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Pollen and Seed Morphology of Some Endemic Taxa in Saint Catherine, Sinai, Egypt

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Abstract

Macro- and micro-morphological features of seeds and pollen grains of 12 endemic taxa belonging to seven families collected from Saint Catherine area, South Sinai, Egypt were examined by light microscope (LM) and scanning electron microscope (SEM). Macro- and micro-morphological characters, of seeds including shape, colour, size, brightness, seed surface, epidermal cell shape, anticlinal boundaries, and periclinal cell wall are presented. Pollen description includes shape, size, apertures and exine ornamentation. This study presents. Seeds of eight taxa and pollen of three taxa have been described for the first time in this study.

Key words: Endemics, Pollen, Seed morphology, Sinai, Saint Catherine

Introduction

Sinai Peninsula is located on the boundaries of Asia and Africa and comprises an area of about 61000 km^2 or 6.1% of the surface of Egypt. Contribution to the flora of Sinai have been reviewed by many authors (Abdallah *et al.* 1984, Ayyad *et al*. 2000; El Hadidi 1989, Danin *et al*. 1985, Danin 1986; El Hadidi *et al.* 1970; Kamel *et al.* 2002; Täckholm 1932 & 1969).

Saint Catherine area encloses most of the mountainous area of South Sinai, occupies about 4350 km^2, including the country's highest mountain, Mount Catherine (2641m, asl) which was declared as protected area in 1988. The geomorphological features of mountainous southern Sinai provide ideal conditions for the endemic species (El Hadidi & Hosni, 2000); most of these species extend to a very small area, so they are under the threat of extinction by both natural and human factors (Omar 2014).

According to Danin (1986), there are 28 endemic species in Sinai, of which 25 occur in the mountainous district of Sinai. El Hadidi & Fayed (1994/95) recorded 27 species endemic to S Sinai, while El Hadidi & Hosni (2000) recorded 30 endemic taxa from Sinai, of these 20 taxa are restricted to mountainous area of southern Sinai. Boulos (2009) recorded 29 taxa from Sinai, of which 22 are restricted to S Sinai. Recently Hosni *et al*. (2013) recorded 38 taxa endemic to Sinai, of which 14 are confined to St. Catherine area. However, until now, no comprehensive survey of seeds and pollen of endemic taxa in Sinai have been carried out. Most studies on endemic flora focused mainly on their morphological identification, biodiversity, growth morphology and conservation (Ayyad *et al.* 2000; Danin 1983, 1986; Cairo University Herbarium staff 1989; Abd El-Wahab *et al.* 2006; Hosni *et al*. 2013; Omar 2014; Kamel *et al.* 2002). To the best of our knowledge, there is no previous complete data available on seed and pollen morphology of endemic taxa in Saint Catherine. Pollen grains of some endemic species in Sinai have been a subject of study by some authors either in the context of the endemic flora of the country (Shehata & Kamel 2007; Ibrahim 2015; El Gamal 2017) or as a taxon within special group (Shehata & Loutfy 2006). Whereas, few studies on seed coat of endemics have been done within the revision of some other taxa (Kamel 2003, Hosny & Zareh 1992/93). It has been shown

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that macro- and micmorphological characters of seeds and pollen are useful and significant for the delimitation of species and genera in many groups of flowering plants (Shehata & Loutfy 2006; Banks *et al.* 2008; Shamso & Toshiyuki 2012; Jagodziński *et al.* 2016; Bazarragchaa *et al.* 2012). The aim of this study was to provide seed and palynological information about some of the endemic taxa of Saint Catherine area; the description of the seed and pollen characteristics may be helpful for identification of these taxa.

Materials and Methods

The present study was based on fresh materials as well as Herbarium specimens kept in Cairo University Herbarium (CAI) and Al Azhar University Herbarium. For plant specimen's collection, field trips in different regions of Saint Catherine Protected area have been made in 2016. The identification of the specimens was confirmed by using keys in the available references (Täckholm, 1974, Boulos 1999-2002), and comparing them with specimens housed at the herbarium of Cairo University; affiliation of taxa to families followed the approach of the Angiosperm Phylogeny Group (Stevens 2001 onwards, APG IV 2016); taxonomic concept for species, subspecies or varieties followed Boulos (2009). The specimens are deposited at Cairo University Herbarium (CAI) and Al Azhar University Herbarium; list of the material studied, with relevant information are shown in Table 1.

For Light Microscopy (LM) specimens were examined under a stereo- microscope, for measurements and calibration stage micrometer was used as well as image J software. Photographs were taken with Premiere MA88-900 digital camera. For scanning electron microscopy (SEM), dry seeds and acetolyzed pollen grains were mounted on stubs using double-sided adhesive tape, then coated with Nano gold then examined and photographed with JIOL JSM SEM at the Electron Microscope unit at The Regional Center for Mycology and Biotechnology, Al Azhar university, Cairo, Egypt.

For seed study: Studied seeds were either collected in the field or obtained from herbarium specimens; at least 3 to 4 mature seeds were examined to analyze morphological variation (shape, size, brightness, hilum position and testa ornamentation). The main features of seeds were summarized in Tables (2 & 3); LM and SEM photographs for each taxon, showing seed character variation were given in (Plates I & II). The terminology used followed Barthlott (1981 & 1990) and Stearn (1992).

For pollen grain study: Pollen material was obtained from flowers at full flowering stage; at least 10 – 15 pollen grains from three- five specimens of each taxon (if available) were selected to cover the range of variation; and were prepared for SEM microscopy according to the technique of Erdtman (1952). For pollen grains characteristics include shape, polarity, measurements and exine ornamentation were given in Table (4); SEM micrographs of pollen were given in Plate (III). The terminology was adopted from Punt *et al.* (2007) and Hesse *et al*. (2009).

Results and Discussion

Twelve taxa belonging to seven families were included in this study collected from Saint Catherine Protected area, S Sinai (Table 1). Seeds of eight taxa and pollen of three taxa had been described for the first time in this study.

***Seed Characters*:**

Morphological characters of examined taxa were given (Table 2), and the photographed obtained were shown in (Plate I). The photographs of the seeds obtained from SEM were analyzed and testa characteristics shown in Table 3 and Plate II.

Table 1: List of the studied taxa and their locations

NO.	Taxa	Family	Location
1	***Anarrhinum pubescens*** Fresen.	**Plantaginaceae s.l.**	Wadi Al Talah , 1/5/2016; *A. M. Sadek* (Al Azhar Univ.) - Wadi Meserdy 4/5/2016; *A. M. Sadek*. (CAI, Al Azhar Univ.)
2	***Bufonia multiceps*** Decne**.**	**Caryophyllaceae**	Wadi Al Ferah 30/4/2016; *A. M. Sadek* (Al Azhar Univ.) Wadi Al Arbiaen 30/4/2016, *A. M. Sadek* (Al Azhar Univ.) – Ain Shekia 2/5/2016; *A. M. Sadek* (CAI, Al Azhar Univ.)
3	***Euphorbia obovata*** Decne.	**Euphorbiaceae**	Wadi Talah 1/5/2016; *A. M. Sadek* (Al Azhar Univ.) - Ain Shekia 2/5/2016*; A. M. Sadek* (CAI), Al Azhar Univ.) – Wadi Taboq 3/5/2016; *A. M. Sadek* (Al Azhar Univ.)
4	***Origanum syriacum*** L. subsp**.** ***sinaicum*** (Boiss.) Greuter & Burdet	**Lamiaceae**	Shag El Gragenia, 29/4/2016; *A. M. Sadek* (CAI, Al Azhar Univ.) - Wadi Al Ferah, 30/4/2016; *A.M. Sadek* (Al Azhar Univ.) Shag Mus,a 30/4/2106; *A. M. Sadek* (Al Azhar Univ.)
5	***Phlomis aurea*** Decne.	**Lamiaceae**	Shag Musa, 30/4/2106; *A. M. Sadek* (CAI, Al Azhar Univ.)- Shag El Gragenia 29/4/2016; *A. M. Sadek* (CAI, Al Azhar Univ.); Wadi Al Ferah, 30/4/2016*; A. M. Sadek* (Al Azhar Univ.)
6	***Plantago sinaica*** Decne.	**Plantaginaceae**	Wadi Al Ferah (N: 28.54440 E: 33.96410), 30/4/2016; *A.M. Sadek* (Al Azhar Univ.) - Wadi Al Arbiaen, 30/4/2016, *A. M. Sadek* (Al Azhar Univ.) – Ain Shekia, 2/5/2016, *A. M.. Sadek* (Al Azhar Univ.)
7	***Polygala sinaica*** Botsch. var. ***sinaica***	**Polygalaceae**	Hamatet Abada, 29/4/2016; *A. M. Sadek* (Al Azhar Univ.) -Shag Musa, 30/4/2106; *A. M. Sadek* (Al Azhar Univ.)
8	***Primula boveana*** Decne. ex Duby	**Primulaceae**	Shag Musa , 30/4/2106*; A. M. Sadek* (Al Azhar Univ.)
9	***Rosa arabica*** Crép.	**Rosaceae**	Shag Musa , 30/4/2106*; A. Sadek* (Al Azhar Univ.)- Wadi Talah, 1/5/2016; *A. M. Sadek* (Al Azhar Univ.)
10	***Silene leucophylla*** Boiss.	**Caryophyllaceae**	Wadi Meserdy, 4/5/2016, *A. M. Sadek*; (Al Azhar Univ.)- Ain Shekia , 2/5/2016, *A. M. Sadek* (Al Azhar Univ.) – Wadi Abo Kasaba 5/5/2016, *A. M. Sadek* (Al Azhar Univ.)
11	***Silene oreosinaica*** Chowdhuri	**Caryophyllaceae**	Shag Musa 30/4/2106; *A. M. Sadek*.(Al Azhar Univ.) – Ain-Shinar, Gebal Catherine, Sinai, 9/10/1983, *A.Hosny* (CAI)
12	***Silene schimperiana*** Boiss.	**Caryophyllaceae**	Shag Musa , 30/4/2106; A. M. Sadek (Al Azhar niv.)- Wadi Al Arbiaen 30/4/2016, *A. M. Sadek* (CAI, Al Azhar Univ.)

