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Palynological Studies and Lectotypification of Malpighiaceae in Thailand

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ABSTRACT. – The pollen morphology of 19 species belonging to six genera of the Malpighiaceae in Thailand was examined by both light- and scanning electron microscopy. Pollen grains were found to be monad and bilateral or radial symmetry. They were apolar, isopolar or heteropolar with a high range of size from very small to medium. The shapes were oblate, oblate spheroidal, prolate spheroidal and subprolate. The ambs were triangular, quadrangular, quinquangular and subcircular. Aperture types were 3−4-colporate, 3-colporate with parasyncolporate, 4-porate, polyporate, monosulcate and trichotomosulcate. Five pollen types were proposed based on the exine sculpturing *viz*. fossulate, granulate, perforate, rugulate and verrucate types. Lectotypes for nine taxa of Malpighiaceae were herein designated, namely *Aspidopterys thorelii*, *Brachylophon anastomosans*, *Hiptage bullata*, *H. candicans*, *H. candicans* var. *angustifolia*, *H. condita*, *H. detergens*, *H. glabrifolia* and *H. lucida*.

KEYWORDS: exine sculpturing, lectotype, Malphigiales, pollen

INTRODUCTION

Malpighiaceae is a flowering plant family containing approximately 1,300 species in 77 genera (Christenhusz et al., 2017) with most of them distributed mainly in the New World while the rest about 17 genera and 150 species occurred in the Old World (Davis and Anderson, 2010). The New World species are definitely separated from the Old World species, with only two New World species scattering in both hemispheres (Anderson, 1990). For Thailand, Sirirugsa (1987, 1991) recognized six genera and 22 species, of which eight and four species were endemic and introduced as ornamental plants, respectively.

The family is generally characterized by small trees or woody climbers. Leaves are simple and usually in opposite arrangement, rarely alternate, and usually have free or fused stipules and petioles often bear glands and the glands are on the lower leaf surface. Inflorescences are racemes or panicles with usually bisexual flowers. The flower is 5-merous, the petals are typically clawed with a ciliate or fimbriate margin. The 10 stamens are equal in length or one much larger than the others are. The superior ovary has three locules and three lobes with three styles that may be free or fused into a single style. Fruits are schizocarp, splitting into samaras or drupaceous mericarps (Anderson, 1990; Sirirugsa, 1991; Shukun and Funston, 2008). Malpighiaceae has occasionally been mentioned to medicinal usage as some of which were used as the medicinal plants by local populations, such as *Galphimia glauca* used in the Mexican traditional medicine for the treatment of nervous excitement (Tortoriello and Lozoya, 1992) and *Byrsonima crassifolia*, and *B. coccolobifolia* used for healing diarrhea and dysentery in northern Brazil (Oliveira et al., 2017).

Malpighiaceae belongs to the order Malpighiales. The current study revealed that the order is the most recalcitrant group within angiosperms since it contained many greatly unstable nodes in the angiosperm phylogenetic tree (Cai et al., 2020). However, several previous molecular and systematics studies of Malpighiaceae demonstrated the monophyletic family with the para- and/or polyphyletic subfamilies, tribes and genera (Anderson, 1981; Cameron et al., 2001; Davis et al., 2001, 2002, 2004) and all tribes previously recognized (Hutchinson, 1967) were polyphyletic except the tribe Gaudichaudieae. Based on the morphological studies, the family exhibited high variation of habit, leaf surface covering, floral and fruit morphology and pollen features resulting in the existence of the infrafamilial classification and delimitation problems (Anderson, 1981).

Generally, palynological characters have been proved valuable tools for taxonomic implications. They were extensively applied to support the morphological-based classification in many plant groups because they provided informative data for supporting or improving the traditional classification system (Chantaranothai, 1997; Pornpongrungrueng and Chantaranothai, 2002; Santiago et al., 2004; Rueangsawang et al., 2013; Mehrvarz et al., 2014; Marinho et al., 2015; Mezzonato-Pires et al., 2015; Souza et al., 2017; Thammarong et al., 2019). They were also frequently combined with molecular data to describe phylogenetic relationships and to reveal lineage traces evidenced in evolutionary studies (Cameron et al., 2001; Davis et al., 2001; Chung et al., 2010; Welsh et al., 2010; Shi et

al., 2013; Cardinal-McTeague and Gillespie, 2016). In Malpighiaceae, most previous studies on palynological features were generally limited to the New World species and emphasized the significant utilization in species identification (Belonsi and Gasparino, 2015) and were used to interpret genera relationships within the family (Makino-Watanabe et al., 1998; Cameron et al., 2001; Davis et al., 2001). Example, Sebastiani et al. (2014) investigated the pollen morphological characteristics of the New World genera, *Janusia* A.Juss., *Aspicarpa* Rich., *Camarea* A.St.-Hil. and *Cotsia* Dubard and Dop. Their results revealed that pollen grains of examined species were apolar and the size varied from medium to large. The shapes were cuboidal, cuboidal-spheroidal and spheroidal with mostly 6-porate (rarely 5−9-porate). The exine ornamentation patterns were faveolate, fossulate, fossulate-perforate, perforate, psilate and rugulate. Belonsi and Gasparino (2015) worked on seven genera, *Banisteriopsis* C.B.Rob., *Byrsonima* Rich. ex Kunth, *Diplopterys* A.Juss., *Heteropterys* Kunth, *Mascagnia* (Bertero ex DC.) Bertero, *Peixotoa* A.Juss. and *Stigmaphyllon* A.Juss. and reported that their pollen grains were apolar (rarely isopolar) with small to medium sizes. The shapes varied from cuboidal to circular with their variation of apertures *viz.* 6−8-porate and 3-colporate. The exine ornamentation patterns were rugulate, micro-reticulate and psilate-rugulate. In Thailand, so far, pollen morphological study of the family has not been done and consequently, this study aims to characterize the palynological characters of Malpighiaceae in Thailand and to contribute pollen data for implication in the taxonomic context of the family.

During working on the pollen morphology of Thai malpighiaceous species, an annotated checklist of the plant's studies required a thorough literature review, extensive visits to herbaria and analysis of type collections. The resulting information has indicated the necessity of lectotypification for eight taxa of the family.

