Pollen morphology of subfamily Malvoideae (Malvaceae sensu lato) in Thailand

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Abstract. Saensouk S, Saensouk P. 2021. Pollen morphology of subfamily Malvoideae (Malvaceae sensu lato) in Thailand. Biodiversitas 22: 5633-5643. The pollen morphology of 19 species with eight variants and ten genera of subfamily Malvoideae (Malvaceae sensu lato) were investigated by light and scanning electron microscopy. The pollen was monad, spheroidal shaped and 45.64-168.00 µm in size. The pollen grains of all species were pantoporate. All pollen had radial symmetry and were apolar. The spines pollen grain of the subfamily Malvoideae in Thailand can be divided into six types. The arrangement of spines on pollens in this study can be divided into two groups. The pollen had various exine sculptures (granulate, microreticulate, and subpsilate). Spines were found to be echinate, baculate, and spinule. Pollen size, aperture, exine sculpture and spine index can be used as characters to identify the subfamily Malvoideae species. Therefore, a key to the 19 species with eight variants and ten genera of subfamily Malvoideae in this study based on pollen morphology was provided. Eight species were studied for their pollen morphology for the first time.

Keywords: Malvaceae, Malvoideae, pollen morphology, Thailand

INTRODUCTION

The family Malvaceae sensu lato is a large family of herbs, shrubs and trees, comprising about 244 genera with c. 4225 species (Kew Science 2021). This large family is composed of nine subfamilies: Byttnerioideae (26 genera, 650 species), Grewioideae (25 genera, 770 species), Sterculioideae (formerly Sterculiaceae, in part; 12 genera, 430 species), Tiliioideae (formerly Tiliaceae, in part; three genera, 50 species), Dombeyoideae (c. 20 genera, c. 380 species), Bombacoidae (c. eight genera, c. 70 species), Helicteroideae: (8-12 genera, 10-90 species), Malvoideae (formerly Malvaceae; 78 genera, 1,670 species) and Bombacoideae (formerly Bombacaceae, in part; 12 genera, 120 species) that encompass the majority of the morphological and taxonomic diversity in the subfamily (Bayer et al. 1999, Bayer and Kubitzki 2003; Kew Science 2021). The largest genera in terms of the number of species include Hibiscus (300 species), Sterculia (250 species), Dombeya (250 species), Pavonia (200 species) and Sida (200 species) (Kew Science 2021).

In the most recent treatment of Malvoideae, Bayer and Kutitzki (2003) divided the subfamily into four tribes: Gossypieae, Hibisceae, Kydieae and Malvae. As considered here, tribe Malvae includes approximately 70 genera (c. 900 species) that encompass the majority of the morphological and taxonomic diversity in the subfamily.

The pollen morphology of some Malvaceae species have been studied by several researchers, namely Surova and Velieve (1984), Christensen (1986), Culhane and Blackmore (1988), El Naggar (2004), El Naggar and Sawady (2008), and Saensouk and Saensouk (2020).

Many characteristics of pollen grains, i.e., size, aperture, spine index and exine sculpture can be used to identify of the plant species. In Thailand, the pollen morphology of this family has only limited work by Saensouk and Saensouk (2020) who studied the pollen morphology of the genus Helicteres in Thailand. Therefore, the aim of this study was to study the pollen morphology of subfamily Malvoideae (Malvaceae sensu lato) in Thailand and use the pollen characters for the classification of the family.