Hosny & Zareh (1992/93) studied the seed morphology of *Silene* species native to Egypt including two of the present studied taxa: *Silene oreosinaica* and *S. schimperiana*, while El Gamal (2017) described seed and pollen of *Silene* species of Saint Catherine area. Kamel (2003) and Shehata & Loutfy (2006) studied the micromorphology of the seed coat in Plantaginaceae from Egypt including *Plantago sinaica*. However, until now, there has been no morphological study of seed of the following taxa: *Anarrhinum pubescens* (Plantaginaceae s.l.), *Bufonia multiceps* (Caryophyllaceae), *Euphorbia obovata* (Euphorbiaceae), *Origanum syriacum* subsp. *sinaicum*, *Phlomis aurea* (Lamiaceae), *Rosa arabica* (Rosaceae), *Polygala sinaica var. sinaica* (Polygalaceae) and *Primula boveana* (Primulaceae).

In the present study the largest seeds have been measured in *Phlomis aurea* (5 - 7 × 1.5 – 3 mm), and the smallest seed in *Primula boveana* (0.7 - 1.2 × 0.4 - 1.2 mm). This study demonstrated the high diversity of seed morphology in terms of seed shape, colour, hilum character, seed coat ornamentation and epidermal cell characters. Most of the studied taxa can be distinguished by their shapes which show considerable variation, it was irregularly cuboid in *Primula boveana* (Plate I, Figure 8) or ellipsoid-trigonous with rounded end and short projection *in Phlomis aurea* (Plates I, Figure 5), to reniform or ellipsoid in the studied taxa of Caryophyllaceae (Plate I, Figures 2,10,11,12). However, the most fascinating shape was observed in *Plantago sinaica* (Plate I, figure 6) being cymbiform. The colour of seeds ranged from dark or light brown to yellow in *Origanum syriacum* subsp. *sinaicum* (Plate I, Figure 4). However, black seeds were observed in *Polygala sinaica* var. *sinaica* in addition to the presence of areol and long soft hairs (Plate I, figure 7). Seed coat surface shows great variation among the studied taxa; it varies from reticulate, tuberculate, colliculate, ruminate or striate. However, some taxa have a quite distinct seed surface; it was ruminate in *Origanum syriacum* subsp. *sinaicum* (Plate II, Figure 4b) and lineolate in *Plantago sinaica* (Plate II, Figure 6b). *Euphorbia* is well known as a genus with a great diversity of seed characters with several different kinds of seed ornaments and the presence or absence of caruncles in the genus are important characters that are widely used to delimit species and sections within the genus (da Silva *et al*. 2016, Pahlevani *et al*. 2015). In the present study, seeds of *Euphorbia obovata* were described for the first time. However, the characteristics of seeds of *Euphorbia obovata* followed the general characters of the genus *Euphorbia* section *Helioscopia* described by Pahlevani *et al*. 2015, namely: broadly oblong to ellipsoid seeds, dorsal face slightly concave with longitudinal furrow transversely grooved,

ecarunculate (Plate I, Figure 3; Plate II, Figure 3a, b). Hong *et al.* (1999), Yildiz (2002) and Dadandi & Yildiz (2015) pointed out that the identification of *Silene* species based on morphological characters may be difficult, especially when they show great variation. Seed macro- and/or micromorphology is an alternative or additional tool to delimit taxa are of great diagnostic and systematic value and sometimes the seed characters alone are satisfactory. Caryophyllaceae was represented in this study by 4 species viz.: *Bufonia multiceps, Silene leucophylla, S.oreosinaica* and *S. schimperiana;* the last three species were studied among other species of *Silene* in Egypt (Zareh & Hosny 1992/93, Ibrahim 2017). To the best of our knowledge no studies on *Bufonia multiceps* have been done before. The seed shape of the studied taxa of Caryophyllaceae were mostly reniform, with inconspicuous ridges and slightly concave lateral faces (Plate I, Figures 10,11,12), whereas it was orbicular in *Bufonia multiceps* (Plate I, Figure 2); testa cell shape was isodiametric to elongated, parallel to each other and radiating from the center with sinuate wall. (Plate II, Figures 2, 10, 11, 12); seed coat showed wide range of variation; it was colliculate in *Bufonia multiceps*, whereas it was tuberculate in studied *Silene* species. However, S. *oreosinaica* showed isodiametric cell pattern, aculeate especially toward the periphery, with finely granulated, sinuate- stellulate periclinal wall; while in the other two species it was elongated and isodiametric cells with acutely-obtusely sinuate wall, and coarsely granulated surface.

Pollen characters

The summary and photographs were represented in (Table 4) and (Plate III, Figures 1-12). Shehata and Kamel (2007) studied pollen morphology of seven endemic and five near endemic species collected from Sinai. Their study although considered as preliminary, has shown that the pollen characteristics of each taxon are highly specific and diagnostic at the generic level. They did not took into account *Euphorbia obovata, Origanum syriacum* subsp. *sinaicum, Polygala sinaica, Rosa arabica, Silene leucophylla, S. oreosinaica* and *S. schimperiana*. Ibrahim (2015) described the pollen grains of 12 endemic species of which *Silene oreosinaica* and *Plantago sinaica* were not included in his treatment. Our findings indicate that all studied taxa share some common features, such as polarity and symmetry; they are all isopolar and radiosymmetry. Size exhibits a wide range of variation it ranged from small, to medium; main polar axis ranged from 13.16 µm in *Primula boveana* (Plate III, Figure 8a) to 33.75 µm in *Silene schimperiana* (Plate III, Figure 12a). Apertures were mostly Trizonocolporate – Trizonocolpate to Polypantoporate or Polyzonocolporate. Exine ornamentation ranged from fossulate in *Origanum syriacum.* subsp. *sinaicum*

