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Pollen morphology of Malvaceae genera from Saudi Arabia and its taxonomic significance

Kadry Abdel khalik[1,2],*, Suad Al-Ruzayza[1], Abdullah Assiri[4], Ahmed Elkordy[2,3]

[1]Biology Department, Faculty of Applied Science, Umm-Al-Qura University, Makkah, Saudi Arabia
[2]Botany and Microbiology Department, Faculty of Science, Sohag University, Sohag, Egypt
[3]Botany and Microbiology Department, College of Science, Taibah University, Ola, Saudi Arabia
[4]Forensic Lab-Criminal Evidence-Ministry of interior, Jeddah, Saudi Arabia

***Corresponding author: Kadry3000@yahoo.com**

Abstract

Pollen morphology of 20 species belong to seven genera (*Abutilon*, *Althaea*, *Hibiscus*, *Malva*, *Pavonia*, *Senra* and *Sida*) of Malvaceae from Saudi Arabia were studied by using light microscope (LM) and scanning electron microscope (SEM). Quantitative and qualitative pollen morphological characters which vary among investigated taxa are found in the pollen polarity, symmetry, size, shape, polar axis, equatorial diameter, *P/E* ratio, average height and width of spine, aperature character and spine index. The pollen grains vary from spheroidal, prolate spheroidal, oblate spheroidal to suboblate. All taxa were characterized by relatively large to medium sized pollen grains, numerous pores scattered irregularly all over the grain, and echinate sculpturing. *Sida ovata* is the largest size pollen grain (138.95) µm. On the other hand, *Malva parviflora* showed the smallest pollen size (52.28 µm). The average height and width of spine varied greatly among studied taxa. The highest spines (20.65µm) found in *Sida ovata*, while the shortest (3.19 µm) was found in *Abutilon pannosum.* Results of the pollen shape, size, and exine sculpture characters offered useful data for evaluating the taxonomy of Malvaceae both on subgeneric and sectional levels. A key for the identification of the investigated taxa based on pollen grains characters is also provided.

Keywords: Malvaceae, Pollen, Saudi Arabia, Taxonomic, Morphology.

Introduction

Malvaceae are a worldwide family of herbs, shrubs and small trees with a primary concentration of genera in the tropical regions and comprises of some 244 genera including 4225 known species (Christenhusz and Byng, 2016). The family has been divided into five or six tribes: Malopeae, Malveae, Hibiscieae, Abutilieae, Ureneae and Decaschistieae (Duke and Doebley, 1995) (Krebs, 1994a,b).

The largest genera in terms of number of species are *Hibiscus* (580, including *Pavonia*), *Sida* (200), *Abutilon* (100), *Dombeya* (225), *Triumfetta* (150), *Grewia* (290) (Stevens, 2001).

The pollen morphology of this family or representatives of it, has attracted many scientists. The most important studies are (Erdtman, 1952; Nair, 1958; Saad, 1960; Nair, 1961; Prasad, 1963; Chaudhuri, 1965; Erdtman, 1969; Martin and Drew, 1969; Barth, 1975; Krapovickas, 1975; Tressens, 1974; Van Campo, 1976; Coetzee and Van Der Schijff, 1979;Hanks and Fryxell, 1979; Fernandez and Candau, 1981; Srivastava, 1982; El Naggar, 2004). Among these, only the most recent have been using SEM, with most having been based only on light microscopical studies.

Owing to the high economic value of some genera of the Malvaceae, several studies have been carried out on different perspectives of this family (El-Hadidi et al., 1999; and El Naggar (2001; 2004)

Saad (1960) considered that the pollen morphology in the family Malvaceae is quite distinctive which could apparently distinguish between the genera.

Furthermore, Christensen (1986) conducted a most comprehensive study on pollen of Malvaceae using both light (LM) and scanning electron microscopy (SEM). Moreover, he compared his results with the recent classification of the family (Hutchinson, 1967) with special reference to phylogeny, cytology and the evolutionary trends in pollen morphology. He pointed out that Malvaceae seems to be an ancient family with the tribes of Malveae and Abutileae having a long and distinct evolutionary history, while Hibisceae and Ureneae are closely allied tribes and can be regarded as the most advanced within the family. However, he admitted that the generic delimitation, is rather difficult among the studied species of the family based on pollen morphology.

Culhane and Blackmore (1988) divided the family into six pollen types, based on number of apertures, grains diameter and spinular morphology. However, Hosni and Araffa (1999) used pollen characteristics in combination with other

morphological characteristics to differentiate between certain taxa from Egypt.

In the flora of Saudi Arabia, Chaudhary (1999) reported 17 genera and 31 species of Malvaceae.

The main object of the present study is to investigate and describe the pollen of some wild taxa of the family Malvaceae growing in Saudi Arabia, and to discuss the results obtained with recent classifications of the family.

Results

Polarity and symmetry

All investigated taxa generally have radially symmetrical apolar or isopolar pollen grains. However, all investigated taxa belong to Genus *Abutilon* characterized by isopolar pollen grains, while the pollen grains were polar in the rest of the studied taxa (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 = 0.875–1.0 Oblate spheroidal
P/E = 1.0 Spheroidal
P/E = 1.1–1.4 Prolate spheroidal
P/E = 1.14–1.33 Subprolate
P/E = 1.33-2.0 Prolate

Fig. 1 shows the mean polar axis plotted against mean equatorial diameter for each species measured. The peroblate and oblate grains was laid above this line and suboblate and oblate spheroidal near this line. The spheroidal grains perfectly resided along the 45° line in Fig. 1, with prolate and perprolate grains below this line and prolate spheroidal and subprolate near the line. In the investigated species, there is no broad variation in pollen shape.

Pollen grains are generally Prolate spheroidal, Spheroidal, Oblate spheroidal or Suboblate. However, it is spheroidal In *Senra incana* (Fig. 6, 18); Oblate spheroidal in *Malva neglecta* (Fig. 5, 13), *Malva verticillata* (Fig. 5, 15), *Pavonia arabica* (Fig. 5, 16), *Sida alba* (Fig. 6, 19) and *S. ovata* (Fig. 6, 20); Suboblate in *Malva parviflora* (Fig. 5, 14); Prolate spheroidal in the rest of studied taxa. In polar view the pollen grains are mostly circular in all studied taxa.

Pollen Size

Pollen grains of the Malvaceae are considered to be the largest among Angiosperms (Christensen, 1986). Pollen size varied greatly among the studied taxa. It ranged from 52.28 µm to 138.95 µm. Pollen grain size was found useful to distinguish between studied species especially at generic level. However, the largest pollen grain exceeds 100 µm found in *Althaea ludwigii*, *Hibiscus micranthus* and *Sida ovata* (Table 2; Fig. 4, 9, 11 and Fig. 6, 20), respectively, while the smallest pollen grain ranges from 52.28 µm to 56.06 µm found in *Malva parviflora* and *Malva neglecta* (Table 2; Fig. 5, 14, 13), respectively. In the rest of the studied taxa, pollen grain ranges from 82.2 µm to 96.3 µm in the taxa of genus *Pavonia, Hibiscus deflersii* and *Malva verticillata* (Table 2; Fig. 5, 16; Fig. 6, 17; Fig. 4, 10; Fig. 5, 15), respectively. Taxa of genera *Abutilon*, *Senra* and *Hibiscus purpureus* characterized by relatively medium pollen grain size ranging from 60.96 µm in *Abutilon pannosum* to 79.38 µm in *Abutilon figarianum* (Table 2; Fig. 3, 5, 6), respectively, while it is 69.52 µm and 72.86 in *Senra incana* and *Hibiscus purpureus*, respectively (Table 2; Fig. 6, 18 and Fig. 4, 12) respectively.

Surface ornamentation

All taxa under investigation were characterized by echinate exine (Table 2, Figs. 2-11). According to El Naggar (2004), one of the most prominent and interesting features of Malvaceous pollen is the echinations or prolongations of the exine into definite spines. Malvaceae is fairly advanced because of the echinate sculpturing and pantoporate character of its pollen grains (Perveen, 1993).

Spines (echinae)

Spines varied greatly in length and width among the investigated taxa. The average height of spines ranged from (3.19) µm in *Abutilon pannosum* to (20.65) µm in *Sida ovata*, while the average width ranging from (1.08) µm for *Abutilon pannosum* to 4.98 µm for *Hibiscus micranthus* (Table 2 and Fig. 12). The number, height, and position of spines vary in the different plant families in which they occur and constitute some of the most significant characters for identification purposes (Pope, 1925). The variations in size, shape and surface distribution of spines in the pollen grains of Malvaceae are of significant value at different taxonomic levels as these are not only recorded at intergeneric level but also between species of the same genus.

Spine index

The proportion between the height and width of the spine at its base defines the spine configuration and is used as a taxonomic characteristic to delimit Malvaceous taxa. The present study shows that the highest value of spine index (5.17) is recorded for *Pavonia arabica*, while, the smallest (2.09) for *Malva parviflora* (Table 2; Fig. 13). The longest spines were observed in *Sida ovata* (20.65 µm), while the shortest in *Abutilon pannosum* (3.19 µm) (Table 2 and Fig.12).

Apertures

All investigated species are characterized by poly panto and zono porate aperturate. However, all taxa of the genus *Abutilon* were characterized by trizonoporate pollen grains (Table 2; Figs. 2, 3, 7, 8) while the rest of taxa under investigation characterized by Polypantoporate pollen grains (Table 2; Figs. 4, 5, 6, 9, 10, 11).

