elliptic, rounded and triangular in polar view. Polar axis (P) – 34.2 µm, equatorial axis – 17.36 µm, P/E ratio – 1.97. Colpi 27.36 µm long with tapering ends. Sexine sculpture reticulate, reticulum homobrochate. Muri straight 0.5 µm wide and simplibaculate. Lumina smooth, polygonal to irregular in shape.

4. *Bufonia multiceps* Decne. (Plate I, Figs 7, 8)

Pollen grains are apolar, pentagonal shape in lateral view, spheroid in optical cross section, polypantoporate. The average pollen diameter 29 µm. Pores circular, 4 µm in diameter, pore membrane beset with densely spaced granular to rounded usually pointed elements. Sexine tectate perforate, perforation densely spaced, supratectal spinules pointed, broad at base and sparsely space.

5. *Hypericum sinaicum* Boiss. (Plate II, Figs 1, 2)

Hypericum sinaicum has an isopolar, radially symmetrical, prolate, tricolpate and small in size pollen grains. The equatorial outline elliptic, rounded to triangular in polar view. Polar axis (P) – 20.5 µm, equatorial axis (E) – 10.52 µm, P/E – 1.95. Colpi 18.4 µm long with pointed to tapering ends. Sexine sculpture reticulates. Reticulum is latimurate. Lumina round in shape and reduced in size along the colpi margins.

6. *Nepeta septemcrenata* Benth. (Plate II, Figs 3, 4)

Pollen grains are isopolar, radially symmetrical, prolate, hexa colpate and medium in size. It is wide elliptic in equatorial view, rounded to oval in polar view. Polar axis (P) – 38.0 µm, equatorial axis (E) – 24.0 µm, P/E –1.58. Colpi 36.6 µm long with pointed ends, narrow, slit like, nearly reach to the poles. Sexine tectate is perforated;

TABLE 2. Summary of pollen morphological data

No.	Species	Size (µm)			Shape	Pollen class	Exine sculpture
		Mean length (range)					
		P	E	P/E			
1	*Anarrhinum pubescens* Fresen.	19.4 (18.2-21.1)	11.52 (9.8-12.5)	1.68	prolate	tricolpate	reticulate
2	*Ballota kaiseri* Täckh.	22.2 (20.2-25.3)	22.9 (20.5-26.2)	0.97	oblate-spheroidal	tricolpate	microreticulate
3	*Brassica deserti* Danin & Hedge	34.2 (30-38)	17.36 (16-19)	1.96	prolate	tricolpate	reticulate
4	*Bufonia multiceps* Decne.	–	–	–	pentagonal	polypantoporate	perforate
5	*Hypericum sinaicum* Boiss.	20.5 (18.6-23)	10.52 (9.2-12)	1.95	prolate	tricolpate	reticulate
6	*Nepeta septemcrenata* Benth.	38.0 (35-41)	24.0 (21-27)	1.58	prolate	hexacolpate	reticulate
7	*Phagnalon nitidum* Fresen.	29.3 (27-31)	21.33 (19-23)	1.37	prolate	tricolporate	spinose, perforate
8	*Phlomis aurea* Decne.	49.1 (44.2-54.1)	24.6 (21.1-28.2)	1.99	prolate	tricolpate	microreticulate
9	*Plantago sinaica* (Barn.) Decne.	–	–	–	spheroidal	porate	scabrate, undulate
10	*Polygala sinaica* Botsch.	33.3 (29-36)	22.0 (17-26)	1.66	prolate	polyzonocolporate	psilate
11	*Primula boveana* Decne. ex Duby.	8.2 (7.5-10)	6.73 (6.0-8.0)	1.21	subprolate	tricolporate	microreticulate
12	*Zygophyllum dumosum* Boiss.	10.29 (9.1-12.3)	7.25 (6.0-9.2)	1.4	prolate	tricolporate	microreticulate

P – polar axis.
E – equatorial axis.

