เรณูวิทยาของพืชวงศ์ Apocynaceae ในประเทศไทย

นางสาวหทัยกาญจน์ สิทธา

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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PALYNOLOGY OF THE FAMILY APOCYNACEAE IN THAILAND

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การรวบรวมตัวอย่างดอกของพันธุ์ไม้วงศ์ Apocynaceae ในประเทศไทย จำนวน 85 ชนิด 36 สกุล เพื่อศึกษาสัณฐานวิทยาของเรณูที่ผ่านกระบวนการอะซิโตไลซิสแล้วด้วยกล้องจุลทรรศน์แบบใช้แสงและกล้องจุลทรรศน์อิเล็กตรอนแบบส่องกราด พบว่า สัณฐานของเรณูมีความหลากหลายมากถึง 23 แบบ เมื่อใช้เกณฑ์รูปแบบการกระจายของเรณู สภาพขั้ว ช่องเปิด ลวดลาย รวมทั้งขนาดและรูปร่างของเรณู เรณูส่วนใหญ่เป็นเม็ดเดี่ยว มีสภาพขั้วสองด้านเหมือนกันหรือต่างกันเล็กน้อย รูปทรงค่อนข้างกลม มีขนาดเล็ก (14-19 ไมโครเมตร) ไปจนถึงขนาดใหญ่มาก (100-106.33 ไมโครเมตร) ช่องเปิดจำนวน 3-4 ช่องเปิดซึ่งเป็นแบบกลมหรือแบบกลมผสมรี ลวดลายของผนังเป็นแบบเรียบไปจนถึงมีรูพรุน

แม้ลักษณะของเรณูของพืชวงศ์ Apocynaceae ที่พบในประเทศไทยจะไม่ค่อยสอดคล้องกับระบบการจัดจำแนกของพืชวงศ์นี้ในปัจจุบันมากนักในแง่ของขอบเขตของหน่วยทางอนุกรมวิธาน แต่จากข้อมูลสัณฐานของเรณูของพืชวงศ์นี้พบว่าเรณูของพืชในวงศ์ย่อย Rauvolfoideae มีความหลากหลายของเรณูค่อนข้างมาก ในขณะที่วงศ์ย่อย Apocynoideae มีเรณูที่ค่อนข้างเป็นแบบเดียวกันมากกว่า นอกจากนี้สัณฐานของเรณูของพืชวงศ์นี้ยังจัดว่าเป็นพืชกลุ่มที่มีความหลากหลายของเรณู ซึ่งมีคุณค่าต่อการนำไปใช้ระบุพืชได้ในหลายระดับทางอนุกรมวิธาน แม้กระทั่งในระดับชนิด ทั้งนี้โดยอาศัยลักษณะของช่องเปิด รูปร่างและขนาดของเรณูเป็นลักษณะสำคัญที่ใช้ในการระบุกลุ่ม ส่วนแนวโน้มการเปลี่ยนแปลงลักษณะของเรณูนั้น ส่วนใหญ่ภายในพืชวงศ์นี้เป็นไปในทิศทางของการลดพื้นที่ของช่องเปิด จากช่องเปิดแบบรีผสมกลมไปเป็นช่องเปิดแบบกลม ดังที่เกิดในเรณูของพืชในวงศ์ย่อย Rauvolfioideae ซึ่งพัฒนาไปเป็นวงศ์ย่อย Apocynoideae นอกจากนี้แนวโน้มการเปลี่ยนแปลงของลักษณะเรณูดังกล่าวอาจพบในการพัฒนาของเรณูแบบกลมผสมรีที่พบในเผ่าของพืชวงศ์นี้ส่วนใหญ่ ไปเป็นเรณูที่มี 2 ช่องเปิดที่มีรูปร่างกลมในเผ่า Alyxieae และนอกจากนี้จากข้อมูลด้านสัณฐานของเรณูจากการศึกษาในครั้งนี้ยังสนับสนุนว่าควรรวมพืชวงศ์ Asclepiadaceae ไปเป็นส่วนหนึ่งของพืชวงศ์ Apocynaceae

ภาควิชา.........พฤกษศาสตร์........................ ลายมือชื่อนิสิต ....หทัยกาญจน์ สิทธา..........
สาขาวิชา.........พฤกษศาสตร์........................ ลายมือชื่ออาจารย์ที่ปรึกษา ....
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HATHAIKARN SITTHA: PALYNOLOGY OF THE FAMILY APOCYNACEAE IN THAILAND. THESIS ADVISOR: ASST. PROF. TOSAK SEELANAN, Ph.D., THESIS COADVISOR: ASST. PROF. CHUMPOL KHUNWASI, Ph.D., 189 pp.

Acetolysed pollen grains from eighty-five species belonging to thirty-six genera of the family Apocynaceae in Thailand were studied on morphology by means of light and scanning electron microscopes. Twenty-three pollen types are recognized based on dispersal unit, polarity, aperture, ornamentation, size as well as shape of pollen grains. Pollen grains are mostly monads, isopolar to subisopolar, subspheroidal, small (14-19 µm) to very large (100-106.33 µm), 3-4-zonocolporate or 3-4-zonoporate, psilate to perforate ornamentation.

Although it seems that pollen morphological evidence of Thai Apocynaceae is not congruent with the current morphological and molecular classification for delimitation of existing taxonomic groups, it does provide some valuable information. Palynologically, Rauvolfioideae is heterogeneous subfamily while Apocynoideae, on the other hand, is much more homogeneous. In the context of identification, because the Apocynaceae is rather eurypalynous family, it is feasible to utilize pollen morphology to identify different taxonomic groups of Thai Apocynaceae, even species, based mainly on the aperture, shape and size. Pollen morphological changes within this family are mainly in the context of reduction of apertural area, colporate to porate, as occurred in the Rauvolfioideae to Apocynoideae, respectively. Furthermore, this palynological trend can be found in the change of colporate basal tribes of Rauvolfioideae to diporate Alyxieae. The palynological data of Thai Apocynaceae support the view that Asclepiadaceae is not distinct family and it should be considered as a part of Apocynaceae with distinct characteristics.

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Academic year:	2007	Co-advisor's signature : Chumpol Khunwasi

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CHAPTER I

INTRODUCTION

Palynology is the study of the pollen and spores of plants, and also comprises of microfossils (Faegri and Iversen, 1964). The palynological research is a relatively recent branch of plant morphology and also provides a great wealth of phylogenetically useful information (e.g. Olvera *et al.*, 2006; Sarwar and Takahashi, 2006; Banks *et al.*, 2008; Telleria, 2008).

In Thailand, there are few palynological works have been done. There are only 2 pollen morphological studies of the Thai flora, i.e. Melastomataceae (Chantaranothai, 1997) and Euphorbiaceae (Chumpol Khunwasi, pers. com.). In addition, many other studies were not in the context of a palynological study for the Thai plant families as a whole, i.e. the tribe Inuleae of Asteraceae (Pornpongrungrueng and Chantaranothai, 2002), 10 genera of Convolvulaceae (Na Songkhla and Khunwasi, 1989), 9 genera of Amaranthaceae (Puangpen Sirirugsa, unpub. data).

Conforming to Erdtman (1952), great variations in pollen morphology were observed. Therefore, it is interesting and of a merit to do such research on the palynology of the apocynaceous plants in Thailand because little is known about the variation of pollen morphology within this family.

In 1810 Robert Brown segregated the Asclepiadaceae out of Apocynaceae Jussieu, based mainly on being the presence of translators in the latter and their absence in the former (Endress and Stevens, 2001; Endress, 2004). Recently the families Apocynaceae and Asclepiadaceae, however, were grouped together into one family, Apocynaceae s.l., because the new information and cladistic interpretations of its support the recognition of a single entity (Civeyrel *et al.*, 1998; Sennblad *et al.*, 1998; Judd *et al.*, 1999; Endress and Bruyns, 2000; Sennblad and Bremer, 2000; Potgieter and Albert, 2001; Sennblad and Bremer, 2002). Although there is still the argument about Apocynaceae circumscription, it is clear that it is divided into five subfamilies: Rauvolfioideae; Apocynoideae; Periplocoideae; Secamonoideae and Asclepiadoideae (Endress and Bruyns, 2000).

In this study, the Apocynaceae classification was fallowed Middleton (1999) including only two subfamilies: Rauvolfioideae and Apocynoideae. The classification system within this family, however, was based on Endress and Bruyns (2000). Apocynaceae s.str. is a family of flowering plants in the order Gentianales, with approximately 1,900 species belonging to 165 genera, 14 tribes distributed widespread in tropical and subtropical regions, with a few genera extending into temperate areas (Mabberley, 1997; Judd *et al.*, 1999; Endress and Bruyns, 2000).

According to Middleton (1999), approximately 125 species of 42 traditional apocynaceous genera were found in Thailand. They were classified into 13 tribes based on Endress and Bruyns (2000) (Table 1.1). The distinguished characters of this family are existence of milky sap, opposite leaves and corolla lobes overlapping to the left or right in bud. This family is distinctive in account of numerous ornamental plants. Nearly all taxa are poisonous and many have medicinal uses (Mabberley, 1997; Judd *et al.*, 1999).

It is expected that the results obtained from this study will be an additional information for taxonomic study of the Thai Apocynaceae as well as a basic for any pollen analysis researches in the future.

Aims of the thesis

1. To investigate pollen flora of the Thai Apocynaceae: to describe the pollen morphology in order to clarify details of variations in pollen morphology, and to construct the key of pollen types along with a discussion of possible pollen morphological trends and systematic value of pollen morphology in this family.

2. To collect the pollen slides of the Apocynaceae in Thailand and deposit them in the herbaria for future references.

Table 1.1 Classification of the Apocynaceae excluding subfamilies Periplocoideae, Secamonoideae and Asclepiadoideae (modified from Endress and Bruyns, 2000).

Subfamily	Tribe	Genera
Rauvolfioideae	Alstonieae	***Alstonia***, *Aspidosperma*, *Geissospermum*, *Haplophyton*, *Laxoplumeria*, *Microplumeria*, *Strempeliopsis*, *Tonduzia*, *Vallezia*
	Vinceae	*Amsonia*, ***Catharanthus***, ***Kopsia***, *Neisosperma*, ***Ochrosia***, *Petchia*, ***Rauvolfia***, *Vinca*
	Willughbeeae	*Ancylobotrys*, ***Bousigonia***, *Chamaeclitandra*, *Clitandra*, *Couma*, *Cyclocotyla*, *Cylindropsis*, *Dictyophleba*, *Hancornia*, *Lacmellea*, ***Leuconotis****, *Orthopichonia*, *Pacouria*, *Parahancornia*, *Saba*, *Vahadenia*, ***Willughbeia***
	Tabernaemontaneae	*Ambelania*, *Bonafousia*, *Callichilia*, *Calocrater*, *Carvalhoa*, *Crioceras*, *Macoubea*, *Malongum*, *Mucao*, *Neocouma*, *Rhigospira*, *Schizozygia*, *Spongiosperma*, *Stemmadenia*, *Stenosolen*, ***Tabernaemontana***, *Tabernanthe*, *Voacanga*, *Woytkowskia*
	Melodineae	*Craspidospermum*, *Diplorhynchus*, ***Dyera****, *Gonioma*, *Kamettia*, ***Melodinus***, *Pycnobotrya*, *Stephanostegia*
	Hunterieae	***Hunteria***, *Picralima*, *Pleiocarpa*
	Plumerieae	***Allamanda***, *Anechites*, *Cameraria*, ***Cerbera***, *Cerberiopsis*, *Himatanthus*, *Mortoniella*, ***Plumeria***, *Skytanthus*, ***Thevetia***
	Carisseae	*Acokanthera*, ***Carissa***
	Alyxieae	***Alyxia***, ***Chilocarpus***, *Condylocarpon*, *Lepinia*, *Lepiniopsis*, *Plectaneia*, *Pteralyxia*

Table 2.1 (continued)

Subfamily	**Tribe**	**Genera**
Apocynoideae	Wrightieae	***Adenium***, *Isonema*, ***Nerium***, *Pleioceras*, *Stephanostema*, ***Strophanthus***, ***Wrightia***
	Malouetieae	*Alafia*, *Allowoodsonia*, *Carruthersia*, *Farquharia*, *Funtumia*, ***Holarrhena***, ***Kibatalia***, *Malouetia*, *Malouetiella*, *Mascarenhasia*, *Pachypodium*, ***Spirolobium***
	Apocyneae	***Aganonerion***, ***Aganosma***, ***Anodendron***, *Apocynum*, *Baharuia*, *Baissea*, ***Beaumontia***, ***Chonemorpha*****, ***Cleghornia*****, *Dewevrella*, *Elytropus*, ***Epigynum*****, *Eucorymbia*, *Forsteronia*, ***Ichnocarpus***, *Ixodonerium*, *Motandra*, *Odontadenia*, *Oncinotis*, *Papuechites*, ***Parameria***, *Parepigynum*, ***Sindechites*****, ***Trachelospermum***, ***Urceola***, *Vallariopsis*, ***Vallaris***
	Mesechiteae	*Allomarkgrafia*, *Galactophora*, *Macrosiphonia*, *Mandevilla*, *Mesechites*, *Quiotania*, *Secondatia*, *Telosiphoniai*, *Tintinnabularia*
	Echiteae	***Amalocalyx***, *Angadenia*, *Artia*, *Asketanthera*, *Cycladenia*, *Echites*, *Ecua*, *Fernaldia*, *Hylaea*, *Laubertia*, *Macropharynx*, *Neobracea*, ***Parsonsia***, *Peltastes*, ***Pentalinon***, ***Pottsia*****, *Prestonia*, *Rhabdadenia*, *Salpinctes*, *Stipecoma*, *Temnadenia*, *Thenardia*

Remarks: -

Genera occurring in Thailand and included in this study were marked in bold. Those in bold followed by asterisk (*) indicated taxa were not sampled.

CHAPTER II

LITERATURE REVIEW

2.1 Morphological character of the Apocynaceae

Trees, shrubs or climbers, rarely herbs; latex present. *Leaves* simple, opposite or, more rarely, verticillate or spirally arranged. *Inflorescence* cymose, rarely fasciculate or solitary; terminal or axillary. *Flowers* hermaphrodite; 5-merous, rarely 4-merous (in *Leuconotis*); actinomorphic or, very rarely, slightly zygomorphic. *Sepals* often with colleters inside. *Corolla* sympetalous; salverform, infundibuliform, urceolate or rotate; lobes overlapping to the left or right, more rarely valvate. *Stamens* inserted on the inside of the corolla tube; completely included or exserted; anthers sagittate or ovate, free or adnate to the pistil head; sometimes with the base and apex sterile. *Disk* present or absent. *Ovary* superior or, rarely, semi-inferior; of 2 separate carpels united into a common style, a single bilocular ovary or a unilocular ovary; pistil head with a stigmatic base and a 2-clef apex. *Fruit* a drupe, berry, capsule or follicle. *Seeds* simple, arillate, winged, with a ciliate margin or with an apical and/or basal coma (Middleton, 1999).

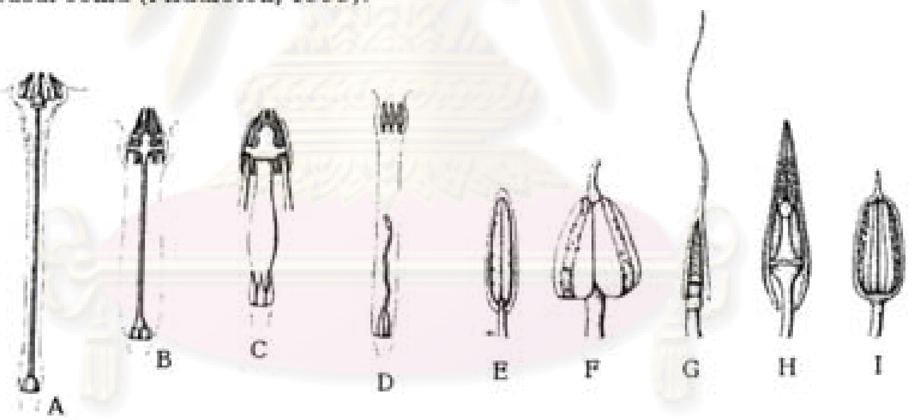

Figure 2.1 Variations of stamen position (A-D) and anthers (E-I) of Apocynaceae. A. Stamens in throat, unattached but with a close association to the style (*Cerbera manghas*); B, C. Stamens attached to style head (B. *Trachelospermum asiaticum*; C. *Pottsia laxiflora*); D. Stamens completely separate from style (*Tabernaemontana peduncularis*); E. Simple undifferentiated anthers (*Tabernaemontana peduncularis*); F. Simple anthers with apical attachment (*Cerbera manghas*); G. Anthers with large areas of sterile tissue and apical attachment (*Strophanthus wallichii*); H. Anthers with sclerenchymatous guide rails and limited fertile area (*Trachelospermum asiaticum*); I. Anthers with limited sterile area (*Holarrhena curtisii*) (Modified from Middleton, 1999).

According to the classification of Endress and Bruyns (2000), Apocynaceae s.str. consists of two subfamilies: Rauvolfioideae and Apocynoideae. The Rauvolfioideae typically have the corolla lobes sinistrorsely contorted in bud, the anthers are mostly unspecialized and free from the style head, and there is a broad array of fruit and seed types, although the seeds are almost always ecomose. The Apocynoideae, in contrast, are characterized by having the corolla lobes dextrorsely contorted in bud and anthers specialized with lignified guide rails and adnate to the style head, forming a gynostegium. The fruit is almost always a dry follicle with comose seeds.

The key characters of all 14 tribes of Apocynaceae s.str. are presented in Table 2.1.

2.2 Previous palynological works on Apocynaceae

The study of Erdtman (1952) was one of the pioneer works on pollen morphological descriptions of the family Apocynaceae. He made the first synthesis of pollen morphological data for taxonomic discussion. He examined pollen morphology of approximately 150 species from 60 genera of Apocynaceae. He found that this family showed eurypalynous which could be recognized by many apertural types, and various size and shapes. He also stated that the morphological diversity of the pollen was most pronounced in subfamily Plumerioideae.

The detailed descriptions of the pollen morphology of 16 Apocynacean plants were then presented by Huang (1972). He also was the first who constructed the pollen key to genera of this family.

Rau and Shukla (1975) studied pollen grains of 9 species belonging to 9 genera of some Indian Apocynaceae. They recognized 3 pollen types with regard to their apertures, i.e. 3-zonicolpate, 3-zonicolporate, and 3-zoniparate. Moreover, they pointed out the various ornamentation patterns of exine surface.

Van Campo *et al.* (1979) examined pollen morphology of 24 species of the genus *Tabernaemontana* and 1 species of related genus. They suggested that some genera ought to be included in *Tabernaemontana* with reference to the general pollen morphology as well as to the fine sculpture of the inner exine surface.

Cousin (1979) characterized the pollen grains of *Vinca rosea* by a distinctly granular sexine and an absence of nexine in the interapertural areas and by a non granular sexine and nexine near the colpus, where the exine has an atypical structure, intermediate between granules and columellae.

Nair (1981) described the pollen morphology of some plants from Western Himalaya in which there are 3 species of Apocynaceae included. He found that the pollen grains were spheroidal with 3-porate or 3-colporate apertures, and psilate ornamentation.

The significance of pollen morphology in 17 genera of Apocynaceae were further studied by Nilsson (1986). He established three groups with reference to morphological or functional similarities or dissimilarities. He also concluded that pollen morphology supported some close relationship genera.

Further contributions to the pollen morphology of the family Apocynaceae were made by Roubik and Moreno (1991). They studied pollen of 21 species from 14 genera of Apocynaceae. They constructed the key to species of these plants, provided with species descriptions of their pollen.

The next major step was made by Van der Ham *et al.* (2001), who investigated the pollen of 44 species belonging to the tribe *Alyxieae*. They found that 2-porate grains were the most common type in this tribe with irregularly disposed and unequal-sized pores. Moreover, the orientation of the polar axis and equatorial plane could not be determined in any of the genera. They indicated that the pollen morphology supported preliminary results of cladistic analyses of chloroplast data. They concluded that this tribe was a monophyletic group nested a 3-colporate clade.

Eleven species of Apocynaceae belonging to 7 genera were palynologically studied by Moreira *et al.* (2004). They showed that two large groups can be identified colporate pollen grains and porate pollen grains. They, finally, concluded that the genera could be separated by palynological characters and within genera their species studied are heterogeneous palynologically.

Van de Ven and Van der Ham (2006) studied 19 *Melodinus* spp.and *Craspidospermum verticillatum* pollen. The pollen grains of the genus *Melodinus* are usually medium-sized monads with 3-4-colporate while *Melodinus coriaceus* is polymorphic as to dispersal unit; mostly tetrads, sometimes monads. In addition, *Craspidospermum verticillatum*, the closest relative of *Melodinus*, has its pollen also in tetrads. In conclusion, on the basis of pollen morphology, it is hypothesized that tetrads evolved independently in *Melodinus* and *Craspidospermum*.

Table 2.1 Key characters of 14 tribes of Apocynaceae s.str. according to Middleton (1999) and Endress and Bruyns (2000)

Tribe	Astivation of corolla	Insertion of stamen	Relationship of anthers with style	Style head	Stigmatic receptive area
Willughbeeae	sinistrorse	slightly upper half	unattached but with a close association to the style head	with collar	beneath basal collar
Vinceae	sinistrorse or dextrorse in *Kopsia* and *Ochrosia*	near throat	completely separate from style, unattached but with a close association to the style head in *Rauvolfia*	with collar	beneath basal collar
Tabernaemontaneae	sinistrorse	upper half	completely separate from style	with or without collar	beneath basal collar or uniformly receptive
Alstonieae	sinistrorse or dextrorse	middle to upper half	completely separate from style	without basal collar and upper wreath	uniformly receptive
Melodineae	sinistrorse	middle to slightly lower half	unattached but with a close association to the style	without basal collar and upper wreath	uniformly receptive
Hunterieae	sinistrorse	upper half	unattached but with a close association to the style	without basal collar and upper wreath	uniformly receptive
Plumerieae	sinistrorse	middle to upper half, very base in *Plumeria*	completely separate from style, weakly coherent to style head in *Allamanda*, apically across top of head in *Thevetia*	with basal collar or lobes, no distinct collar in *Plumeria*; well-developed upper wreath in *Allamanda*	no data

Table 2.1 (continued)

Tribe	Astivation of corolla	Insertion of stamen	Relationship of anthers with style	Style head	Stigmatic receptive area
Carisseae	sinistrorse or dextrorse	upper half	unattached but with a close association to the style	scarcely differentiated without callar	uniformly receptive
Alyxieae	sinistrorse	upper half in *Alyxia*, slightly lower in *Chilocarpus*	completely separate from *style in Chilocarpus*, unattached but with a close association to the style in *Alyxia*	without basal collar and upper wreath	uniformly receptive
Wrightieae	dextrorse (except *Wrightia*)	included to exserted	weakly attached to base of style head	with basal collar and upper wreath of longer hairs	beneath basal collar
Malouetieae	dextrorse	included to exserted	attached to middle of style head	globose with narrowly conical upper part or broadly fusiform	on sides of lower cylindical part below adnation of anthers
Apocyneae	dextrorse (except *Parameria*)	inserted near the base of corolla tube	attached at about middle of style head	broadly fusiform	on lower cylindrical region below adnaton of anthers
Mesechiteae	dextrorse	inserted at base of throat	attached to the projection at lower part of style head	with 5 arms	on underside or lower region of style head
Echiteae	dextrorse	partially to completely exserted	attached near base of style head	cylindrical to narrowly fusiform, broadest and with collar at base and	on underside of style head beneath collar

CHAPTER III

MATERIALS AND METHODS

3.1 Plant materials

Pollen samples were obtained from voucher specimens deposited at BKF, PSU, and BCU herbaria. Due to unavailability of pollen from some voucher specimens as well as to access variation in palynological characteristics in different locality, additional field collection was made and these voucher specimens were deposited at BCU.

Field collection for herbarium specimens and pollen materials were made throughout Thailand during 2005 to 2007. Ten to twenty mature flowers of each species were kept and dried in paper envelopes. In addition, three duplications of plant specimens were collected and kept at the Kasin Suvatabhanhu Herbarium, Department of Botany, Chulalongkorn University (BCU).

The pollen of all the genera in Thailand have been examined (Table 1.1), with the exception of the *Leuconotis*, *Dyera*, *Chonemorpha*, *Cleghornia*, *Epigynum*, *Sindechites* and *Pottsia* for which there is no pollen material available. A total of 114 pollen samples belonging to 85 species representing the 36 genera, 13 tribes of Thai Apocynaceae were included in this study. A list of all voucher specimens is provided in Appendix A. Eighty-one pollen samples were obtained from the specimens deposited in BKF, PSU, and BCU. The rest were from the field collection.

3.2 Equipments

1) Paper envelopes
2) A plant press, size 30-46 cm
3) A pair of hand pruners
4) Plastic bags
5) Hand-lens
6) Camera
7) Collector's number cards

3.3 Chemical and supplies

1) 10% Potassium hydroxide
2) Glacial acetic acid
3) Acetic acid anhydride
4) Concentrated sulfuric acid
5) 70%, 90%, and absolute ethyl alcohol
6) Distilled water
7) Benzene
8) Silicone oil, AK 2,000
9) Glycerine jelly (according to the recipe of Hearns and Inouye (1993))
10) Paraffin wax
11) Immersion oil
12) Label stickers
13) Vials 1/2 dram
14) Sieving crucible
15) Beaker 50 ml and 100 ml
16) Hot plate
17) Centrifuge Hettich Tuttlingen model EBA 8S and centrifuge tubes
18) Microscopic slides and cover glasses
19) Stage micrometer, scale 1:10 μm
20) Light Microscope (LM) Olympus model CH30 and Olympus model B51 equip with digital camera unit DP70
21) Scanning electron microscope (SEM) Joel model JSM-5410 LV

3.4 Laboratory procedures

The pollen grains were first released from the anthers by boiling in 10% KOH approximately 5 minutes. They were then acetolysed according to the method of Erdtman (1960) as follows:

1) Wash pollen residues with distilled water 3 times.
2) Remove water by means of glacial acetic acid.
3) Remove most organic matters with acetolysis mixture (chemically pure acetic anhydride : concentrated sulphuric acid; 9:1) and boiled in 70°C heating water for 1 minute.
4) Wash with glacial acetic acid.
5) Wash with distilled water 3 times.

In each step, the mixture was centrifuged at 3,000 rpm. inside the fume hood to ensure pollen retention after each chemical treatment/wash.

However, there were few pollen grains in some samples and they usually got lost during slide preparation, the pollen preparation was followed the glycerine jelly fishing (Erdtman, 1960). This method was carried out in depressed microscopic slides, and absorbing paper was used to remove solution in each step.

Following acetolysis, the pollen were dehydrated in an ethanol series, and further pollen preparation was done for LM and SEM observations.

3.4.1 Preparation of pollen for LM investigation

Benzene was added to acetolyse pollen grains, and left for overnight. Then, silicone oil was added, and transferred into 1/2-dram vials for permanent collection. The permanent slides of each pollen sample were made using silicone oil as mounting medium and sealed with paraffin wax.

In cases of slide preparation for the glycerine jelly fishing method, glycerine jelly was used as mounting medium instead of silicone oil and sealed with paraffin wax.

The permanent slides of all pollen samples were deposited at the Kasin Suvatabhanhu Herbarium, Department of Botany, Chulalongkorn University (BCU).

3.4.2 Preparation of pollen for SEM investigation

Absolute ethyl alcohol was added to acetolyse pollen grains before subjecting dehydrated by critical-point-drying. Then, CPDed pollen was mounted on aluminum stubs, sputter coated with gold-palladium.

3.5 Pollen character measurement

Pollen sample from each species was observed under LM and micrographs were taken with 100× objective lens and 3.3× or 5× photo lens. SEM observation was carried out at 15 kV, and electron micrographs were taken at 1,000 to 15,000 magnifications.

The polar axis (P), equatorial diameter (E) and polar area index were measured from at least 8 mature pollen grains using an oil immersion 100× objective lens, and the P/E values were calculated for each pollen grain measured. Finally, a key to pollen types for the identification was constructed.

Palynological terminology used in this present work follows Punt *et al.* (2007). Definitions of pollen characters used in this study are provided in Appendix B.

CHAPTER IV

RESULTS

From the total of 125 species of 42 traditional apocynaceous genera belonging to 13 tribes found in Thailand (Middleton, 1999; Endress and Bruyns, 2000), of which 85 species (ca. 68%) of Thai Apocynaceae were included in this study. These were accounted for only 4.47% of all Apocynaceae s.str. around the world.

Thus far, only 19 species belonging to 17 genera, 10 tribes of Thai Apocynaceae were included in previous palynological studies (Huang, 1972; Rau and Shukla, 1975; Van Campo *et al.*, 1979; Cousin, 1979; Nair, 1981; Nilsson, 1986; Roubik and Moreno, 1991; Van der Ham *et al.*, 2001; Moreira *et al.*, 2004; Van de Ven and Van der Ham, 2006). From this investigation, it was estimated that about 25 per cent more palynological data of Apocynaceae was increased from previous studies.

4.1 General pollen morphology

4.1.1 Light microscopy

Pollen grains are mostly monads, rarely tetrahedral tetrads. The pollen grains usually are isopolar to subisopolar, rarely apolar or heteropolar. The polar field index of pollen grains vary from small (0.12) to large (0.80). The circumference of pollen grains in polar view can vary from circular to elliptic, triangular, rectangular or hexa-angular. The pollen grains can occur in peroblate to prolate, but usually occurring in suboblate to prolate spheroidal, rarely barrel-shaped or bone-shaped. The variation in size formed a gradient from small (14-19 µm) - to very large (100-106.33 µm) – sized. The most common types of apertures found in most species are zonocolporate and zonoporate, rarely zonocolpate, zonopororate or pantoporate. Endoaperture lalongate, constricted or not, with horns, H-shaped, or united in equatorial endocingulum. The basic numbers of apertures are three and four, rarely two or five, or more than ten. The exine sculpture of Apocynaceae pollen is usually psilate to perforation, or granulate due to infratectal elements.

4.1.2 Scanning electron microscopy

The exine sculpturing can be psilate, perforate, fossulate, foveolate, verrucate, scabrate, granulate or microreticulate. The tectum at interapertural area usually has different sculpturing from the others of the grain. In many species, the exine sculpture is usually psilate to perforate with more or less granules on the tectum. In addition, it may reveal fossulate with perforations in the fossulate. The ornamentation around apertures sometimes psilate and imperforate. Infratectal of the exine usually very short columellar or granulate. Inner nexine surface usually granulate to verrucate, especially around aperture. The aperture may be covered by a thickened lid or operculum, resulting in an operculate aperture.

4.2 Key to pollen types

1. a Aperture porate 2

1. b Aperture colporate or pororate or colpate 8

2. b Grain subisopolar to heteropolar 3

2. a Grain isopolar or apolar 4

3. a Grain barrel-like shape; large-sized grain .... *Alyxia reinwardtii* type

3. b Grain oblate to suboblate; small-sized grain .... *Anodendron affine* type

4. a Grain polypantoporate .... *Ichnocarpus polyanthus* type

4. b Grain zonoporate 5

5. a Grain (1-)2-zonoporate .... *Chilocarpus costatus* type

5. b Grain (2-)3-4(-5)-zonoporate 6

6. a Inner nexine surface band-like gemmate .... *Spirolobium cambodianum* type

6. b Inner nexine surface granulate or uneven or smooth 7

7. a Inner nexine surface smooth; large-sized grain; relative large pore;
exine thickness less than 1 μm .... *Amalocalyx microlobus* type

7. b Inner nexine surface granulate or uneven; small- to large-sized grain;
exine thickness 1-3 μm, somewhat less than 1 μm .... *Adenium obesum* type

8. a Grain tetrahedral tetrad .... *Melodinus orientalis* type

8. b Grain monad 9

9. a Semitectate grain; sexine perforate to microreticulate 10

9. b Tectate grain; sexine psilate, perforate, foveolate,
fossulate or verrucate 11

10. a Endoaperture colpi; grain medium- to large-sized .... *Thevetia peruviana* type

10. b Endoaperture pori; grain large- to very large-sized .... *Cerbera manghas* type

11. a Ornamentation fossulate to verrucate; amb hexa-angular with 3
bilobate-apertural sides; mesocolpium concave .... *Ochrosia oppositifolia* type

11. b Ornamentation psilate, perforate or foveolate; mesocolpium psilate
to fossulate; amb circular, triangular or rectangular 12

12. a Grain 3-zonocolpate to 3-zonocolporate;

pumpkin-like shape .... *Rauvolfia cambodiana* type

12. b Grain (2-)3-4(-5)-zonocolporate or 3 zonopororate; subspheroidal shape 13

13. a Grain 3(-4)-zonocolporate with very short
ectoaperture to 3-zonopororate .... *Willughbeia coriacea* type

13. b Grain (2-)3-4(-5)-zonocolporate 14

14. a Grain 2-zonocolporate; slightly small-sized grain ...... *Alstonia angustiloba* type

14. b Grain 3-4(-5)-zonocolporate; medium- to large-sized grain 15

15. a Endoaperture sometimes develop more than one within one ectoaperture;
exine thickness very thin; sexine finely psilate......... *Allamanda cathartica* type

15. b Endoaperture never develop more than one within one ectoaperture;
exine thickness usually more than 1 µm; sexine psilate
to perforate or fossulate 16

16. a Grain (3-)4-zonocolporate with incomplete aperture, or pantocolporate 17

16. b Grain 3-4(-5)-zonocolporate, never found incomplete aperture
or pantocolporate grain 18

17. a Grain large; ectocolpi slightly long, widened at equator, and tapering
towards the pole, sometimes syncolporate; sexine perforate,
sometimes with granules or flat verrucate .... *Kopsia arborea* type

17. b Grain small to medium; ectocolpi relative short, usually closed
at equator; sexine psilate to perforate .... *Melodinus cambodiensis* type

18. a Endoaperture endocingulum, or diffused endoaperture
with very distinct and equatoriales costa endocolpi;
3-4-zonocolporate grain .... *Tabernaemontana bovina* type

18. b Endoaperture diffused or not, costa endopori distinct or not;
3-4(-5)-zonocolporate grain 19

19. a Exine thickness at mesocolpium uneven, thinner around the aperture,
appearing like ridge around mesocolpial depression 20

19. b Exine thickness uneven or not, never appearing any ridges 21

20. a Grain medium-sized; amb triangular with straight or slightly
convex sides; mesocolpium always depressed .... *Catharanthus roseus* type

20. b Grain large-sized; amb triangular with more straight sides;
mesocolpium depressed or not .... *Alstonia curtisii* type

21. a Endopori with small horizontal horns .... *Astonia rostrata* type

21. b Endopori regular with no extension 22

22. a Grain large-sized; ectocolpi narrow elliptic or strip-like, very long,
equal to or slightly shorter than polar axis .... *Kopsia angustipetala* type

22. b Grain mostly medium-sized; ectocolpi elliptic, relative short,
usually shorter than polar axis .... *Alstonia macrophylla* type

4.3 Description of pollen types

4.3.1 *Alyxia reinwardtii* type (Type 1)

Pollen class:	2-zonoporate (very rarely 3-porate)
Polarity:	Subisopolar
Dispersal unit:	Monad
Polar field index:	-
P/E ratio:	(1.05-)1.52(-2.35)
Shape class:	Irregular barrel-shaped
Size class:	Large P = (55.00-)64.50(-75.00) μm, E = (26.00-)44.63(-64.00) μm
Polar outline:	Oblong or oblong-elliptic
Equatorial outline:	Oblong with one convex side and one more or less straight or concave sides, or irregular barrel-shaped
Aperture:	Pori round, relatively large compared to the size of grains, sometimes slightly unequal in size, (10.00-)27.41(-54.00) μm in diameter; annulus distinct, (1.50-)3.95(-11.00) μm in width. In 3-porate grain, pori strongly unequal in size and irregularly distributed.
Exine:	Tectate, exine thickness 0.8-3 μm, gradually increase towards the mesoporium and apoporium.
Ornamentation:	Psilate to perforate (LM). Perforate (SEM), sometimes with sparsely foveolate; perforation round or slit-like, smaller than 0.5 μm, irregularly distributed on smooth, somewhat, on rough or undulate surface.
Included taxa:	Subfamily Rauvolfoideae Tribe Alyxieae: *Alyxia reinwardtii* (Plate 1 A-B; Plate 63 A), *A. siamensis* (Plate 1 C-F; Plate 2 A-B; Plate 63 B-D), *A. thailandica* (Plate 2 C-F; Plate 63 E-G)

4.3.2 *Anodendron affine* type (Type 2)

Pollen class:	(1-)2(-3)-zonoporate or zonocolpate
Polarity:	Isopolar
Dispersal unit:	Monad
Polar field index:	-

P/E ratio: (0.53-)0.70(-0.88)

Shape class: Oblate to suboblate

Size class: Small to medium

P = (15.00-)18.70(-23.00) µm, E = (21.00-)26.99(-33.00) µm

Polar outline: Regular to irregular elliptic, oblong-elliptic

Equatorial outline: Various, circular, elliptic, regular or irregular bone-shaped

Aperture: Various in shape. Colpi lolongate elliptic, widened at the equator and tapering to acute ends, or colpi lalongate rectangular-elliptic, or pori round, oblong-elliptic, elliptic; margin distinct, unequal in size, (1.00-)1.99(-3.50) × (2.50-)3.31(-4.50) µm; annulus distinct, 2-3 µm in thickness; operculum absent. In bone-shape pollen grain, aperture always situated at the constricted area.

Exine: Tectate, exine thickness ca. 1 µm. Exine stratification obscure; inner surface of nexine uneven.

Ornamentation: Psilate (LM). Psilate (SEM) somewhat with uneven or undulate surface, or with sparsely minute granules and perforation (smaller than 0.5 µm).

Included taxa: Subfamily Apocynoideae

Tribe Apocyneae: *Anodendron affine* (Plate 3 A-D; Plate 64 A-C), *A. coriaceum* (Plate 3 E-F; Plate 4 A-B; Plate 64 D-G), *A. paniculatum* (Plate 4 D-F; Plate 5 A-F; Plate 64 H-J)

4.3.3 *Ichnocarpus polyanthus* type (Type 3)

Pollen class: Polypantoporate

Polarity: Apolar

Dispersal unit: Monad

Polar field index: -

P/E ratio: -

Shape class: Prolate spheroidal to prolate

Size class: Medium to large

P = (25.00-)44.08(-68.00) µm, E = (23.00-)38.25(-58.00) µm

Polar outline: Circular

Equatorial outline: Circular to elliptic-circular

Aperture: Pori round or elliptic, margin distinct or indistinct, number varies, 10-24, unevenly or irregularly distributed; diameter varies, (1.00-)2.50(-7.00) µm; annulus distinct, 1.5-3 µm in thickness; operculum present or absent.

Exine: Tectate, exine thickness up to 1 µm. Exine stratification obscure; inner surface of nexine uneven with granulate, verrucate or irregular shaped elements, more or less densely around apertures.

Ornamentation: Psilate (LM). Psilate (SEM) somewhat with uneven or undulate surface, or with sparsely minute granules and perforation (smaller than 0.5 µm).

Included taxa: Subfamily Apocynoideae

Tribe Apocyneae: *Ichnocarpus polyanthus* (Plate 6 A-F; Plate 65 A-B), *I. serpyllifolius* (Plate 7 A-C; Plate 65 C-E), *Trachelospermum asiaticum* (Plate 65 F-G), *T. lucidum* (Plate 7 D-F; Plate 65 H-I)

4.3.4 *Chilocarpus costatus* type (Type 4)

Pollen class: 2-zonoporate

Polarity: Isopolar to subisopolar

Dispersal unit: Monad

Polar field index: -

P/E ratio: (1.00-)1.11(-1.43)

Shape class: Irregular prolate spheroidal

Size class: Medium to large

P = (32.00-)42.23(-54.00) µm, E = (23.00-)39.97(-54.00) µm

Polar outline: Circular

Equatorial outline: Circular to elliptic-circular

Aperture: Pori round, sometimes slightly unequal in size, (3.50-)11.24(-18.00) µm in diameter; unevenly distributed in some grains; annulus distinct, 3-4 µm in width and usually with granulate sexine elements along margin.

Exine:	Tectate, exine thickness 1-2 µm. Exine stratification obscure. Inner nexine surface irregular verrucate.
Ornamentation:	Psilate (LM). Perforate (SEM), perforation round or slit-like, smaller than 0.5 µm, irregularly distributed on smooth, somewhat, on rough or undulate surface.
Included taxa:	Subfamily Rauvoifioideae
	Tribe Alyxieae — *Chilocarpus costatus* (Plate 8 A-C; Plate 66 A-E), *C. denudatus* (Plate 8 D-F; Plate 66 F)

4.3.5 *Spirolobium cambodianum* type (Type 5)

Pollen class:	3(-4-5)-porate
Polarity:	Isopolar to subisopolar
Dispersal unit:	Monad
Polar field index:	-
P/E ratio:	(0.67-)0.75(-0.82)
Shape class:	Oblate to suboblate
Size class:	Medium to large
	P = (31.00-)35.25(-42.00) µm, E = (41.00-)46.88(-52.00) µm
Polar outline:	Circular
Equatorial outline:	Circular to elliptic-circular
Aperture:	Simple apertures, pori circular, equal to slightly unequal in size, (3.00-)6.83(-11.00) µm in diameter, sometimes unequal-spaced pori. Annuli distinct, 2.00-3.00 µm thick, nexinous granules or gemmae sometimes slightly exert at the pori.
Exine:	Tectate, exine thickness about 1.00-2.00 µm. Sexine thinner than the nexine, infratectum very thin. Inner nexine surface granulate to gemmate, a number of granules or gemmae gradually increase towards the middle of the polar area and around equatorial zone, and band-like gemmae around the apertures.
Ornamentation:	Psilate (LM). Psilate to sparsely perforate (SEM), pores very small, less than 1.00 µm in diameter, circular, the distance between the pores longer than their diameters.
Included taxa:	Subfamily Apocynoideae

	Tribe Malouetieae	*Spirolobium cambodianum* (Plate 9 A-F; Plate 67 A-E)

4.3.6 *Amalocalyx microlobus* type (Type 6)

Pollen class:	3-4(-5)-zonoporate
Polarity:	Isopolar
Dispersal unit:	Monad
Polar field index:	-
P/E ratio:	(0.76-)0.88(-1.00)
Shape class:	Suboblate to oblate spheroidal
Size class:	Medium to large P = (35.20-)43.33(-52.40) µm, E = (38.43-)49.58(-57.60) µm
Polar outline:	Circular
Equatorial outline:	Circular to elliptic-circular
Aperture:	Pori round or slightly lalongate elliptic, margin distinct and regular, diameter varies, (3.00-)11.67(-21.00) µm; annulus distinct, 1-3 µm in thickness; operculum present or absent.
Exine:	Tectate, exine thickness up to 1 µm. Exine stratification obscure; inner surface of nexine uneven.
Ornamentation:	Psilate (LM). Psilate (SEM) somewhat with uneven or undulate surface, or with sparsely minute granules and perforation (smaller than 0.5 µm).
Included taxa:	Subfamily Apocynoideae

	Tribe Echiteae	*Amalocalyx microlobus* (Plate 10 A-C; Plate 68 A-C), *Parsonsia alboflavescens* (Plate 10 D-F; Plate 68 D)

Remarks:

In *Amalocalyx microlobus*, the pollen grains are very often shrunken and probably susceptible to acetolysis. Therefore, it was difficult to study these pollen grains with LM and SEM. Shrinkage might be due to very thin exine thickness with often less than 1 µm poorly developed exine.

Although the exine as a whole is usually acetolysis-resistant, endexine appears to be less resistant to acetolysis than ektexine (Walker and Doyle, 1975). This is probably the reason that the largely endexinous aperture membranes of pollen grains are frequently found broken in pollen that has been subjected to acetolysis which found in *Parsonsia alboflavescens* pollen grains.

4.3.7 *Adenium obesum* type (Type 7)

Pollen class: (2-)3-4(-5)-zonoporate

Polarity: Isopolar

Dispersal unit: Monad

Polar field index: -

P/E ratio: (0.68-)0.89(-1.09)

Shape class: Oblate to prolate spheroidal

Size class: Small to large
P = (12.00-)31.97(-70.00) µm, E = (14.00-)36.23(-80.00) µm

Polar outline: Circular

Equatorial outline: Circular to elliptic-circular

Aperture: Pori round or slightly elliptic, sometimes unevenly distributed, margin usually distinct and regular, diameter varies, (1.00-)4.27(-10.50) µm; annulus usually distinct, or indistinct (in *Urceola lucida*) varies in thickness, 1-5 µm; operculum with granules.

Exine: Tectate, exine thickness ca. 1 µm or less or up to 2 µm (in *Wrightia viridiflora*). Sexine thicker than or as thick as nexine; columella absent, infratectal alveolate or obscure; inner surface of nexine uneven with granulate, verrucate or irregular shaped elements, more densely around the apertures and apoporium area.

Ornamentation: Psilate (LM). Psilate (SEM) with sparsely minute granules and perforation (smaller than 0.5 µm), somewhat with uneven or undulate surface.

Included taxa: Subfamily Apocynoideae
Tribe Wrightieae *Adenium obesum* (Plate 22 A-D; Plate 73 E-G), *Nerium oleander* (Plate 22 E-F; Plate 23 A-B; Plate 73 H-I), *Strophanthus gratus* (Plate 23 C-F; Plate 73 M-O), *S. perakensis* (Plate 24 A-C; Plate 73 P; Plate 74 A-B), *S. wallichii*, *Wrightia antidysenterica* (Plate

	24 D-F; Plate 74 E-F), *W. arborea* (Plate 25 A-D; Plate 74 G), *W. dubia* (Plate 15 D-F; Plate 72 E), *W. laevis* (Plate 25 E-F; Plate 26 A-B; Plate 74 H), *W. lanceolata* (Plate 26 C-F; Plate 74 I-J), *W. pubescens* (Plate 19 E-F; Plate 20 A-F; Plate 73- C-D), *W. religioisa* (Plate 27 A-F; Plate 74 K-L), *W. sirikitae* (Plate 13 D-F; Plate 70 E-F), *W. viridiflora*
Tribe Malouetieae	*Holarrhena curtisii* (Plate 16 A-F; Plate 72 C), *H. pubescens* (Plate 17 A-F; Plate 72 D), *Kibatalia arborea* (Plate 14 A-D; Plate 71 A-C), *K. macrophylla* (Plate 14 E-F; Plate 71 D-E), *K. maingayi* (Plate 15 A-C; Plate 71 F-I)
Tribe Apocyneae	*Aganonerion polymorphum* (Plate 18 A-F; Plate 72 A-B), *Aganosma marginata* (Plate 21 A-F; Plate 73 A-B), *Beaumontia grandiflora* (Plate 12 A-F; Plate 70 A-B), *B. murtonii* (Plate 13 A-C; Plate 70 C-D), *Urceola lucida* (Plate 11 A-C; Plate 69 A-C), *U. micrantha* (Plate 11 D; Plate 69 H-I), *U. minutiflora* (Plate 11 E; Plate 69 D-G), *U. rosea* (Plate 11 F; Plate 69 J-K), *Vallaris glabra* (Plate 19 A-D; Plate 72 F-H), *V. solanacea* (Plate 28 A-F; Plate 74 C-D)
Tribe Echiteae	*Pentalinon luteum* (Plate 29 A-F; Plate 73 J-L)

Key to subtypes of pollen:

1. a Grain small-sized, 3-porate .... ***Urceola lucida* subtype**

(Including: *Urceola lucida*; *U. micrantha*; *U. minutiflora*; *U. rosea*)

1. b Grain medium- to large-sized, (2-)3-4(-5)-porate 2

2. a Grain large-sized, (3-)4(-5)-porate, exine thickness less than or ca. 1 µm .... ***Beaumontia grandiflora*** **subtype**
(Including: *Beaumontia grandiflora*; *B. murtonii*; *Wrightia sirikitae*)

2. b Grain medium-sized, or slightly large-sized, (2-)3-4(5)-porate 3

3. a Grain (2-)3-porate, slightly large-sized, exine thickness 1-3 µm, sexine psilate to perforate .... ***Kitabalia arborea*** **subtype**
(Including: *Kibatalia arborea*; *K. macrophylla*; *K. maingayi*)

3. b Grain (2-3-)4(-5)-porate, medium-sized, somewhat operculum present 4

4. a Grain 3-4(-5)-porate, sexine with more or less granules .... ***Wrightia dubia*** **subtype**
(Including: *Wrightia dubia*; *Holarrhena curtisii*; *H. pubescens*, *Aganonerion polymorphum*; *Vallaris glabra*)

4. b Grain (2-)3-4(5)-porate, sexine without any granules 5

5. a Grain (3-)4(5)-porate, sexine perforate to fossulate with perforations in the fossulate......... ***Wrightia pubescens*** **subtype**
(Including: *Wrightia pubescens*; *Aganosma marginata*)

5. b Grain (2-)3-4(-5)-porate, sexine psilate to perforate .... ***Adenium obesum*** **subtype**
(Including: *Adenium obesum*; *Nerium oleander*; *Strophanthus gratus*; *S. perakensis*; *Wrightia antidysenterica*; *W. arborea*; *W. laevis*; *W. lanceolata*; *W. religiosa*; *W. viridiflora*; *Vallaris solanacea*; *Pentalinon luteum*)

Remarks:

Beaumontia has larger size pollen but thinner exine, less than 1 µm. In the tribe Malouetieae, the tectum of *Beaumontia* pollen grains has distinct sexine element.

4.3.8 *Melodinus orientalis* type (Type 8)

Pollen class:	3-colporate.
Pollen unit:	Calymmate tetrahedral tetrads, sometimes tetragonal tetrads (about 5 %).
Size class:	Large. Diameters of the top of the grain (g) = (42.00-)46.20(-53.00) µm. The length of the variations between the three sides of polar triangle of each tetrad, D =

	(55.00-)67.53(-80.00) µm, d= (39.00-)47.32(-55.00) µm, and r = (25.33-)27.94(-31.67) µm.
Exine:	Tectate, exine thickness 1.50-2.00 µm thick.
Aperture:	3-colporate, furrow-like apertures often in interradial positions. The double furrow (2f) (2 demicolpi) length = (14.00-)21.00(-28.00) µm, width = (5.00-)6.33(-8.00) µm. The distances between the three colpus ends (t) = (20.00-)30.19(-36.00) µm. Margo present, costae about 3.00 µm thick.
Ornamentation:	*In LM*: Tectum psilate. *In SEM*: The tectum psilate to perforate, pores small, circular, less than 1.00 µm in length and diameter, the distance between the pores shorter than, as long as or longer than their diameters.
Included taxa:	Subfamily Rauvolfioideae Tribe Melodineae *Melodinus orientalis* (Plate 30 A-D; Plate 75 A-F)

4.3.9 *Thevetia peruviana* type (Type 9)

Pollen class:	3-zonocolporate
Polarity:	Isopolar
Dispersal unit:	Monad
Polar field index:	(0.57-)0.61(-0.66)
P/E ratio:	(0.71-)0.80(-0.92)
Shape class:	Oblate to oblate spheroidal
Size class:	Medium to large P = (39.00-)43.33(-49.00) µm, E = (49.00-)54.42(-57.00) µm
Polar outline:	Triangular with more or less straight or slightly convex sides.
Equatorial outline:	Elliptic to circular-elliptic with slightly protruding at the middle of ectoaperture.
Aperture:	Ectoapertures — colpi narrow, much shorter than polar axis, sometimes widened at the equator ad tapering towards the pole, ends acute or obtuse, margin regular, (2.00-)4.88(-7.00) × (21.00-)24.50(-29.00) µm; margo present; costa ectocolpi indistinct. Endoapertures — colpi, lalongate elliptic or oblong-elliptic, (8.00-)17.00(-

22.00) × (4.00-)5.29(-6.00) µm; costa endopori present, distinct.

Exine: Semitectate, exine thickness 2 µm or more, sexine thicker than nexine. Infratectum granulate.

Ornamentation: Microreticulate (LM), lumina irregular in shape and size, muri straight, as thick as or thicker than lumina, somewhat foveolate. Microreticulate to foveolate, or punctate (SEM) lumina or perforation round, elliptic, or irregular in shape and size, more or less ca. 1 µm.

Included taxa: Subfamily Rauvolfioideae

Tribe Plumerieae — *Thevetia peruviana* (Plate 31 A-F; Plate 76 A-E)

4.3.10 *Cerbera manghas* type (Type 10)

Pollen class: 3-zonocolporate

Polarity: Isopolar

Dispersal unit: Monad

Polar field index: (0.26-)0.38(-0.53)

P/E ratio: (0.84-)0.98(-1.20)

Shape class: Suboblate to subprolate

Size class: Large to very large

P = (54.00-)79.41(-93.63) µm, E = (58.00-)82.52(-106.33) µm

Polar outline: Circular to triangular-circular with convex or slightly straight sides.

Equatorial outline: Elliptic to circular-elliptic.

Aperture: Ectoapertures — colpi narrow or slit-like, indistinct or hardly visible, shorter than polar axis, sometimes widened at the equator and tapering towards the pole, ends acute or obtuse, (2.00-)8.99(-18.80) × (-38.00-)48.89(-56.02) µm; margo present; costa ectocolpi indistinct. Endoapertures — pori, lalongate elliptic to elliptic-circular, usually much opened, (2.00-)9.85(-18.80) × (6.00-)15.92(-24.00) µm; costa endopori present.

Exine: Semitectate, exine thickness 0.7-1.5 µm or more, sexine thicker than nexine. Infratectum alveolate to granulate.

Ornamentation: Microreticulate (LM), lumina round, muri regular, as thick as or thinner than lumina, sometimes perforate. Perforate (SEM), perforation round, elliptic, or slit-like, less than 1 µm in diameter.

Included taxa: Subfamily Rauvolfioideae

Tribe Plumerieae — *Cerbera manghas* (Plate 32 A-F; Plate 77 A-C), *C. odollam* (Plate 33 A-F; Plate 77 D-F)

Remarks:

This pollen type is related to *Thevetia peruviana* type in more or less microreticulate to perforate ornamentation but the latter has colpate endoaperture while the *Cerbera manghas* type has porate endoaperture. And within this type, pollen of *C. odollam* has smaller size than *C. manghas*.

4.3.11 *Ochrosia oppositifolia* type (Type 11)

Pollen class: 3-zonocolporate

Polarity: Isopolar

Dispersal unit: Monad

Polar field index: (0.24-)0.32(-0.45)

P/E ratio: (0.79-)0.89(-0.99)

Shape class: Suboblate to oblate spheroidal

Size class: Medium to large

P = (31.00-)35.75(-42.50) µm, E = (33.33-)40.37(-53.00) µm

Polar outline: Hexa-angular with 3 bilobate-apertural sides alternate with 3 concave areas of the middle part of mesocolpium.

Equatorial outline: Elliptic to circular-elliptic.

Aperture: Ectoapertures — colpi narrow or slit-like, slightly shorter than polar axis, slightly widened at the equator and tapering towards the pole, margin distinct, ends acute or obtuse; margin thin, sometimes indistinct; costa ectocolpi absent or indistinct . Endoapertures — pori, lalongate elliptic or circular-elliptic, equatorial ends diffused, indistinct or invisible; costa endocolpi distinct or indistinct.

Exine: Tectate, exine thickness ca. 1 μm, sexine thicker or as thick as nexine. Exine stratification obscure, columella invisible.

Ornamentation: Psilate to fossulate or verrucate (LM). Fossulate, verrucate or perforate, pore irregular in shape or circular, less than 1 μm in diameter (SEM).

Included taxa: Subfamily Rauvolfioideae

Tribe Vinceae *Ochrosia oppositifolia* (Plate 34 A-F; Plate 78 A-D)

4.3.12 *Rauvolfia cambodiana* type (Type 12)

Pollen class: 3-zonocolpate to 3-zonocolporate

Polarity: Isopolar

Dispersal unit: Monad

Polar field index: (0.31)0.44(-0.59)

P/E ratio: (0.26-)0.45(-0.63)

Shape class: Peroblate to oblate

Size class: Medium to large

P = (17.50-)34.30(-48.75) μm, E = (36.67-)75.57(-99.67) μm

Polar outline: Triangular to circular-triangular, with slightly concave or straight sides, and with, more or less, 2 protruded-lobe besides the margins of each aperture.

Equatorial outline: Elliptic to circular-elliptic.

Aperture: Ectoapertures — colpi, slightly shorter than polar axis, slightly widened at the equator and tapering towards the pole, margin distinct, ends acute or obtuse, (0.32-)7.07(-18.00) × (5.00-)12.32(-22.50) μm; margo thin, sometimes indistinct; costa ectocolpi absent or indistinct. Endoapertures — pori, elliptic or circular-elliptic, equatorial ends diffused, indistinct or invisible; costa endocolpi distinct or indistinct.

Exine: Tectate, exine thickness 1.0-3.5 μm, uneven, thickest part located at both apocolpial areas and extended to the equator, appearing like 3 pairs of ridges radiated from both polar ends to the margins of each colpi, exine thinner between the area of two adjacent pair of ridge;

	sexine thicker or as thick as nexine. Exine stratification obscure, columella invisible.
Ornamentation:	Psilate, and granulate or scabrate at the thinner part of nexine, due to the infratectal elements (LM). Psilate with minute perforation, or with uneven or roughly surface at the center of mesocolpium (SEM).
Included taxa:	Subfamily Rauvolfioideae
	Tribe Vinceae — *Rauvolfia cambodiana* (Plate 35 A-C; Plate 79 A-C), *R. serpentina* (Plate 35 D-F; Plate 79 D-F), *R. sumatrana* (Plate 36 A-F; Plate 79 G-H), *R. verticillata* (Plate 37 A-F; Plate 79 I-K)

Remarks:

In this type, pollen of *R. sumatrana* seems to be different from other *Rauvolfia* species by its faintly ridged tectum.

4.3.13 *Willughbeia coriacea* type (Type 13)

Pollen class:	3(-4)-zonocolporate to 3-zonopororate
Polarity:	Isopolar
Dispersal unit:	Monad
Polar field index:	(0.37-)0.64(-0.80)
P/E ratio:	(0.72-)0.86(-0.96)
Shape class:	Oblate to oblate spheroidal
Size class:	Medium
	P = (21.00-)31.93(-47.00) µm, E = (27.00-)36.00(-50.00) µm
Polar outline:	Circular to triangular-circular with convex sides.
Equatorial outline:	Elliptic to circular-elliptic.
Aperture:	Ectoapertures — colpi, much shorter than polar axis, circular-elliptic to rhomboid-elliptic, widely opened at equator, margin distinct, entire or parallel, ends acute to obtuse or round; pori circular; margo (or annulus in pori) distinct, ca. 1.5-2 µm. Endoapertures — lalongate colpi, elliptic to rhombic-elliptic or narrow elliptic, sometimes nearly congruent to the ectoaperture; costa

	endocolpus (or endoporus) distinct, sometimes equatorial ends diffused.
Exine:	Tectate, exine thickness ca. 1 µm, sexine as thick as, or slightly thinner than nexine, exine stratification obscure.
Ornamentation:	Psilate or granulate due to infratectal elements (LM). Psilate with minute perforation, pore less than 1 µm in diameter (SEM).
Included taxa:	Subfamily Rauvolfioideae
	Tribe Willughbeeae — *Willughbeia coriacea* (Plate 38 E-F; Plate 39 A-F; Plate 40 A-C; Plate 80 F-H), *W. edulis* (Plate 38 A-D; Plate 80 A-E), *W. grandiflora* (Plate 40 D-F; Plate 80 I-L)

Key to subtypes of pollen:

1\. a Ecto- and endoaperture slightly small and narrow; margin parallel.. ***Willughbeia edulis* subtype**

1\. b Ecto- and endoaperture larger and widely opened, nearly congruent together, sometimes pororate grain.................... ***Willughbeia coriacea* subtype** (Including: *W. coriacea*; *W. grandiflora*)

Remarks:

Pollen grains of *W. edulis* are more or less similar to *W. grandiflora* and *W. coriacea* but the ecto- and endoaperture are smaller and not widely opened. The difference between pollen grains of *W. grandiflora* and *W. coriacea* is the smaller size of the former species.

4.3.14 *Alstonia angustiloba* type (Type 14)

Pollen class:	2-colporate.
Polarity:	Isopolar to subisopolar.
Dispersal unit:	Monad.
Polar field index:	(0.32-)0.33(-0.36).
P/E ratio:	(0.76-)0.93(-1.04).

Shape class: Suboblate to prolate spheroidal.

Size class: Small to medium
P = (19.00-)23.14(-27.00) µm, E = (22.00-)25.00(-28.00) µm.

Polar outline: Circular.

Equatorial outline: Circular to elliptic.

Exine: Tectate, exine thickness 1.00-1.50 µm. Inner nexine surface uneven with very small granules, and more denser around the apertures.

Aperture: Ectoapertures — colpi narrowly elliptic, (2.00-)3.62(-5.00) × (11.50-)14.48(-17.00) µm in length, widened at the equator and tapering towards the poles, ends diffused, margins indistinct. Endoapertures — lalongate, pori circular to circular-elliptic, (2.00-)3.62(-5.00) × (2.09-)2.30(-2.51) µm in size, costae present.

Ornamentation: Psilate (LM) and finely psilate (SEM).

Included taxa: Subfamily Rauvolfioideae
Tribe Alstonieae — *Alstonia angustiloba* (Plate 42 A-B; Plate 81 A-C)

Remarks:

Among colporate pollen grains in the subfamily Rauvolfioideae, *Alstonia angustiloba* pollen are unique with their 2-colporate apertures while the others have 3-4(-5)-colporate pollen grains. This pollen type, moreover, has very fine psilate with no perforation in the tectum.

4.3.15 *Allamanda cathartica* type (Type 15)

Pollen class: 3-zonocolporate

Polarity: Isopolar

Dispersal unit: Monad

Polar field index: (0.29-)0.38(-0.47)

P/E ratio: (0.88-)1.04(-1.24)

Shape class: Oblate spheroidal to subprolate

Size class: Medium to large
P = (45.00-)51.13(-55.00) µm, E = (42.00-)49.81(-57.48) µm

Polar outline:	Circular to triangular-circular with more or less convex sides.
Equatorial outline:	Elliptic to circular-elliptic.
Aperture:	Ectoapertures — colpi narrow or slit-like, margin distinct, regular or jagged, slightly shorter than polar axis, sometimes widened at the equator and tapering towards the pole, ends acute or obtuse, somewhat diffused, 3.5-8 × 42-45 µm; margo present; costa ectocolpi indistinct. Endoapertures — colpi lalongate elliptic or oblong-elliptic, sometimes diffused into endocrack of nexine, 10-12.5 × 2.5-8.5 µm; costa endocolpi present. According to SEM, some grains seemed to develop more than one endoapertures within one ectocolpi, one at the equator and the other at the end of ectocolpi.
Exine:	Tectate, exine thickness very thin, less than 1 µm, sexine thinner or as thick as nexine. Exine stratification obscure. Columella present but hardly visible, more clearly in surface view rather than optical section.
Ornamentation:	Psilate with roughly pattern of columella (LM). Psilate with rough or undulate surface at the middle area of mesocolpium (SEM).
Included taxa:	Subfamily Rauvolfioideae Tribe Plumerieae *Allamanda cathartica* (Plate 42 C-F; Plate 81 D-I)

4.3.16 *Kopsia arborea* type (Type 16)

Pollen class:	(3-)4-zonocolporate
Polarity:	Isopolar to subisopolar
Dispersal unit:	Monad
Polar field index:	(0.27-)0.32(-0.36).
P/E ratio:	(0.84-)0.91(-1.00).
Shape class:	Suboblate to oblate spheroidal.
Size class:	Large P = (56.03-)59.00(-65.07) µm, E = (60.40-)65.27(-69.80) µm.
Polar outline:	Circular

Equatorial outline: Circular to circular-elliptic

Exine: Tectate, exine thickness about 1.00 μm. Sexine stratification obscure.

Aperture: Ectoapertures — colpi narrow elliptic or strip-like, long, slightly shorter than polar axis, (1.00-)5.33(-10.00) × (19.00-)42.67(-55.00) μm, closed or widened at the equator and tapering towards the poles, sometimes found incomplete apertures, or pantocolporate, ends acute and blunt, sometimes united at the ends of some colpi, margo present. Endoapertures — lolongate, diffused, pori circular-elliptic, (4.00-)6.50(-10.00) × (6.00-)11.14(-15.00) μm, costae present.

Ornamentation: Perforate (LM). Perforate, sometimes perforate with small granules or flattened verrucae, pores small, circular, less than 1.00 μm in length and diameter (SEM).

Included taxa: Subfamily Rauvolfioideae

Tribe Vinceae *Kopsia arborea* (Plate 43 A-F; Plate 44 A-F; Plate 82 A-C)

4.3.17 *Melodinus cambodiensis* type (Type 17)

Pollen class: (3-)4-colporate

Polarity: Subisopolar

Dispersal unit: Monad

Polar field index: (0.33-)0.49(-0.63)

P/E ratio: (0.80-)0.88(-1.04)

Shape class: Suboblate to prolate spheroidal

Size class: Small to medium

P = (20.00-)23.67(-26.00) μm, E = (23.00-)26.92(-30.00) μm

Polar outline: Circular, circular-elliptic, or rectangular-obtuse

Equatorial outline: Circular to circular-elliptic

Exine: Tectate, exine thickness up to 1.00 μm thick. Sexine as thick as the nexine, infratectum alveolate.

Aperture: Ectoapertures — colpi narrow or slit-like and rather short, (2.50-)3.00(-4.00) × (10.00-)12.89(-15.00) μm, closed or sometimes opened and widened at the equator

	and tapering towards the poles, ends acute, sometimes found incomplete apertures, or pantocolporate, margo distinct. Endoapertures — lalongate, pori circular, (4.00-)4.40(-5.00) × (2.50-)3.30(-3.50) µm, costae distinct, up to 3.00 µm thick. The incomplete aperture often colpate without the endoaperture, colpi rather narrow, strip-like shape, (1.88-)5.25(-10.74) × (0.36-)0.74(-1.07) µm, ends obtuse, hardly opened.
Ornamentation:	Perforate (LM). Psilate to perforate with perforations of varying size and shape, either round or slit-like, less than 1.00 µm in length and diameter, sometimes indistinctly fossulate(SEM).
Included taxa:	Subfamily Rauvolfioideae
	Tribe Melodineae *Melodinus cambodiensis* (Plate 45 A-F; Plate 46 A-C; Plate 82 D-I)

Remarks:

Pollen grains of this pollen type are outstanding with their unique apertures which slightly or strongly unequal in size and shape, irregularly distributed and usually found incomplete apertures or pantocolporate grains.

4.3.18 *Tabernaemontana bovina* type (Type 18)

Pollen class:	3-4 zonocolporate
Polarity:	Isopolar
Dispersal unit:	Monad
Polar field index:	(0.12-)0.49(-0.66)
P/E ratio:	(0.71-)0.95(-1.41)
Shape class:	Oblate to prolate
Size class:	Small to large
	P = (26.66-)39.89(-56.00) µm, E = (21.66-)42.53(-59.00) µm
Polar outline:	Circular to triangular with more or less convex sides in 3 aperturate grain. Rectangular, in 4 aperturate grain, with slightly convex or straight sides.
Equatorial outline:	Circular or elliptic-circular with curved sides.
Aperture:	Ectoapertures — colpi, elliptic to oblong-elliptic, widened at the equator and tapering towards the poles,

ends acute or obtuse, (2.42-)6.53(-10.00) × (8.50-)20.65(-35.00) µm; margo present, distinct. Endoapertures — endocingulum (band-like continuous equatorial zone), varying in width between (1.67-)8.56(-15.23) µm; or endoapertures pori, lalongate elliptic or oblong elliptic with diffuse ends, (5.00-)7.97(-13.00) × (16.00-)23.08(-32.00) µm; costa endocinguli or costa endopori distinct, (4.00-)5.31(-8.00) µm in width.