(Plate III, Figure 4b) , psilate in *Polygala sinaica* var. *sinaica* (Plate III, Figure 7b), striate in *Rosa arabica* (Plate III, Figure 9b), microechinate in *Bufonia multiceps* (Plate III, Figure 2b) and was biretculate in *Phlomis aurea* (Plate III, Figure 5b), verrucate-granulate to reticulate, microechinate, or microreticulate in the rest of the studied taxa. According to Banks *et al.* (2008) the pollen morphology of Polygalaceae has long been recognized as distinctive, and it has been used as a valuable diagnostic character at the family level. The pollen of *Polygala sinaica* var. *sinaica* was polyzonocolporate, oblate spheroidal, with psilate surface and granulate colpal membrane (Plate III, Figure 7 a,b), which correlate with other species of *Polygala*. The shape of the studied pollen varied from prolate in *Antirrhinum pubescens* (Plate III, Figure 1a), to prolate spheroid in *Rosa arabica* (Plate III,Figure 10a) whereas the rest of the studied taxa exhibit oblate-spheroid to spheroidal grains. The characters of pollen grains are important and deciding factor for the systematic study of various genera under the family Lamiaceae. In the present study the hexazonocolpate pollen was observed in *Origanum syriacum* subsp. *sinaicum* (subfamily *Nepetoideae)* with fossulate exine (Plate III, figure 4a, b), whereas trizonocolpate was observed in *Phlomis aurea* (subfamily *Lamioideae*) with bireticulate ornamentation (Plate III,Figure 5a, b); these results coincide with that of the family Lamiaceae recorded earlier (Acylacin 2003, Bazarragchaa *et al.* 2012). In Caryophyllaceae, the number and position of apertures as well as the sculpturing pattern are found to be of taxonomic value and useful in species delimitation (Yildiz 2005). Pollen of the studied taxa of Caryophyllaceae showed superficial resemblance, they were all spheroidal and polypantoporate, exine ornamentation were mainly microechinate- microperforate, pores were circular and operculate, operculum surface was granulate - microechinate. However, the pores were distinctly sunken in *Bufonia multiceps* (Plate III, Figure 2, a) or completely prominent in the other species. The studied *Silene* speciecs can be easily distinguished by exine ornamentation being verrucate, granulate in *S. oreosinaica*, and foveolate microechinate in *S. leucophylla* while in *S.schimperiana*, exine was punctate, microechinate. Additionally, operculum surface was echinate in *S.schimperiana* and granulate in the other two taxa **(**Plate III, Figures 10, 11, 12). These finding were in accordance with pollen description of Caryophyllaceae (Ghazanfar, 1984, Yildiz 2005; Kaplan 2008; Shamso &Toshiyuki 2012; Mostafavi & Mehregan 2014).

In conclusion, the characteristic features of pollen and seeds of taxa included in this study were useful in identification and were new addition to the flora of the endemic species of Sinai, Egypt; some of these taxa have not been studied before.

Table 2: Morphological characters of the seeds of the studied taxa

No	Seeds Characters	Shape	Length × Width mm	Seed lateral face		Brightness	Color	Hilum	
	Taxa			dorsal	ventral			position	level
1	***Anarrhinum pubescens***	**narrowly ellipsoid**	**0.7 – 0.9 × 0.3 – 0.4**	**convex**	**concave**	**dull**	**Brown, dark-brown**	**sub-basal**	**Semi-depressed**
2	***Bufonia multiceps***	**orbicular**	**1.3 - 1.5 × 0.8 – 1**	**slightly concave**	**slightly concave**	**dull**	**light brown**	**median**	**depressed**
3	***Euphorbia obovata***	**oblong - ellipsoid**	**2 – 2.2 × 1.2 – 1.4**	**convex**	**slightly concave**	**dull**	**whitish brown**	**sub-basal**	**raised**
4	***Origanum syriacum L.* subsp. *sinaicum***	**broadly obovoid**	**0.8 - 1 × 0.5 – 0.6**	**convex**	**convex**	**dull or faint lustrous**	**yellow**	**basal**	**raised**
5	***Phlomis aurea***	**Ellipsoid, trigonus with Obtuse apex**	**5 - 7 × 1.5 - 3**	**flat**	**concave with central elevated ridge**	**lustrous**	**brown, whitish at apex**	**basal**	**excavate**
6	***Plantago sinaica***	**cymbiform**	**3 – 3.5 × 1 – 1.5**	**convex**	**deeply concave**	**lustrous**	**dark-brown**	**ventral**	**flat**
7	***Polygala sinaica* var. *sinaica***	**ellipsoid - oblong**	**3 – 3.5 × 0.8 - 1**	**flat**	**convex**	**shiny**	**black**	**sub-basal**	**flat with areol**
8	***Primula boveana***	**irregular cuboid**	**0.7 - 1.2 × 0.4 - 1.2**	**flat**	**flat**	**dull**	**whitish dark-brown**	**sub-basal**	**slightly raised**
9	***Rosa arabica***	**prolonged ellipsoid**	**4 × 1.5**	**convex**	**convex**	**dull or faint lustrous**	**Brown, dark - brown**	**basal**	**raised**
10	***Silene leucophylla***	**reniform**	**0.6 – 0.9 × 0.5 – 0.7**	**slightly concave**	**slightly concave**	**lustrous**	**dark-brown**	**ventral**	**depressed**
11	***Silene oreosinaica***	**orbicular - reniform**	**0.93–0.98 ×0.76-0.81**	**slightly concave**	**slightly concave**	**lustrous**	**light brown**	**ventral**	**depressed**
12	***Silene schimperiana***	**reniform**	**1 - 1.5 × 0.8 – 1**	**slightly concave**	**slightly concave**	**slightly lustrous**	**dark-brown**	**ventral**	**depressed**

Table 3: Micromorphological characters of seed coat of the studied taxa

NO.	Taxa	Surface Pattern	Epidermal cells shape	Anticlinal wall		Periclinal wall	
				level	shape	level	surface
1	*Anarrhinum pubescens*	pappillate - tuberculate	polygonal	raised	straight	concave	centrally papillate-tuberculate
2	*Bufonia multiceps*	colliculate	isodiametric	channeled	sinuate	convex	colliculate
3	*Euphorbia obovata*	irregularly and shallowly tuberculate - rugulose	obscure	obscure	obscure	obscure	obscure
4	*Origanum syriacum L.* subsp. *sinaicum*	ruminate	obscure	obscure	obscure	obscure	obscure
5	*Phlomis aurea*	striate - rugose	obscure	obscure	obscure	obscure	obscure
6	*Plantago sinaica*	lineolate	obscure	obscure	obscure	obscure	obscure
7	*Polygala sinaica* var. *sinaica*	shallowly reticulate with long hairs	indistinct polygonal	slightly raised	straight	depressed	smooth
8	*Primula boveana*	reticulate-verrucate	polygonal	slightly raised	straight	slightly concave	verrucate
9	*Rosa arabica*	scalariform - reticulate	polygonal	raised	straight	concave	smooth
10	*Silene leucophylla*	ridges densely granulate	isodiametric and elongated	channeled	sinuate (v-undulate)	convex	granulated
11	*Silene oreosinaica*	ridges aculeate at the periphery	mostly isodiametric	channeled	sinuate, stellulate	flat; convex at back face	Finely granulate
12	*Silene schimperiana*	ridge densely granulate	elongated	channeled	sinuate (u-undulate)	flat	granulated