PLATE I

Scanning Electron Micrographs showing pollen grains in overall view and surface detail

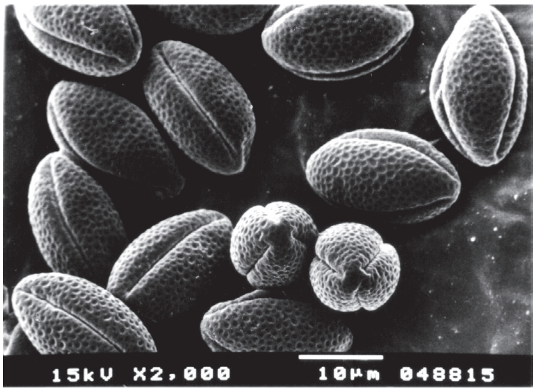

Fig. 1. *Anarrhinum pubescens*, polar and equatorial view

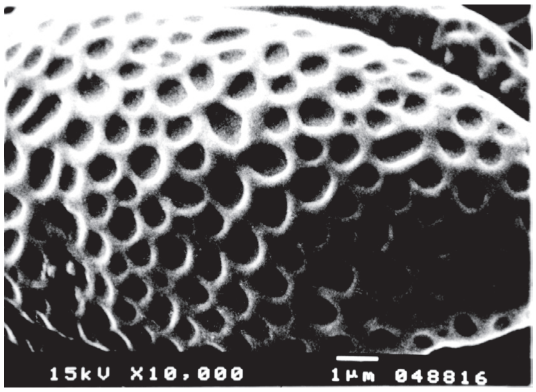

Fig. 2. *Anarrhinum pubescens*, magnified part of exine

Fig. 3. *Ballota kaiseri,* equatorial view

Fig. 4. *Ballota kaiseri,* polar view

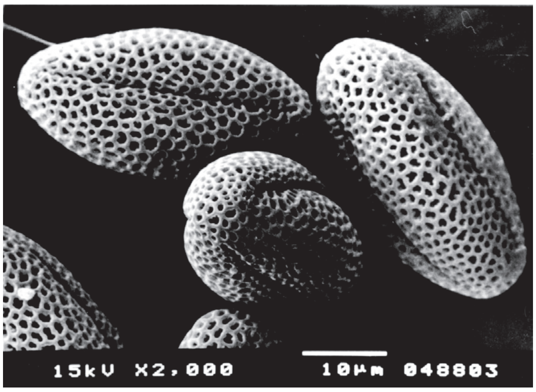

Fig. 5. *Brassica deserti*, polar and equatorial view

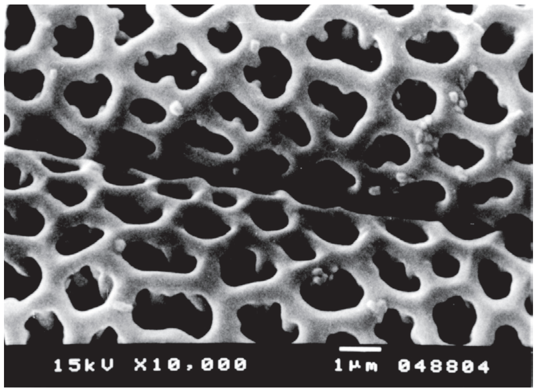

Fig. 6. *Brassica deserti*, magnified part of exine

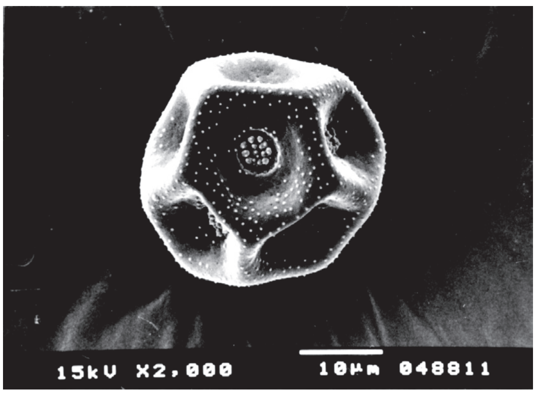

Fig. 7. *Bufonia multiceps*, overall view

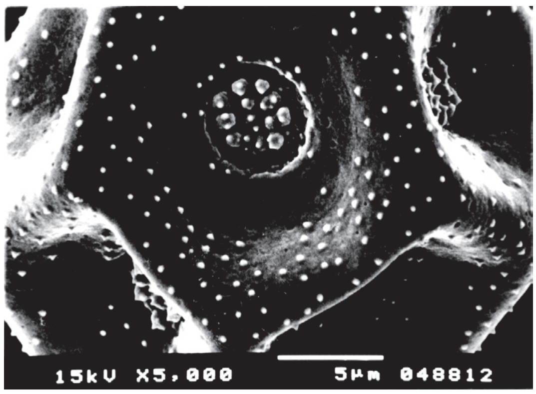

Fig. 8. *Bufonia multiceps*, magnified part of exine

perforation varying in size and shape. Supratectal sculpture reticulates. Reticulum angustimurate. Muri straight and smooth Lumina of varying shapes and sizes.

7. *Phagnalon nitidum* Fresen. (Plate II, Figs 5, 6)

Phagnalon nitidum has isopolar, radially symmetrical, prolate, tricolporate and medium in size pollen grains. Polar axis (P) – 29.3 μm, equatorial diameter (E) – 21.33 μm, P/E ratio – 1.37. Colpi 24.6 μm long with tapered ends. Ora lolongate with ovate-elliptic shape (6.6 × 2.6 μm). Sexine sculpture, spinose, densely perforated. Spines 4.0 μm long with tapering ends and wide bases, the bases perforate.

8. *Phlomis aurea* Decne. (Plate II, Figs 7, 8)

Pollen grains are isopolar, radially symmetrical, prolate, tricolpate and medium in size; elliptic in equatorial view, rounded in polar view. Polar axis (P) – 49.1 μm, equatorial diameter (E) – 24.6 μm, P/E ratio – 1.99. Colpi converge to the polar ends, colpi 46.6 μm long with tapering ends. Sexine sculpture microreticulates. Muri smooth and sinuous. Lumina differ in shape and reduced in size along the colpi margins and apocolpia, the bottom of lumina is perforated, perforation minute and densely spaced.