Key to the studied taxa based on pollen grains characters

1a. Pollen grain trizonoporate.....2
1b. Pollen grain polypantoporate.....9
2a. Pollen grains with mean polar axis (P) ranges from 60.96 to 68.37 µm.....3
2b. Pollen grains with mean polar axis (P) ranges from 75.02 to 79.38 µm.....5
3a. Spine index less than 3.00..... *Abutilon pannosum*
3b. Spine index exceed 3.00.....4
4a. Average height of spine ± 7.32 µm..... *Abutilon muticum*
4b. Average height of spine ± 4.08 µm..... *Abutilon ramosum*
5a. Spine index less than 3.00.....*Abutilon grandifolium*

5b. Spine index exceed 3.00.....6
6a. Average height of spine < 6 µm.....7
6b. Average height of spine > 6 µm.....8
7a. Spine index 4.02..... *Abutilon fruticosum*
7b. Spine index 4.74..... *Abutilon bidentatum*
8a. Spine index 3.56.....*Abutilon hirtum*
8b. Spine index 4.51.....*Abutilon figarianum*
9a. Pollen grains with mean polar axis (P) exceeds 100 µm.....10
9b. Pollen grains with mean polar axis (P) less than 100 µm.....12
10a. Pollen grains Oblate spheroidal, with mean polar axis (P) up to 139 µm..... *Sida ovate*
10b. Pollen grains Prolate spheroidal, with mean polar axis (P) up to 129 µm.....11
11a. Average height of spine ±16.85 µm.....*Hibiscus micranthus*
11b. Average height of spine ± 6.00 µm.....*Althaea ludwigii*
12a. Pollen grains Spheroidal, with very short spines 3.26 µm..... *Senra incana*
12b. Pollen grains Prolate spheroidal, Oblate spheroidal and Suboblate.....13
13a. Pollen grains Suboblate, with mean polar axis (P) 52.28 µm..... *Malva parviflora.*
13b. Pollen grains Prolate spheroidal, Oblate spheroidal.....14
14a. Pollen grains prolate spheroidal 15
14b Pollen grains Oblate spheroidal.....17
15a. Pollen grains with mean polar axis (*P*) up to 75.00 µm, with relatively short spines (±4.43 µm)..... *Hibiscus purpureus.*
15b. Pollen grains with mean polar axis (*P*) > 75.00 µm, up to 97.00 µm, with relatively long spines (12.50-16.00 µm).....16
16a. Spine index 3.00.....*Hibiscus deflersii*
16b. Spine index > 3.00.....*Pavonia burchellii*
17a. Pollen grains with mean polar axis (*P*) up to 56.06 µm..... *Malva neglecta.*
17b. Pollen grains with mean polar axis (*P*) > 56.06 µm, up to 95.00.....18
18a. Average height of spine ± 6.78 µm..... *Malva verticillata*
18b. Average height of spine > 6.78 µm, up to 17.00 µm.....19
19a. Spine index 3.41..... *Sida alba*
19b. Spine index 5.17..... *Pavonia arabica*

Discussion

Palynologically Malvaceae is a stenopalynous family and pollen characters of this family are almost uniform (Tahavi, 2000). Saad (1960) studied the pollen morphology of 35 species of Malvaceae. He emphasized the importance of the aperture and spine characteristics, as well as exine stratification to distinguish between different taxa.

The results provide valuable characters for pollen morphological differences, which can be used as key characters for the distinction of certain taxa.

The pollen grains of genus *Abutilon* are easily distinguished by spines with basal cushions (Figs. 7-8, 1-8). All investigated species related to genus *Abutilon* characterized by isopolar, prolate spheroidal, trizonoporate pollen grains. The size of pollen grains among the examined species of the genus *Abutilon* varied between ~ 60.96 µm (mean polar axis) in *Abutilon pannosum* to ~ 79.38 µm (mean polar axis) in *Abutilon figarianum* (Table 2). The average height of spine could be used as a distinguish characters among the investigated taxa of genus *Abutilon*. However, the shortest spine (~3.19 µm) found in *Abutilon pannosum*, while the longest spine (~7.08 µm) found in *Abutilon figarianum* (Table 2; Fig.12).

Sida is characterized by large pollen grain size. It is of a high taxonomic value among studied species of genus *Sida. S. ovata* has the largest pollen grain size among all investigated Malvaceous taxa in this study (138.95 µm), while it is (94.39 µm) in *S. alba*. (Table 2; Fig. 6, 12-20). Moreover, taxa of genus *Sida* characterized by variable and relatively long spines (~12.95 µm and ~20.65 µm in *S. alba* and S. ovata respectively) (Table 2; Fig. 12). Therefore, the average height of spine is of a high taxonomic value, and easily could be used as discriminative aid among studied species of genus *Sida*.

Tribe *Abutileae* includes the subtribes *Abutilinae* and *Sidinae*. The pollen grains of the species of this tribe are readily distinguished by spines with basal cushions (Hutchinson, 1967). The large size and long spines of genus *Sida* is evidence that the species of *Sidinae* are more advanced than those of *Abutilinae* (Christensen, 1986).

Hibiscus is easily distinguished by relatively large sized pollen grains ranging from (~ 72.86) µm in *H. purpureus* to (~129.17) µm in *H. micranthus* (Table 2; Fig. 4, 12, 11), respectively. Moreover, the pollen grains are prolate spheroidal in shape, polypantoporate and apolar (Table 2; Fig. 4, 10-12; Fig. 9, 10-12). The average height of spine among the *Hibiscus* species is of high taxonomically significant. However, *Hibiscus purpureus* is easily distinguished by relatively short spines (~ 4.43 µm) (Fig. 9, 12) among the closely related species (*H. deflersii* and *H.* micranthus), which they characterized by relatively long spines (~12.56 µm and ~16.85 µm) (Fig. 9, 10-11), respectively.

In the genus *Pavonia*, the pollen grains are relatively large in size, ranging from (~87.8 µm) in *P. arabica* to (91.5 µm) in *P. burchellii* (Table 2; Fig. 5, 16; Fig. 6, 17), respectively. The pollen grain size is of a less taxonomic value in distinguishing between investigated taxa of genus *Pavonia.* The shape of pollen grains is of a high taxonomic value among studied taxa of genus *Pavonia.* However, it is oblate spheroidal in *P. arabica* and prolate spheroidal in *P. burchellii.* (Figur 1; Fig. 5, 16; Fig. 6, 17), respectively. Taxa of genus *Pavonia* characterized by relatively long spines (~17.00 µm). It can be used to distinguish the genus from other Malvaceous taxa. Moreover, spine index also could be served as a discriminative tool among studied *Pavonia* species (Fig. 13). However, it is (3.81) in *P. burchellii*, while (5.17) in *P. arabica* (Table 2). The pollen morphological character of the studied taxa of *Pavonia* (tribe Ureneae) presented great similarity in its characters with those of the taxa of Hibisceae. Christensen (1986) concluded that the resemblance in pollen

Table 1. List of taxa used in the study (Chaudary 1999), a comparison of t traditional (Hutchinson 1967) and phylogenetic classifications (APG IV, 2016).

No	Taxa	Source and voucher	Hutchinson 1967	APG IV, 2016
1	*Abutilon bidentatum* Hochst.	Wadii Thalolah near AL-Baha, Suad Al-Ruzayza, 11 (UQU proposed abbreviation)	Tribe: Abutileae Hutch. Subtribe: Abutilinae	Tribe :Malveae
2	*Abutilon hirtum* (Lam.) Sweet, Hort.	Mahil Aseir, Suad Al-Ruzayza, 8 15 (UQU proposed abbreviation)	Tribe: Abutileae Hutch. Subtribe: Abutilinae	Tribe :Malveae
3	*Abutilon figarianum* Webb, Fragm.	Wadii Qusai, Suad Al-Ruzayza, 5 (UQU proposed abbreviation)	Tribe: Abutileae Hutch. Subtribe: Abutilinae	Tribe :Malveae
4	*Abutilon fruticosum* Guill. & Perr.	Near Al-Howtah, Alfarhan and J. Thomas, 22274 (KSU)	Tribe: Abutileae Hutch. Subtribe: Abutilinae	Tribe :Malveae
5	*Abutilon pannosum* (G.Forst.) Schltdl.	Al-Edabi, Suad Al-Ruzayza, 17 (UQU proposed abbreviation)	Tribe: Abutileae Hutch. Subtribe: Abutilinae	Tribe :Malveae
6	*Abutilon ramosum* (Cav.) Guill. & Perr.	Shada mountiain, Suad Al-Ruzayza,2 (UQU proposed abbreviation)	Tribe: Abutileae Hutch. Subtribe: Abutilinae	Tribe :Malveae
7	*Abutilon grandifolium* (Willd.) Sweet	Fifa mountain, Suad Al-Ruzayza,15 (UQU proposed abbreviation)	Tribe: Abutileae Hutch. Subtribe: Abutilinae	Tribe :Malveae
8	*Abutilon muticum* Sweet, Hort.	Alardah, Suad Al-Ruzayza,6 (UQU proposed abbreviation)	Tribe: Abutileae Hutch. Subtribe: Abutilinae	Tribe :Malveae
9	*Althaea ludwigii* L.	Qassim Road, Suad Al-Ruzayza, 22 (UQU proposed abbreviation)	Tribe: Malveae A. Gray Subtribe: Malvinae	Tribe :Malveae
10	*Hibiscus deflersii* Schweinf. ex Cufod.	Taif, Suad Al-Ruzayza , 37 (UQU proposed abbreviation)	Tribe: Hibisceae Endl	Tribe: Hibiscieae
11	*Hibiscus purpureus* L.	Fifa mountain, Alfarhan and J. Thomas, 999 (KSU)	Tribe: Hibisceae Endl	Tribe: Hibiscieae
12	*Hibiscus micranthus* L.f.	Raidah, Suad Al-Ruzayza, 34 (UQU proposed abbreviation)	Tribe: Hibisceae Endl	Tribe: Hibiscieae
13	*Sida alba* L.,	Fifa mountain, J. Thomas and R. basahi, 21876 (KSU)	Tribe: Abutileae Hutch. Subtribe: Sidinae (K.Schum.) Hutch	Tribe :Malveae
14	*Sida ovata* Forssk.	Fifa mountain,Mohamed Ibrahim 2033 (KSU)	Tribe: Abutileae Hutch. Subtribe: Sidinae (K.Schum.) Hutch	Tribe :Malveae
15	*Malva parviflora* L.,	Alkarj, Suad Al-Ruzayza, 29 (UQU proposed abbreviation)	Tribe: Malveae A. Gray Subtribe : Malvinae	Tribe :Malveae
16	*Malva verticillata* L.,	AL-ahsaa, Suad Al-Ruzayza, 32 (UQU proposed abbreviation)	Tribe: Malveae A. Gray Subtribe : Malvinae	Tribe :Malveae
17	*Malva neglecta* Wallr.	Ushaqur, near Riyadh, Suad Al-Ruzayza, 2 (UQU proposed abbreviation)	Tribe: Malveae A. Gray Subtribe: Malvinae	Tribe :Malveae
18	*Pavonia arabica* Hochst. & Steud. ex Boiss.,	Wadi Bani Zaher, S. Chaudhary, 7087 (RAWRC)	Tribe: Ureneae Benth. & Hook	Tribe: Hibiscieae
19	*Pavonia burchellii* (DC.) R.A. Dyer	Jeddah, Suad Al-Ruzayza, 40 (UQU proposed abbreviation)	Tribe: Ureneae Benth. & Hook	Tribe: Hibiscieae
20	*Senra incana* Cav.,	Harrat Al-Shara, Suad Al-Ruzayza, 41(UQU proposed abbreviation)	Tribe: Hibiscieae	Tribe: Hibiscieae