Exine: Tectate, exine thickness ca. 1 µm. Sexine thicker, or as thick as nexine. Exine stratification alveolate or obscure.

Ornamentation: Psilate (LM). Perforate (SEM), perforations round or slit-like, smaller than 0.5 µm, somewhat with rough or undulate surface.

Included taxa: Subfamily Rauvolfioideae

Tribe Tabernaemontaneae — *Tabernaemontana bovina* (Plate 49 C-F; Plate 84 E-I), *T. bufalina* (Plate 48 A-F; Plate 83 I-N), *T. corymbosa* (Plate 50 A-F; Plate 84 M-P), *T. divaricata* (Plate 49 A-B; Plate 84 A-D), *T. pandacaqui* (Plate 51 A-E; Plate 79 A-C), *T. pauciflora* (Plate 47 A-D; Plate 83 A-D), *T. peduncularis* (Plate 47 E-F; Plate 83 E-H)

Key to subtypes of pollen:

1. a Endoaperture endocingulum..2

1. b Endoaperture always diffused with distinct costa endopori.......... ***Tabernaemontana pauciflora* subtype** (Including: *T. pauciflora*; *T. peduncularis*)

2. a Sometimes endoaperture discontinuous and diffused;

costa endopori or endocinguli distinct and
equatoriales............................ ***Tabernaemontana bufalina*** **subtype**

2. b Never found any discontinuous endoapertures;
costa endocinguli distinct..3

3. a Exine thickness 2.5-3 µm; small- to medium-sized grain;
ectocolpi very narrow slit-like and
never opened at equator........ ***Tabernaemontana divaricata*** **subtype**

3. b Exine thickness ca. 1 µm; medium- to large sized grain;
ectocolpi elliptic to oblong-elliptic and opened at equator....................4

4. a Sexine undulating psilate; ectocolpi narrow;
endocinguli narrow at equator;
medium- to large-sized grain....... ***Tabernaemontana bovina*** **subtype**

4. b Sexine perforate; ectocolpi widened;
endocinguli broad;
medium-sized grain............. ***Tabernaemontana corymbosa*** **subtype**
(including: *T. corymbosa*; *T. pandacaqui*)

4.3.19 *Catharanthus roseus* type (Type 19)

Pollen class:	3-zonocolporate
Polarity:	Isopolar
Dispersal unit:	Monad
Polar field index:	(0.28-)0.33(-0.36)
P/E ratio:	(1.04-)1.12(-1.29)
Shape class:	Prolate spheroidal to subprolate
Size class:	Medium to large P = (48.75-)50.69(-54.00) µm, E = (41.00-)45.57(-48.00) µm
Polar outline:	Triangular with more or less straight side
Equatorial outline:	Elliptic to circular-elliptic
Aperture:	Ectoapertures — colpi narrow or slit-like, slightly shorter than polar axis, widened at the equator and tapering towards the pole, margin distinct, parallel, ends acute or obtuse, (1.50-)2.07(-3.00) × (34.00-)38.43(-42.00) µm; margo present, distinct, ca. 3 µm; costa ectocolpi present. Endoapertures — pori, lalongate elliptic or oblong-elliptic, equatorial ends diffused, indistinct or invisible, (8.00-)8.79(-10.00) ×

	(5.00-)5.71(-7.00) µm; costa endopori present at the polar ends.
Exine:	Tectate, exine thickness ca. 1 µm, sexine thicker or as thick as nexine. Infratectal alveolate. Exine thickness at mesocolpium uneven, thicker around the middle area of mesocolpium, appearing like elliptic or circular ridge around mesocolpial depression.
Ornamentation:	Perforate to microreticulate with distinctly psilate margo and granulate to scabrate at the depression of mesocolpium (LM). Perforate with granule to fossulate at the middle area of mesocolpium (SEM).
Included taxa:	Subfamily Rauvolfioideae
	Tribe Vinceae — *Catharanthus roseus* (Plate 52 A-F; Plate 85 A-D)

4.3.20 *Alstonia curtisii* type (Type 20)

Pollen class:	3-zonocolporate
Polarity:	Isopolar
Duspersal unit:	Monad
Polar field index:	(0.30-)0.39(-0.48)
P/E ratio:	(0.83-)0.96(-1.05)
Shape class:	Suboblate to prolate spheroidal
Size class:	Large
	P = (65.00-)68.00(-71.00) µm, E = (65.00-)70.67(-78.00) µm
Polar outline:	Triangular with straight sides or slightly convex
Equatorial outline:	Elliptic to circular-elliptic
Exine:	Tectate, exine thickness uneven, 1.00-2.00 µm thick, thicker at mesocolpia and around the aperture, columella invisible. Nexine surface around ectoapertures uneven.
Aperture:	Ectoapertures — colpi elliptic, (5.32-)12.00(-15.00) × (28.17-)40.25(-48.00) µm, broad or widened at the equator and tapering towards the poles, ends acute; margo distinct, (6.00-)7.00(-8.00) µm thick. Endoapertures — lalongate, pori circular to oblong-

	elliptic, diffuse at equatorial ends, (8.00-)9.50(-11.00) × (5.00-)9.33(-13.00) µm; costa present.
Ornamentation:	Perforate (LM). Perforate; mesocolpia coarsely perforate to indistinct fossulate with perforations in the fossulae, sometimes indistinct verrucate (SEM).
Included taxa:	Subfamily Rauvolfioideae
	Tribe Alstonieae *Alstonia curtisii* (Plate 85 E-H)

Remarks:

Pollen grains of *Alstonia curtisii* are more or less related to *Catharanthus roseus* with their ridge-like around apertures but the former has relatively larger-sized than the latter. The ornamentation of *C. roseus* pollen grains is more perforate than *A. curtisii*. The shape of pollen grains is prolate spheroidal to subprolate in *C. roseus* while *A. curtisii* has suboblate to prolate spheroidal shape and the polar outline of the former is more straight-side triangular than the latter.

4.3.21 *Alstonia rostrata* type (Type 21)

Pollen class:	(2-)3-zonocolporate
Polarity:	Isopolar
Dispersal unit:	Monad
Polar field index:	(0.35-)0.40(-0.45)
P/E ratio:	(0.77-)0.88(-0.93)
Shape class:	Suboblate to oblate spheroidal
Size class:	Medium
	P = (30.00-)35.10(-38.00) µm, E = (38.00-)39.80(-42.00) µm
Polar outline:	Circular to sub-triangular with convex sides
Equatorial outline:	Circular to circular-elliptic
Exine:	Tectate, exine thicknesss about 1.00 µm, columella very short, distinct.
Aperture:	Ectoapertures — colpi narrow elliptic, slightly shorter than polar axis, (4.50-)6.85(-11.00) × (23.00-)25.20(-26.00) µm, broad or widened at the equator and tapering towards the poles, ends obtuse; costa present. Endoapertures — lalongate, pori circular with small equatorial extension or horizontal horns, (6.00-)8.00(-

10.00) × (8.00-)10.20(-13.00) µm, costa present, distinct.

Ornamentation: Psilate to perforate (LM). Psilate to finely perforate; mesocolpium often perforate to sparsely fossulate, sometimes sparsely verrucate (SEM).

Included taxa: Subfamily Rauvolfioideae

Tribe Alstonieae *Alstonia rostrata* (Plate 53 A-F; Plate 85 I-L)

Remarks:

Pollen grains of *Alstonia rostrata* type are outstanding with their horizontal horns of endopori together with finely psilate exine surface. There is no any other endopori with small equatorial extension found in any species of this present study.

4.3.22 *Kopsia angustipetala* type (Type 22)

Pollen class: (2-)3-zonocolporate

Polarity: Isopolar

Dispersal unit: Monad

Polar field index: (0.19-)0.30(-0.43)

P/E ratio: (0.76-)1.01(-1.41)

Shape class: Suboblate to prolate

Size class: Large

P = (59.67-)70.11(-77.50) µm, E = (55.00-)70.77(-85.00) µm

Polar outline: Circular

Equatorial outline: Elliptic to circular-elliptic

Exine: Tectate, exine thickness rather thin, less than or ca. 1.00 µm. Sexine thicker than the nexine, infratectum very thin.

Aperture: Ectoapertures — colpi, narrow elliptic long strip-like, equal to or slightly shorter than polar axis, (3.50-)8.84(-16.00) × (53.00-)65.19(-80.50) µm, broad or widened at the equator and tapering towards the poles, ends acute, sometimes obtuse; margo present. Endoapertures — lalongate, diffused, pori circular to circular-elliptic, (8.00-)15.15(-20.00) × (10.00-)15.87(-23.00) µm; costa distinct, 3-6 µm thick.

Ornamentation: Perforate (LM). Perforate with perforations less than 1.00 µm (SEM).

Included taxa: Subfamily Rauvolfioideae

Tribe Vinceae — *Kopsia angustipetala* (Plate 54 A-D; Plate 85 M-P), *K. pauciflora* (Plate 54 E-F; Plate 55 A-C; Plate 86 A-D), *K. rosea* (Plate 55 D-F; Plate 86 E-G)

Remarks:

This pollen type is related to *Kopsia arborea* type with long strip-like ectocolpi, large-sized grain, very thin exine thickness and perforate ornamentation. Pollen grains of *K. arborea* type, however, maybe found incomplete apertures or pantocolporate, ectocolpi sometimes united at the ends and sexine sometimes perforate with small granules or flattened verrucae.

4.3.23 *Alstonia macrophylla* type (Type 23)

Pollen class: 3-4(-5)-zonocolporate

Polarity: Isopolar

Dispersal unit: Monad

Polar field index: (0.27-)0.47(-0.76)

P/E ratio: (0.63-)0.87(-1.09)

Shape class: Oblate to prolate spheroidal

Size class: Small to large

P = (18.15-)30.19(-44.00) µm, E = (22.00-)34.79(-53.00) µm

Polar outline: Circular, triangular-circular, triangular or rectangular with more or less straight or slightly convex or concave sides; the middle area of mesocolpium sometimes with slightly depression.

Equatorial outline: Elliptic to circular-elliptic

Aperture: Ectoapertures — colpi elliptic, narrow or slit-like, opened or widened at the equator and tapering towards the pole, ends acute or obtuse, (1.00-)3.74(-6.50) × (8.92-)18.92(-28.00) µm; margo present, mostly distinct. Endoapertures — pori or colpi, lalongate, elliptic or oblong-elliptic or circular-elliptic, equatorial ends diffused or not, distinct or invisible, (1.00-) 5.11

(-12.00) × (4.50-)9.99(-22.00) µm; costa endopori or endocolpi present, distinct or indistinct.

Exine: Tectate, exine thickness ca. 1 µm, sometimes 2-4 µm, sexine thicker, as thick as or thinner than nexine. Infratectal granulate to alveolate or obscure. Exine thickness maybe uneven, thicker around the middle area of mesocolpium. Nexine sometimes with irregular endocrack.

Ornamentation: Psilate to perforate (LM). Psilate to perforate, sometimes fossulate; mesocolpium uneven psilate, perforate, fossulate or verrucate (SEM).

Included taxa: Subfamily Rauvolfioideae

Tribe Alstonieae	*Alstonia macrophylla* (Plate 59 C-F; Plate 88 D-G), *A. scholaris* (Plate 60 A-C; Plate 88 H-K)
Tribe Willughbeeae	*Bousigonia angustifolia* (Plate 56 A-F; Plate 87 A-E)
Tribe Melodineae	*Melodinus cochinchinensis* (Plate 58 A-C; Plate 87 F-H)
Tribe Hunterieae	*Hunteria zeylanica* (Plate 58 D-F; Plate 88 A-C)
Tribe Plumerieae	*Plumeria obtusa* (Plate 57 A-F; Plate 87 I-L), *P. Rubra* (Plate 87 M-P)
Tribe Carisseae	*Carissa carandas* (Plate 60 D-F; Plate 61 A-B; Plate 88 L-O), *C. grandiflora* (Plate 62 A-F; Plate 89 E-H), *C. Spinarum* (Plate 61 C-F; Plate 89 A-D)

Key to subtypes of pollen:

1. a Grain 4(-5)-zonocolporate............. ***Bousigonia angustifolia* subtype**

1. b Grain 3(-4)-zonocolporate...2

2. a Sexine psilate without perforation or fossula,
not differ at mesocolpium.......................... ***Plumeria obtusa* subtype**
(Including: *Plumeria obtusa*; *P. Rubra*; *Melodinus cochinchinensis*)

2. b Sexine perforate or psilate with more or less perforations or fossulae,

mesocolpium more perforate, fossulate or verrucate..........................3

3. a Ectoaperture broad elliptic, not tapering towards the poles, ends obtuse..***Hunteria zeylanica* subtype**

3. b Ectoaperture narrow elliptic or slit-like, tapering towards the poles, ends acute or obtuse..4

4. a Mesocolpium without depression at the middle area; amb circular or circular-triangular or rectangular with slightly convex sides..........................***Alstonia macrophylla* subtype** (Including: *Alstonia macrophylla*; *A. scholaris*; *Carissa carandas*)

4. b Mesocolpium with slightly depression at the middle area; amb triangular with straight or slightly concave sides...5

5. a Sexine very fine psilate with sparsely round perforations; margin of ectocolpi regular.......................***Carissa spinarum* subtype**

5. b Sexine perforate with round or slit-like perforations; margin of ectocolpi irregular or jagged.............***Carissa grandiflora* subtype**

Table 4.1 Pollen morphological data of Apocynaceae in Thailand (Pol. = Polarity: I = Isopolar, S = Subisopolar, H = Heteropolar, A = Apolar; P.I. = Polar field index; P/E = P/E ratio; Shape class: per = peroblate, ob = oblate, ssp = subspkeroidal, sob = suboblate, osp = oblate spheroidal, psp = prolate spheroidal, spr = subprolate, pr = prolate; P×E = Polar grain size showing mean for polar axis (P) and equatorial diameter (E); Size class: S = Small, M = Medium, L = large, XL = very large; Exine th. = Exine thickness; Size of ecto. = Size of ectoaperture; Size of endo. = Size of endoaperture; Ornamentation: psi = psilate, per = perforate, fov = foveolate, mret = microreticulate, fos = fossulate, gra = granulate, ver = verrucate; tetrad: g = Diameters of the top of the grain; D, d, r = The length of the variations between the three sides of polar triangle of each tetrad; 2f = The double furrow of colpi length)

Species	Pollen type	Aperture	Pol.	P.I.	P/E	P×E (µm)	Shape class	Size class	Exine th. (µm)	Size of ecto. (µm)	Size of endo. (µm)	Ornamentation LM	Ornamentation SEM
Bousigonia													
B. angustifolia	23-1	4(-5)-colporate	I	0.45	0.84-0.93	38×44	sob-osp	M	1-4	4×21	16×6	per	per-fos
Willughbeia													
W.coriacea	13-2	3(-4)-colporate	I	0.64	0.78-0.94	26×31	sob-osp	M	1	4×11	7×5	per	per
W. edulis	13-1	3-colporate	I	0.66	0.72-0.85	25×30	ob-sob	M	1	4×11	9×4	per	per
W. grandiflora	13-2	3-colporate	I	0.64	0.92-0.96	44×47	osp	M	1	11×17	18×12	per	per
Catharanthus													
C. roseus	19	3-colporate	I	0.33	1.04-1.29	51×46	psp-spr	M	1	2×39	9×6	per	per
Kopsia													
K. angustipetala	22	3-colporate	I	0.35	0.91-0.99	73×75	osp	L	1	8×60	17×15	per	per
K. arboreae	16	3-4-colporate	S	0.32	0.84-1.00	59×65	sob-psp	L	1	5×43	7×11	per	per
K. pauciflora	22	3-colporate	I	0.22	0.76-1.10	69×80	sob-psp	L	<1	9×77	17×19	per	per
K. rosea	22	(2-)3-colporate	I	0.29	0.96-1.41	69×59	osp-pr	L	1	9×60	11×14	per	per
Ochrosia													
O. oppositifolia	11	(2-)3(-4)-colporate	I-S	0.32	0.79-0.99	36×40	sob-osp	M-L	1	4×35	5×8	fos	per-fos-ver

Table 4.1 (continued)

Species	Pollen type	Aperture	Pol.	P.I.	P/E	P×E (µm)	Shape class	Size class	Exine th. (µm)	Size of ecto. (µm)	Size of endo. (µm)	Ornamentation LM	Ornamentation SEM
Rauvolfia													
R.cambodiana	12	3-colporate	I	0.45	0.40-0.56	41×90	per-ob	L	1-3.5	4×12	4×11	psi	psi-per
R. serpentina	12	3-colporate	I	0.39	0.32-0.63	38×83	per-ob	L	0.5-3.5	11×17	8×15	psi	psi-per
R. sumatrana	12	3(-4)-colporate	I-S	0.49	0.30-0.61	25×61	per-ob	M-L	0.5-5	2×8	2×7	psi	per
R. verticillata	12	3-colporate	I	0.42	0.26-0.56	30×75	per-ob	L	1-3	12×11	10×11	psi	psi-per
Alstonia													
A. angustiloba	14	2-colporate	I	0.33	0.76-1.04	23×25	sob-psp	S-M	1-1.5	4×15	4×2	psi	psi
A. curtisii	20	3-colporate	I	0.39	0.83-1.05	68×71	sob-psp	L	1-2	12×40	10×9	per	per
A. macrophylla	23-4	3-colporate	I-S	0.65	0.73-0.89	22×26	ob-osp	S-M	0.5-3.5	3×14	7×9	psi	psi-per
A. rostrata	21	(2-)3-colporate	I	0.40	0.77-0.93	35×40	sob-psp	M	1	7×25	8×10	psi-per	psi-per
A. scholaris	23-4	3(-4)-colporate	I	0.40	0.63-0.84	26×36	ob-sob	M	0.5-1	4×18	6×5	psi	psi-per
Tabernaemontana													
T. bovina	18-4	(3-)4-colporate	I-S	0.53	0.83-0.87	43×50	sob	M-L	1	4×13	3-11	psi	psi-per
T. bufalina	18-2	4-colporate	I-S	0.51	0.81-1.03	31×33	sob-psp	M	1	7×15	2-10	per	per
T. corymbosa	18-5	(3-)4-colporate	I-S	0.53	0.96-1.07	43×43	osp-psp	M	1	8×24	8-12	per	per
T. divaricata	18-3	4-colporate	I-S	0.27	0.71-1.41	35×36	ob-pr	S-M	2.5-3	8×23	4-15	psi	psi
T. pandacaqui	18-5	(3-)4-colporate	I-S	0.48	0.81-0.97	37×41	sob-osp	M	1	6×25	3-13	per	per
T. pauciflora	18-1	3(-4)-colporate	I-S	0.49	0.83-0.98	45×49	sob-osp	M-L	1	7×27	27×7	per	per
T. peduncularis	18-1	3-colporate	I-S	0.60	0.86-1.10	43×45	sob-psp	M-L	1	7×22	23×8	per	per

Table 4.1 (continued)

Species	Pollen type	Aperture	Pol.	P.I.	P/E	P×E (µm)	Shape class	Size class	Exine th. (µm)	Size of ecto. (µm)	Size of endo. (µm)	Ornamentation LM	Ornamentation SEM
Melodinus													
M. cambodiensis	17	(3-)4-colporate	S	0.49	0.80-1.04	24×27	sob-psp	S-M	1	3×13	4×3	per	per
M. cochinchinensis	23-2	3-colporate	S	0.45	0.73-0.88	36×45	ob-sob	M	1	4×20	11×3	psi	psi-per
*M. orientalis**	8	3-colporate						L	1.5-2			psi	psi-per
Hunteria													
H. zeylanica	23-3	3(-4)-colporate	I	0.53	0.79-0.94	28×32	sob-psp	M	1	4×17	14×9	per	per-fos
Allamanda													
A. cathartica	15	3-colporate	I-S	0.38	0.88-1.24	51×50	osp-spr	M-L	<1	4×43	12×6	psi	psi
Cerbera													
C. manghas	10	3-colporate	I	0.34	0.91-0.97	92×98	osp	L-XL	1-2.5	14×52	14×18	per	per-fov
C. odollam	10	3-colporate	I	0.40	0.84-1.20	67×65	sob-spr	L	1-1.5	4×45	6×13	per	per-fov
Plumeria													
P. obtusa	23-2	3(-4)-colporate	I	0.39	0.78-0.95	22×26	sob-osp	S-M	1	3×16	5×2	psi	psi
P. rubra	23-2	3-colporate	I	0.31	0.79-0.89	25×29	sob-osp	M	1	3×20	6×3	psi	-
Thevetia													
T. peruviana	9	3-colporate	I	0.61	0.71-0.92	43×54	ob-osp	M-L	2	5×25	17×5	per-mret	per-fov-mret

Note:

* *M. orientalis*: tetrahedral tetrads (tetragonal tetrads 5 %); g = (42.00-)46.20(-53.00) µm; D = (55.00-)67.53(-80.00) µm, d= (39.00-)47.32(-55.00) µm, r = (25.33-)27.94(-31.67) µm.

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Table 4.1 (continued)

Species	Pollen type	Aperture	Pol.	P.I.	P/E	P×E (μm)	Shape class	Size class	Exine th. (μm)	Size of ecto. (μm)	Size of endo. (μm)	Ornamentation LM	Ornamentation SEM
Carissa													
C. carandas	23-4	3(-4)-colporate	I	0.60	0.79-0.95	42×47	sob-osp	M-L	2	5×21	17×6	psi-per	per-ver
C. grandiflora	23-6	3-colporate	I	0.49	0.81-0.97	31×35	sob-osp	M	1.5-2	3×19	9×5	psi	psi-per-fos
C. spinarum	23-5	3-colporate	I	0.50	0.95-1.09	37×36	osp-psp	M	2	4×23	9×4	psi	psi-per
Chilocarpus													
C. costatus	4	2-porate	I-S	-	1.00-1.27	50×45	ssp	M-L	1	-	8-18	per	per
C. denudatus	4	(1-)2-porate	I-S	-	1.00-1.43	34×40	ssp	M	1.5-2	-	4-18	per	per
Alyxia													
A. reinwardtii	1	2-porate	S	-	1.28-2.35	61×36	barrel-like	L	1.5-2	-	10-27	psi	psi-per
A. siamensis	1	2(-3)-porate	S	-	1.16-1.79	63×43	barrel-like	L	2-3	-	12-48	per-mret	per-fov
A. thailandica	1	2-porate	S	-	1.05-1.60	69×57	barrel-like	L	0.8-1.6	-	18-54	per	per-fov
Adenium													
A. obesum	7-6	(3-)4(-5)-porate	I	-	0.89-1.00	37×40	osp	M	1	-	1-9	psi	per
Nerium													
N. oleander	7-6	4(-5)-porate	I	-	0.80-0.97	33×38	sob-osp	M	1-2	-	1-6	psi	psi-per
Strophanthus													
S. gratus	7-6	(3-)4(-5)-porate	I	-	0.77-0.91	31×37	sob-osp	M	1	-	3-6	psi	psi-per
S. perakensis	7-6	(2-)3-porate	S	-	0.80-0.92	33×38	sob-osp	M	1	-	3-6	psi	psi-per
S. wallichii	7-6	(2-)3(-4)-porate	I	-	0.68-0.97	28×33	ob-osp	M	1	-	3-6	psi	psi-per

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Table 4.1 (continued)

Species	Pollen type	Aperture	Pol.	P.I.	P/E	P×E (μm)	Shape class	Size class	Exine th. (μm)	Size of ecto. (μm)	Size of endo. (μm)	Ornamentation	
												LM	SEM
Wrightia													
W. antidysenterica	7-6	(3-)4-porate	I	-	0.78-0.97	34×39	sob-osp	M	1	-	4-6	psi	per
W. arborea	7-6	(3-)4-porate	I	-	0.87-0.96	28×31	sob-osp	M	1	-	3-8	per	per
W. dubia	7-4	(3-)4-porate	I	-	0.87-0.98	36×39	sob-osp	M	1	-	4-8	psi	psi-per
W. laevis	7-6	3(-4)-porate	S	-	0.86-0.95	30×33	sob-osp	M	1	-	2-5	per	per
W. lanceolata	7-6	4-porate	S	-	0.77-0.91	39×47	sob-osp	M	1	-	3-7	psi	per
W. pubescens	7-5	4(-5)-porate	I	-	0.72-0.97	26×30	ob-osp	M	1	-	2-6	per	per-fos
W. religiosa	7-6	4-porate	I	-	0.75-0.97	26×32	sob-osp	M	1	-	2-6	per	per
W. sirikitae	7-2	(3-)4-porate	I	-	0.85-0.96	49×54	sob-osp	L	1-1.5	-	5-10	psi	psi-gra
W. viridiflora	7-6	4(-5)-porate	I	-	0.94-1.06	34×35	osp-psp	M	1.5-2	-	3-6	psi	-
Holarrhena													
H. curtisii	7-4	3(-4-5)-porate	I	-	0.88-1.04	30×32	osp-psp	M	1	-	3-7	psi	psi-per
H. pubescens	7-4	3(-4-5)-porate	I	-	0.82-0.91	29×33	sob-osp	M	1	-	3-7	per	psi-per
Kibatalia													
K. arborea	7-3	(2-)3-porate	I-S	-	0.77-0.97	49×57	sob-osp	L	2-3	-	3-15	psi	psi-per
K. macrophylla	7-3	(2-)3-porate	I-S	-	0.90-1.00	50×53	osp	M-L	1-2	-	4-10	psi	psi
K. maingayi	7-3	(2-)3-porate	I-S	-	0.85-0.98	40×44	sob-osp	M	1-2	-	2-6	psi	per
Spirolobium													
S. cambodianum	5	(3-)4(-5)-porate	I-S	-	0.67-0.82	35×47	ob-sob	M-L	1-2	-	3-11	psi	psi-per
Aganonerion													
A. polymorphum	7-4	3(-4)-porate	I	-	0.76-0.96	22×26	sob-osp	M-L	<1	-	3-6	per	per-gra

Table 4.1 (continued)

Species	Pollen type	Aperture	Pol.	P.I.	P/E	P×E (μm)	Shape class	Size class	Exine th. (μm)	Size of ecto. (μm)	Size of endo. (μm)	Ornamentation LM	Ornamentation SEM
Aganosma													
A. marginata	7-5	3(-4)-porate	I	-	0.86-0.92	24×26	sob-osp	M	<1	-	2-4	psi	per-fos
Anodendron													
A. affine	2	(1-)2(-3)-porate	S-H	-	0.58-0.83	20×28	ob-sob	S-M	1	-	2×4	psi	psi
A. coriaceum	2	2(-3)-porate	S-H	-	0.53-0.88	17×27	ob-sob	S-M	1	-	2×3	psi	psi
A. paniculatum	2	2-porate	S-H	-	8.59-0.87	19×26	ob-sob	S-M	1	-	2×4	psi	psi
Beaumontia													
B. grandiflora	7-2	4(-5)-porate	I	-	0.92-1.09	53×54	osp-psp	L	<1-1	-	3-8	per	per-gra
B. murtonii	7-2	4(-5)-porate	I	-	0.79-1.01	60×66	sob-psp	L	1	-	4-11	psi	psi-per
Ichnocarpus													
I. polyanthus	3	13-23-porate	A	-	1.00-1.52	33×28	psp-pr	M	<1	-	1-4	psi	psi-per
I. serpyllifolius	3	12-18-porate	A	-	1.00-1.25	34×31	psp-spr	M	<1	-	1-4	psi	psi
Parameria													
P. polyneura	7-1	(2-)3-porate	I-S	-	0.77-0.96	23×25	sob-osp	S-M	1	-	3-6	psi	psi-per
Trachelospermum													
T. asiaticum	3	14-24-porate	A	-	1.02-1.32	47×42	psp-spr	M-L	<1	-	1-4	psi	psi
T. lucidum	3	10-18-porate	A	-	1.08-1.45	62×51	psp-spr	L	1	-	1-7	psi	psi-per
Urceola													
U. lucida	7-1	3-porate	I-S	-	0.79-0.96	18×20	sob-osp	S	1	-	2-4	psi	psi-per
U. micrantha	7-1	3-porate	S	-	0.75-0.89	14×16	sob-osp	S	1	-	1-2	psi	psi
U. minutiflora	7-1	3-porate	I-S	-	0.77-0.94	16×19	sob-osp	S	1	-	1-4	psi	psi-per

Table 4.1 (continued)

Species	Pollen type	Aperture	Pol.	P.I.	P/E	P×E (µm)	Shape class	Size class	Exine th. (µm)	Size of ecto. (µm)	Size of endo. (µm)	Ornamentation LM	Ornamentation SEM
Urceola													
U. rosea	7-1	3-porate	I-S	-	0.74-0.96	23×27	ob-osp	S-M	1	-	1-5	psi	psi-per
Vallaris													
V. glabra	7-4	(3-)4-porate	I	-	0.86-1.00	28×31	sob-osp	M	1	-	2-5	psi	per-gra
V. solanacea	7-6	3-porate	I	-	0.83-1.00	40×43	sob-osp	M	1-2	-	3-8	psi	per
Amalocalyx													
A. microlobus	6	(3-)-4-porate	I	-	0.87-0.93	45×50	sob-osp	M-L	<1	-	7-21	psi	psi
Parsonsia													
P. alboflavescens	6	(3-)4(-5)-porate	S	-	0.76-1.00	45×50	sob-osp	M-L	<1	-	3-17	per	per
Pentalinon													
P. luteum	7-6	(3-)4(-5)-porate	I	-	0.86-1.03	41×44	sob-osp	M	<1-1	-	4-8	psi	per

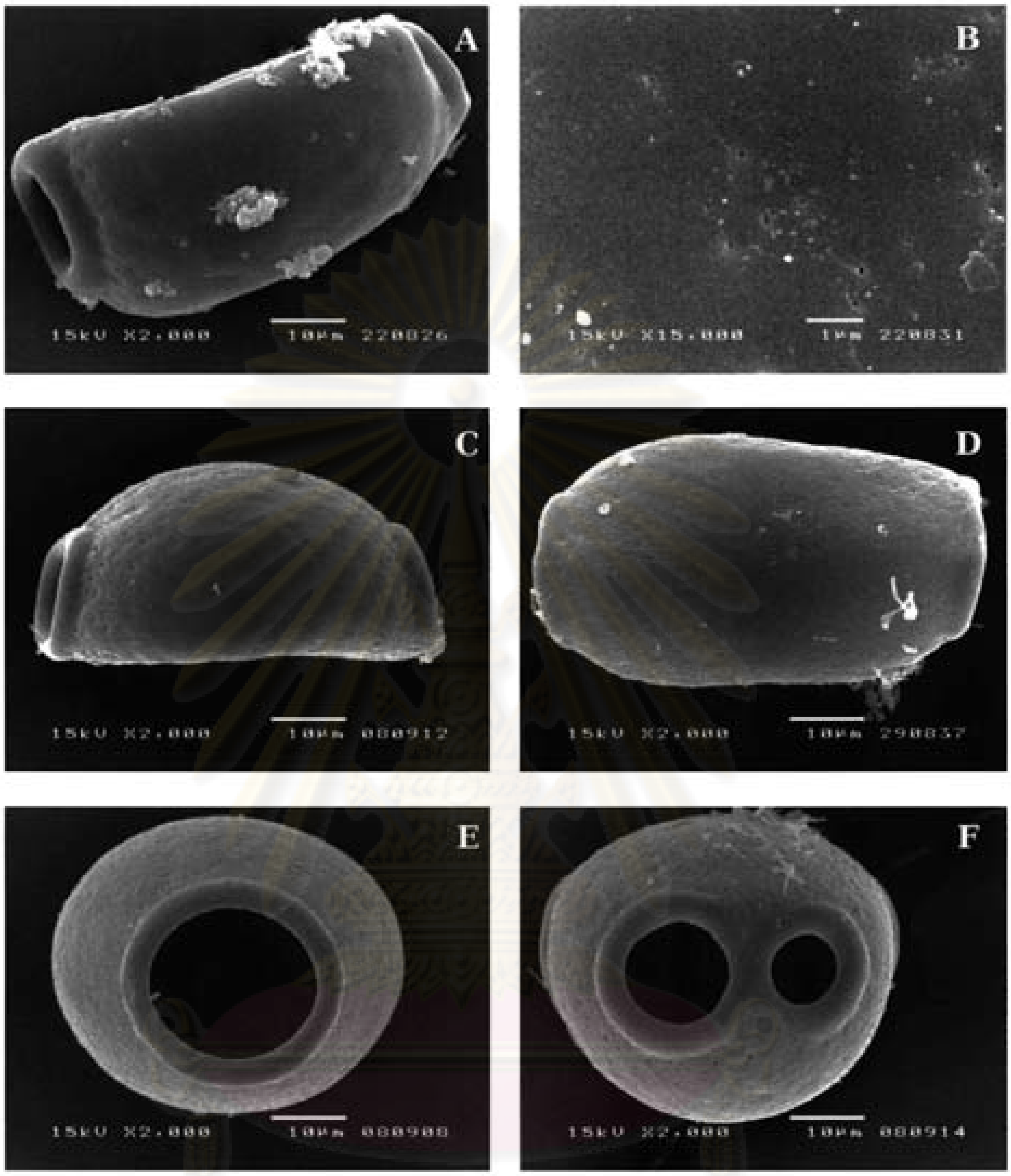

Plate 1 SEM micrographs: A-B. ***Alyxia reinwardtii* Blume** (A) Equatorial view, tubular shape, (B) Sexine surface psilate with perforation; C-F. ***Alyxia siamensis* Craib** (C) Equatorial view with more or less oblique barrel-like shape, (D) Polar view with cylindrical amb, (E) Porate aperture with very distinct annulus, outwardly thickening of the exine, (F) Triporate pollen grain showing two aperturate side of the grain.

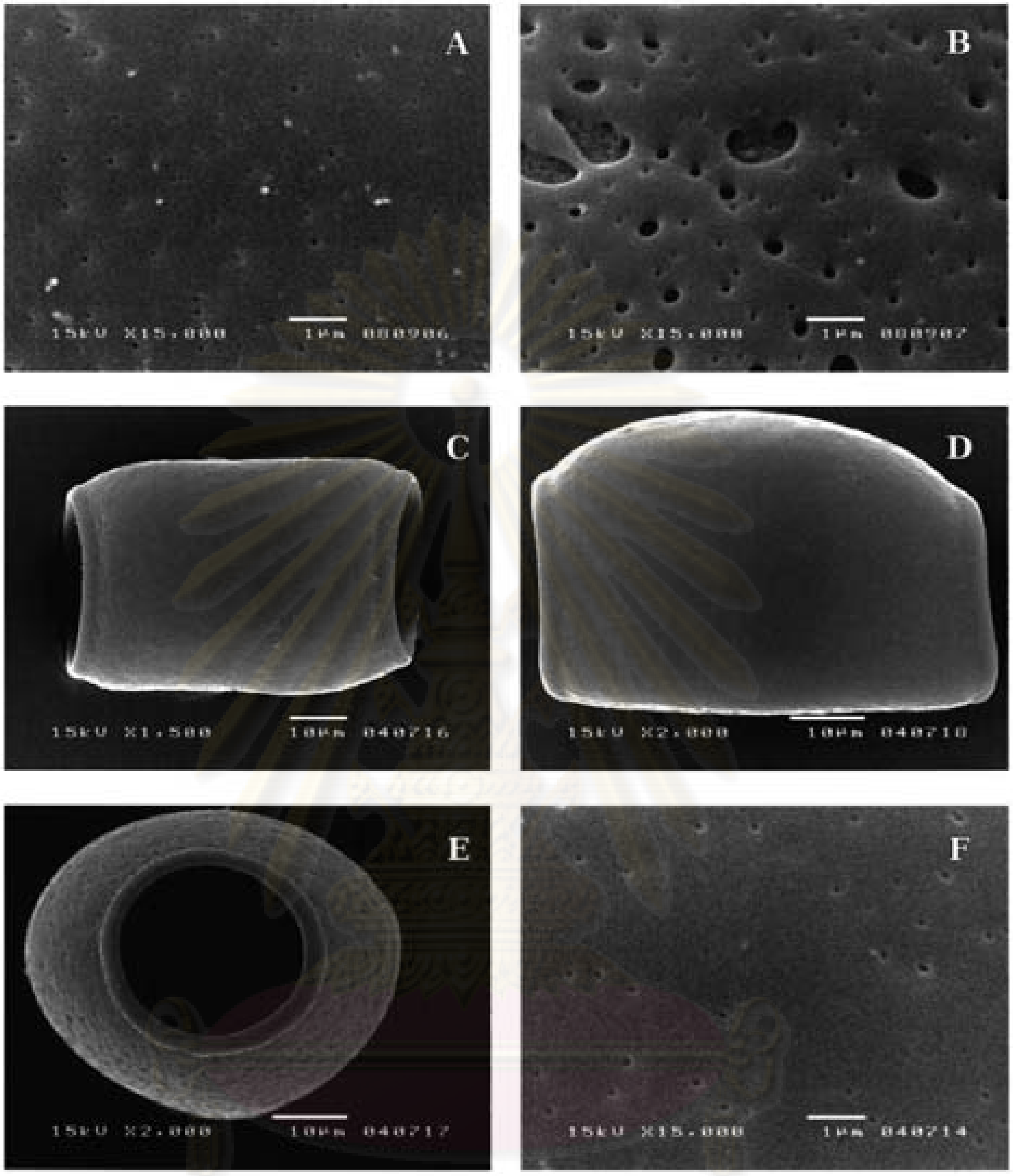

Plate 2 SEM micrographs: A-B. ***Alyxia siamensis* Craib** (A) Sexine surface psilate with perforation, (B) Sexine surface foveolate; C-F. ***A. thailandica* D.J. Middleton** (C) Equatorial view with barrel-like shape, (D) Equatorial view with more or less oblique barrel shape, (E) Equatorial view showing porate aperture with very distinct annulus, outwardly thickening of the exine, (F) Sexine surface psilate with perforation.

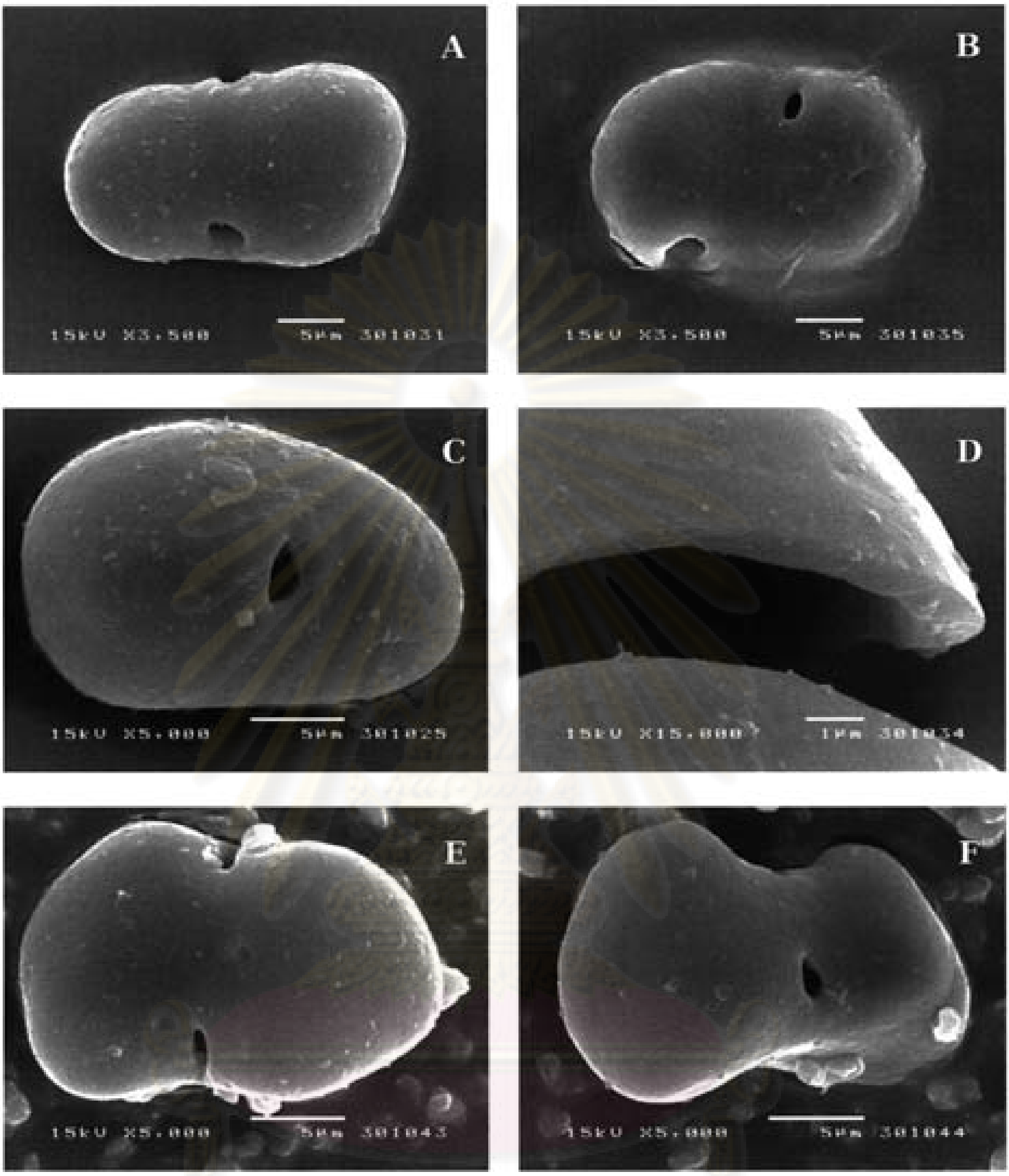

Plate 3 SEM micrographs: A-D. ***Anodendron affine*** **(Hook. & Arn.) Druce** (A) Equatorial view, subisopolar, (B) Equatorial view, heteropolar, (C) Porate elliptic with annulus, (D) Tectate exine; E-F. ***A. coriaceum*** **(Blume) Miq.** (E) Equatorial view, subisopolar grain, (F) Bone-like shape with aperture colpi and equatoriales.

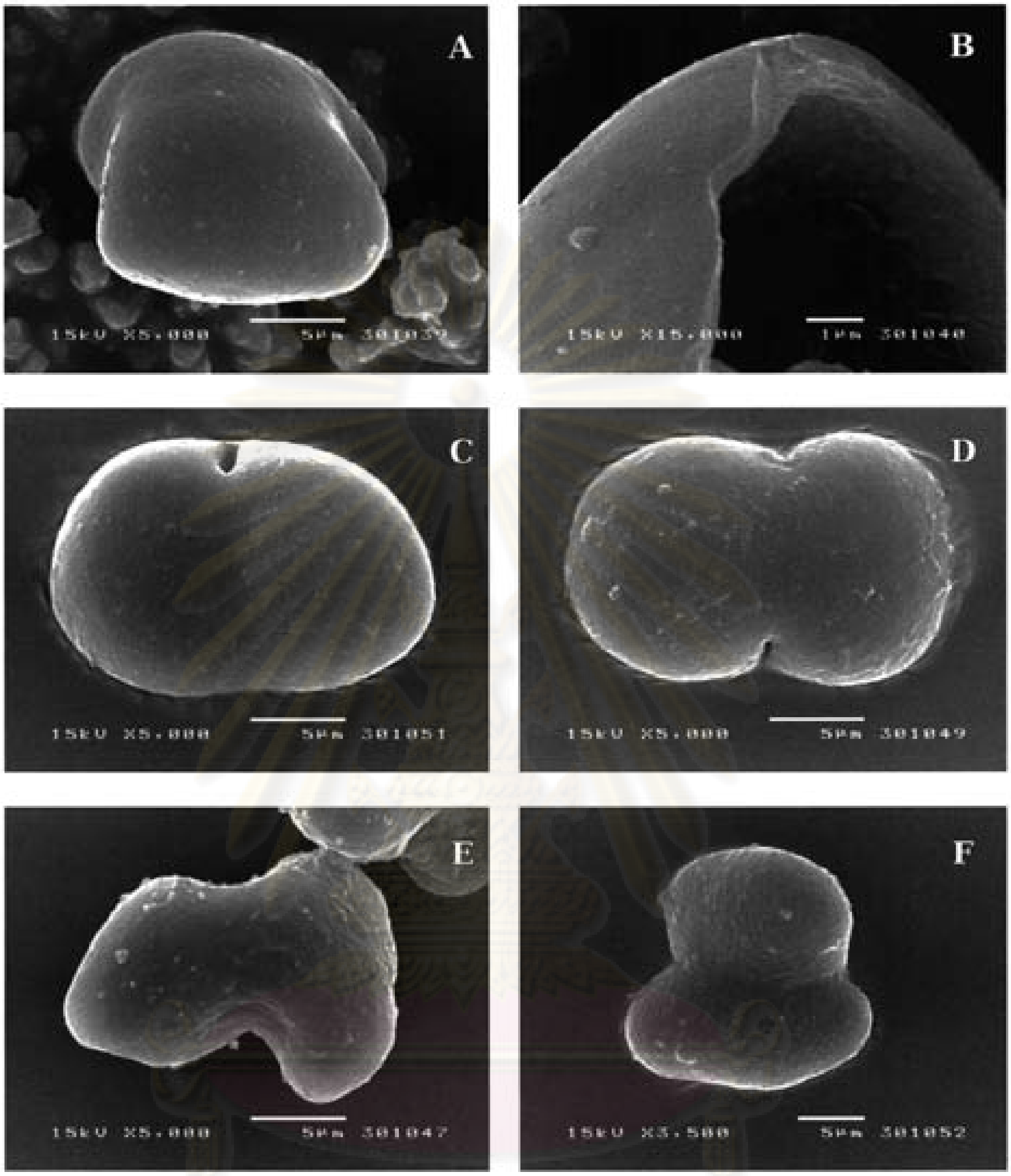

Plate 4 SEM micrographs: A-B. ***Anodendron coriaceum* (Blume) Miq.** (A) Polar view with elliptic amb, (B) Tectate exine; D-F. ***A. paniculatum* A.DC**. (C) Equatorial view with aperture slightly colpi and equatoriales, (D) Equatorial view, isopolar, (E)-(F) Equatorial view, bone-like shape.

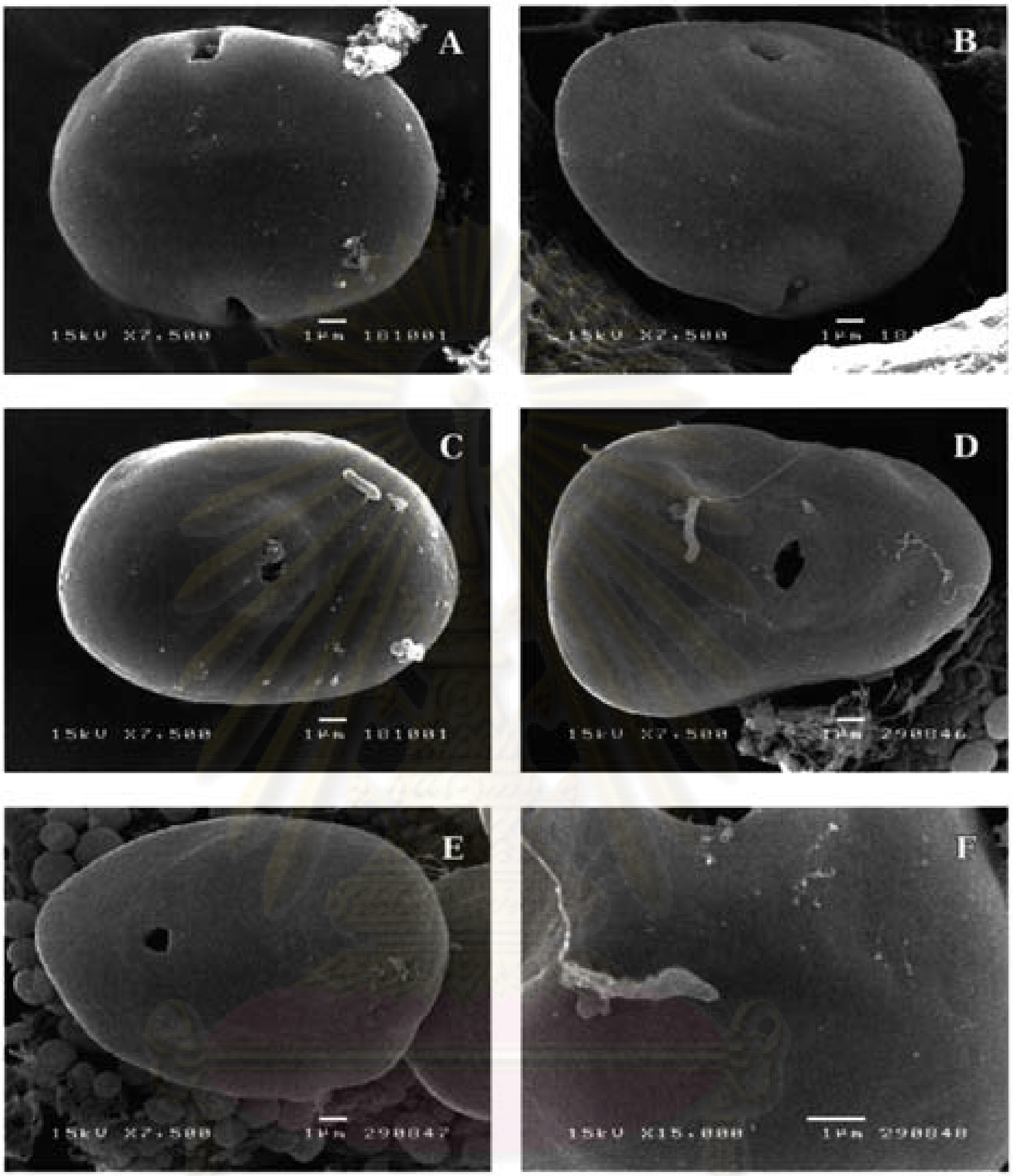

Plate 5 SEM micrographs: A-F. ***Anodendron paniculatum* A.DC.** (A) Equatorial view, isopolar, (B) Equatorial view, subisopolar, (C) Porate with annulus, (D) Porate slightly elliptic, (E) Porate circular, (F) Smooth psilate sexine surface.

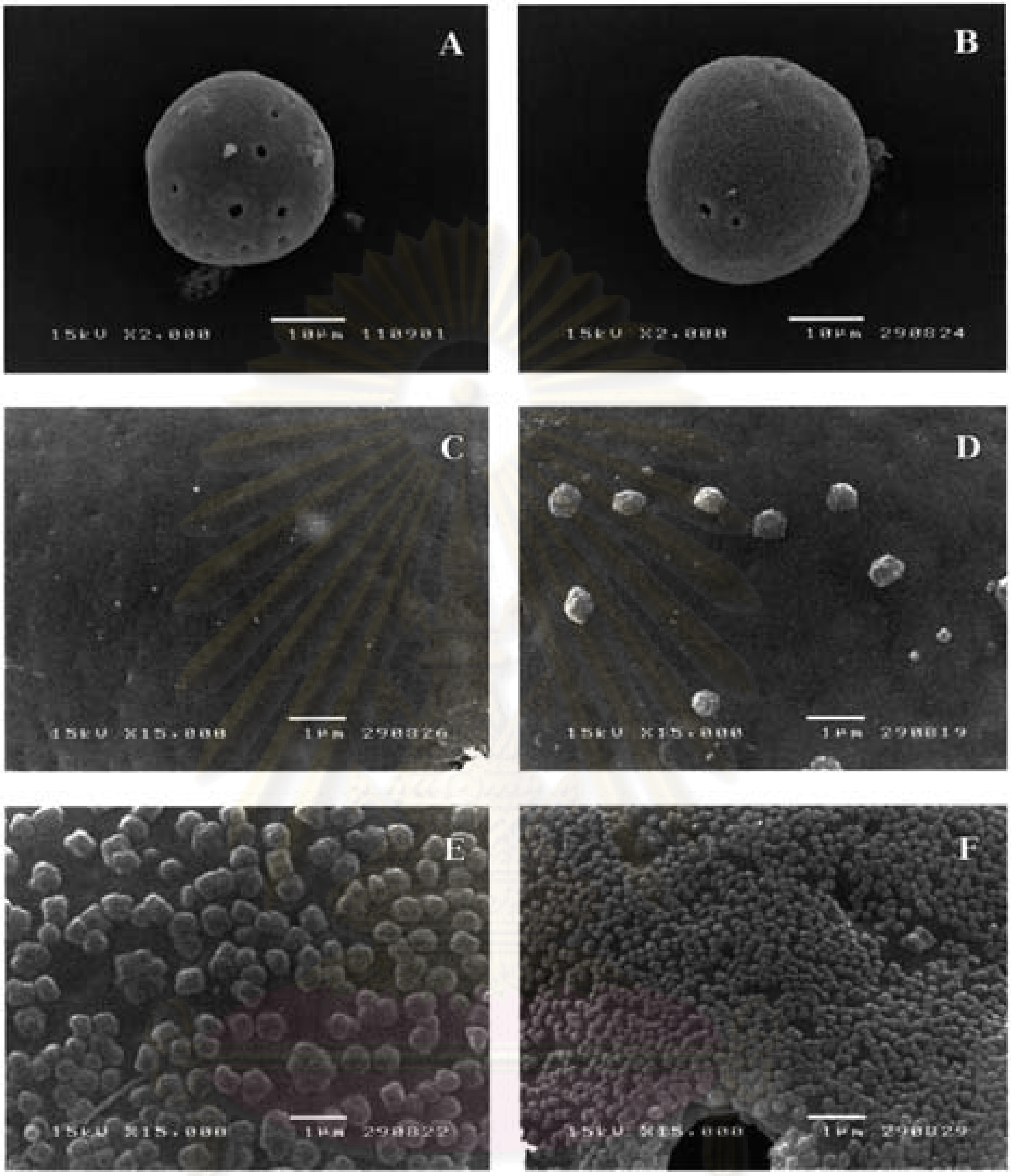

Plate 6 SEM micrographs: A-F. ***Ichnocarpus polyanthus*** **(Blume) P.I. Forst**. (A)-(B) Apolar, polypantoporate grain, (C) Smooth psilate, (D) Psilate with sparsely granules, (E) Psilate with densely granules, (F) Psilate with densely very small granules.

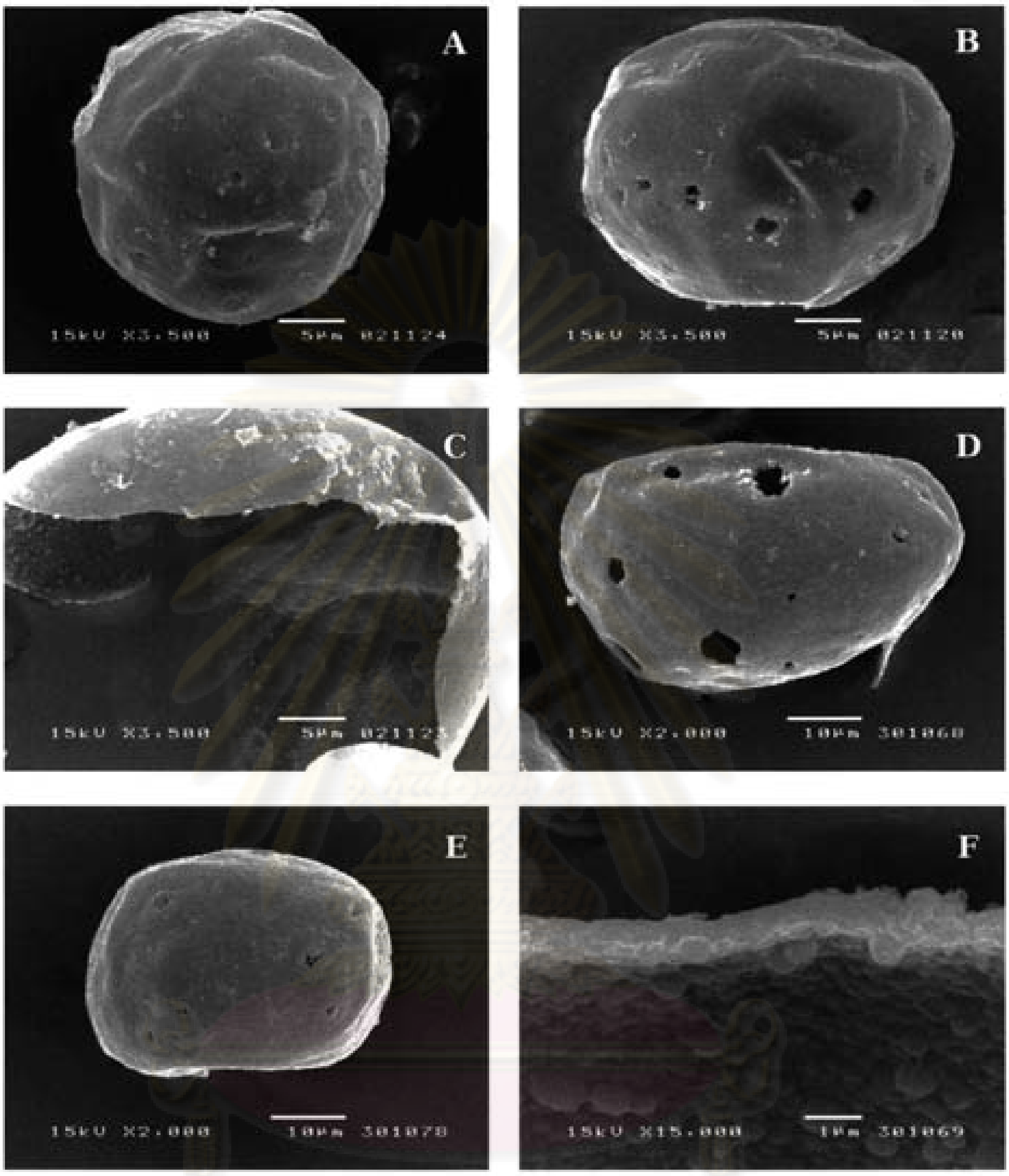

Plate 7 SEM micrographs: A-C. ***Ichnocarpus serpyllifolius* (Sieb. & Zucc.) Nakai** (A)-(B) Apolar, polypantoporate grain, (C) Porate with very distinct annuli inside nexine; D-F. ***Trachelospermum lucidum* (D.Don) K. Schum.** (D)-(E) Apolar, polypantoporate grain, (F) Inner nexine surface granulate.

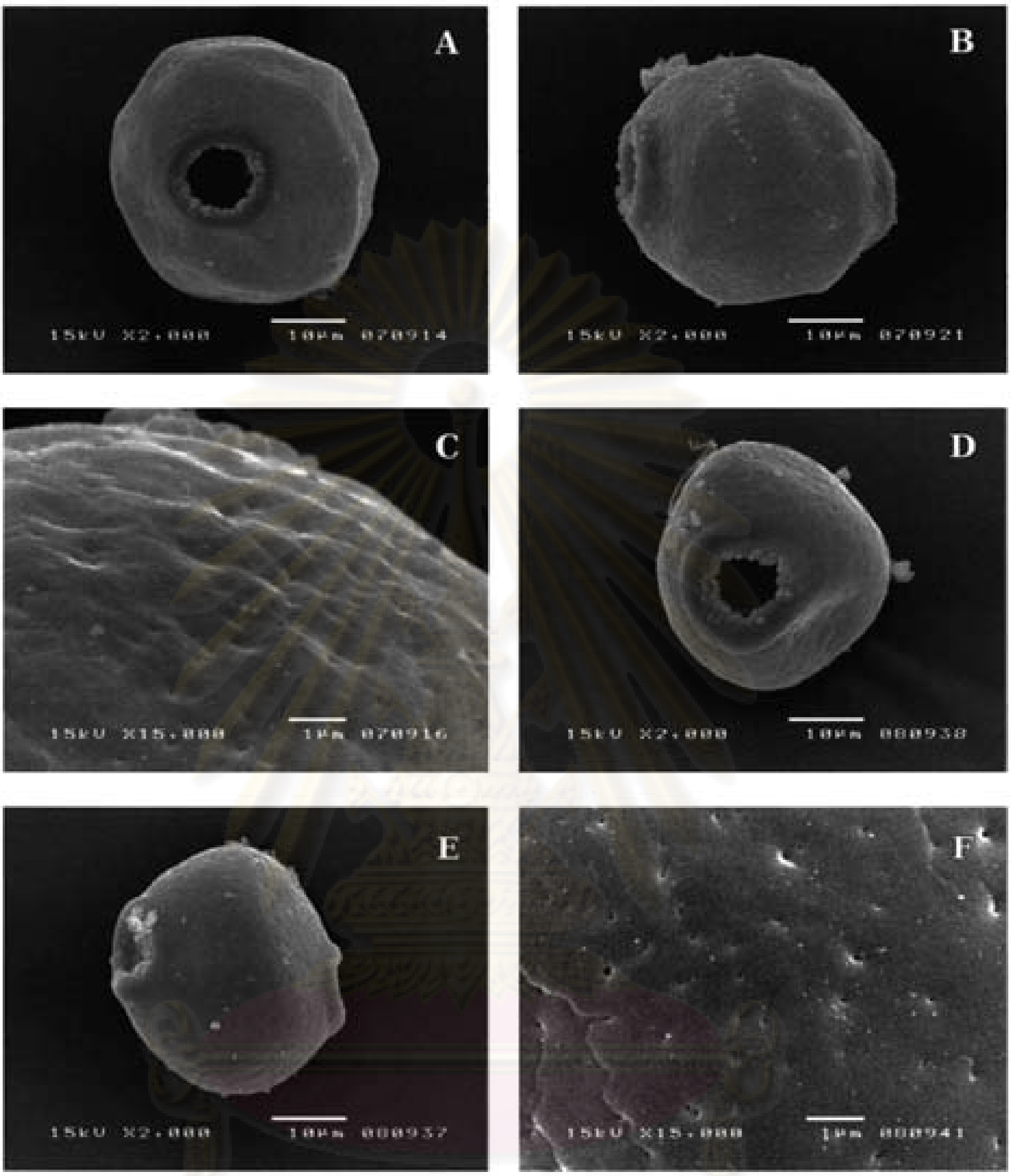

Plate 8 SEM micrographs: A-C. ***Chilocarpus costatus* Miq.** (A) Porate with nexinous verrucae usually slightly exert at the pori, annulus very distinct, (B) Equatorial view, diporate grain, (C) Perforate sexine surface; D-F. ***C. denudatus* Blume** (D) Porate with nexinous verrucae usually slightly exert at the pori, annulus very distinct, (E) Equatorial view with slightly unequal in size of pori, (F) Perforate sexine surface.

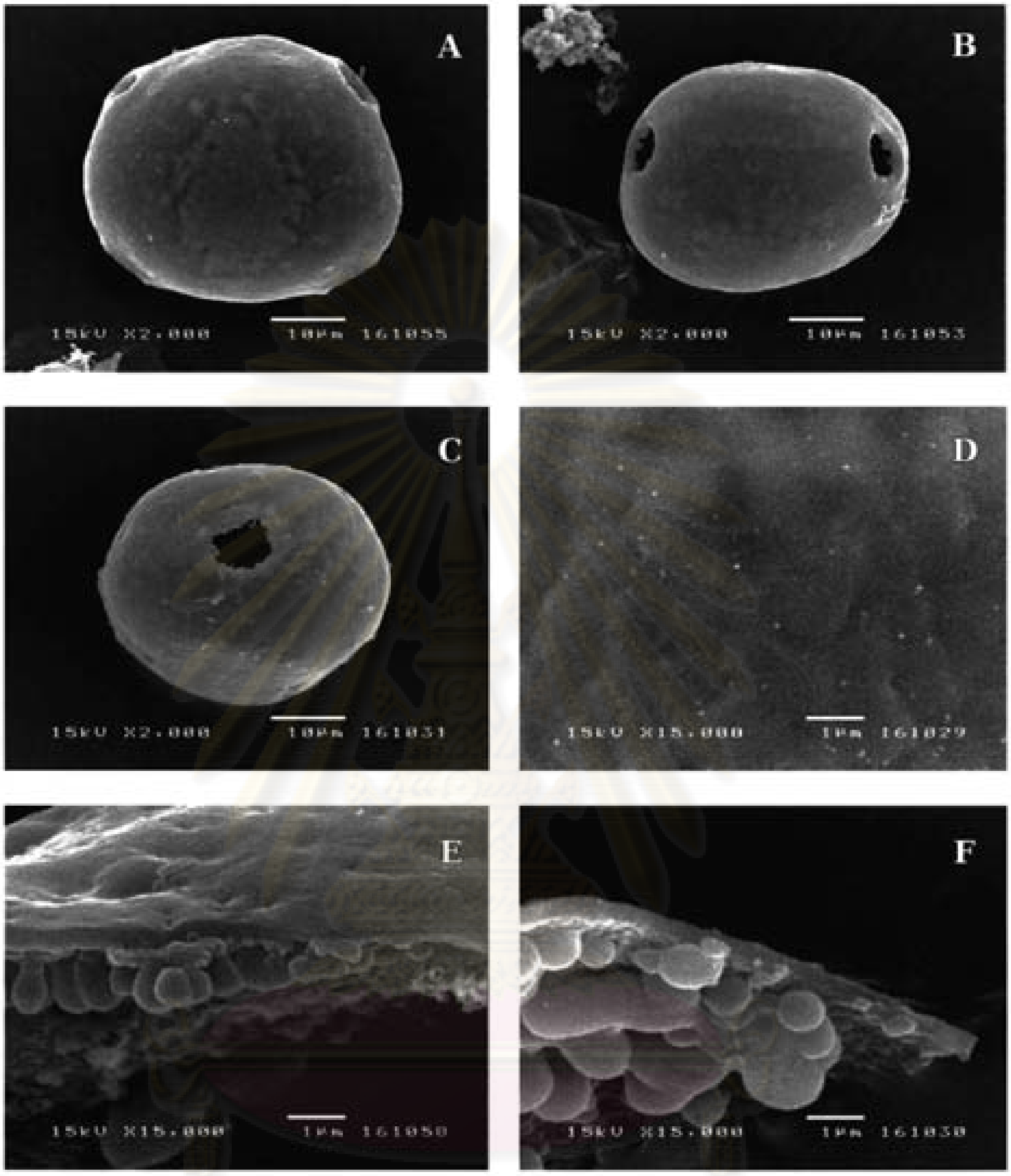

Plate 9 SEM micrographs: A-F. ***Spirolobium cambodianum* Baillon** (A) Polar view , (B) Equatorial view, (C) Porate with nexinous verrucae, annulus very distinct, (D) Psilate sexine surface, (E)-(F) Inner nexine surface granulate to gemmate, exine thickness very thin.