9. *Plantago sinaica* (Barn.) Decne. (Plate III, Fig. 1)

Pollen grains are apolar, usually isodiametric (spheroidal), the average diameter 31 μm, porate, provided with few pores (4-6). Pores are evenly distributed over the pollen surface, faintly delimited and covered by a membrane flecked with granules. Pores are circular to irregularly shape. Pore diameter varies from 2 to 3 μm. Sexine surface sculpture is scabrate and undulates.

10. *Polygala sinaica* Botsch. var. *sinaica* (Plate III, Figs 2, 3)

Pollen grains are isopolar, radially symmetrical, prolate, polyzonocolporate (20 colpi) and medium in size. It is elliptic in equatorial view; circular in polar with inset colpi. Polar axis (P) – 33.3 μm, equatorial axis (E) – 22.0 μm, P/E ratio – 1.51. Colpi of unequal length (from 25.3 to 28.6 μm long); colpi ends rounded and covered with smooth operculum. Sexine divided into bands because of the polycolporate condition, surface of bands are smooth.

11. *Primula boveana* Decne. (Plate III, Fig. 4)

Grains of *Primula boveana* are isopolar, radially symmetrical, subprolate, tricolporate, and small in size. Polar axis (P) – 8.2 μm, equatorial axis (E) – 6.73 μm, P/E ratio – 1.21. Colpi 7.2 μm long with tapering ends, ora lolongate, outline irregular. Membrane beset with granules. Sexine sculpture microreticulate. Muri straight, lumina are reduced in size at the colpi margins and apocolpia.

12. *Zygophyllum dumosum* Boiss. (Plate III, Figs 5, 6)

Pollen grains are isopolar, radially symmetrical, prolate, syncolporate and small in size. It is elliptic in equatorial view, rounded to triangular in polar view. Polar axis (P) – 10.29 μm, equatorial diameter (E) – 7.25 μm, P/E ratio – 1.4. Colpi long 10 μm with tapering ends. Ora lolongate. Sexine sculpture, micro reticulate, reticulum homobrochate. Muri straight and smooth. Lumina are more or less polygonal in shape.