MATERIALS AND METHODS

Pollen grains of 19 species representing all six genera of Malpighiaceae occurring in Thailand (Table 1) were examined. However, three species, namely *Aspidopterys* sp., *Hiptage detergens* Craib and *Malpighia coccigera* L. were not included in this analysis because of a lack of pollen grains and *Thryallis gracilis* (Bartl.) Kuntze has been mentioned here as a valid name of *Galphimia gracilis* Bartl. reported by Sirirugsa (1991). One to four samples of each species were obtained from dried herbarium specimens and field collections. The grains were acetolysed according to Erdtman (1960), for the light microscopy (LM) study, pollen grains were mounted in silicon oil for making permanent slides. For scanning electron microscopy (SEM) study, pollen grains were dried using critical point drying (CPD) and then placed on the aluminum stubs, fasten on double-sided adhesive tape before sputter coating with a gold-palladium mixture. The morphological characters of at least 10 pollen grains of each sample were comprehensively examined *viz*. symmetry, polar, size class, shape, amb, aperture type and sculpturing pattern. The measurement of the polar axis (P), equatorial diameter (E), colpus length and pore diameter were investigated, mean and standard deviation were calculated, P/E was used to indicate the pollen shape. The permanent slides were housed in the reference collection at Udon Thani Rajabhat University, Thailand. The terminology follows Erdtman (1952, 1966), Punt et al. (2007) and Hesse et al. (2009).

RESULTS

The general pollen features of each genus were described and the summary of pollen characteristics of each species was provided in Table 2.

Aspidoterys

Pollen grains monad, bilateral or radial symmetrical, mostly apolar to rarely heteropolar, oblate, oblate spheroidal, prolate spheroidal to subprolate. Amb quadrangular, subcircular or triangular. Aperture trichotomosulcate, 4-porate, polyporate or monosulcate. Polar axis = 10.0−38.0 μm, equatorial diameter = 18.0−38.0 μm. Colpi absent. Pore diameter 3−7 μm. Exine sculpturing fossulate, granulate, rugulate or verrucate.

Brachylophon

Pollen grains monad, bilateral symmetrical, isopolar, oblate spheroidal or prolate spheroidal. Amb subcircular. Aperture 3-colporate. Polar axis = 9.0−13.0 μm, equatorial diameter = 8.0−15.0 μm. Colpi 6−8 μm. Pore diameter 1−2 μm. Exine sculpturing perforate.

Hiptage

Pollen grains monad, bilateral symmetrical, apolar, rarely heteropolar, prolate spheroidal or oblate. Amb triangular, quinquangular or subcircular. Aperture trichotomosulcate, 4-porate or polyporate. Polar axis = 10.0−45.0 μm, equatorial diameter = 17.0−40.0 μm. Colpi absent. Pore diameter 3−5 μm. Exine sculpturing fossulate, rugulate or verrucate.

TABLE 1. List of plant specimens used in the study.

Species	Voucher
1. *Aspidopterys concava* (Wall.) A. Juss.	*Niyomdham & Ueachirakan 1854* (AAU)
	Phengklai et al. 13428 (BKF)
2. *A. glabriuscula* A. Juss.	*Srisanga 1505* (QBG)
	Srisanga 1513 (QBG)
	Srisanga 1728 (QBG)
3. *A. nutans* (Roxb. ex DC.) A. Juss.	*Kerr 9145* (AAU)
	La-ongsri et al. 4285 (QBG)
	Maxwell 71-646 (AAU)
4. *A. hirsuta* A. Juss.	*Maxwell 96-1295* (BKF)
5. *A. thorelii* Dop	*La-ongsri et al. 2472* (QBG)
	Maknoi 7133 (QBG)
6. *A. tomentosa* A. Juss.	*Maknoi 6581* (QBG)
	Maxwell 76-112 (AAU)
	Maxwell 79-1150 (AAU)
	Norsaengsri et al. 7639 (QBG)
7. *Brachylophon anastomosans* Craib	*Niyomdham & Puudja 4697* (BKF)
	Niyomdham & Puudja 4743 (BKF)
8. *B. curtisii* Oliv.	*Larsen et al. 42681* (AAU)
	Larsen et al. 42706 (AAU)
9. *Hiptage benghalensis* (L.) Kurz	*Maneenuch & Wilaiwan 1* (KKU)
	Pongamornkul 5709 (QBG)
10. *H. bullata* Craib	*Van de Bult 1158* (BKF)
11. *H. calcicola* Sirirugsa	*Middleton et al. 2496* (AAU)
12. *H. condita* Craib	*Norsaengsri & Tathana 7805* (QBG)
13. *H. gracilis* Sirirugsa	*Norsaengsri et al. 7641* (QBG)
14. *H. lucida* Pierre	*Sidajium 5* (BKF)
15. *H. monopteryx* Sirirugsa	*Phonsena et al. 5825* (BKF)
16. *H. triacantha* Pierre	*Bunme s.n.* (BKF)
17. *Malpighia glabra* L.	*Maneenuch & Wilaiwan 2* (KKU)
	S.N. (AAU)
18. *Thryallis gracilis* (Bartl.) Kuntze	*Maneenuch & Wilaiwan 3* (KKU)
19. *Tristellateia australasiae* A. Rich.	*Phengklai & Smitinand 6091* (BKF)

Malpighia

Pollen grains monad, radial symmetrical, apolar, oblate spheroidal. Amb subcircular. Aperture polyporate. Polar axis = 25.0−30.0 μm, equatorial diameter = 23.0−30.0 μm. Colpi absent. Pore diameter 3−6 μm. Aperture polyporate. Exine sculpturing fossulate.

Thryallis

Pollen grains monad, bilateral symmetrical, isopolar, oblate spheroidal. Amb triangular. Aperture 3-colporate with parasycolpate. Polar axis = 10.0−15.0 μm, equatorial diameter = 13.0−18.0 μm. Colpi 6−8 μm. Pore diameter 3−5 μm. Exine sculpturing perforate.

Tristellateia

Pollen grains monad, bilateral symmetrical, isopolar, prolate spheroidal. Amb subcircular. Aperture 4-colporate. Polar axis = 18.0−23.0 μm, equatorial diameter = 15.0−20.0 μm. Colpi 10−12 μm. Pore diameter 3−5 μm. Exine sculpturing regulate.