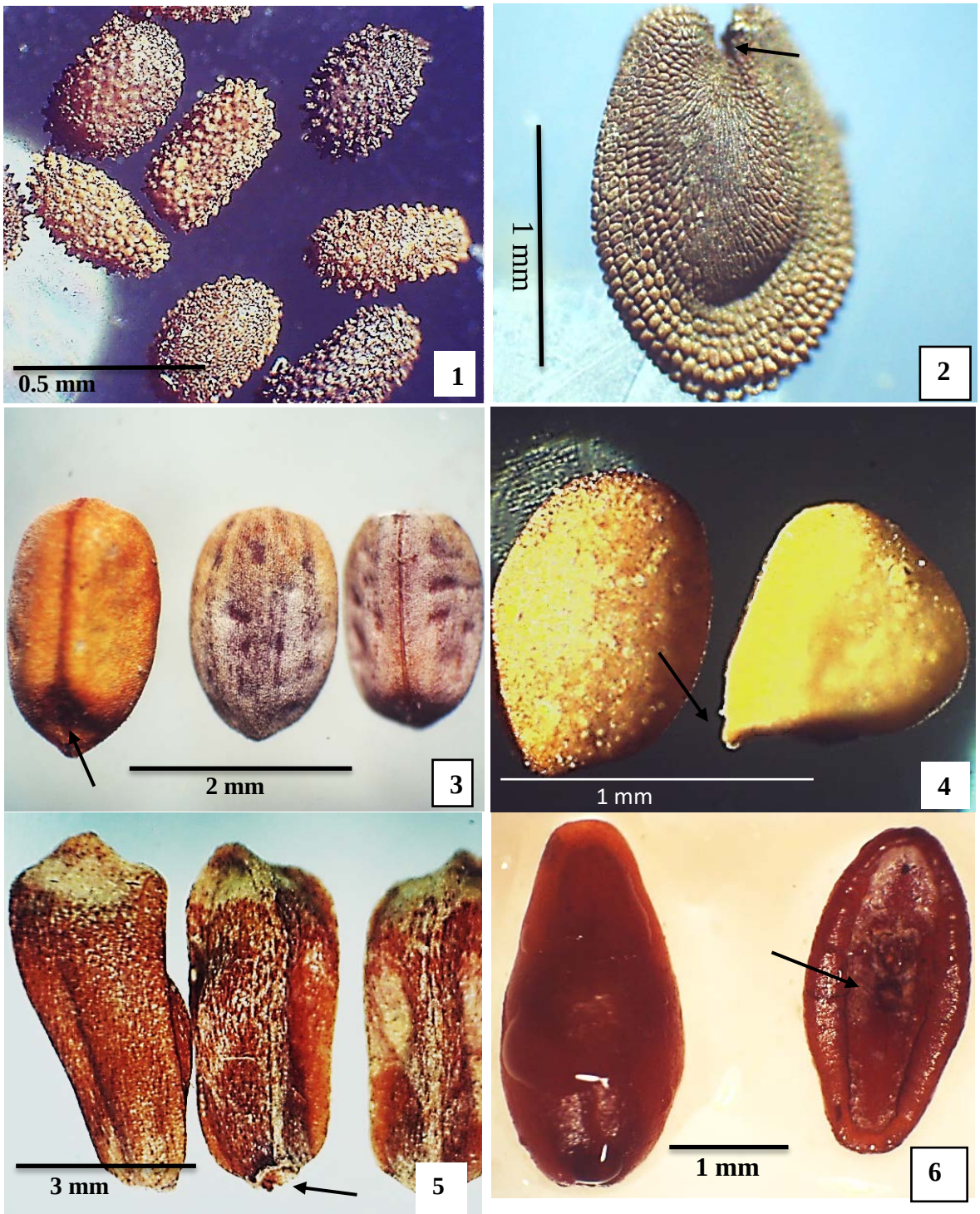


Plate I. LM micrographs of seeds to show the general shape of seed, color and brightness **Fig. 1- *Anarrhinum pubescens*** narrowly ellipsoid seed, brown; **Fig.2- *Bufonia multiceps*** orbicular, light brown**; Fig.3- *Euphorbia obovata*** ellipsoid light brown**; Fig. 4 -*Origanum syriacum*** subsp. ***sinaicum*** obovoid, yellow with raised hilum**; Fig.5 - *Phlomis aurea*** ellipsoid, trigonous, with rounded ends and short projection,, brown ; **Fig.6- *Plantago sinaica*** var.***sinaica*** cymbiform, dark brown with deeply concave ventral side (Arrow referred to hilum position)

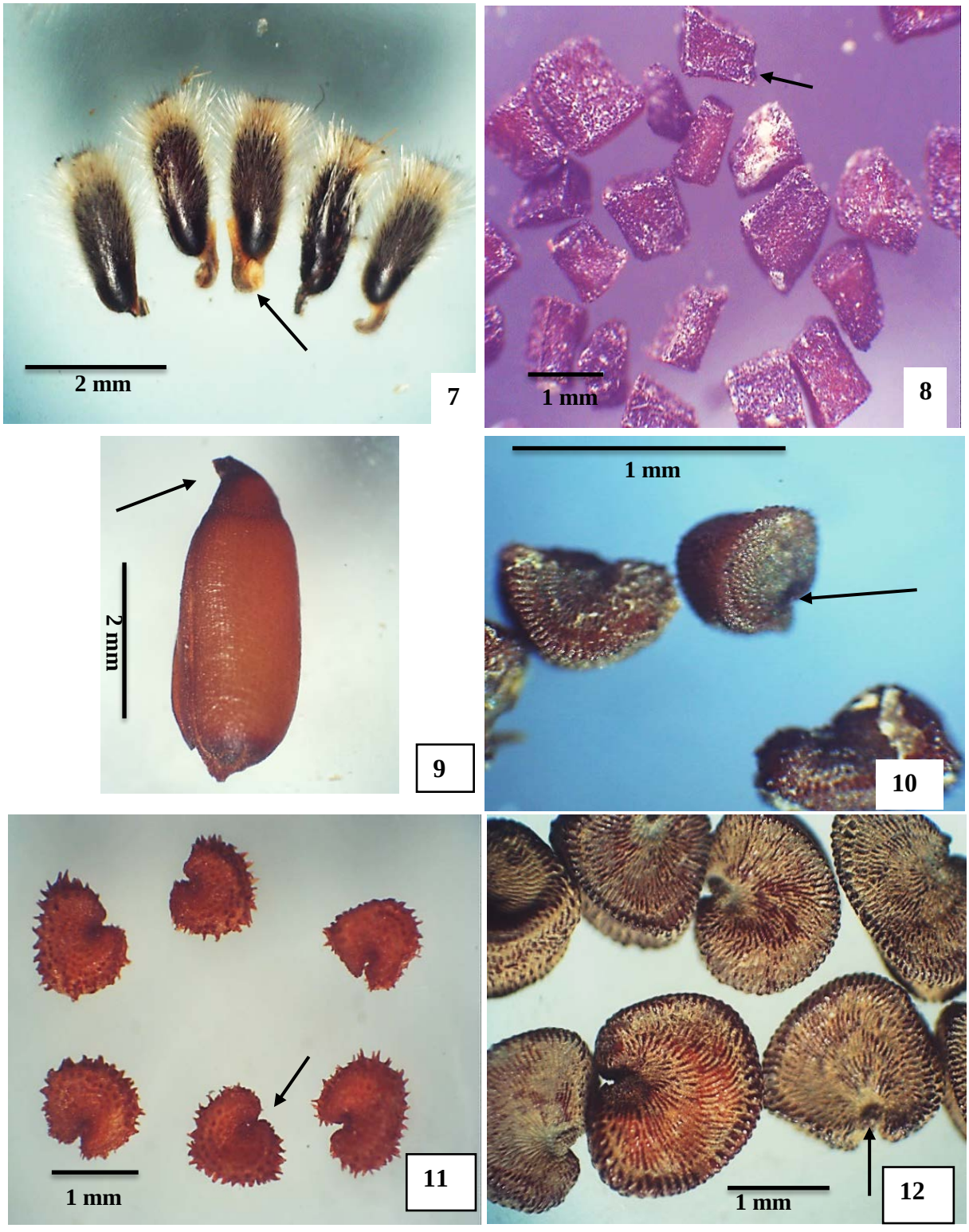


Plate 1 (cont.)- Fig.7-*Polygala sinaica* var. ***sinaica*** ellipsoid, black, shiny with long hairs, aerol present**; Fig. 8 -** ***Primula boveana*** prismatic, cuboid brown **; Fig.9-** ***Rosa arabica*** ellipsoid, brown with raised hilum;**Fig.10 -** ***Silene leucophylla*** reniform dark brown**; Fig.11 –** ***Silene oreosinaica*** orbicular –reniform brown cell shape**; Fig.12-** ***Silene schimperiana*** reniform, brown (Arrow referred to hilum position)