DISCUSSION AND CONCLUSION

The pollen morphology is generally considered as a good taxonomic marker (Nowicke and Skvarla 1977, 1979, Ding et al. 2005). The constant features and the sculpturing of the exine make pollen grains a highly recognizable object by which parent genera or even species may be recognized. It has also helped to solve problems of great biological interest like, the history of flora, past climates, prehistoric environments, as well as standardization of honeys and drugs (Lewis and Vinary 1983, Moore et al. 1991, Martin 2001).

The pollen morphology of endemic species world wide has been studied by some authors as: Lecuona et al. (1986) who studied the pollen morphology of 15 endemic taxa of the Macaronesica region. More recently, Premathilake and Nilsson (2001) studied the pollen morphology of 27 endemic species of the Horton plains National Park, Sri Lanka. These studies and similar ones have contributed to a great extent to our knowledge on endemism, and phylogenetical studies.

The present study, although considered as preliminary, has shown that the pollen characteristics of each taxon are highly specific and diagnostic at the generic level. However, the study did not record any significant variation at the species level in all the studied taxa apart from their counterpart species in the Mediterranean region and worldwide, that was recorded in previous studies (Al Wadi and Richards 1992, Ayyad et al. 1992, El-Ghazaly and Anderbergl 1995, El-Naggar and Abdel Hafez 2003, and several others). Thus rendering the pollen morphology criterion a highly stable one, and so its significance as a good taxonomic marker in both identification and classification was reassessed.

The aforementioned findings can be deduced from the present survey by citing the following examples:

1. According to Erdtman et al. (1961), the Scrophulariaceae is considered as a more or less stenopalynous family. In the present study, *Anarrhinum pubescens* is prolate, tricolpate with reticulate exine sculpture in accordance of those of Karim and El-Oqlah (1989) who described the pollen morphology of some *Anarrhinum* species among other taxa of Scrophulariaceae.

2. *Brassica deserti* is characterized by prolate, tricolpate pollen grains with reticulate exine sculpture. The present result is in agreement with El-Naggar (1988) who studied the pollen morphology of *Brassica deserti* among other species belonging to the tribe Brassiceae.

3. *Bufonia multiceps* has more or less spheroidal polypantoporate pollen grains, pores without distinct annulus, membrane flecked with dense granules. These porate pollen grains are similar to a large extent to those of Plantaginaceae; this result is in agreement with El-Ghazaly (1991) who pointed to the similarity of the pollen grains morphology between members of Plantaginaceae and Caryophyllaceae.

4. The pollen morphology of Labiatae has been emphasized by several authors (Varghese and Verma 1968, Irene et al. 1994 and Akyalcin 2003). It is regarded as a eurypalynous family; their species showed a great array of pollen types exhibiting differences in apertures and exine structure. Their number of apertures ranged from three to six colpi, while exine surface showed reticulate

PLATE II

Scanning Electron Micrographs showing pollen grains in overall view and surface detail