Table 2. Pollen morphological characters of the investigated taxa of Malvaceae in Saudi Arabia.

No.	Taxon	Polar axis (*P*) µm	Equatorial axis (*E*) µm	*P/E*	Pollen shape	Aperature character	Polarity	Exine sculpture	Average height of spine µm	Average width of spine µm	Spine index
1	*Abutilon grandifolium*	76.78	73.97	1.04	Prolate spheroidal	Trizonoporate	Isopolar	Echinate	4.68	1.82	2.57
2	*Abutilon hirtum*	75.06	71.98	1.05	Prolate spheroidal	Trizonoporate	Isopolar	Echinate	6.02	1.69	3.56
3	*Abutilon bidentatum*	75.67	73.19	1.04	Prolate spheroidal	Trizonoporate	Isopolar	Echinate	5.17	1.09	4.74
4	*Abutilon muticum*	68.37	63.56	1.08	Prolate spheroidal	Trizonoporate	Isopolar	Echinate	7.32	2.29	3.20
5	*Abutilon pannosum*	60.96	59.23	1.03	Prolate spheroidal	Trizonoporate	Isopolar	Echinate	3.19	1.08	2.95
6	*Abutilon figarianum*	79.38	77.2	1.03	Prolate spheroidal	Trizonoporate	Isopolar	Echinate	7.08	1.57	4.51
7	*Abutilon fruticosum*	75.02	72.74	1.04	Prolate spheroidal	Trizonoporate	Isopolar	Echinate	5.22	1.30	4.02
8	*Abutilon ramosum*	62.66	61.34	1.03	Prolate spheroidal	Trizonoporate	Isopolar	Echinate	4.08	1.09	3.74
9	*Althaea ludwigii*	101.62	97.12	1.05	Prolate spheroidal	Polypantoporate	Apolar	Echinate	5.99	1.92	3.12
10	*Hibiscus deflersii*	96.3	91.26	1.06	Prolate spheroidal	Polypantoporate	Apolar	Echinate	12.56	4.19	3.00
11	*Hibiscus micranthus*	129.17	117.78	1.10	Prolate spheroidal	Polypantoporate	Apolar	Echinate	16.85	4.98	3.38
12	*Hibiscus purpureus*	72.86	71.68	1.02	Prolate spheroidal	Polypantoporate	Apolar	Echinate	4.43	1.37	3.23
13	*Malva neglecta*	56.06	57.56	0.98	Oblate spheroidal	Polypantoporate	Apolar	Echinate	6.03	1.88	3.21
14	*Malva parviflora*	52.28	60.11	0.87	Suboblate	Polypantoporate	Apolar	Echinate	4.80	2.30	2.09
15	*Malva verticillata*	82.2	84.36	0.98	Oblate spheroidal	Polypantoporate	Apolar	Echinate	6.78	1.67	4.06
16	*Pavonia arabica*	87.8	90.57	0.97	Oblate spheroidal	Polypantoporate	Apolar	Echinate	16.85	3.26	5.17
17	*Pavonia burchellii*	91.5	88.27	1.04	Prolate spheroidal	Polypantoporate	Apolar	Echinate	16.06	4.22	3.81
18	*Senra incana*	69.52	69.32	1.00	Spheroidal	Polypantoporate	Apolar	Echinate	3.86	1.74	2.22
19	*Sida alba*	94.39	99.31	0.96	Oblate spheroidal	Polypantoporate	Apolar	Echinate	12.95	3.80	3.41
20	*Sida ovata*	138.95	139.96	0.99	Oblate spheroidal	Polypantoporate	Apolar	Echinate	20.65	4.73	4.37

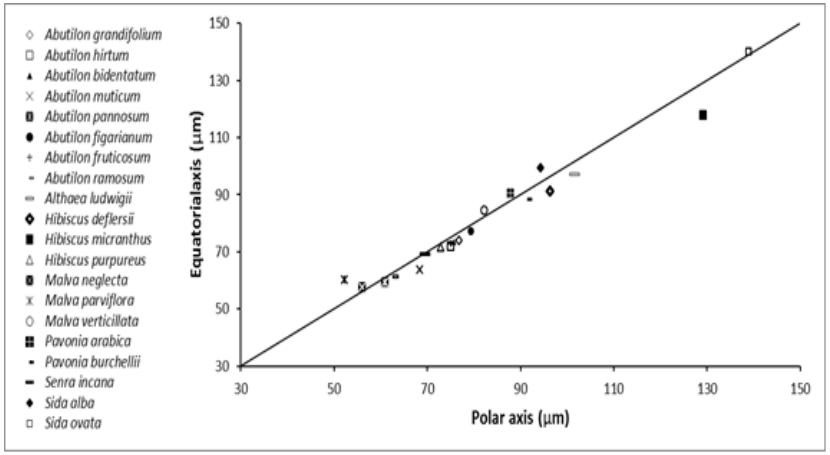

Fig 1. Pollen size and shape.