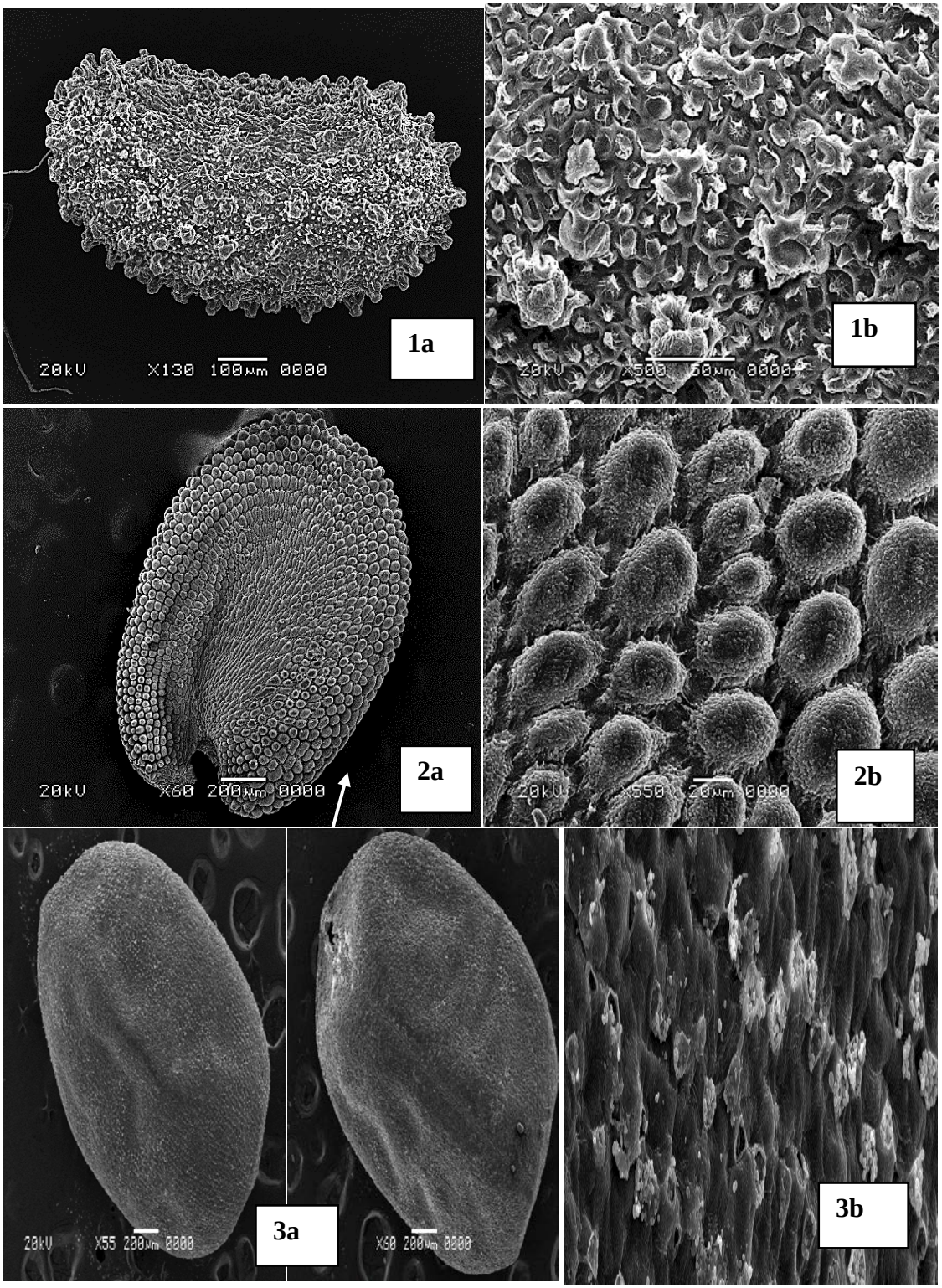


Plate II: SEM micrographs of seeds of the studied taxa **a** mature seed **b** testa cell shape and ornamentations **Fig. 1a-*Anarrhinum pubescens*** **1b** papillate- granulate surface***;*** **Fig. 2a- *Bufonia multiceps*** **2b** sinuate, colliculate surface***;*** **Fig. 3a-*Euphorbia obovata*** **3b** Irregularly and shallowly tuberculate - rugulose

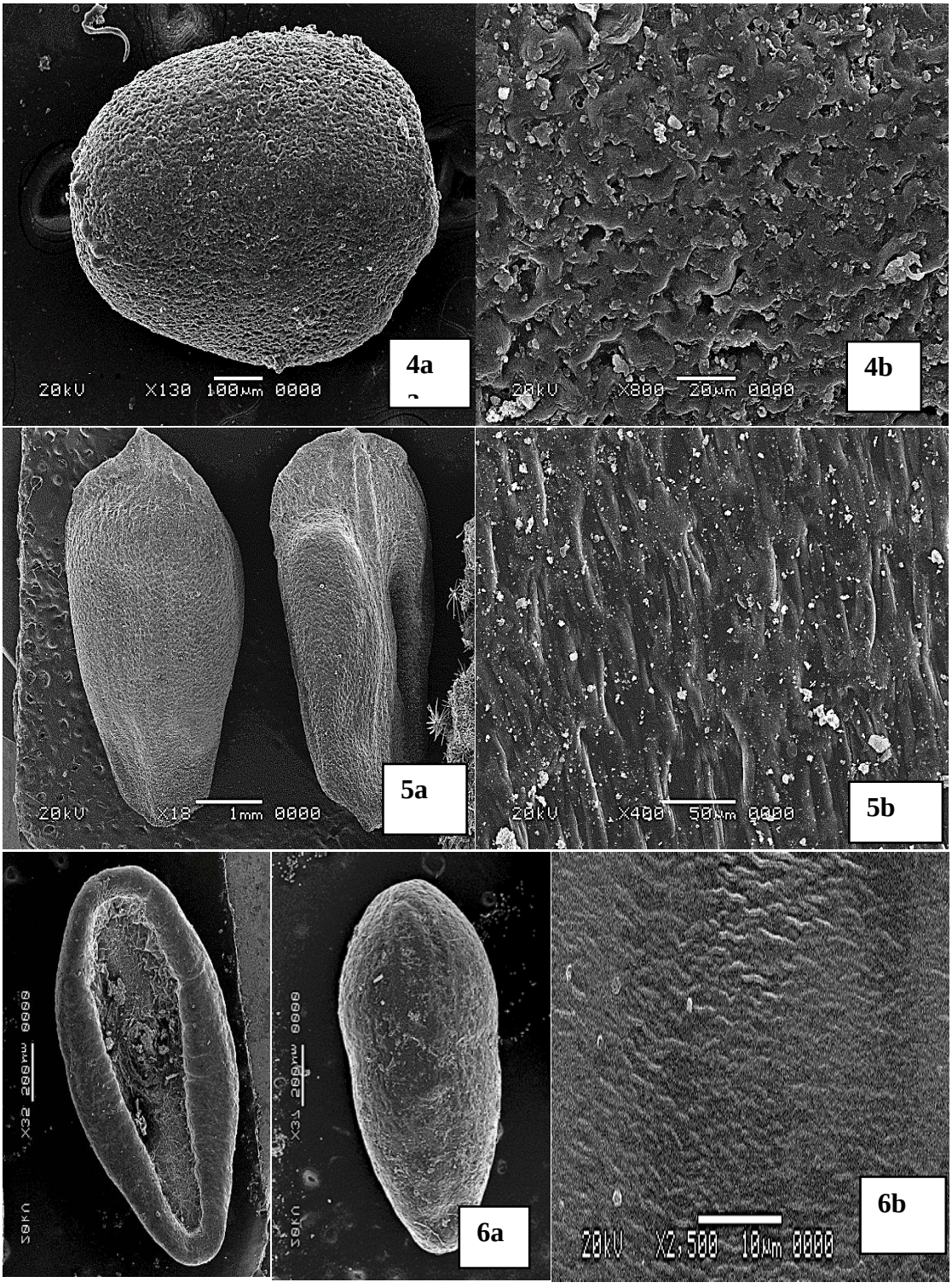


Plate II (cont.) Fig 4a. ***Origanum syriacum*** subsp**.** ***sinaicum*** **a** tubercled **4b** ruminate surface**; Fig. 5a -** ***Phlomis aurea*** left ventral view; right dorsal view **5b** striate rugose surface**; Fig. 6a-** ***Plantago sinaica*** **a** left ventral view; right dorsal view **6b** lineolate seed surface