NEW LECTOTYPIFICATIONS

1. Aspidopterys thorelii Dop, Bull. Soc. Bot. France 55: 428. 1908. Type: Lakhou, the expedition du Me Kong, 1866−1868, *Thorel 3027* (lectotype **P**[P02429007!] designated here; isolectotypes **P**[P00904884! & P00904885!]).

TABLE 2. A summary of pollen characters of Thai malpighiaceous species. Measurements represent mean, low and high values and standard diviation, Amb = the outline of pollen as seen in a polar view. CL = colpus length, E = equatorial diameter, Ob = oblate, OS = oblate spheroidal, P = polar axis, PD = pore diameter, PS = prolate spheroidal, P/E = ratio of polar length and equatorial diameter, Su = subprolate. All measurements are in μm.

Species	P (MEAN±SD)	E (MEAN±SD)	Size class	P/E (shape)	Amb	Aperture type	CL (MEAN±SD)	PD (MEAN±SD)	Ornament-ation
1. *Aspidopterys concava*	10−15 (12.70±1.64)	20−25 (22.70±2.06)	small	0.56 (Ob)	triangular	trichoto-mosulcate	-	4−6 (5.10±0.57)	fossulate
2. *A. glabriuscula*	23−30 (25.90±2.08)	20−28 (24.40±2.07)	small-medium	1.06 (PS)	subcircular	4-porate	-	3−6 (5.40±0.70)	rugulate
3. *A. nutans*	20−35 (24.60±4.55)	18−38 (24.70±5.96)	small-medium	1.00 (OS)	subcircular	mono-sulcate	-	4−6 (5.30±0.67)	granulate
4. *A. hirsuta*	28−38 (33.80±3.16)	28−38 (32.60±2.80)	medium	1.04 (PS)	subcircular	polyporate	-	6−7 (6.50±0.53)	verrucate
5. *A. thorelii*	23−28 (25.10±2.18)	23−25 (24.00±1.05)	small-medium	1.05 (PS)	quadrangular	polyporate	-	3−5 (4.20±0.92)	verrucate
6. *A. tomentosa*	23−35 (28.70±2.36)	18−33 (24.10±1.86)	small-medium	1.20 (Su)	quadrangular	polyporate	-	3−7 (5.80±1.79)	verrucate
7. *Brachylophon anastomosans*	9−11 (10.10±0.74)	8−10 (9.50±0.97)	very small-small	1.06 (PS)	subcircular	3-colporate	6−8 (6.60±0.89)	1−2 (1.60±0.55)	perforate
8. *B. curtisii*	10−13 (12.40±1.26)	10−15 (12.60±1.51)	small	0.98 (OS)	subcircular	3-colporate	6−8 (7.00±0.82)	1−2 (1.40±0.48)	perforate
9. *Hiptage benghalensis*	25−45 (31.50±5.40)	25−40 (31.50±4.50)	medium	1.00 (PS)	quinquan-gular	polyporate	-	4−5 (4.30±0.48)	rugulate
10. *H. bullata*	10−13 (21.40±2.41)	20−25 (22.30±1.70)	small	0.51 (Ob)	triangular	trichoto-mosulcate	-	3−5 (4.44±0.73)	fossulate
11. *H. calcicola*	10−16 (14.33±3.21)	23−30 (27.33±3.79)	small-medium	0.52 (Ob)	triangular	trichoto-mosulcate	-	3−5 (4.60±1.06)	fossulate
12. *H. condita*	20−28 (24.20±3.21)	23−25 (24.00±1.05)	small-medium	1.01 (PS)	subcircular	polyporate	-	4−5 (4.20±0.42)	verrucate
13. *H. gracilis*	17−21 (19.30±1.34)	17−20 (18.50±1.65)	small	1.04 (PS)	subcircular	4-porate	-	4−5 (4.5±0.71)	verrucate
14. *H. lucida*	20−23 (21.28±1.11)	20−23 (21.14±1.21)	small	1.01 (PS)	subcircular	polyporate	-	3−5 (3.50±1.01)	verrucate
15. *H. monopteryx*	25−33 (26.70±2.82)	25−30 (26.20±1.88)	medium	1.02 (PS)	quadrangular	4-porate	-	4−5 (4.60±0.52)	verrucate
16. *H. triacantha*	20−25 (21.80±2.40)	18−25 (20.20±2.70)	small	1.08 (PS)	quadrangular	4-porate	-	4−5 (4.30±0.48)	verrucate
17. *Malpighia glabra*	25−30 (26.10±1.85)	23−30 (26.50±2.17)	medium	0.98 (OS)	subcircular	polyporate	-	3−6 (4.60±0.97)	fossulate
18. *Thryallis gracilis*	10−15 (13.40±0.97)	13−18 (14.10±1.66)	small	0.95 (OS)	triangular	3-colporate, parasyncol-porate	6−8 (7.00±0.67)	3−5 (4.44±0.37)	perforate
19. *Tristellateia australasiae*	18−23 (19.10±1.66)	15−20 (18.10±2.28)	small	1.06 (PS)	subcircular	4-colporate	10−12 (11.20±0.92)	3−5 (3.80±0.79)	rugulate

Note.— Dop (1908) described *Aspidopterys thorelii* based on *Thorel 3037* collected from Lakhou (P02429007), during the expedition du Me Kong, 1866−1868 as indicated in the first publication. We have studied his collection and found an erroneous interpretation of collection number. The number should be *Thorel 3027*. We have also examined the other two sheets (P00904884 and P00904885) which indicated the same number and collected from Huay mue, Laos. However, the sheet P02429007 has more detail and is well preserved, therefore, it is designated here as the lectotype.

The mention of the type specimen number and locality in the Flora of Thailand by Sirirugsa (1991) was an erroneous interpretation. The type, *Thorel 3027* collected from Lakhou which is located in Savannakhet, Laos, not in Nakhon Phanom, Thailand.

2. Brachylophon anastomosans Craib, Bull. Misc. Inform. Kew 1926(4): 157. 1926. Type: Thailand, Yala (former Pattani), Bannang Sata (Sta), ca 50 m alt., 23 July 1923, *Kerr 7306* (lectotype **K**[K000739258!] designated here, isolectotypes **ABD**[ABDUH:2/113!], **BK**[BK257153!], **BM**[BM000611530! & **BM**000611531!], **K**[K000739259!], **TCD**[TCD0013234!]).