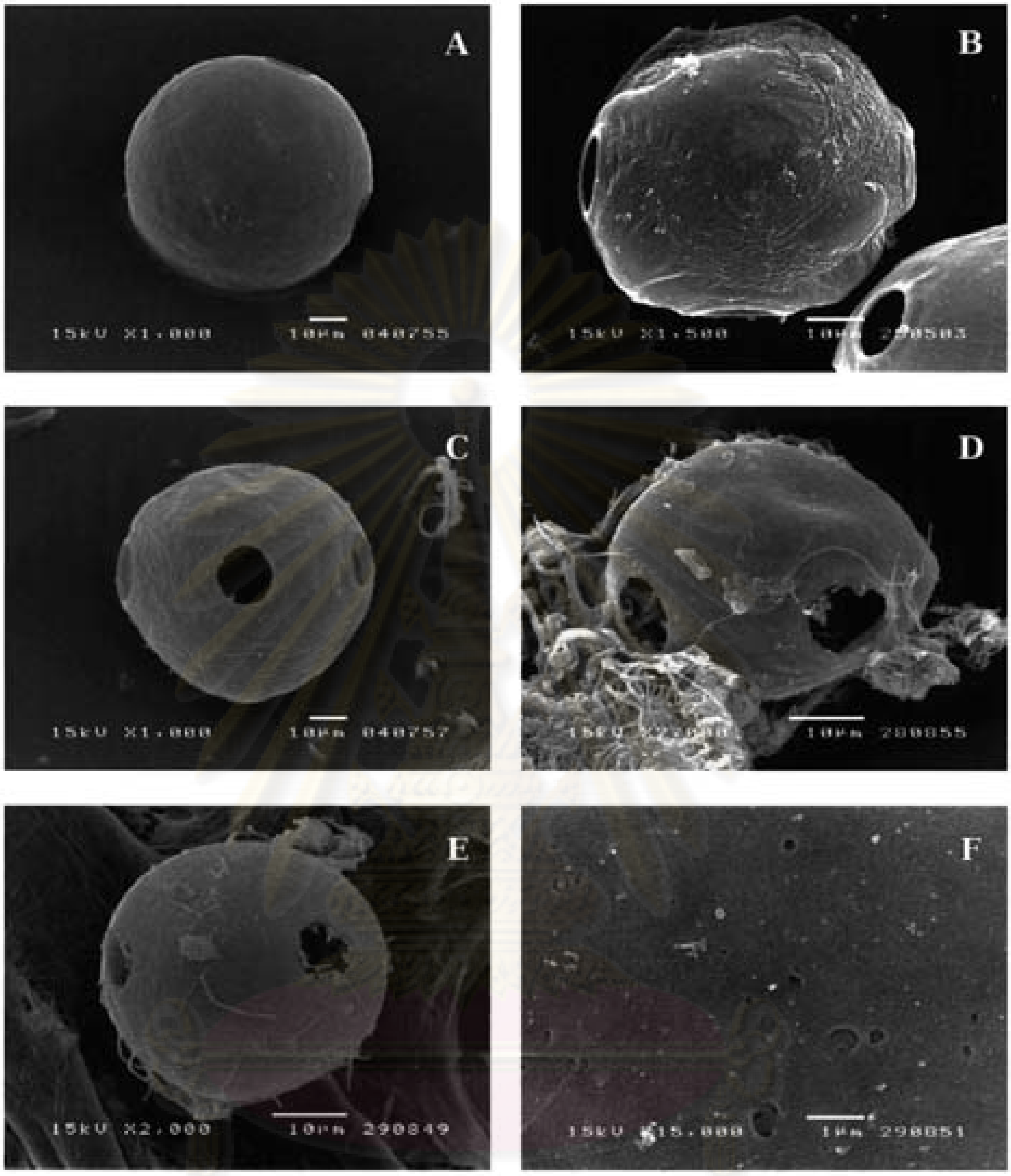

Plate 10 SEM micrographs: A-C. ***Amalocalyx microlobus* Pierre ex Spire** (A) Polar view, (B) Polar view, undulating psilate, imperforate sexine surface, (C) Equatorial view; D-F. ***Parsonsia alboflavescens* (Dennst.) Mabb.** (D)-(E) Equatorial view, (F) Psilate with perforations sexine surface.

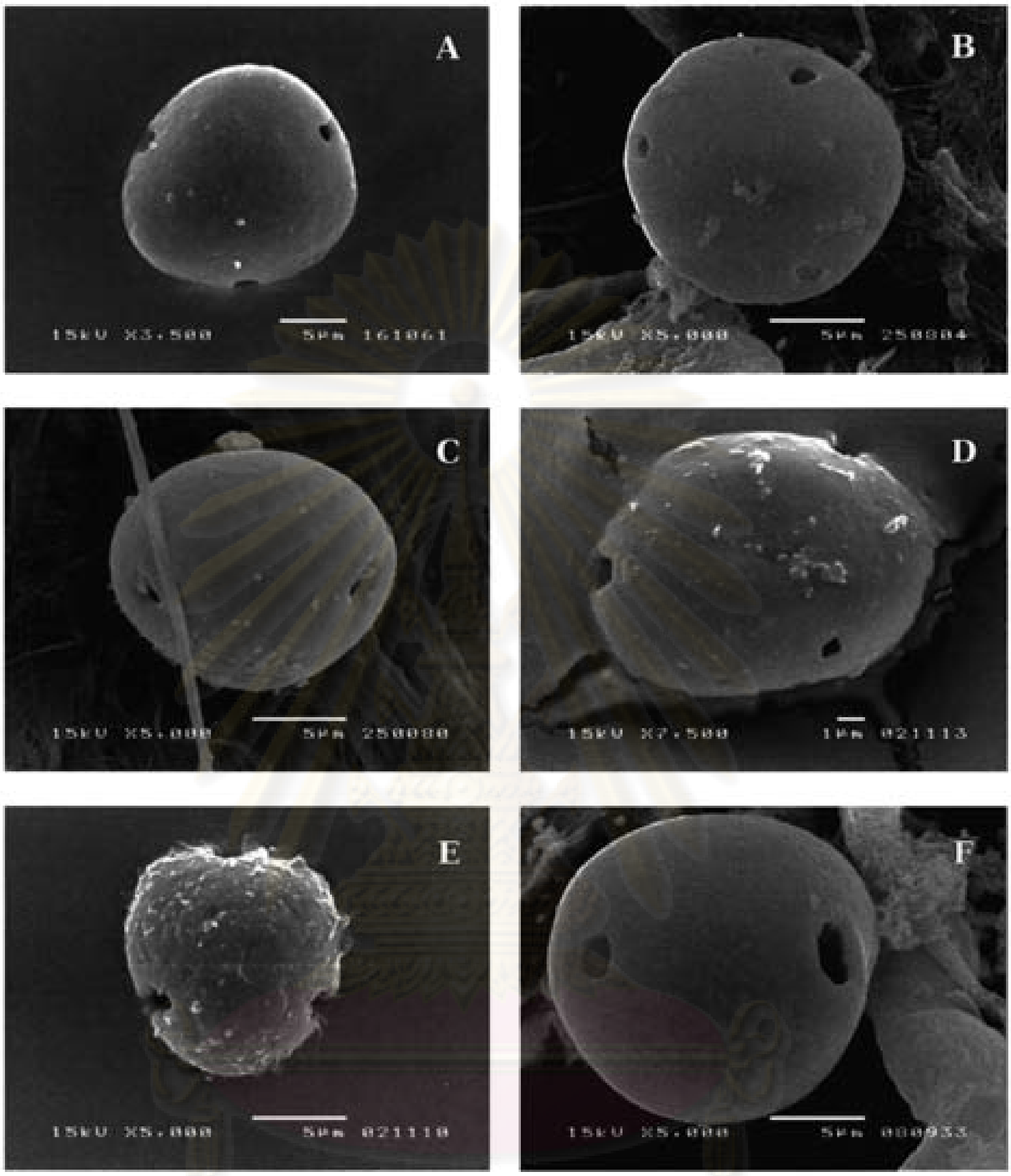

Plate 11 SEM micrographs: A-C. ***Urceola lucida* (Wall. ex G.Don) Kurz** (A)-(B) Polar view, (C) Equatorial view, subisopolar; D. ***U. micrantha* (Wall. ex G.Don) D.J. Middleton** Polar view; E. ***U. minutiflora* (Pierre) D.J. Middleton** Polar view; F. ***U. rosea* (Hook. & Arn.) D.J. Middleton** Equatorial view.

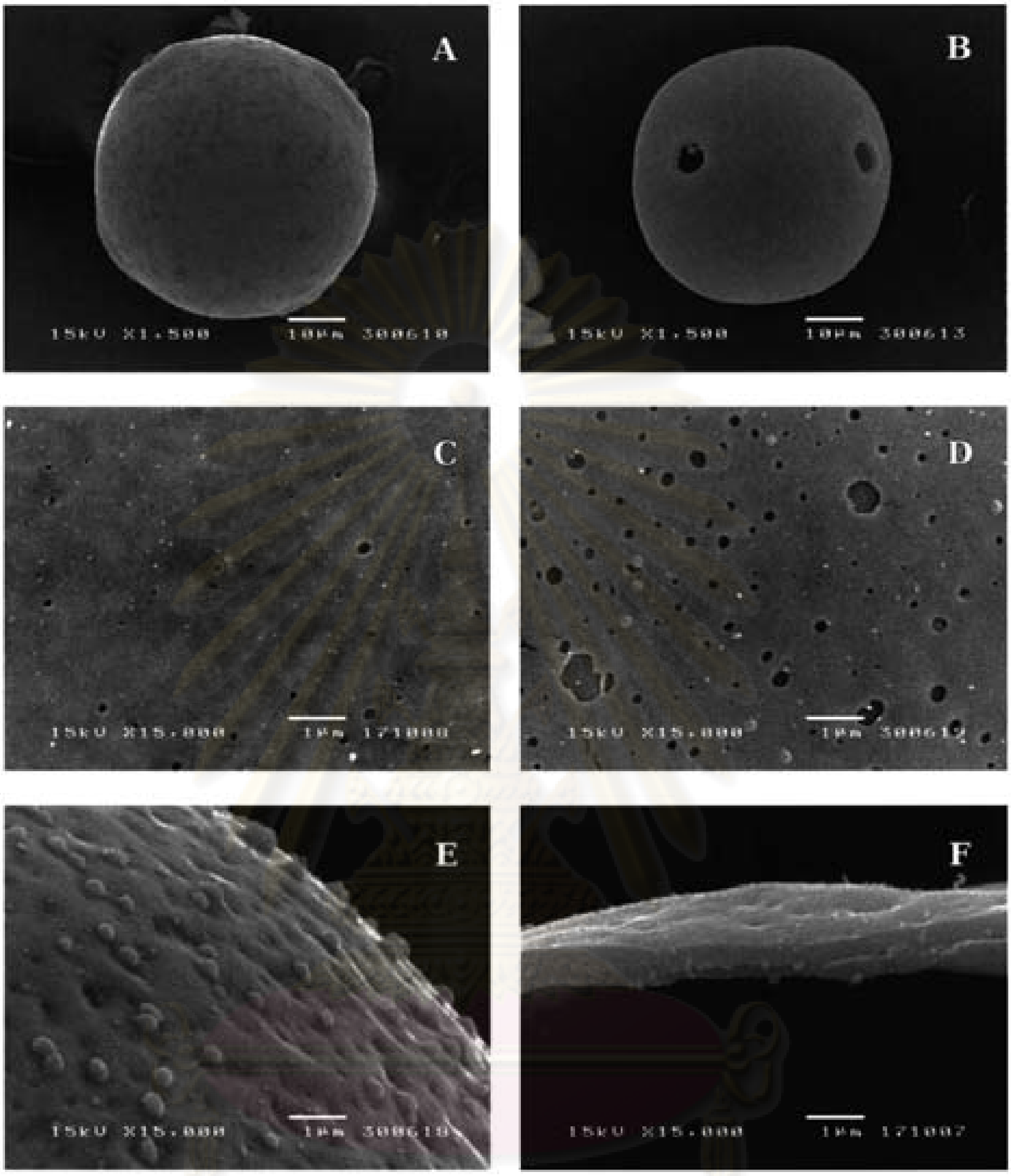

Plate 12 SEM micrographs: A-F. ***Beaumontia grandiflora*** **Wall.** (A) Polar view, (B) Equatorial view showing pori with distinct annuli, (C) Psilate with perforations, (D) Perforate, (E) Perforate with granules, (F) Tectate exine, sexine as thick as the nexine, infratectum very thin.

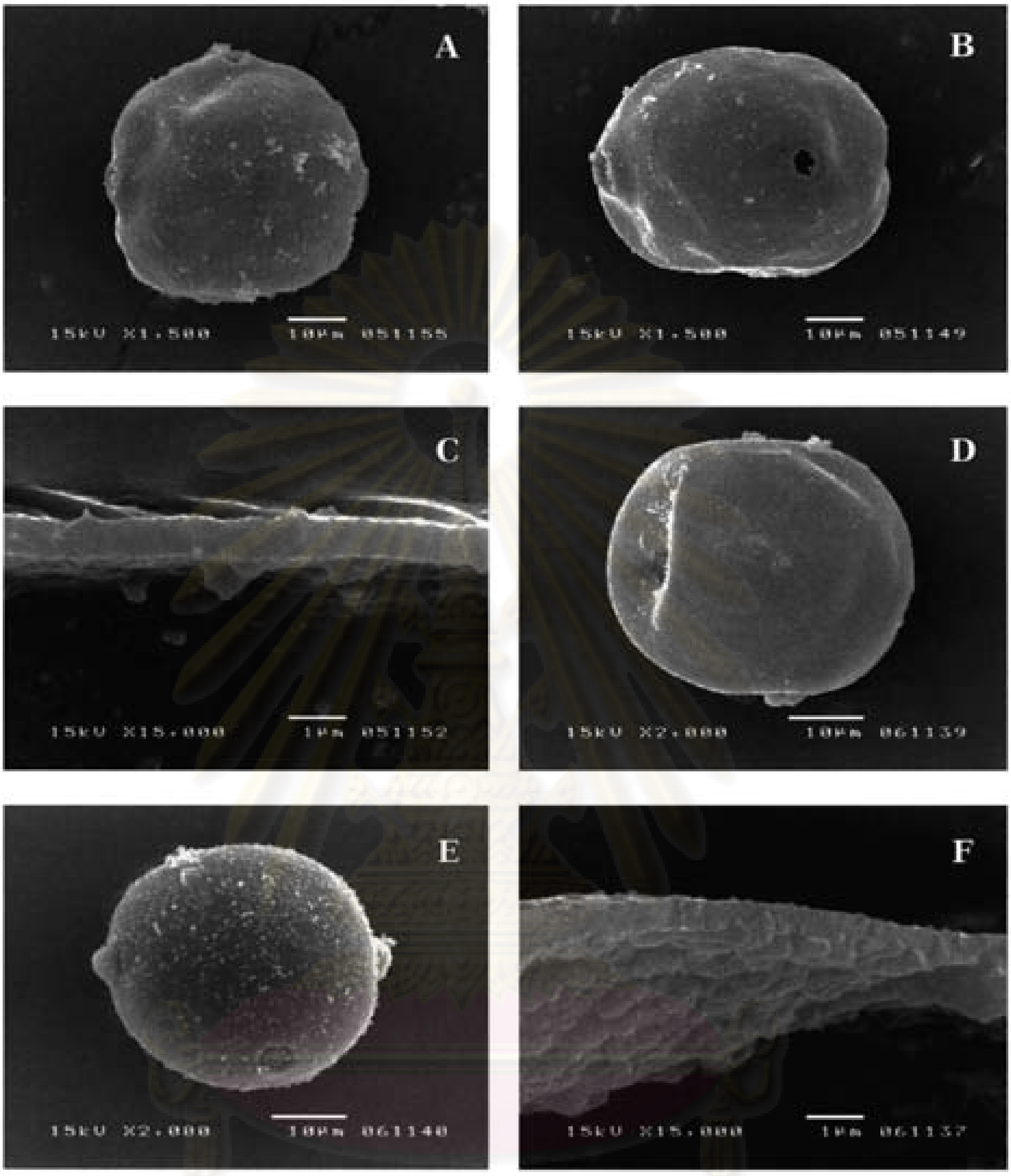

Plate 13 SEM micrographs: A-C. ***Beaumontia murtonii*** **Craib** (A) Polar view showing protrude annuli, (B) Equatorial view showing pori with distinct annuli, (C) Tectate exine; D-F. ***Wrightia sirikitae*** **D.J.Middleton & Santisuk** (D) Equatorial view, (E) Polar view, operculate pori, (F) Tectate exine, exine thickness very thin.

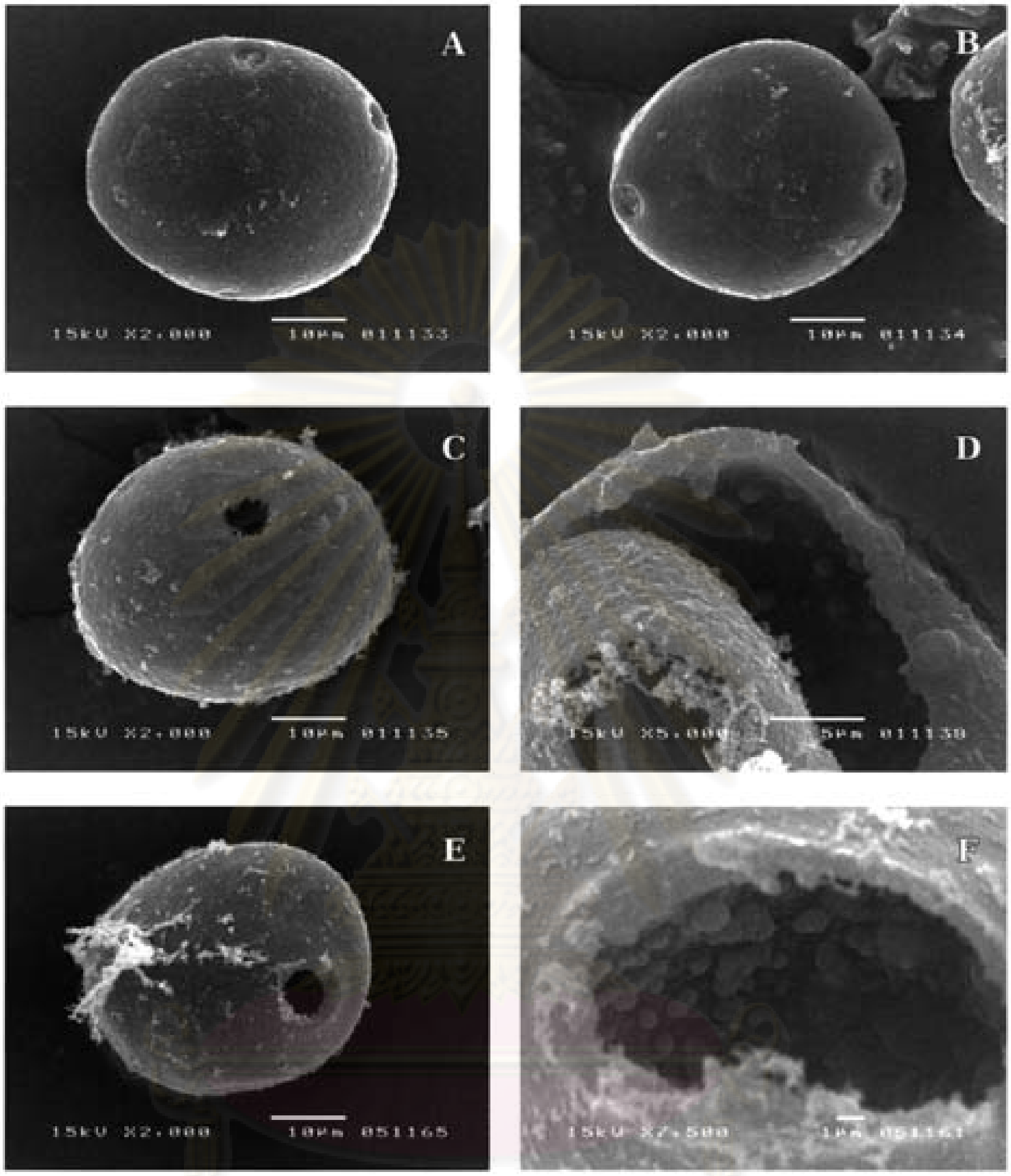

Plate 14 SEM micrographs: A-D. ***Kibatalia arborea* (Blume) G.Don** (A) Oblique polar view with slightly unequal-spaced pori, (B) Equatorial view with pori operculate, (C) Equtorial view, porate with distinct annulus, (D) Tectate exine, inner nexine surface sparsely granulate; E-F. ***K. macrophylla* (Pierre ex Hua) Woodson** (E) Oblique polar view, porate very distinct annulus, (F) Inner nexine surface sparsely verrucate.

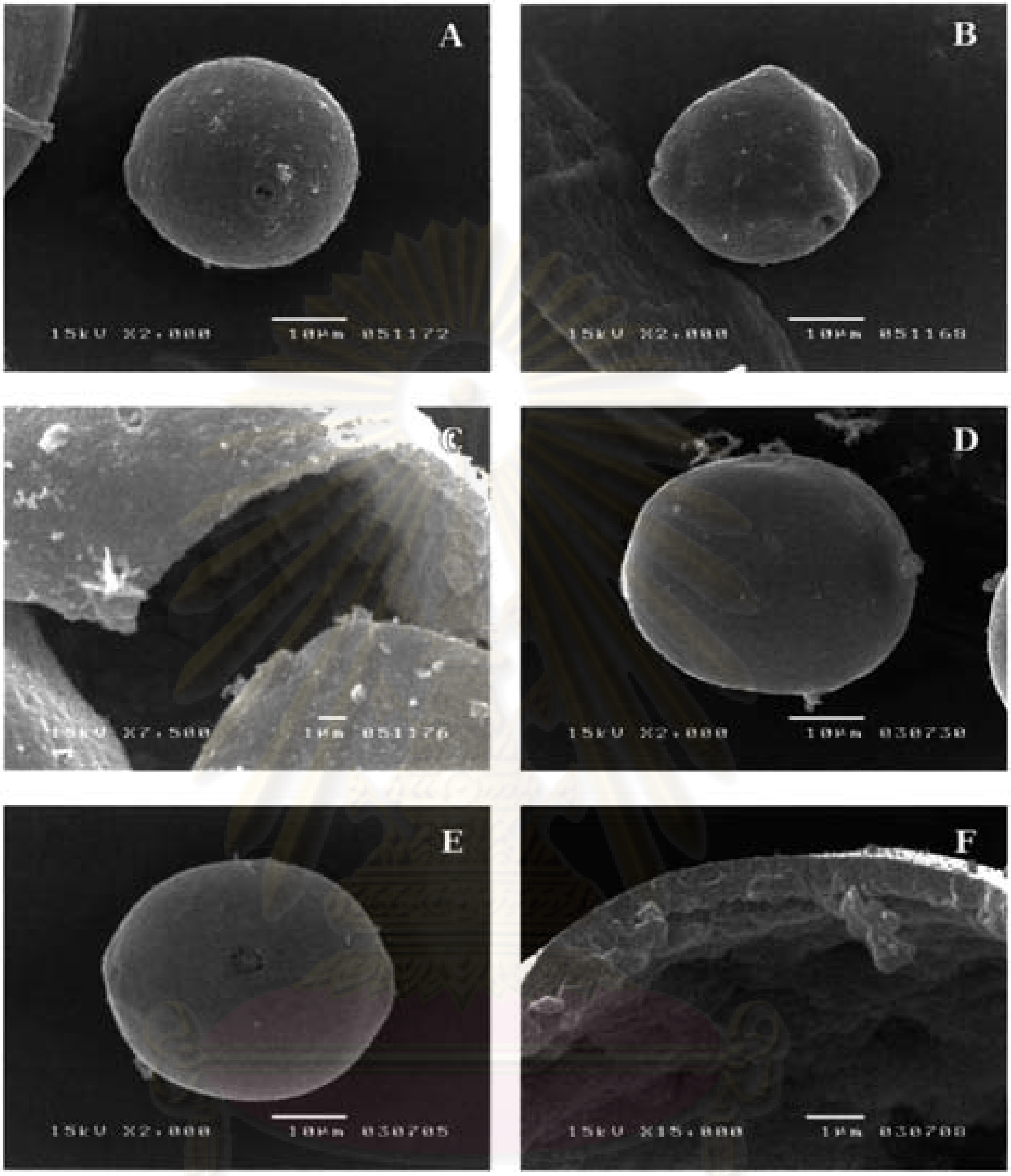

Plate 15 SEM micrographs: A-C. ***Kibatalia maingayi* (Hook.f.) Woodson** (A) Equatorial view showing porate with very distinct annulus, (B) Equatorial view showing pori with very distinct and protrude annuli, (C) Inner nexine surface sparsely verrucate; D-F. ***Wrightia dubia* (Sims) Spreng.** (D) Polar view with unequal-spaced pori, operculate pori, (E) Equatorial view showing porate with distinct annulus and porate operculate, (F) Tectate exine, sexine thicker than the nexine, infratectum very thin, inner nexine surface uneven, coarsely undulating psilate.

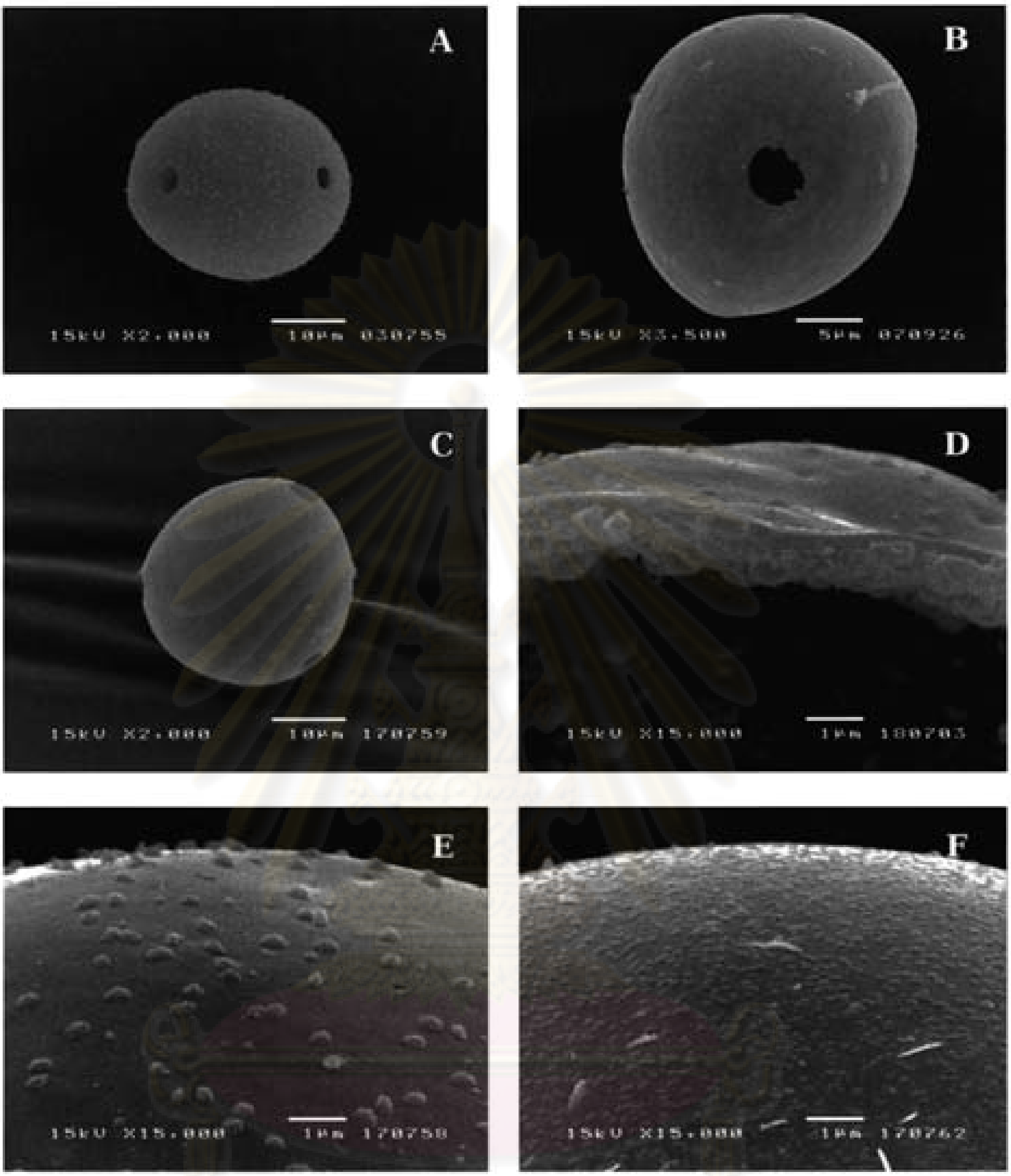

Plate 16 SEM micrographs: A-F. ***Holarrhena curtisii*** **King & Gamble** (A) Equatorial view with slightly unequal in size of pori, (B) Equatorial view showing porate with annulus, (C) Polar view, (D) Tectate exine, inner nexine surface sparsely granulate, (E) Sparsely granulate sexine surface, (F) Densely granulate sexine surface.

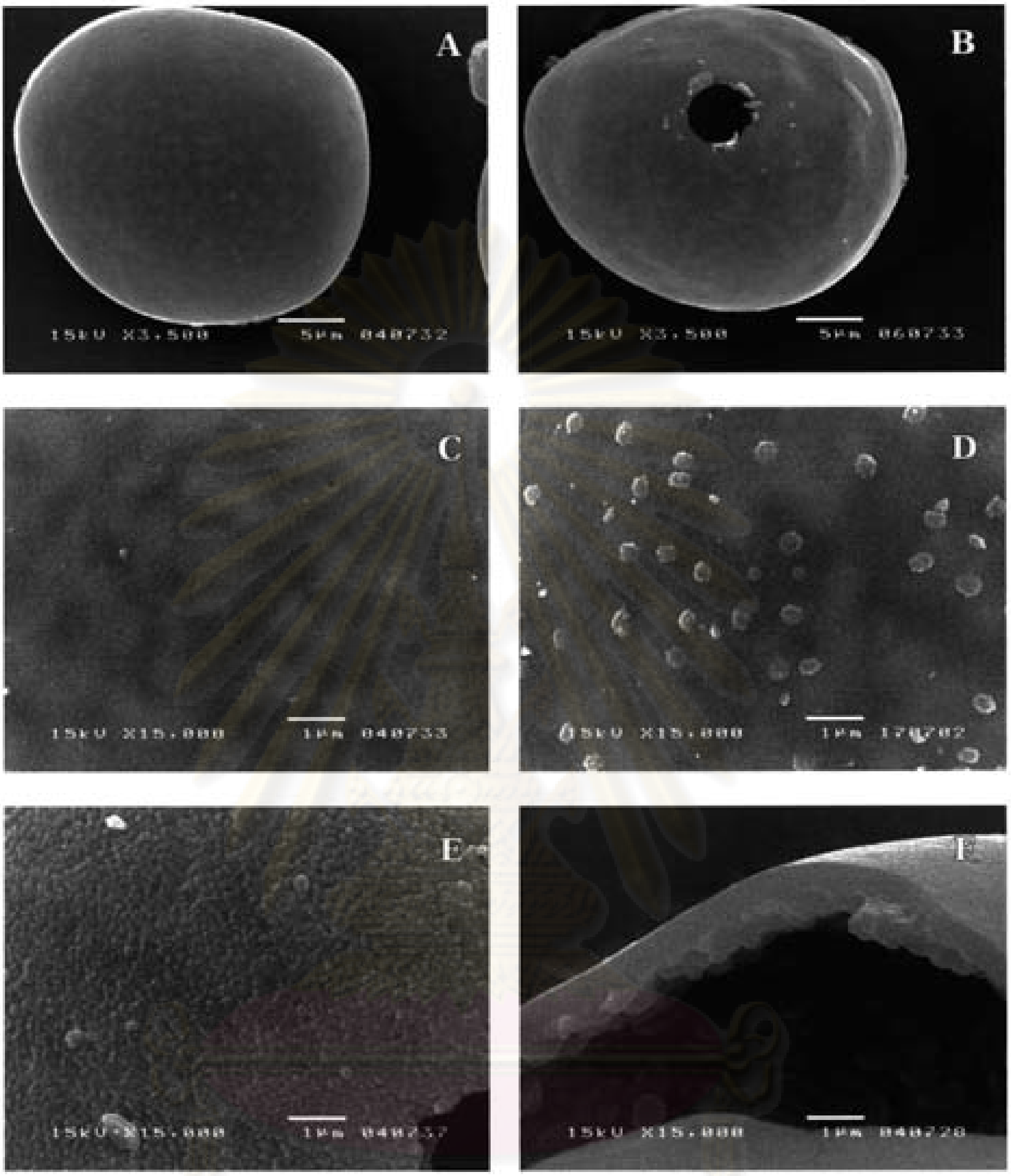

Plate 17 SEM micrographs: A-F. ***Holarrhena pubescens*** **Wall. ex G.Don** (A) Polar view with irregular circular amb, (B) Equatorial view, (C) Smooth psilate sexine surface, (D) Psilate with sparsely granules, (E) Densely granulate exine surface, (F) Tectate exine, sexine thicker than the nexine, inner nexine surface sparsely granulate.

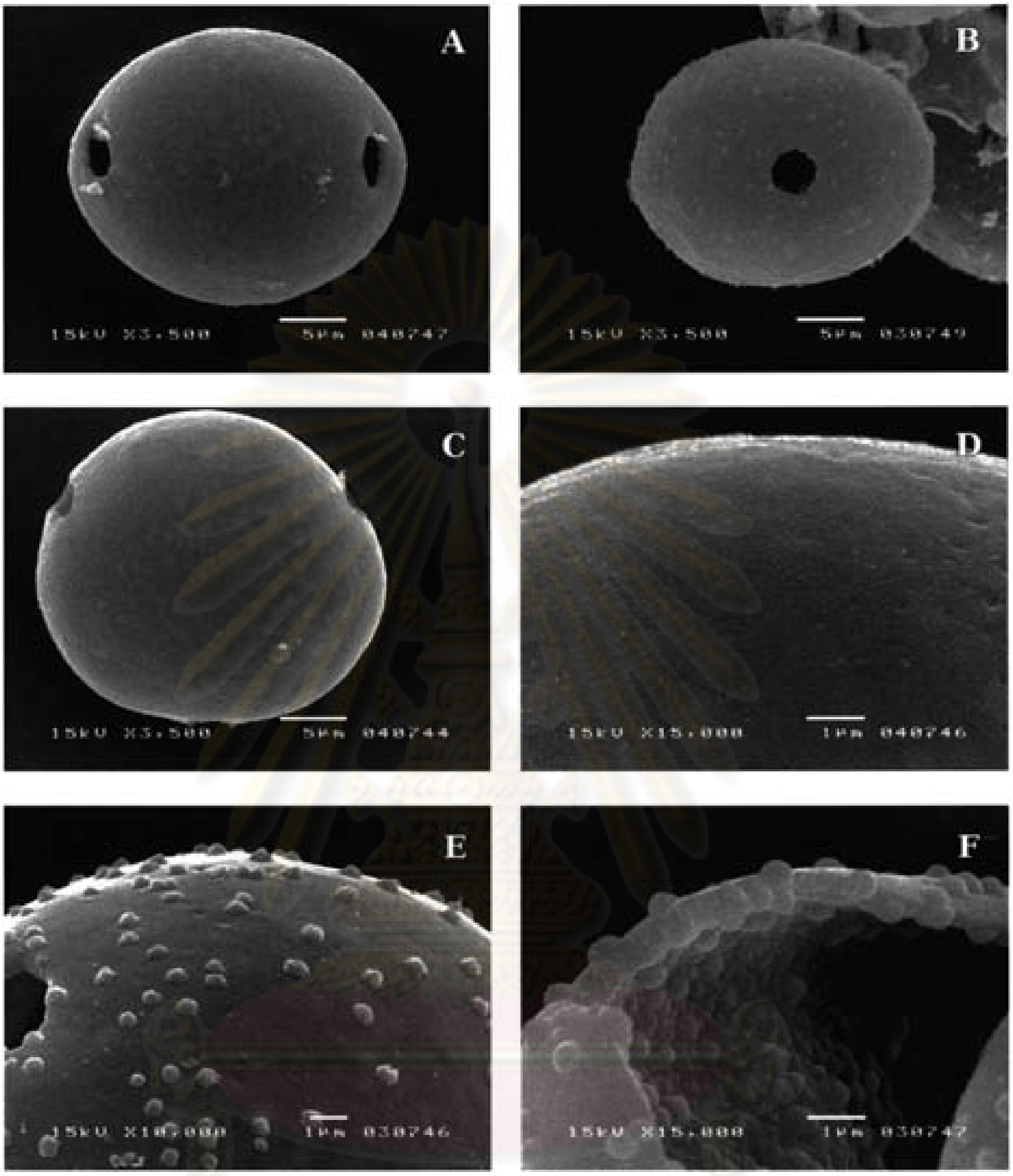

Plate 18 SEM micrographs: A-F. ***Aganonerion polymorphum*** **Pierre ex Spire** (A)-(B) Equatorial view, (C) Polar view, (D) Psilate sexine surface, (E) Granulate with sparsely perforations, (F) Tectate exine, exine stratification obscure, inner nexine surface granulate.

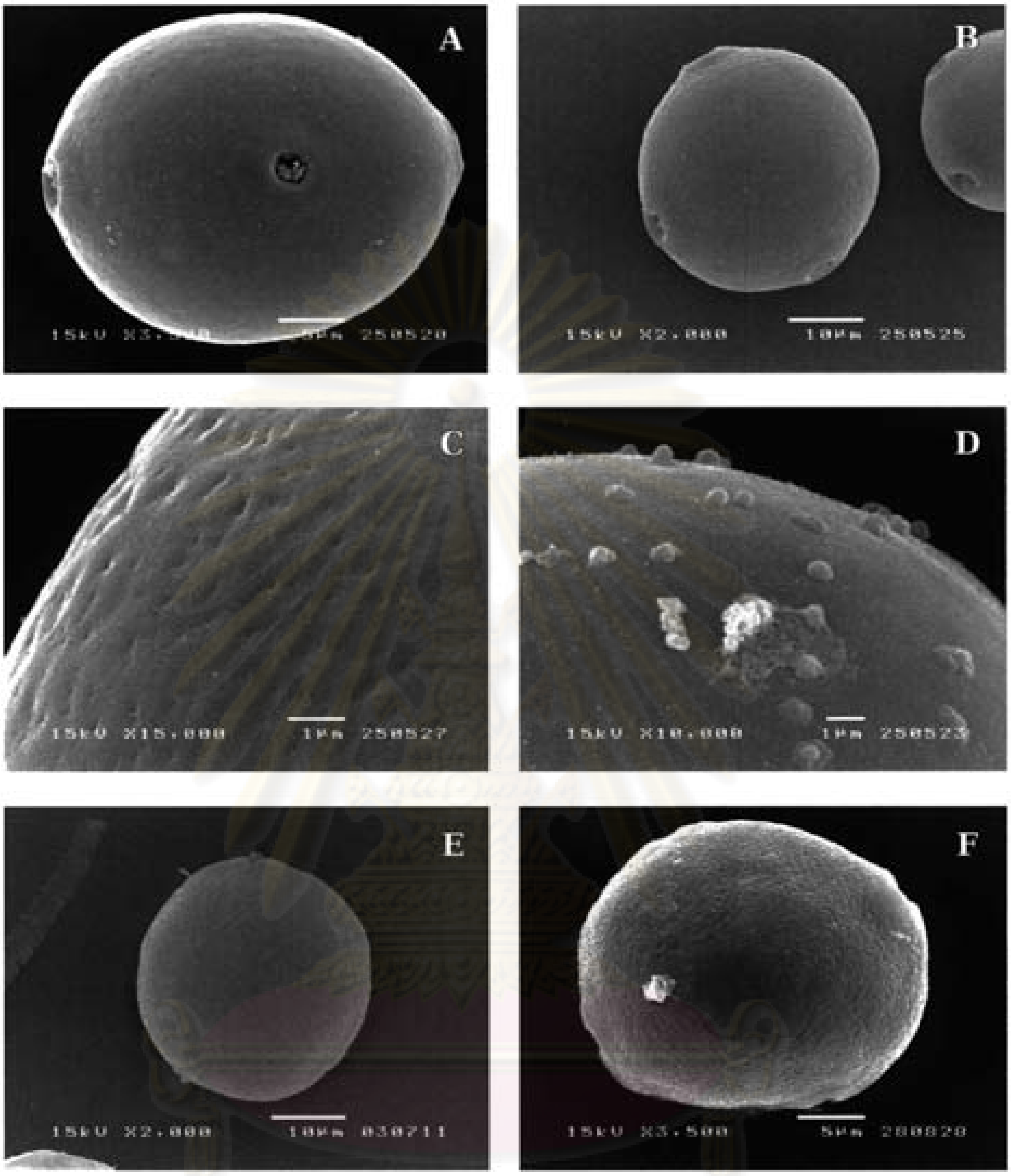

Plate 19 SEM micrographs: A-D. ***Vallaris glabra* (L.) O. Kuntze** (A) Equatorial view showing very distict annuli and operculate pori, (B) Olique polar view showing very distict annuli and operculate pori, (C) Perforate sexine surface, (D) Psilate with sparsely granules; E-F. ***Wrightia pubescens* R.Br.** (E) Polar view with circular amb, triporate grain, (E) Polar view with circular-elliptic amb, 4-porate grain.

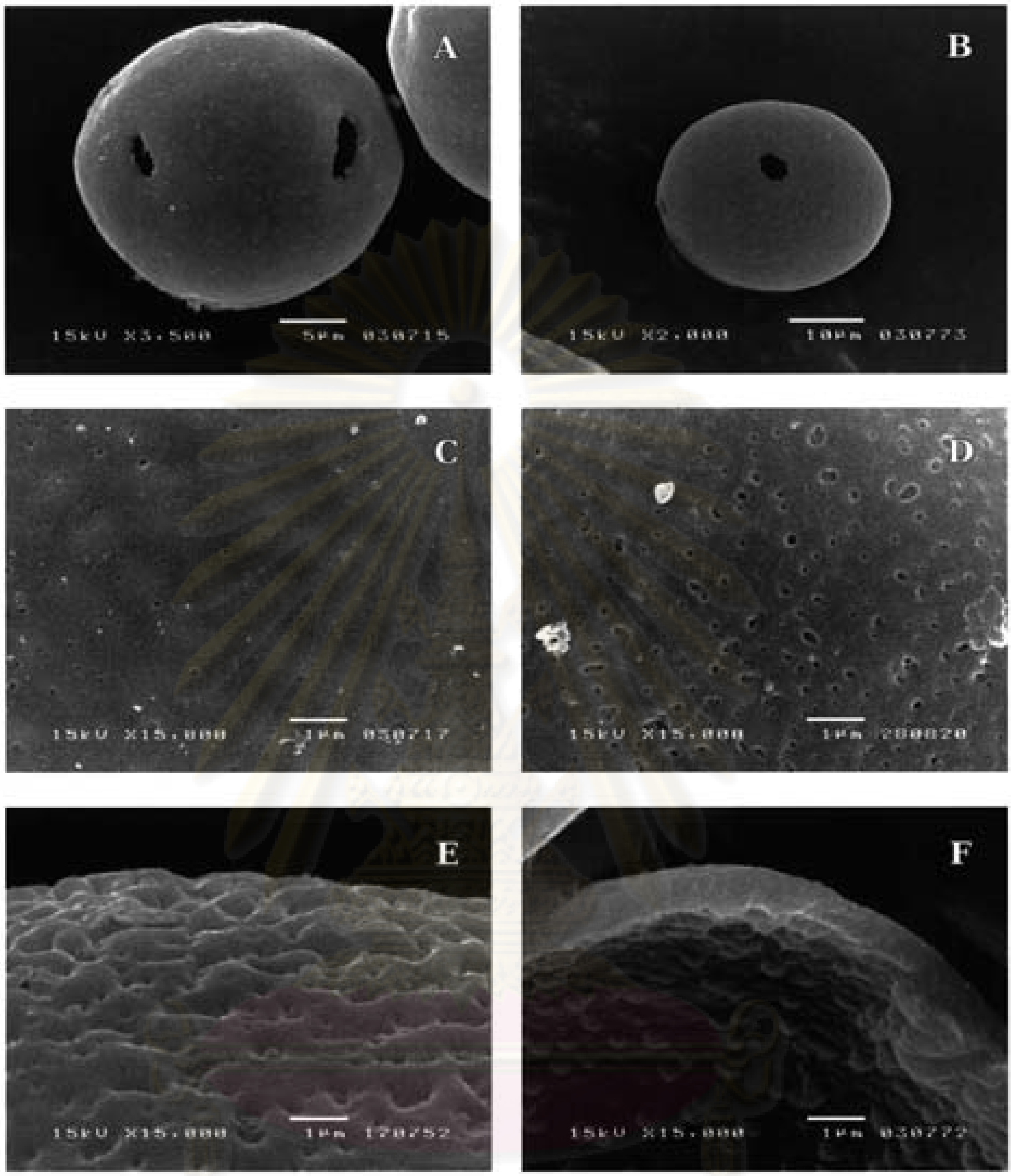

Plate 20 SEM micrographs: A-F. ***Wrightia pubescens*** **R.Br.** (A) Equatorial view with slightly unequal in size of pori, (B) Oblique equatorial view, (C) Psilate with perforations sexine surface, (D) Perforate, (E) Fossulate with perforations in the fossulae, (F) Tectate exine, inner nexine surface sparsely granulate.

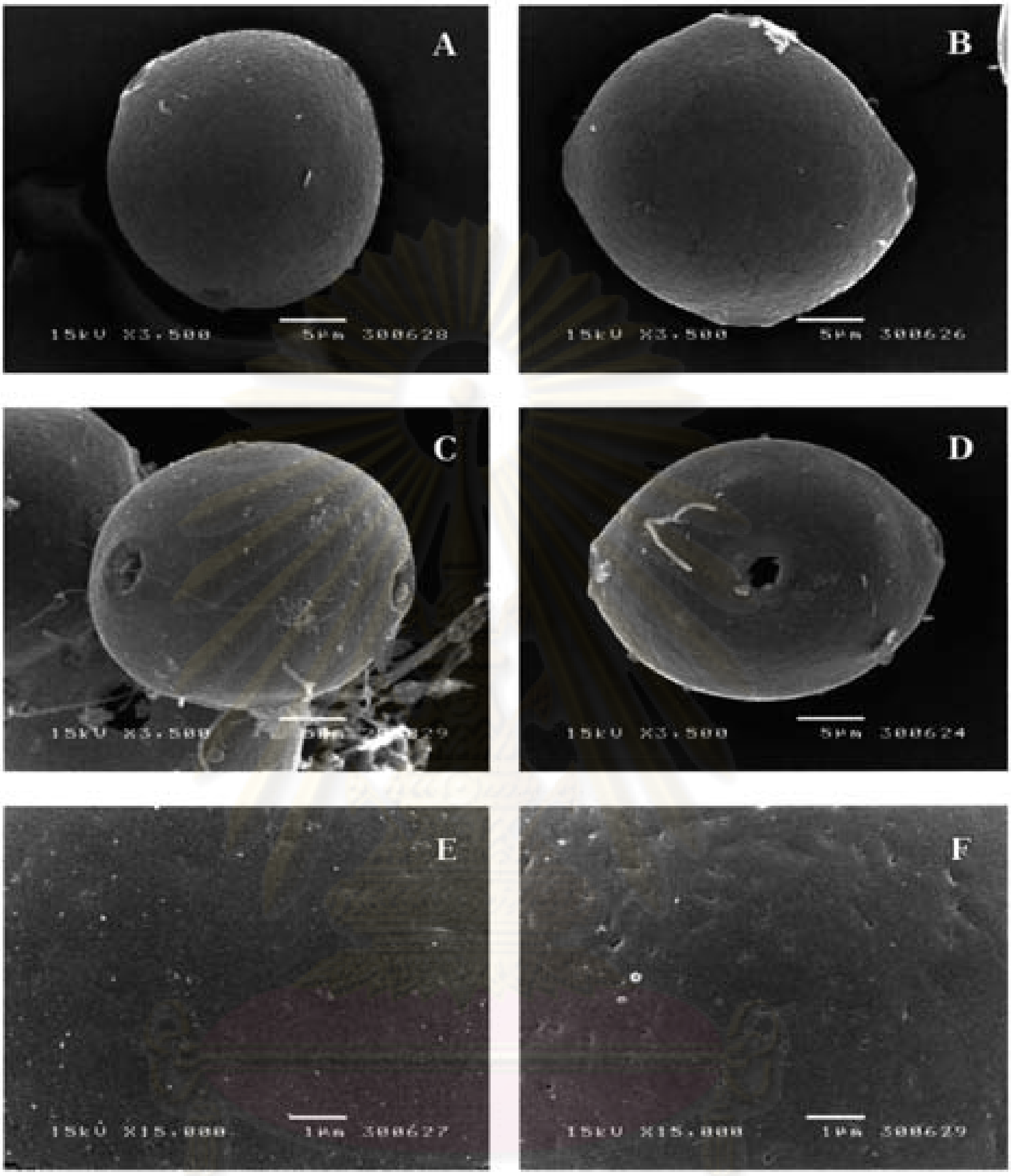

Plate 21 SEM micrographs: A-F. ***Aganosma marginata*** **(Roxb.) G.Don** (A) Oblique polar view, (B) Polar view with 4-porate aperture, annulus very distinct, (C)-(D) Equatorial view with very distinct annuli, (E) Smooth psilate sexine surface, (F) Psilate with perforations on the surface.

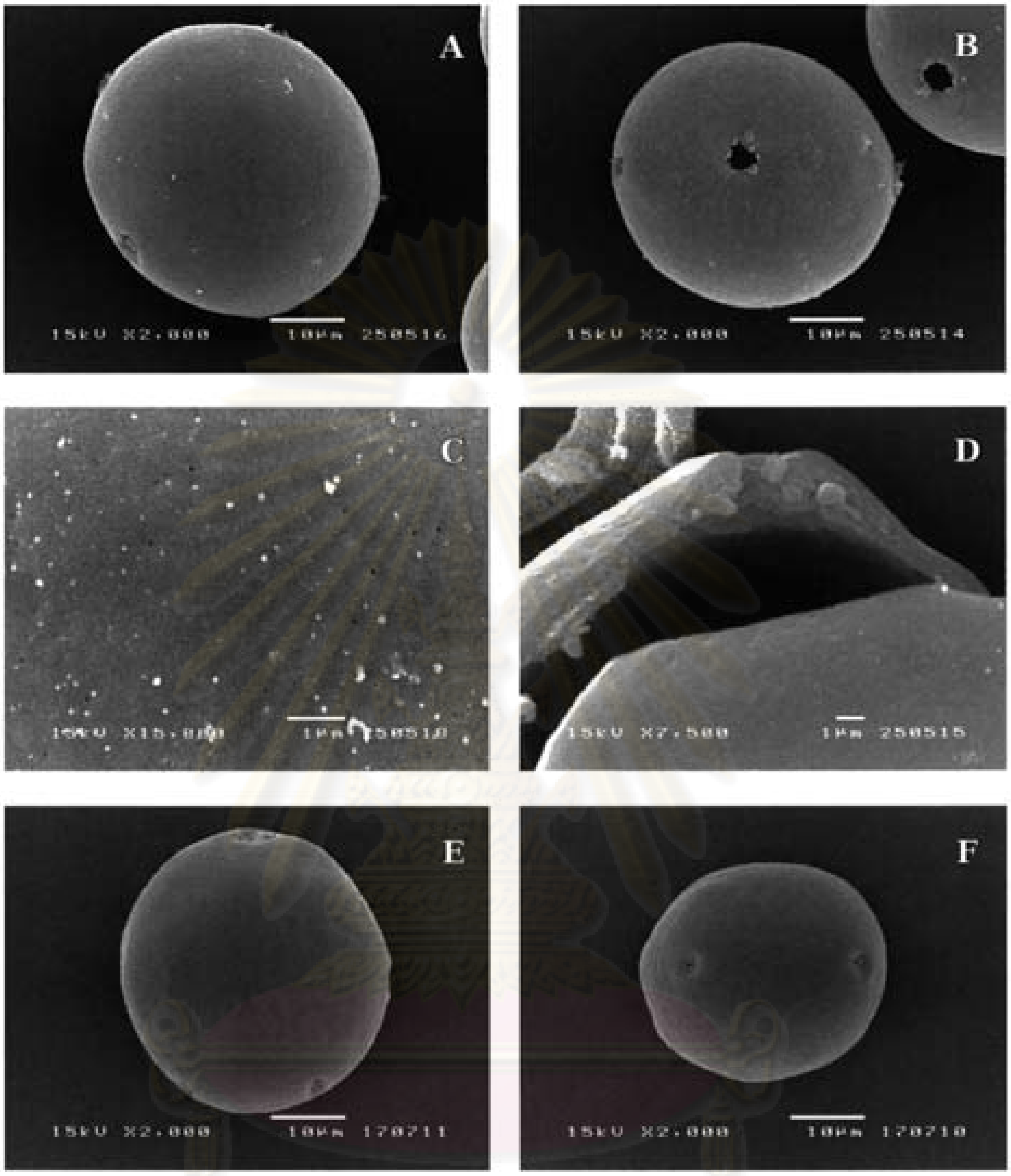

Plate 22 SEM micrographs: A-D. ***Adenium obesum* (Forsk.) Roem. & Schult.** (A) Slightly oblique polar view showing operculate pori, (B) Equatorial view showing operculate pori, (C) Psilate with perforation on the surface of sexine, (D) Tectate exine with granulate infratectum, inner nexine surface granulate around the pore; E-F. ***Nerium oleander* L.** (E) Equatorial view with unequal-spaced and operculate pori, (F) Equatorial view showing operculate pori, distinct annuli.

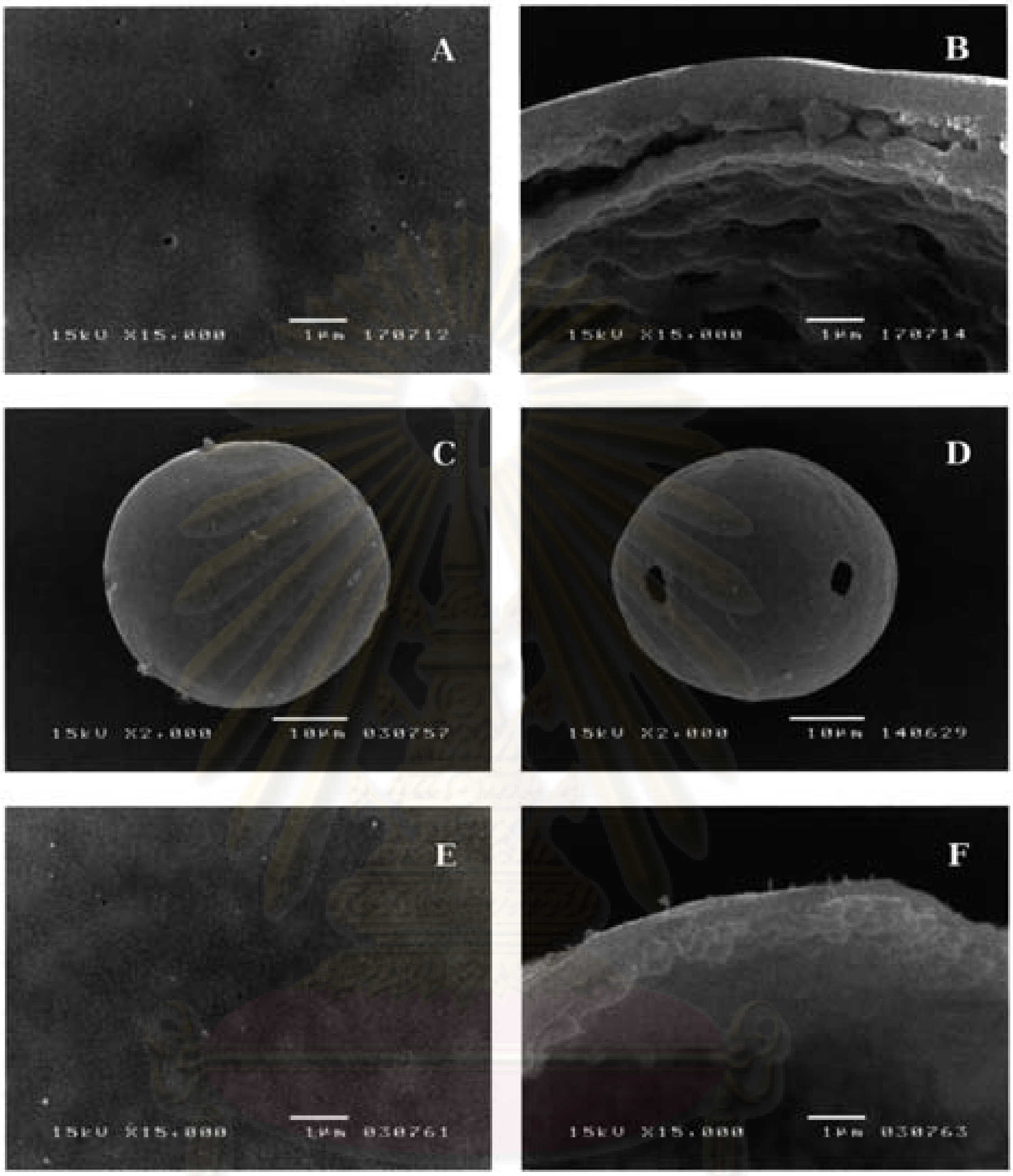

Plate 23 SEM micrographs: A-B. ***Nerium oleander* L.** (A) Psilate with perforation on the sexine surface, (B) Tectate exine, sexine thicker than the nexine, infratectum granulate, inner nexine surface coarsely undulating foveolate with irregular rounded depressions more than 1 μm in diameter; C-F. ***Strophanthus gratus* (Wallich & Hook.) Bail.** (C) Polar view showing operculate pori, (D) Equatorial view, (E) Smooth psilate sexine surface, (F) Tectate exine, exine stratification obscure, inner nexine surface granulate.

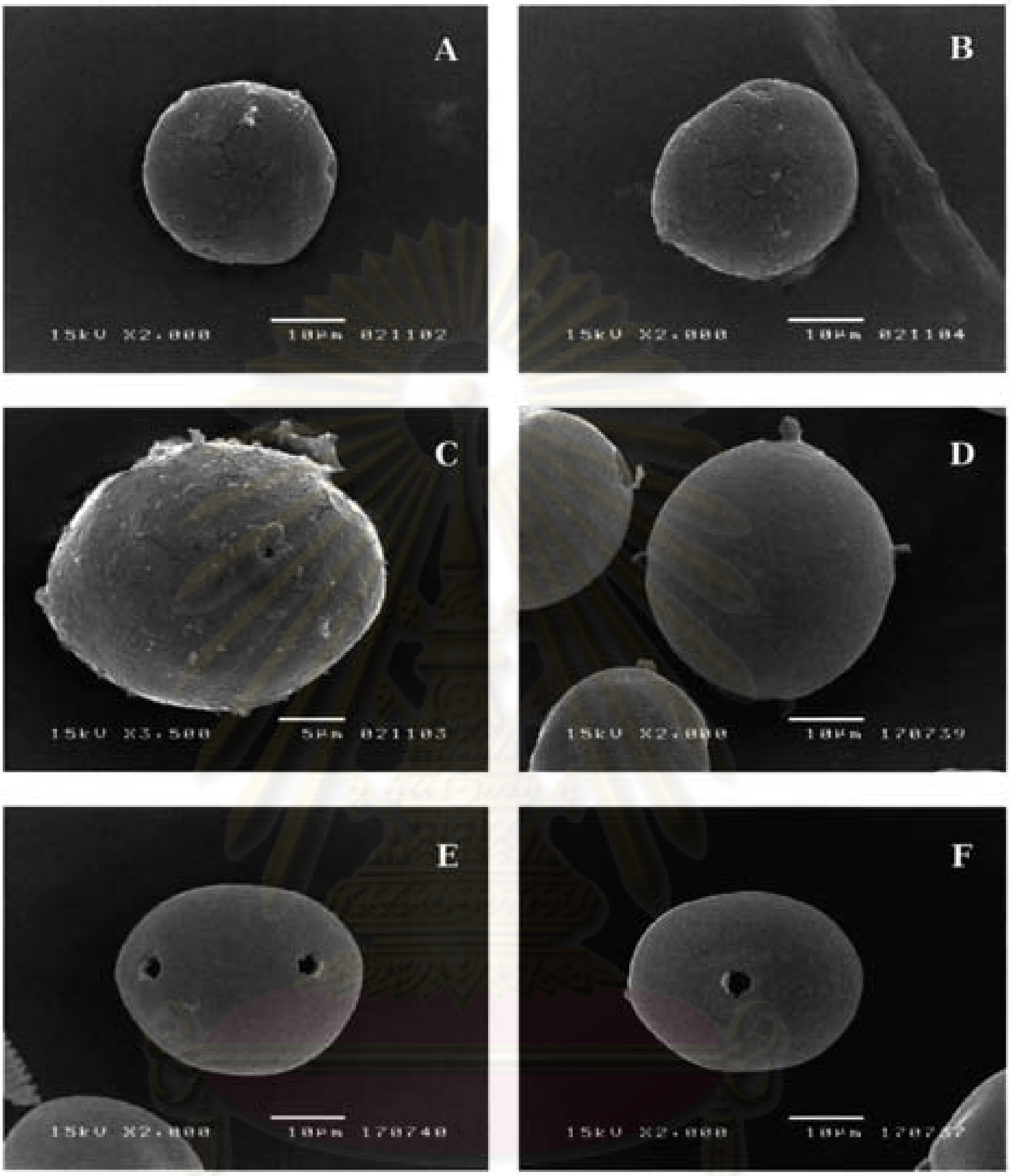

Plate 24 SEM micrographs: A-C. ***Strophanthus perakensis*** **Scortechini ex King & Gamble** (A) Polar view, (B) Oblique equatorial view showing very distinct annulus, operculate pore, (C) Equatorial view; D-F. ***Wrightia antidysenterica*** **(L.) R. Br.** (D) Polar view showing operculate pori, (E) Equatorial view showing operculate pori, (F) Equatorial view showing operculate pore with distinct annulus.

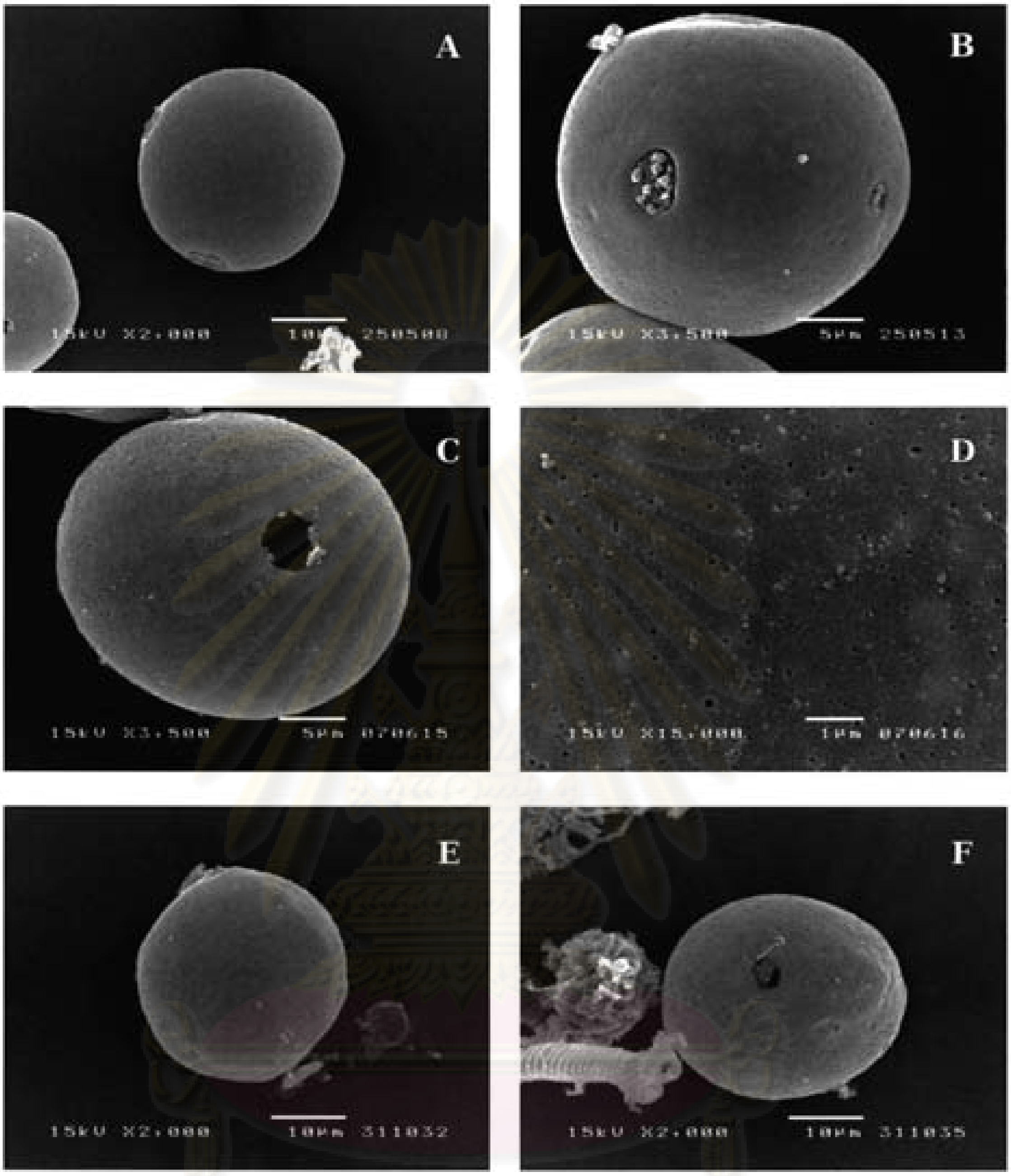

Plate 25 SEM micrographs: A-D. ***Wrightia arborea*** **(Dennst.) Mabb.** (A) Polar view, (B) Equatorial view showing strongly unequal in size of pori, operculate pori with granulate surface, (C) Equatorial view, (D) Perforate sexine surface; E-F. ***W. laevis*** **Hook.f.** (E) Polar view, (F) Equatorial view showing operculate pore.

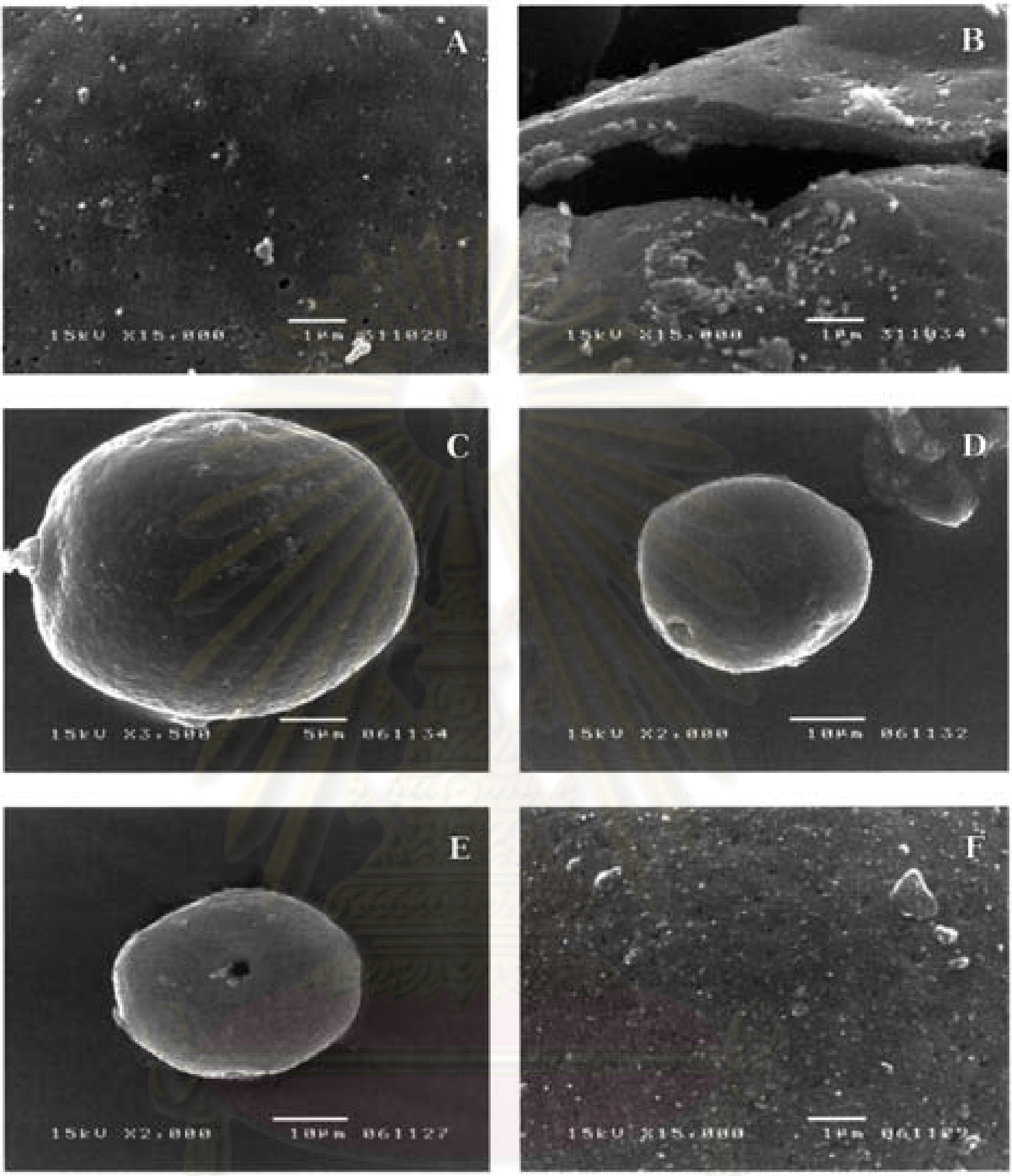

Plate 26 SEM micrographs: A-B. ***Wrightia. laevis*** **Hook.f.** (A) Psilate with perforations on the sexine surface, (B) Tectate exine, sexine as thick as the nexine, infratectum very thin; C-F. ***W. lanceolata*** **Kerr** (C) Polar view showing operculate pori, (D) Oblique equatorial view showing operculate pori, (E) Equatorial view showing distinct annulus, (F) Psilate with perforations on the sexine surface.