MATERIALS AND METHODS

The pollen of 19 species with eight variants and ten genera from subfamily Malvoideae (Malvaceae sensu lato) from Thailand were studied between 2019 and 2021. The list of voucher specimens in the subfamily Malvoideae (Malvaceae sensu lato) is deposited in the Mahasarakham University Herbarium, Thailand (Table 1). Pollen grains were obtained from material fixed in 70% ethanol. Samples were analyzed using standard methods (acetylosis) described by Erdtman (1966). The pollen was studied by light microscopy (LM) and scanning electron microscopy (SEM). For LM, the pollen grains were measured for 30 grains from each individual. For the observation by SEM, the pollen grains were dried, coated with a spatter coater and observed with a scanning electron microscope, JEOL: JSM 6460 LV. Palynological terminology follows that of Erdtman (1966) and Punt et al. (1994). The spine index was the proportions between the height and width of the spine at its base.
RESULTS AND DISCUSSIONS

Tables 1 and 2 and Figures 1 and 2 show that the pollen grains in 19 species with eight variants and ten genera of the subfamily Malvoideae (family Malvaceae sensu lato) were collected from several places in Thailand. All species and specimens were reported to be generally spheroidally shaped, with radials symmetrical. The present study is in accordance with Perveen et al. (1994) and El Naggar (2004) that the pollen grains in Malvaceae are usually spheroidal and prolate or colporate with an echinate sculpture. At the same time, only spheroidal with echinate sculpture pollen grains were recognized by Christensen (1986) and Bibi et al. (2008, 2010). The sizes of the pollen grains ranged between 45.64-214.50 µm. The pollen sizes of the spines ranged from 3.33 (Abutilon × hybridum) to 23.74 (Decaschistia siamensis) µm. The spine indexes ranged from 0.76 (Abutilon × hybridum) to 3.08 (Abelmoschus esculentus) µm. The pollen size, aperture, exine sculpture and spine index can be used as characters to identify the subfamily of Malvoideae species.

Table 1. Specimens from 19 species with eight variants, ten genera were investigated and all specimens investigated are deposited at Mahasarakham University Herbarium, Thailand.

| Species                          | Voucher   | Location (Provinces) |
|----------------------------------|-----------|----------------------|
| Abelmoschus esculentus (L.) Moench | P. Saensouk 01/56 | Maha Sarakham       |
| A. moschatus Medik.              | P. Saensouk 02/56 | Maha Sarakham       |
| Abutilon × hybridum Voss         | P. Saensouk 03/56 | Nakhon Phanom       |
| Ab. hirtum (Lam.) Sweet          | P. Saensouk 04/56 | Sakon Nakhon        |
| Ab. indicum (L.) Sweet           | P. Saensouk 05/56 | Khon Kaen            |
| Bombbycidendron greviolifolium (Hassk.) Zoll. & Moritzi | P. Saensouk 10/56 | Chiang Mai           |
| Decaschistia siamensis Craib      | P. Saensouk 06/56 | Petchabun           |
| Gossypium barbadense L.           | P. Saensouk 07/56 | Nong Khai            |
| Hibiscus sabdariffa L.            | P. Saensouk 08/56 | Roi-Et              |
| H. glandulifer Craib              | P. Saensouk 09/56 | Udorn Thani         |
| H. mutabilis L.                   | P. Saensouk 11/56 | Phetchaburi         |
| H. radiatus Cav.                  | P. Saensouk 12/56 | Ubonratchathani     |
| H. rosa-sinensis L. (red flower)  | P. Saensouk 13/56 | Maha Sarakham       |
| H. rosa-sinensis L. (yellow flower)| P. Saensouk 14/56 | Maha Sarakham       |
| H. rosa-sinensis L. (pink flower) | P. Saensouk 15/56 | Maha Sarakham       |
| H. rosa-sinensis L. (orange flower)| P. Saensouk 16/56 | Maha Sarakham       |
| H. surattensis L.                 | P. Saensouk 17/56 | Suratthani           |
| H. vitifolius L.                  | P. Saensouk 18/56 | Kalasin             |
| Malaviscus arboreus Dill. ex Cav. (red flower) | P. Saensouk 19/56 | Nonthaburi          |
| M. arboreus Dill. ex Cav. (white flower) | P. Saensouk 20/56 | Nonthaburi          |
| Sida cordifolia L. (small leaf)   | P. Saensouk 21/56 | Kalasin             |
| S. cordifolia L. (large leaf)     | P. Saensouk 22/56 | Kalasin             |
| Thespesia populnea (L.) Sol. ex Corrêa | P. Saensouk 23/56 | Nakhon Ratchasima   |
| Urena lobata L.                   | P. Saensouk 24/56 | Khon Kaen            |

