

## Pollen Characteristics of *Polygala*, *Salomonina* and *Xanthophyllum* (Polygalaceae) in Thailand

PUNTIWA KRACHAI<sup>1</sup>, PRANOM CHANTARANOTHAI<sup>1\*</sup> AND NARUMOL PIWPUAN<sup>2</sup>

<sup>1</sup>*Applied Taxonomic Research Center, Department of Biology, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand*

<sup>2</sup>*Department of Science and Technology, Nong Khai Campus, Khon Kaen University, Nong Khai 43000, Thailand*

**ABSTRACT.**– The pollen morphology was investigated in 20 species of *Polygala*, *Salomonina* and *Xanthophyllum* (Polygalaceae) by means of light microscopy (LM) and scanning electron microscopy (SEM). Characteristics regarded as particularly distinctive include pollen symmetry, polar type and the sculpturing pattern at the apocolpium. Based on pollen morphology, *Xanthophyllum* should not be raised up to the level of a distinct familial taxa.

**KEY WORDS:** Pollen, *Polygala*, *Salomonina*, *Xanthophyllum*, Thailand

### INTRODUCTION

The family Polygalaceae belongs to order Polygales and is comprised of 18 genera with *ca.* 1,000 species worldwide. Most species are widely represented in the temperate and tropical regions, and the family is divided into three tribes, Polygaleae, Moutabeae and Xanthophylleae (Hutchinson, 1967). The last tribe is considered to be a separate family, Xanthophyllaceae, by Cronquist (1981), whereas Heywood et al. (2007) classified the Polygalaceae into four tribes viz Polygaleae, Carpolobieae, Moutabeae and Xanthophylleae. Only representative species from the tribes Polygaleae and Xanthophylleae are present in Thailand,

with five genera and 36 species. Within Thailand the Polygaleae tribe contains four genera: *Epirixanthes*, *Polygala*, *Salomonina* and *Securidaca*, whilst the Xanthophylleae has one genus, *Xanthophyllum* (Pendry, 2001). Some species of Thai Polygalaceae have medicinal uses, such as *Polygala chinensis*, *Salomonina cantoniensis*, *S. longicilliata* and *Xanthophyllum lanceatum* (Mahidol University Foundation, 2000).

The pollen morphology of Polygalaceae has not been extensively examined. Only a few species were described by Erdtman (1966), Paiva and Santos Dias (1990) and Furness and Stafford (1995). Pollen grains of Polygalaceae are zonocolporate, suboblate to subprolate and often with obscure exine stratification (Erdtman, 1966). The pollen morphology of the family has never been studied in Thailand and, therefore, the aims of the present work are to classify, describe

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\* Corresponding author:

Tel: (6643)-342-908

Fax: (6643)-364-169

Email: pranom@kku.ac.th

**TABLE 1.** Pollen morphology of Thai Polygalaceae (Apo = apocolpium, CL = colpi length, E = equatorial axis, Ex = exine thickness, Me = mesocolpium, SP = sculpturing pattern, P = polar axis, ret = reticulate, retD = reticulate with depression, rug = rugulate).

Taxa	Type	Polarity	Symmetry	Amb	shape	P ( $\mu\text{m}$ )
<b>Tribe Polygaleae</b>						
<i>Polygala</i>						
<i>Polygala</i> section <i>Pseudosemiocardium</i>						
<i>P. cardiocarpa</i>	G-I	heteropolar	bilateral	oblate	oblate	23-29 (26.3 $\pm$ 1.9)
<i>P. malesiana</i>	G-I	heteropolar	bilateral	oblate	oblate	25-30 (27.8 $\pm$ 1.6)
<i>P. umbonata</i>	G-I	heteropolar	bilateral	oblate	oblate	13-20 (17.9 $\pm$ 1.7)
<i>Polygala</i> section <i>Chamaebuxus</i>						
<i>P. arillata</i>	G-IITIIIA	isopolar	radial	circular	suboblate	42-51 (46.1 $\pm$ 2.3)
<i>P. karensium</i>	G-I	heteropolar	bilateral	oblate	oblate	34-46 (41.0 $\pm$ 3.4)
<i>P. venosa</i>	G-IITIIIB	isopolar	radial	circular	subprolate	50-64 (56.1 $\pm$ 4.4)
<i>Polygala</i> section <i>Polygala</i>						
<i>P. chinensis</i>	G-IITIIIA	isopolar	radial	circular	subprolate	29-39 (33.8 $\pm$ 2.6)
<i>P. erioptera</i>	G-IITI	isopolar	radial	circular	oblate-spheroidal	19-27 (22.0 $\pm$ 2.0)
<i>P. longifolia</i>	G-IITIIIA	isopolar	radial	circular	prolate	29-55 (39.0 $\pm$ 8.8)
<i>P. persicariifolia</i>	G-IITI	isopolar	radial	circular	oblate-spheroidal	32-38 (34.6 $\pm$ 1.7)
<i>P. polifolia</i>	G-IITI	isopolar	radial	circular	prolate	31-44 (40.8 $\pm$ 4.0)
<i>P. triflora</i>	G-IITIIIA	isopolar	radial	circular	subprolate	37-46 (40.8 $\pm$ 3.9)
<i>Salomonina</i>						
<i>S. cantoniensis</i>	G-IITI	isopolar	radial	circular	subprolate	30-39 (33.0 $\pm$ 2.6)
<i>S. ciliata</i>	G-IITI	isopolar	radial	circular	oblate-spheroidal	33-40 (35.0 $\pm$ 2.0)
<i>S. kradungensis</i>	G-IITI	isopolar	radial	circular	oblate-spheroidal	37-48 (41.3 $\pm$ 3.0)
<i>S. longiciliata</i>	G-IITI	isopolar	radial	circular	oblate-spheroidal	27-35 (31.2 $\pm$ 2.8)
<i>S. thailandica</i>	G-IITI	isopolar	radial	circular	oblate-spheroidal	35-48 (40.4 $\pm$ 3.2)
<b>Tribe Xanthophylleae</b>						
<i>Xanthophyllum</i>						
<i>X. ellipticum</i>	G-IITIIIB	isopolar	radial	circular	prolate-spheroidal	26-33 (28.8 $\pm$ 1.7)
<i>X. geesinkii</i>	G-IITIIIB	isopolar	radial	circular	suboblate	22-29 (24.8 $\pm$ 1.8)
<i>X. lanceatum</i>	G-IITIIIB	isopolar	radial	circular	oblate-spheroidal	25-33 (28.2 $\pm$ 2.8)