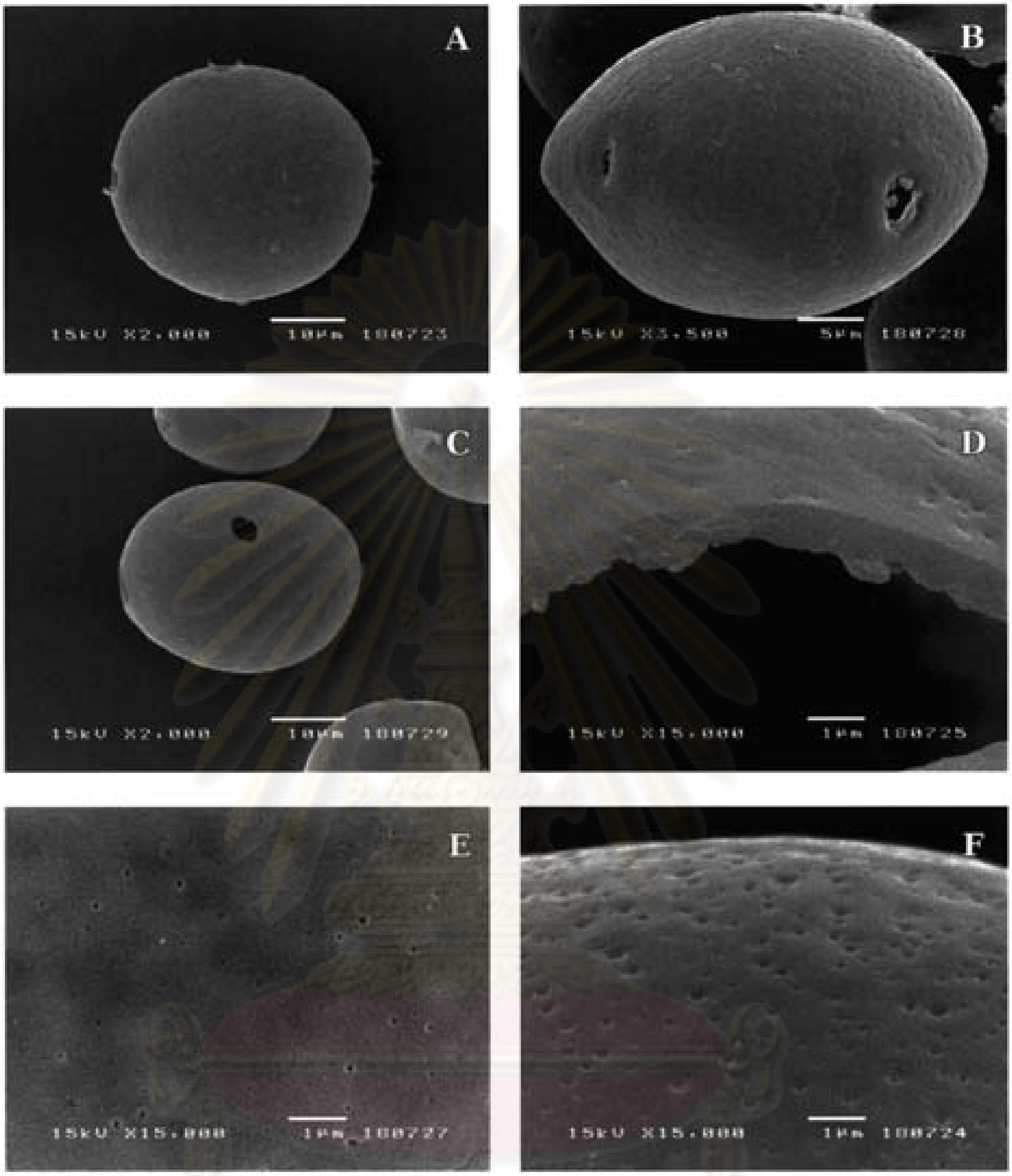

Plate 27 SEM micrographs: A-F. ***Wrightia religioisa* Benth. ex Kurz** (A) Polar view showing operculate pori, (B) Equatorial view showing slighly unequal in size of pori, distinct annuli and operculate, (C) Oblique equatorial view, (D) Tectate exine, exine stratification obscure, (E) Psilate with perforation on the sexine surface, (F) Perforate sexine surface.

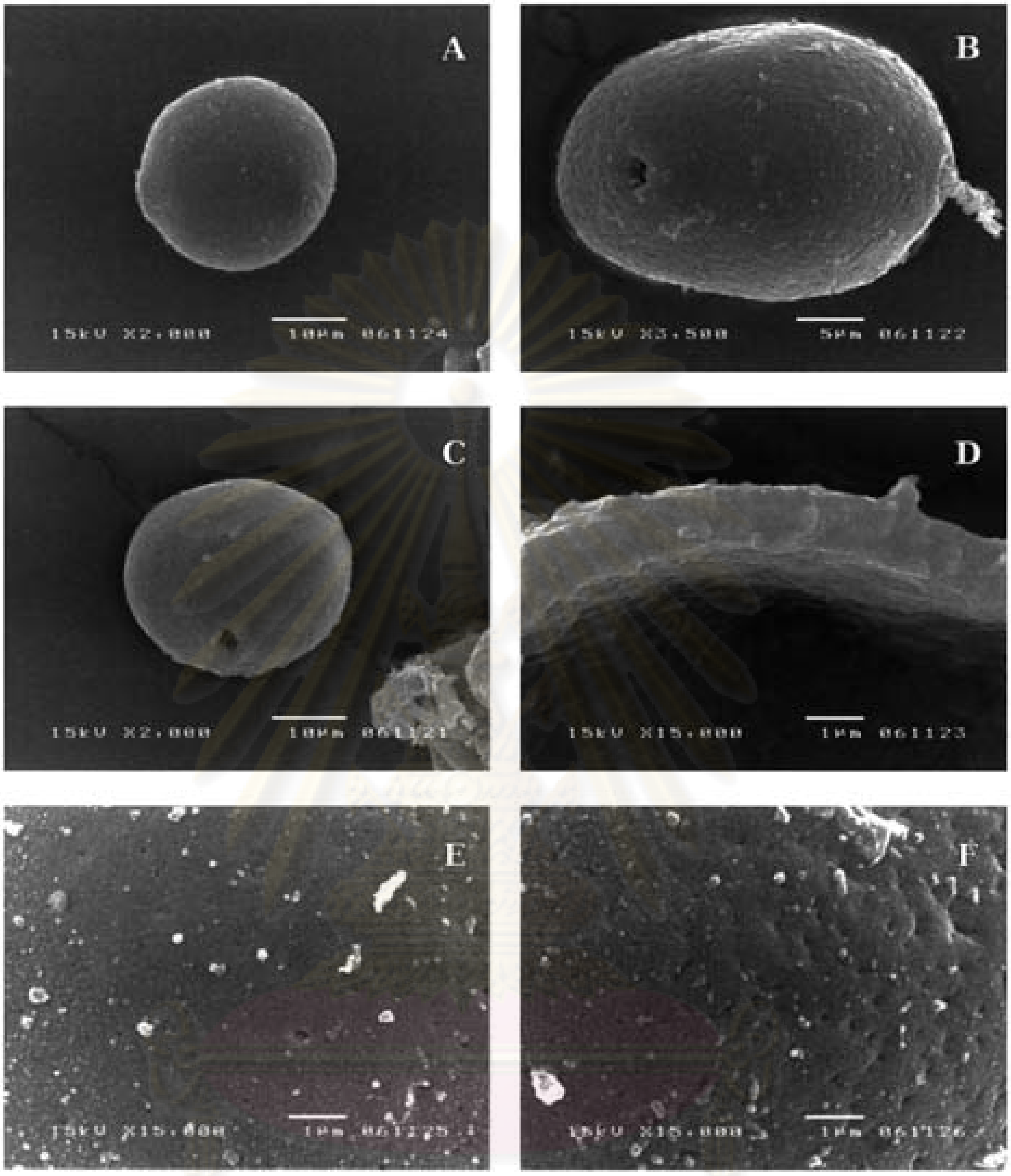

Plate 28 SEM micrographs: A-F. ***Vallaris solanacea* (Roth) O. Kuntze** (A) Oblique equatorial view showing operculate pore, (B) Equatorial view showing annulus, (C) Oblique equatorial view showing operculate pore, (D) Tectate exine, (E) Psilate with sparsely perforation on the surface of sexine, (F) Perforate sexine surface.

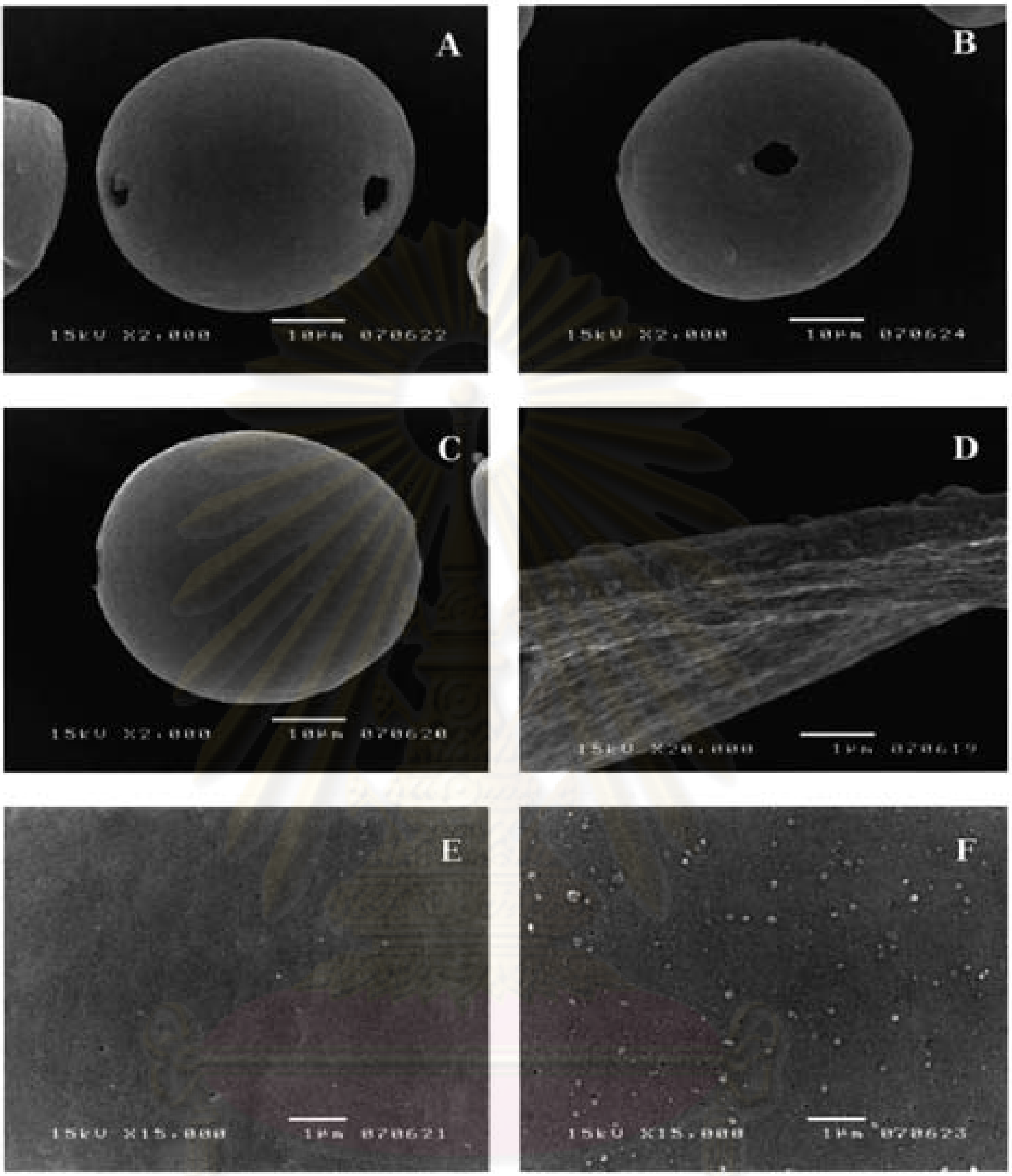

Plate 29 SEM micrographs: A-F. ***Pentalinon luteum* (L.) B.F. Hansen & Wunderlin** (A)-(B) Equatorial view, (C) Polar view with circular-elliptic amb, (D) Tectate exine, sexine thicker than the nexine, infratectum granulate, (E) Smooth psilate with sparsely perforation on the sexine surface, (F) Perforate sexine surface.

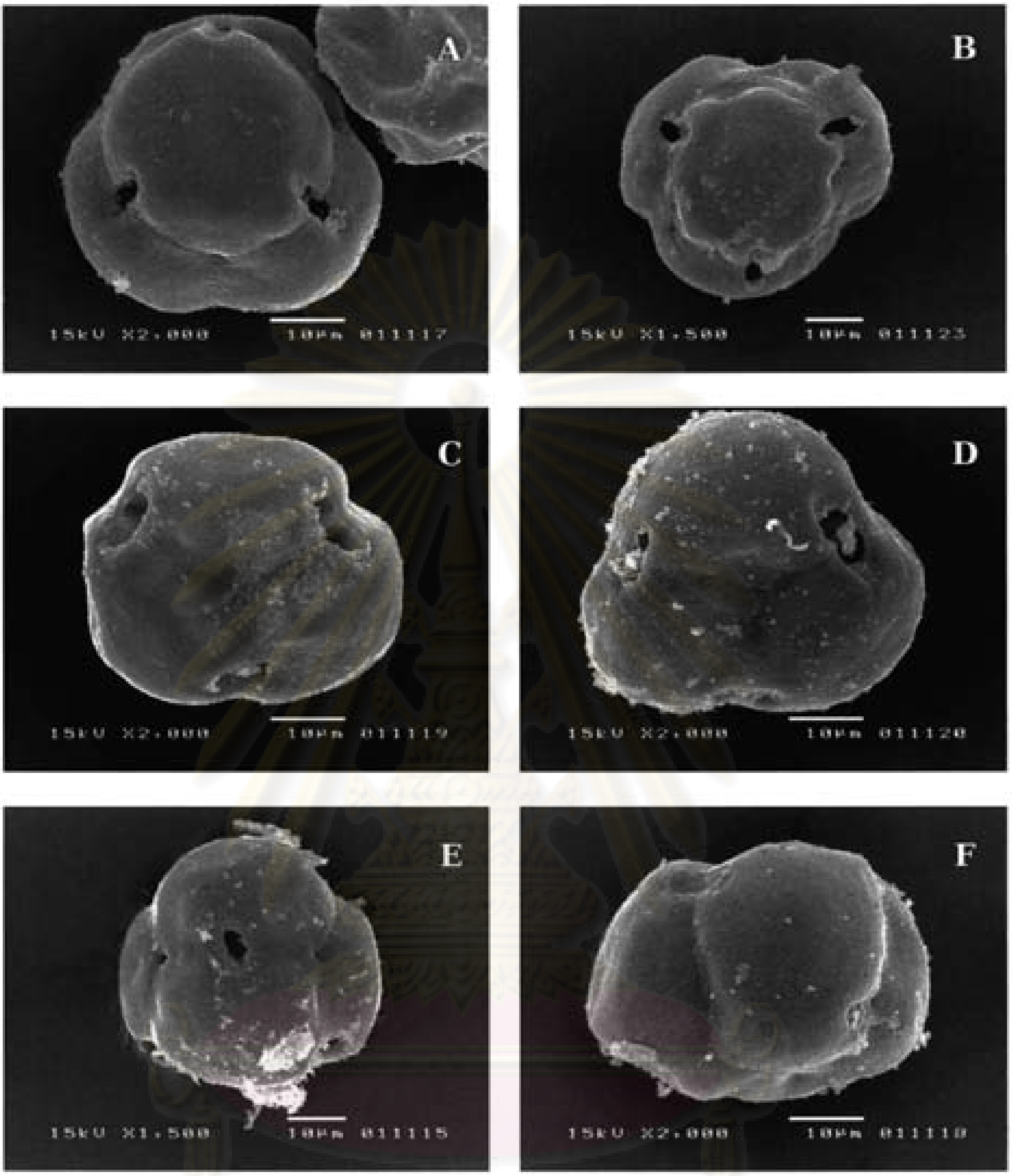

Plate 30 SEM micrographs: A-F. ***Melodinus orientalis*** **Blume** (A)-(B) Tetrahedral tetrad, (C)-(D) The lower side of tetrad showing 3 demicolpi, the furrow-like apertures often in interradial positions, (E) Decussate tetrad, (F) Tetragonal tetrad

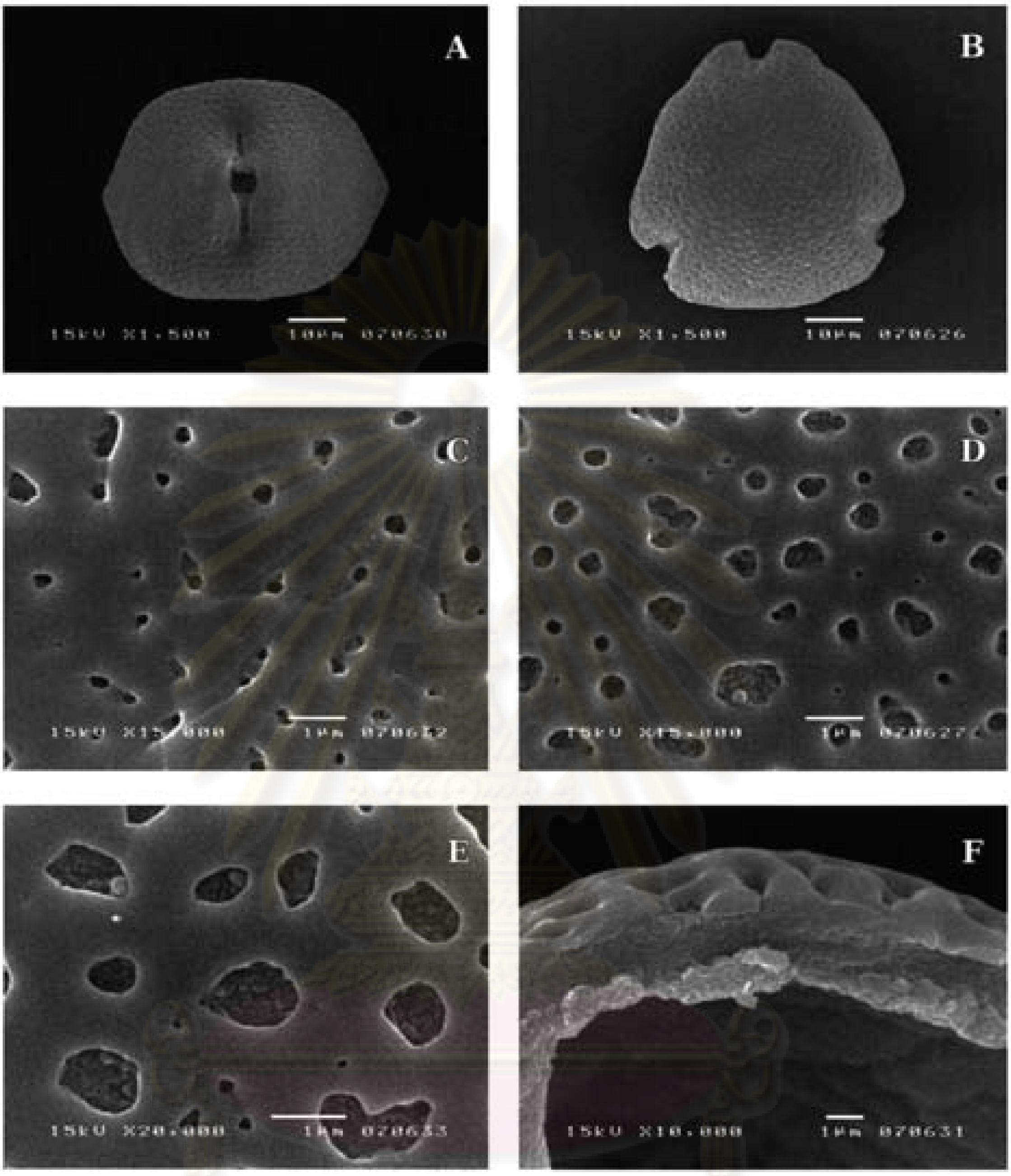

Plate 31 SEM micrographs: A-F. ***Thevetia peruviana*** **(Pers.) K. Schum.** (A) Equatorial view, (B) Polar view with obtuse-triangular amb, (C) Perforate sexine surface, (D)-(E) Microreticulate sexine surface, (F) Semitectate exine, sexine thinner than the nexine.

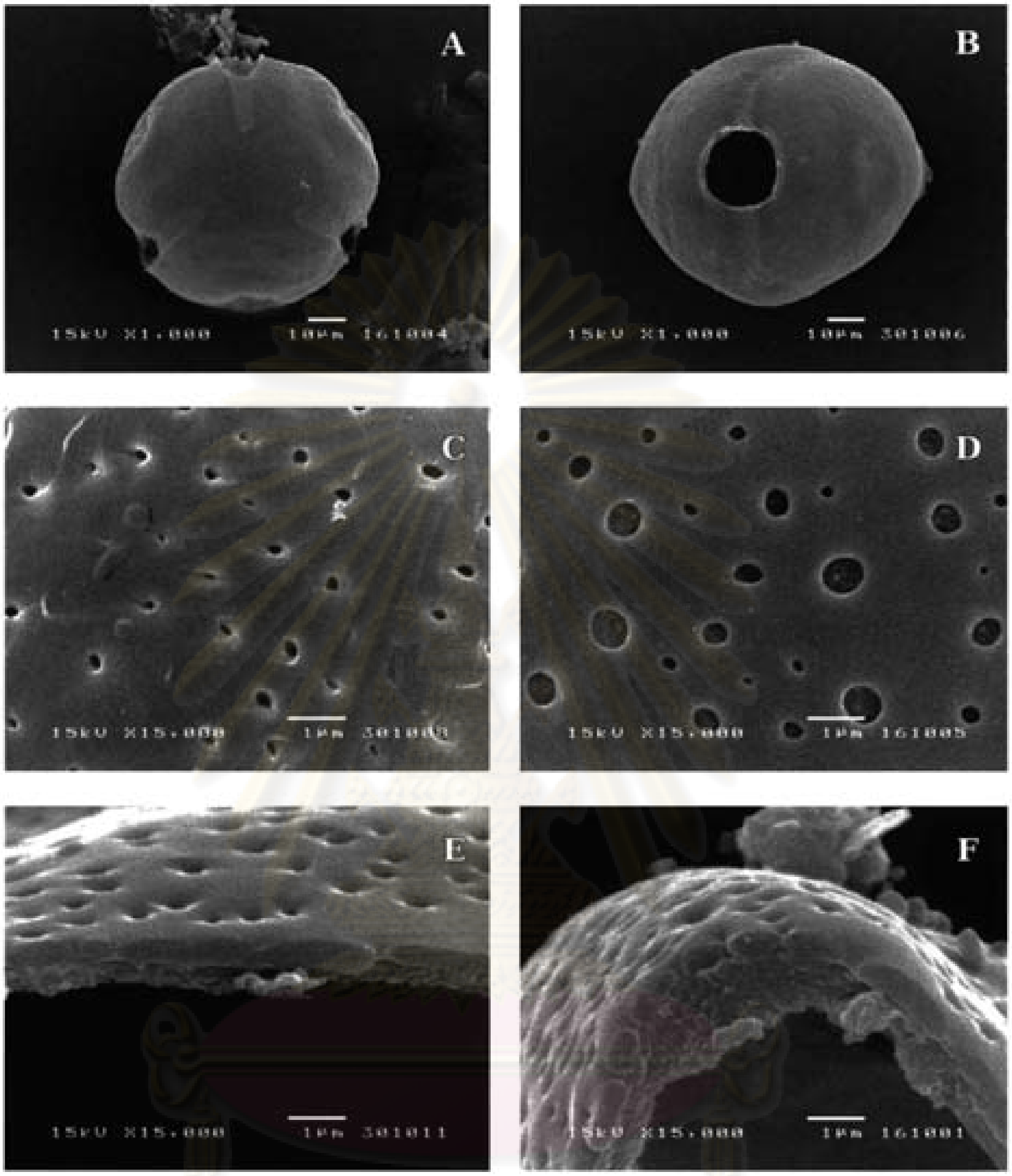

Plate 32 SEM micrographs: A-F. ***Cerbera manghas*** **L.** (A) Polar view, (B) Equatorial view, (C) Perforate sexine surface, (D) Foveolate sexine surface, (E)-(F) Semitectate exine, sexine thicker than nexine.

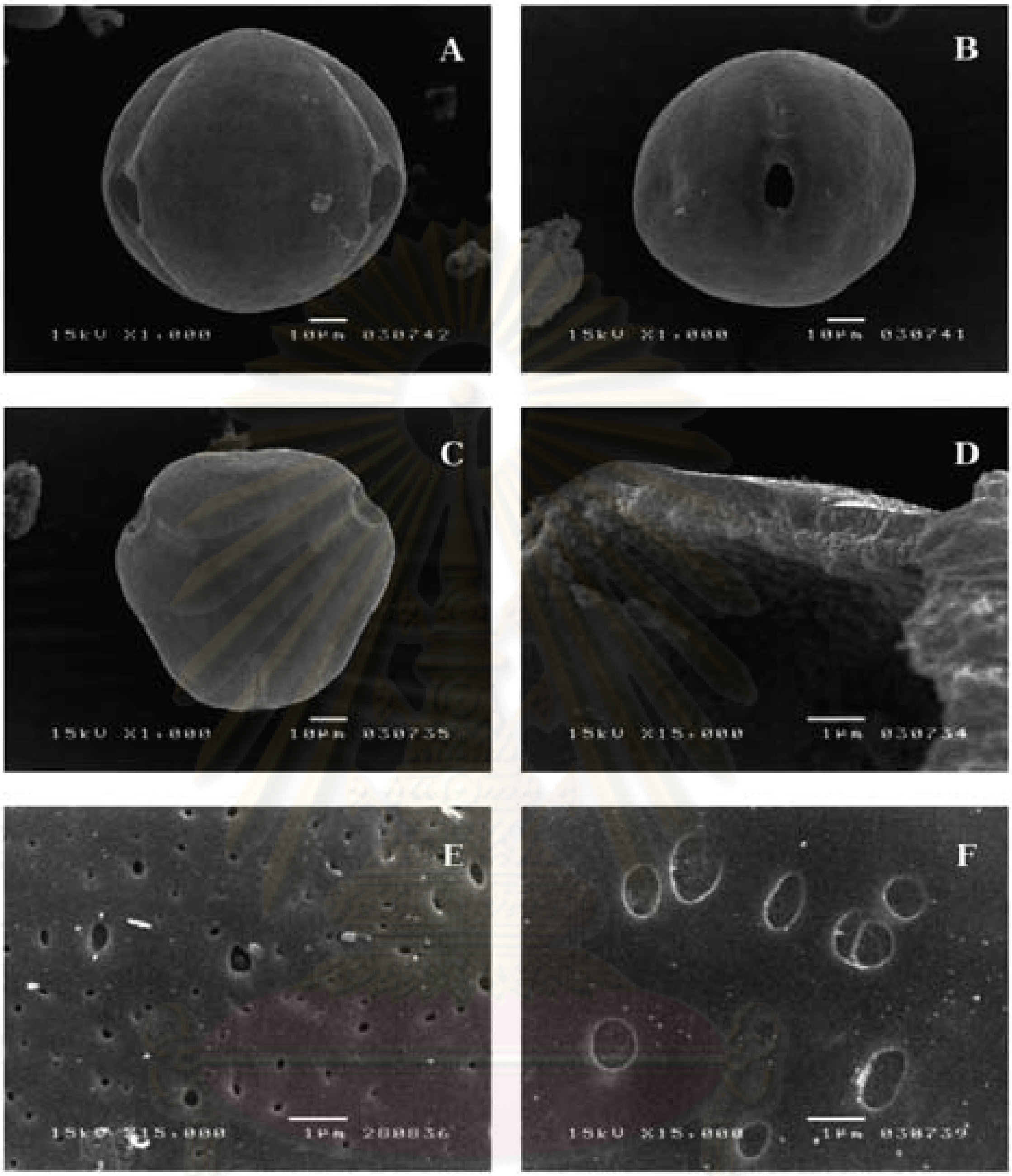

Plate 33 SEM micrographs: A-F. ***Cerbera odollam*** **Gaertner** (A)-(B) Equatorial view, (C) Polar view with obtuse-triangular amb, (D) Tectate exine, sexine thicker than nexine, (E) Perforate sexine surface, (F) Foveolate sexine surface.

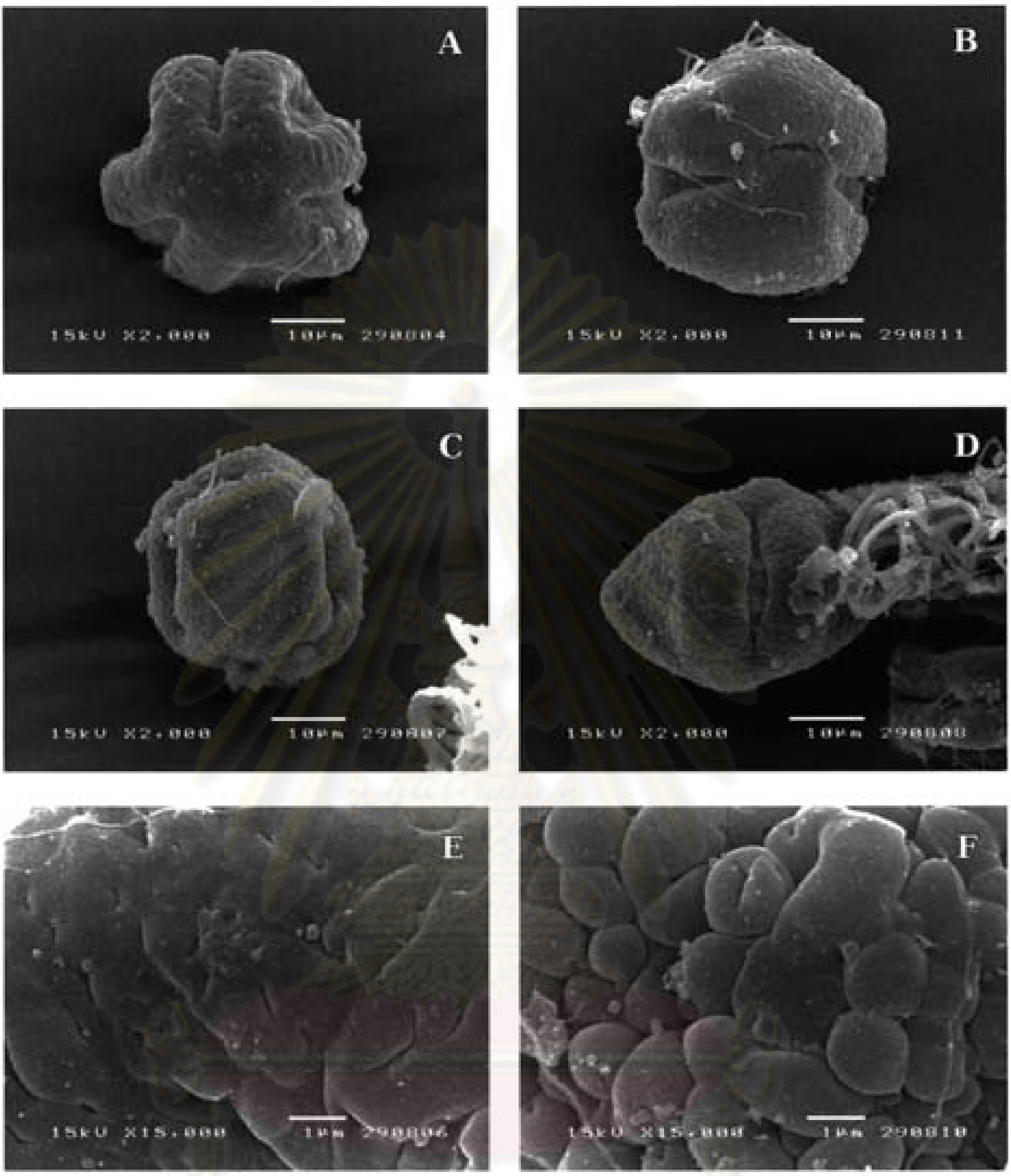

Plate 34 SEM micrographs: A-F. ***Ochrosia oppositifolia*** **(Lam.) K. Schum.** (A) Polar view with hexa-angular amb with 3 bilobate-apertural sides alternate with 3 concave areas of the middle part of mesocolpium, (B) Polar view showing dicolporate aperture, (C) Equatorial view showing depression at mesocolpium, (D) Equatorial view, (E) Fossulate sexine surface, (F) Verrucate sexine surface.

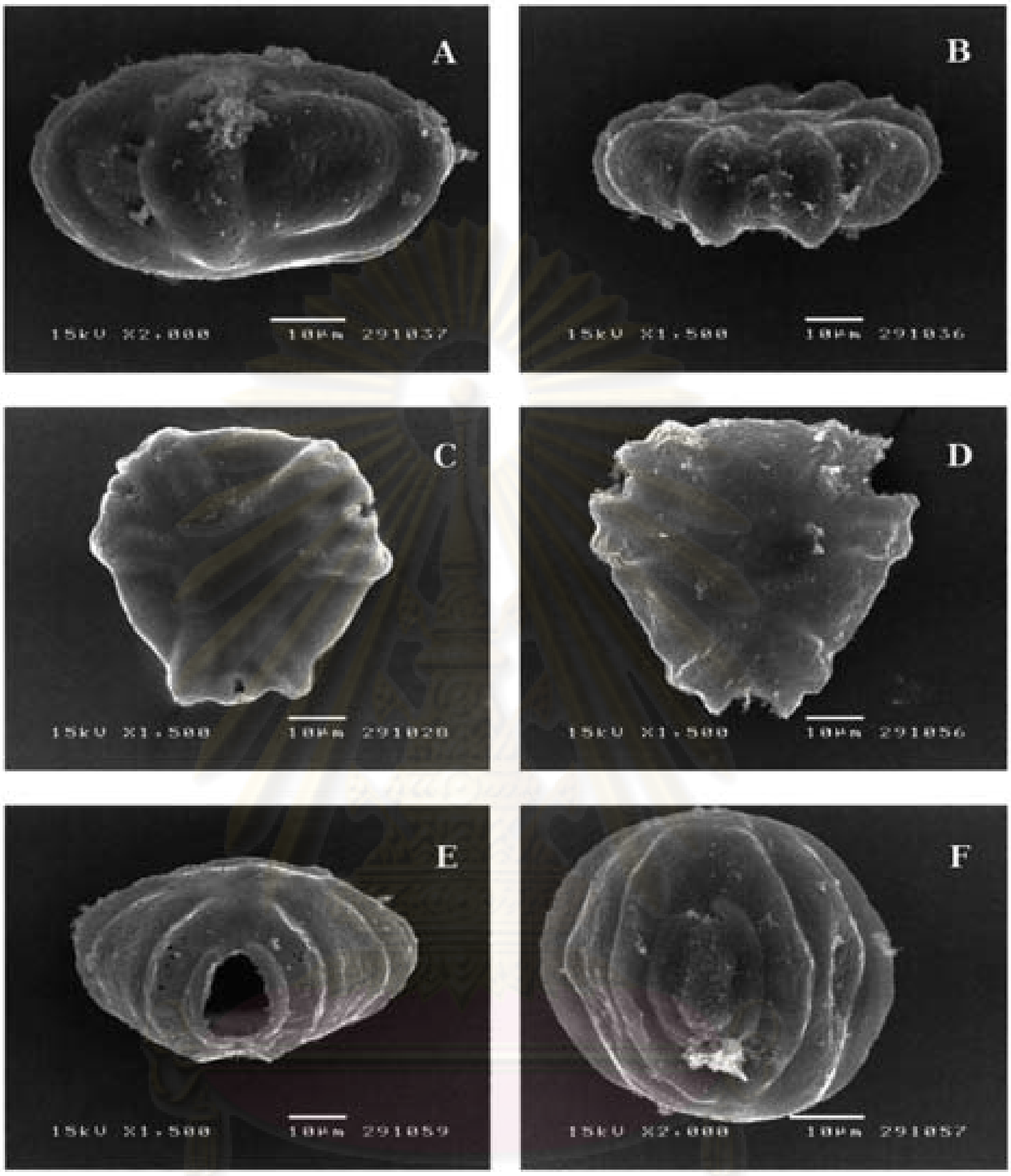

Plate 35 SEM micrographs: A-C. ***Rauvolfia cambodiana* Pierre ex Pitard** (A)-(B) Equatorial view, (C) Polar view with triangular, with slightly convex sides, and with, more or less, 3 protruded-lobe besides the margins of each aperture; D-F. ***R. serpentina* (L.) Benth. ex Kurz** (D) Polar view with triangular, with slightly straight sides, and with, more or less, 3 protruded-lobe besides the margins of each aperture,(E) Equatorial view, pumpkin-like shape, (F) Equatorial view, subsperoidal shape.

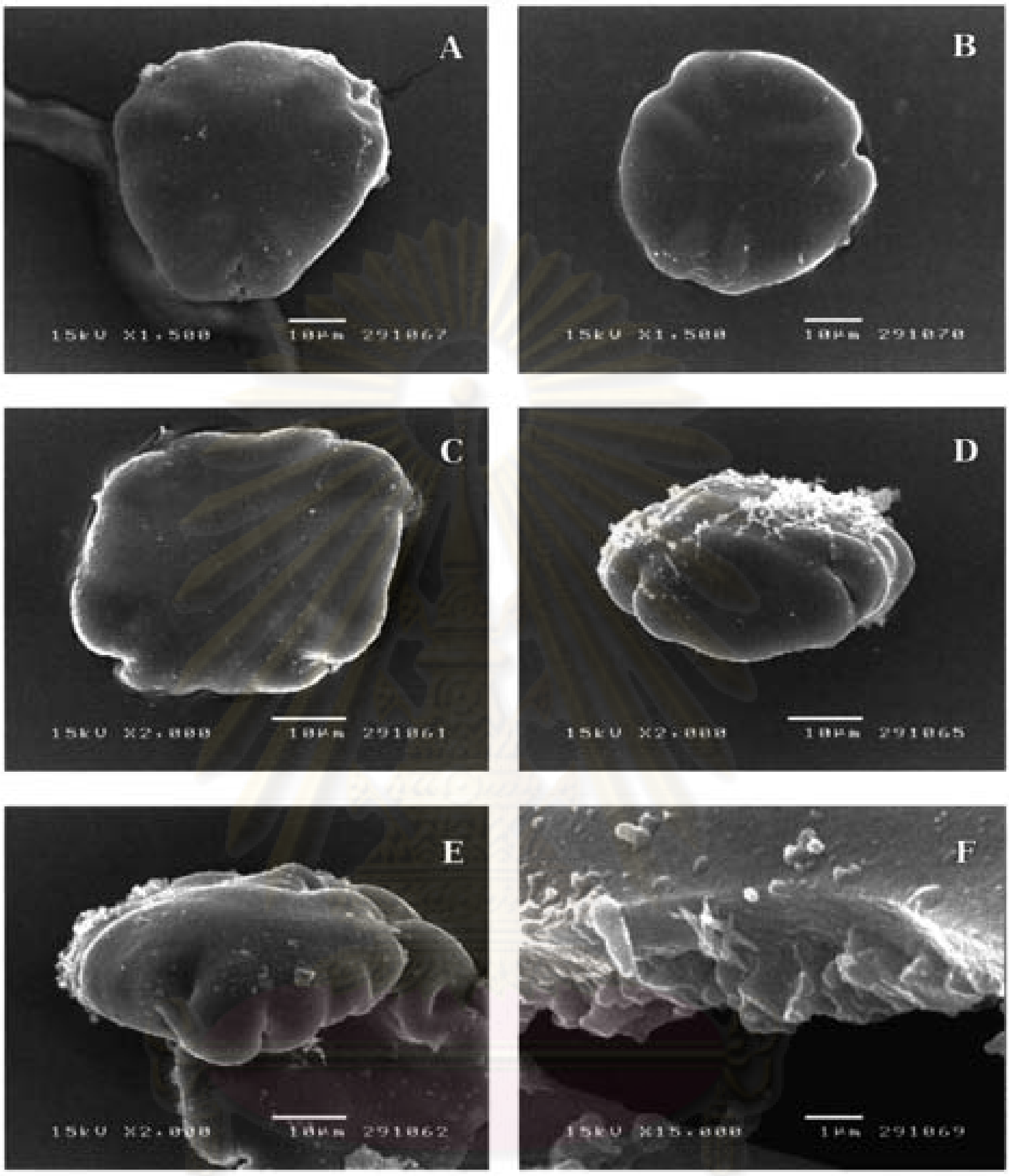

Plate 36 SEM micrographs: A-F. ***Rauvolfia sumatrana*** **Jack** (A) Polar view with triangular amb, (B) Polar view with circular-triangular amb, (C) Polar view with rectangular amb, (D)-(E) Equatorial view, (F) Tectate exine.

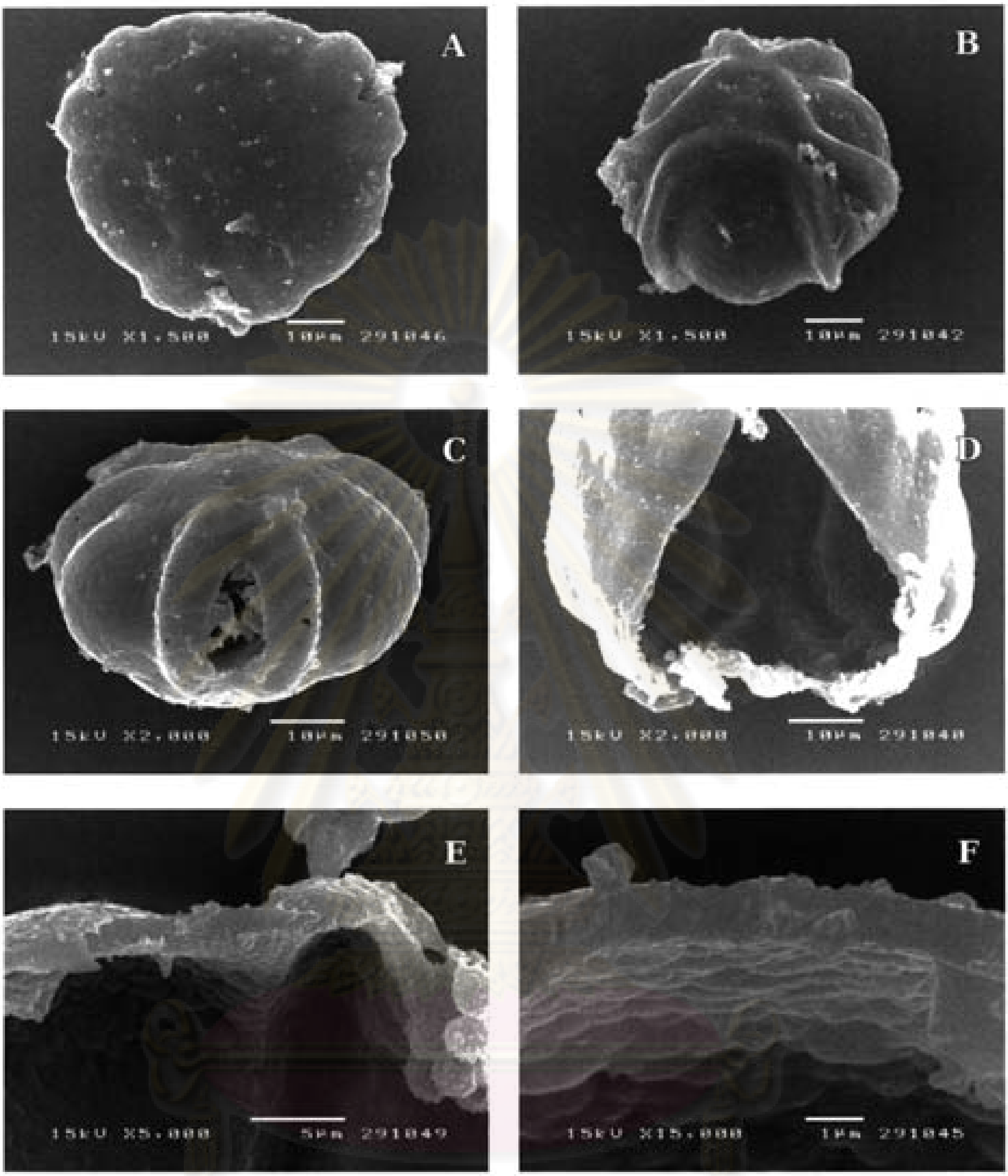

Plate 37 SEM micrographs: A-F. ***Rauvolfia verticillata*** **(Lour.) Baillon** (A) Polar view with circular-triangular, with slightly convex sides, and with, more or less, 3 protruded-lobe besides the margins of each aperture, (B) Polar view with circular amb, protruded-lobe besides the margins of each aperture united end, (C) Equatorial view, pumpkin-like shape, (D)-(E) exine thickness uneven, exine thinnest between the area of two adjacent pair of ridge, (F) Tectate exine.

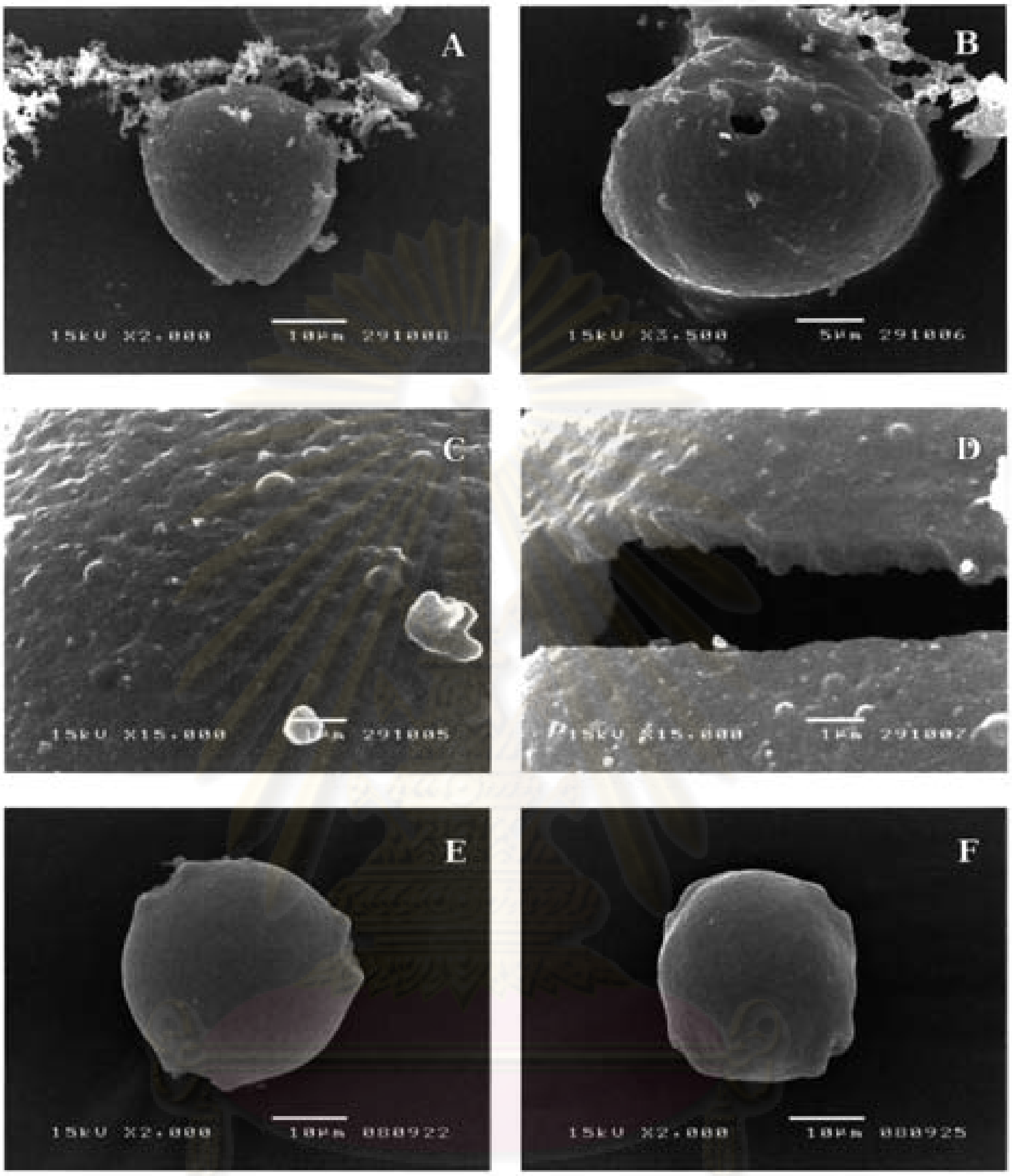

Plate 38 SEM micrographs: A-D. ***Willughbeia edulis*** **Roxb.** (A) Polar view, (B) Equatorial view, (C) Perforate sexine surface, (D) Tectate exine; E-F. ***W. coriacea*** **Wall.** (E) Polar view with circular-triangular with convex sides, (F) Polar view with rectangular amb.

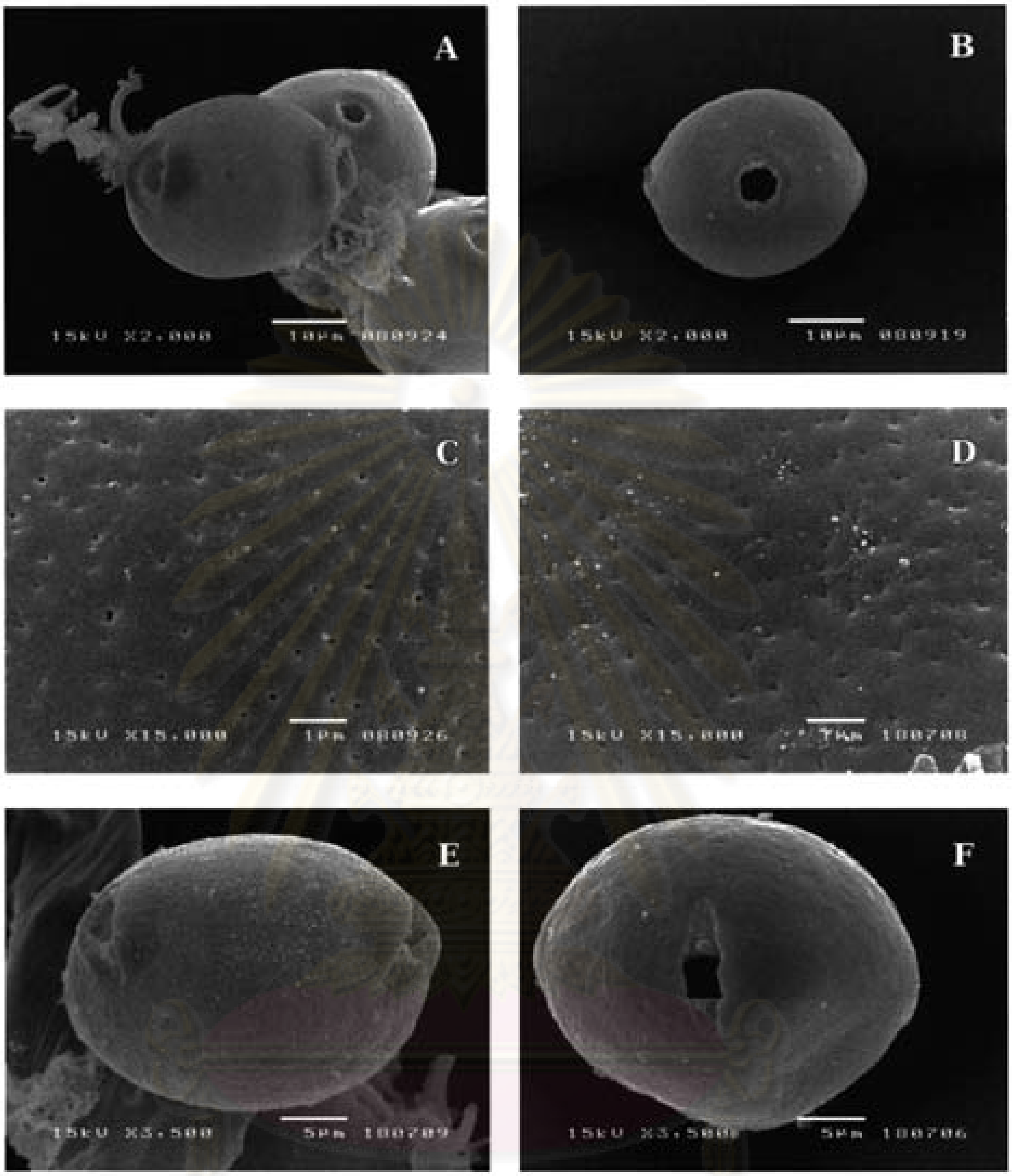

Plate 39 SEM micrographs: A-F. ***Willughbeia coriacea*** **Wall.** (A)-(B) Equatorial view showing very short ectocolpi, (C)-(D) Perforate sexine surface, (E)-(F) Equatorial view showing slightly short but narrow ectocolpi.

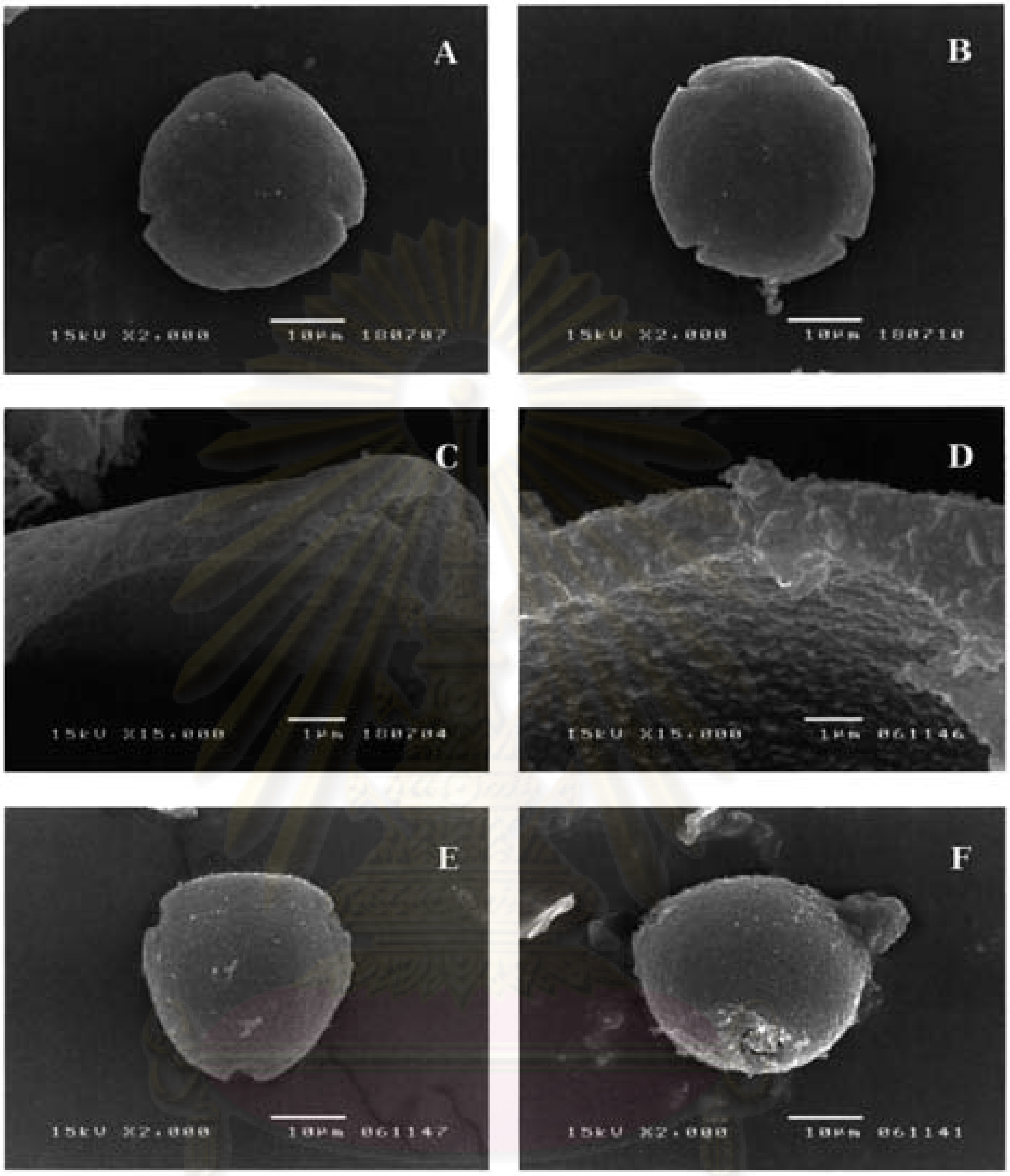

Plate 40 SEM micrographs: A-C. ***Willughbeia coriacea* Wall.** (A) Polar view showing circular-triangular amb with concave sides, (B) Polar view with rectangular amb with concave sides,(C) Tectate exine; D-F. ***W. grandiflora* Dyer ex Hook.f.** (D) Tectate exine, (E) Polar view showing circular-triangular amb with slightly straight sides, (F) Oblique equatorial view.

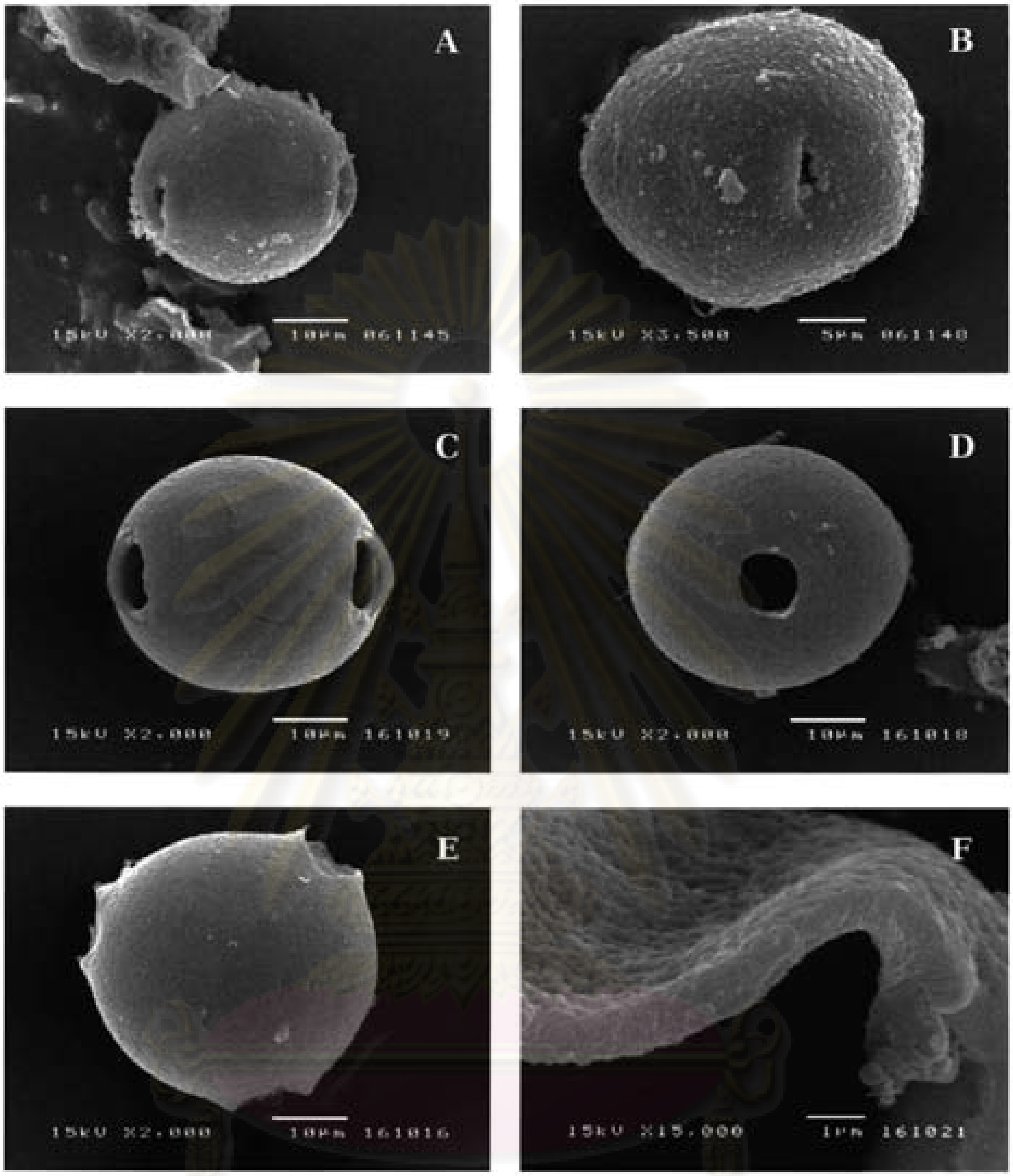

Plate 41 SEM micrographs: A-F. ***W. grandiflora*** **Dyer ex Hook.f.** (A)-(B) Equatorial view showing ecto- and endoaperture slightly small and narrow, margin parallel, (C)-(D) Equatorial view showing ecto- and endoaperture larger and widely opened, nearly congruent together, (E) Polar view with circular-triangular amb, (F) Tectate exine.

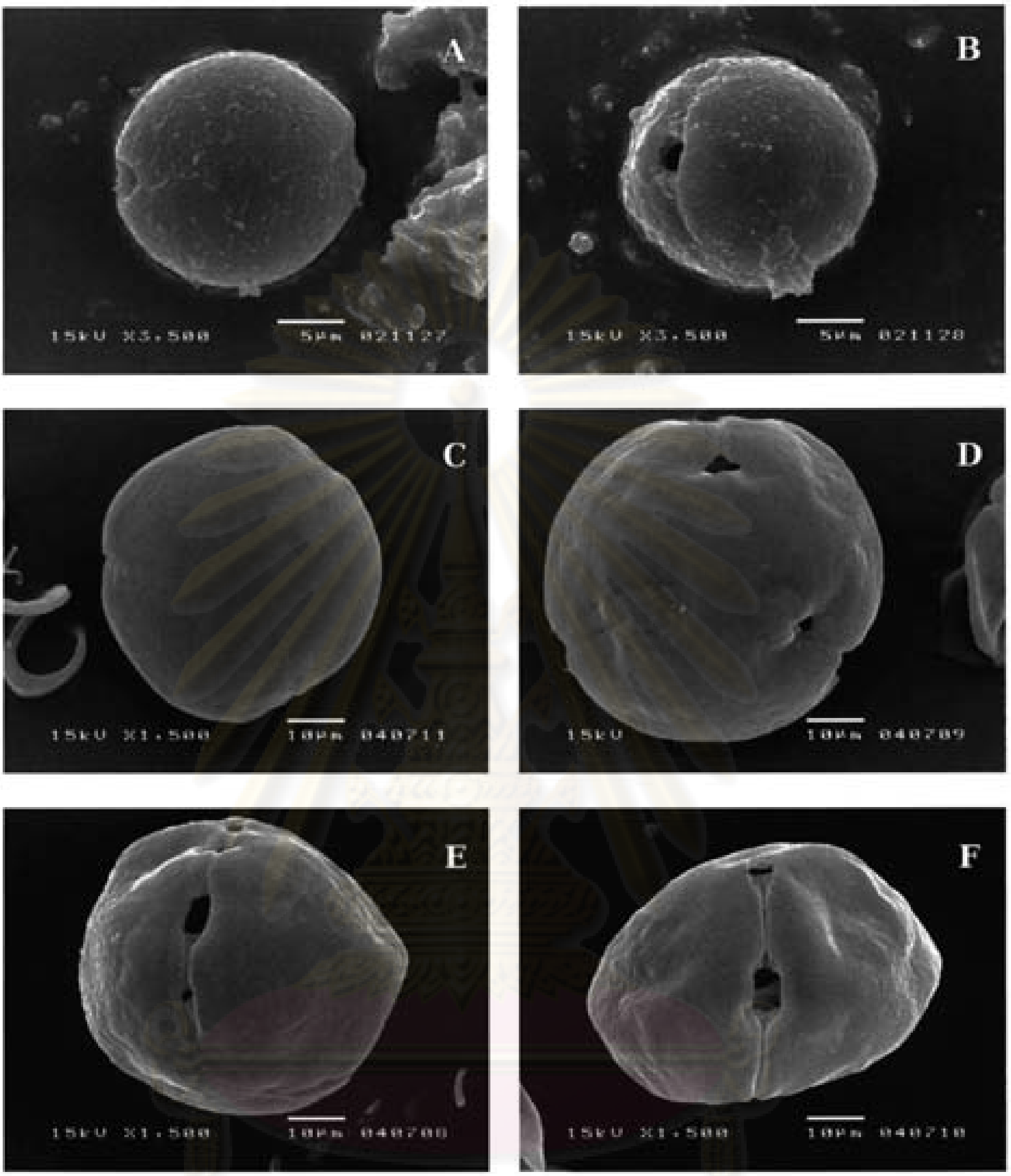

Plate 42 SEM micrographs: A-B. ***Alstonia angustiloba* Miq.** (A) Polar view with dicolporate aperture, (B) Equatorial view; C-F. ***Allamanda cathartica* L.** (C) Polar view, (D) Polar view with endoaperture at the ends of ectocolpi, (E)-(F) Equatorial view with more than one endoaperture within one ectocolpate, one at the equator and the other at the ends of ectocolpi.