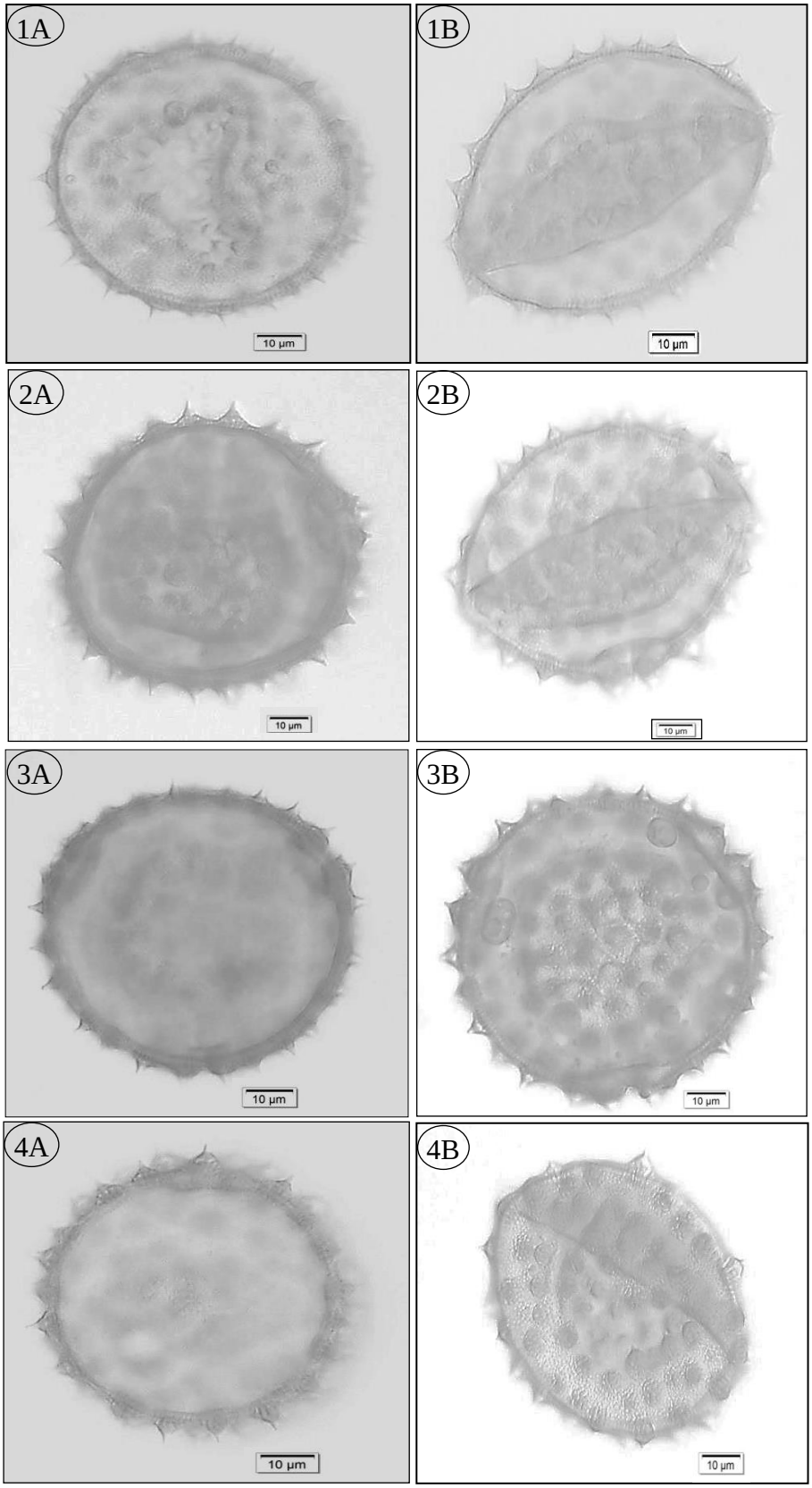

Fig 2. LM micrographs of pollen grains. (A) Polar view, (B) equatorial view. 1. *Abutilon bidentatum*; 2. *Abutilon grandifolium*; 3. *Abutilon hirtum*; 4. *Abutilon muticum.*

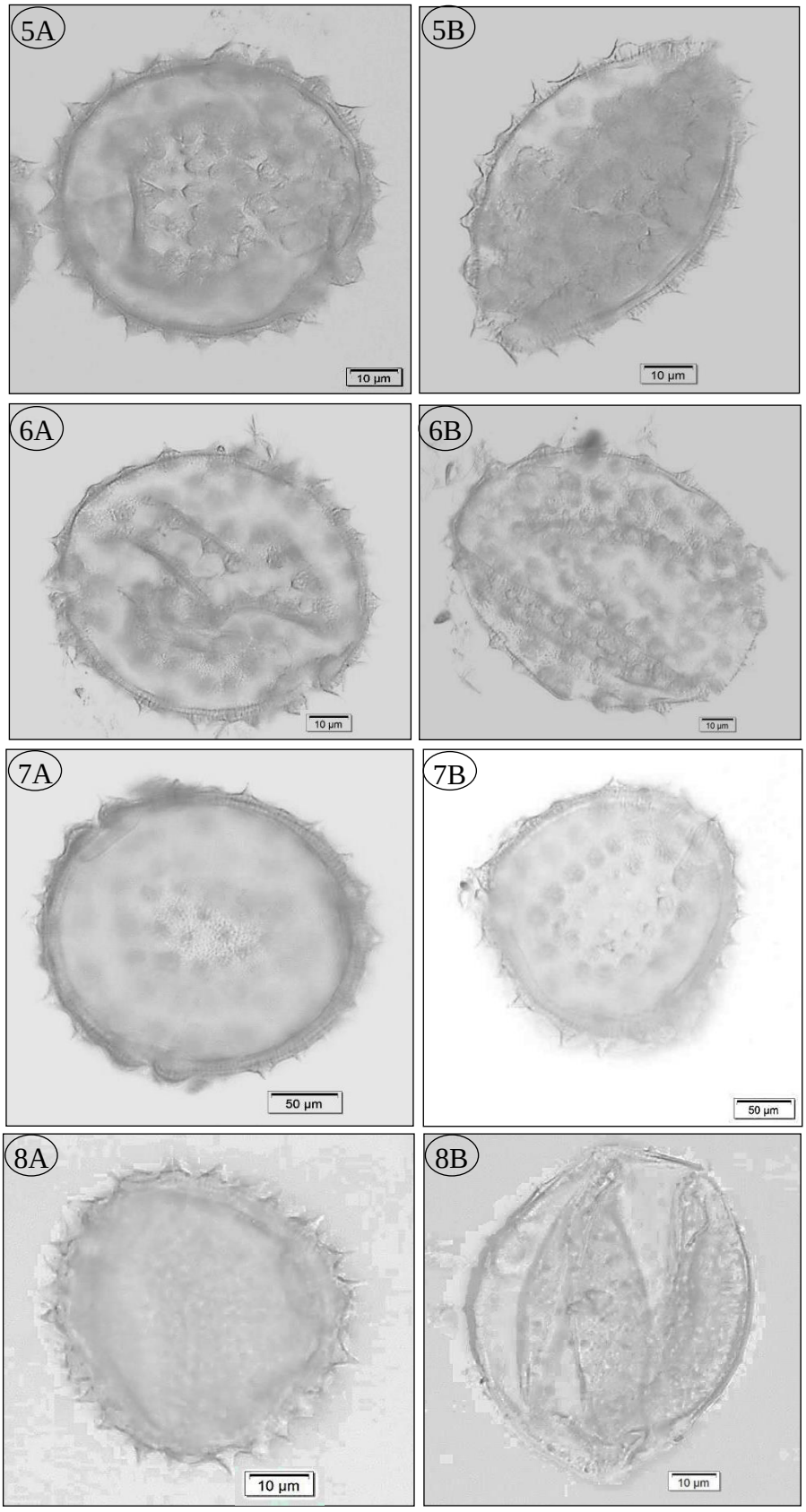

Fig 3. LM micrographs of pollen grains. (A) Polar view, (B) equatorial view. 5. *Abutilon pannosum*; 6. *Abutilon figarianum*; 7. *Abutilon fruticosum*; 8. *Abutilon ramosum*.

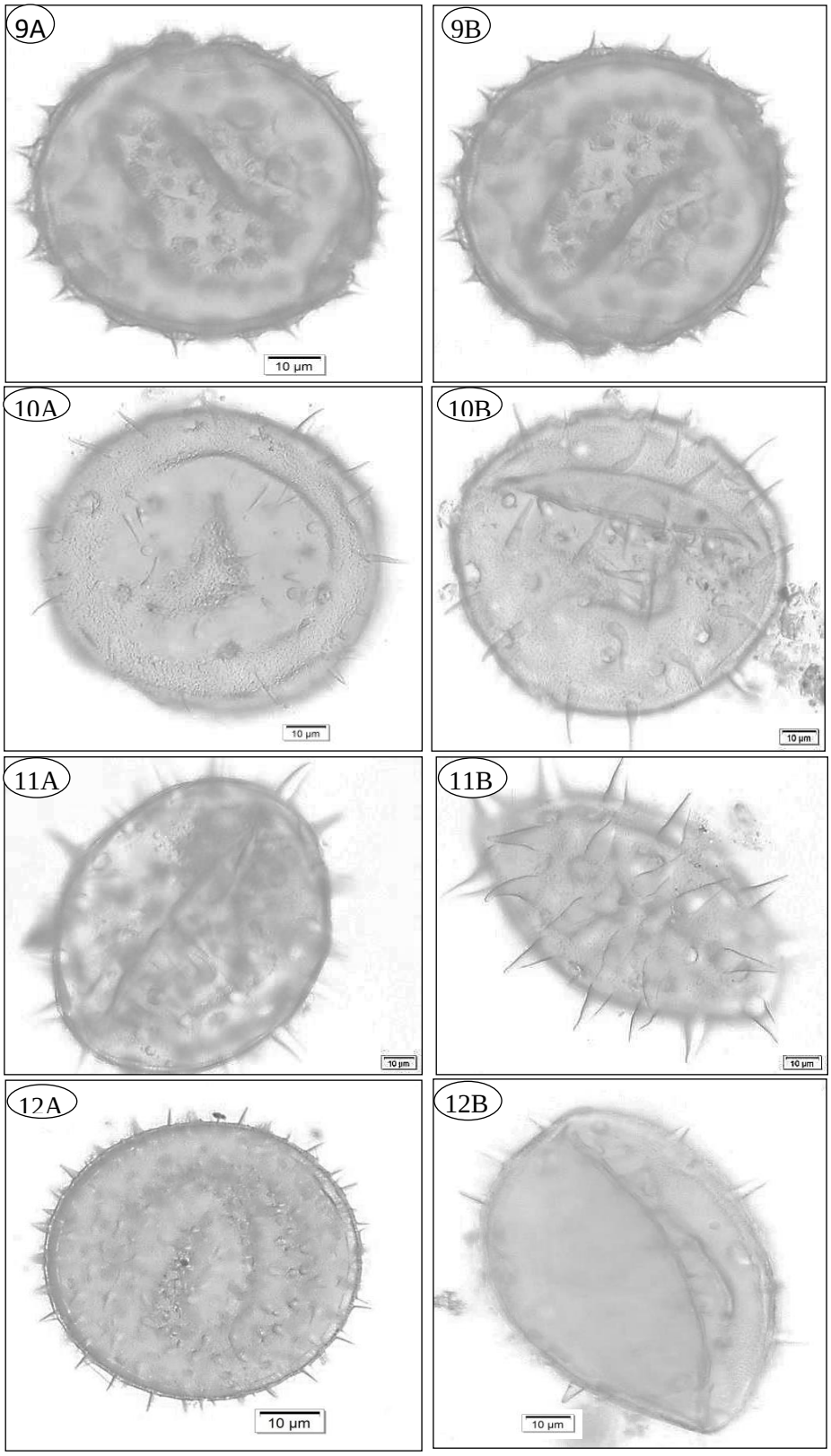

Fig 4. LM micrographs of pollen grains. (A) Polar view, (B) equatorial view. 9. *Althaea ludwigii*; 10. *Hibiscus deflersii*; 11. *Hibiscus micranthus*; 12. *Hibiscus purpureus.*