General description of subfamily Malvoideae pollen morphologies in Thailand

Description: Pollen grains aperture pantoporate, apolar, radial symmetry, spheroidal. Exine sculpturing granulate, microreticulate, and subpsilate. Spines echinate, baculate, and spinule. The spine shape apex sharp-pointed or blunt, length 23.74-3.33 µm, width 10.53-3.22 µm. Spines and apertures are arranged horizontal regulation, random - the spine index 3.08-0.76 (Table 2, Figures 1 and 2).

The aperture of pollen in the subfamily Malvoideae from Thailand

The aperture of pollen in subfamily Malvoideae from Thailand in this study was presented pantoporate (Figures 1 and 2). Therefore, this character cannot be used for identification in this study.

Exine sculpturing of pollen grain in subfamily Malvoideae in Thailand

Various exine sculpturing forms on pollens of all species from the subfamily Malvoideae in this study were reported. Therefore, it can be separated into two exine sculptures, i.e. granulate, microreticulate, and subpsilate. Five species – Abutilon × hybridum, H. glanduliferus, H. mutabilis, Sida cordifolia (large leaf), and Urena lobata had been found microreticulate on exine sculpture. Whereas the exine sculpture pollens of remaining taxa were found to be subpsilate (Table 2). However, Bibi et al. (2010) reported exine sculpture or tectum sculpture between the spines of family Malvaceae, which was microreticulate-punctuate, granulate, punctuate, subpsilate, smooth, sub echinate and verrucate.
The spine of pollen from the subfamily Malvoideae in Thailand

The spines of all taxa in this study were found echinate, baculate, and spinule. The spinule was found in *Abelmoschus esculentus*, *A. moschatus*, *Abutilon hirtum*, *Bombycidendron grewilli*-*folium*, *Decaschistia siamensis*, *Hibiscus sabdarif*-*fa*, *I. H. glanduliferus*, *K. H. mutabilis*, *L. H. radiates*, *M. H. rosa-sinensis* (red flower), *N. H. rosa-sinensis* (yellow flower), O. H. rosa-sinensis (pink flower), P. H. rosa-sinensis (orange flower), Q. H. surattensis, R. H. vitifolius*, *Malvaviscus arboreus* (red flower), T. M. arboreus (white flower), U. *Sida cordifolia* (small leaf), V. S. cordifolia (large leaf), W. *Theespesia populnea*, X. *Urena lobata*.) Scale bars = 40 µm.

The spine of pollen from the subfamily Malvoideae in Thailand

The spine index in this study was found to be between *Abelmoschus esculentus* (3.08) and *Abutilon × hybridum* (0.76) (Table 2). Shaheen et al. (2009b) used a spine index for the first time to characterize the pollen of the genus *Malva*, and found that it was of significant taxonomic importance.

The spine types of pollen in subfamily Malvoideae in Thailand:

This study was found various spines of pollens in the subfamily Malvoideae from Thailand. Therefore, the spines pollen grain of subfamily Malvoideae in Thailand can be divided into six types (Table 2, Figures 1-2).

**Spine type 1:** The characteristic was not broad at the base. The width of the spiny base is similar to the apex spiny, gradually tapering towards an apex with a blunt tip. Six species were recorded in the type, namely *Abelmoschus esculentus* (Figures 1A, 2A1-A2), *Hibiscus radiates* (Figures 1L, 2L1-L2), *H. rosa-sinensis* (red flower) (Figures 1M, 2M1-M2), *H. rosa-sinensis* (orange flower) (Figures 1P, 2P1-P2), *Malvaviscus arboreus* (red flower) (Figures 1S, 2S1-S2) and *Urena lobata* (Figures 1X, 2X1-X2).