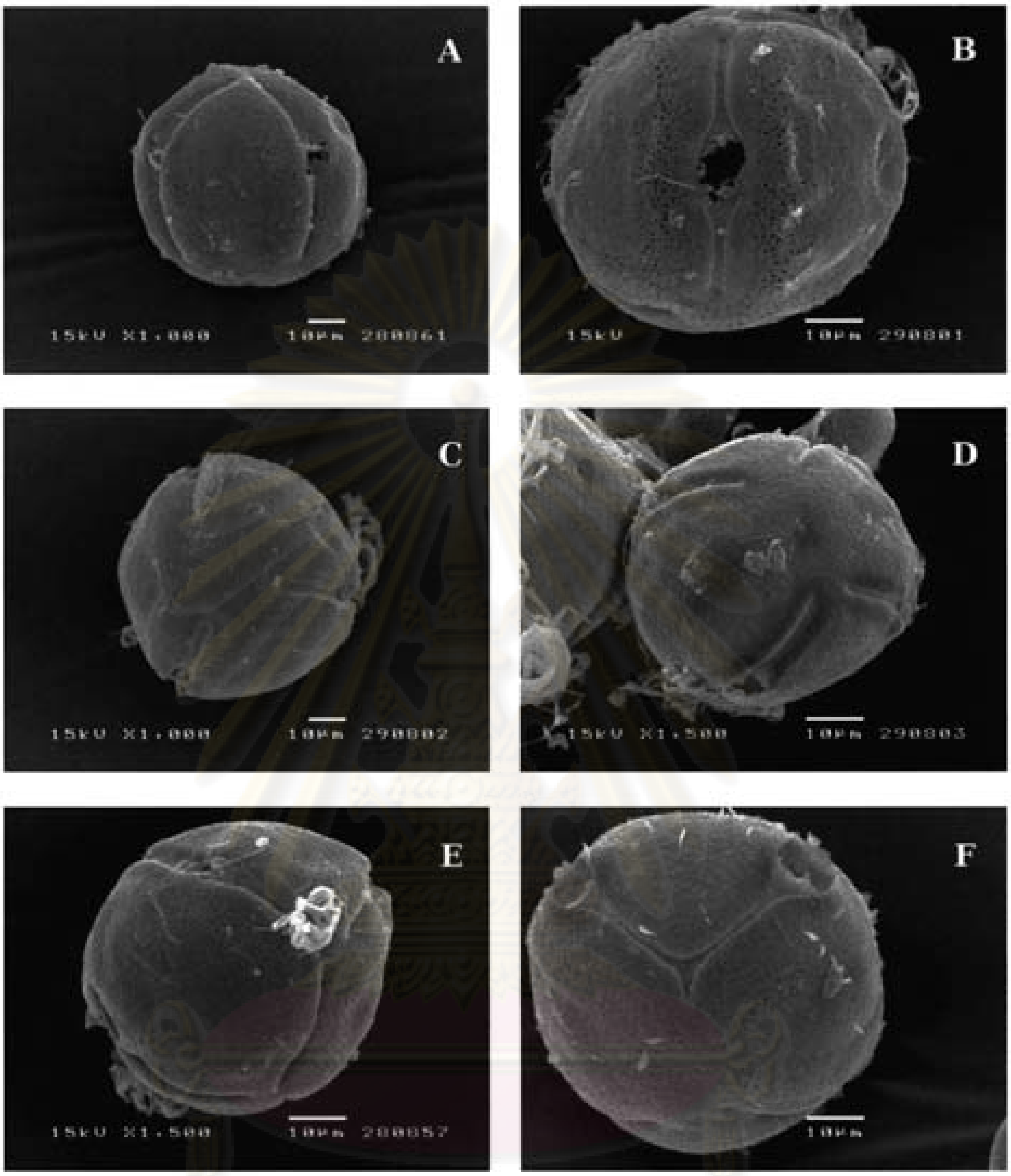

Plate 43 SEM micrographs: A-F. ***Kopsia arborea*** **Blume** (A) Equatorial view showing the close ends of two ectocolpi, (B) Equatorial view, (C) Polar view with tricolporate aperture, (D) Polar view with 4-colporate aperture, (E) Pantocolporate grain, (F) Syn-ectocolpate grain.

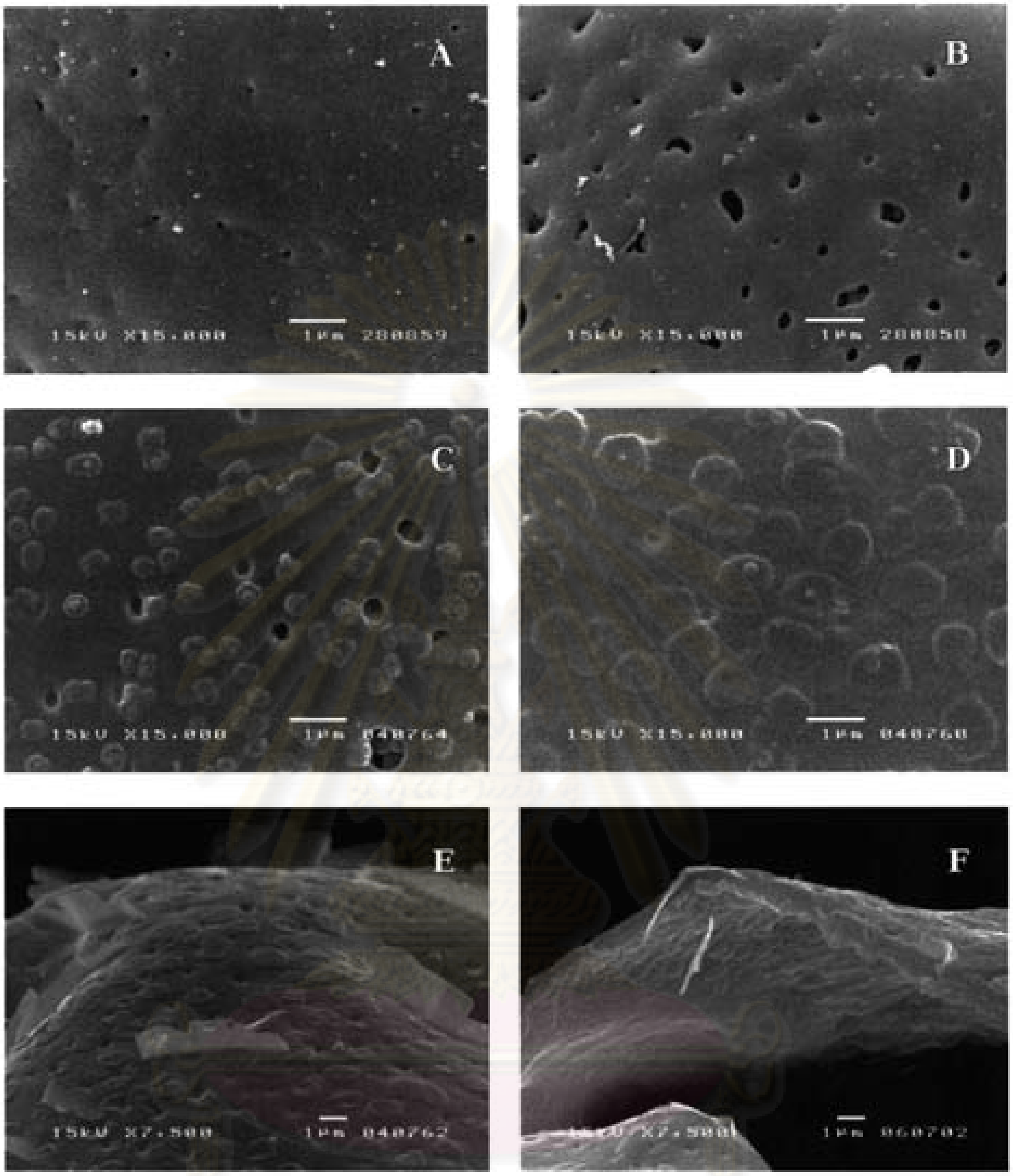

Plate 44 SEM micrographs: A-F. ***Kopsia arborea*** **Blume** (A) Psilate with perforations on sexine surface, (B) Perforate, (C) Perforate with small granules, (D)-(E) Perforate with small granules or flattened verrucae, (F) Tectate exine.

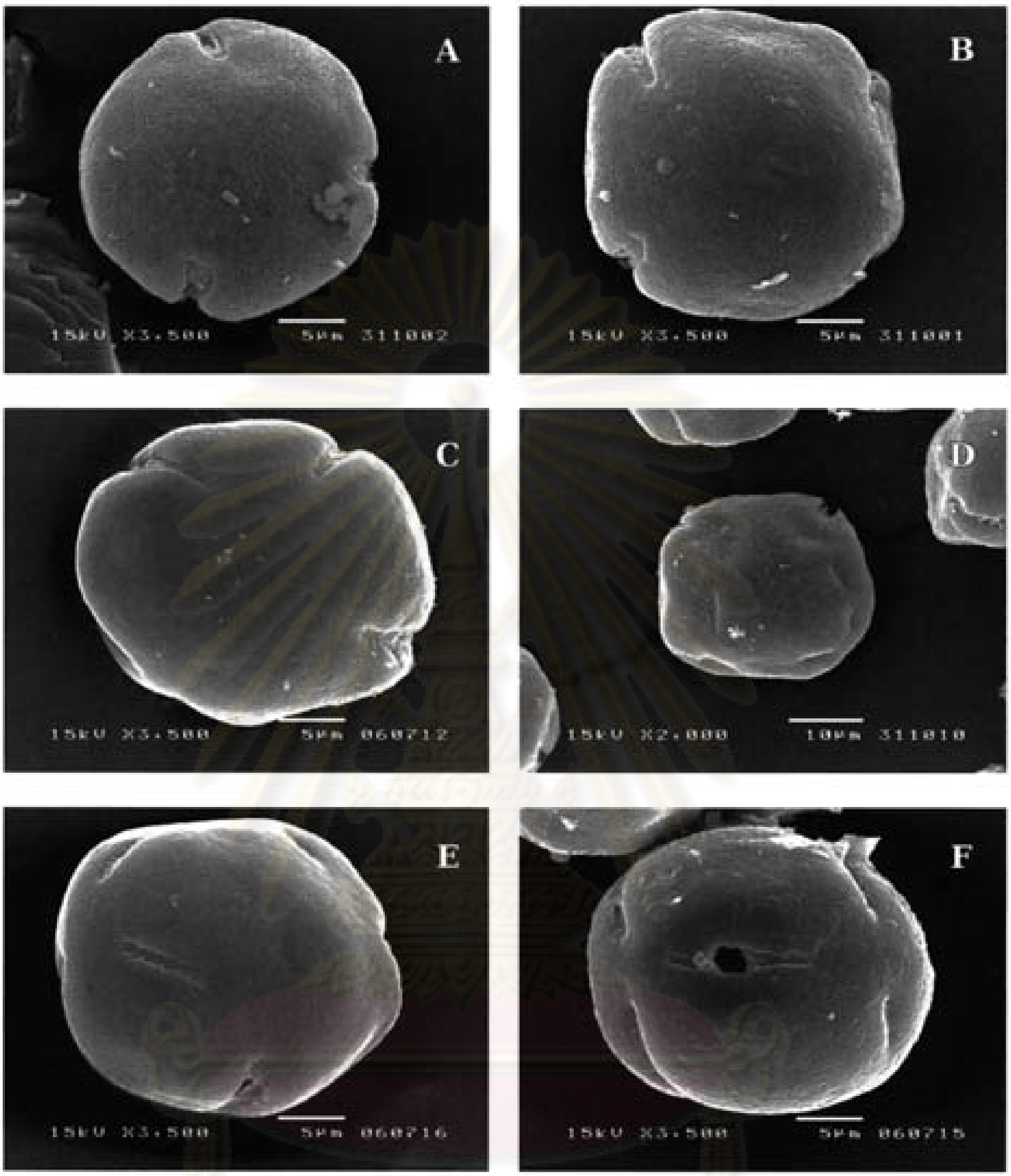

Plate 45 SEM micrographs: A-F. ***Melodinus cambodiensis*** **Pierre ex Spire** (A) Polar view with tricolporate aperture, circular amb, (B) Polar view with 4-colporate aperture, rectangular amb, (C) Polar view with irregular rectangular amb, (D)-(E) Polar view with pseudocolpi, (F) Pantocolporate grain.

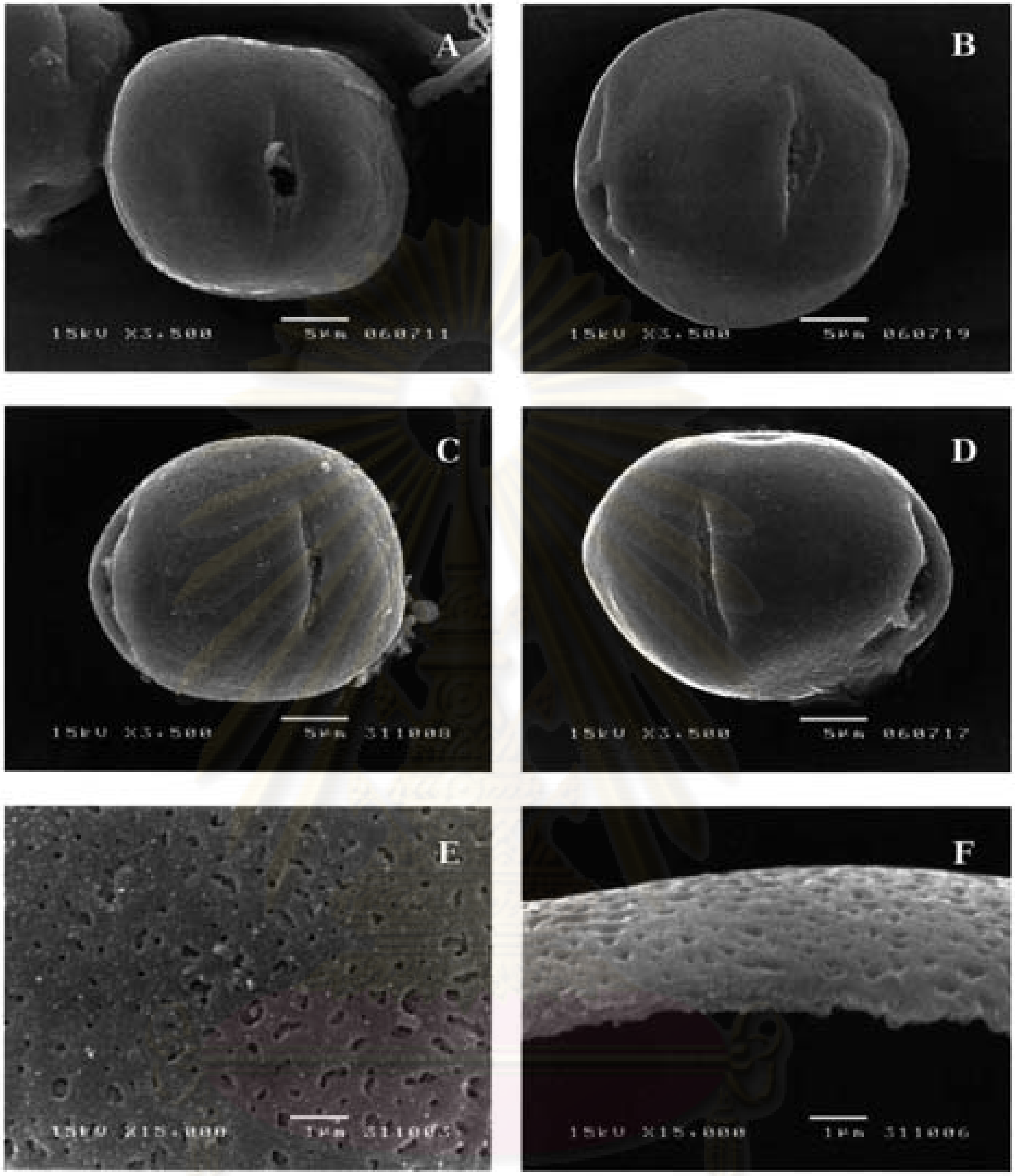

Plate 46 SEM micrographs: A-F. ***Melodinus cambodiensis* Pierre ex Spire** (A)-(B) Equatorial view, (C)-(D) Equatorial view showing pseudocolpi, (E) Perforate sexine surface, (F) Tectate exine, sexine as thick as nexine.

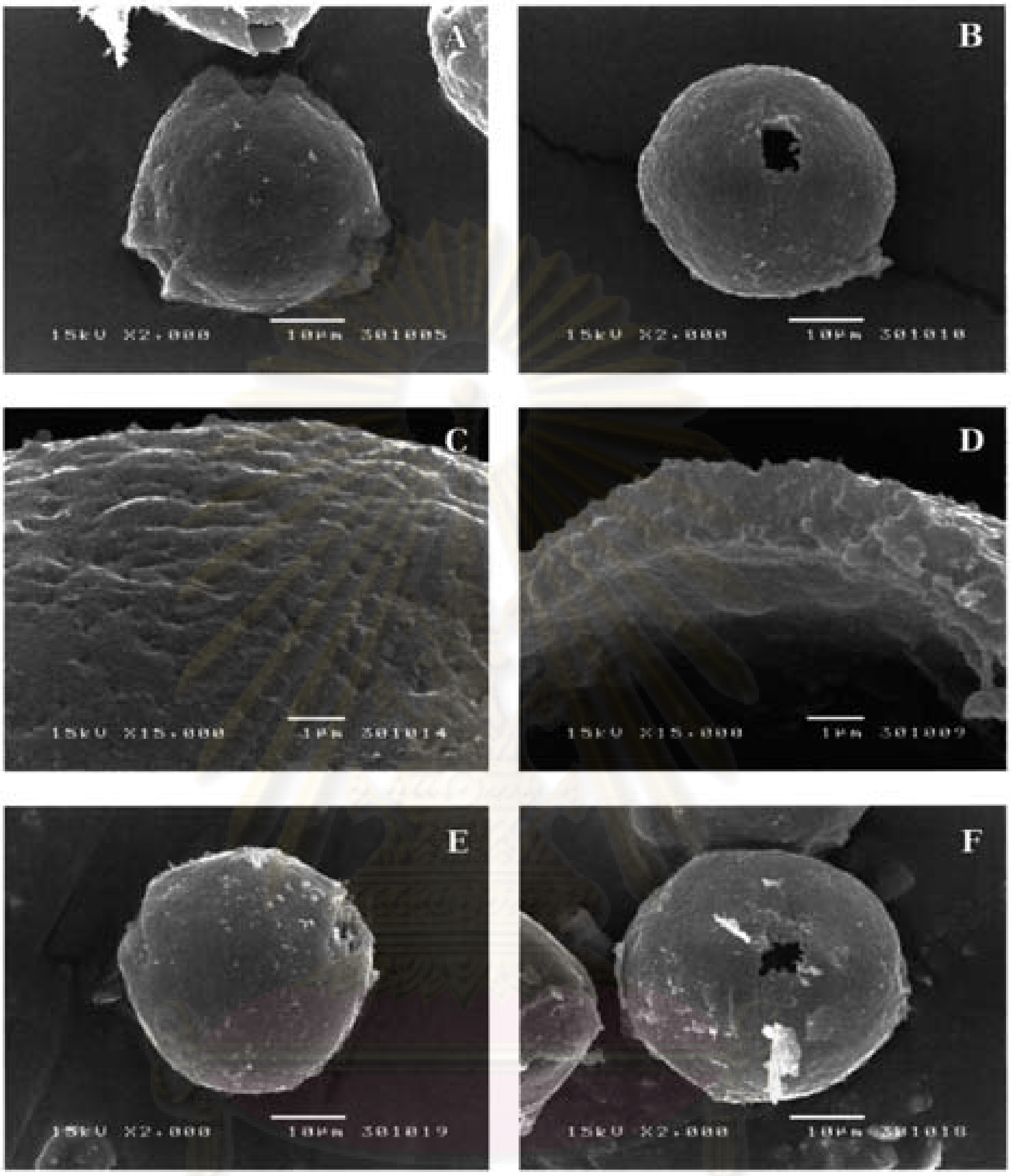

Plate 47 SEM micrographs: A-D. ***Tabernaemontana pauciflora* Blume** (A) Polar view, (B) Equatorial view, (C) Perforate sexine surface, (D) Tectate exine; E-F. ***T. Peduncularis* Wall.** (E) Slightly oblique polar view, (F) Equatorial view.

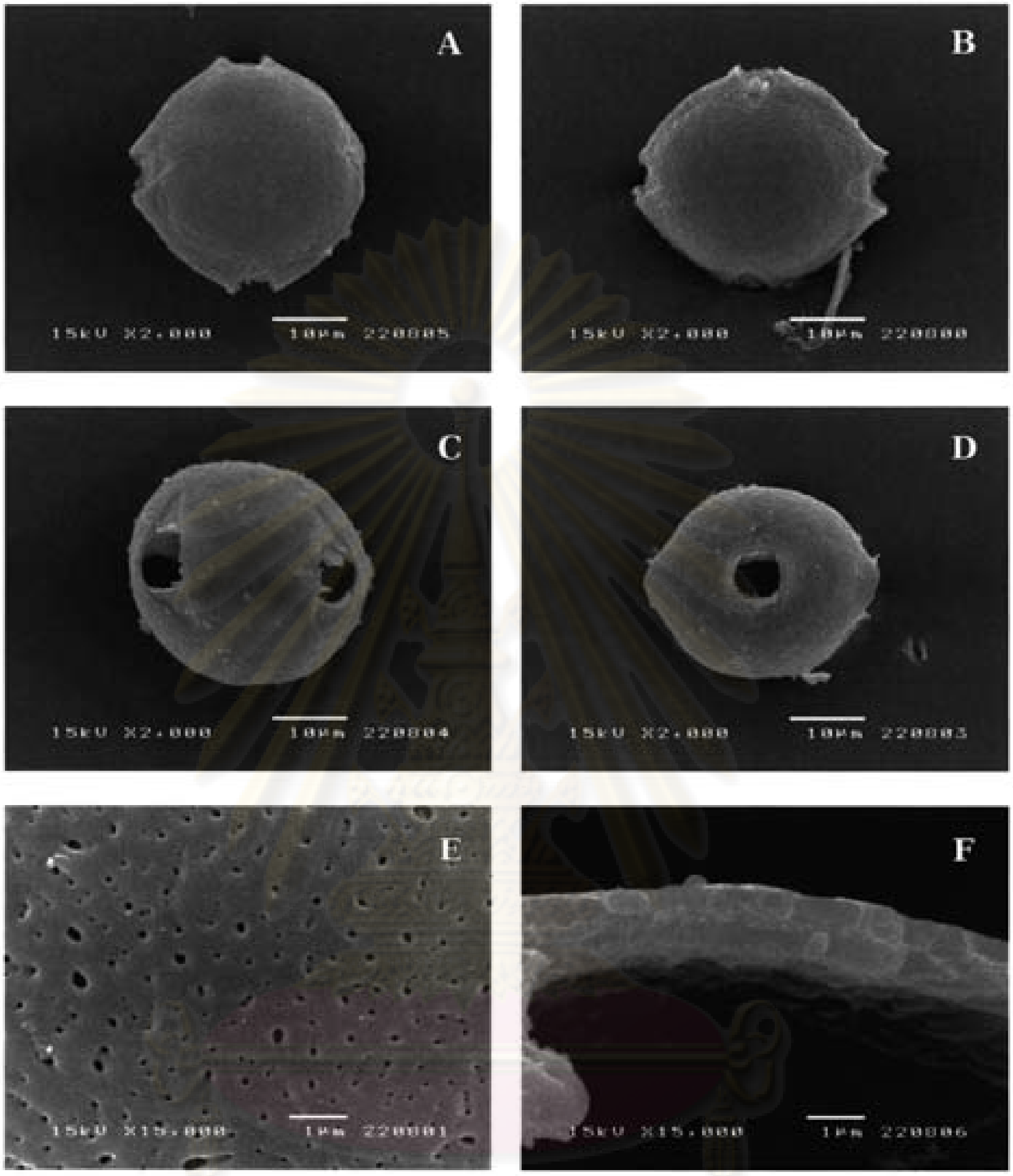

Plate 48 SEM micrographs: A-F. ***Tabernaemontana bufalina* Lour.** (A)-(B) Polar view, (C)-(D) Equatorial view, (E) Perforate sexine surface, (F) Tectate sexine, the sexine as thick as the nexine.

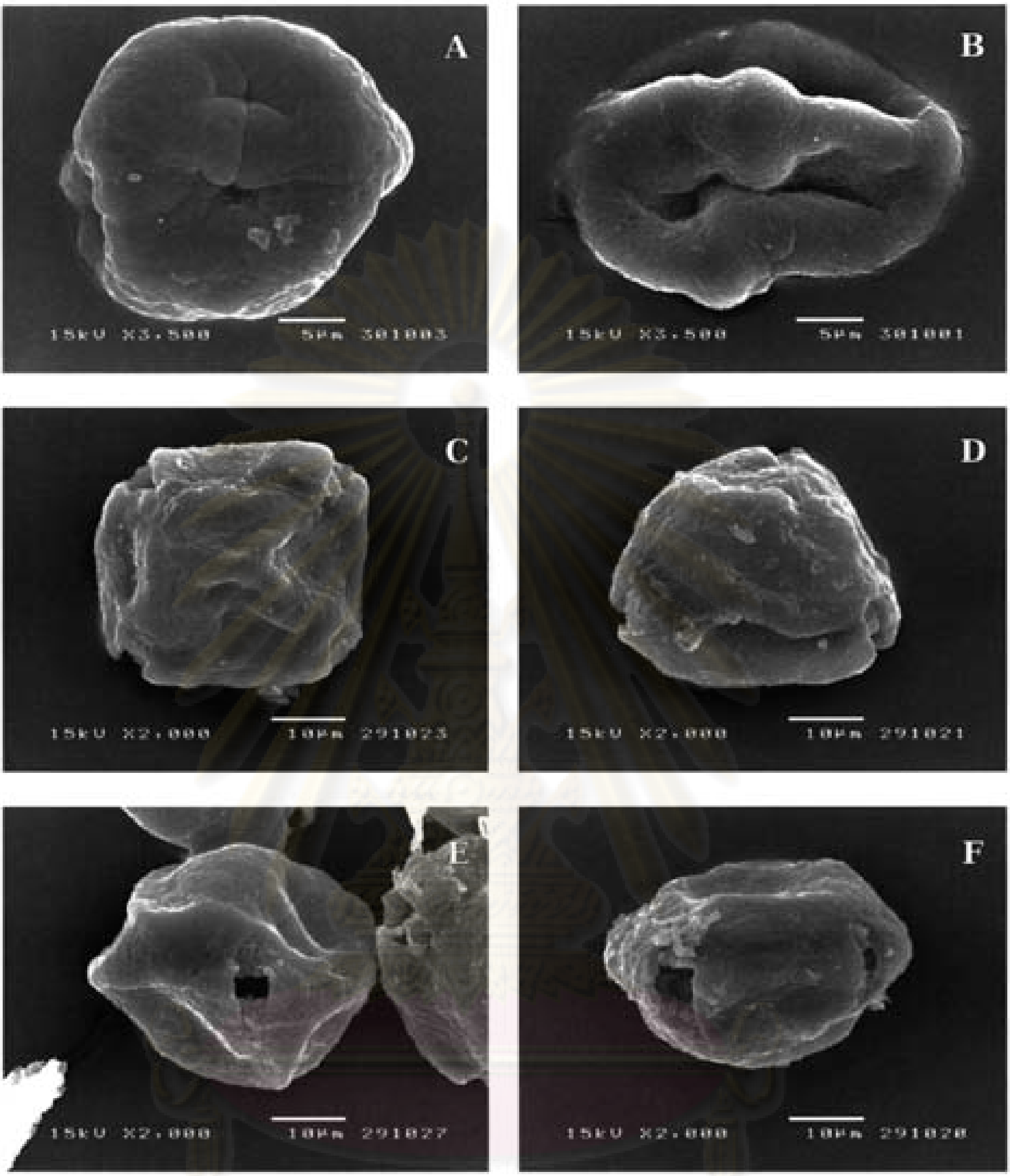

Plate 49 SEM micrographs: A-B. ***Tabernaemontana divaricata*** **(L.) R.Br. ex Roem & Schult.** (A) Equatorial view with prolate spheroidal shape, (B) Equatorial view with prolate shape; C-F. ***T. bovina*** **Lour.** (C) Polar view, rectangular amb with straight sides, (D) Polar view, tringular amb, (E)-(F) Equatorial view.

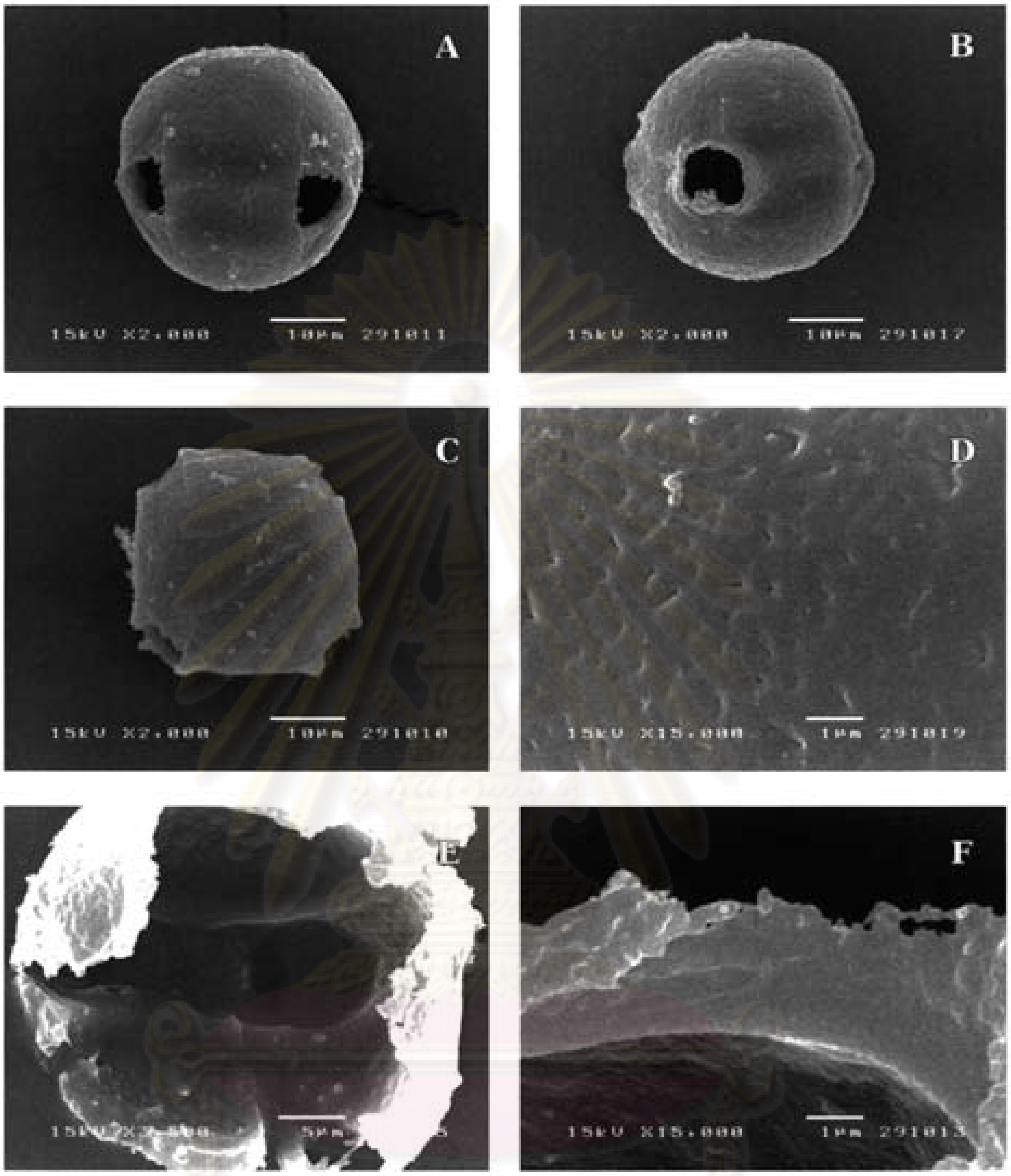

Plate 50 SEM micrographs: A-F. ***Tabernaemontana corymbosa*** **Wall** (A)-(B) Equatorial view, (C) Polar view with rectangular amb, (D) Perforate sexine surface, (E) Endoaperture endocingulum (band-like continuous equatorial zone), very distinct costa endocingulum, (F) Exine thickness of costa endocingulum.

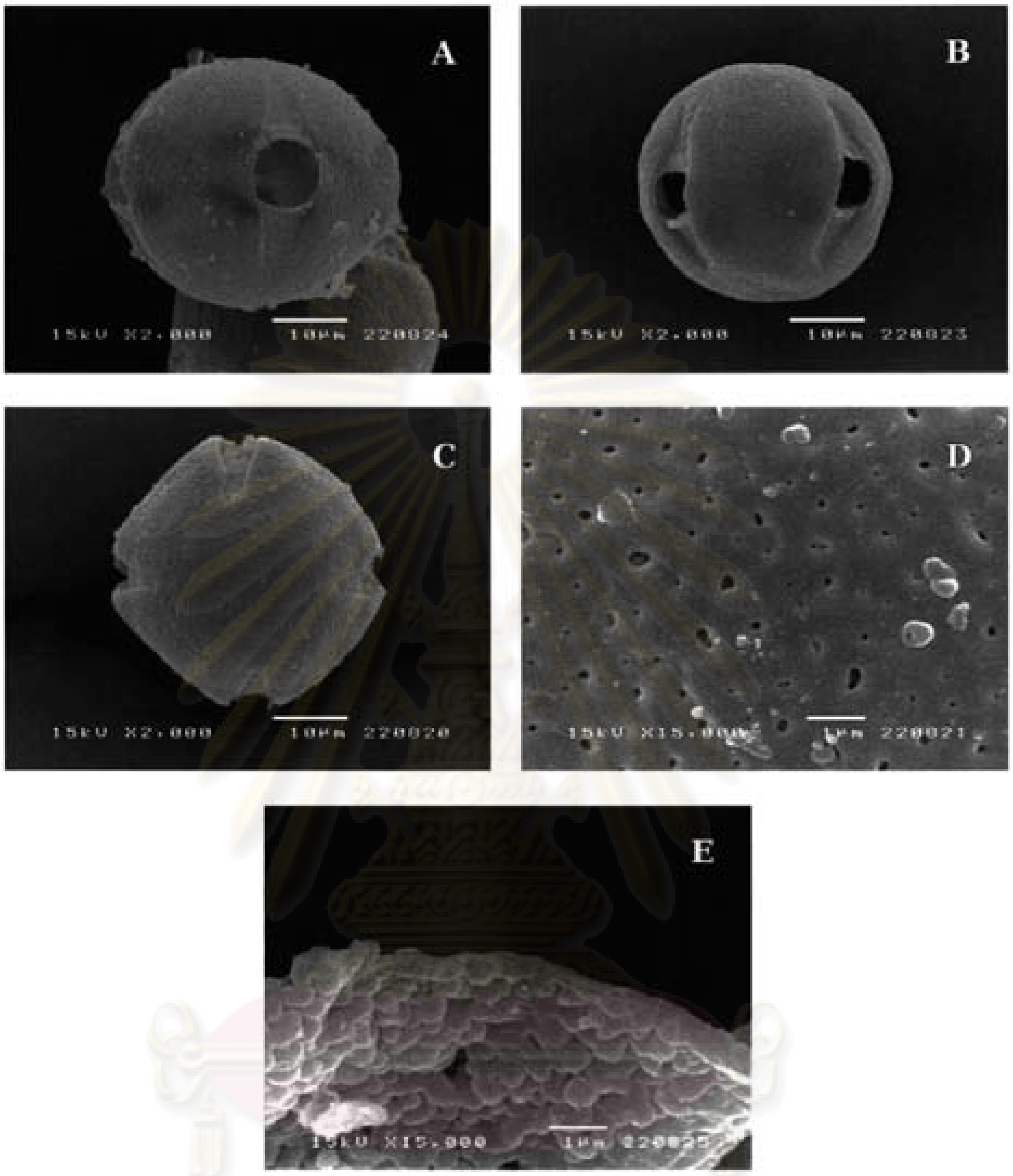

Plate 51 SEM micrographs: A-E. ***Tabernaemontana pandacaqui* Poir.** (A)-(B) Equatorial view, (C) Polar view with rectangular amb, (D) Perforate sexine surface, (E) Inner nexine surface granulate.

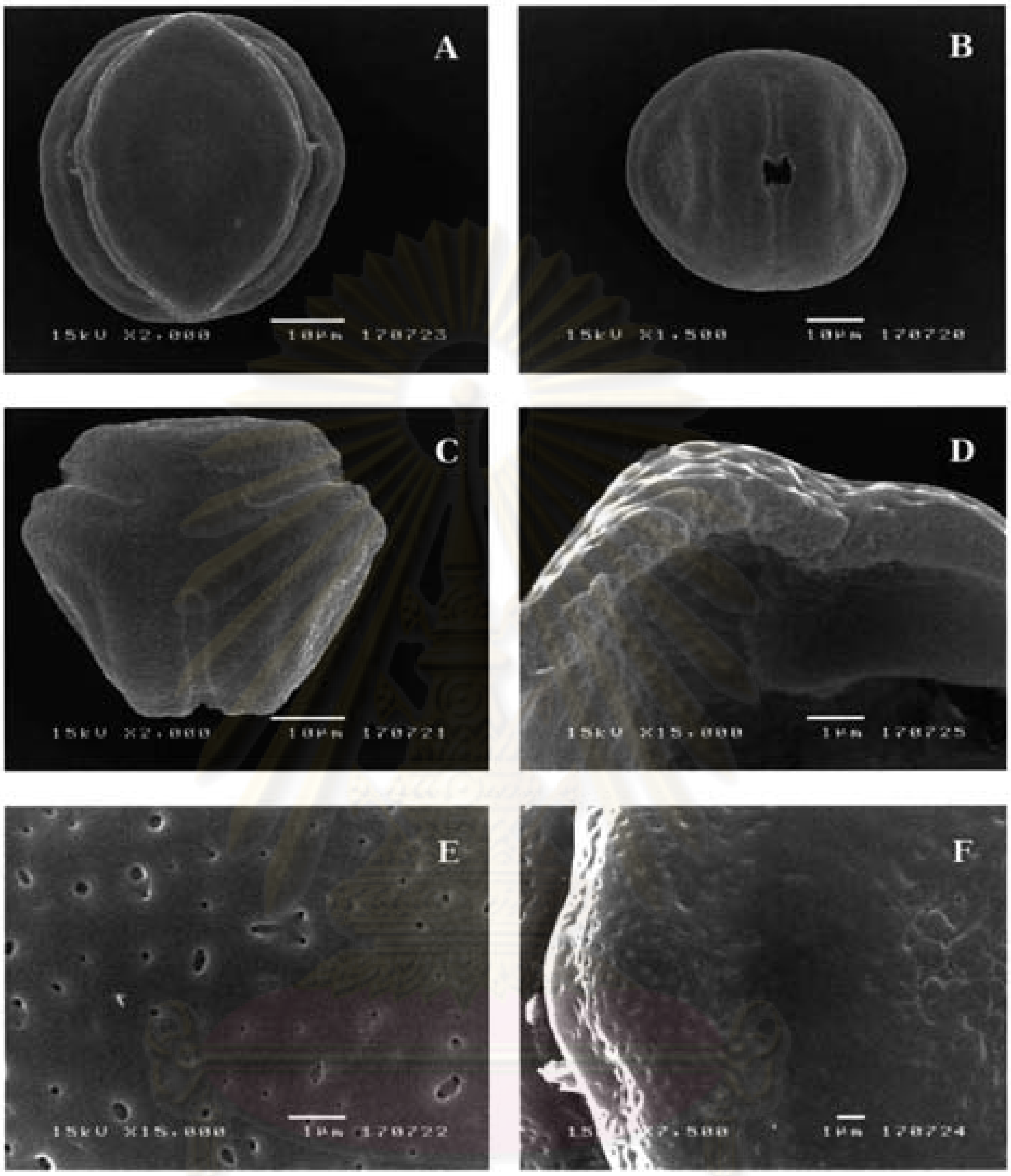

Plate 52 SEM micrographs: A-F. ***Catharanthus roseus* (L.) G.Don** (A)-(B) Equatorial view showing depression at mesocolpium, (C) Polar view showing triangular amb with straight sides, (D) Tectate exine with the thinnest at ridge around ectocolpi, (E)-(F) Perforate sexine surface.

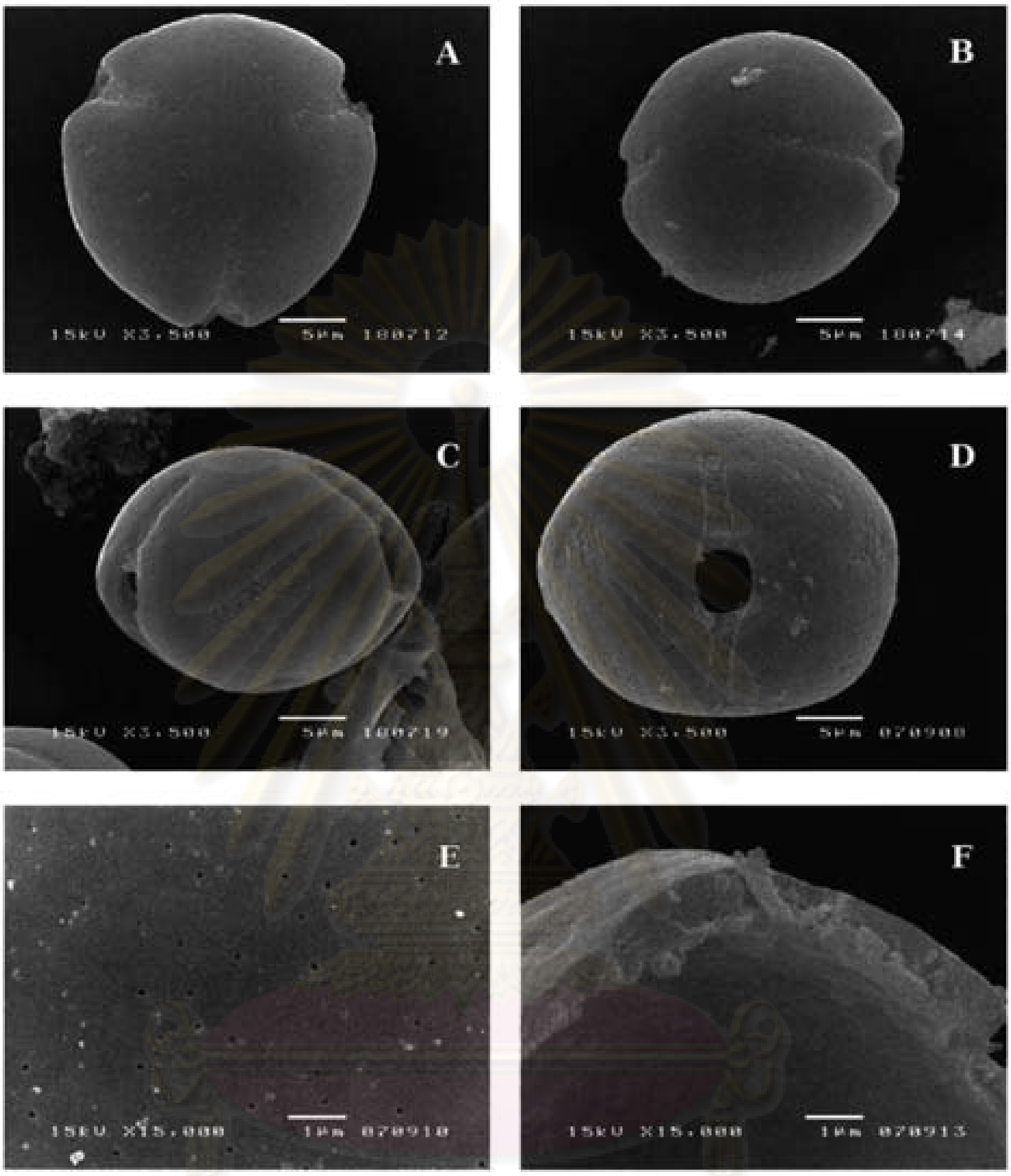

Plate 53 SEM micrographs: A-F. ***Alstonia rostrata*** **Fischer** (A) Polar view with tricolporate aperture, (B) Polar view with dicolporate aperture, (C)-(D) Equatorial view with fossulate exine surface at mesocolpium, (E) Perforate sexine surface, (F) Tectate exine, the sexine thicker than nexine.

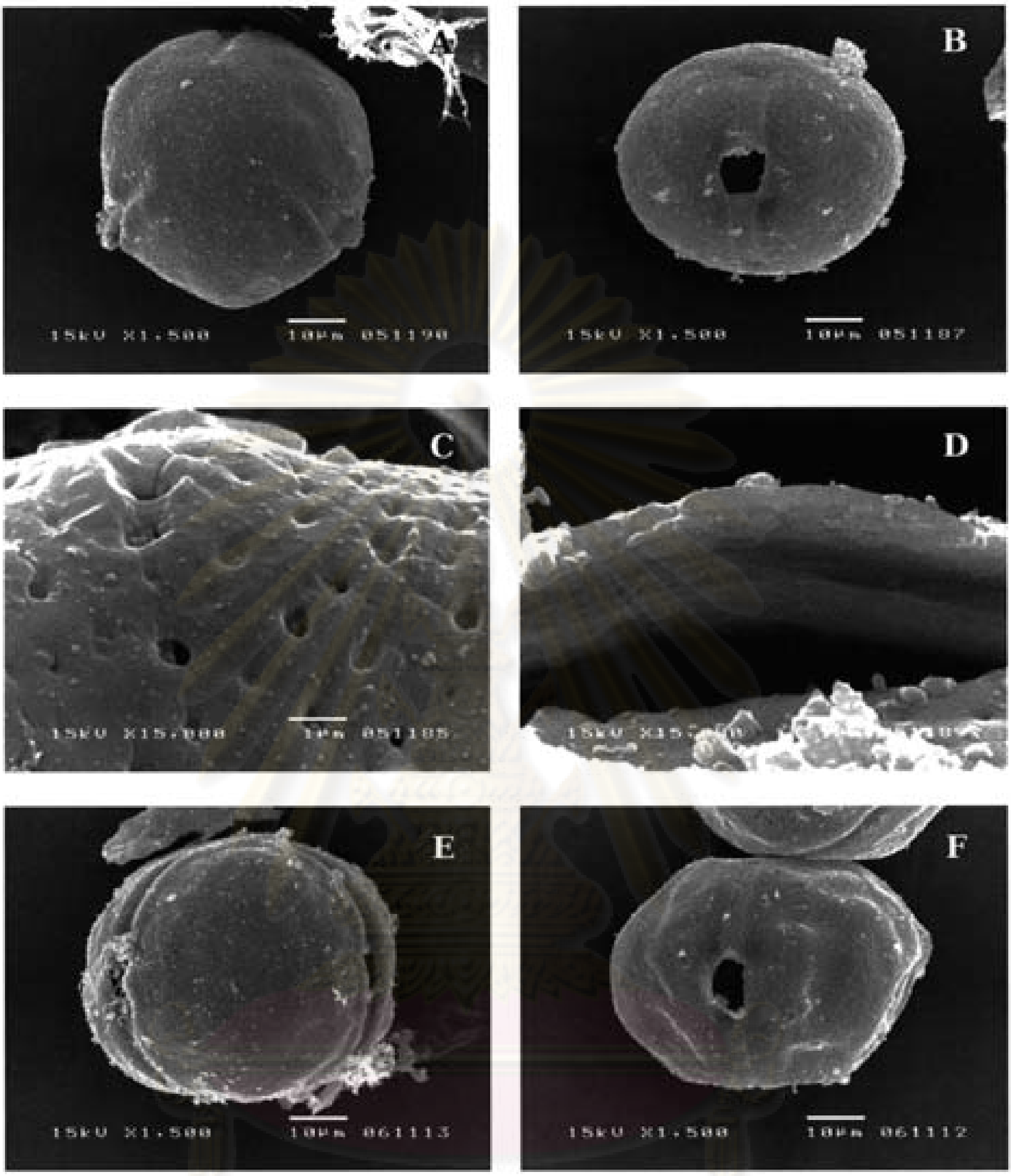

Plate 54 SEM micrographs: A-D. ***Kopsia angustipetala*** **Kerr** (A) Polar view, (B) Equatorial view, (C) Perforate sexine surface, (D) Tectate exine, the sexine thicker than nexine; E-F. ***K. pauciflora*** **Hook f.** (E)-(F) Equatorial view.

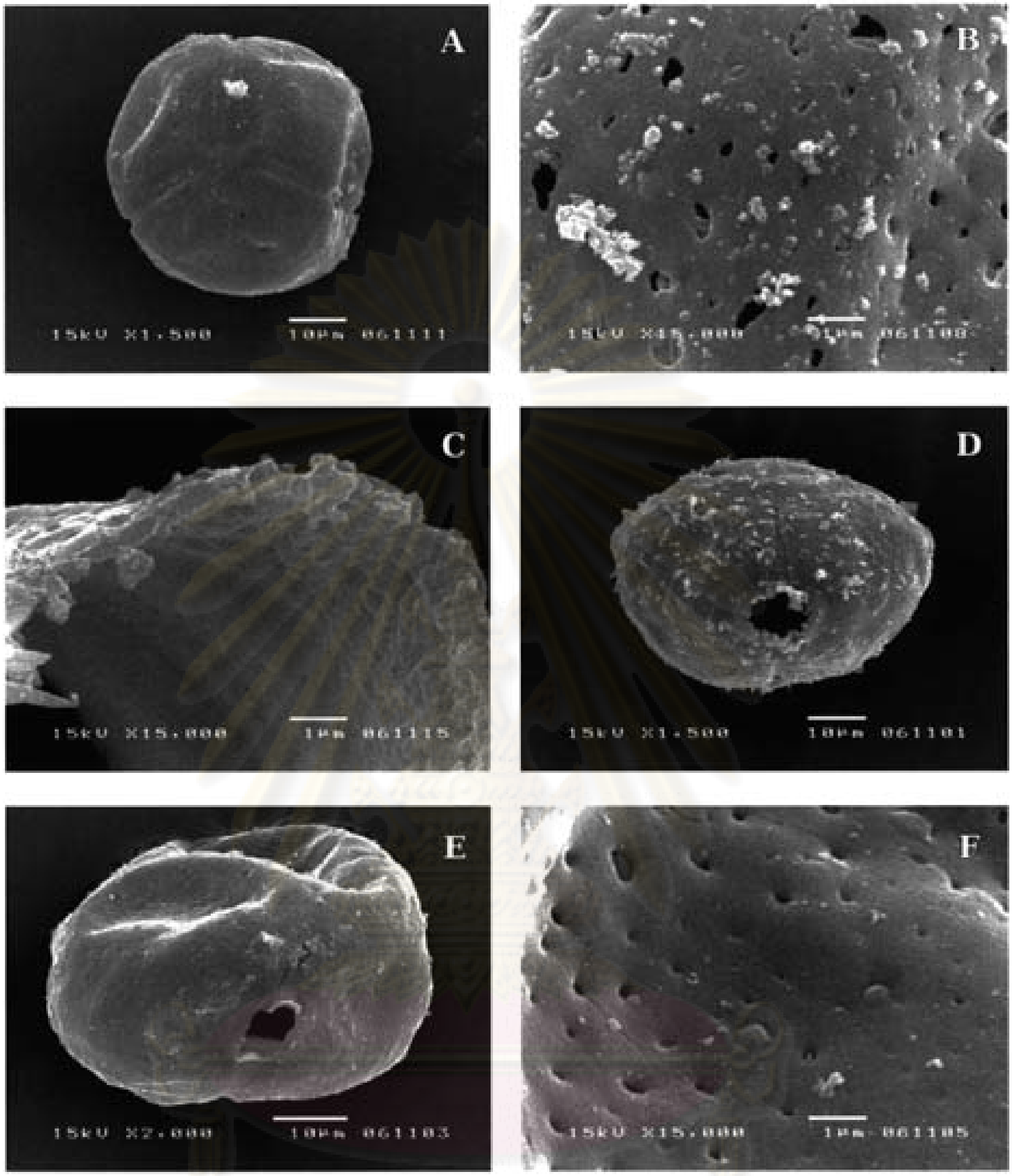

Plate 55 SEM micrographs: A-C. ***Kopsia pauciflora*** **Hook.f.**(A) Polar view, (B) Foveolate sexine surface, (C) Tectate exine with very thin exine thickness; D-F. ***K. rosea*** **D.J. Middleton** (D)-(E) Equatorial view, (F) Perforate sexine surface.

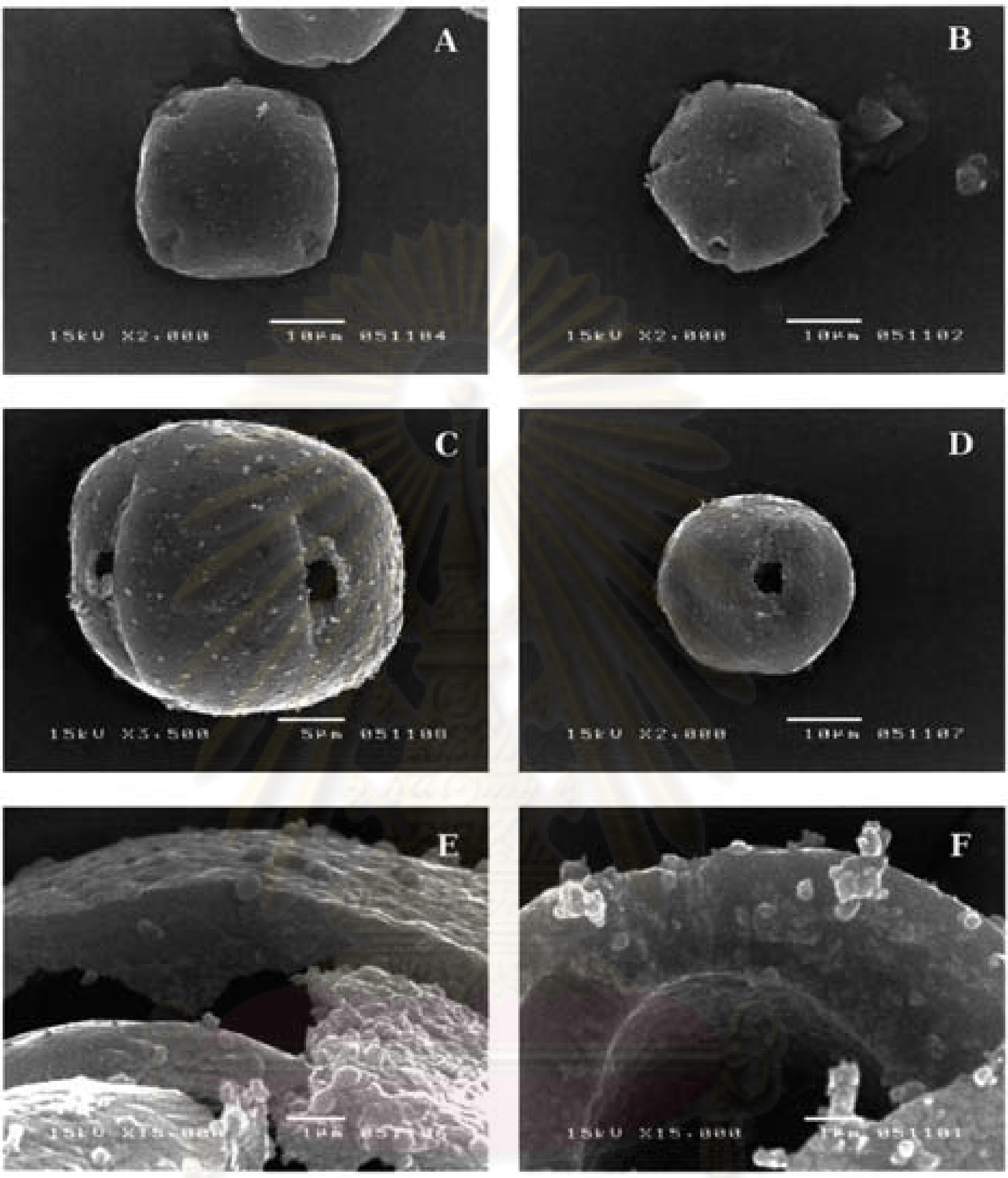

Plate 56 SEM micrographs: A-F. ***Bousigonia angustifolia*** **Pierre ex Spire** (A) Polar view with 4-colporate aperture, (B) Polar view with 5-colporate aperture, (C)-(D) Equatorial view, (E) Tectate exine, exine thickness unequal, (F) Tectate exine.

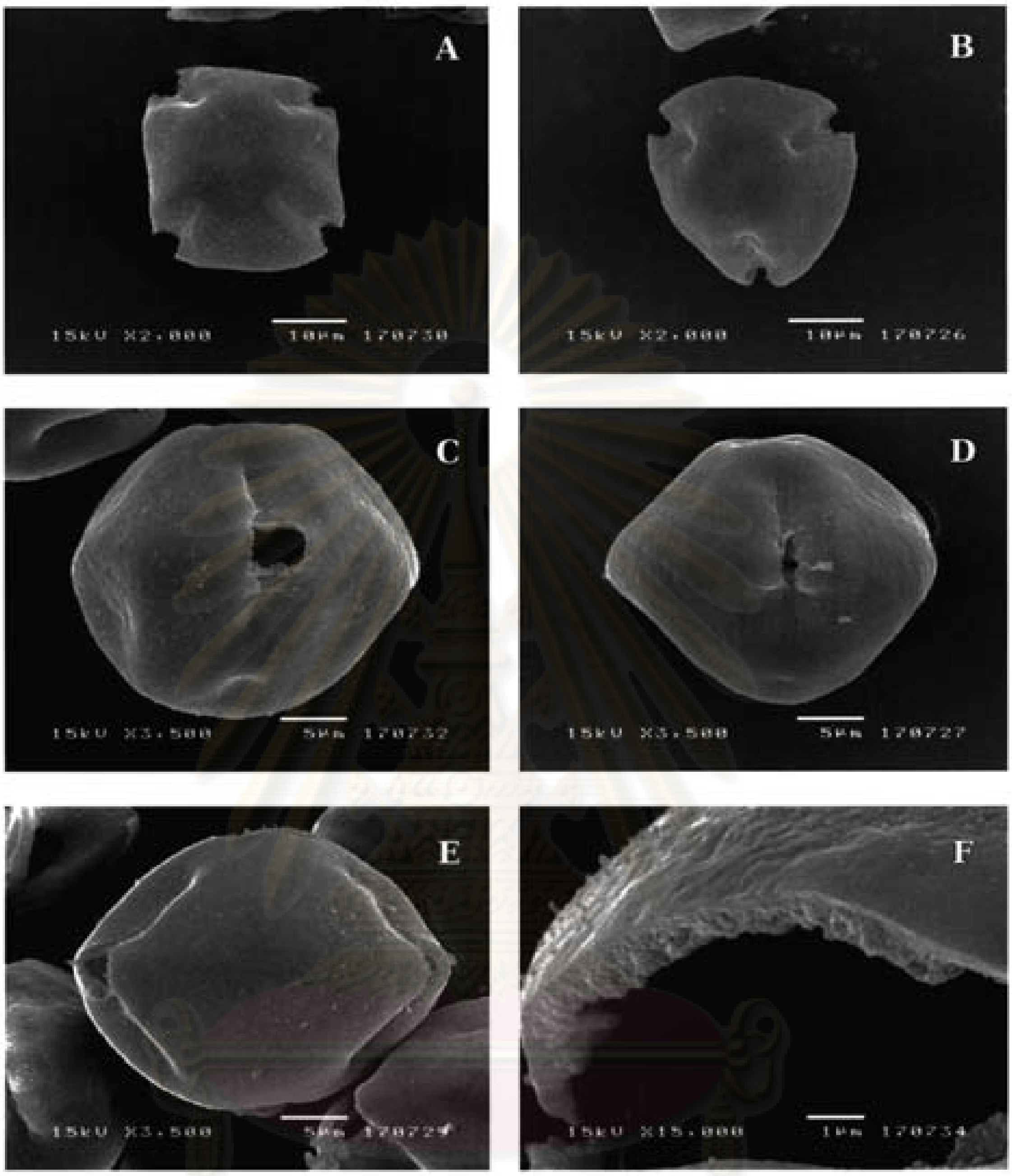

Plate 57 SEM micrographs: A-F. ***Plumeria obtusa*** **L.** (A) Polar view showing rectangular amb with straight sides, (B) Polar view showing triangular with slightly convex sides, (C) Equatorial view showing widened ectoaperture at equator, (D) Equatorial view showing close ectoaperture at equator, (E) Equatorial view, (F) Tectate exine.

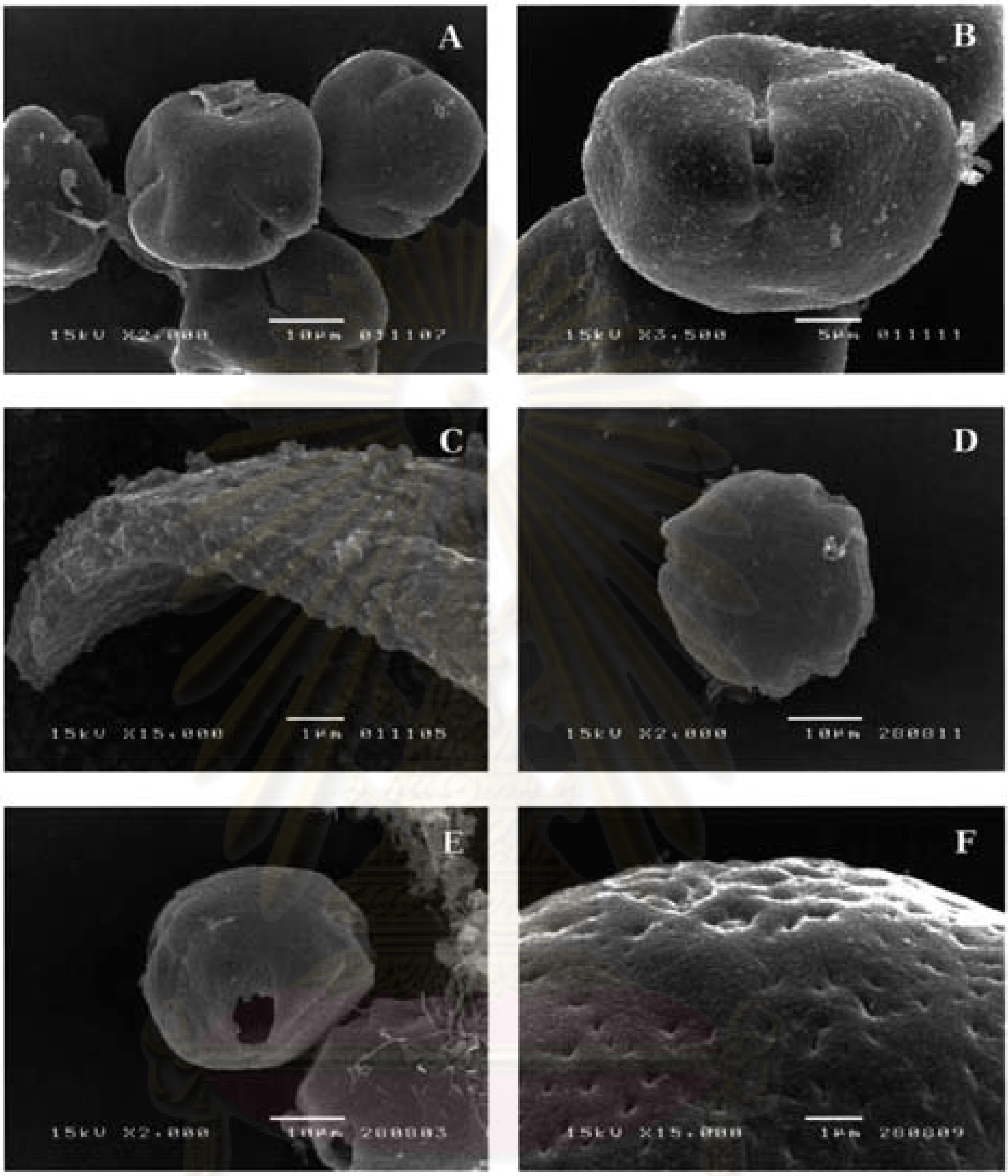

Plate 58 SEM micrographs: A-C. ***Melodinus cochinchinensis* (Lour.) Merr.** (A) Polar view with rectangular amb, (B) Equatorial view, (C) Tectate exine; D-F. ***Hunteria zeylanica* (Retz.) Gardner ex Thwaites** (D) Polar view, (E) Slightly oblique equatorial view, (F) Perforate sexine surface.

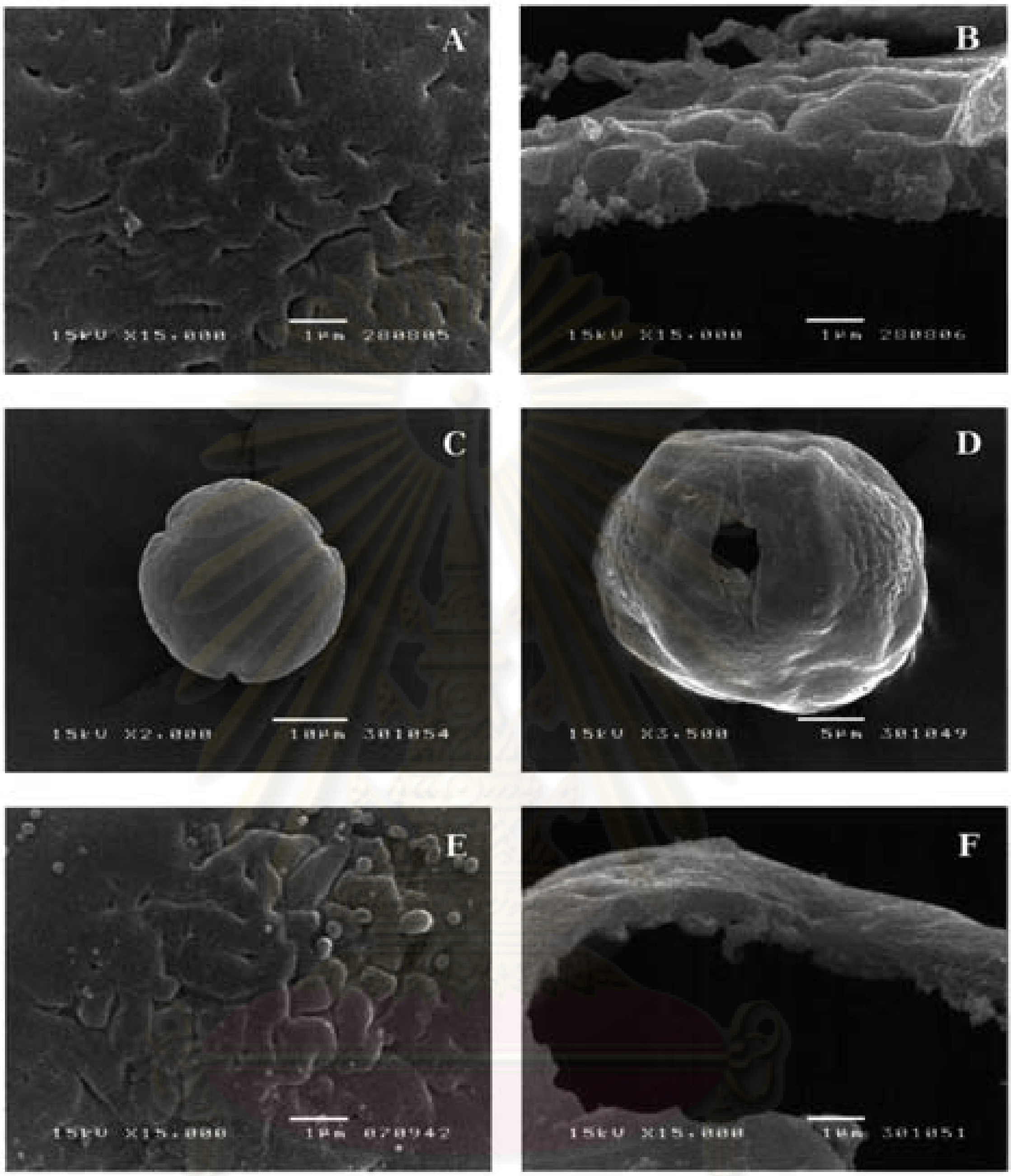

Plate 59 SEM micrographs: A-B. ***Hunteria zeylanica* (Retz.) Gardner ex Thwaites** (A) Fossulate sexine surface, (B) Tectate exine; C-F. ***Alstonia macrophylla* Wall. ex G.Don** (C) Polar view, (D) Equatorial view showing fossulae at mesocolpium, (E) Fossulate sexine surface at mesocolpium, (F) Tectate exine.