Note.— The original description of *Brachylophon anastomosans* was based on *Kerr 7306*. The type has seven sheets and is housed in different herbaria, the sheet K000739258 at **K** is the most complete and well-preserved collection, therefore, it is designated here as the lectotype.

3. Hiptage benghalensis (L.) Kurz, J. Asiat. Soc. Bengal 43(2): 136. 1874. Type: Sri Lanka, s.d., *Paul Hermann s.n.* (lectotype **BM**[BM000621671], Fig. 3;

isolectotypes **BM**[BM000621672], **BM**[BM000621673], **BM**[BM000621674], designated by Singh (2017).

Hiptage candicans Hook. f. var. *angustifolia* Craib, Fl. Siam. 1: 202. 1926. Type: Thailand, Chiang Mai, Mae Sa (Ma Sar), ca 450 m (1,500 ft) alt., Mar. 1913, *Winit 69* (lectotype **K**[K000739305!] designated here; isolectotype **ABD**[ABDUH:2/115!]).

Note.— *Hiptage candicans* Hook. f. var. *angustifolia* was described by Craib (1926) based on *Winit 69*. The type has two sheets, one housed at **ABD** and the other at **K**. The sheet at **K** is designated here as the lectotype.

4. Hiptage benghalensis ssp**. candicans** (Hook. f.) Sirirugsa, Fl. Thai. 5(3): 279. 1991. ___ *H. candicans* Hook. f., Fl. Brit. India 1: 419. 1874. Type: Myanmar (Burma), banks below Yenangheun, Dec. 1826, *Wallich Numer. List 9020* (lectotype **K-W**[K000739253!] designated here; isolectotypes **K-W**[K000739252! & K001132111!].

Note.—Sirirugsa (1991) placed *Hiptage candicans* as a subspecies under *H. benghalensis* and indicated the type from Myanmar (Burma). *Hiptage candicans* was described based on *Wallich Numer List 9020* which has three sheets. The sheet K000739253 is designated because it has larger floral buds.

5. Hiptage bullata Craib, Bull. Misc. Inform. Kew 1926(4): 155. 1926. Type: Thailand, Nakhon Sawan, Kaeng Ap Nang, Mae Ping Rapids, 180 m (600 ft) alt., 17 Mar. 1913, *Kerr 294*5 (lectotype **K**[K000739251!] designated here; isolectotypes **ABD**[ABDUH: 2/114!], **BM**[BM000795194!]).

Note.— *Hiptage bullata* was first described by Craib (1926) based on *Kerr 294*5 which has three sheets. The sheet at **K**, K000739251 is the best and designated here as the lectotype.

6. Hiptage condita Craib, Bull. Misc. Inform. Kew 1926(4): 156. 1926. Type: Thailand, Chiang Rai, Mae Kok, Doi Tham Tu Pu, ca 530 m alt., 6 Mar. 1924, *Garrett 154* (lectotype **K** [K000739301!] designated here; isolectotypes **ABD**[ABDUH:2/116!], **BM**[BM000796256! & BM000796257!], **TCD**[TCD0013239!], **BK**, **C**)

Note.— *Garrett 154* was mentioned in the original description of *Hiptage condita*. Two specimens of the type were mentioned in **BK** and **C** (Sirirugsa, 1991). We have not found them. However, five other sheets were consulted, the specimen at **K**, K000739301 is designated here as the lectotype.

7. Hiptage detergens Craib, Bull. Misc. Inform. Kew 1926(4): 157. 1926. Type: Thailand, Phangnga (Pungah), Ko Pan Yee (Pulau Panji), 11 Dec. 1928, *Hanif et Nur 4007* (lectotype **K**[K000739250!] designated here; isolectotype **ABD**[ABDUH:2/117!]).

Note.— Craib (1926) described *Hiptage detergens* based on *Hanif et Nur 4007*. The specimen at **K** is designated here as the lectotype.

8. Hiptage glabrifolia Craib, Bull. Misc. Inform. Kew 1915(10): 425. 1915. Type: Thailand, Chiang Mai, Mae Ping Rapid, Kaeng Soi, ca 180 m alt., 16 Mar. 1913, *Kerr 2941* (lectotype **K**[K000739302!] designated here; isolectotypes **ABD**[ABDUH:2/118!], **BM**[BM000796264!], **E**[E00346277!]).

Note.— The description of *Hiptage glabrifolia* was based on *Kerr 2941*. The type has four sheets, the sheet housed at **K**, K000739302, is the most complete and well-preserved specimen and therefore, designated as the lectotype.

9. Hiptage lucida Pierre, Fl. For. Cochinch. 18: t. 273. 1893. Type: Vietnam, Cochin-china, 1865-1877, *Pierre 4562* (lectotype **P**[P04783918!] designated here; isolectotypes **BM**[BM000796258!], **NYBG** [NY00071289! & NY00071290!], **P**[P04783917!]).

Note.— *Pierre 4562* has five duplicates and the sheet preserved in **P**, P04783918 is designated here as lectotype because it is the most complete specimen with complete flowers, floral line drawing and a handwritten description.

DISCUSSION

Previous palynological studies demonstrated Malpighiaceae is euripalynous family (Erdtman, 1952; Anderson, 1982; Sebastiani et al., 2014 and Belonsi and Gasparino, 2015) and the present result clearly supported the euripalynous of Malpighiaceae as it contained genera with highly polymorphic pollen grains.