**Spine type 2:** The characteristic was broad at the base, gradually tapering towards the apex with a more or less acute tip, i.e. *Abutilon × hybridum* (Figures 1C, 2C1-C2), *Ab. indicum* (Figures 1E, 3E1-E2), *Gossypium bazzillien*-*se* (Figures 1H, 2H1-H2), *Hibiscus mutabilis* (Figures 1K, 2K1-K2), *H. surattensis* (Figures 1Q, 2Q1-Q2), *Sida cordifolia* (small leaf) (Figures 1U, 2U1-U2), *S. cordifolia* (large leaf) (Figures 1V, 2V1-V2) and *Theespesia populnea* (Figures 1W, 2W1-W2) were recognized in this spine type.

**Spine type 3:** The characteristic was not broad at the base. The width of the spiny base is similar to the apex spiny, gradually tapering towards an apex with a more or less acute tip. Five species (*Abelmoschus moschatus* (Figures 1B, B1-B2), *Abutilon hirtum* (Figures 1D, 2D1-D2), *Bombycidendron grewilli*-*folium* (Figures 1F, 2F1-F2), *Decaschistia siamensis* (Figures 1G, 2G1-G2), *H. rosa-sinensis* (pink flower) (Figures 1O, 2O1-O2), and *H. vitifolius* (Figures 1R, 2R1-R2) were found in this spine type.

**Spine type 4:** The characteristic was concave at the base, gradually tapering towards the apex with a more acute tip, like drops of water. Only *Hibiscus sabdariffa* (Figures 1I, 2I1-I2) was recognized in this spine type.

**Spine type 5:** The characteristic was broad and spread flat at the base, gradually tapering towards the apex with a more acute tip. Only *Hibiscus glanduliferus* (Figures 1J, 2J1-J2) was recognized in this spine type.

**Spine type 6:** The characteristic was broad at the base, gradually tapering towards an apex with a blunt tip. Two species, *Hibiscus rosa-sinensis* (yellow flower) (Figures 1N, 2M1-M2) and *Malvaviscus arboreus* (white flower) (Figures 1T, 2T1-T2), were reported in this spine type.
Figure 3. SEM micrographs of pollen grains of: A1-A2. Abelmoschus esculentus, B1-B2. A. moschatus, C1-C2. Abutilon × hybridum, D1-D2. Ab. hirtum, E1-E2. Ab. idicum, F1-F2. Bombycidendron grewiifolium, G1-G2. Decaschistia siamensis, H1-H2. Gossypium barbadense, I1-I2. H. glanduliferus, K1-K2. H. mutabilis, L1-L2. H. Radiatus, M1-M2. H. rosa-sinensis (red flower), N1-N2. H. rosa-sinensis (yellow flower), O1-O2. H. rosa-sinensis (pink flower), P1-P2. H. rosa-sinensis (orange flower), Q1-Q2. H. surattensis, R1-R2. H. vitifolius, S1-S2. Malvaviscus arboreus (red flower), T1-T2. M. arboreus (white flower), U1-U2. Sida cordifolia (small leaf), V1-V2. S. cordifolia (large leaf), W1-W2. Thespesia populnea, X1-X2. Urena lobata

**Arrangement of spines of pollen grain in subfamily Malvoideae in Thailand:**

The arrangement of spines on the pollen in this study could be divided into two groups, i.e., Group A and Group B (Table 2).

**Group A:** Spines and apertures were arranged horizontal regulation. *Bombycidendron grewiifolium* and *Hibiscus rosa-sinensis* (pink flower) were recognized in this group.

**Group B:** Spines and apertures were arranged randomly. All species and all samples except *Bombycidendron grewiifolium* and *Hibiscus rosa-sinensis* (pink flower) were recognized in this group.

**Pollen shape**

The shape of the pollen grains was spheroidal in all taxa. These results agree with those of Christensen (1986), Perveen et al. (1994), El Naggar (2004), Babi et al. (2008) and Shaheen et al. (2009a, b). Shaheen et al. (2009b) studied the pollen shape of *Abutilon*, which was sub-oblate to oblate-spheroidal (Table 2).