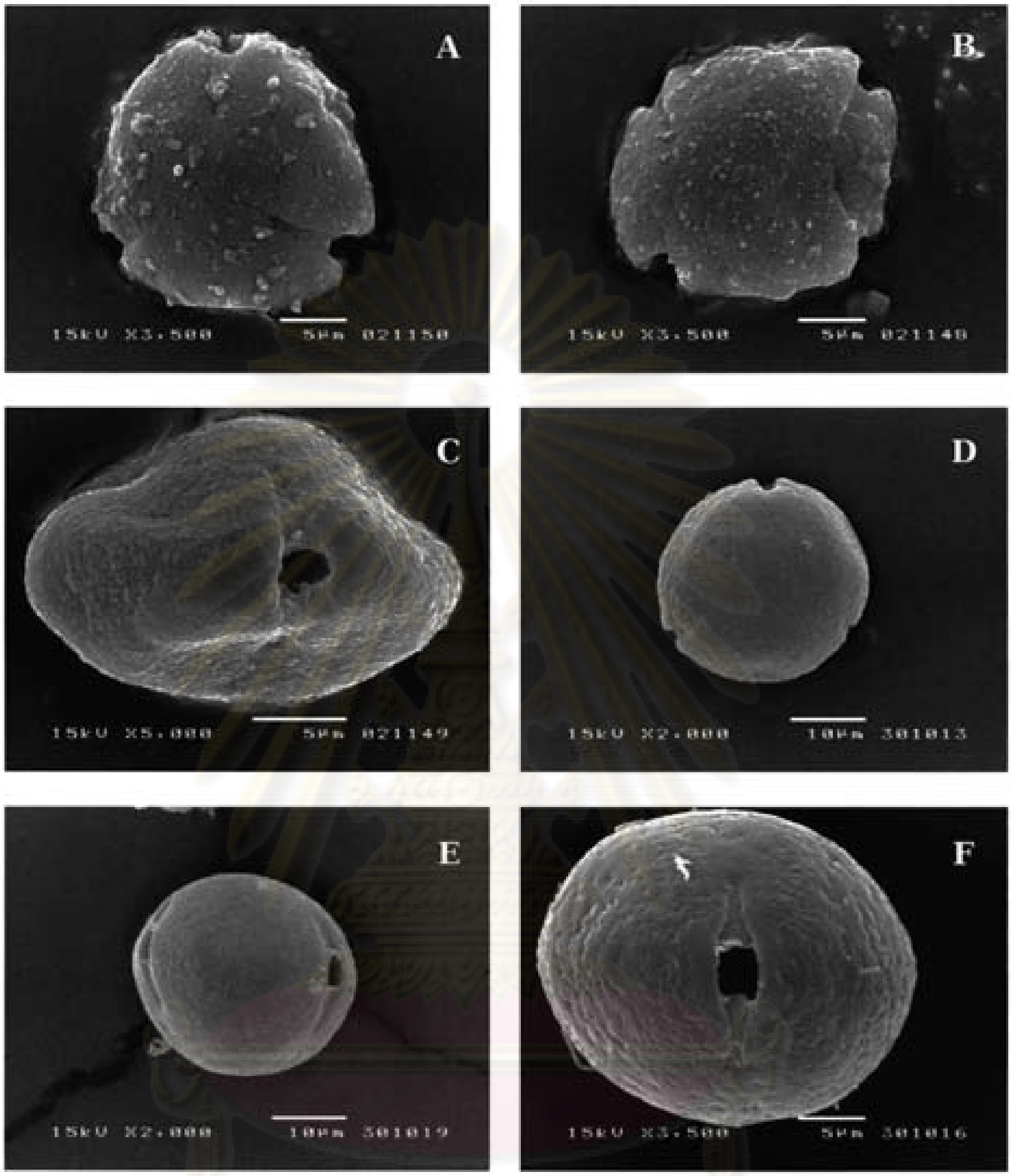

Plate 60 SEM micrographs: A-C. ***Alstonia. scholaris* (L.) R.Br.** (A) Polar view showing triangular amb with slightly straight sides, (B) Polar view showing rectangular amb with slightly straight sides; D-F. ***Carissa carandas* L.** (D) Polar view, (E)-(F) Equatorial view.

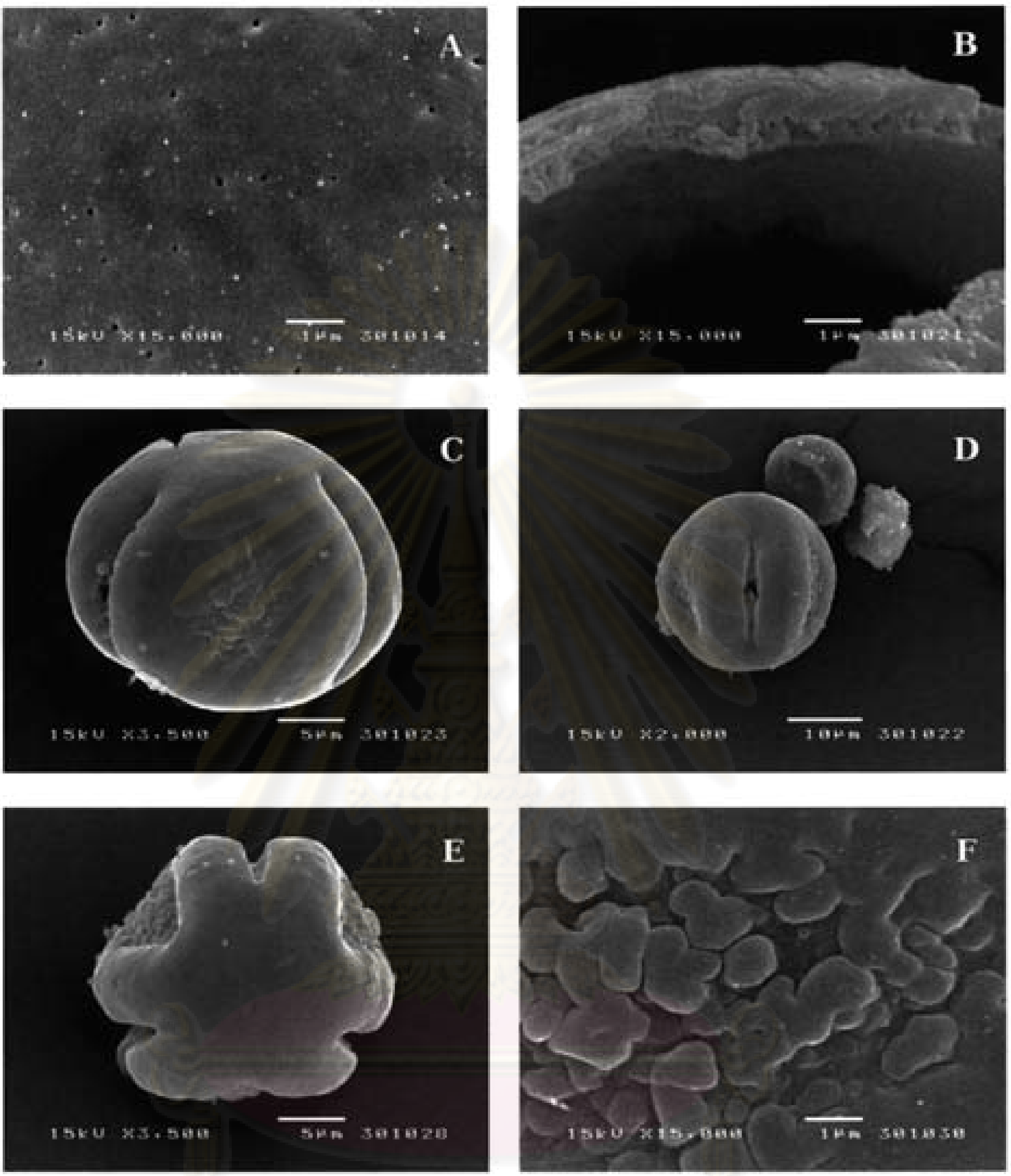

Plate 61 SEM micrographs: A-B. ***Carissa carandas* L.** (A) Psilate with perforateion on the sexine surface, (B) Tectate exine, the sexine thicker than nexine; C-F. ***C. spinarum* L.** (C)-(D) Equatorial view showing verrucae at mesocolpium, (E) Polar view showing triangular amb with straight sides, (F) Verrucate sexine surface.

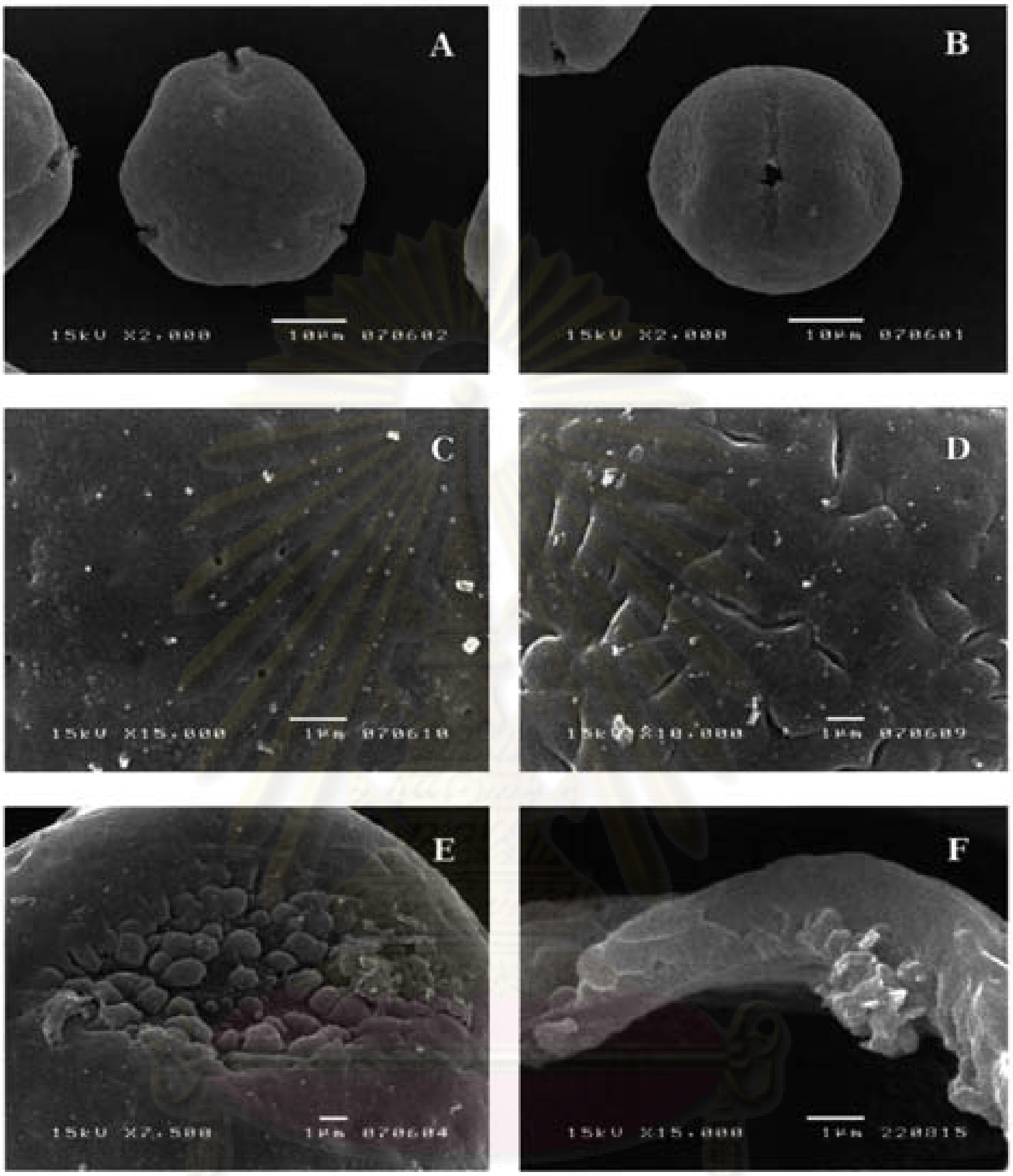

Plate 62 SEM micrographs: A-F. ***Carissa grandiflora* (E.Mey.) A.DC.** (A) Polar view showing triangular amb with straight sides, (B) Equatorial view showing depression at mesocolpium, (C) Psilate with perforations on the sexine surface, (D) Fossulate sexine surface, (E) Verrucate sexine surface at mesocolpim, (F) Tectate exine, the sexine thicker than nexine.

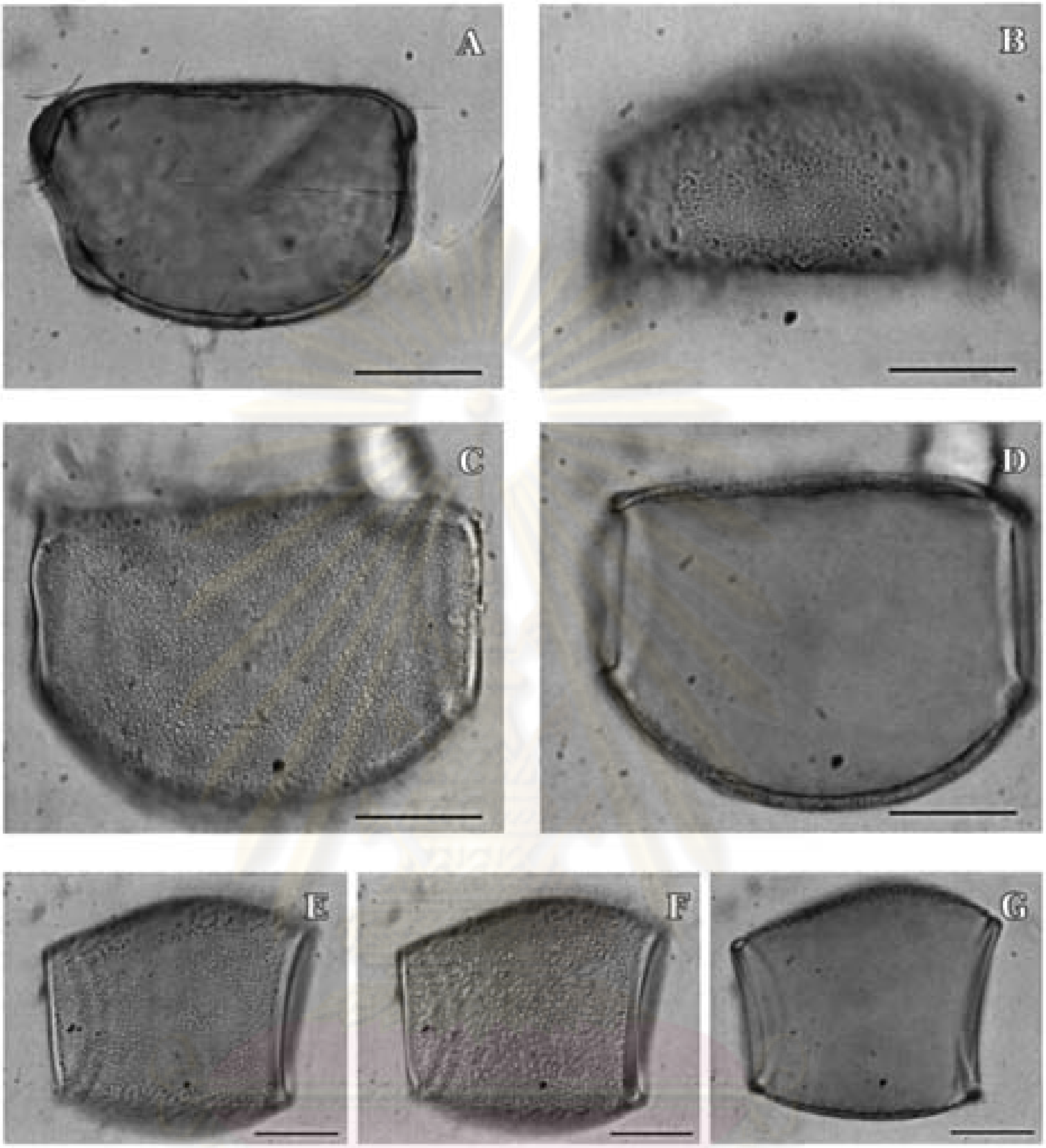

Plate 63 LM micrographs: A. ***Alyxia reinwardtii*** **Blume** Equatorial view, optical section; B-D. ***A. siamensis*** **Craib** (B) Equatorial view, surface, (C) Equatorial view, surface, (D) Equatorial view, optical section; E-F. ***A. thailandica*** **D.J. Middleton** (E) Equatorial view, surface, (F) Equatorial view, surface, (G) Equatorial view, optical section (scale 30 μm).

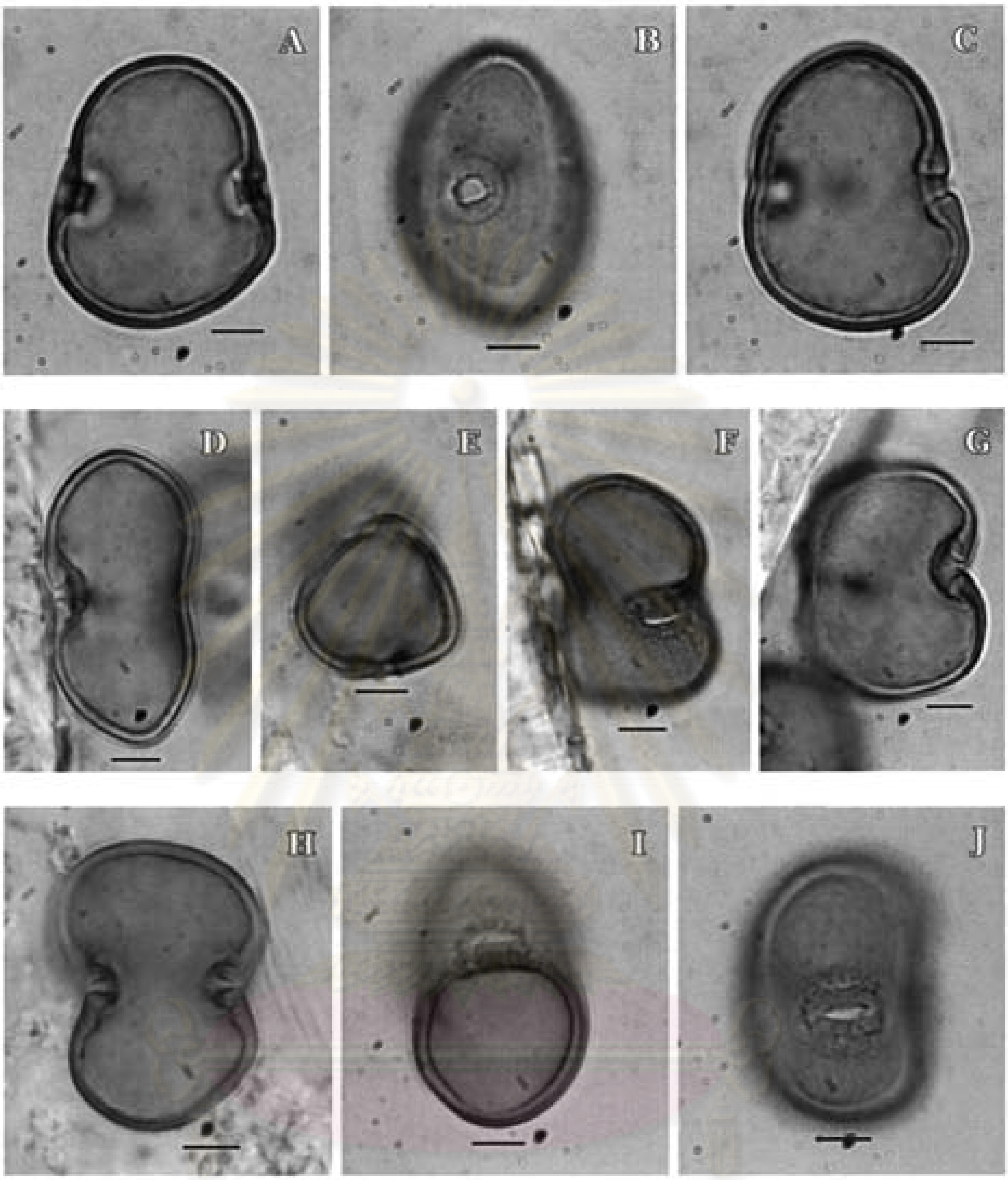

Plate 64 LM micrographs: A-C. ***Anodendron affine* (Hook. & Arn.) Druce** (A) Equatorial view, optical section, (B) Equatorial view at surface showing annulus, (C) Equatorial view at optical section showing annulus; D-G. ***A. coriaceum* (Blume) Miq.** (D) Equatorial view, optical section, (E) Polar view optical section, (F)-(G) Equatorial view, optical section; H-J. ***A. paniculatum* A.DC (H)** Equatorial view, optical section, (I) Polar view optical section , (J) Equatorial view, surface (scale 5 µm).

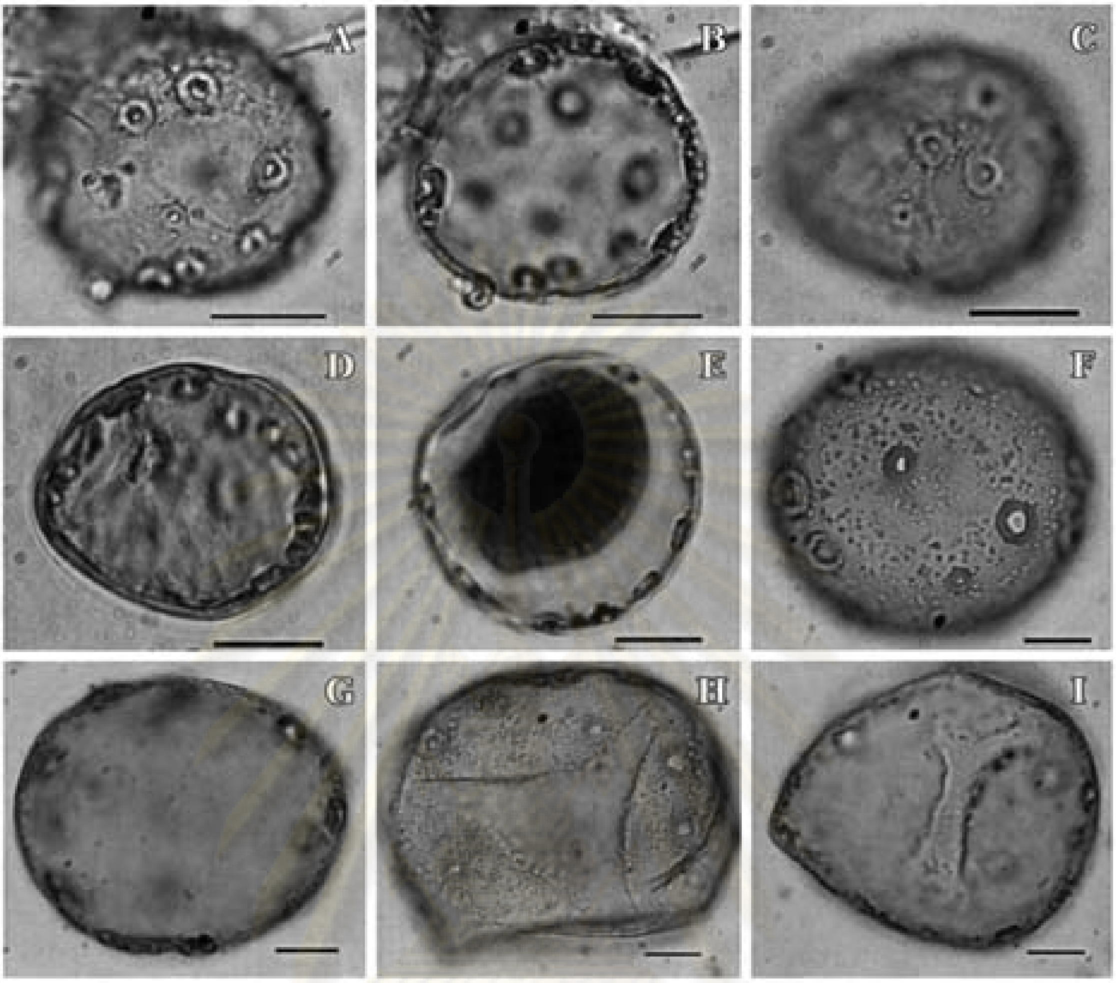

Plate 65 LM micrographs: A-B. ***Ichnocarpus polyanthus* (Blume) P.I. Forst.** (A) Surface, (B) Optical section; C-E. ***I. serpyllifolius* (Blume) P.I. Forst.** (C) Surface, (D)-(E) Optical section; F-G. ***Trachelospermum asiaticum* (Sieb. & Zucc.) Nakai** (F) Surface, (G) Optical section; H-I. ***T. lucidum* (D.Don) K. Schum.** (H) Surface, (I) Optical section (scale 10 µm).

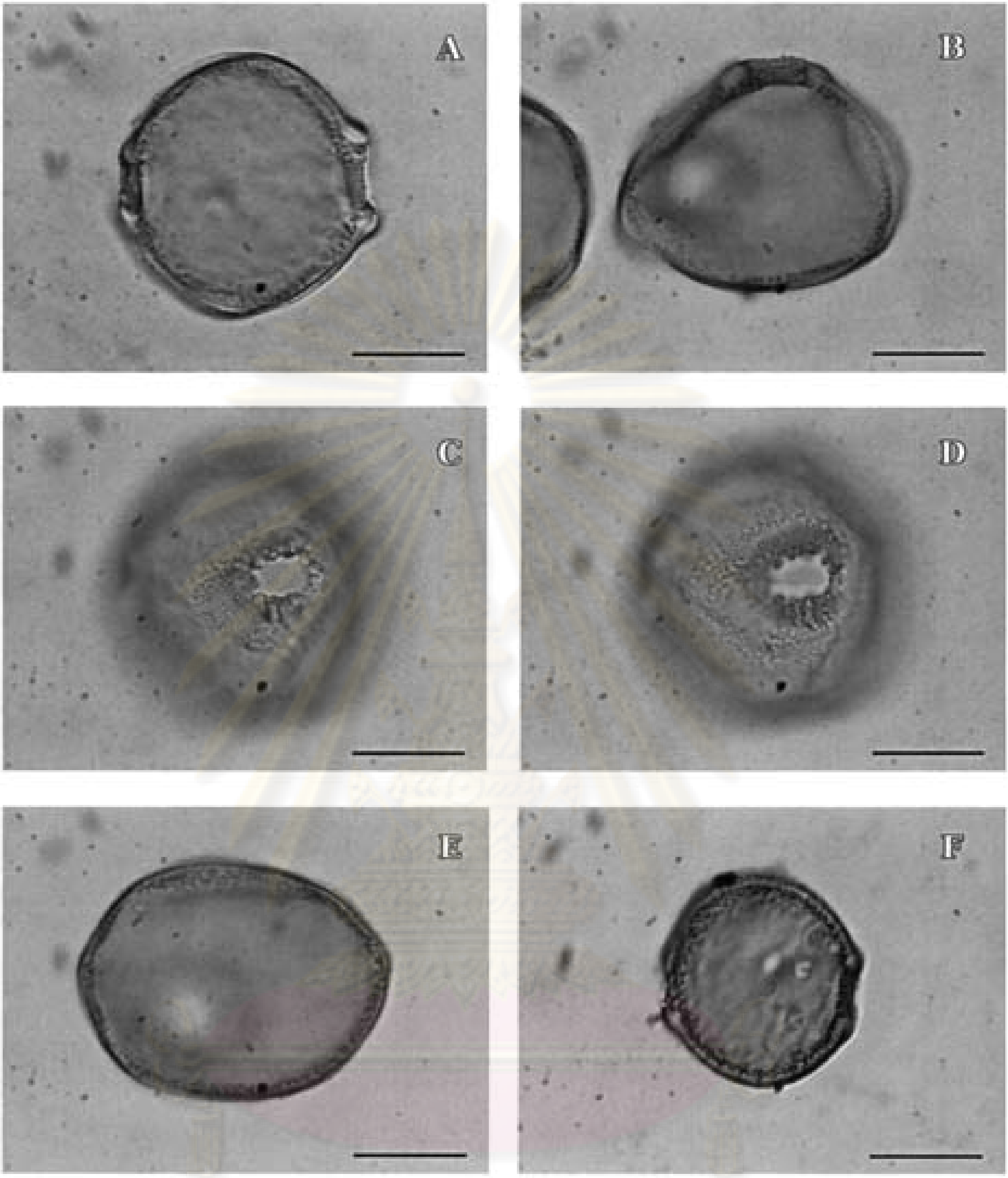

Plate 66 LM micrographs: A-E. ***Chilocarpus costatus* Miq.** (A)-(B) Equatorial view, optical section (C)-(D) Surface at porate, (E) Equatorial view, optical section; F**. *C. denudatus* Blume** Equatorial view, optical section (scale 30 μm).

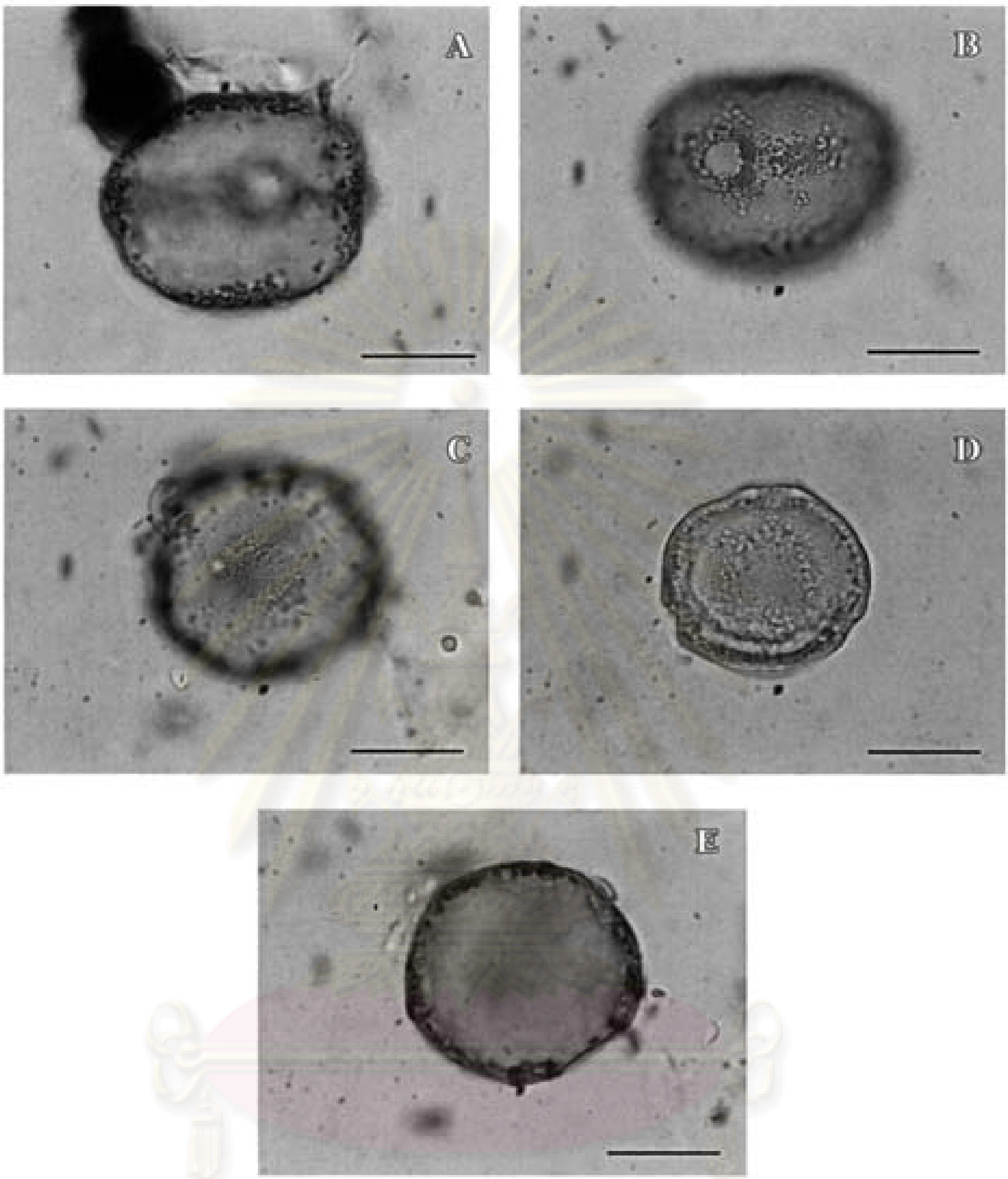

Plate 67 LM micrographs: A-E. ***Spirolobium cambodianum* Baillon** (A) Equatorial view, optical section, (B) Equatorial view, surface, (C) Polar view, surface, (D)-(E) Polar view, optical section (scale 30 µm).

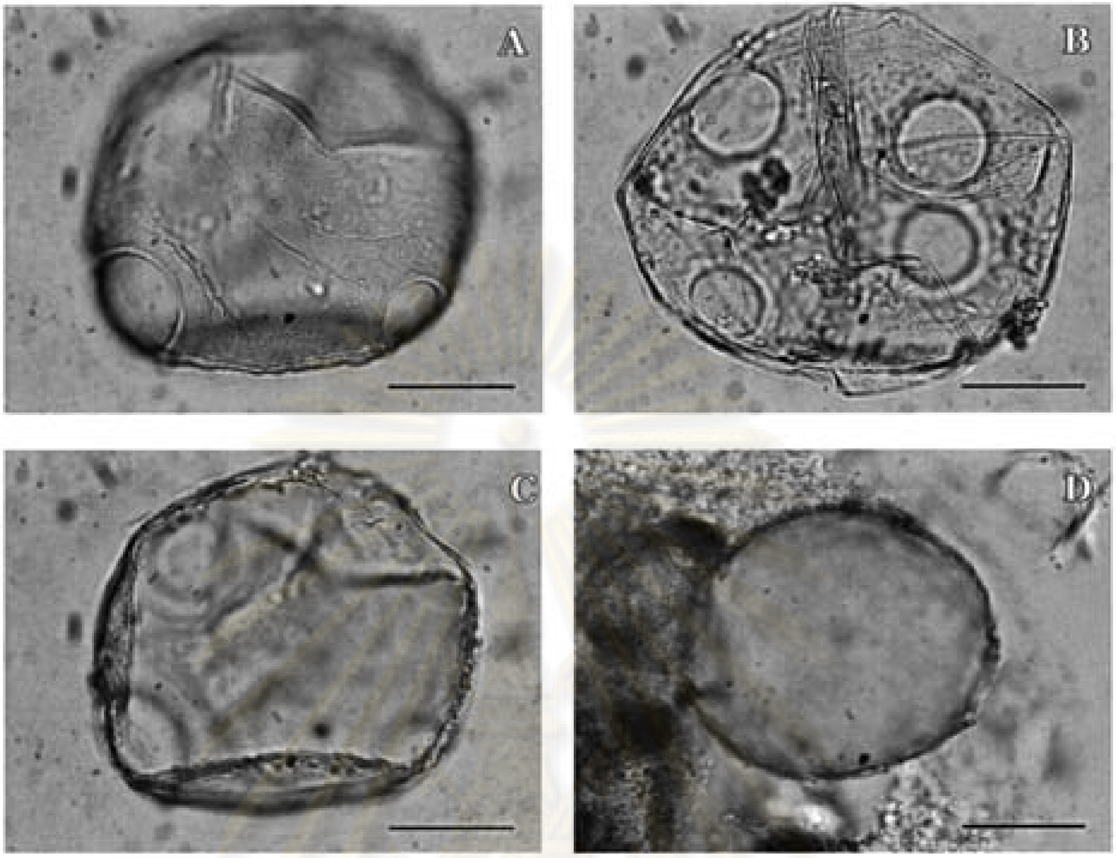

Plate 68 LM micrographs: A-C. ***Amalocalyx microlobus* Pierre ex Spire** (A) Surface, (B) Equatorial view, optical section,(C) Polar view, optical section; D. ***Parsonsia alboflavescens* (Dennst.) Mabb.** Polar view, optical section (scale 30 µm).

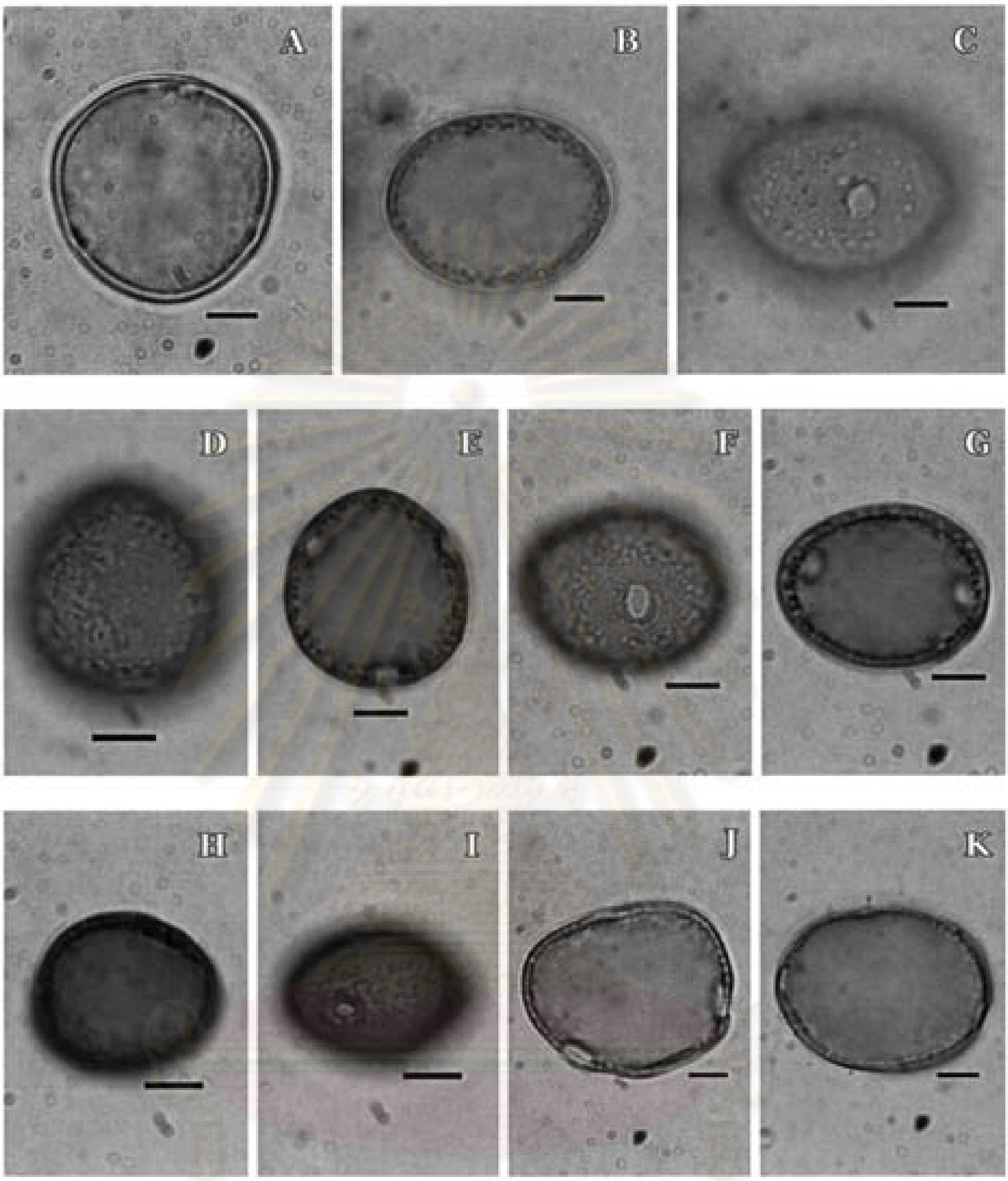

Plate 69 LM micrographs: A-C. ***Urceola lucida*** **(Wall. ex G.Don) Kurz** (A) Polar view, optical section, (B) Equatorial view, optical section, (C) Equatorial view, surface at porate; D-G. ***U. minutiflora*** **(Pierre) D.J. Middleton** (D) Polar view, surface, (E) Polar view, optical section, (F) Equatorial view, surface at porate, (G) Equatorial view, optical section; H-I. ***U. micrantha*** **(Wall. ex G.Don) D.J. Middleton** (H) Polar view, optical section, (I) Equatorial view, surface at porate; J-K. ***U. rosea*** **(Hook. & Arn.) D.J. Middleton** (J) Polar view, optical section, (K) Equatorial view, optical section (scale 5 µm).

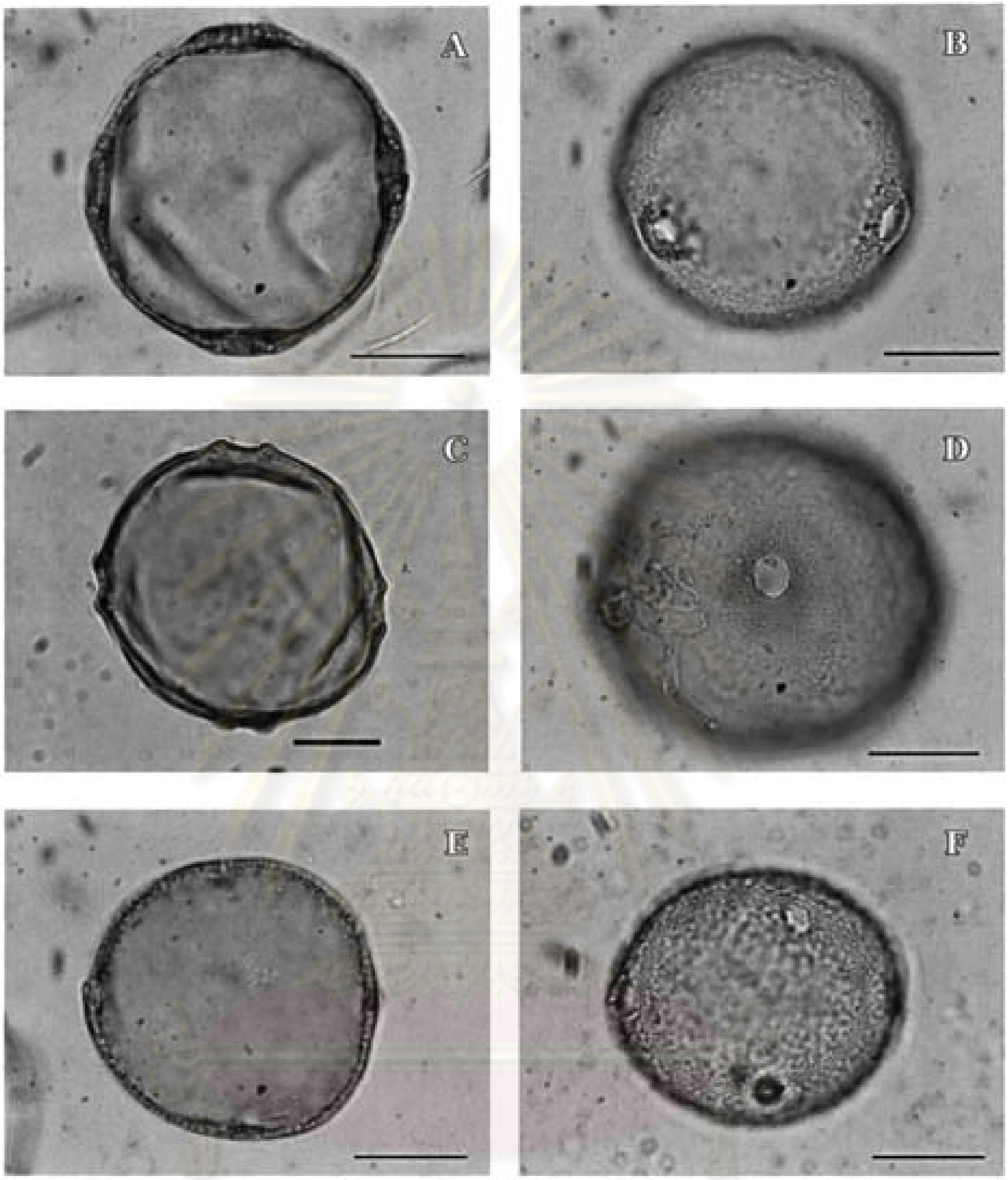

Plate 70 LM micrographs: A-B. ***Beaumontia grandiflora* Wall.** (A) Polar view, optical section, (B) Oblique equatorial view, surface; C-D. ***B. murtonii* Craib** (C) Polar view, optical section, (D) Equatorial view, surface; E-F. ***Wrightia sirikitae* D.J.Middleton & Santisuk** (E) Polar view, optical section, (F) Oblique equatorial view, surface (scale 30 µm).

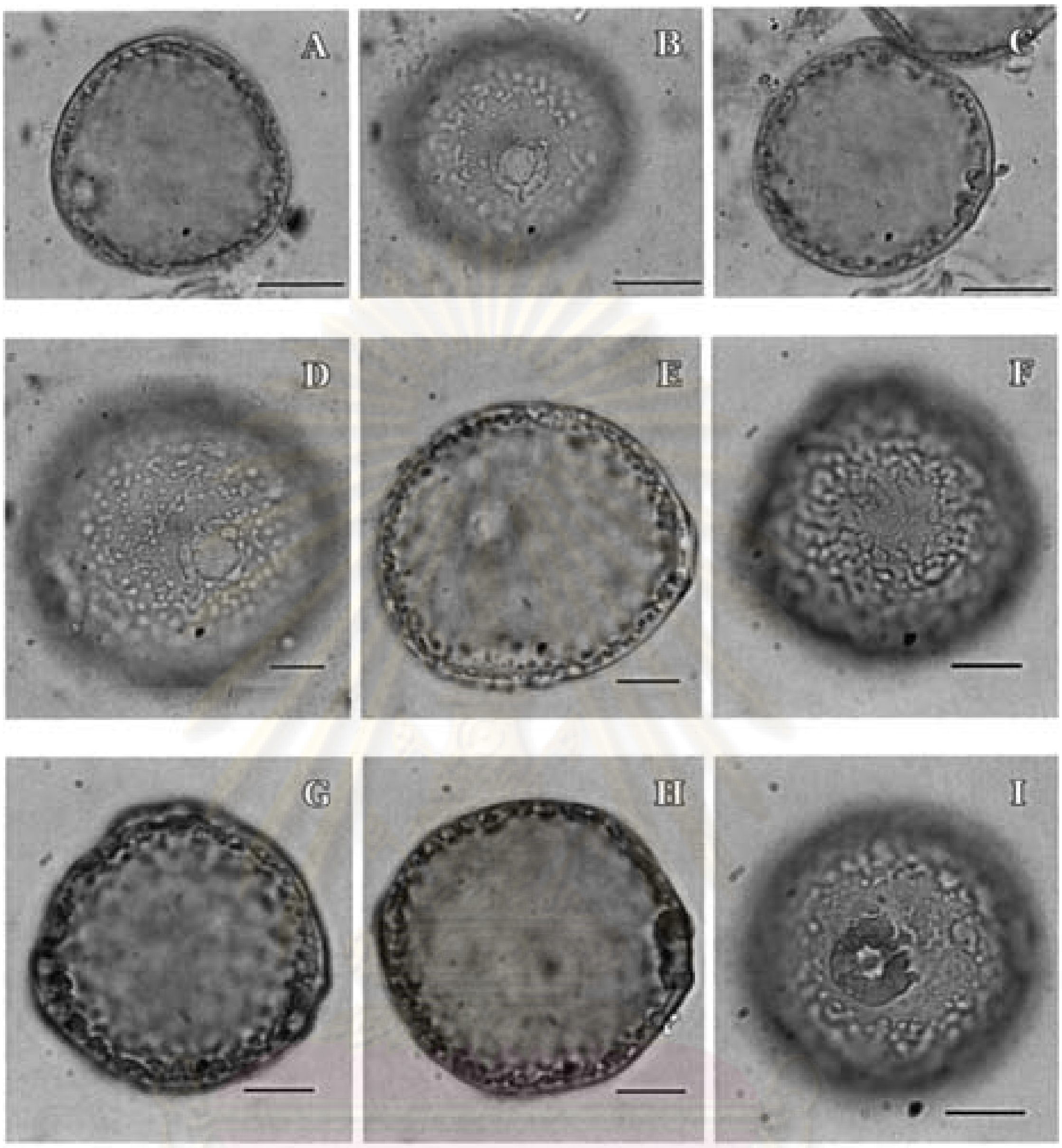

Plate 71 LM micrographs: A-C. ***Kibatalia arborea* (Blume) G.Don** (A) Polar view, optical section, (B) Polar view, surface, (C) Equatorial view, optical section (scale 30 µm); D-E. ***K. macrophylla* (Pierre ex Hua) Woodson** (D) Equatorial view, surface, (E) Equatorial view, optical section (scale 10 µm); F-I. ***K. maingayi* (Hook.f.) Woodson** (F) Polar view, surface, (G) Polar view, optical section, (H) Equatorial view, optical section, (I) Equatorial view, surface at porate (scale 10 µm).

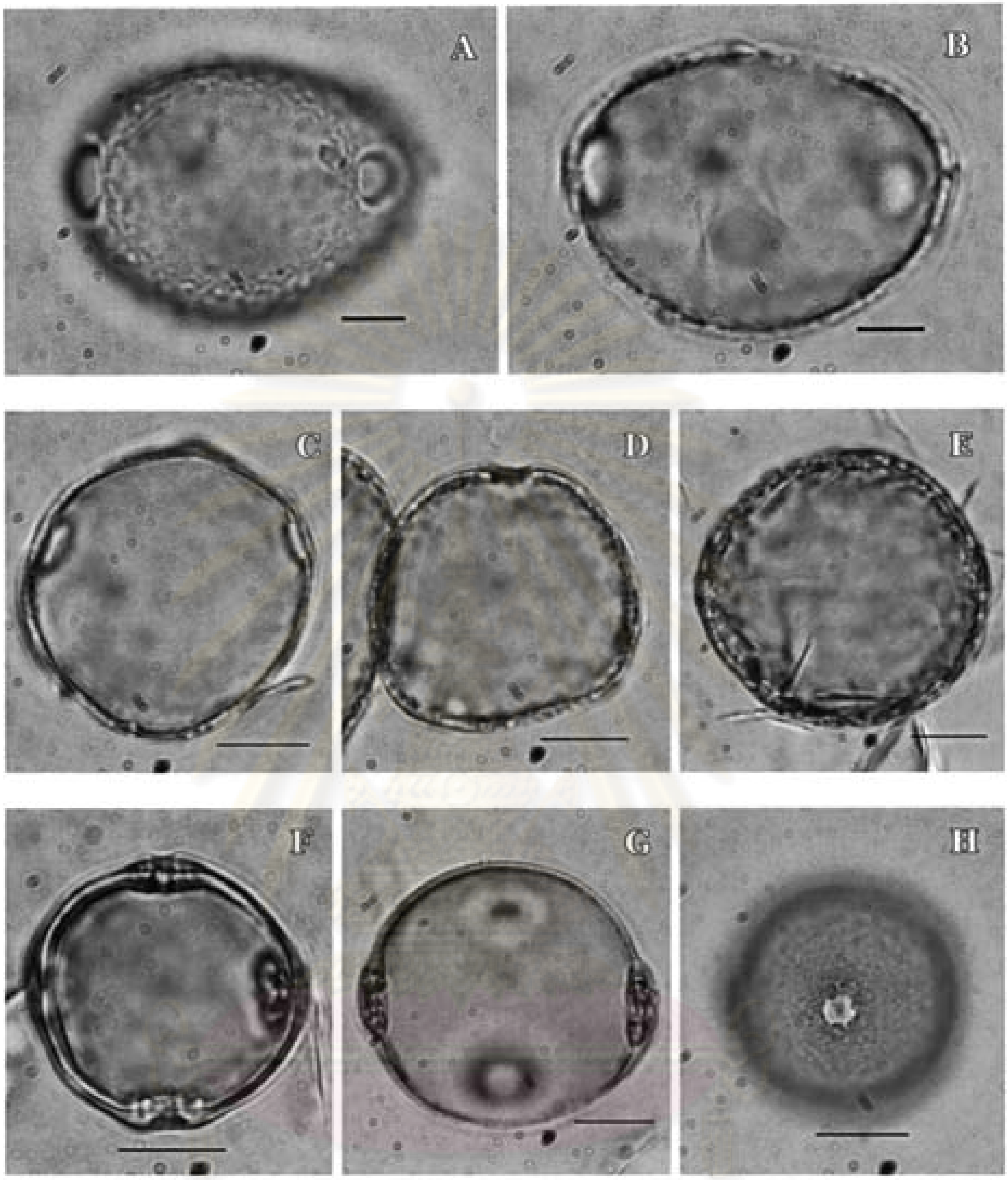

Plate 72 LM micrographs: A-B. ***Aganonerion polymorphum* Pierre ex Spire** (A) Equatorial view, surface, (B) Equatorial view, optical section (scale 5 µm); C. ***Holarrhena curtisii* King & Gamble** Equatorial view, optical section (scale 10 µm); D. ***H. pubescens* Wall. ex G.Don** Equatorial view, optical section (scale 10 µm); E. ***Wrightia dubia* (Sims) Spreng.** Polar view, optical section (scale 10 µm); F-H. ***Vallaris glabra* (L.) O. Kuntze** (F) Polar view, optical section, (G) Equatorial view, optical section, (H) Equatorial view, surface (scale 10 µm).

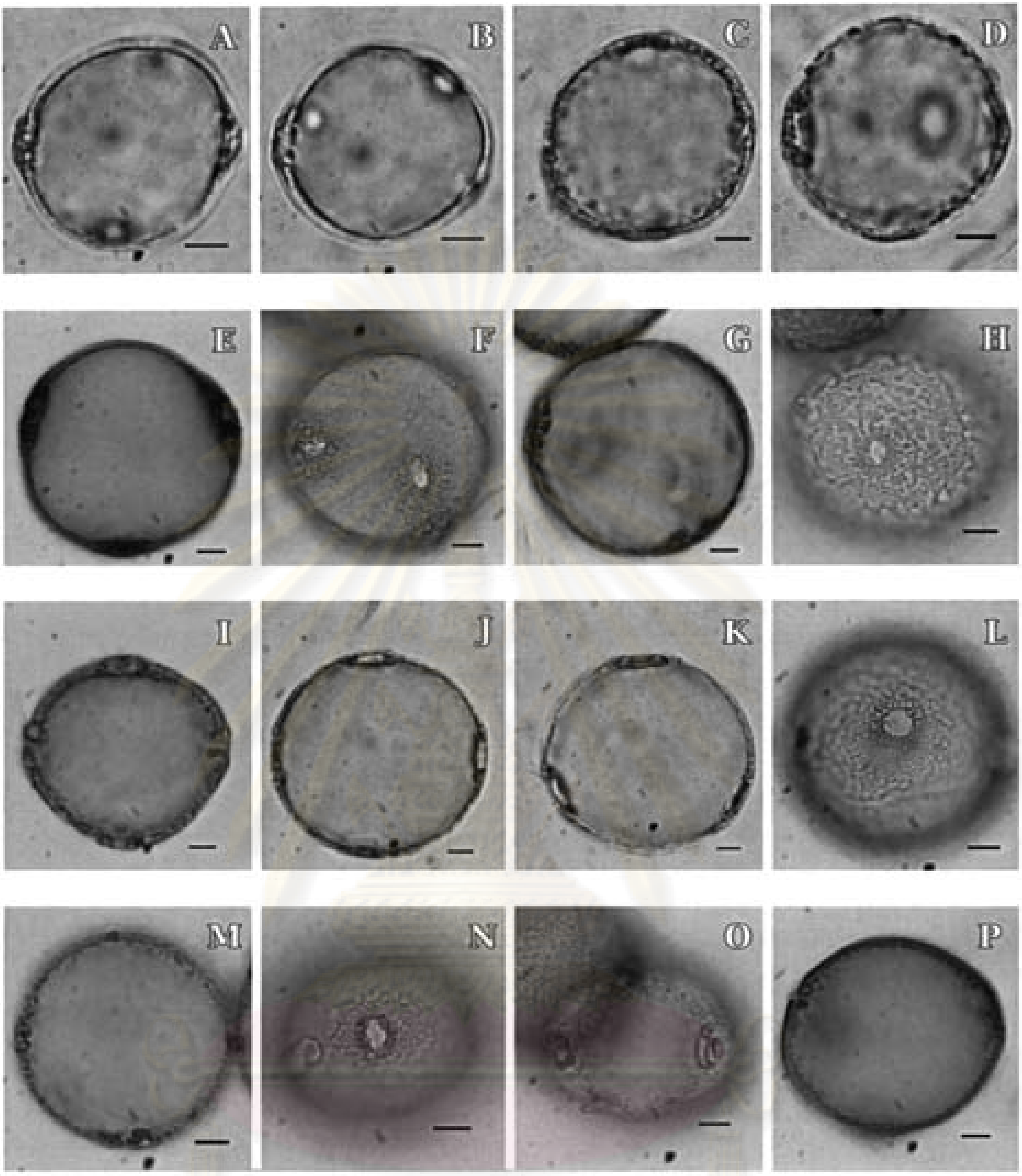

Plate 73 LM micrographs: A-B. ***Aganosma marginata*** **(Roxb.) G.Don** (A) Equatorial view, optical section, (B) Oblique polar view, optical section; C-D. ***Wrightia pubescens*** **R.Br.** (C) Polar view, optical section, (D) Equatorial view, optical section; E-G ***Adenium obesum*** **(Forsk.) Roem. & Schult.** (E) Polar view, optical section, (F) Equatorial view, surface, (G) Oblique equatorial view, optical section H-I. ***Nerium oleander*** **L.** (H) Equatorial view, surface at porate, (I) Polar view, optical section; J-L. ***Pentalinon luteum*** **(L.) B.F. Hansen & Wunderlin** (J)-(K) Polar view, optical section, (L) Equatorial view, surface at porate; M-O. ***Strophanthus gratus*** **(Wallich & Hook.) Bail.** (M) Polar view, optical section, (N) Equatorial view, surface at porate, (O) Equatorial view, surface at porate; P. ***S. perakensis*** **Scortechini ex King & Gamble** Polar view, optical section (scale 5 µm).

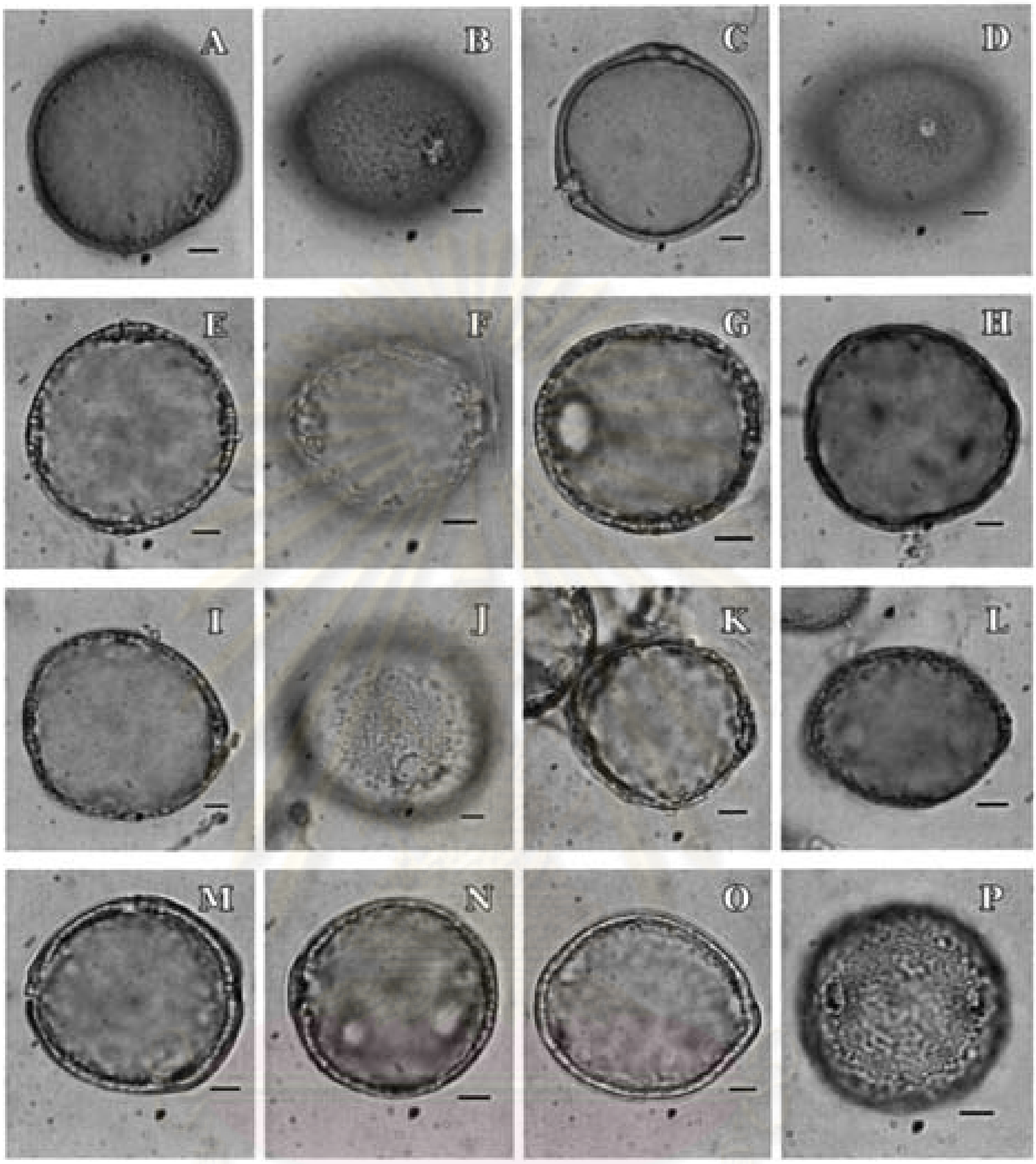

Plate 74 LM micrographs: A-B. ***Strophanthus perakensis*** **Scortechini ex King & Gamble** (A) Polar view, optical section, (B) Equatorial view, surface at porate; C-D. ***Vallaris solanacea*** **(Roth) O. Kuntze** (C) Polar view, optical section, (D) Equatorial view, surface at porate; E-F. ***Wrightia antidysenterica*** **(L.) R. Br.** (E) Polar view, optical section, (F) Equatorial view, annulus section; G. ***W. arborea*** **(Dennst.) Mabb.** Oblique polar view, optical section; H. ***W. laevis*** **Hook.f.** Polar view, optical section; I-J. ***W. lanceolata*** **Kerr** (I) Polar view, optical section, (J) Oblique equatorial view, surface at porate; K-L. ***W. religiosa*** **Benth. ex Kurz** (K) Polar view, optical section, (L) Equatorial view, optical section; M-P. ***W. viridiflora*** **Kerr** (M) Polar view, optical section, (N)-(O) Equatorial view, optical section, (P) Equatorial view, surface at porate (scale 5 µm).

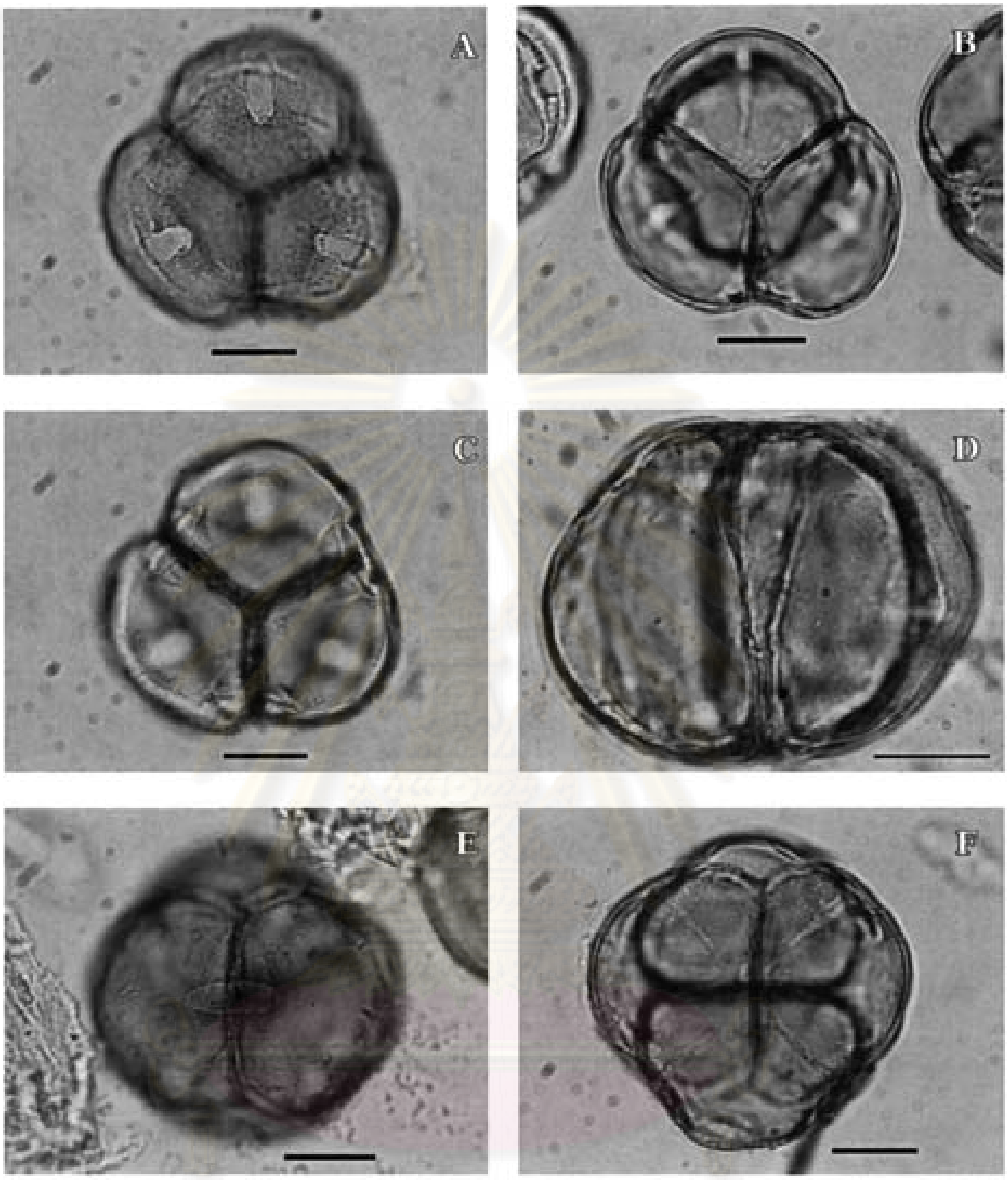

Plate 75 LM micrographs: A-F. ***Melodinus orientalis*** **Blume** (A) Surface, (B) Optical section of tetrahedral tetrad, (C) Surface of the lower side of tetrahedral tetrad , (D) Optical section of tetragonal tetrads, (E) Surface of decussate tetrad, (F) Optical section of decussate tetrad (scale 30 μm).