The pollen morphology of this study is mostly consistent with previous investigations of other genera in Malpighiaceae (Sebastiani et al., 2014 and Belonsi and Gasparino, 2015). However, some additional data were observed. Generally, pollen grains of examined species were monad with mostly bilateral or rarely radial symmetry. The radial symmetry was found in *Aspidopterys hirsuta* and *Malpighia glabra*. Polar exhibited apolar, isopolar or heteropolar. Pollen sizes of examined species were slightly smaller than in other genera of Malpighiaceae (Sebastiani et al., 2014;

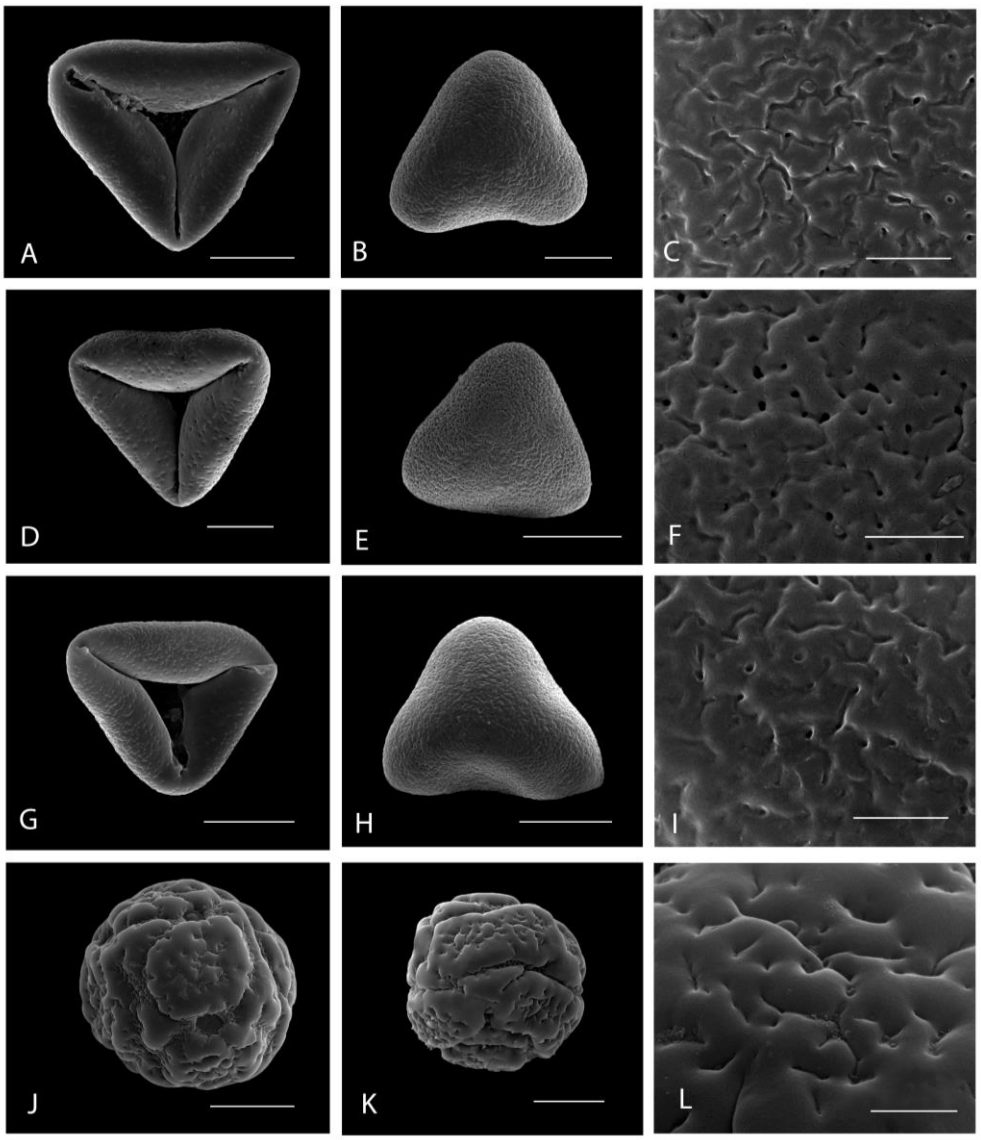

FIGURE 1. SEM micrographs of Thai Malpighiaceae pollen grains, Fossulate type: A-C *Aspidopterys concava*, D-F *Hiptage bullata*, G-I *H. calcicola*, J-L *Malpighia glabra*. A, B, D, E, G, H, J polar view; K equatorial view; C, F, I, L exine surface. Scale bars: 10 μm for A, B, D, E, G, H, J, K and 2 μm for C, F, I, L.

Belonsi and Gasparino, 2015). They varied from very small (P = 9−11 μm, E = 8−10 μm) to medium (P = 25−45 μm, E = 25−40 μm). The very small pollen was the additional character for Malpighiaceae and it presented in one species, *Brachylophon anastomosans.* Pollen shapes showed a highly variable. They were oblate, oblate spheroidal, prolate spheroidal or subprolate with quadrangular, quinquangular, subcircular or triangular ambs. Aperture types were 3−4-colporate, 3-colporate with parasyncolporate, 4-porate, polyporate, monosulcate and trichotomosulcate. Besides the data mentioned above we found that the triangular amb was correlated with the appearance of trichotomosulcate aperture type that occurred in *Aspidopterys concava*, *Hiptage bullata* and *H. calcicola*. Ornamentation is one of the most interesting characters of pollen grains because it normally provides diagnostic data for taxonomic utilization in many plant groups (Kim and Zavada, 1993; Schols et al., 2003; Cai et al., 2008; Celenk et al., 2008; Sebastiani et al., 2014; Belonsi and Gasparino, 2015). Based on the ornamentation patterns we observed the variation and consistency of these characters and we proposed five types of pollen grains *viz.* fossulate type, granulate type, perforate type, rugulate type and verrucate type.

1. Fossulate type (Fig. 1)
Species included: *Aspidopterys concava*, *Hiptage bullata*, *H. calcicola* and *Malpighia glabra*.