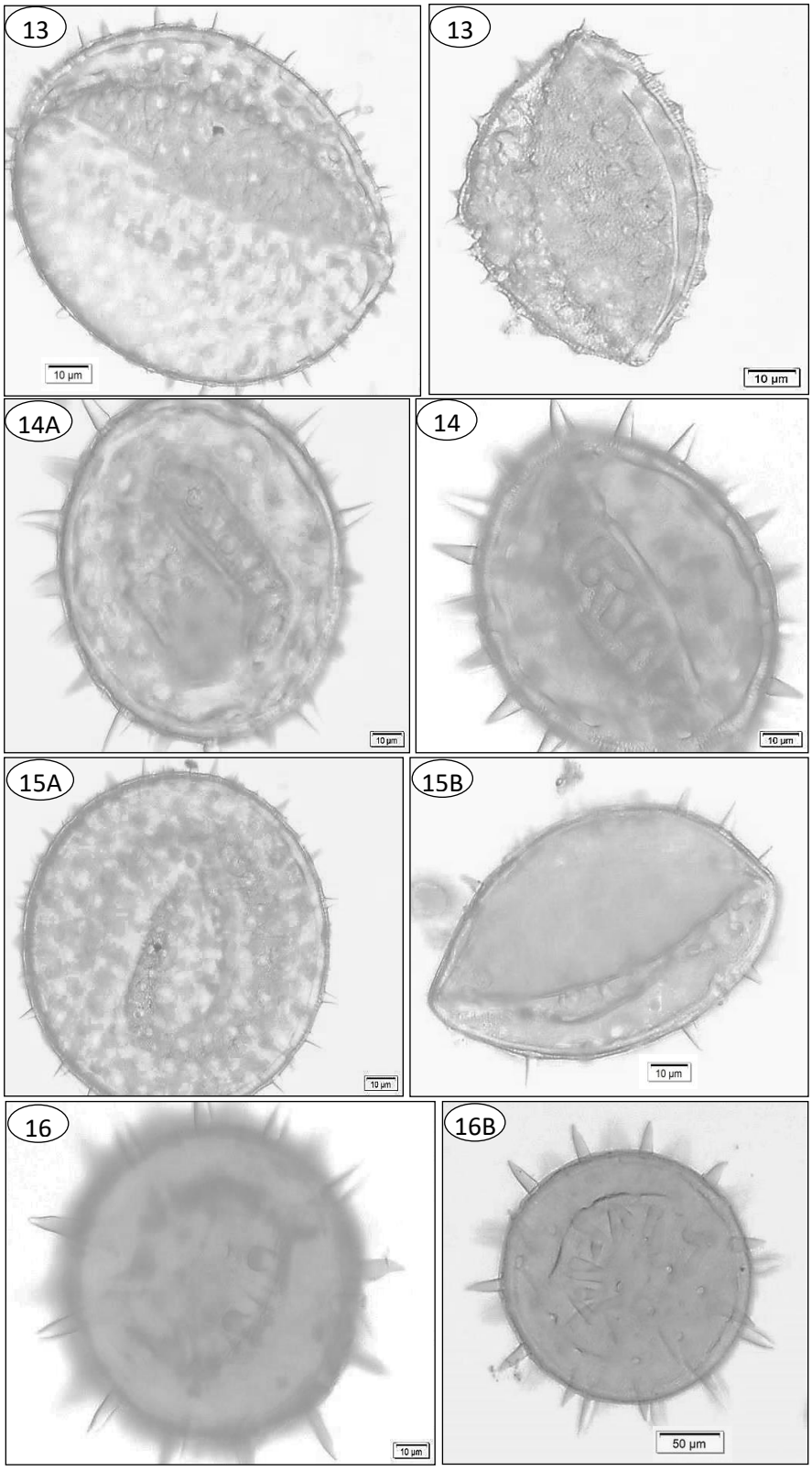

Fig 5. LM micrographs of pollen grains. (A) Polar view, (B) equatorial view. 13. *Malva neglecta*; 14. *Malva parviflora*; 15. *Malva verticillata*; 16. *Pavonia arabica*.

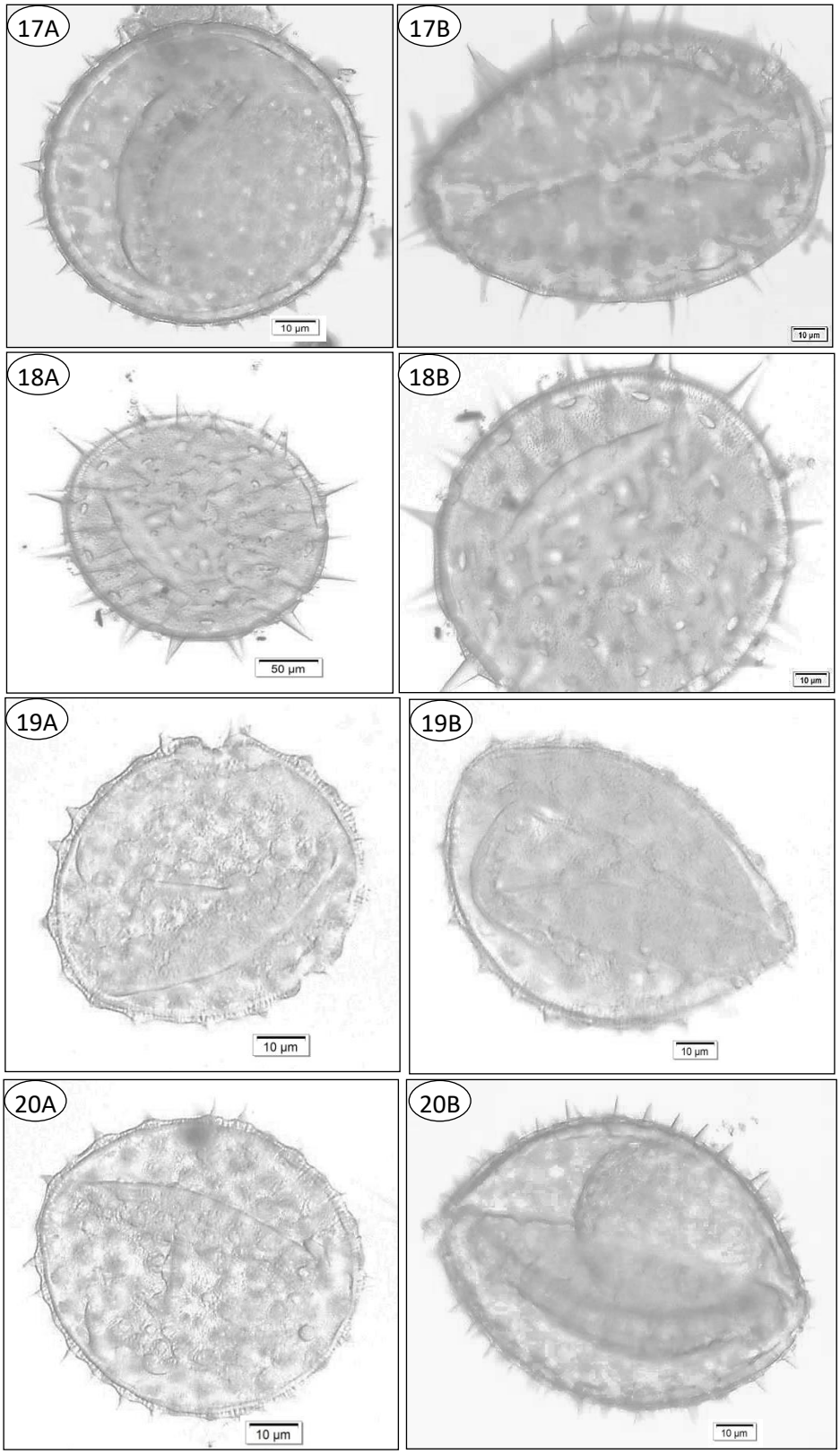

Fig 6. LM micrographs of pollen grains. (A) Polar view, (B) equatorial view. 17. *Pavonia burchellii*; 18. *Senra incana*; 19. *Sida alba*; 20. *Sida ovata.*