**Pollen size**

The pollen sizes of this study was found medium (1 species), large (8 species), very large (10 species with 6 variants) and gigantic (1 species) (Table 2). All pollens in
this study were ranged from 45.64 (Abutilon indicum)-214.50 (Thespesia populnea) µm, which differed from the report of Tahavi (2000) that Hibiscus pollen was the largest among all the genera of the family. Bibi et al. (2008) reported that the pollen grains of Malvaviscus arboreus had the largest pollen size.

**Genus Abelmoschus:** The pollen size in this study was 61.73-109.25 µm (A. esculentus and A. moschatus) (Table 2). Christensen (1986) found the pollen size of Abelmoschus crinitus was 122 x 127 µm, which was larger than in this study. On the other hand, Bibi et al. (2010) reported the pollen size of A. esculentus as 160 x 140 µm.

**Genus Abutilon:** The pollen size of the three species in this genus (Table 2) was 45.64-127.10 µm. Christensen (1986) recognized a pollen size of five species, including A. hirtum (47x43 – 75x66 µm), which was smaller than this study (A. hirtum = 127.10 µm). Moreover, Bibi et al. (2010) investigated the pollen size of Ab. indicum (69 µm), which was smaller than in this study (Table 2). Shaheen et al. (2009b) reported the smallest pollen size from the polar axis of Abutilon mollae (37.5 µm); similar to that of El Naggar (2004) who reported the smallest pollen size of A. theophrasti (37µm), but in this study, the smallest pollen size was 45.64 µm in Ab. indicum. Therefore, the smallest pollen size in the family Malvaceae was the pollen in the genus Abutilon.

**Genus Bombbycidentron:** The very large pollen size was 126.20 µm, which was found only in Bombbycidentron greviifolium. This is the first report of this.

**Genus Decaschistia:** The very large pollen size was found in this study (Decaschistia siamensis = 112.60 µm). This study was similar to the report of Christensen (1986).

**Genus Gossypium:** There was only one species in this study of pollen size (G. barbadense = 78.60 µm). Christensen (1986) studied the pollen size of G. hirsutum (79 x 77 µm).

The genus Hibiscus: The pollen morphology of the genus Hibiscus was apolar according to previous studies by Perveen et al. (1994) and El Naggar (2004), while El Naggar (2004) investigated the pollen size of H. rosa-sinensis as 73-75 µm, but it differs from this study. Perveen et al. (1994) also reported the pollen size of the genus Hibiscus, which was 87.3-116.6 µm. Christensen (1986) studied the pollen of Malvaceae and found that the pollen size of Hibiscus (14 species examined including H. sabdariffa and H. surattensis) is 83-115 µm differs from this study (74.17-151.42 µm) due to the effect of different regions and environments such as air, soil, humid or moist. Babi et al. (2010) described pollen size of the genus Hibiscus ranging from 124-169 µm but the pollen size of H. rosa-sinensis is 124-165 µm. Shaheen et al. (2009a, b) studied pollen of the genus Hibiscus ranging from 80-170 µm. The present studies are also agree with the previous authors and reported the pollen size of the genus Hibiscus in the range of 74.17-151.42 µm. At the same time, in H. rosa-sinensis range from 109-151.42 µm. Therefore, the size of pollen H. rosa-sinensis is related to variation in species.