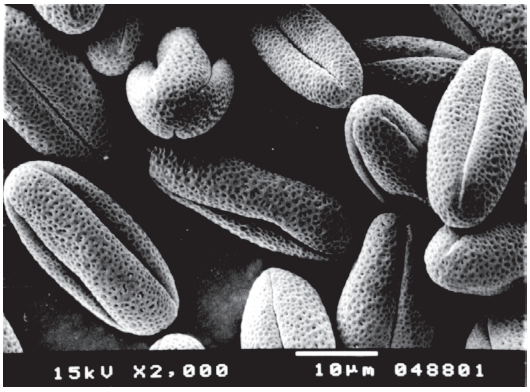

FIG. 1. *Hypericum sinaicum,* polar and equatorial view

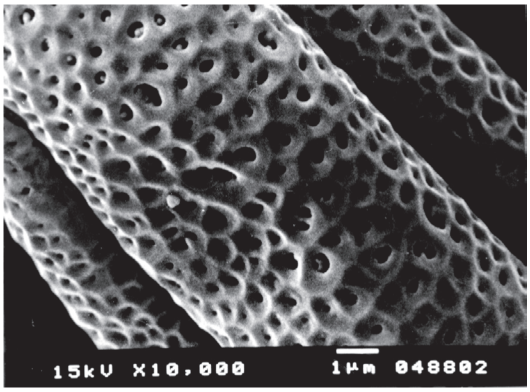

FIG. 2. *Hypericum sinaicum,* magnified part of exine

FIG. 3. *Nepeta septemcrenata,* polar and equatorial view

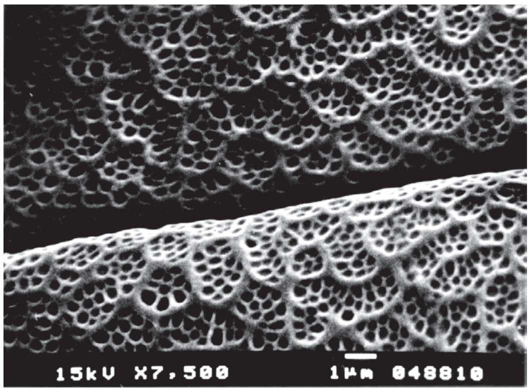

FIG. 4. *Nepeta septemcrenata,* magnified part of exine

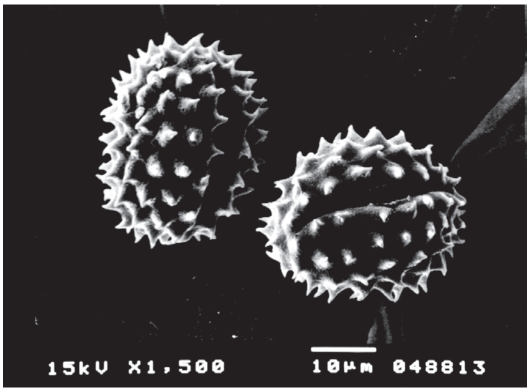

FIG. 5. *Phagnalon nitidum,* equatorial view

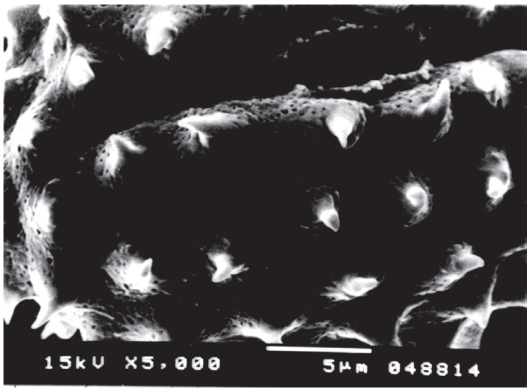

FIG. 6. *Phagnalon nitidum,* magnified part of exine

FIG. 7. *Phlomis aurea,* equatorial view

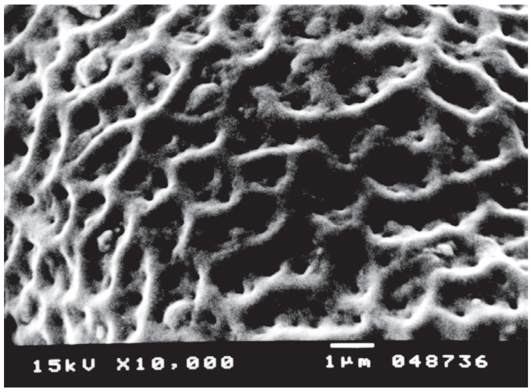

FIG. 8. *Phlomis aurea,* magnified part of exine

PLATE III

Scanning Electron Micrographs showing pollen grains in overall view and surface detail