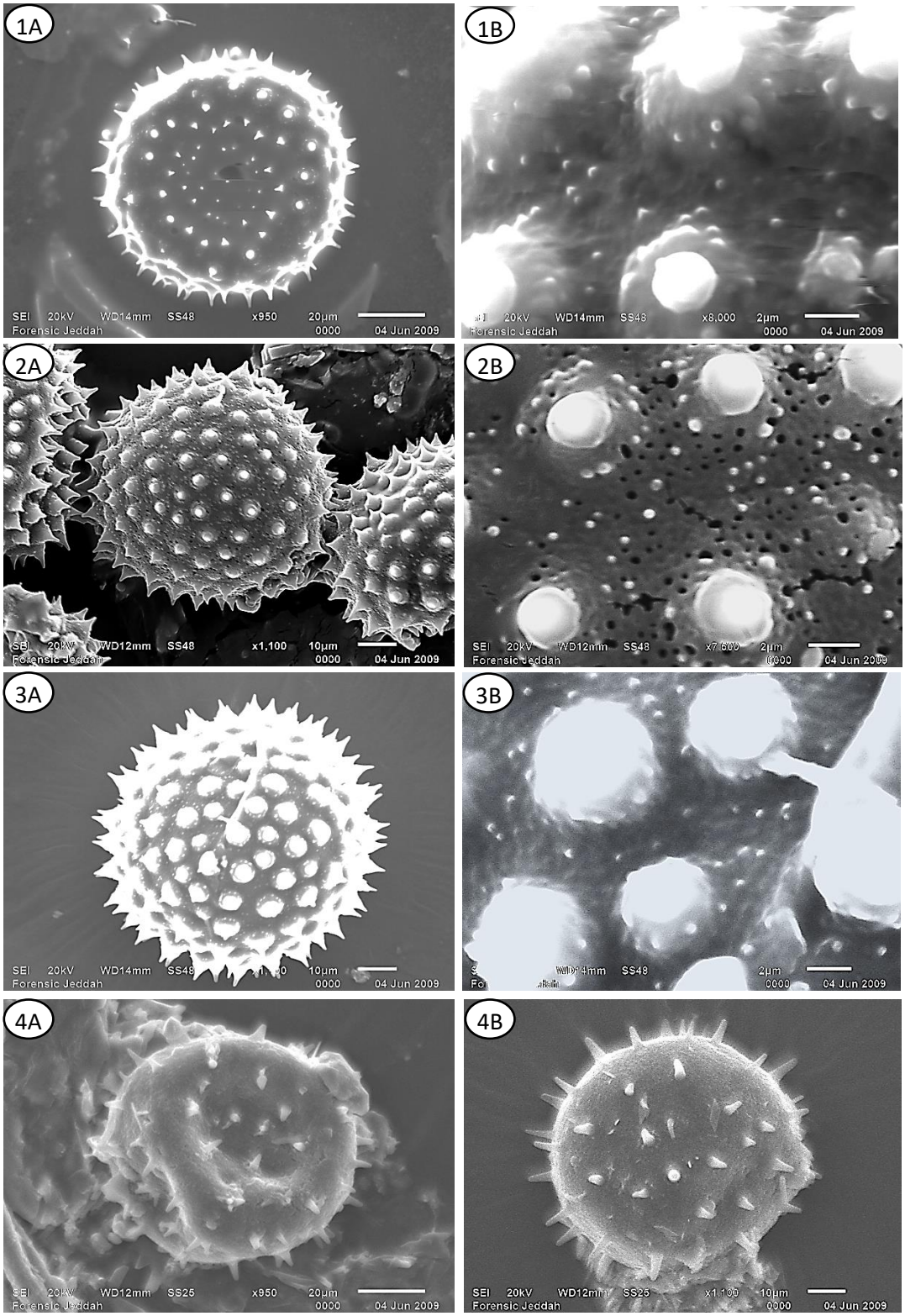

Fig 7. SEM micrographs of pollen grains. (A) entire pollen grains, (B) surface ornamentation of exine. 1. *Abutilon bidentatum*; 2. *Abutilon grandifolium*; 3. *Abutilon hirtum*; 4. *Abutilon muticum.*

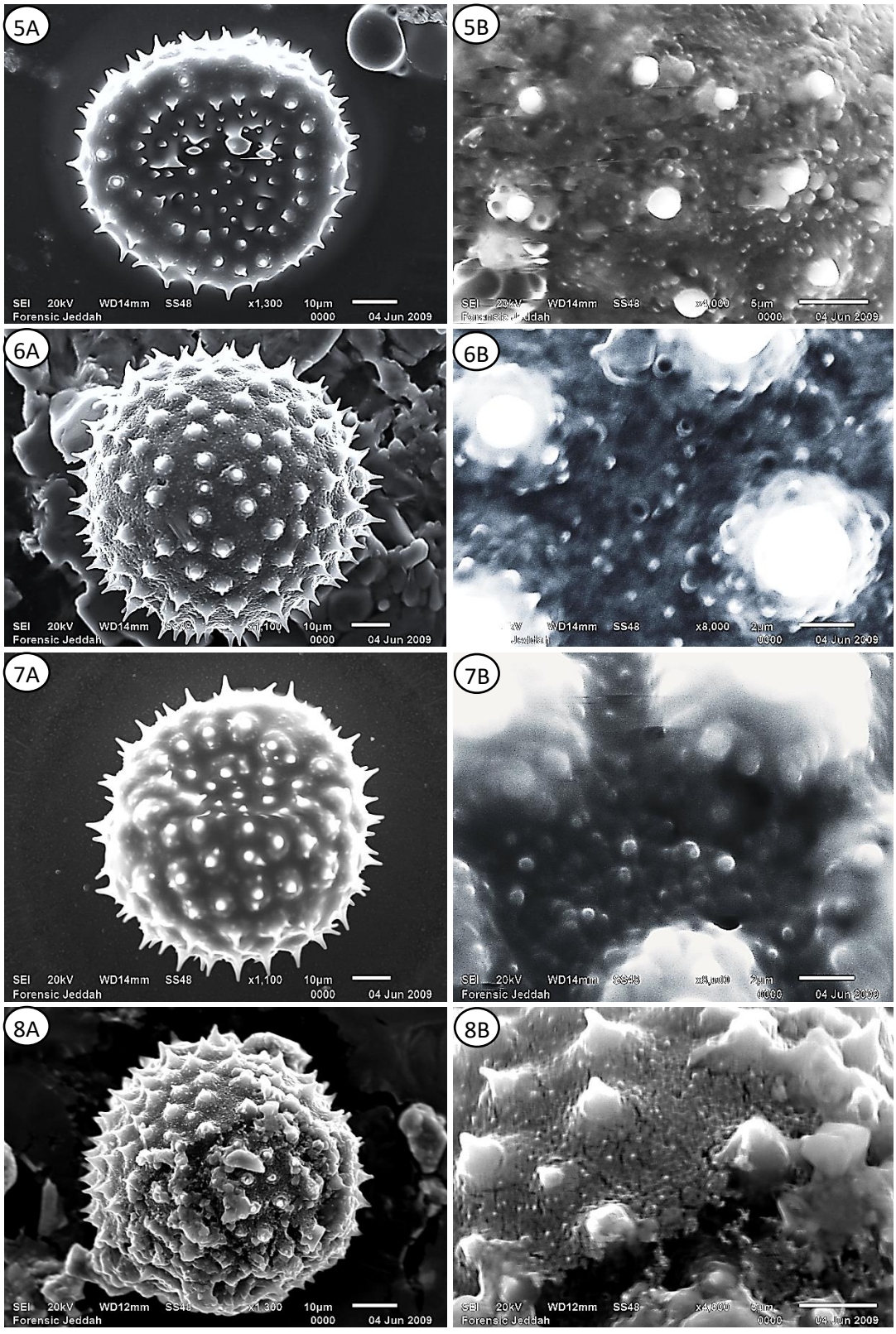

Fig 8. SEM micrographs of pollen grains. (A) entire pollen grains, (B) surface ornamentation of exine. 5. *Abutilon pannosum*; 6. *Abutilon figarianum*; 7. *Abutilon fruticosum*; 8. *Abutilon ramosum*.