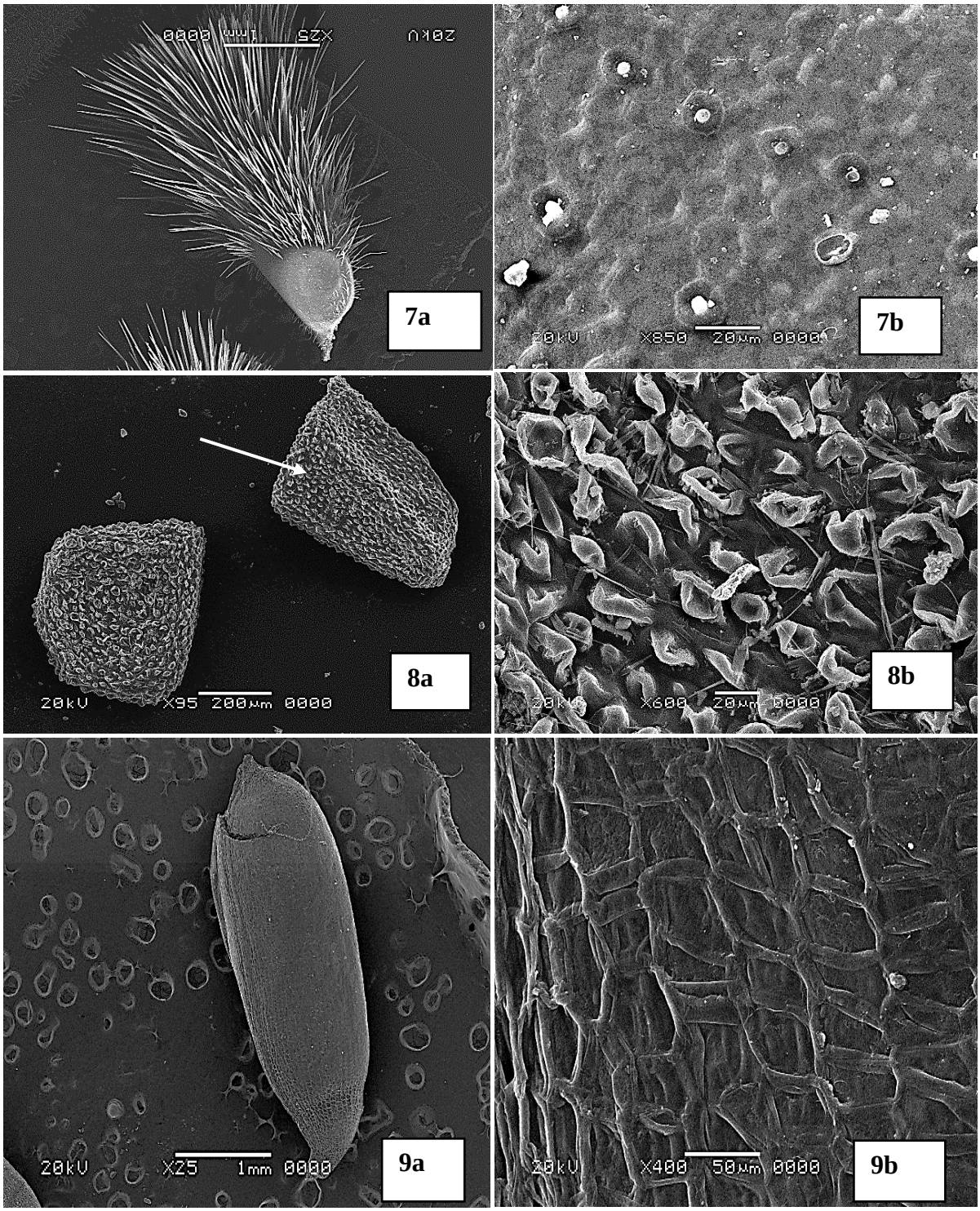


Plate II (cont.) **Fig. 7a** ***Polygala sinaica*** var. ***sinaica*****, 7b** smooth reticulate surface**; 8a.*Primula boveana* 8b** reticulate-verrucate pattern***;*** **Fig. 9a-*Rosa arabica* 9b** scalariform reticulate pattern

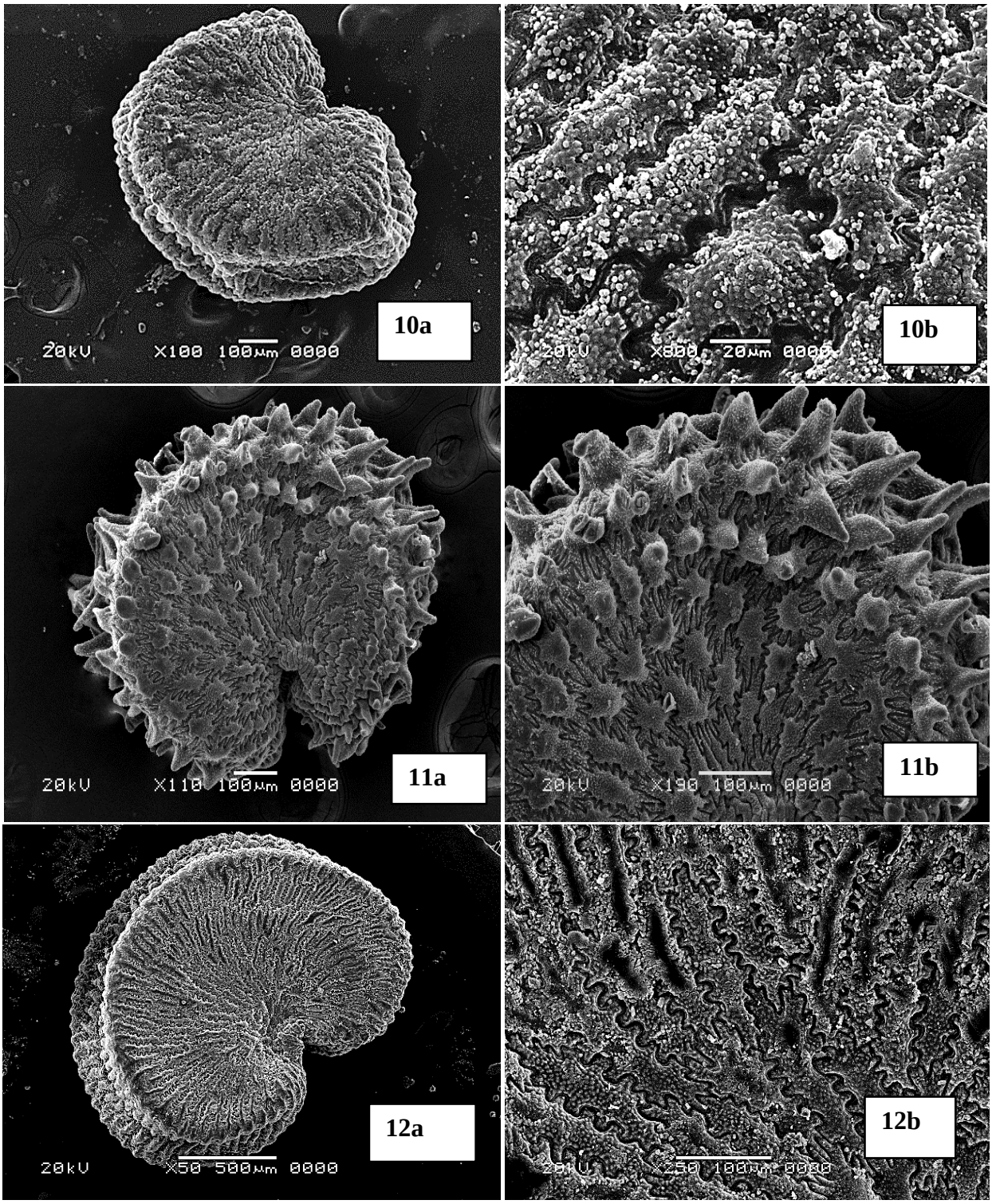


Plate II- (cont.) Fig. 10a *Silene leucophylla* 10b anticlinal wall sinuate (v- shaped), periclinal granulated **Fig. 11a. *Silene oreosinaica* 11b** sinuate, stellulate anticlinal wall and finely granulate periclinal wall**; Fig. 12a- *Silene schimperiana,* 12b** anticlinal wall sinuate (u-shaped) granulated periclinal wall

Table (4): Pollen characteristics and measurements of the pollen grains of the studied taxa