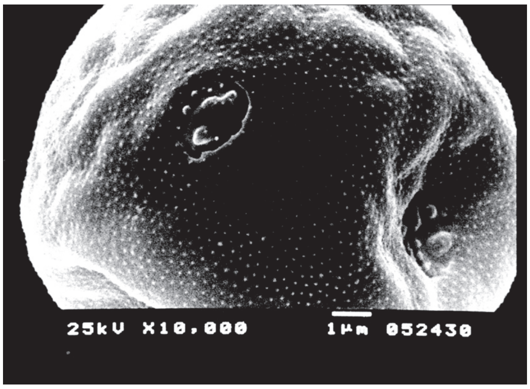

Fig. 1. *Plantago sinaica*, magnified part of exine with pores

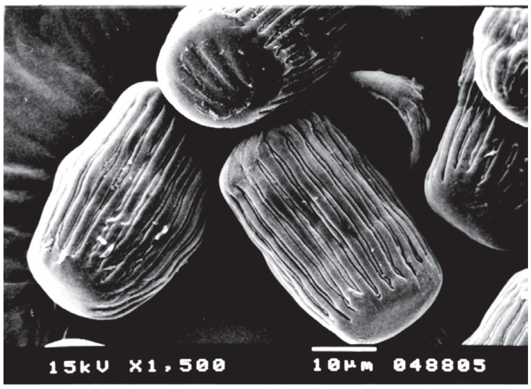

Fig. 2. *Polygala sinaica*, polar and equatorial view

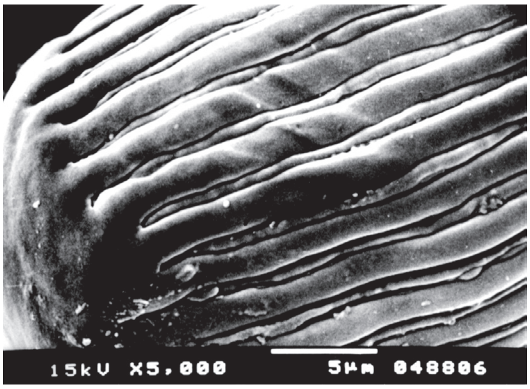

Fig. 3. *Polygala sinaica*, magnified part of exine

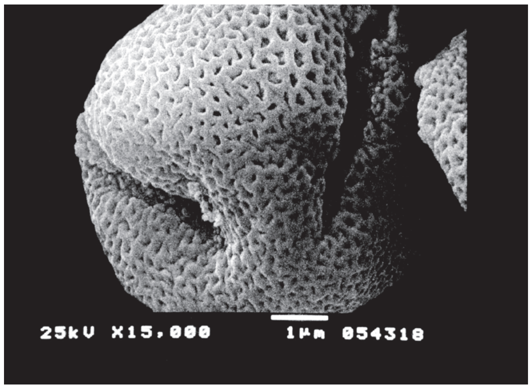

Fig. 4. *Primula boveana*, polar view

Fig. 5. *Zygophyllum dumosum*, polar and equatorial view

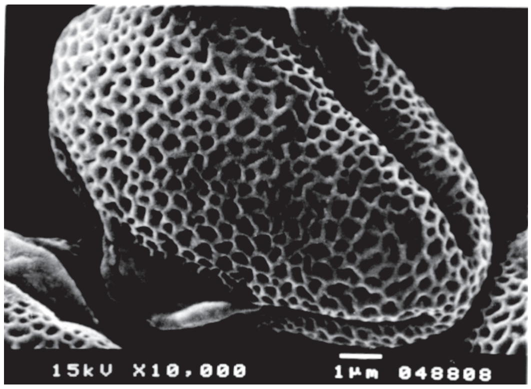

Fig. 6. *Zygophyllum dumosum*, magnified part of exine

to micro reticulate pattern. Based on the present study, *Ballota kaiseri* and *Phlomis aurea* have tricolpate pollen grains with micro reticulate exine ornamentation. Whereas, *Nepeta septemcrenata* showed hexacolpate grains with reticulate surface pattern.

5. Pollen grains of *Plantago sinica* are spheroid with a few pores, covered by membranes flecked with granules. The exine sculpture is scabrate to undulate; this result in accordance to previous work by Saad (1986), who studied the above species among others of *Plantago*.

6. One of the most notable elements of the Polygalaceae is the typical polyzonocolporate pollen grains (Pavia and Santos Dias 1990). Out of the present study; *Polygala sinaicum* has polyzonocolporate grains with psilate exine surface.

As a conclusion, this preliminary survey on pollen morphology of endemic taxa of Sinai may help in throwing more light on these taxa, thus encouraging further studies, utilizing other criteria. Moreover, it may contribute to some extent to previous and future studies on the flora of Sinai.

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