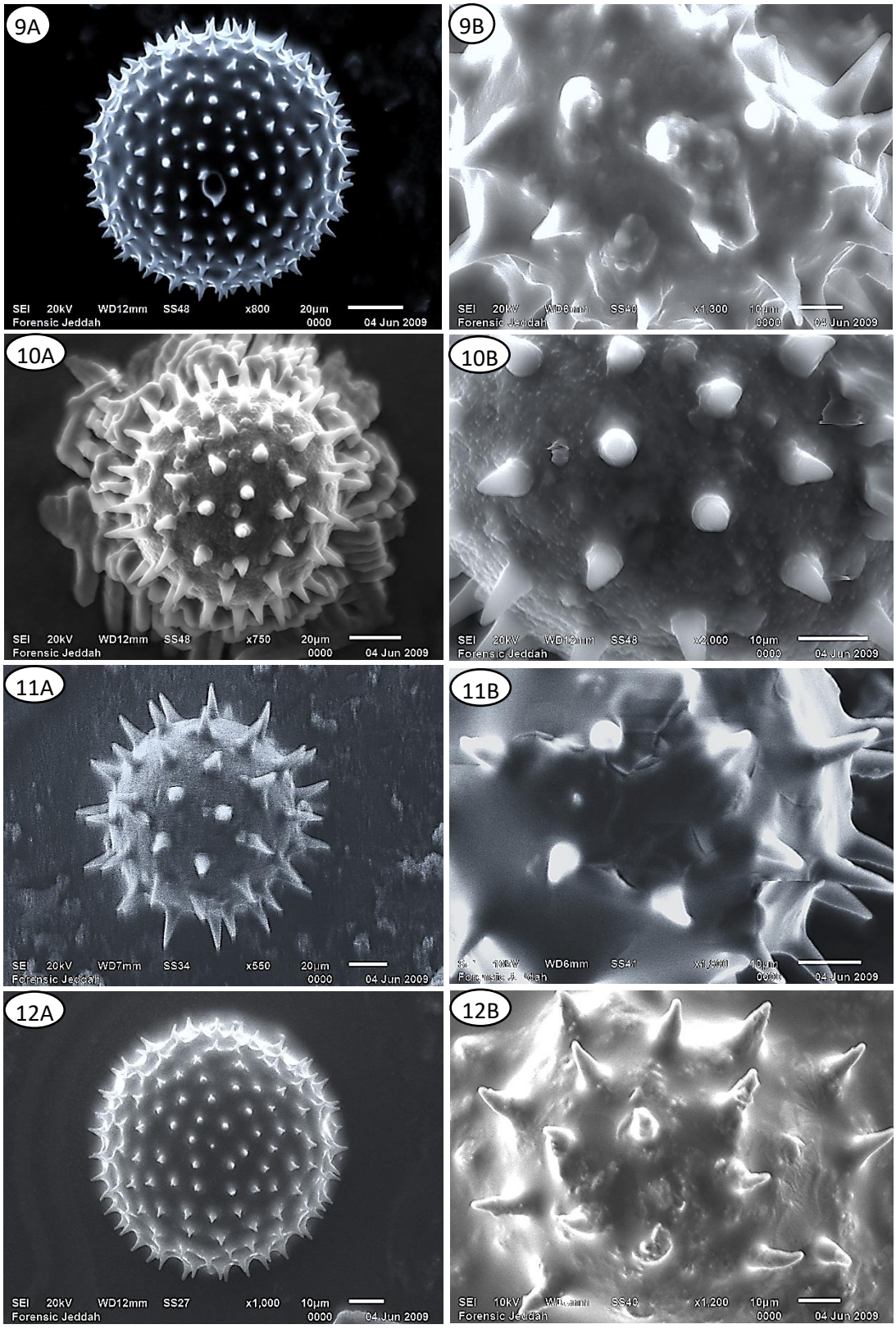

Fig 9. SEM micrographs of pollen grains. (A) entire pollen grains, (B) surface ornamentation of exine. 9. *Althaea ludwigii*; 10. *Hibiscus deflersii*; 11. *Hibiscus micranthus*; 12. *Hibiscus purpureus*.

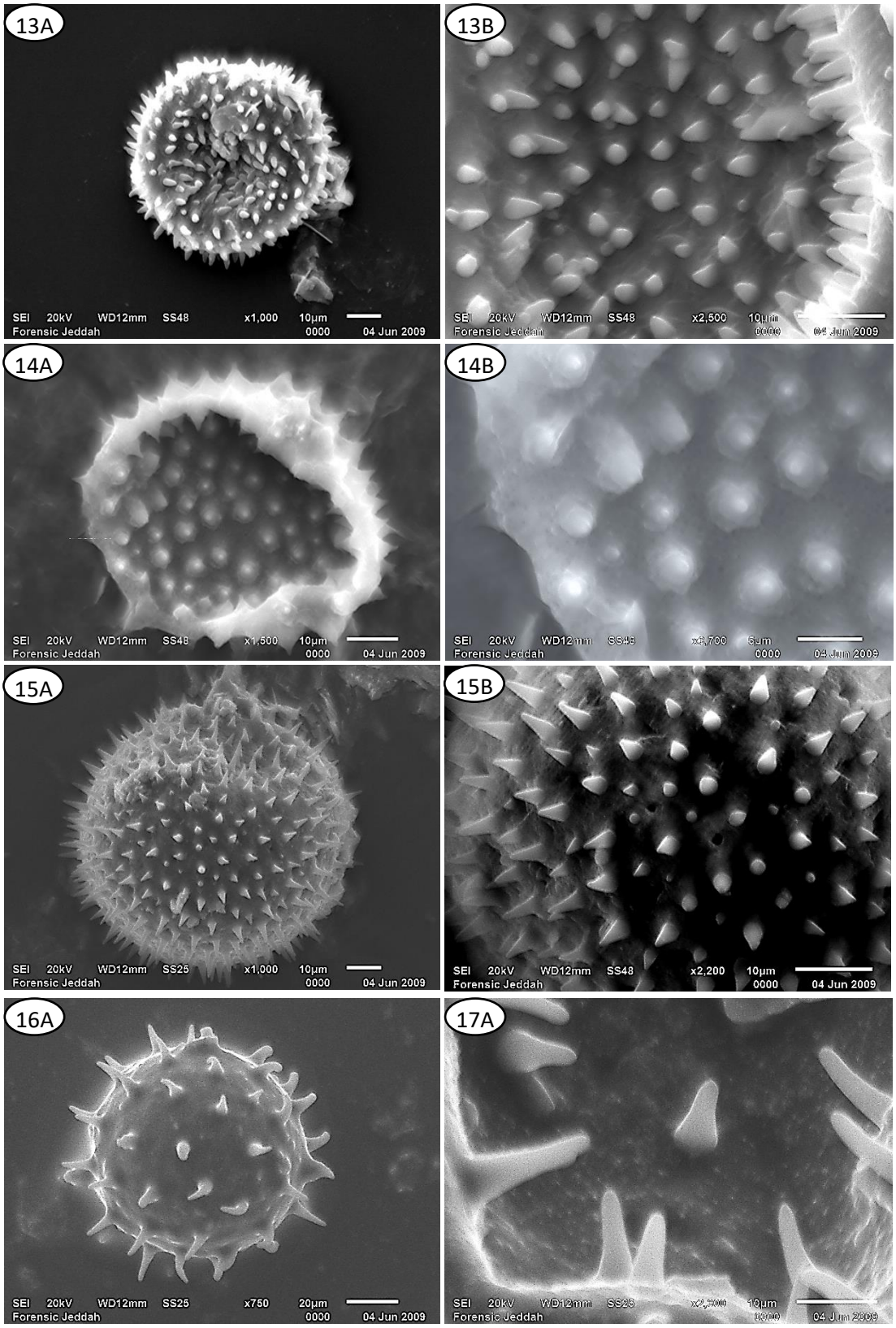

Fig 10. SEM micrographs of pollen grains. (A) entire pollen grains, (B) surface ornamentation of exine. 13. *Malva neglecta*; 14. *Malva parviflora*; 15. *Malva verticillata*; 16. *Pavonia arabica.*

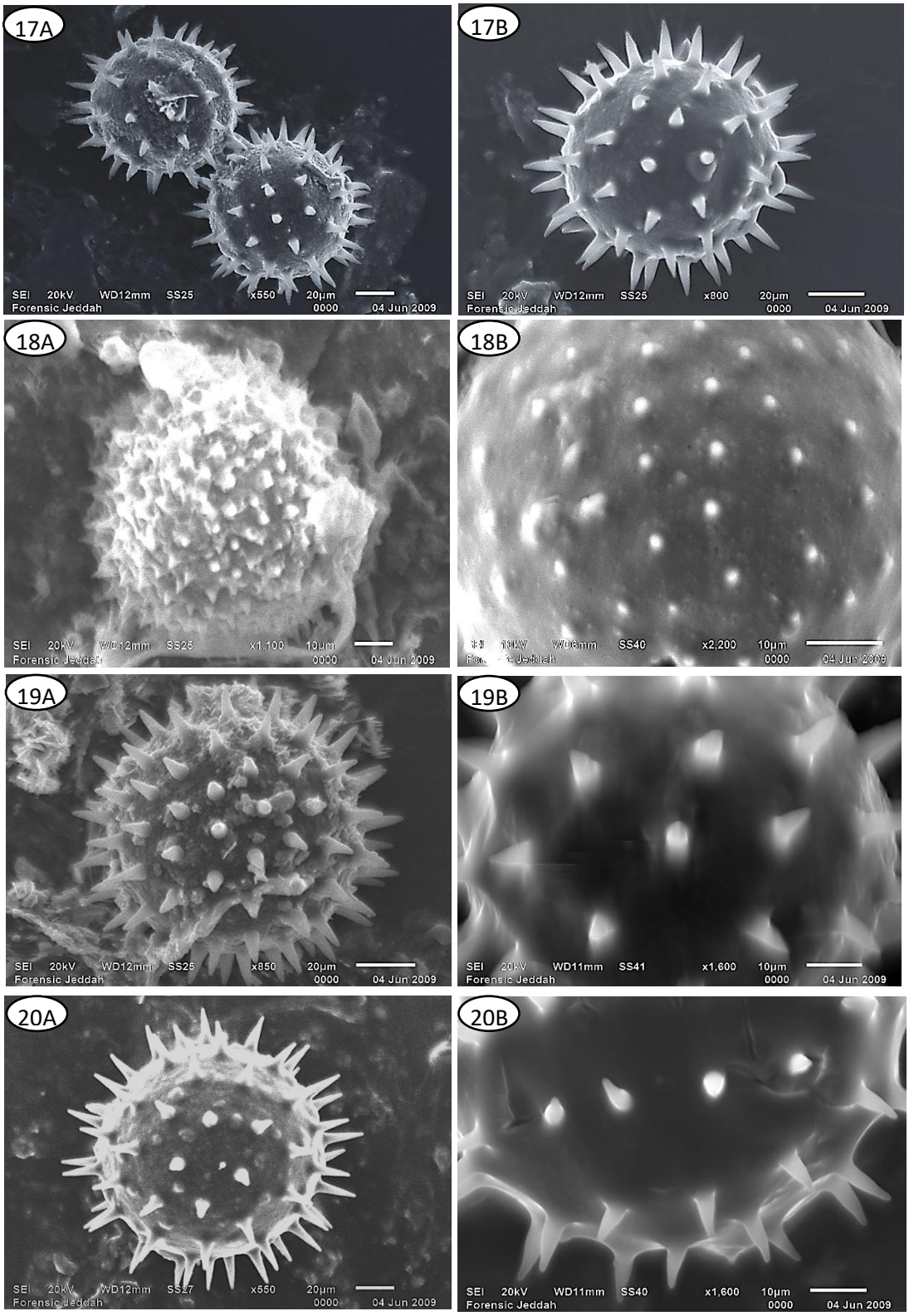

Fig 11. SEM micrographs of pollen grains. (A) entire pollen grains, (B) surface ornamentation of exine. 17. *Pavonia burchellii*; 18. *Senra incana*; 19. *Sida alba*; 20. *Sida ovata.*