Taxa	Polarity	Symmetry	Size Long Mean (Range) µm				Shape	Aperture Class	Exine Ornamentation
			Size	**Polar Axis (P)**	**Equatorial Axis (E)**	**P/E × 100**			
Anarrhinum pubescens	**isopolar**	**radiosymmetric**	**Small**	**18.26 (17.67-18.65)**	**10.46 (9.14-10.92)**	**174.56**	**Prolate**	**Trizonocolporate**	**reticulate-Foveolate**
Bufonia multiceps	**isopolar**	**radiosymmetric**	**Small**	**21.56 (20.85-22.28)**	**21.56 (20.85-22.28)**	**100**	**Spheroidal**	**Polypantoporate**	**microechinate**
Euphorbia obovata	**isopolar**	**radiosymmetric**	**Medium**	**26.57 (26.44-26.93)**	**30.06 (29.39-30.45)**	**88.38**	**Oblate-Spheroidal**	**Trizonocolporate**	**perforate to fossulate**
Origanum syriacum subsp. *sinaicum*	**isopolar**	**radiosymmetric**	**Small**	**18.47 (16.78-21.2)**	**21.09 (18.06-22.42)**	**88.09**	**Oblate-Spheroidal**	**Hexazonocolpate**	**reticulate-fossulate**
Phlomis aurea	**isopolar**	**radiosymmetric**	**Medium**	**28.47 (28.35-28.63)**	**29.31 (29.13-29.44)**	**97.15**	**Oblate-Spheroidal**	**Trizonocolpate**	**bireticulate,**
Plantago sinaica	**isopolar**	**radiosymmetric**	**Small**	**19.94 (18.64-21.24)**	**19.94 (18.64-21.24)**	**100**	**Spheroidal**	**Pantoporate**	**verrucate with granules**
Polygala sinaica var. *sinaica*	**isopolar**	**radiosymmetric**	**Small**	**22.73 (22.64-22.91)**	**23.48 (22.84-23.86)**	**96.83**	**Oblate-Spheroidal**	**polyzonocolporate**	**psilate**
Primula boveana	**isopolar**	**radiosymmetric**	**Small**	**13.16 (12.75-13.58)**	**14.29 (14.09-14.5)**	**92.12**	**Oblate-Spheroidal**	**Trizonocolporate**	**microreticulate**
Rosa arabica	**isopolar**	**radiosymmetric**	**Medium**	**26.44 (25.76-27.29)**	**24.57 (25.47-25.74)**	**107.61**	**Prolate-Spheroidal**	**Trizonocolporate**	**striate**
Silene leucophylla	**isopolar**	**radiosymmetric**	**Small**	**23.2 (22.76-23.65)**	**23.2 (22.76-23.65)**	**100**	**Spheroidal**	**Pplypantoporate**	**foveolate, microechinate**
Silene oreosinaica	**isopolar**	**radiosymmetric**	**Medium**	**25.82 (25.48-26.16)**	**25.82 (25.48-26.16)**	**100**	**Spheroidal**	**Polypantoporate**	**verrucate with granules**
Silene schimperiana	**isopolar**	**radiosymmetric**	**medium**	**33.75 (32.75-34.45)**	**33.75 (32.75-34.45)**	**100**	**Spheroidal**	**Polypantoporate**	**anulo-punctate microechinate**

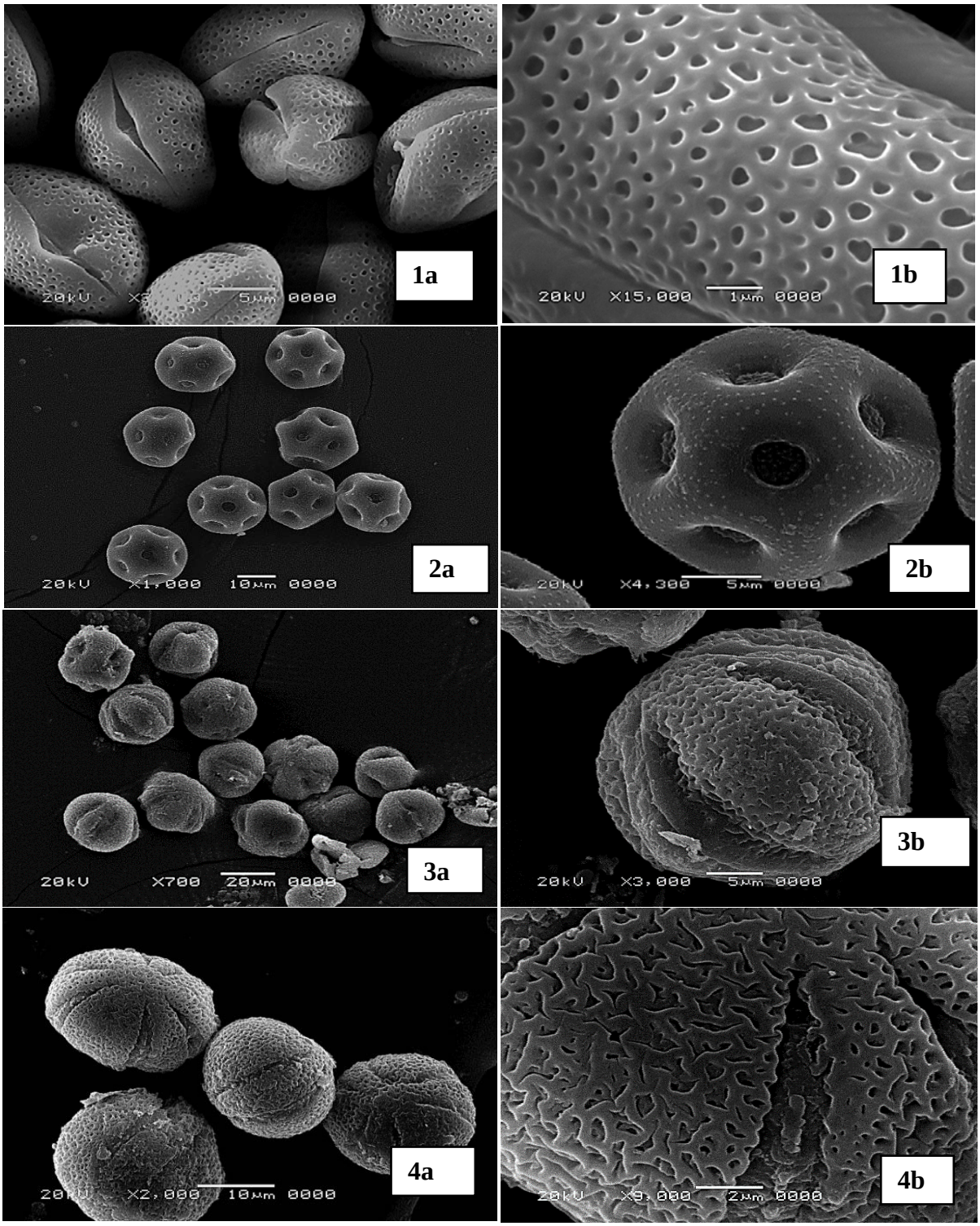


Plate III- SEM micrographs of pollen grains of studied taxa **Figures 1-12** (**a**)showing whole grain; (**b**) showing exine ornamentation **Fig.1** ***Anarrhinum pubescens*** **a.** prolate trizonocolporate **b** reticulate-foveolate ornamentation; **Fig.2**- ***Bufonia multiceps*** **a.** spheroidal, polypantoporate pollen **b** sunken pores and microechinate exine, operculum microechinate; **Fig. 3** ***Euphorbia obovata*** **a** oblate-spheroidal, trizonoacolporate pollen **b** perforate to fossulate ornamentation***;*** **Fig. 4 -** ***Origanum syriacum*** subsp. ***sinaicum*** **a** oblate- spheroidal, hexazonocolpate pollen **b** reticulate- fossulate ornamentation