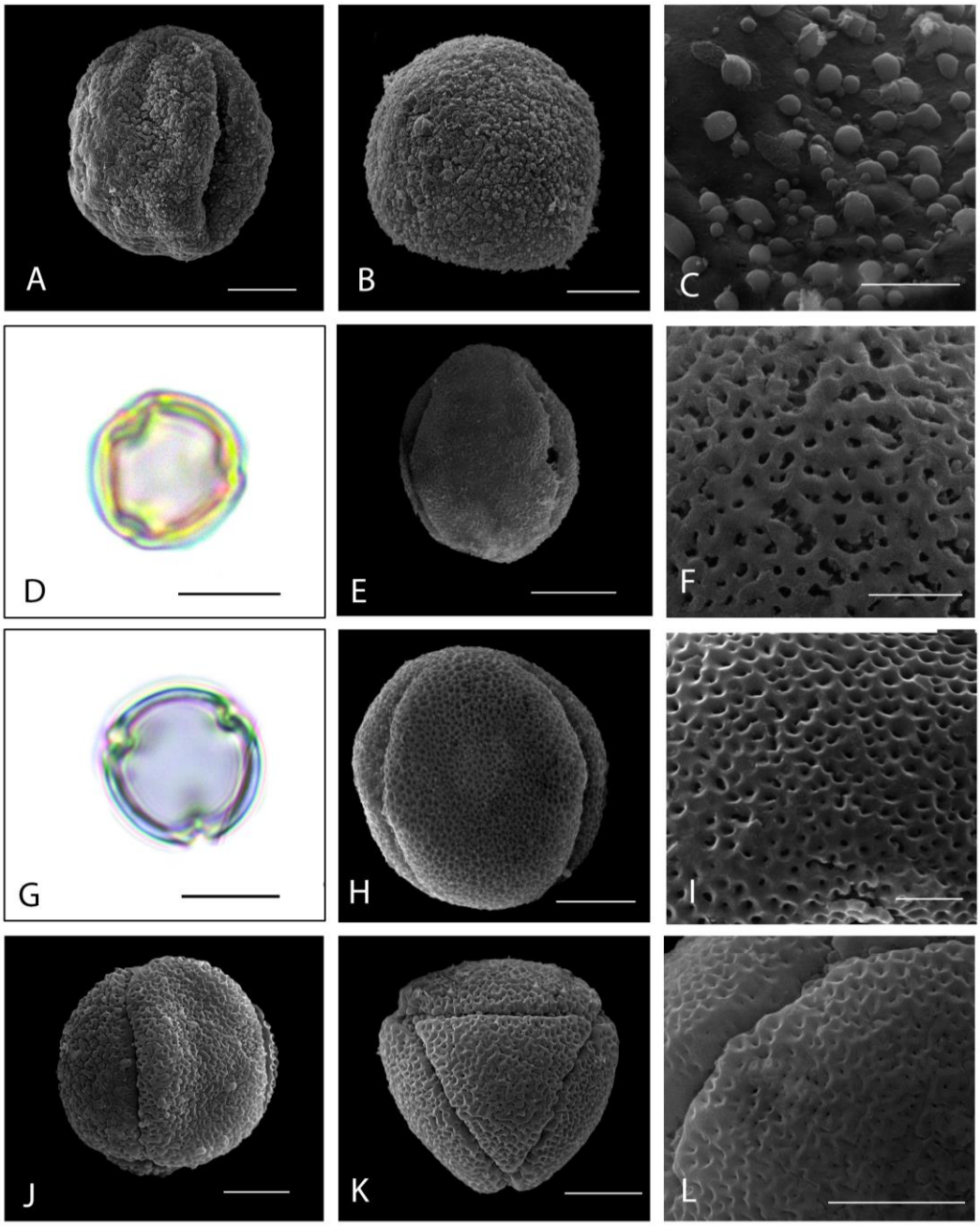

FIGURE 2. Pollen of Thai Malpighiaceae, Granulate type: SEM micrographs; A, B, C, E, F, H, I, J, K, L: LM micrographs; D, G. A-C *Aspidopterys nutans*; Perforate type: D-F *Brachylophon anastomosans*, G-I *B. curtisii*, J-L *Thryallis gracilis*. A, B, E, H, J equatorial view; D, G, K polar view; C, F, I, L exine surface. Scale bars: 10 μm for A, B, D, E, G, H, J, K and 2 μm for C, F, I, L.

Pollen grains apolar or heteropolar, small to medium, oblate or oblate spheroidal (P = 10−30 μm, E = 20−30 μm), amb triangular or subcircular, aperture trichotomosulcate or polyporate.

2. Granulate type (Fig. 2)
Species included: *Aspidopterys nutans*.

Pollen grains apolar, small-medium, oblate spheroidal (P = 20−35 μm, E = 18−38 μm), amb subcircular, aperture monosulcate.

3. Perforate type (Fig. 2)
Species included: *Brachylophon anastomosans*, *B. curtisii* and *Thryallis gracilis*.

Pollen grains isopolar, very small to small, oblate spheroidal or prolate spheroidal (P = 9−23 μm, E = 8−20 μm), amb subcircular or triangular, aperture 3-colporate or 3-colporate with parasyncolporate.