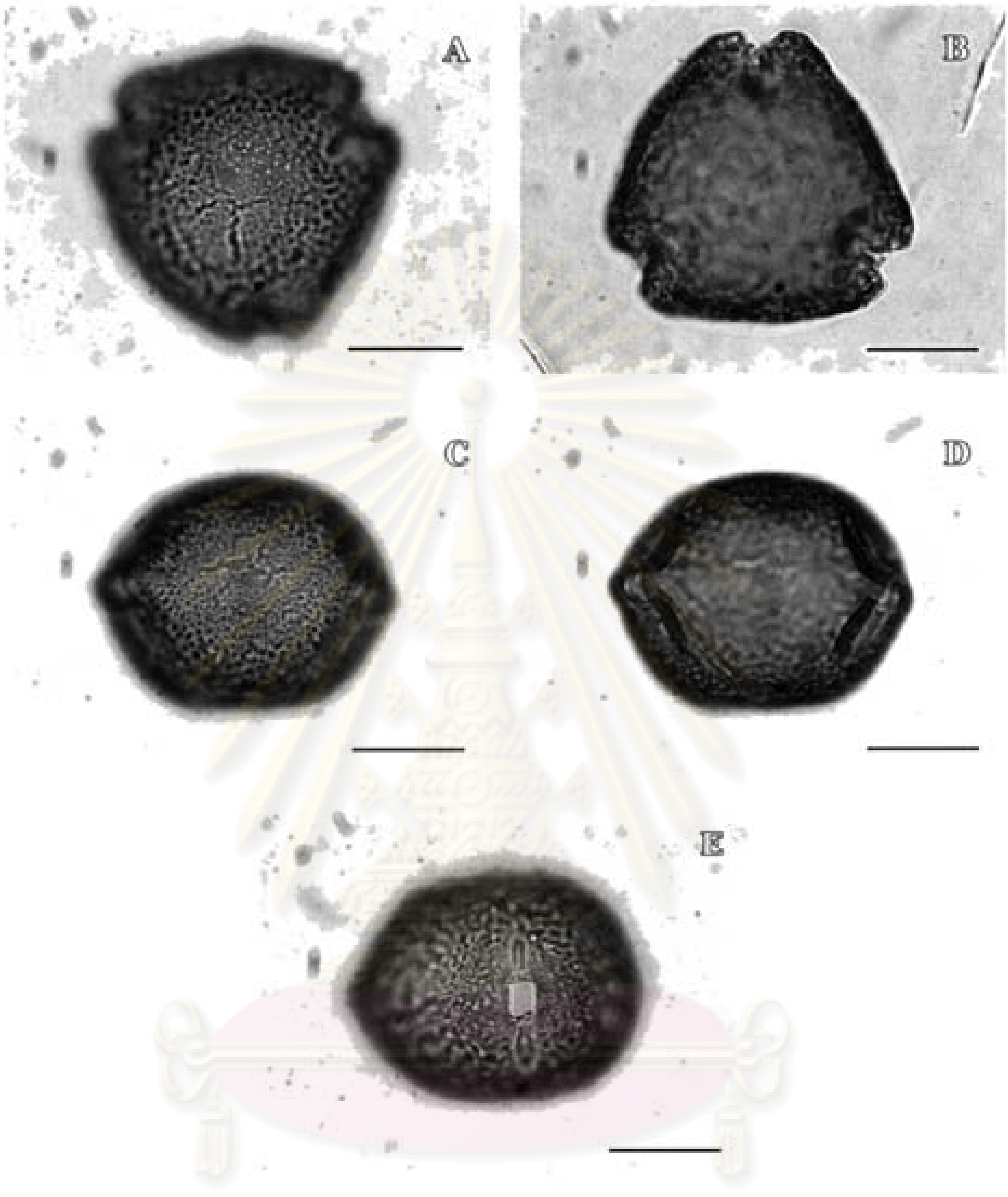

Plate 76 LM micrographs: A-E. ***Thevetia peruviana* (Pers.) K. Schum.** (A) Polar view, surface, (B) Polar view, optical section, (C) Equatorial view, surface, (D) Equatorial view, optical section, (E) Equatorial view, surface at colporate (scale 30 μm).

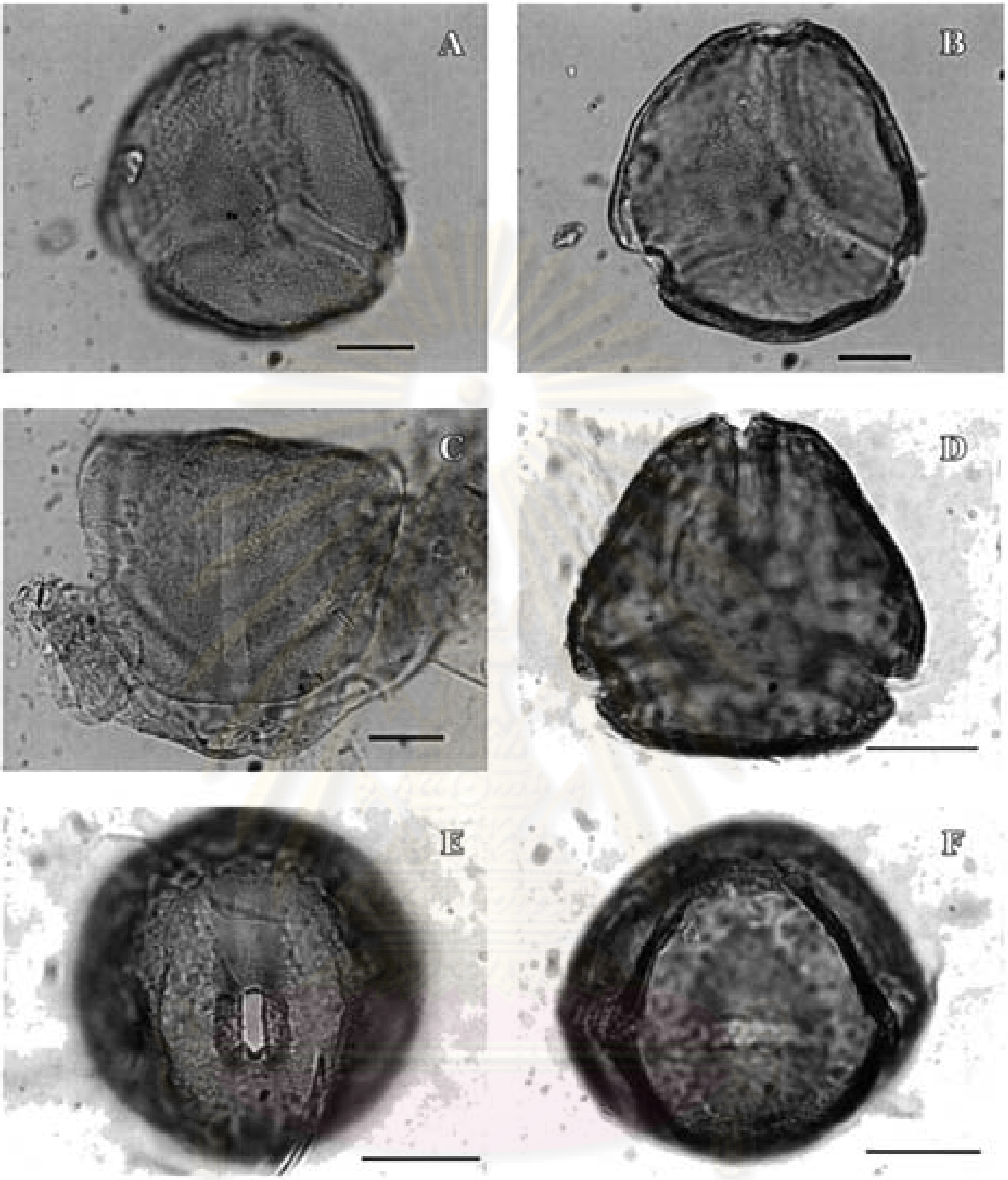

Plate 77 LM micrographs: A-C. ***Cerbera manghas*** **L.** (A) Polar view, surface, (B) Polar view, optical section, (C) Equatorial view, surface at colporate; D-F. ***C. odollam*** **Gaertner** (D) Polar view, optical section, (E) Equatorial view, surface at colporate, (F) Equatorial view, optical section at costa ectocolpi (scale 30 µm).

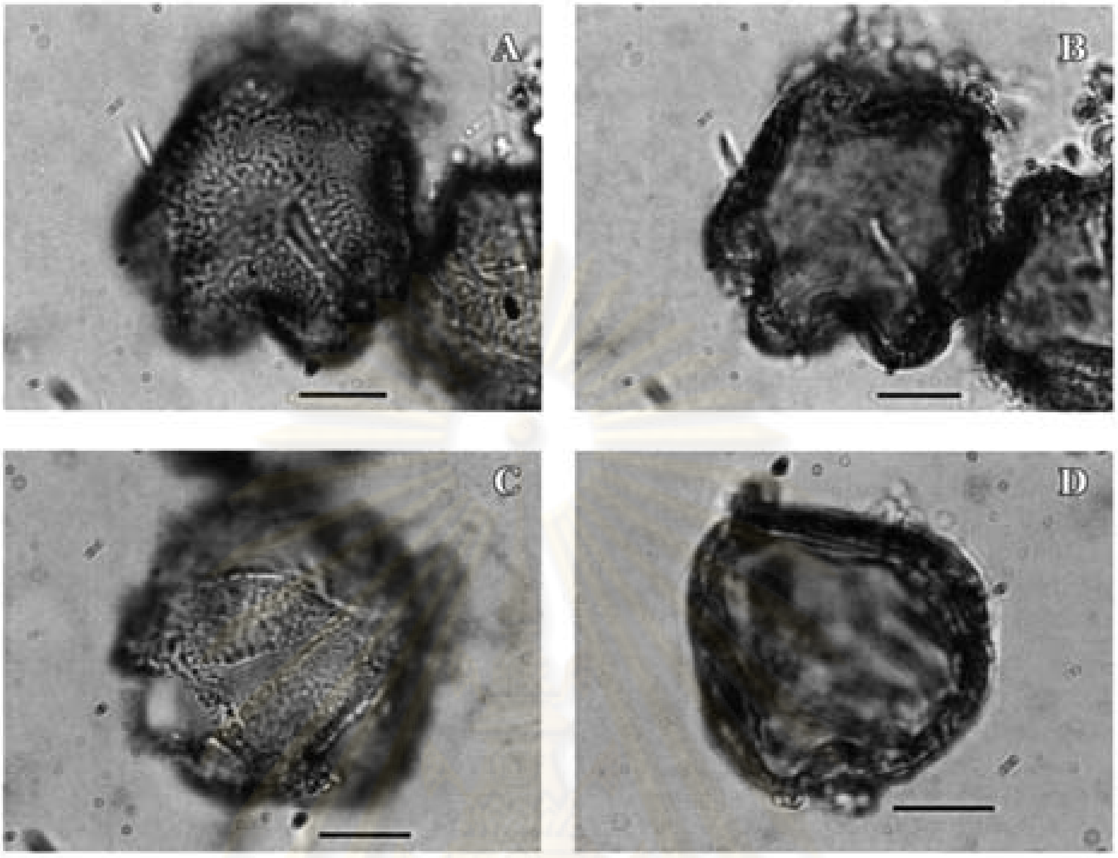

Plate 78 LM micrographs: A-D. ***Ochrosia oppositifolia*** **(Lam.) K. Schum.** (A) Polar view, surface, (B) Polar view, optical section, (C) Oblique equatorial view, surface, (D) Oblique equatorial view, optical section at costa ectocolpi (scale 10 µm).

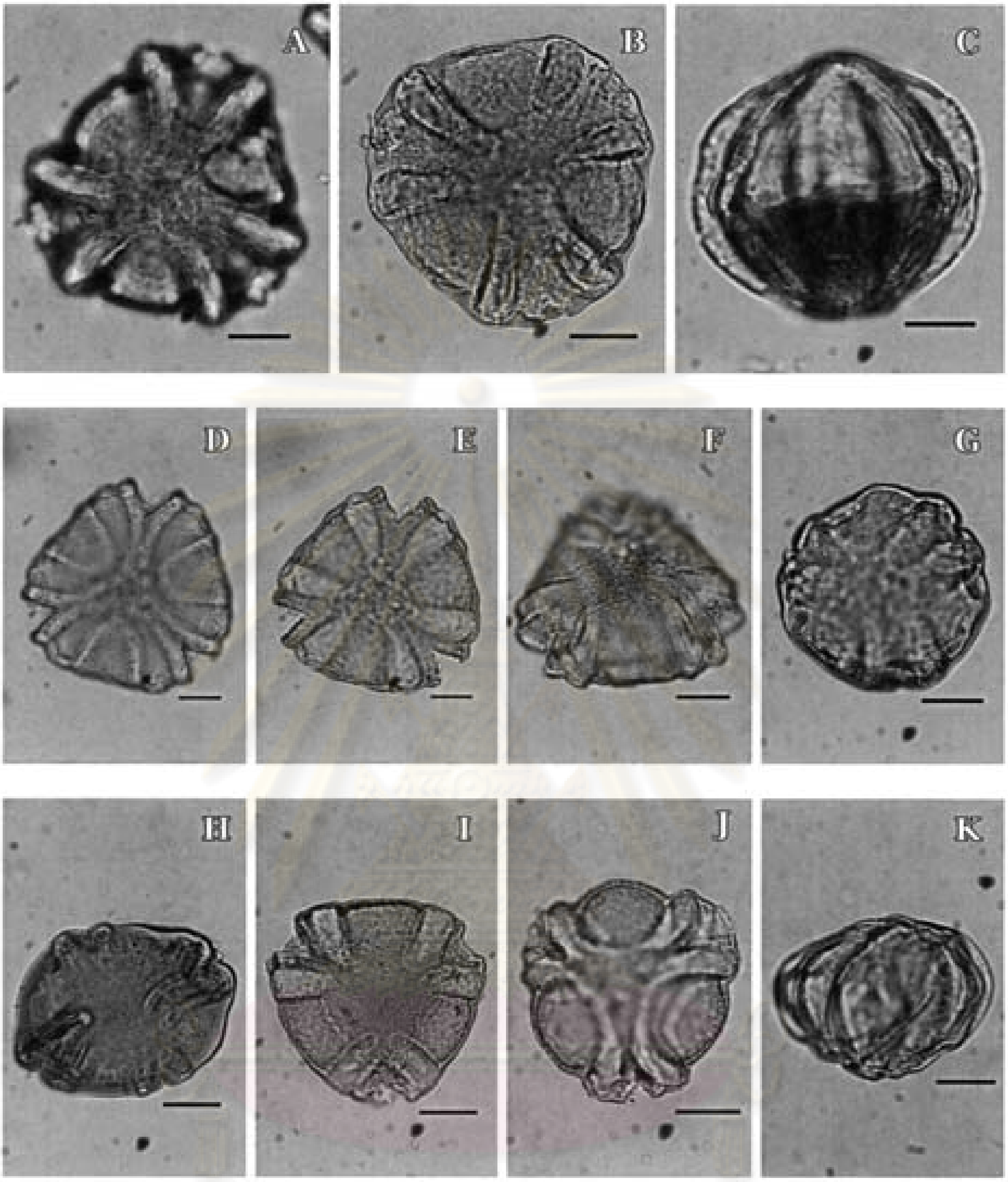

Plate 79 LM micrographs: A-C. ***Rauvolfia cambodiana* Pierre ex Pitard** (A) Polar view, surface, (B) Polar view, optical section, (C) Equatorial view, optical section at costa ectocolpi; D-F. ***R. serpentina* (L.) Benth. ex Kurz** (D) Polar view, surface, (E) Polar view, optical section, (F) Oblique equatorial view, surface; G-H. ***R. sumatrana* Jack** (G)-(H) Polar view, optical section; I-K. ***R. verticillata* (Lour.) Baillon** (I) Polar view, surface, (J) Polar view, optical section, (K) Oblique equatorial view, optical section at costa ectocolpi (scale 30 µm).

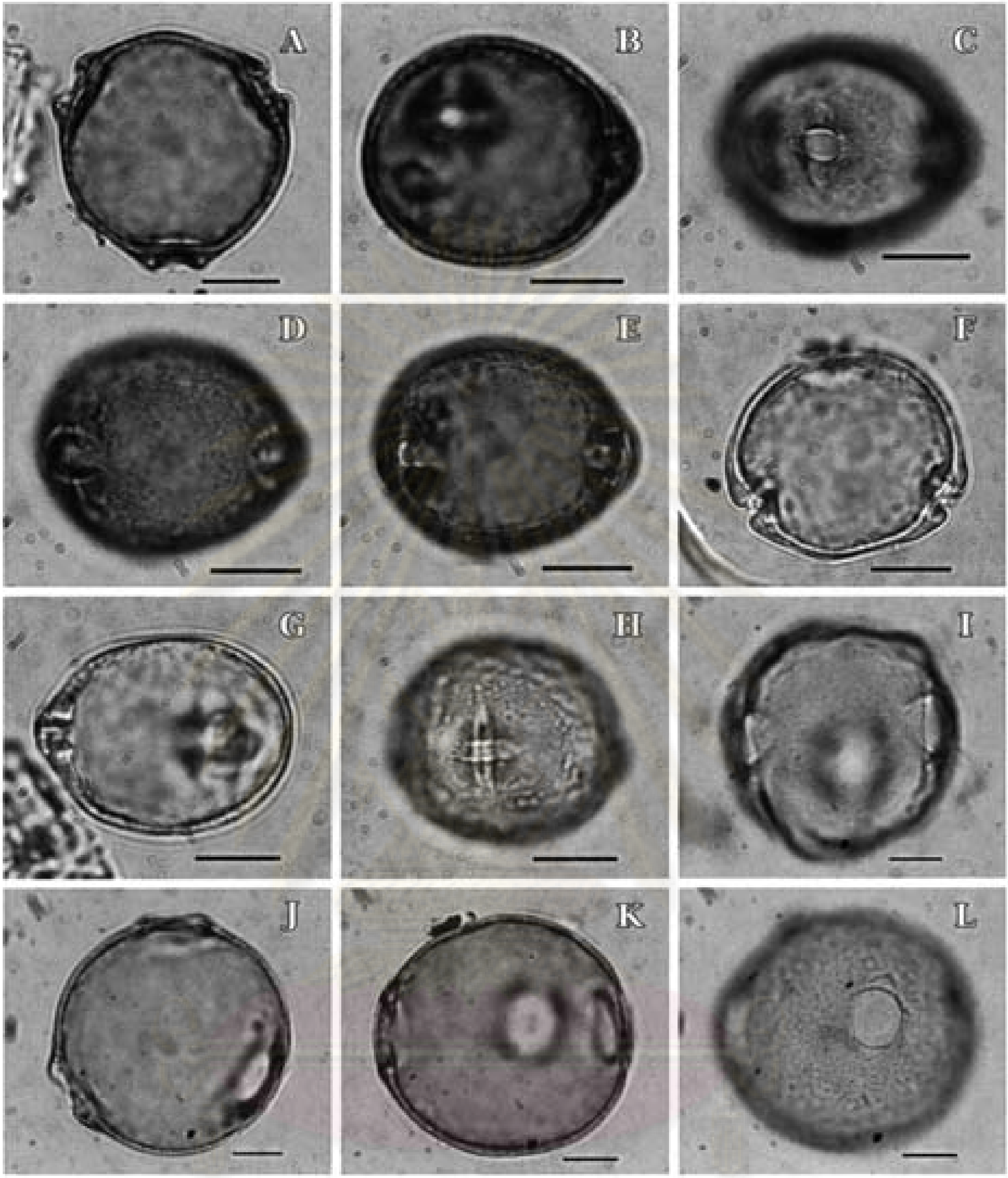

Plate 80 LM micrographs: A-E. ***Willughbeia edulis*** **Roxb.** (A) Polar view, optical section, (B) Equatorial view, optical section, (C)-(D) Equatorial view, surface, (E) Equatorial view, optical section at costa endopori, F-H. ***W. coriacea*** **Wall.** (F) Equatorial view, optical section at costa endopori; (G) Equatorial view, optical section at costa endopori, (H) Equatorial view, surface; I-L. ***W. grandiflora*** **Dyer ex Hook.f.** (I) Equatorial view, surface, (J) Oblique polar view, optical section, (K) Oblique equatorial view, optical section, (L) Oblique equatorial view, surface (scale 10 µm).

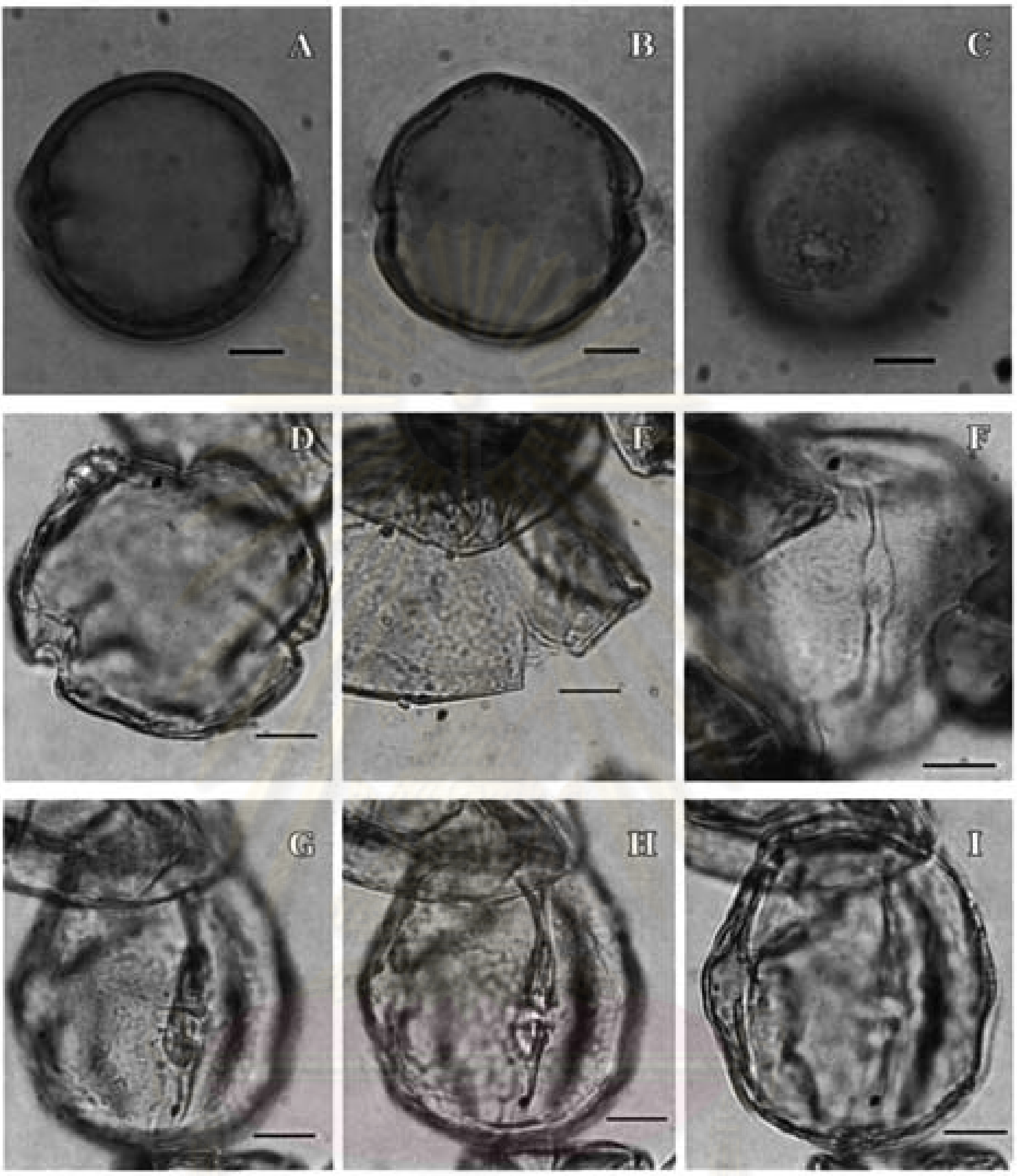

Plate 81 LM micrographs: A-C. ***Alstonia angustiloba* Miq.** (A)-(B) Polar view, optical section, (C) Equatorial view, surface at colporate (scale 5 µm); D-I. ***Allamanda cathartica* L.** (D) Polar view, optical section, (E) Optical section at colporate, (F)-(H) Equatorial view, surface at colporate, (I) Equatorial view, optical section (scale 10 µm).

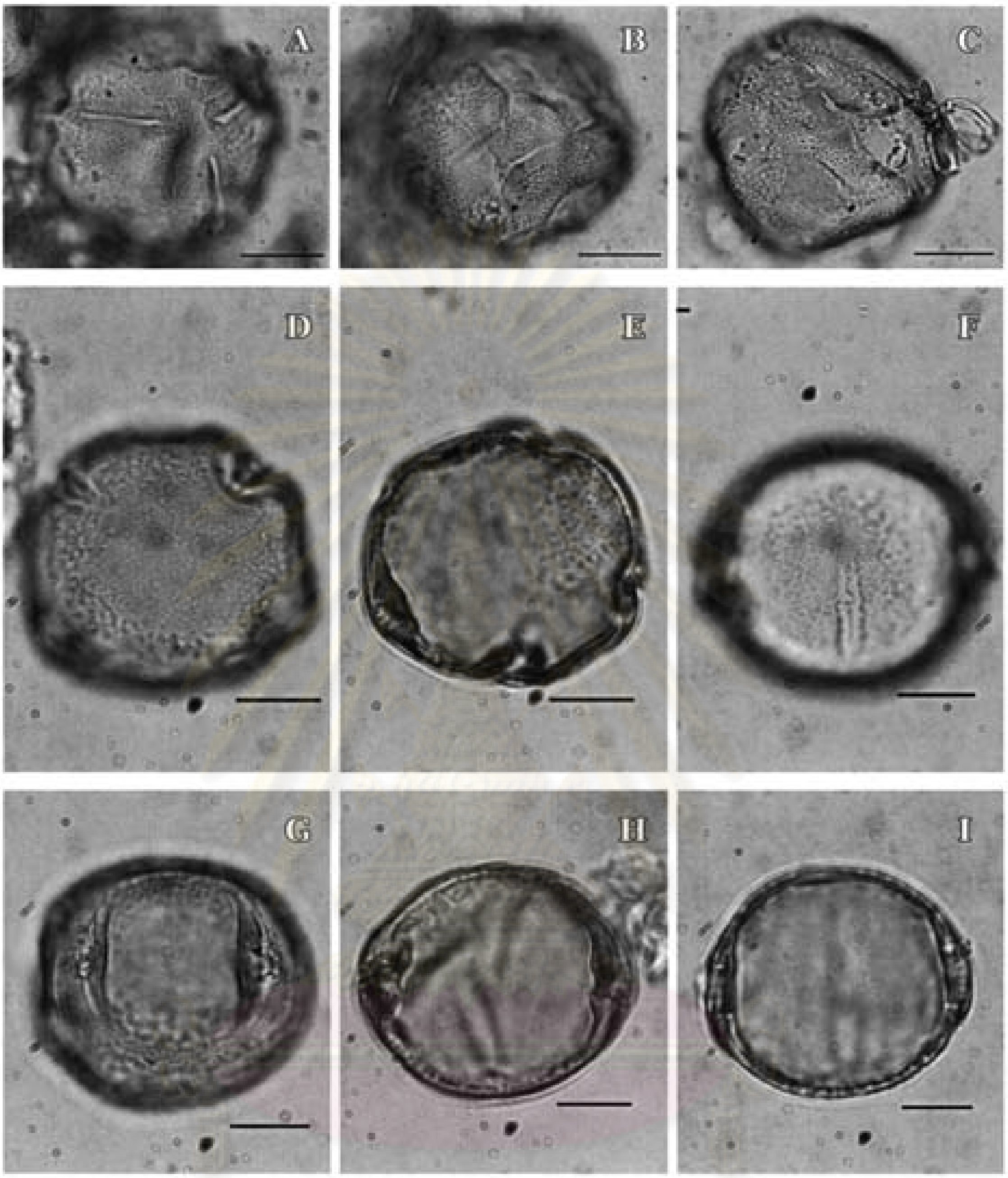

Plate 82 LM micrographs: A-C. ***Kopsia arborea*** **Blume** (A)-(B) Polar view, surface, (C) Equatorial view, surface at colporate (scale 30 μm); D-I. ***Melodinus cambodiensis*** **Pierre ex Spire** (D) Polar view, surface, (E) Polar view, optical section, (F) optical section surface at pseudocolpate, (G) optical section, optical section at costa ectocolpi, (H)-(I) Equatorial view, optical section (scale 10 μm).

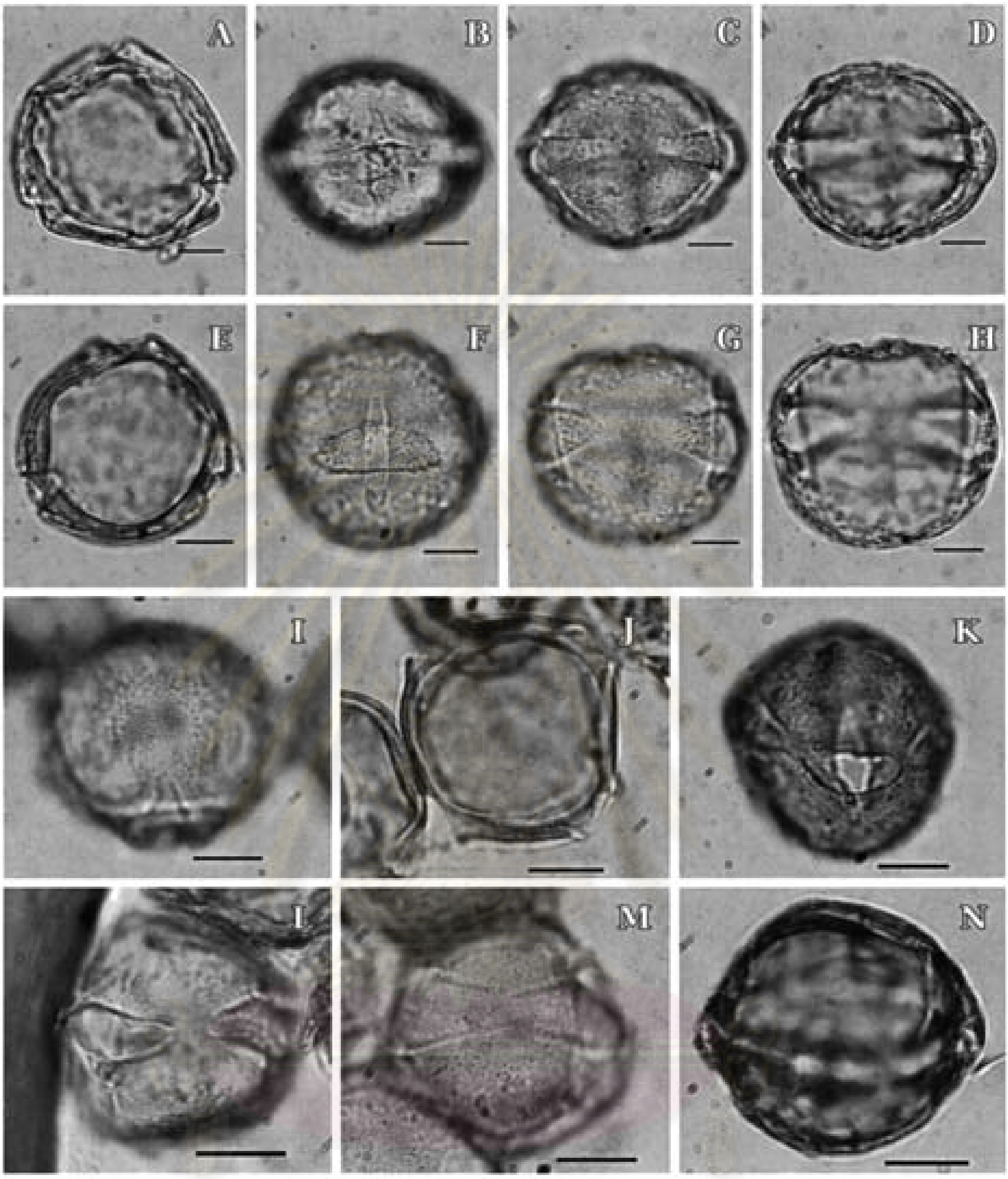

Plate 83 LM micrographs: A-D. ***Tabernaemontana pauciflora* Blume** (A) Polar view, optical section, (B)-(C) Equatorial view, surface, (D) Equatorial view, optical section; E-H. ***T. peduncularis* Wall.** (E) Polar view, optical section, (F)-(G) Equatorial view, surface, (H) Equatorial view, optical section; I-N. ***T. bufalina* Lour.** (I) Polar view, surface, (J) Polar view, optical section, (K)-(M) Equatorial view, surface, (N) Equatorial view, optical section (scale 10 μm).

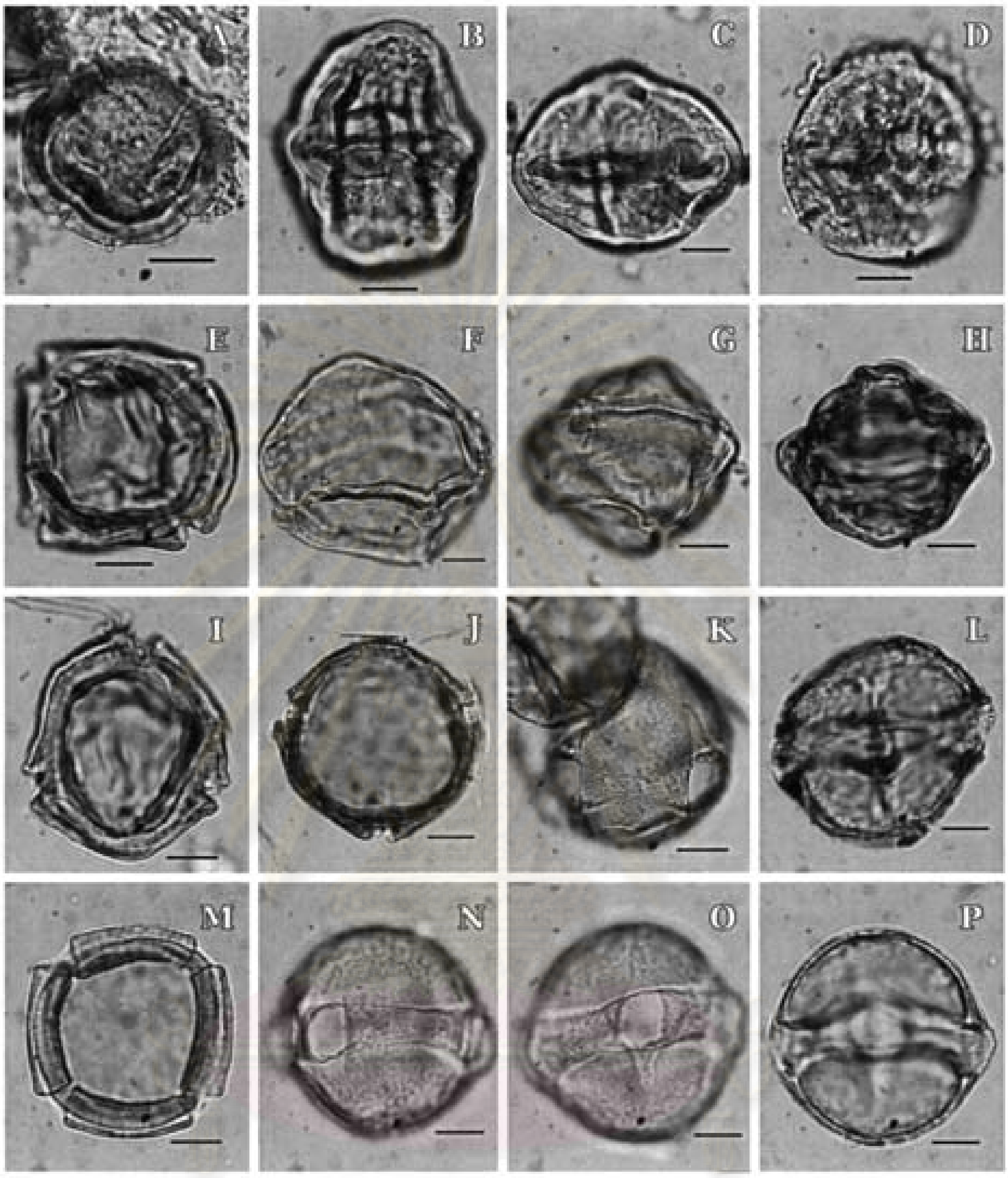

Plate 84 LM micrographs: A-D. ***Tabernaemontana divaricata*** **(L.) R.Br. ex Roem & Schult.** (A) Polar view, optical section, (B)-(C) Equatorial view, optical section, (D) Equatorial view, optical section at endocingulum; E-I. ***T. bovina*** **Lour.** (E) Polar view, optical section, (F)-(G) Equatorial view, surface, (H) Equatorial view, optical section, (I) Polar view, optical section; J-L. ***T. pandacaqui*** **Poir.** (J) Polar view, optical section, (K) Equatorial view, surface, (L) Equatorial view, optical section; M-P. ***T. corymbosa*** **Wall.** (M) Polar view, optical section, (N)-(O) Equatorial view, surface, (P) Equatorial view, optical section (scale 10 µm).

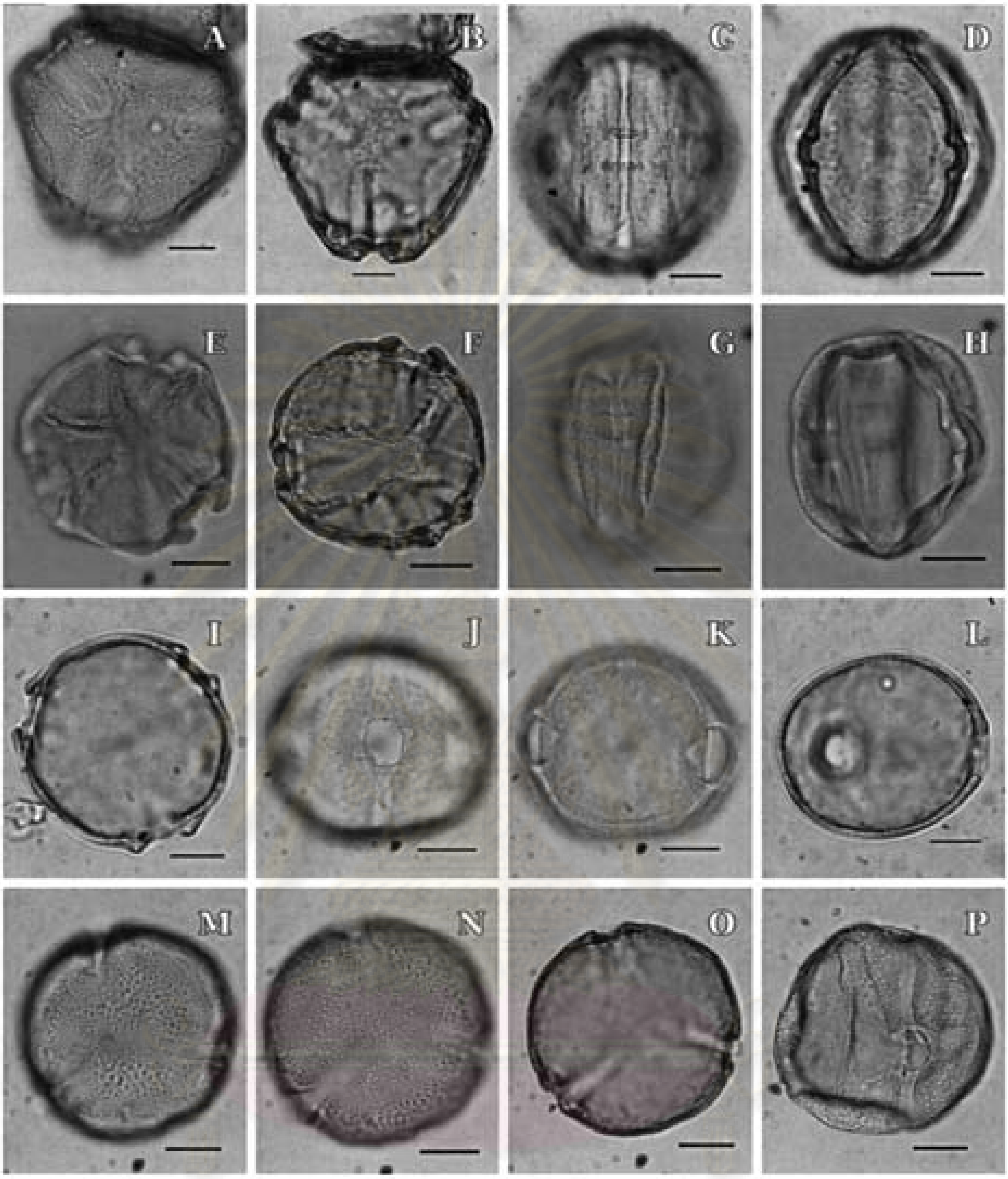

Plate 85 LM micrographs: A-D. ***Catharanthus roseus* (L.) G.Don** (A) Polar view, surface, (B) Polar view, optical section, (C) Equatorial view, surface, (D) Equatorial view, optical section at costa ectocolpi (scale 10 µm); E-H. ***Alstonia curtisii* King & Gamble** (E) polar view, surface, (F) Polar view, optical section, (G) Equatorial view, surface, (H) Equatorial view, optical section costa ectocolpi (scale 30 µm); I-L. ***A. rostrata* Fischer**, (I) Polar view, optical section, (J)-(K) Equatorial view, surface, (L) Equatorial view, optical section (scale 10 µm); M-P. ***Kopsia angustipetala* Kerr** (M)-(N) Polar view, surface, (O) Polar view, optical section, (P) Equatorial view, surface (scale 30 µm).

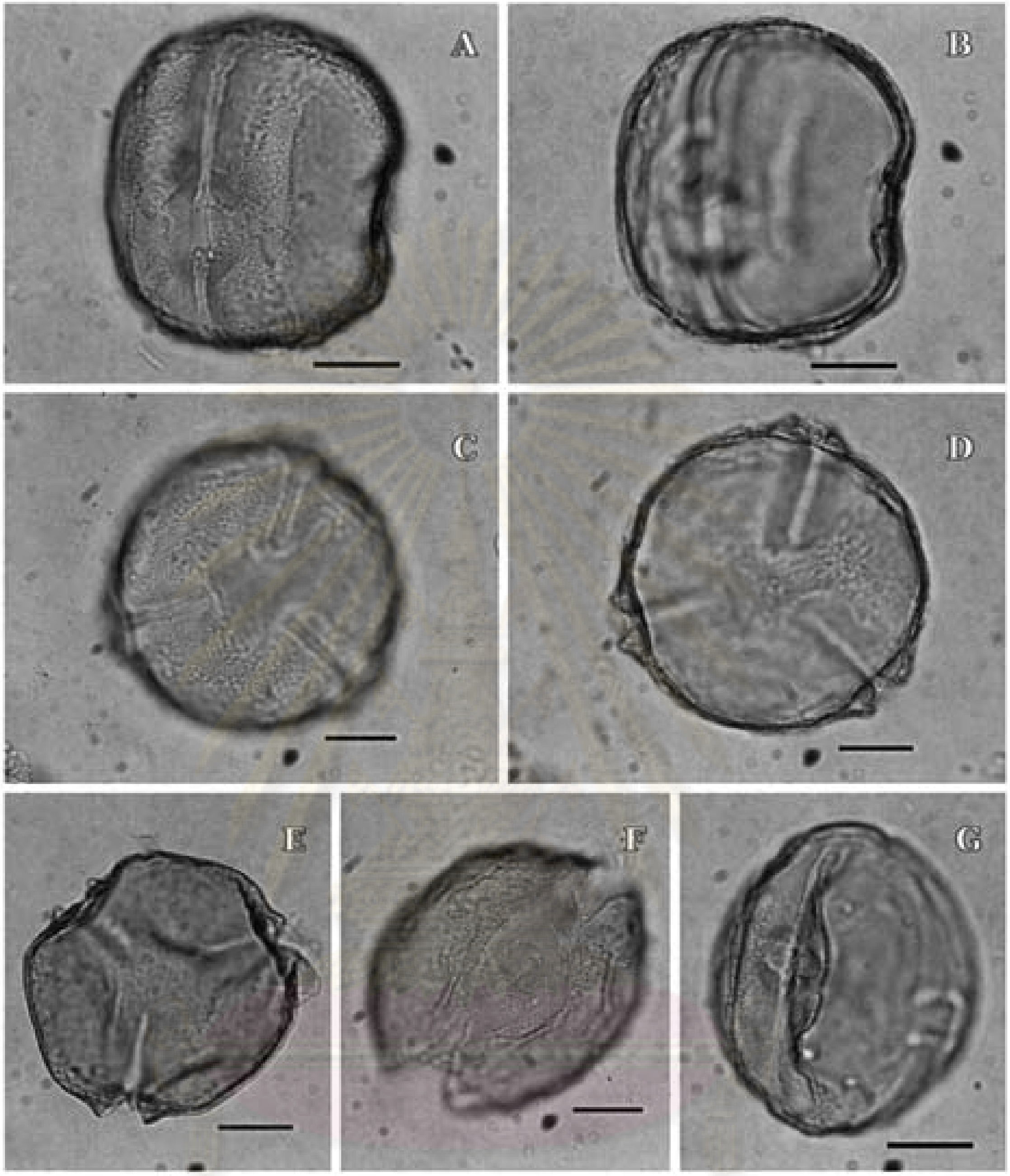

Plate 86 LM micrographs: A-D. ***Kopsia pauciflora* Hook.f.** (A) Equatorial view, surface, (B) Equatorial view, optical section, (C) Polar view, surface, (D) Polar view, optical section(scale 30 µm); E-G. ***K. rosea* D.J. Middleton** (E)-(F) Polar view, optical section, (G) Equatorial view, surface (scale 30 µm).

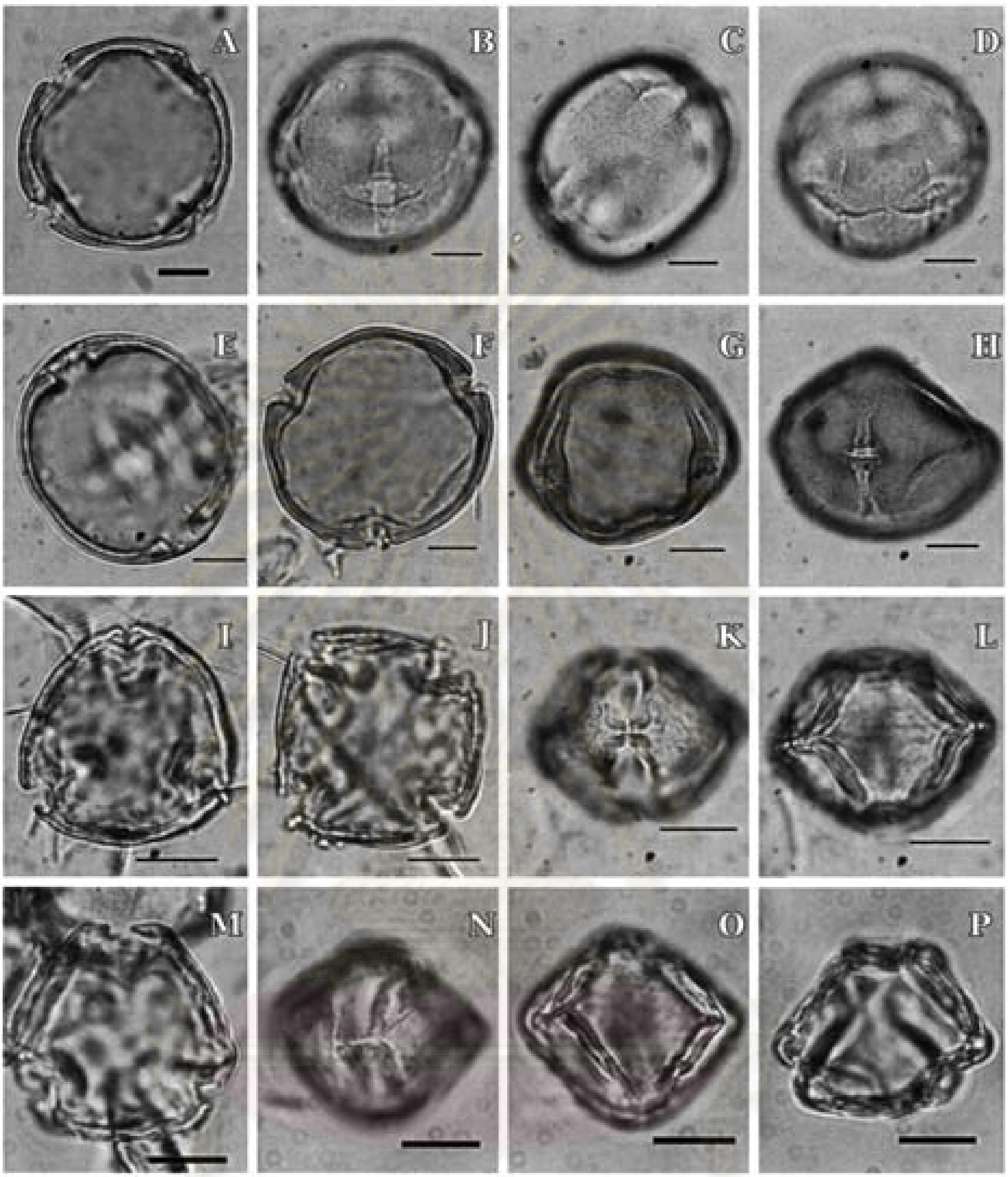

Plate 87 LM micrographs: A-E. ***Bousigonia angustifolia*** **Pierre ex Spire** (A) Polar view, optical section, (B)-(D) Equatorial view, surface; E-H. ***Melodinus cochinchinensis*** **(Lour.) Merr.** (E) Equatorial view, optical section, (F) Polar view, optical section, (G) Equatorial view, optical section at costa ectocolpi, (H) Equatorial view, surface (scale 10 µm); I-L. ***Plumeria obtusa*** **L.** (I)-(J) Polar view, optical section, (K) Equatorial view, surface, (L) Equatorial view, optical section at costa ectocolpi; M-P. ***P. rubra*** **L.** (M) Polar view, optical section, (N) Equatorial view, surface, (O) Equatorial view, optical section at costa ectocolpi, (P) Oblique polar view, optical section. (scale 10 µm).

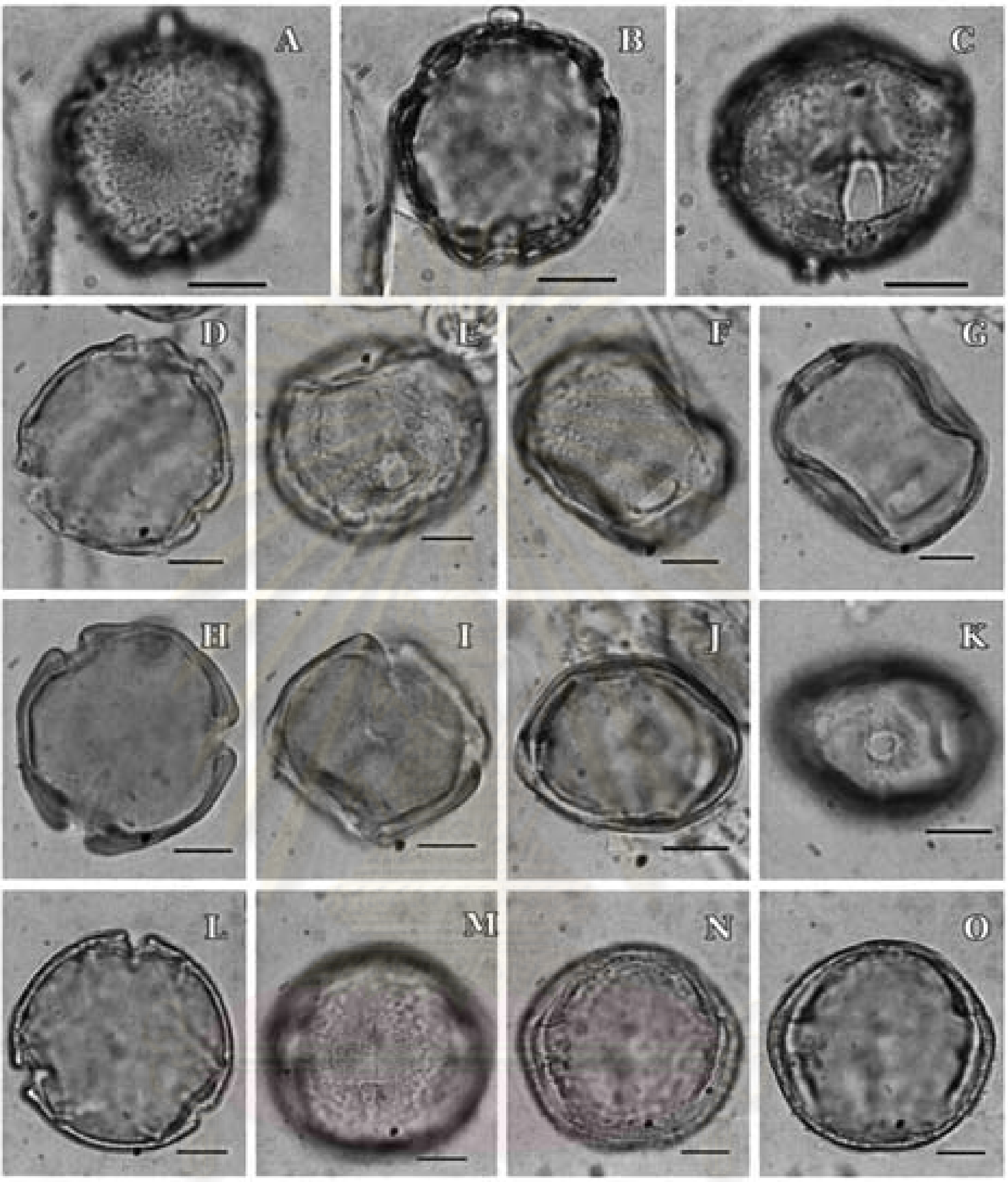

Plate 88 LM micrographs: A-C. ***Hunteria zeylanica* (Retz.) Gardner ex Thwaites** (A) Polar view, surface, (B) Polar view, optical section, (C) Equatorial view, surface; D-G. ***Alstonia macrophylla* Wall. ex G.Don** (D) Polar view, optical section , (E)-(F) Equatorial view, surface, (G) Equatorial view, optical section; H-K. ***A. scholaris* (L.) R.Br.**, (H)-(I) Polar view, optical section, (J) Equatorial view, optical section, (K) Equatorial view, surface; L-O. ***Carissa carandas* L.** (L) Polar view, optical section, (M) Equatorial view, surface, (N) Equatorial view, optical section at costa ectocolpi, (O) Equatorial view, optical section. (scale 10 μm).

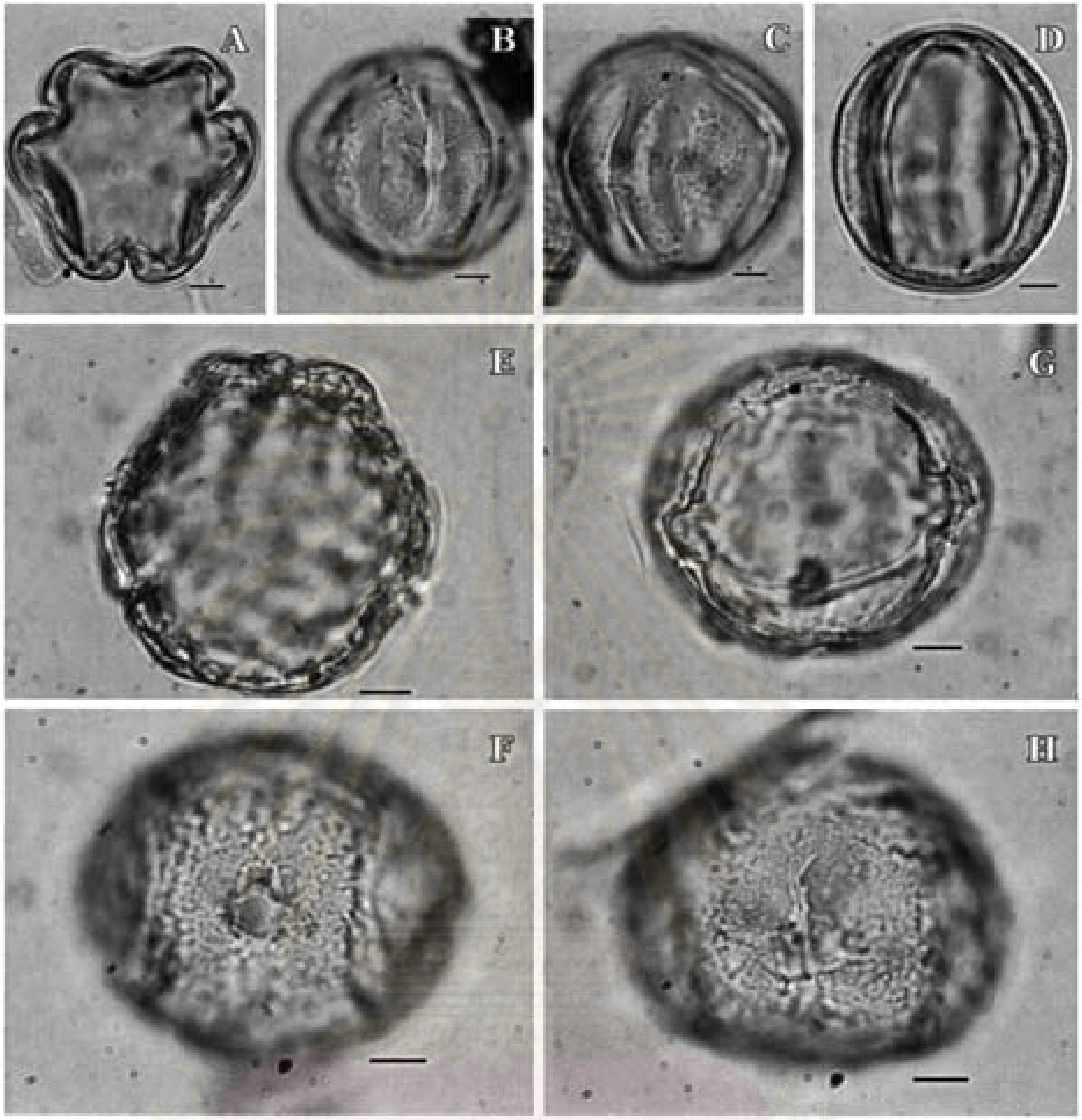

Plate 89 LM micrographs: A-D. ***Carissa spinarum* L.** (A) Polar view, optical section, (B) Equatorial view, surface, (C) Equatorial view, optical section at costa ectocolpi, (D) Equatorial view, optical section; E-H**. *C. grandiflora* (E.Mey.) A.DC.** (E) Polar view, optical section, (G) Equatorial view, optical section at costa ectocolpi, (F), (H) Equatorial view, surface (scale 5 µm).

CHAPTER V

DISCUSSION AND CONCLUSION

5.1 Pollen Morphology and pollen morphological trends

There is a considerable variation in the pollen morphology of the Thai Apocynaceae in the present study. It is divided into 23 pollen types based on dispersal unit, polarity, aperture, exine stratification, ornamentation, size as well as shape of pollen grains. The palynological data are used to suggest some possible morphological trends as shown in table 5.1.

5.1.1 Dispersal Unit

In general, Thai apocynaceous plants shed their pollen grains as monad, however, tetrahedral tetrad (rarely decussate) is found in *Melodinus orientalis*. van de Ven and van der Ham (2006) also reported tetrad condition in *M. orientalis*, but they found monad also occurred in one specimens of *M. orientalis*. Unfortunately only one specimen of *M. orientalis* could be collected in this study and no monad was found in the pollen materials.

Monad clearly represents the basic angiosperm dispersal unit (Walker and Doyle, 1975). Here, it is also accepted that in the Apocynaceae, the tetrad is more advanced characters over monad condition. It is accepted that the number of grains per pollen dispersal unit has genetic and ecological consequences: the more grains per pollen dispersal unit, the greater the probability that seeds in a fruit will have the same male parent; the greater the amount of pollen adhering to the stigma, the greater the male competition (Pacini and Hesse, 2002).

5.1.2 Polarity and symmetry

Pollen grains of most genera of Thai Apocynaceae are isopolar with radial symmetry. However the subisopolar is found in *Alyxia*, *Chilocarpus* which results from the different outline of poles in equatorial view. Although van der Ham (2001) stated that the orientation of the polar axis and equatorial axis in pollen grains of *Alyxia* and *Chilocarpus* could not be determined, but a number of palynological studies have accepted the subisopolarity of them (Walker, 1976, Frederiksen *et al.*, 1985, Nilsson *et al.*, 2002)

In *Anodendron*, its diaperturate grains show some degree of variation in position of apertures. The majority of pollen grains have regularly distribution of apertures on the equator, however, some grains show the slightly to distinctly oblique position of aperture, i.e. one aperture is on the equator but the another situate more or less near to the pole or both of them are in the different poles. Moreover, some grains have irregular polar outline or irregular Amb. The combination of these characters results in the isopolar, subisopolar to heteropolar pollen grains of *Anodendron*.

The apolar condition is found in pantoporate pollen grains of *Trachelospermum* and *Ichnocarpus*. These two genera also show asymmetrical pollen grains caused by irregularly distributed of their apertures.

According to the study of Walker and Doyle (1975), radiosymmetric isopolarity (radial symmetry and isopolar grain) is proposed to be the common character of angiosperm. It might evolve from the bilateral heteropolarity or the apolar inaperturate pollen grain, respectively. Apolar pantoporate pollen grain found in Apocynaceae, such as in *Ichnocarpus*, may be secondary derivative of isopolar pollen. And bi-radial pollen grains, as found in the genus *Chilocarpus*, may also evolve from radial symmetrical, isopolar grains. Bi-radial grains may further change its shape from spheroidal to equatorially elongate, thus producing subisopolar, (secondarily) bilateral grains as found in the genus *Alyxia*. From this point of view, it suggests that in the Apocynaceae, radiosymmetric, isopolar grain might probably be the most primitive character. In addition, bi-radial isopolar pollen grain is more advanced and may evolve to be bilateral, subisopolar pollen grain. Independently, apolar polypantoporate grains have derived from the common radiosymmetric, isopolar pollen grains.

5.1.3 Polar field index

The polar field index of pollen grains varies from small area (about 0.12) as in *Tabernaemontana divaricata*, to large (about 0.8) as in *Willughbeia edulis*.

5.1.4 Outline and shape

The polar outline or Amb of pollen grains of most genera vary from circular to triangular with more or less straight or slightly convex or concave sides, however, rectangular outline is found in 4-aperturate grain of *Melodinus cambodiensis* and

Tabernaemontana spp. Some taxon show a remarkable characters, i.e. *Ochrosia oppositifolia,* its pollen grains reveal hexa-angular with 3-bilobate apertural sides alternate with 3-concave areas of the middle part of mesocolpium.

The circumference of most pollen grains in equatorial view varies from circular to circular-elliptic with slightly protruding at the middle of ectoaperture as found in *Thevetia peruviana.* However some certain genus, i.e *Alyxia,* shows its distinctive polar outline. Its barrel-like or sausage-like or oblong contour in equatorial view with one convex side and one straight or concave side, which has never been found in any taxa in the family, gives the remarkable character for identification.

Within *Anodendron,* its equatorial outline shows some degree of variation. In normal grains, they are circular, elliptic but a number of grains are irregular in outline or has a bone-shaped grains, or elliptic with various degree of constriction at the equatorial zone where their apertures are situated.

According to the P/E ratio, pollen of Thai Apocynaceae exhibits a tremendous shape from peroblate to prolate (P/E =0.26-1.88). However, the majority of pollen grains are suboblate to oblate-spheroidal (P/E = 0.76-0.99) or prolate-spheroidal to subprolate (P/E = 1.00-129).

Although, the peroblate grains are accounted both in the *Alyxia* and *Rauvolfia,* the former is unique in its barrel-like as described above, and the latter is represent by its pumpkin-like appearance. On the other hand, pollen grains of the *Anodendron affine* type show its distinctive feature of prolate grains (P = 1.13-1.88)

Globose-spherical or spheroidal pollen grains is accepted as an advanced character state evolving from primitive boat-shaped pollen of primitive angiosperm. Spheroidal to subspheroidal pollen grain may further develop into both oblate and prolate grain (Walker, 1976). It is therefore proposed here that subspheroidal pollen grains of Apocynaceae are pleisiomorphic character and may have evolved separately into prolate and oblate grains. Peroblate grains have consequently evolved from oblate grains and represent more advanced character within the family. Moreover, the barrel-like pollen grains make up a unique derived group evolving independently from oblate pollen grain.

5.1.5 Size

The size of pollen grains of Thai Apocynaceae ranges from small size (ca. 14 microns as in *Urceola micrantha*) to very large size (ca. 106 microns as in *Cerbera manghas*). However, most pollen have medium size grains. The pollen grains of genera, *Kopsia, Rauvolfia, Hunteria, Cerbera, Alyxia* and *Beaumontia*, are relatively larger than those of other taxon. Their ranges are from 45 to 100 microns of the longest axis.

5.1.6 Apertures

Number of aperture - The basic number of aperture for Thai Apocynaceae is three. However decreasing or increasing in number of aperture is often accounted in many genera. The pollen grains of *Ochrosia, Alyxia, Chilocarpus, Kitabalia, Anodendron*, as well as a number of species of *Alstonia, Kopsia* and *Strophanthus* reveal 2-aperturate pollen. Monoaperturate is sometimes found in some grains of *Chilocarpus denudatus* and *Anodendron affine*. On the other hand, the pollen grains of *Beaumontia*, some species of *Tabernaemontana, Wrightia, Nerium oleander* and *Bousigonia angustifolia* represent 4(-5)–aperturate pollen grains. Triaperturate grains have never been found in these taxa. Moreover, the genera *Trachelospermum* and *Ichnocarpus* show the obvious high number of aperture of 10-24 and 12-23, respectively.

Type of aperture - On one hand, the basic aperture type which is found in almost all of genera in the subfamily Rauvoifioideae is colporate. However the pollen grains of the two genera, i.e. *Alyxia* and *Chilocarpus*, are the exception, as they are found to be porate. On the other hand, porate is clearly remarkable character of the whole subfamily Apocynoideae.

In the colporate grain, most of the ectoaperture are typically narrow, slit-like, long colpi. However, short, elliptic ectocolpi are found in *Willughbeia*. They may become more rounded as circular-elliptic and nearly congruent with the endoapertures, thus resulting, more or less like pororate grains.

Endoapertures are mostly lalongate elliptic with diffused equatorial ends. The ring-shaped endoaperture or endocingulum is uniquely found in pollen grains of *Tabernaemontana*. In contrast, lolongate elliptic endoaperture is accounted in *Rauvolfia* pollen, and sometimes it congruent with ectoaperture, thus colpate-like condition seems to be appeared.

The number of endoaperture is usually one per one ectocolpi. However, the diploporate grain (one ectocolpus with two or more endoapertures) found to develop in some pollen grains of the *Allamanda cathartica* type. But the endoapertures is not equally distributed, one situated at the equator as usual and the another at one of the polar ends.

Position of aperture - The position of aperture is mostly equatorial (zonoaperturate), however pantoporate are accounted in certain genera, i.e. *Ichnocarpus* and *Trachelospermum*. In *Melodinus cambodianum*, the pollen grains are basically zonocolporate, but some grains are often marked with short colpi-like features at both poles, which give the appearance of pantoaperturate-like grains. This heteromorphism is also found in the pollen grains of *Centaurium pulchellum* (Gentianaceae). It is possible that this atypical forms may not be caused by irregularity at the meiosis, but rather in response to accommodate the volume change of the pollen which induced by occupation of new habitats and/or by humidity changes in the natural environment (Pire and Dematteis, 2007).

In evolutionary context, apertural characteristics are of paramount importance. Regarding apertural characters, tricolpate pollen is the main and basic type found in most eudicots while other aperture types such as 5-colpate, 6-colpate, porate, colporate and pororate are regarded as derived among the eudicots (Walker and Doyle, 1975; Lee, 1978; Furness and Rudall, 2004). Dajoz *et al.* (1991) suggested that pollen apertures are under strong selection pressure. An increase in pollen aperture number offers a potential selective advantage because it increases the number of prospective germination sites, thus facilitating contact between at least one aperture and the stigmatic surface, and thereby potentially increasing the fertilization rate. Such an increase occurred at the base of the eudicot clade, coupled with an apparently fundamental shift in aperture position from polar to equatorial.