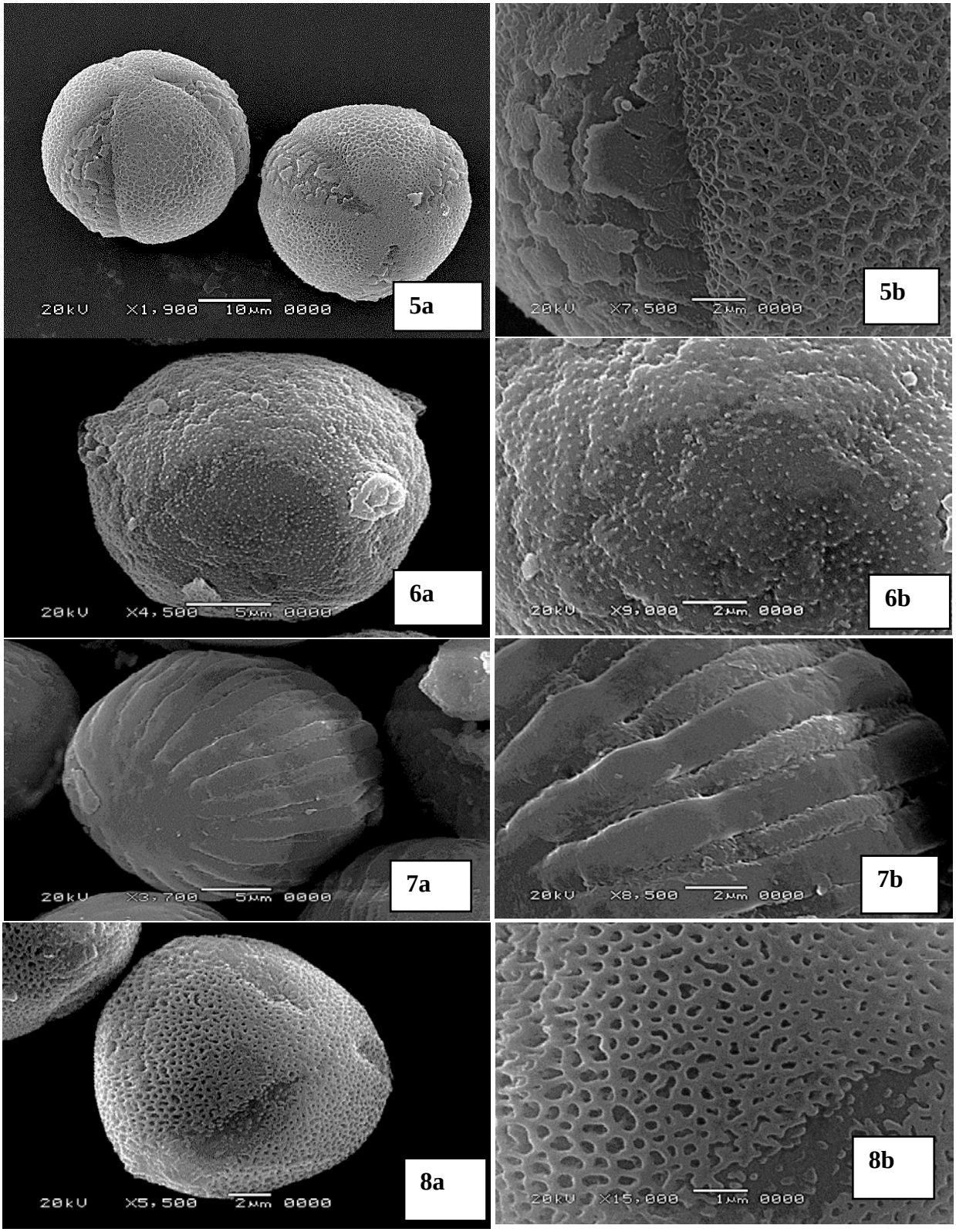
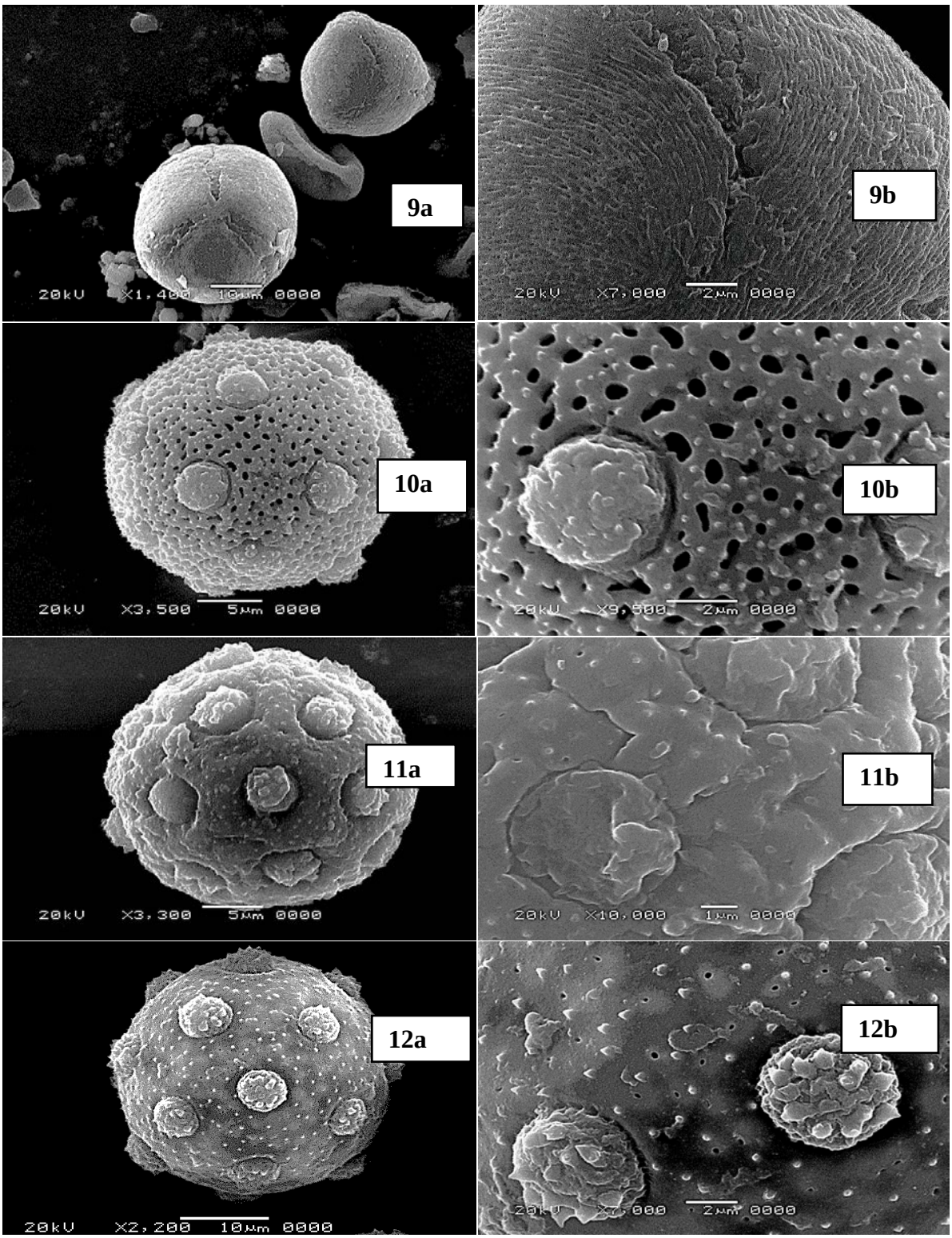


Plate III (cont.), Fig. 5-*Phlomis aurea:* **a** oblate-spheroidal, trizonocolpate pollen **b** ornamentation bireticulate*;* **Fig. 6**- ***Plantago sinaica:*** **a** spheroidal, polypantoporate pollen **b** verrucate exine with granules; **Fig**. **7**- ***Polygala sinaica*** var. ***sinaica:*** **a** oblate spheroid**,** polyzonocolporate pollen, **b** psilate ornamentation**; Fig. 8** - ***Primula boveana:*** **a** oblate-spheroid trizonocolporate pollen, **b** microreticulate



Microechinate Plate III (cont.)Fig.9-*Rosa arabica* a prolate-spheroidal, trizonocolporate pollen, **b** striate ornamentation; **Fig.10- *Silene* leucophylla a** spheroidal, polypantoporate pollen **b** foveate**,,**microechinate ornamentation, with granulate operculum; **Fig. 11 *S. oreosinaica* a** spheroidal, polypantoporate **b** verrucate, granulate ornamentation, with granulate operculatum **Fig.12- *S. schimperiana* a** spheroidal polypantoporate with microechinate **b** punctate, microechinate with echinate operculum

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