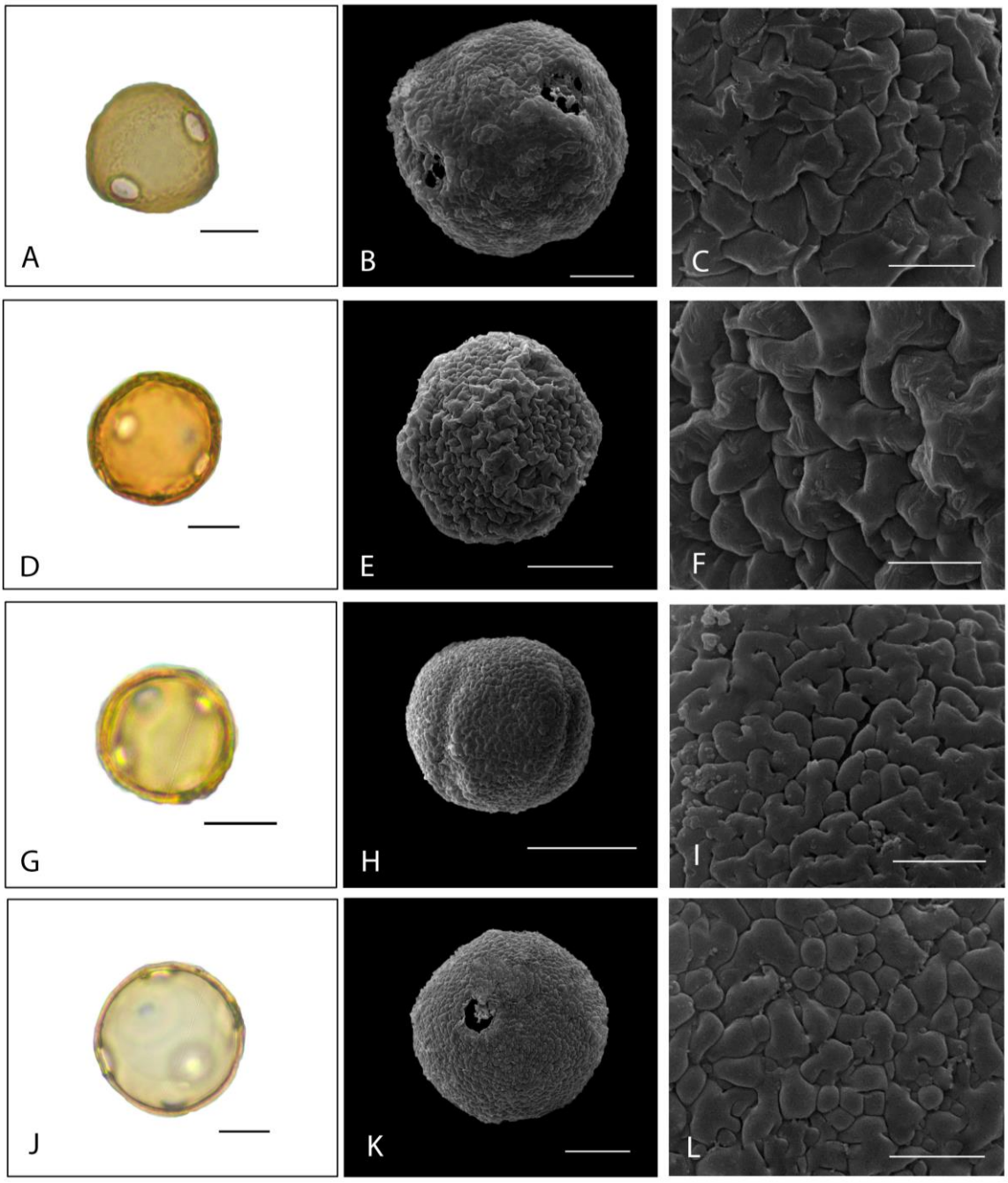

FIGURE 3. Pollen of Thai Malpighiaceae, Rugulate type: LM micrographs in polar view; A, D, Gand J: SEM micrographs; B, C, E, F, H, I, K, and L. A-C *Aspidopterys glabriuscula*, D-F *Hiptage benghalensis*, G-I *Tristellateia australasiae*; Verrucate type: J-L *A. hirsuta* A, B, D, E, G, H equatorial view; J, K polar or subpolar view; C, F, I, L exine surface. Scale bars: 10 μm for A, B, D, E, G, H, J, K and 2 μm for C, F, I, L.

4. Rugulate type (Fig. 3)

Species included: *Aspidopterys glabriuscula*, *Hiptage benghalensis* and *Tristellateia australasiae*

Pollen grains apolar or isopolar, small to medium, prolate spheroidal (P = 18−45 μm, E = 15−40 μm), amb quinquangular or subcircular, aperture 4-colporate, 4-porate or polyporate.

5. Verrucate type (Figs. 3-5)

Species included: *Aspidopterys hirsuta*, *A. thorelii*, *A. tomentosa*, *Hiptage condita*, *H. gracilis*, *H. lucida*, *H. monopteryx* and *H. triacantha*.

Pollen grains apolar, small to medium, prolate spheroidal or subprolate (P = 17−38 μm, E = 17−38 μm), amb quadrangular or subcircular, aperture 4-porate or polyporate.