Therefore, it is proposed that Thai Apocynaceae typically are elongated and slit-like tricolporate pollen and can occasionally be reduced to pores, and in some cases the number can increase to four, five, six, or more. Moreover, polypantoporate pollen may be the most advanced grains in the family. However, one and two apertures may be considered to be an advanced character evolving from the common tri-aperturate grains independently (Thanikaimoni, 1986). In the same way, the complication of endoaperture may occur: one endoaperturate grains may develop more than one endoapertures within one ectocolpi (Punt, 1967, Thanikaimoni, 1986).

In addition, the equatorial extension of endoapertural area can also occur: colporate grains may evolve to colporate pollen with endocingulum (Thanikaimoni, 1986).

5.1.7 Exine stratification and ornamentation

The exine of Apocynaceae are tripartite, being subdivided into a tectum, columella or infratectum and nexine. However, the stratification is usually obscure, especially under the light microscope.

Basically, the pollen grains of the Apocynaceae are tectate. The semitectate condition is rarely found, as in the *Thevetia peruviana* type and the *Cerbera manghas* type. Tectate pollen grains may be found as either tectate-imperforate (without any holes in the tectum) or tectate-perforate (with small holes).

Almost all of the pollen grain of Apocynaceae found in the present study seem to be lack of columella or columella indistinct or very obscure. The infratectum is then, often, thin and/or irregular and alveolate. The inner nexine surface is occasionally granulate, especially in the *Alyxia reinwardtii* type, the *Chilocarpus costatus* type and the Adenium obesum type, and always appear as band-like of gemmae in the *Spirolobium cambodianum* type.

Walker (1974) stated that a major evolutionary trend in angiosperm exine structure appears to run from pollen which is tectate-imperforate to tectate-perforate and semitectate pollen, and thence more rarely to intectate pollen. Here it is accepted this trend for the changing of tectate-imperforate to semitectate grain in Apocynaceae.

Although it has been considered that Apocynaceae pollen are rather homogenous with a rather smooth surface (Erdtman, 1952), this present study show a considerable variation among the ornamentation of Apocynaceae, especially as seen under the SEM. Observing with the light microscope, the majority of the pollen grains are psilate, except in the *Ochrosia oppositifolia* type, which has distinctly verrucate ornamentation and microreticulate in the *Thevetia peruviana* type and the *Cerbera manghas* type. However, under the SEM, the details shown variable of supratectal ornamentation on some psilate surface (under light microscope), i.e. perforate, fossulate, foveolate, granulate and scabrate.

Evolutionary trends in pollen wall architecture offer great potential as sources of phylogenetic information of major importance (Walker and Doyle, 1975). With respect to exine sculpturing types, primitive angiosperm pollen appears to have been more or less psilate, while foveolate, fossulate, scabrate, verrucate and reticulate sculpture are considered to be advanced characters. However, sculpturing itself undoubtedly represents a more or less reversible character which must be interpreted in terms of individual correlations observed within any given taxa (Walker, 1976).

Thus, the completely psilate seem to be the basic ornamentation of the family and then derived independently into two separate lines. One line is a type of a structural pattern consisting of perforation in various degree of size and shape (i.e. perforate, foveolate, microreticulate). The other consists of various kind of projection on the tectum surface (i.e. scabrate, granulate and verrucate).

5.2 Taxonomic significance and some insights from Apocynaceae phylogeny on pollen morphological changes

In this section, the distribution of pollen types throughout the family is compared with the currently accepted classification, as well as with current ideas of infrafamilial relationships from the previous cladistic analyses. Thus, congruence between pollen types and infrafamilial delimitations of Endress and Bruyns (2000) was discussed. An attempt was also made to show the proposed pollen morphological changes in relation to the phylogenetic relationships from a cladistic analysis of Sennblad and Bremer (2002).

5.2.1 Pollen types with relation to infrafamilial delimitations

The distribution of the pollen types, together with some floral characters of Thai Apocynaceae in relation to the infrafamilial classification can be seen in Table 5.2 which the pollen types are numbered as in Chapter IV.

According to the classification of Endress and Bruyns (2000), within the Apocynaceae s.str., the Rauvolfioideae are especially heterogeneous while in the more specialized subfamily Apocynoideae, on the other hand, is much less heterogeneous. These views correlate with palynological investigations of Thai Apocynaceae in which the Rauvolfioideae have more diverse of pollen characters than of the Apocynoideae. Moreover, the distributions of pollen morphology within the latter are more homogeneous with only five pollen types and six subtypes, while there are 18 pollen types with six subtypes recognized in the former.

Although the monophyly of subfamily Rauvolfioideae and Apocynoideae is not supported by recent molecular phylogenies (Sennblad *et al.*, 1998; Sennblad and Bremer, 2000; Potgieter and Albert, 2001; Sennblad and Bremer, 2002; Endress, 2004), both subfamilies morphologically are well separated (Endress and Bruyns, 2000). The subfamily Rauvolfioideae is morphologically distinct from Apocynoideae with respect to the positions of anther and style head, and the aestivation of corolla lobe. In Rauvolfioideae, the anthers are free from style head and corolla-lobe aestivation in bud typically overlaps to the left (sinistrorse). The Apocynoideae, in contrast, are characterized by having the anthers united with the style head and corolla-lobe aestivation in bud overlapping to the right (dextrorse) or valvate (Middleton, 1999; Endress and Bruyns, 2000). It is noteworthy that these very useful key characters correlate well with palynological evidences from the present study as well. The pollen types recognized from each subfamily never overlap to each other. Thai Apocynaceae pollen grains are clearly divisible into two fundamentally different types (each with its own derivatives): colporate pollen in Rauvolfioideae versus porate pollen grains in Apocynoideae. Similar porate aperture, however, also occurs in Rauvolfioideae such as those found in *Chilocarpus costatus* type (Type 4) and in *Alyxia reinwardtii* type (Type 1), but *Alyxieae* differs from Apocynoideae by its relative large-sized grain, special barrel-shaped pollen and pori with annulus outwardly thickening of the exine.

In contrast to the palynological clear-cut distinction at the subfamilial level, the intrasubfamilial level shows no specificity on palynoligcal characters except a few cases. It seems that pollen morphological evidence is highly incongruent with the delimitation of tribes or genera within subfamilies. Some tribe/genera have more than one pollen type while some pollen types may be found in several different tribes, genera or species.

At tribal level, there is little correlation between pollen types and tribes of Thai Apocynaceae. While most pollen types are not congruent with tribal delimitations according to the classification of Endress and Bruyns (2000), only *Wrightieae* is palynological homogeneity as revealing of only one pollen type, the *Adenium obesum* type (Type 7). The homogeneity of *Wrightieae* also is reflected by some floral characters (Table 5.2). This tribe always has infundibuliform corolla or salverform to subrotate flower with stamens exserted from the corolla tube, and connate stamens attached to style head. However, this Type 7 is not exclusive to the *Wrightieae*; this pollen type can be found in every tribe of Apocynoideae. Interestingly, there is the evidence of pollen type relative to floral characters of the subfamily Apocynoideae. Regarding to Type 7, the plants usually have the same form of corolla and stamens as found in *Wrightieae* with the exception of some genera (e.g. *Holarrhena, Aganonerion, Aganosma,* and *Parameria*) which have free stamens separated from style head. With regard to *Spirolobium cambodianum* type (Type 5), although it has infundibuliform, it differs from Type 7 by having free stamens instead of connate stamens. In the same unique way of *Anodendron affine* type (Type 2), it differs from Type 7 plants by having special floral character: villous inside corolla tube, globular style head with apex sharp point, and salverform corolla with constricted at throat. The *Ichnocarpus polyanthus* type (Type 3) comprised of two genera: *Ichnocarpus* and *Trachelospermum*, has unique floral character with globular style head.

At generic level, there is highly correlation between pollen types and genera of Thai Apocynaceae. The pollen grains reveal some qualitative characters in recognition the plants at this taxonomic level. The majority of genera are characterized by one pollen type, with the exception of *Alstonia, Melodinus* and *Kopsia*, which have pollen of more than one palynological type (Table 5.2). This may suggest that the Thai Apocynaceae genera have distinctive pollen morphological characters that support their generic status. Although most pollen types circumscribe genera of Rauvolfioideae, the *Alstonia macrophylla* type (Type 23) is the one pollen type circumscribing groups of genera (e.g. *Alstonia, Bousigonia, Melodinus, Hunteria, Plumeria,* and *Carissa*) in this subfamily.

At the species level, all specimens investigated belonging to the same species were characterized by the same pollen type. This indicates that no intraspecific variation was observed in this study. Furthermore, there are as many as 10 species that reveal some qualitative characters in recognition the Thai Apocynaceae plants at species level, namely Type 5, 8, 9, 11, 14, 15, 16, 19, 20 and 21 (Table 5.2).

The results from this present study indicate that tribal delimitations proposed by Endress and Bruyns (2000) were less congruent with the present palynological morphology in details. This probably results from unstable tribal delimitations as they noted that the tribes within Rauvolfioideae and Apocynoideae continue to be refined and additional studies need to be done in order to come up with satisfactory tribal classification system in both subfamilies. Furthermore, in constructing a tribal classification for the Rauvolfioideae, the tribal delimitation has almost always been based only on fruit characters in stead of unmonotonously dissimilar flowers of them. This kind of delimitation results to palynological heterogeneity within subfamily because pollen characters probably more correlate with floral morphology than fruit characters.

Although there is less palynological congruent within Thai Apocynaceae, they are clearly more similar to each other than to the rest of other families in the same order, Gentianales (Nilsson , 1969; Verhoeven and Venter, 2001; Nilsson *et al.*, 2002; Vinckier and Smets, 2002; Huysmans *et al.*, 2003; D'Hondt *et al.*, 2004).

5.2.2 Some insights from Apocynaceae phylogeny on pollen morphological changes

According to pollen morphological changes proposed in Table 5.1, the outline representing the relationships of them together with pollen types or group of pollen types was made in Figure 5.1. The discussion was made in the sense of phylogeny based on a consensus tree of Sennblad and Bremer (2002).

Recent phylogenetic studies of Apocynaceae suggested that the Rauvolfioideae had almost always been considered to be more ancestral, and the Apocynoideae the more derived subfamily (Sennblad *et al.*, 1998; Sennblad and Bremer, 2000; Potgieter and Albert, 2001; Sennblad and Bremer, 2002). This view correlates well with the palynological characters in this study. Regarding Figure 5.1, the basalmost pollen types are more likely those with 3-4(-5)-colporate, monad, subspheroidal, and psilate-perforate pollen grains. In addition, all of pollen types belonging to Apocynoideae were considered to be more derived groups.

In regard to Rauvolfioideae, three pollen types, e.g. *Alstonia curtisii* type, *Astonia rostrata* type and *Alstonia macrophylla* type, were palynologially considered to be the ancestral of this subfamily. However, these pollen types belong to various tribes: Willughbeeae, Alstonieae, Melodineae, Hunterieae, Plumerieae and Carisseae, and, with the exception of Willughbeeae, these tribes are not the basal groups (Sennblad and Bremer, 2002). These three pollen types may, therefore, palynologically be a common ancestral character of this subfamily.

In the case of semitectate pollen group, *Thevetia peruviana* type and *Cerbera manghas* type, both pollen types support the close relationship between *Thevetia* and

Cerbera, which have been placed as a sister group within Plumerieae in the cladogram of Sennblad and Bremer (2002). However, the origin of these pollen types within subfamily is equivocal (Figure 5.1). Due to proposed evolutionary changes of palynological characters in this study, this semitectate group may derive directly from the tectate basal group, or it may derive through *Catharanthus roseus* type belonging to Vinceae. In contrast, according to phylogenetic tree of Sennblad and Bremer (2002), the former is the most plausible evolutionary trend of these pollen types because such phylogenetic study gives no evidence of a close relationship of Plumerieae and Vinceae.

Regarding the most unique tribe of Rauvolfioideae, the occurrence of diporate pollen in Alyxieae provides additional evidence supporting the monophyly of this taxon as suggested by Van der Ham et al. (2001). In addition, it is proposed from this study that biradial subisopolar pollen grains of *Chilocarpus costatus* type have given rise to bilateral subisopolar pollen as found in *Alyxia reinwardtii* type (Table 5.1). This view was supported by the cladistic analyses of Van der Ham et al. (2001) and those of Sennblad and Bremer (2002), in which *Chilocarpus* is the basal of the tribe, and is a the sister taxon to a clade made up of *Alyxia* and other members of this tribe. The observation of Van der Ham et al. (2001) indicates that *Chilocarpus* is the nearest to other Rauvolfioideae showing subspheroidal, biradial subisopolar and medium-sized pollen grains. *Alyxia*, makes up a derived group, characterized by large pollen grain size and a remarkable bilateral subisopolar pollen.

There are several possible palynological trends proposed in this study regarding to the origin of diporate pollen in Alyxieae (Figure 5.1). These diporate types may evolve directly from the other basal colporate types. In addition, it probably derived from colporate ancestor through very short ectocolpate *Willughbeia coriacea* type (Willughbeeae) or dicolporate *Alstonia angustiloba* type (Alstonieae). However, recent phylogenetic study of Sennblad and Bremer (2002) gives no evidence of a close relationships between Alyxieae and neither Willughbeeae nor Alstonieae. Therefore, it seems most likely that the pollen types of Alyxieae may have evolved independently from basal colporate grains of Rauvolfioideae.

As mentioned above, Rauvolfioideae is considered to be the "basal" subfamily with colporate pollen grains. This suggests that colporate may probably be pleisiomorphic while porate aperture is apomorphic. If this trend is correct, the presence of unique porate grains found in the tribe Alyxieae is the most derived character of Rauvolfioideae and probably also is closely related to the porate grains of more derived subfamily Apocynoideae. Therefore, it seems more likely that subfamily Apocynoideae have evolved from Alyxieae. This hypothesis is consistent with previous results of Sennblad and Bremer (2002) because such phylogenetic studies give evidence of a close relationship of Alyxieae and subfamily Apocynoideae. However, Alyxieae was placed in the same clade of their cladogram with *Carissa* to be sister taxa. Therefore, it could be alternatively interpreted as support for the hypothesis of Potgieter and Albert (2001) that *Carissa* come out as the most advanced taxon of the Rauvolfioideae. If this tree is a good reflection of the actual relationships of both tribes, then the similar porate pollen grains found in Alyxieae and subfamily Apocynoideae are the results of parallel evolution within family Apocynaceae with a common palynological background.

With respect to the subfamily Apocynoideae, all tribes (e.g. Wrightieae, Malouetieae, Apocyneae and Echiteae) reveal the basal palynological characters: 3-4(-5)-porate and subspheroidal pollen grains (Figure 5.1). Three pollen types (e.g. *Adenium obesum* type, *Spirolobium cambodianum* type and *Amalocalyx microlobus* type) may, therefore, palynologically be a common ancestral character of this subfamily.

Regarding *Ichnocarpus polyanthus* type belonging to Apocyneae, its polypantoporate pollen may evolve from many origins (Figure 5.1). It probably derives from several pollen types of Rauvolfioideae: *Allamanda cathartica* type, *Melodinus cambodiensis* type, or *Kopsia arborea* type. However, it seems most likely that *Ichnocarpus polyanthus* type has evolved from basal porate Apocynoideae. This view is consistent with the phylogenetic relationship presented by Sennblad and Bremer (2002), in which there is no evidence supporting the correlation between Apocyneae and other tribes of subfamily Rauvolfioideae. Therefore, it is hypothesized that *Ichnocarpus polyanthus* type probably evolved in Apocyneae independently from relative taxa.

The presence of unique states of many pollen types not mentioned above suggests that they probably evolved in each subfamily independently from relative taxa.

Finally, in comparison of pollen morphology of traditional Apocynaceae with those of Asclepiadaceae, the Apocynaceae and Asclepiadaceae have already been cited as showing a trend analogous to that in the Orchidaceae from single grains to tetrads and pollinia (Walker, 1976; Endress and Bruyns, 2000; Verhoeven and Venter, 2001). However, in this study, tetrads pollen grains were found in *Melodinus orientalis* type which belong to basal Apocynaceae and also never occurred in the more derived subfamily, Apocynoideae. This suggests that tetrads may be autoapomorphic to *Melodinus*. This view is supported by Sennblad and Bremer (2002) and Van de Ven and Van der Ham (2006). Therefore, the tetrads of *Melodinus* and Periplocoideae of Asclepiadaceae s.str. represent a remarkable case of convergent evolution, or homoplasious in phylogenetic sense.

5.2.3 Implication of pollen morphology for the taxonomy of Apocynaceae s.str. and Asclepiadaceae

Although there are many possible hypotheses of this family proposed by taxonomists, new evidence from more detailed and extensive morphological studies, as well as the rapidly growing of molecular information suggest that the Apocynaceae s.str. and Asclepiadaceae should be grouped together into one family, Apocynaceae s.l. (Civeyrel *et al.*, 1998; Sennblad *et al.*, 1998; Judd *et al.*, 1999; Endress and Bruyns, 2000; Sennblad and Bremer, 2000; Potgieter and Albert, 2001; Sennblad and Bremer, 2002).

Palynologically, Thai Apocynaceae is here considered to be a eurypalynous family by having a great diversity of pollen morphology. This data, therefore, does not support any possibilities of the circumscription of this family. However, pollen morphology of Thai Apocynaceae reveals some evidences suggesting for recognition as one large family, Apocynaceae s.l., by several reasons including: a gradation of aperture character from the Apocynaceae to the Asclepiadaceae; a tendency in morphological changes within family from monad to tetrad and pollinia; and the similarity in exine stratification.

Morphologically, the Apocynaceae and Asclepiadaceae are clearly more similar to each other than to the rest of the Gentianales (Endress and Bruyns, 2000; Verhoeven and Venter, 2001). In this study, there is a gradation from the Apocynaceae to the Asclepiadaceae based on palynological data. There is a phylogenetic line of development that is reflected in pollen structure. The evolutionary trends that can be fallowed are 3- or 4-colporate grains in Rauvolfioideae, which are more primitive than the 3- or 4-porate grains in Apocynoideae. Asclepiadaceae, on the other hand, is characterized by varying of the number of pores from 4- to 6-porate as found in Periplocoideae, to inaperturate in most genera of Secamonoideae and Asclepiadoideae (Verhoeven and Venter, 2001).

These palynological data of Asclepiadaceae could be regarded as more advanced than Apocynoideae s.str. with 4 to 6 pore or inapeturate rather than 3 to 4 as found in Rauvolfioideae and Apocynoideae.

The second reason for merging these two families is the tendency from monad to tetrad pollen grains. In the Apocynaceae s.str., pollen grains are mostly monads and free tetrads. Tetrad are not common in the subfamily Rauvolfioideae, occurring in only five of the 84 genera. Further, they are found in three genera of Apocynoideae (Nilsson, 1986; Endress and Bruyns, 2000; Verhoeven and Venter, 2001; Van de Ven and Van der Ham, 2006). Asclepiadaceae are characterized by having tetrads or pollinia, which are shed onto translators (Verhoeven and Venter, 2001). Among Asclepiadaceae the Periplocoideae are distinguished from other two subfamilies by the the presence of both free tetrad and pollinia, while Secamonoideae and Asclepiadoideae have pollen dispersing in pollinia (Endress and Bruyns, 2000; Verhoeven and Venter, 2001). Due to the presence of free tetrads as found in Apocynaceae s.str. as well as the presence of pollinia as found in the Secamonoideae and Asclepiadoideae, these characters support a position for Periplocoideae intermediate between Apocynaceae s.str. and the more advanced subfamilies of Asclepiadaceae s.str. This argument is also supported by independent studies of morphology (Endress and Bruyns, 2000) as well as molecular phylogeny (Civeyrel *et al.*, 1998; Sennblad *et al.*, 1998; Sennblad and Bremer, 2000; Potgieter and Albert, 2001; Sennblad and Bremer, 2002).

Furthermore, in this study, the exine of Apocynaceae pollen are tripartite, being subdivided into a tectum, columella or infratectum, and nexine. The infratectum is usually indistinct or granulate. This characteristic is similar to those of the Asclepiadaceae pollen. They are characterized by having the exine consisting of a tectum subtended by a granular layer (Verhoeven and Venter, 2001). This suggests a close relationship between these subfamilies based on exine stratification.

Based on arguments above, palynological data from this study are congruent with submerging Asclepiadaceae into Apocynaceae as cladistic analyses and molecular studies suggested.

5.3 Conclusion

There is considerable variation in the pollen morphology of the Thai Apocynaceae, which has been divided into 23 pollen types based on dispersal unit, polarity, apertures, exine structure on the details of ornamentation, size and shape of pollen grains. Rauvolfioideae are palynologically heterogeneous subfamily while Apocynoideae, on the other hand, pollen characters are much more homogeneity.

It seems that pollen morphological evidence is not highly congruent with the current classification for delimitation of existing groups, but it does provide some valuable information. With regard to the subdivision of Apocynaceae by Endress and Bruyns (2000), we can conclude that the subfamily Rauvolfioideae and Apocynoideae can be well characterized by pollen characters. Furthermore, pollen data have proven to be useful for evaluating some generic delimitation within subfamily. Pollen types circumscribe genera or groups of genera, and some subtypes distinguish species. In contrast, it seems to be difficult to differentiate between tribes or species of Thai Apocynaceae on the basis of palynological characters only. Palynological evidence does not agree with the current tribal classification except in the case of the tribe *Wrightieae*. This suggests that the tribes within Rauvolfioideae and Apocynoideae continue to be refined a more data are added.

When the pollen data were included onto the new molecular classification of Sennblad and Bremer (2002), there was little correlation between pollen types and the tribes especially within Rauvolfioideae because the pollen types probably evolved in this subfamily independently from relative taxa. However, on the basis of pollen morphology there is evident supporting the view that subfamily Apocynoideae have evolved from Rauvolfioideae.

In the context of identification, the Apocynaceae is rather eurypalynous family. Although its ornamentation has less diversity, more or less in psilate pattern under the light microscope, but the aperture, shape and size is quite useful for identification. On the basis of pollen morphology, there is good evidence for the identification of different taxonomic ranks in Thai Apocynaceae, even at species level. The most outstanding and unique pollen characteristics of the different taxonomic ranks are summarized in Table 5.3.

The palynological data of Thai Apocynaceae support the view that Asclepiadaceae is not distinct family and it should be considered as a part of Apocynaceae with distinct characteristics.

Table 5.1 Proposed of possible pollen morphological trends of Thai Apocynaceae

Dispersal Unit		
	1.	monad → tetrad
Polarity		
	2.	isopolar → subisopolar / heteropolar
	3.	isopolar → apolar
Symmetry		
	4.	radial symmetry → biradial symmetry → bilateral symmetry
	5.	radial symmetry → asymmetry
Shape		
	6.	spheroidal → oblate → peroblate (included barrel-like grain)
	7.	spheroidal → prolate
Aperture		
	8.	increasing in number of aperture
	9.	decreasing in number of aperture
	10.	zonoaperturate → pantoaperturate
	11.	lalongate endoaperture → endocingulum
	12.	one endoaperture → two or more endoaperture per 1 compound aperture
	13.	colporate with long ectocolpi → colporate with short ectocolpi / pororate → porate
Exine		
	14.	tectate imperforate → tectate perforate → semitectate
Ornamentation		
	15.	psilate → perforate / fossulate → foveolate → microreticulate
	16.	psilate → scabrate / granulate / verrucate

Table 5.2 Distribution of pollen types and some floral characters according to the classification of Endress and Bruyns (2000) (salver = salverform; salver-con = salverform with constricted at throat; infun = infundibuliform; up = stamen inserted at upper half of tube; mid = stamen inserted at middle of tube; low = stamen inserted at lower half of tube; close = stamens unattached but with a close association to the style head)

Subfamily	Tribe	Genus	Pollen type	Corolla form	Stamen position	Stamens	Relationship of stamen and style head
Rauvolfioideae	Alstonieae	*Alstonia*	14,20,21,23	salver	mid	free	separate
	Vinceae	*Catharanthus*	19	salver	up	free	separate
		Kopsia	16, 22	salver	up	free	separate
		Ochrosia	11	salver	up	free	separate
		Rauvolfia	12	salver	up	free	close
	Willughbeeae	*Bousigonia*	23	salver	mid	free	close
		Willughbeia	13	salver	low to mid	free	close
	Tabernaemontaneae	*Tabernaemontana*	18	salver	low to mid	free	separate
	Melodineae	*Melodinus*	8, 17, 23	salver	mid	free	close
	Hunterieae	*Hunteria*	23	salver	up	free	close
	Plumerieae	*Allamanda*	15	infun	mid to up	free	weakly coherent
		Cerbera	10	salver	mid to top	connate	separate
		Plumeria	23	infun	base	free	separate
		Thevetia	9	infun	mid to up	connate	separate but apically across top of pistil
	Carisseae	*Carissa*	23	salver	up	free	close
	Alyxieae	*Alyxia*	1	salver	up	free	close
		Chilocarpus	4	salver	low to mid	free	separate

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Table 5.2 (continued)

Subfamily	Tribe	Genus	Pollen type	Corolla form	Stamen position	Stamens	Relationship of stamen and style head
Apocynoideae	Wrightieae	*Adenium*[1]	7	infun	low to mid	connate	adnate
		Nerium[2]	7	infun	mid	connate	adnate
		Strophanthus[3]	7	infun	up	connate	adnate
		Wrightia[4]	7	subrotate	exserted	connate	adnate
	Malouetieae	*Holarrhena*[5]	7	salver	base	free	separate
		Kibatalia[6]	7	salver	exserted	connate	adnate
		Spirolobium	5	infun	low	free	separate or weakly adnate
	Apocyneae	*Aganonerion*	7	salver	base	free	adnate
		Aganosma	7	salver-con	mid to up	connate	adnate
		Anodendron[7]	2	salver-con	base	connate	adnate
		Beaumontia[8]	7	infun	low but exserted	connate	adnate
		Ichnocarpus[9]	3	salver-con	low to mid	just attached	adnate

Notes:

(1) long and bristle stamen appendages, 1.5 cm acumen

(2) long and twisted pubescent stamen appendage, 7-9 cm

(3) long stamen appendage, exserted from corolla tube

(4) except: *W. dubia* with corolla infundibuliform and stamen completely in corolla tube; corolla salverform in *W. antidysenterica* and *W. sirikitae*

(5) mucronate apex stamen

(6) large bulbous swelling appendage behind anther

(7) villous inside corolla tube, globular style head with apex sharp point

(8) flower showy

(9) globular or cup-shaped style head

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Table 5.2 (continued)

Subfamily	Tribe	Genus	Pollen type	Corolla form	Stamen position	Stamens	Relationship of stamen and style head
Apocynoideae	Apocyneae	*Parameria*	7	salver	base	free	adnate
		Trachelospermum (10)	3	salver	up, exserted or not	connate	adnate
		Urceola (11)	7	infun	base	connate	adnate
		Vallaris (12)	7	infun	exserted	connate	adnate
	Echiteae	*Amalocalyx*	6	infun	mid	just attached	adnate
		Parsonsia	6	salver	exserted	connate	adnate
		Pentalinon	7	infun	mid	connate	adnate

Notes:

(10) globular style head

(11) minute flower

(12) large bulbous swelling appendage behind anther

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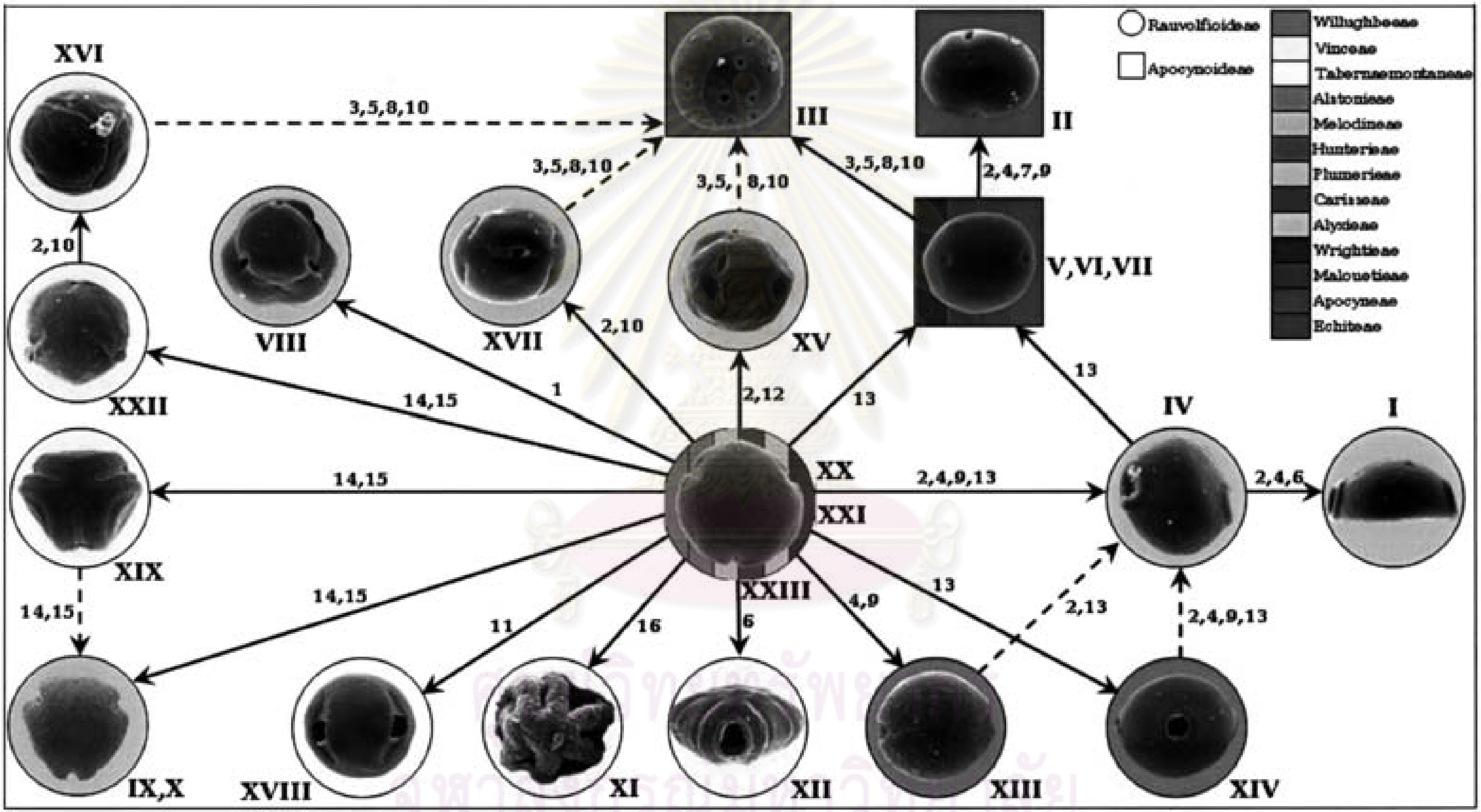

Figure 5.1 The outline representing the relationships of pollen morphological changes of pollen morphology together with pollen types or group of pollen types of Thai Apocynaceae. Solid lines represent the most likely pathway for pollen morphological changes. Dashed lines represent alternative pathway for pollen morphological changes. The numbers at the lines represent pollen morphological trends proposed in Table 5.1. Roman numerals are pollen types as discussed in text.

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Table 5.3 The outstanding pollen characteristics of the different taxonomic ranks

Taxonomic rank	Distinguishing characters
Subfamily	
Rauvolfioideae	colporate pollen, except for Alyxieae with porate
Apocynoideae	porate pollen grains
Tribe	
Alyxieae	diporate, relatively large pori with annulus outwardly thickening of the exine
Genus	
Willughbeia	tricolporate, with very short ectocolpi
Rauvolfia	tricolporate or tricolpate, endoaperture indistinct or invisible, peroblate, pumpkin-like pollen
Tabernaemontana	endoaperture endocingulum, or equatorial diffused ends with very distinct and equatoriales costa endopori or endocinguli
Alyxia	diporate, with very large pori, peroblate, barrel shaped pollen
Anodendron	diporate or dicolpate, small-sized grains, subprolate to prolate, more or less bone-like pollen
Ichnocarpus	polypantoporate with spheroidal pollen shape, psilate to more or less granulate ornamentation
Trachelospermum	polypantoporate with slightly irregular subspheroidal pollen shape, psilate ornamentation
Species	
Catharanthus roseus	Perforate to microreticulate with distinctly psilate at margo of ectocolpi, and granulate to scabrate at the depression of mesocolpium
Ochrosia oppositifolia	fossulate, verrucate or perforate ornamentation
Alstonia angustiloba	dicolporate pollen

Table 5.3 (continued)

Taxonomic rank	Distinguishing characters
Species	
Alstonia rostrata	endoapertures circular with small equatorial extension or horizontal horns
Melodinus orientalis	tetrad pollen
Allamanda cathartica	two or more endoaperture per 1 compound aperture
Thevetia peruviana	microreticulate to perforate ornamentation
Spirolobium cambodianum	inner nexine surface granulate to gemmate at polar area and around equatorial zone, band-like gemmae around the apertures

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APPENDICES

APPENDIX A

A LIST OF VOUCHER SPECIMENS

Specimens are listed alphabetically at species level; abbreviations of herbaria from where specimens were retrieved for pollen collection are in the parentheses.

Adenium obesum (Forsk.) Roem. & Schult. — cultivated in Chulalongkorn University, Bangkok, H.Sittha 06-05 (BCU).

Aganonerion polymorphum Pierre ex Spire — Phu Pan National Park, Sakon Nakorn, H.Sittha 05-14 (BCU); Phu Pan National Park, Sakon Nakorn, H.Sittha 05-16 (BCU); Saraburi, H.Sittha 06-03 (BCU).

Allamanda cathartica L. — cultivated in Chulalongkorn University, Bangkok, H.Sittha 06-25 (BCU).

Aganosma marginata (Roxb.) G.Don — Gow Seng Hill, Songkla, J.F.Maxwell 85-381 (PSU); Klong Hoy Kong, Songkla, J.F.Maxwell 85-937, (PSU); Kao Yai National Park, Nakorn Nayok, H.Sittha 05-07 (BCU); Tad Ton National Park, Chaiyaphum, H.Sittha 06-10 (BCU).

Alstonia angustiloba Miq. — Chat Warin Waterfall, Narathiwat, C.Niyomdham 4113 (BKF).

Alstonia curtisii King & Gamble — Tham Sue, Krabi, R.Pooma et al. 3607 (BKF).

Alstonia macrophylla Wall. ex G.Don — Ko Hong Hill, Songkla, J.F.Maxwell 85-894 (PSU); H&C s.n. (PSU); Kao Kohong, Songkla, C.Hamilton & G.Congdon 82 (BCU).

Alstonia rostrata Fischer — Khao Ko Hong, Songkla, H&C 82 (PSU); P.Sirirugsa 457 (PSU).

Alstonia scholaris (L.) R.Br. — Thung Salaeng Luang National Park, Phitsanulok, G.Murata et al. 38494 (BKF); cultivated in Chulalongkorn University, Bangkok, H.Sittha 06-08 (BCU).

Alyxia reinwardtii Blume — Prince of Sonkhla University, Haad Yai Campus, Songkla, Choathip 80 (PSU); Groong Ching Falls, Nakorn Si Thammarat, J.F.Maxwell 86-565 (PSU); Khoa Nan National Park, Nakorn Si Thammarat, H.Sittha 06-09 (BCU).

Alyxia siamensis Craib — Khao Nan National Park, Nakorn Si Thammarat, H.Sittha 06-49 (BCU).

Alyxia thailandica D.J. Middleton — Khao Yai National Park, Nakorn Nayok, H.Sittha 06-07 (BCU).

Amalocalyx microlobus Pierre ex Spire — Mae Rim, Chiang Mai, H.Sittha 05-12 (BCU).

Anodendron affine (Hook. & Arn.) Druce — Sumoto city, Honshu, Japan, N.Fukuoka & N.Kurosaki 1599 (BKF).

Anodendron coriaceum (Blume) Miq. — Khao Luang National Park, Nakorn Si Thammarat, Plernchit 416 (BKF).

Anodendron paniculatum A.DC. — Khao Yai National Park, Nakhon Nayok, A.Boonkongchart 66 (BKF); J.F.Maxwell 86-233 (PSU).

Beaumontia grandiflora Wall. — Makkasan, Bangkok, H.Sittha 06-01 (BCU).

Beaumontia murtonii Craib — Smitinand 1172 (BKF).

Bousigonia angustifolia Pierre ex Spire — Doi Phuka National Park, Nan, T.Santisuk 6925, (BKF).

Carissa carandas L. — Pak Nam, Samutprakan, Choomsai Sombangse 19 (BCU).

Carissa grandiflora (E.Mey.) A.DC. — cultivated at Ko Hong Post Office, Songkla, Song See 46 (PSU).

Carissa spinarum L. — Lam Narai, Loburi, S.Suddee 45 (BCU); Klong Hoy Kong, Songkla, J.F.Maxwell 86-388 (PSU).

Catharanthus roseus (L.) G.Don — cultivated in Chulalongkorn University, Bangkok, H.Sittha 05-26 (BCU).

Cerbera manghas L. — Ban Bang Chak, Nakorn Si Thammarat, M.Mekanawakul 80-20 (PSU); Sridith K. 835 (PSU); Pathiew, Chumphon, Herb. Trip 819 (BCU).

Cerbera odollam Gaertner — cultivated in Chulalongkorn University, Bangkok, H.Sittha
05-22 (BCU).

Chilocarpus costatus Miq. — Su-ngai Padi, Narathiwat, J.F.Maxwell 87-504 (PSU).

Chilocarpus denudatus Blume — Khao Sok, Surat Thani, K.Larsen et al. 40840 (PSU).

Holarrhena curtisii King & Gamble — Phu Pan National Park, Sakon Nakorn, H.Sittha 05-17 (BCU); Malacca Creek, G.Congdon 503 (PSU).

Holarrhena pubescens Wall. ex G.Don — Khao Yai National Park, Nakorn Nayok, H.Sittha 05-05 (BCU); Saraburi, KKS 078 (BCU).

Hunteria zeylanica (Retz.) Gardner ex Thwaites — Sai Rung Falls, Trang, J.F.Maxwell 87-415 (PSU).

Ichnocarpus polyanthus (Blume) P.I. Forst. — Tunkamang, Chaiyaphum, R.Geesink et al. 7162 (BKF); Pa Hin Ngam National Park, Chaiyaphum, H.Sittha 06-11 (BCU).

Ichnocarpus serpyllifolius (Blume) P.I. Forst. — Khao Chong National Park, Trang, SP 195 (BKF).

Kibatalia arborea (Blume) G.Don — Khao Luang National Park, Nakorn Si Thammarat, Sanan 1054 (BKF).

Kibatalia macrophylla (Pierre ex Hua) Woodson — Doi Chiang Dao, Chiang Mai, J.F.Maxwell 89-575 (BKF).

Kibatalia maingayi (Hook.f.) Woodson — Botanical Gardens, Singapore, Nur SF 35849 (BKF).

Kopsia angustipetala Kerr — Nasaithong, Laos, Th.Wongprasert s.n. (BKF).

Kopsia arborea Blume — cultivated in Kasetsart University, Bangkok, H.Sittha 05-13 (BCU).

Kopsia pauciflora Hook.f., Ba-cho — Narathiwat, SP 8 (BKF).

Kopsia rosea D.J. Middleton — Ao Duck, Krabi, T.Smitinand & E.C.Abbe 6577 (BKF).

Melodinus cambodiensis Pierre ex Spire — Khao Yai National Park, Nakorn Nayok, H.Sittha 05-06 (BCU).

Melodinus cochinchinensis (Lour.) Merr. — Nam Nao National Park, Phetchaboon, S.Nilphanit 12 (BKF), Surat Thani, C.Phengklai et al. 3882 (PSU).

Melodinus orientalis Blume — Khao Luang National Park, Nakorn Si Thammarat, TDBS 12098 (BKF).

Nerium oleander L. — cultivated in Chulalongkorn University, Bangkok, H.Sittha 05-20 (BCU).

Ochrosia oppositifolia (Lam.) K. Schum. — Khao Yai National Park, Nakorn Nayok, H.Sittha 06-48 (BCU).

Parameria polyneura Hook.f. — Bangbao, Trad, T.Smitinand 3805 (BKF).

Parsonsia alboflavescens (Dennst.) Mabb. — R.Geesink & T.Santisuk 5257 (BKF); Tepa, Songkla, J.F.Maxwell 85-418 (PSU).

Pentalinon luteum (L.) B.F. Hansen & Wunderlin — cultivated in Chulalongkorn University, Bangkok, H.Sittha 05-27 (BCU).

Plumeria obtusa L. — cultivated in Chulalongkorn University, Bangkok, H.Sittha 05-28 (BCU).

Plumeria rubra L. — cultivated in Chulalongkorn University, Bangkok, H.Sittha 05-29 (BCU).

Rauvolfia cambodiana Pierre ex Pitard — Nam Nao National Park, Phetchabun, Snong 20 (BKF).

Rauvolfia serpentina (L.) Benth. ex Kurz — Khao Soidao, Chantaburi, FD 246 (BKF).

Rauvolfia sumatrana Jack — Bangkhew, Bangkok, T.Smitinand s.n. (BKF).

Rauvolfia verticillata (Lour.) Baillon — Phu Kradung, Loei, Dee 705 (BKF).

Spirolobium cambodianum Baillon — Prince of Songkhla University, Songkla, K5-24 (PSU); Kuan Kah Long, Satun, J.F.Maxwell 84-77 (PSU).

Strophanthus gratus (Wallich & Hook.) Bail. — cultivated at Muang, Chonburi, H.Sittha 05-24 (BCU).

Strophanthus perakensis Scortechini ex King & Gamble — Bang Plad, Dhonburi, T.Smitinand 5561 (BKF).

Strophanthus wallichii A.DC. — Khao Chong, Trang, SP 88 (BKF); Tarutao National Park, Satun, J.F.Mawell 87-395 (PSU); Adang Island, Satun, Congdon 1220 (PSU).

Tabernaemontana bovina Lour. — Doi Tung, Chiang Rai, T.Smitinand s.n. (BKF).

Tabernaemontana bufalina Lour. — Kood Island, Trad, C.Leeratiwong 2002-73 (PSU).

Tabernaemontana corymbosa Wall. — Phu Wua Wildlife Sanctuary, R.Pooma 1594 (BKF).

Tabernaemontana divaricata (L.) R.Br. ex Roem & Schult. — Muang, Saraburi, Dee 97 (BKF).

Tabernaemontana pandacaqui Poir. — cultivated at Nataree district, Songkla, Pradit 11 (PSU).

Tabernaemontana pauciflora Blume — Khao Soidao, Chiang Mai, T.Santisuk s.n. (BKF).

Tabernaemontana peduncularis Wall. — Khao Chong, Trang, S.D. et al. 1564 (BKF).

Thevetia peruviana (Pers.) K. Schum. — cultivated in Chulalongkorn University, Bangkok, H.Sittha 05-30 (BCU).

Trachelospermum asiaticum (Sieb. & Zucc.) Nakai — Khao Yai National Park, Nakhon Nayok, A.Boonkongchart 62 (BKF).

Trachelospermum lucidum (D.Don) K. Schum. — Saingahmpang, Chiang Mai, J.F.Maxwell 96-540 (BKF).

Urceola lucida (Wall. ex G.Don) Kurz — Ko Hong Hill, Songkla, P.Sirirugsa 771 (PSU); Sichon, Nakorn Si Thammarat, J.F.Maxwell 87-215 (PSU).

Urceola micrantha (Wall. ex G.Don) D.J. Middleton — Kampor, Cambodia, T.Smitinand 6528 (BKF).

Urceola minutiflora (Pierre) D.J. Middleton — Non Sang, Udon Thani, K.Bunchuai 1638 (BKF).

Urceola rosea (Hook. & Arn.) D.J. Middleton — Ton Nga Chang Wildlife Sanctuary, Songkla, C.Leeratiwong 2002-126 (PSU); Sai Kow Falls, Pattani, J.F.Maxwell 85-728 (PSU).

Vallaris glabra (L.) O. Kuntze — cultivated in Chulalongkorn University, Bangkok, H.Sittha 05-21 (BCU); Suan Jidlada, Bangkok, H.Sittha 06-06 (BCU).

Vallaris solanacea (Roth) O. Kuntze — Phu Kradung, Loei, Dee 418 (BKF).

Willughbeia coriacea Wall. — Gahrome Falls, Nakorn Si Thammarat, W.Ramsri 102 (PSU); Khao Yai National Park, Nakorn Nayok, H.Sittha 05-09 (BCU).

Willughbeia edulis Roxb. — Matong, Chantaburi, Chit 310 (BKF).

Willughbeia grandiflora Dyer ex Hook.f. — Ton Deang Peat Swamp Forest, Narathiwat, C.Niyomdham 4982 (BKF); Su-ngai Padi, Narathiwat, J.F.Maxwell 87-588 (PSU).

Wrightia antidysenterica (L.) R. Br. — cultivated in Chulalongkorn University, Bangkok, H.Sittha 05-31 (BCU).

Wrightia arborea (Dennst.) Mabb. — Tad Ton National Park, Chaiyaphum, H.Sittha 06-02 (BCU).

Wrightia dubia (Sims) Spreng. — Sai Roong Falls, Trang, J.F.Maxwell 87-413 (PSU); Ronphibun, Nakorn Si Thammarat, H.Sittha 05-10 (BCU).

Wrightia laevis Hook.f. — Gahrome Falls, Nakorn Si Thammarat, J.F.Maxwell 85-393 (PSU); Khao Nan National Park, Nakorn Si Thammarat, KNP 056 (BCU).

Wrightia lanceolata Kerr — Sam Roi Yot, Ratchaburi, K.Larsen et al. 1203 (BKF).

Wrightia pubescens R.Br. — Prince of Songkhla University, Haad Yai Campus, Songkla, J.F.Maxwell 85-410 (PSU); J.F.Maxwell 85-410 (PSU); Saraburi, H.Sittha 05-32 (BCU); cultivated in Chulalongkorn University, Bangkok, H.Sittha 06-04 (BCU).

Wrightia religiosa Benth. ex Kurz — cultivated in Chulalongkorn University, Bangkok, H.Sittha 05-33 (BCU).

Wrightia sirikitae D.J.Middleton & Santisuk — Wat Phraphuttabat, Saraburi, Th.Wongprasert 012-02 (BKF).

Wrightia viridiflora Kerr — Sai Yok, Kanchanaburi, TDBS 10457 (BKF).

APPENDIX B

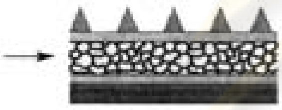
GLOSSARY

Definitions of pollen characters used in this study modified from Punt *et al.* (2007). Terminologies are listed alphabetically.

Acetolysis

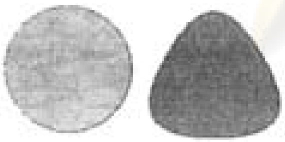
A widely used technique for preparing pollen and spore exines for study.

Alveolate (adj.)



Describing a type of sexine/ectexine structure, in which the infratectal layer is characterised by partitions forming compartments of irregular size and shape.

Amb

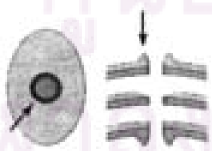


The outline of a pollen grain or spore seen in polar view.

Angulaperturate (adj.)

Describing an equatorially aperturate pollen grain with the apertures situated at the angles of the outline in polar view.

Annulus (pl. annuli, adj. annulate)

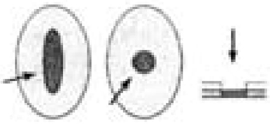


An area of the exine surrounding a pore that is sharply differentiated from the remainder of the exine, either in ornamentation or thickness.

Aperture (adj. aperturate)

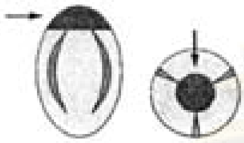
A specialized region of the pollen wall, that is thinner than the remainder of the sporoderm and generally differs in ornamentation and/or in structure.

Aperture membrane



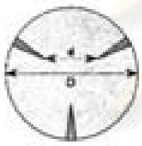
The exine which forms the floor of an ectoaperture.

Apocolpium (pl. apocolpia)



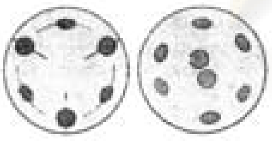
A region at the pole of a zonocolpate pollen grain delimited by lines connecting the apices of the colpi.

Apocolpium index



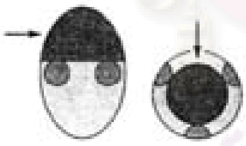
The ratio of the distance between the apices of two ectocolpi (d) of a zonocolpate pollen grain to its equatorial diameter (D). Synonym of polar area index.

Apolar (adj.)



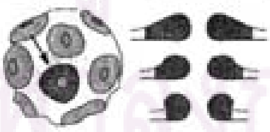
Describing pollen and spores without distinct polarity.

Apoporium (pl. apoporia)



An area at the pole of a zonoporate pollen grain that is delimited by a line connecting the borders of the pores.

Aspis (pl. aspides, adj. aspidate)

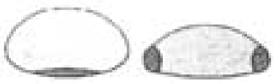


A prominently protruding thickening of the exine around a pore.

Atectate (adj.)

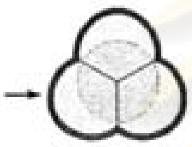
Describing pollen grains that have an exine with little or no internal structure.

Bilateral (adj.)



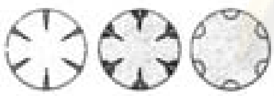
Describing pollen and spores having a single, principal plane of symmetry.

Calymmate (adj.)



Describing tetrads or polyads in which the sexine/ectexine of each monad is well differentiated and forms a continuous envelope around the unit.

Circumaperturate (adj.)

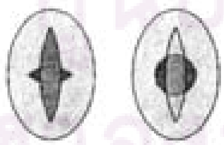


Describing a pollen grain with equatorial apertures that are regularly arranged around a circular outline.

Coaperturate (adj.)

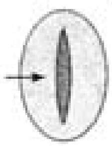
Describing permanent tetrads in which the apertures of neighbouring monads join.

Colporus (pl. colpori, adj. colporate)



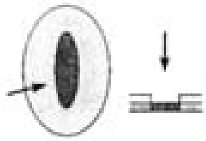
A compound aperture consisting of an ectocolpus with one or more endoapertures.

Colpus (pl. colpi, adj. colpate)



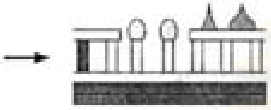
An elongated aperture with a length/breadth ratio greater than 2.

Colpus membrane



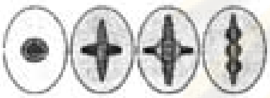
The aperture membrane of a colpus.

Columella (pl. columellae, adj. columellate)



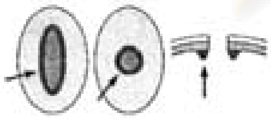
A rod-like element of the sexine/ectexine, either supporting a tectum.

Compound aperture



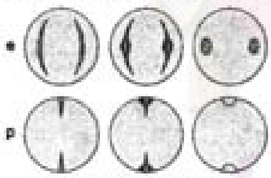
An aperture with two or more components that are situated in more than one wall layer.

Costa (pl. costae, adj. costate)



A thickening of the nexine/endexine bordering an endoaperture, or following the outline of an ectoaperture.

Dicolpate, dicolporate, diporate (adj.)



Describing pollen grains with two ectocolpi, two compound apertures or two pores.

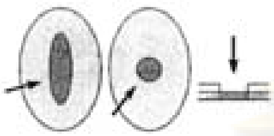
Dispersal unit

The morphological unit in which mature pollen grains or spores are shed, which may range from individuals (monads), to pairs (dyads), groups of four (tetrads), or groups of more than four (polyads). Larger, indeterminate numbers of pollen grains or spores may also be dispersed as pollinia or massulae.

Distal (adj.)

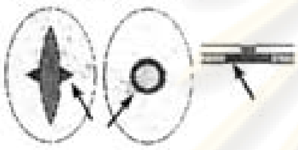
A common descriptive term used in contrast to proximal, applied in palynology to features on the surface that face outward in the tetrad stage.

Ectoaperture



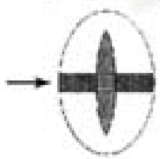
An aperture in the outer layer of the sporoderm.

Endoaperture



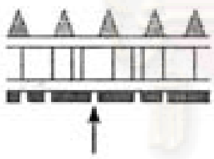
An aperture in the inner layer of the sporoderm, often the inner aperture of a compound aperture.

Endocingulum (pl. endocingula, adj. endocingulate)



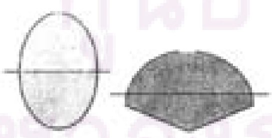
A ring-shaped endoaperture continuous around a pollen grain and lying in the equatorial plane.

Endocrack



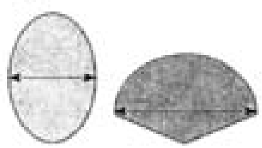
An irregular groove occurring in the inner surface of the nexine/endexine and readily apparent in acetolysed pollen.

Equator



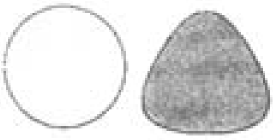
The dividing line between the distal and proximal faces of a pollen grain or spore.

Equatorial diameter



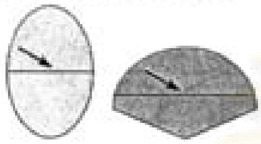
A line, lying in the equatorial plane, perpendicular to the polar axis and passing through it.

Equatorial outline



General description of the equator when a pollen grain is seen in polar view.

Equatorial plane

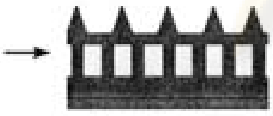


The plane perpendicular to the polar axis and lying midway between the poles.

Eurypalynous (adj.)

Describing plant taxa characterized by possession of a great diversity of palynomorphs.

Exine (pl. exines, adj. exinal, exinous)

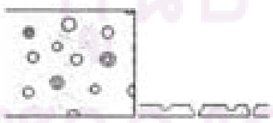


The outer layer of the wall of a palynomorph, which is highly resistant to strong acids and bases, and is composed primarily of sporopollenin.

Fossula (pl. fossulae, adj. fossulate)

A feature of ornamentation consisting of an elongated, irregular groove in the surface.

Foveola (pl. foveolae, adj. foveolate)

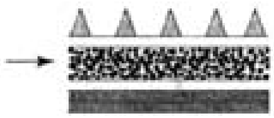


A feature of ornamentation consisting of more or less rounded depressions or lumina more than 1µm in diameter. The distance between foveolae is greater than their breadth.

Gemma (pl. gemmae, adj. gemmate)

A sexine element which is constricted at its base, higher than 1µm, and that has approximately the same width as its height.

Granular exine



A type of exine stratification in which the infratectal layer is composed of more or less rounded, granules rather than of columellae or other structures.

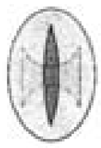
Granulum (pl. granula, adj. granulate, granulose)

A very small and rounded element of the sexine/ectexine that is less than 1µm in all directions.

Harmomegathy (adj. harmomegathic)

The process by which pollen grains and spores change in shape to accommodate variations in the volume of the cytoplasm caused by changing hydration.

H-endoaperture

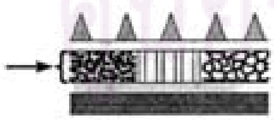


An elaborate endoaperture, consisting of a central part which connects two lateral, longitudinal elongations, forming an "H" shape.

Heteropolar (adj.)

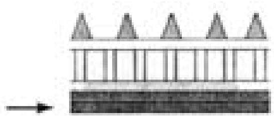
Describing pollen or spores in which the distal and proximal faces of the exine are different, either in shape, ornamentation or apertural system.

Infratectum (pl. infratecta, adj. infratectate)



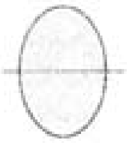
A general term for the layer beneath the tectum, which may be alveolar, granular, columellar, or structureless.

Intine



The innermost of the major layers of the pollen grain wall underlying the exine and bordering the surface of the cytoplasm.

Isopolar (adj.)



Describing a pollen grain or spore in which the proximal and distal faces of the exine are alike.

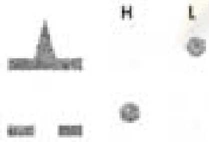
Lalongate (adj.)

Describing the shape of a transversely elongated endoaperture.

Limb

Synonym of equatorial outline.

LO-analysis

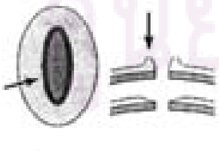


A method for analyzing patterns of sexine organization by means of light microscopy.

Lolongate (adj.)

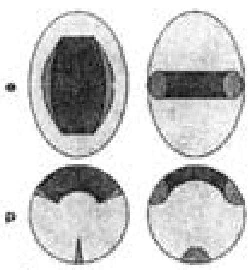
Describing the shape of a longitudinally elongated endoaperture.

Margo (pl. margines, adj. marginate)



An area of exine around an ectocolpus that is differentiated from the remainder of the sexine, either in ornamentation or by difference in thickness.

Mesocolpium (pl. mesocolpia) and **Mesoporium** (pl. mesoporia)



The area of a pollen grain surface delimited by lines between the apices of adjacent colpi or the margins of adjacent pores.

Microreticulum (adj. microreticulate)

A reticulate ornamentation consisting of muri and lumina smaller than 1μm.

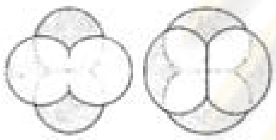
Microspore

A general term for the smaller spores of heterosporous plants that is the spores from which the microgametophyte develops.

Monad

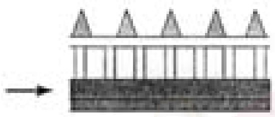
A pollen grain or spore dispersed as an individual unit, rather than in association with others, such as in a dyad, tetrad or polyad.

Multiplanar tetrad



A tetrad in which the individual members are arranged in more than one plane.

Nexine



The inner, non-sculptured part of the exine which lies below the sexine.

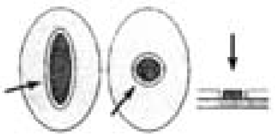
Oblate (adj.)

Describing the shape of a pollen grain or spore in which the polar axis is shorter than the equatorial diameter.

Oblate spheroidal (adj.)

Describing the shape of a pollen grain or spore in which the ratio between the polar axis and the equatorial diameter is 0.88-1.00.

Operculum (pl. opercula, adj. operculate)



A distinctly delimited sexine/ectexine structure which covers part of an ectoaperture and which is completely isolated from the rest of the sexine.

Optical (cross-) section

The image seen in optical microscopy when the plane of focus is half way through a palynomorph.

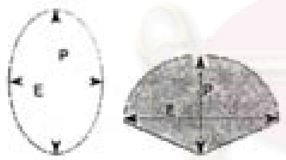
Ornamentation

A general term that is useful for describing the organization of features.

Os (pl. ora, adj. orate)

Synonym of endoaperture.

P/E ratio



The ratio of the length of the polar axis (P) to the equatorial diameter (E).

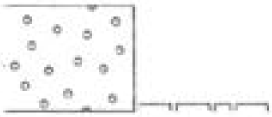
Palynology

The study of pollen grains and spores and of other biological materials that can be studied by means of palynological techniques.

Pantoaperturate (adj.)

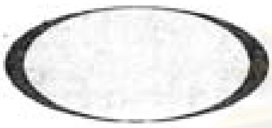
Describing a pollen grain with apertures spread over the surface sometimes forming a regular pattern.

Perforate (adj.)



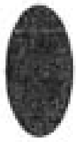
A general adjective indicating the presence of holes, applied in palynology to holes less than 1μm in diameter and generally situated in the tectum.

Peroblate (adj.)



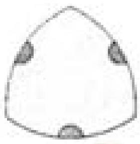
Describing the shape of a pollen grain or spore in which the ratio between the polar axis and the equatorial diameter is less than 0.50.

Perprolate (adj.)



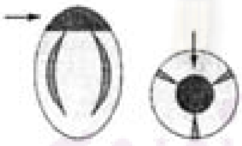
Describing the shape of a pollen grain or spore in which the ratio between the polar axis and the equatorial diameter is more than 2.

Planaperturate (adj.)



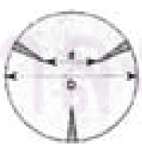
Describing a pollen grain with an angular outline, in which the apertures are situated in the middle of the sides when seen in polar view, rather than at the angles.

Polar area



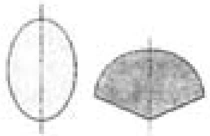
Synonym of apocolpium.

Polar area index (pl. polar area indices)



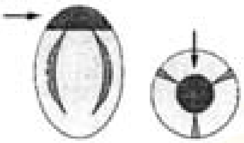
Synonym of apocolpium index.

Polar axis (pl. polar axes)



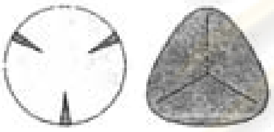
The straight line between the distal and proximal poles of a pollen grain or spore.

Polar field



Synonym of apocolpium.

Polar view

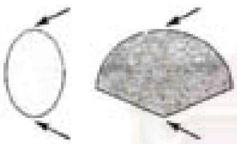


A view of a pollen grain or spore in which the polar axis is directed towards the observer.

Polarity

The condition of having distinct poles.

Pole



Either of the two extremities of the polar axis.

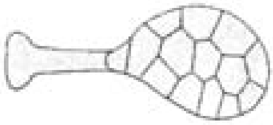
Pollen

The microgametophyte of seed plants developed from the microspore.

Pollen type

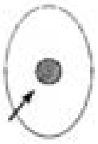
A pollen morphological category, subsidiary to a pollen class, and including pollen grains which can be distinguished either by one distinct character or by a unique combination of characters.

Pollinium (pl. pollinia)



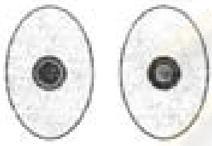
A general term for aggregations of many pollen grains which form dispersal units.

Pore (pl. pores, adj. porate)



A general term, applied in palynology to a circular or elliptic aperture with a length/breadth ratio less than 2.

Pororate (adj.)



Describing a pollen grain with compound apertures in which both the ectoaperture and the endoaperture are pores and the two are not congruent.

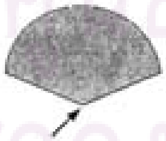
Prolate

Describing the shape of a pollen grain or spore in which the polar axis is larger than the equatorial diameter.

Prolate spheroidal

Describing the shape of a pollen grain or spore in which the ratio between the polar axis and the equatorial diameter is 1.00-1.14.

Proximal pole



The centre of the proximal face.

Pseudoaperture (adj. pseudoaperturate)

A thinning of the exine which, although superficially resembling an aperture, is not associated with a thickening of the intine and is presumed not to function as an exitus.

Pseudocolpus (pl. pseudocolpi, adj pseudocolpate)

A colpus-like pseudoaperture.

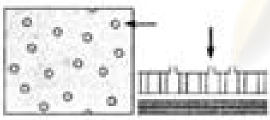
Pseudopore (pl. pseudopores, adj. pseudoporate)

A pore-like pseudoaperture.

Psilate (adj.)

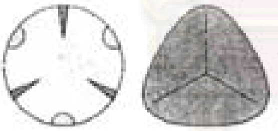
Describing a pollen or spore with a smooth surface.

Punctum (pl. puncta, adj. punctate)



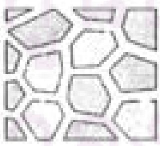
A rounded or elongate tectal perforation, less than 1μm in length or diameter.

Radially symmetric (adj.)



Describing a pollen grain or spore with two or more vertical planes of symmetry, but, if only two such planes are present, then their axes are of equal length.

Reticulum (pl. reticula, adj. reticulate)



A network-like pattern consisting of lumina or other spaces wider than 1μm bordered by elements narrower than the lumina.

Scabrate (adj.) (sing. scabra, pl. scabrae)

Describing elements of ornamentation, of any shape, smaller than 1μm in all directions.

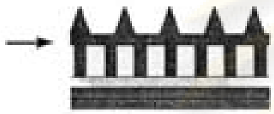
Sculpturing (adj. sculptured)

The surface relief, or topography, of a pollen grain or spore.

Semitectum (adj. semitectate)

A partially discontinuous tectum in which the tectal perforations are equal to or wider than the muri and usually larger than 1μm in diameter.

Sexine



The outer, sculptured layer of the exine, which lies above the nexine.

Shape classes (pl.)

Categories of pollen and spore shape based on the relations between polar axis (P) and equatorial diameter (E).

Spheroidal

Describing the shape of a pollen grain or spore in which the polar axis and the equatorial diameter are approximately equal.

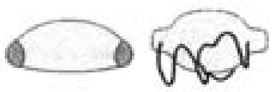
Sporopollenin

The name given to the acetolysis resistant biopolymers which make up most of the material of the exine.

Stenopalynous (adj.)

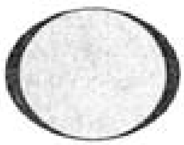
Describing plant taxa characterized by only a slight variation in their palynomorphs.

Subisopolar (adj.)



Describing a pollen grain or spore in which the proximal and distal faces are slightly different.

Suboblate (adj.)

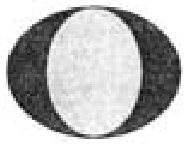


Describing the shape of a pollen grain or spore in which the ratio between the polar axis and the equatorial diameter is 0.75-0.88.

Subprolate (adj.)

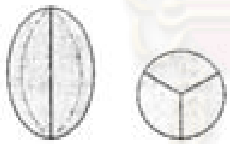
Describing the shape of a pollen grain or spore in which the ratio between the polar axis and the equatorial diameter is 1.14-1.33.

Subspheroidal (adj.)



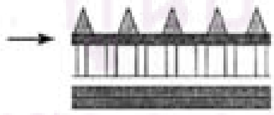
Describing the shape of a pollen grain or spore in which the ratio between the polar axis and the equatorial diameter is 0.75-1.33.

Syncolp(or)ate (adj.)



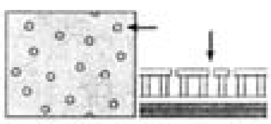
Describing a pollen grain with two or more simple (or compound) colpi the ends of which anastomose at the pole.

Tectum (pl. tecta, adj. tectate)



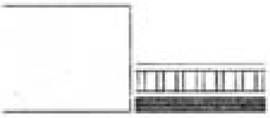
The layer of sexine, which forms a roof over the columellae, granules or other infratectal elements.

Tectum perforatum (adj. tectate perforate)



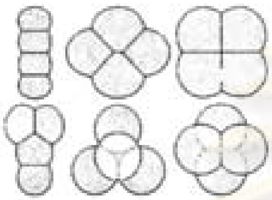
A tectum with perforations smaller than 1μm in diameter.

Tectum imperforatum (adj. tectate imperforate)



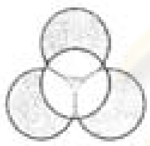
With a continuous tectum, without perforations.

Tetrad



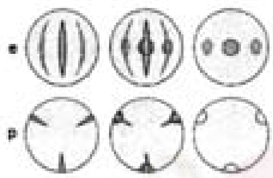
A general term for a group of four united pollen grains or spores, either as a dispersal unit or as a developmental stage.

Tetrahedral tetrad



A multiplanar tetrad in which each member is in contact with three others, so that the centers of the grains define a tetrahedron.

Tricolpate, tricolporate, triporate (adj.)

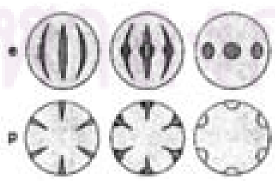


Describing pollen grains with three ectocolpi, three compound apertures or three pores.

Verruca (pl. verrucae, adj. verrucate)

A wart-like sexine element, more than 1µm wide, that is broader than it is high and is not constricted at the base.

Zonoaperturate (adj.)



Describing a pollen grain with apertures situated only at the equator.

BIOGRAPHY

Miss Hathaikarn Sittha was born in Nakorn Si Thammarat Province, Thailand, on 22nd March, 1982. She earned her Bachelor Degree of Science (Biology) from the Department of Biology, Faculty of Science, Prince of Songkla University, Songkhla, in 2004. Then, she continued her study for Master of Science in Department of Botany, Faculty of Science, Chulalongkorn University in 2005-2008.