**Genus Hibiscus:** The pollen morphology of the genus Hibiscus was apolar according to previous studies by Perveen et al. (1994) and El Naggar (2004), while El Naggar (2004) investigated the pollen size of H. rosa-sinensis as 73-75 µm, but it differs from this study. Perveen et al. (1994) also reported the pollen size of the genus Hibiscus, which was 87.3-116.6 µm. Christensen (1986) studied the pollen of Malvaceae and found that the pollen size of Hibiscus (14 species examined including H. sabdariffa and H. surattensis) is 83-115 µm differs from this study (74.17-151.42 µm) due to the effect of different regions and environments such as air, soil, humid or moist. Babi et al. (2010) described pollen size of the genus Hibiscus ranging from 124-169 µm but the pollen size of H. rosa-sinensis is 124-165 µm. Shaheen et al. (2009a, b) studied pollen of the genus Hibiscus, which ranged from 80-170 µm. The present study agrees with previous authors who reported the pollen size of the genus Hibiscus in the range of 74.17-151.42 µm. H. rosa-sinensis was in the range from 109-151.42 µm. Therefore, the size of the pollen of H. rosa-sinensis was related to the variation in the species.

**Genus Malvaviscus:** The results from the Table 2 show the very large pollen sizes of Malvaviscus arboreus with two variants, i.e. red flower (168 µm) and white flower (149.75 µm) have been studied according to in the previous study by Babi et al. (2010).

**Genus Sida:** The large pollen sizes of both variants from Sida cordifolia, small leaf (82.50 µm) and large leaf (67.50 µm) have been studied, according to in the previous study by Chistensen (1986).

**Genus Thespesia:** The gigantic pollen size of Thespesia populnea ranged to 214.50 µm, according to the previous study by Chistensen (1986) but differs from Tahavi (2000) report that Hibiscus pollen was the largest among all the genera of the family. While, Bibi et al. (2008) reported the pollen grains of Malvaviscus arboreus to have the largest pollen size.

**Genus Urena:** Only Urena lobata was reported very large pollen size (115.87 µm), according to the previous study by Chistensen (1986).
Table 2. Pollen morphology data of 19 species with eight variants and 10 genera, subfamily Malvoideae (Malvaceae sensu lato) from Thailand