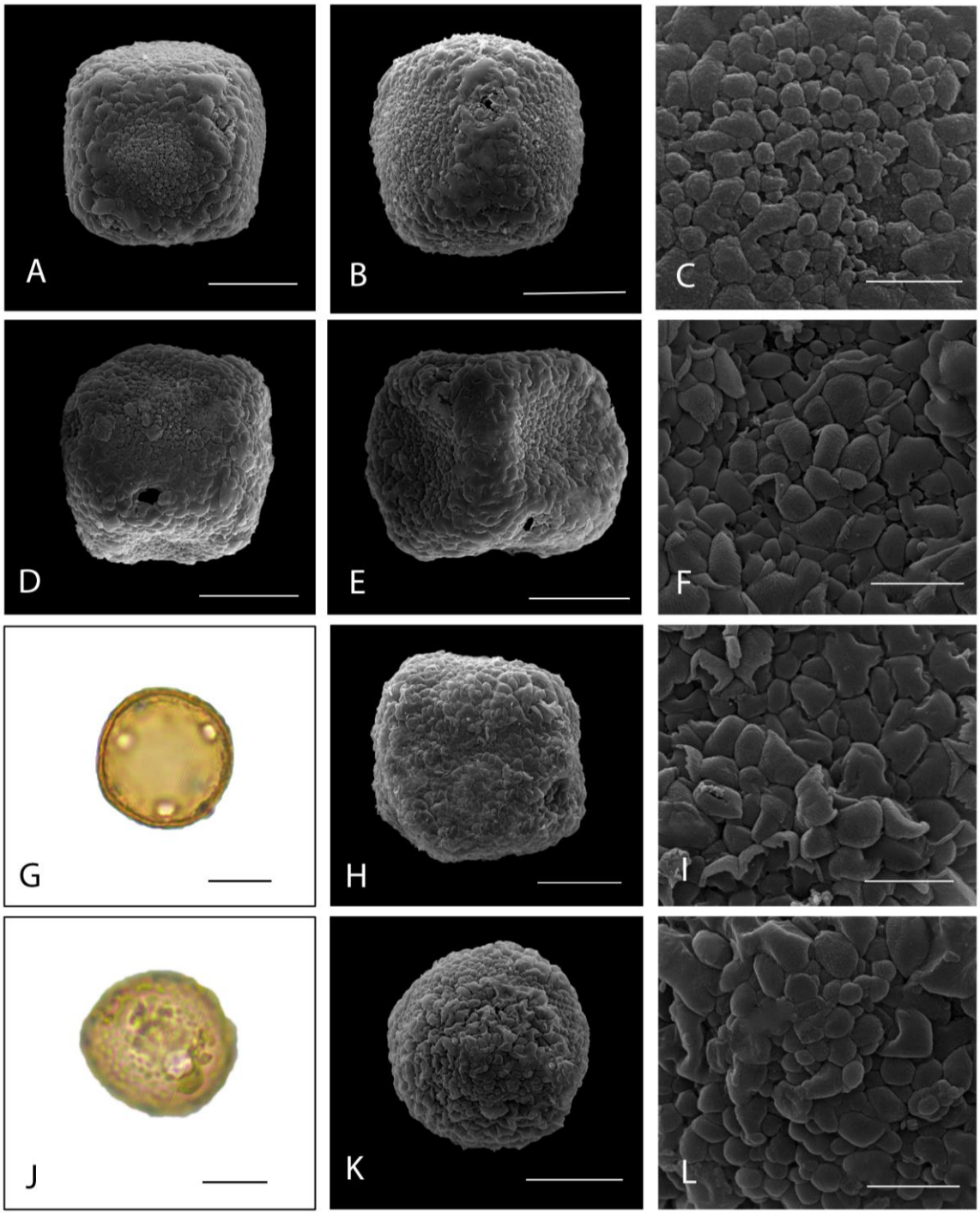

FIGURE 4. Pollen of Thai Malpighiaceae, Verrucate type: SEM micrographs in polar view; A, B,C, D, E, F, H, I, K, L: LM micrographs; G, J. A-C *Aspidopterys thorelii*, D-F *A. tomentosa*, G-I *Hiptage condita*, J-L *H. gracilis*. A, D, G, J polar or subpolar view; B, E, H, K equatorial or subequatorial view; C, F, I, L exine surface. Scale bars: 10 μm for A, B, D, E, G, H, J, K and 2 μm for C, F, I, L.

Comparing to the study on the pattern of ornamentation in other Malpighiaceae genera (Sebastiani et al., 2014 and Belonsi and Gasparino, 2015), there were two patterns not found in our study, psilate and micro-reticulate. These two patterns might be used to infer the pollen characteristics of the New World species. However, to confirm this inference the palynological study of more expanded species are still needed.

In conclusion, this study provided the first report of the palynological data for Malpighiaceae in Thailand. The result showed that the pollen morphological characters were available significant supplement data

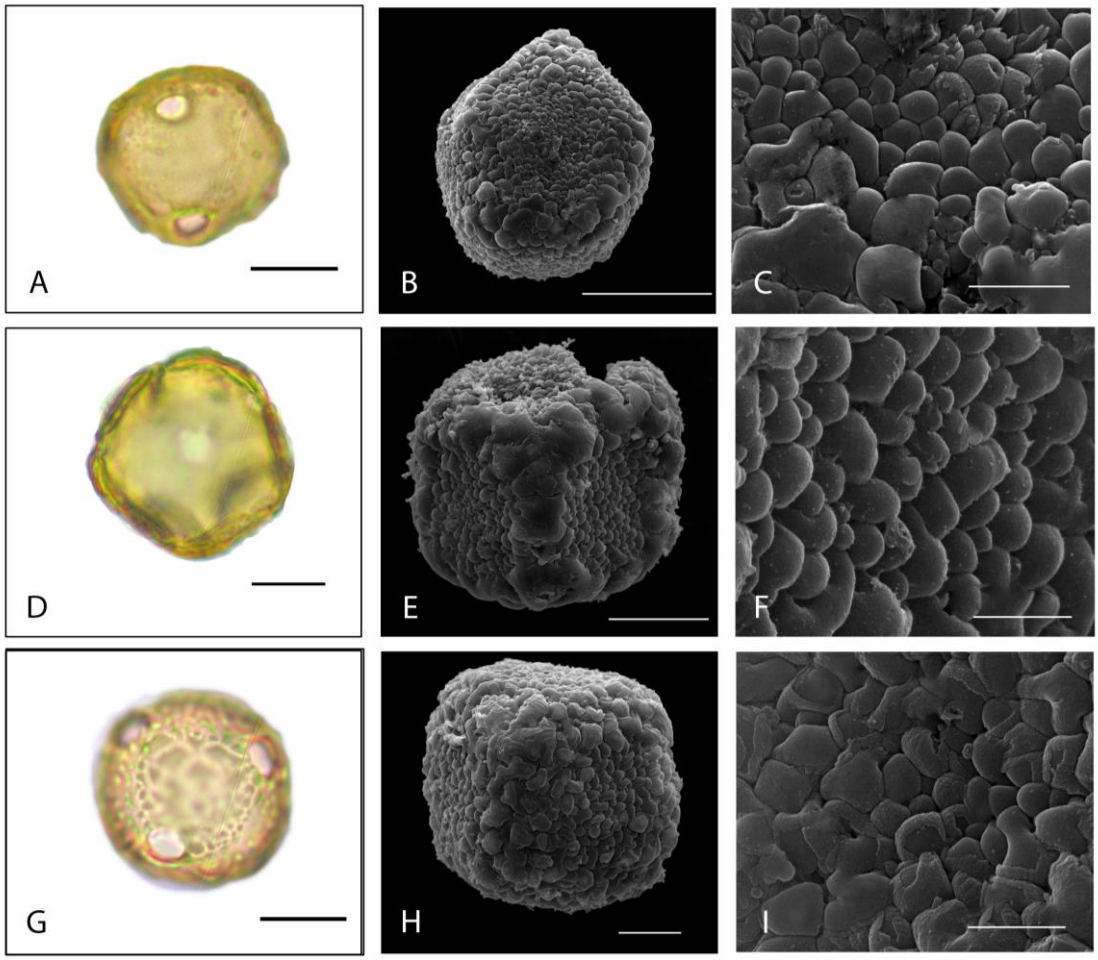

FIGURE 5. Pollen of Thai Malpighiaceae, Verrucate type: LM micrographs in polar view; A, D and G: SEM micrographs; B, C, E, F, H and I. A-C *H. lucida*, D-F *Hiptage monopteryx*, G-I *H. triacantha*. A, B, D, G polar or subpolar view; E, H equatorial view; C, F, I exine surface. Scale bars: 10 μm for A, B, D, E, G, H and 2 μm for C, F, I.

to the traditional morphology-based classification of the family. However, these features alone do not contribute any beneficial data for generic or specific circumscriptions. Combined analysis with other significant characters, such as leave and stem anatomy or leave and fruit micromorphology have been required for taxonomic purposes.

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