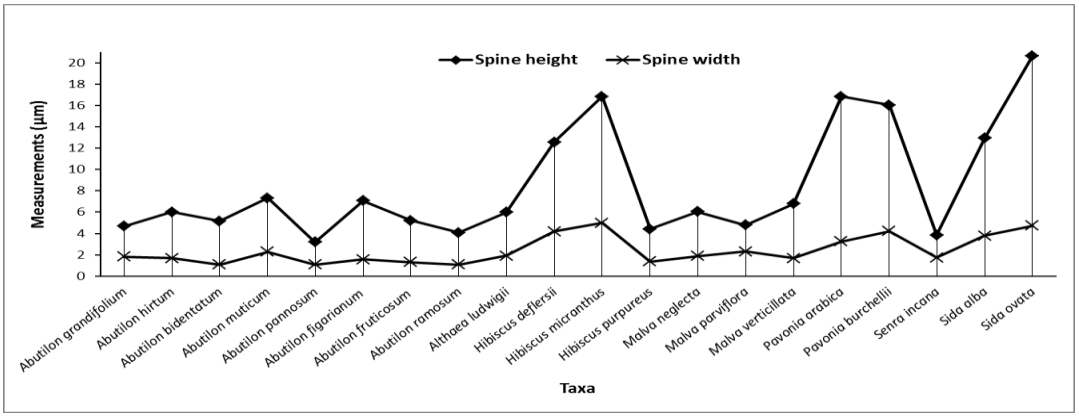

Fig. 12. Spine height and width variation among the investigated Malvaceous taxa.

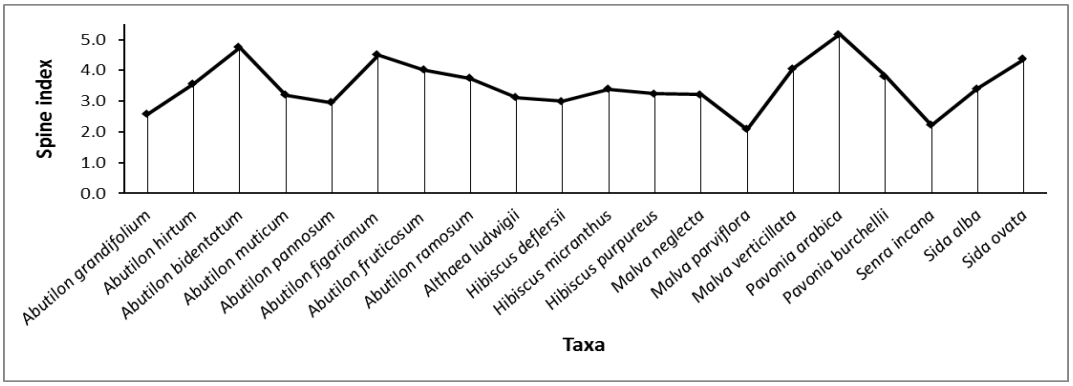

Fig 13. Variation in spine index of investigated Malvaceous taxa.

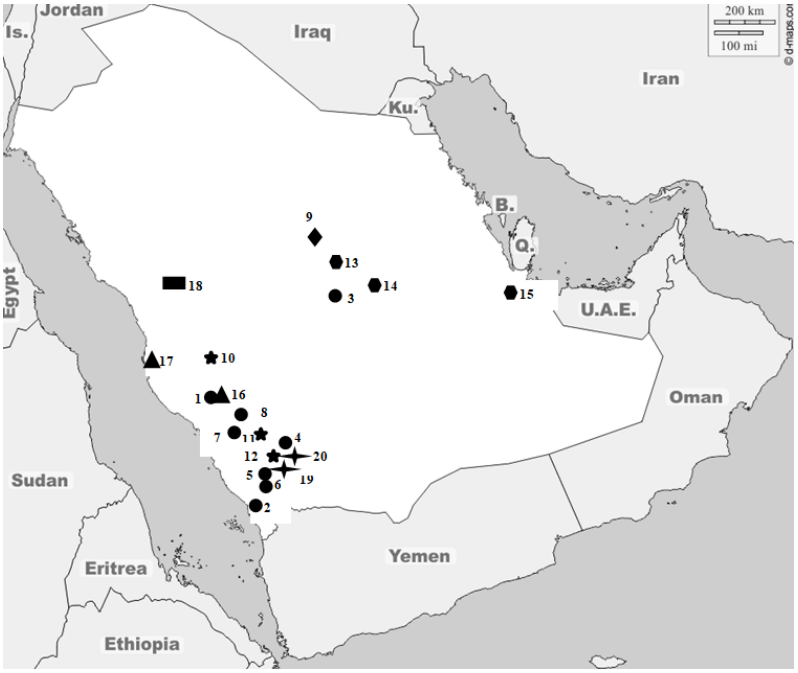

Fig 14. Location map of Malvaceae in Saudi Arabia. ●1. *Abutilon bidentatum.* 2. *Abutilon figarianum.* 3. *Abutilon fruticosum.* 4. *Abutilon grandifolium*. 5. *Abutilon hirtum.* 6. *Abutilon muticum.*7. *Abutilon pannosum.* 8. *Abutilon ramosum*◆ 9. *Althaea Ludwigii.* ★10. *Hibiscus deflersii.* 11. *Hibiscus micranthus.* 12. *Hibiscus purpureus.* ▲ 13. *Malva neglecta*. 14. *Malva parviflora.*15. *Malva verticillata* ● 16. *Pavonia arabica.* 17. *Pavonia burchelii.* ■ 18. *Senra incana.* ✦ 19. *Sida alba.*20. *Sida ovata*.

features of both tribes could be explained by parallel evolution.

The pollen grains of genus *Malva* characterized by relatively medium size ranging from (~52.28 µm) in *Malva parviflora* to (~82.2 µm) in *Malva verticillata* (Table 2; Fig. 5, 13-15). Pollen grain shape was found to be useful in discriminate *Malva parviflora* from the other closely related studied species. However, *Malva parviflora* has suboblate shape, while *Malva neglecta* and *Malva verticillata* have oblate spheroidal (Table 2 and Fig. 1).

Althaea ludwigii characterized by relatively large pollen grain size (~101.62 µm), Prolate spheroidal in shape, polypantoporate, average height of spine is about (6.00 µm) and 3.12 µm spine index (Table 2; Fig 4, 9; Fig. 9, 9).

The pollen grains of *Senra incana* characterized by relatively small size among investigated taxa (~69.52 µm); Spheroidal in shape, Polypantoporate, average height of spine is about (3.86µm) and 2.22 spine index (Table 2; Fig. 6, 18; Fig. 11, 18).

The current findings agree with those of Perveen et al., (1994), El Naggar (2004), and Hosni and Araffa (1999) that pollen grain in Malvaceae are usually spheroidal or globular in outline and are colporate or porate with an echinate sculpture. Tectum uniformly echinate with monomorphic spine in most of the taxa.

Materials and Methods

The present study is based on the pollen morphology of 20 wild taxa belonging to seven genera of family Malvaceae. Samples of pollen of each species were collected from living material or herbarium specimens (Table 1, Fig. 14).

For light microscopy (LM) pollen grains were acetolysed according to Erdtman (1952) and Reitsma (1969). Before acetolysis the pollens were treated with 10 % KOH for about 10 minutes to remove the oils and waxes to open the apertures and making them easier to study. Pollen grains were then mounted in safranin-stained glycerin jelly and micro morphological observations were made with Olympus type BH-2. Photomicrographs were taken with Olympus photomicroscope

For Scanning Electron Microscopy (SEM) acetolysed pollen grains were directly transferred to aluminum stub covered with double sided cello tape and the stubs were sputter-coated with gold for 5 min in an E1100 (Polaron Equipment). After coating, the specimens were examined with a Jeol JSM 5200 scanning electron microscope and using accelerating voltages at 20–25 KV. All photomicrographs were taken at the central laboratory of Forensic Criminal evidence-Ministry of Interior, Jeddah, Saudi Arabia. The measurements were based on 15-20 readings from each specimen. Various pollen characters viz. pollen class, shape, size, aperture, and exine ornamentation were investigated and the terminology used is in accordance with (Erdtman, 1952; Kremp, 1965; Huang, 1972; Faegri and Iverson, 1975).

Conclusion

The pollen morphology of the investigated taxa of the *Malvaceae* suggests that some characters are of a high taxonomic value and can be useful in evaluating the taxonomic relationships among the studied species. These include pollen polarity, symmetry, size, shape, polar axis, equatorial diameter, *P/E* ratio, average height and width of spine, aperature character and spine index. Palynological markers can be used as a reliable tool to delimit *Abutilon, Hibiscus* and *Sida* at generic level. It is further concluded that data from palynological studies is of significant taxonomic importance and must be integrated with traditional morphology-based classification to delimit different taxa at the specific level.

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