| Species                              | Pollen size (µm) | Aperture character | Length of spine (µm) | Width of spine (µm) | Spine index | Spine of spines type | Arrangement of spines type | Exine sculpture | Previous study       |
|--------------------------------------|------------------|--------------------|----------------------|---------------------|-------------|----------------------|-----------------------------|-----------------|---------------------|
| Abelsmoschus esculentus              | 61.73±6.85       | Large              | 23.42±2.10           | 7.62±0.72           | 3.08        | spinule              | Group B                     | subpsilate       | Bibi et al. (2010)  |
| A. moschatus                         | 109.25±5.05      | Very large         | 22.5±1.02            | 8.97±0.45           | 2.51        | spinule              | Group B                     | subpsilate       |                    |
| Abutun x hybridum                    | 65.60±5.17       | Large              | 3.33±1.20            | 4.37±0.51           | 0.76        | echinate             | Group B                     | microreticulate   |                    |
| Ab. hirtum                           | 127.10±4.52      | Very large         | 21.57±1.22           | 7.60±0.61           | 2.84        | spinule              | Group B                     | subpsilate       | Chistensen (1986)   |
| Ab. indicum                          | 45.64±2.99       | Medium             | 6.9±0.23             | 7.59±0.34           | 0.91        | echinate             | Group B                     | subpsilate       | Bibi et al. (2010)  |
| Bombicidendron greviifolium          | 126.20±4.77      | Very large         | 23.42±1.91           | 9.6±0.74            | 2.43        | spinule              | Group B                     | subpsilate       |                    |
| Decaschistia siamensis               | 112.60±2.55      | Large              | 23.74±1.02           | 10.5±0.82           | 2.25        | spinule              | Group B                     | subpsilate       | Chistensen (1986)   |
| Gossypium barbadense                 | 78.60±3.62       | Large              | 12.10±0.48           | 7.51±0.34           | 1.61        | echinate             | Group B                     | subpsilate       |                    |
| Hibiscus sabdariffa                  | 119.30±3.24      | Very large         | 12.01±0.53           | 4.56±0.21           | 2.63        | baculate             | Group B                     | subpsilate       | Chistensen (1986)   |
| H. glandulifera                      | 76.30±3.24       | Large              | 12.39±0.44           | 6.54±0.23           | 1.89        | echinate             | Group B                     | microreticulate   |                    |
| H. mutabilis                         | 74.17±4.17       | Large              | 7.25±1.37            | 4.40±0.46           | 1.65        | echinate             | Group B                     | microreticulate   |                    |
| H. radiatus                          | 109.18±6.84      | Very large         | 12.22±2.73           | 7.07±0.17           | 1.73        | baculate             | Group B                     | subpsilate       |                    |
| H. rosa-sinensis (red flower)        | 151.42±4.02      | Very large         | 15.72±1.71           | 8.63±0.84           | 1.83        | baculate             | Group B                     | subpsilate       | Bibi et al. (2010)  |
| H. rosa-sinensis (yellow flower)     | 149.75±6.48      | Very large         | 15.25±1.20           | 8.80±0.39           | 1.73        | baculate             | Group B                     | subpsilate       | Bibi et al. (2010)  |
| H. rosa-sinensis (pink flower)       | 110.42±6.86      | Very large         | 15.29±1.37           | 8.70±0.53           | 1.76        | spinule              | Group A                     | subpsilate       | Bibi et al. (2010)  |
| H. rosa-sinensis (orange flower)     | 109.00±7.12      | Very large         | 13.50±1.41           | 8.73±0.45           | 1.55        | baculate             | Group B                     | subpsilate       | Bibi et al. (2010)  |
| H. surattensis                       | 83.42±5.03       | Large              | 10.03±0.75           | 6.12±0.28           | 1.64        | echinate             | Group B                     | subpsilate       | Chistensen (1986)   |
| H. vitifolius                         | 119.08±4.07      | Very large         | 22.5±2.27            | 9.10±0.31           | 1.89        | spinule              | Group B                     | subpsilate       |                    |
| Malvaicus arbores (red flower)       | 168.00±6.93      | Very large         | 14.43±3.24           | 7.62±0.54           | 1.89        | baculate             | Group B                     | subpsilate       | Bibi et al. (2010)  |
| M. arbores (white flower)            | 149.75±6.48      | Very large         | 17.5±2.40            | 9.43±0.72           | 1.88        | echinate             | Group B                     | subpsilate       | Bibi et al. (2010)  |
| Sida cordifolia (small leaf)         | 82.50±6.09       | Large              | 8.08±1.08            | 5.10±0.20           | 1.58        | echinate             | Group B                     | microreticulate   | Chistensen (1986)   |
| S. cordifolia (large leaf)           | 67.50±5.84       | Large              | 6.8±1.12             | 6.19±0.25           | 1.10        | echinate             | Group B                     | granulate        | Chistensen (1986)   |
| Thespiesia populnea                  | 214.50±5.55      | Gigantic           | 11.42±2.15           | 3.22±0.36           | 2.29        | echinate             | Group B                     | subpsilate       | Chistensen (1986)   |
| Urena lobata                         | 115.87±5.56      | Very large         | 15.00±1.14           | 7.60±0.61           | 1.97        | baculate             | Group B                     | microreticulate   | Chistensen (1986)   |
Key to species based on pollen morphology

It is constructed base on pollen morphology as below:

1. Arrangement of spines Group A ........................................ 2
   Arrangement of spines Group B ........................................ 3
2. Spine index 2.43 ...................................................... Bombycidentron grewiifolium
   Spine index 1.76 ........................................ Hibiscus rosa-sinensis (pink flower)
3. Exine sculpture granulate or microreticulate .......... 4
   Exine sculpture subsulcate ........................................ 8
4. Pollen very large size; spine baculate .......... Urena lobata
   Pollen large size; spine echinate .................. 5
5. Spine type 2 ...................................................... Hibiscus glanduliferus
   Spine type 5 ...................................................... Abutilon × hybridum
6. Spine index under 1.0 ................................. Abutilon × hybridum
   Spine index over 1.0 ........................................ 7
7. Exine sculpture granulate .......... Sida cordifolia (large leaf)
   Exine sculpture microreticulate .......... Hibiscus mutabilis
8. Spine spinule ...................................................... 9
   Spine baculate or echinate .................................. 13
9. Pollen very large size ........................................ 10
   Pollen large size ........................................... 11
10. Spine index under 2.0 .............................. Hibiscus vitifolius
    Spine index over 2.0 ........................................ 11
11. Pollen size under 115 µm .......................... 12
    Pollen size over 115 µm ........................... 12
12. Spine index under 2.3; Pollen size over 110 µm ....... Deucaschistia siamensis
    Spine index over 2.3; Pollen size under 110 µm ........ Abutilon hirtum
13. Spine echinate .................................................. 14
    Spine baculate ................................................ 18
14. Pollen very medium size .............................. Abutilon indicum
    Pollen large, very large or gigantic size ........ 15
15. Spine type 6 ........................ Malvaviscus arboreus (white flower)
    Spine type 2 .................................................. 16
16. Pollen gigantic size ................................ Thespesia populnea
    Pollen large or very large size ................................ 17
17. Spine length 12.10 µm; spine width 7.51 µm; spine index 1.61 ................................. Gossypium barbadense
    Spine length 10.03 µm; spine width 6.12 µm; spine index 1.64 ........................................ Hibiscus surattensis
18. Exine sculpture microreticulate .......... Sida cordifolia (small leaf)
    Exine sculpture subsulcate .......................... 19
19. Pollen size over 140 µm .......................... 20
    Pollen size over 140 µm ................................ 22
20. Spine index under 2 ................................. Hibiscus sabdariffa
    Spine index over 2 ........................... Hibiscus rosasinensis (orange flower)
21. Spine length 12.22 µm; spine width 7.07 µm; spine index 1.73 ........................ Hibiscus radiatus
    Spine length 13.50 µm; spine width 8.73 µm; spine index 1.55 ........................ Hibiscus rosa-sinensis (red flower)
22. Spine type 1 ...................................................... 23
    Spine type 6 ...................................................... Hibiscus rosa-sinensis (yellow flower)
23. Pollen size 151.42 µm; spine length 15.72 µm; spine width 8.63 µm; spine index 1.83 ........................ Hibiscus rosasinensis (red flower)
    Pollen size 168 µm; spine length 14.43 µm; spine width 7.62 µm; spine index 1.89 .... Malvaviscus arboreus (red flower)

In conclusion, the pollen morphology of 19 species with eight variants and ten genera of subfamily Malvoideae (Malvaceae sensu lato) from Thailand was studied under light and scanning electron microscopy. The pollen grains of all species were found to be monad, spheroidal in shape and 45.64-168.00 µm in size. The pollens in this study were recognized as pantoporate. All pollen grains had radial symmetry and were apolar. Exine sculpturing was granulate, microreticulate, and subsulcate. Spines were reported to be echinate, baculate, and spinule. Therefore, the spines of the pollen grains from the subfamily Malvoideae in Thailand can be divided into six types. The arrangement of spines on pollens in this study can be divided into two groups (Group A and Group B). Pollen size, aperture, exine sculpturing and spine index can be used as characters to identify the subfamily Malvoideae species. The results showed that the pollens of four variants of H. rosa-sinensis were related in many pollen morphologies but differ in the pollen size, spine type, spine indexes and exine sculpturing. For pollen morphology of both variants of Malvaviscus arboreus were closely related in many pollen morphologies of them but differs in the range of pollen size, spine type, spine indexes and exine sculpturing. While, pollen morphology of both variants of Sida cordifolia were closely related in many pollen morphologies of them but differs in the range of pollen size, spine type, and spine indexes. Eight species, i.e. Abelmoschus moschatus, Abutilon × hybridum, Bombycidentron grewiifolium, Gossypium barbadense, Hibiscus glanduliferus, H. mutabilis, H. radiates, H. vitifolius, were studied for their pollen morphology for the first time. The key to all the species in this study was based on the morphology of the pollen provided.

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