and illustrate the pollen morphology of the Thai Polygalaceae.

## MATERIALS AND METHODS

The pollen from 20 taxa of Polygalaceae in Thailand were collected in the field by the third author and examined by light microscopy (LM) and scanning electron microscopy (SEM). The pollen was prepared according to the standard method of acetolysis (Erdtman, 1966). For LM, pollen was mounted in silicone oil and sealed with paraffin. Measurements were based on 15 pollen grains per species. The polar axis (P), equatorial axis (E), exine thickness (EX),

colpus length (CL) and number of colpi (NC) were recorded. For SEM, acetolysed pollen grains were suspended in a drop of absolute alcohol, then transferred to stubs and coated with gold-palladium mixture. SEM micrographs were taken with Leo 1450VP SEM. Descriptive terminology is according to Erdtman (1966).

## RESULTS

### General pollen description

The family Polygalaceae pollen is monad, isopolar or heteropolar, radially or bilaterally symmetric, zonocolporate, small to large-sized (P = 13 - 64  $\mu\text{m}$ , E = 20 - 78  $\mu\text{m}$ ) and oblate to prolate in shape. The

TABLE 1. Cont.

E (µm)	Number of apertures	CL (µm)	Ex (µm)	SP	
				Me	Apo
44-58 (51.0±3.8)	20-24 (21.8±1.3)	12-16 (13.8±1.3)	2-3 (2.1±0.3)	psilate	retD
48-66 (54.1±4.4)	24-29 (27.6±1.4)	13-18 (15.2±1.7)	2-3 (2.2±0.4)	psilate	retD
30-37 (34.3±2.3)	22-27 (24.4±1.6)	7-11 (8.8±1.01)	1-2 (1.8±0.2)	psilate	retD
49-57 (53.4±2.8)	16-20 (17.3±0.9)	30-38 (33.6±1.8)	6-10 (7.1±1.3)	psilate	psilate
58-78 (67.8±7.2)	19-21 (20.2±0.6)	19-30 (24.7±4.0)	3-5 (4.3±0.6)	psilate	retD
40-49 (44±3.2)	11-14 (12.4±1.0)	33-40 (35.8±2.3)	3-6 (4.4±0.9)	psilate	psilate
26-33 (28.0±3.1)	20-22 (21.4±1.0)	22-32 (25.3±2.8)	4-6 (5.0±0.5)	psilate	psilate
20-28 (23.0±2.0)	17-22 (19.0±1.7)	16-22 (17.9±1.4)	3-5 (4.0±0.5)	psilate	ret
22-29 (23.6±1.7)	21-27 (24.0±2.0)	5-10 (6.8±1.5)	5-6 (5.3±0.4)	psilate	psilate
31-40 (34.6±3.1)	15-18 (16.6±0.8)	23-29 (25.0±1.5)	4-7 (5.2±0.7)	psilate	ret
22-28 (24.0±1.6)	25-30 (27.2±1.4)	20-32 (26.6±3.6)	5-7 (5.8±0.6)	psilate	ret
30-39 (33.8±2.9)	19-23 (21.4±1.1)	25-32 (27.2±2.3)	5-8 (6.6±0.8)	psilate	psilate
23-30 (25.3±2.0)	18-23 (21.1±1.1)	19-28 (23.0±2.6)	3-6 (5.0±0.8)	psilate	ret-ru
31-41 (35.9±2.7)	12-16 (13.9±1.0)	20-26 (23.0±2.0)	4-7 (5.8±0.9)	psilate	ret-ru
33-48 (42.7±4.7)	12-14 (12.5±0.6)	21-33 (27.93±3.0)	5-8 (6.2±1.0)	psilate	ret-ru
28-38 (33.3±2.6)	10-13 (12.1±0.6)	17-23 (20.2±1.5)	4-7 (5.0±0.8)	psilate	ret-ru
36-50 (41.4±3.9)	11-13 (12.4±0.6)	20-31 (25.3±3.5)	5-9 (6.7±1.1)	psilate	ret-ru
23-29 (26.0±1.8)	7-9 (8.13±0.5)	19-25 (21.2±1.7)	2-4 (2.6±0.5)	psilate	psilate
28-32 (29.4±1.4)	9-10 (9.7±0.4)	16-21 (18.2±1.2)	4-5 (4.6±0.5)	psilate	psilate
26-37 (31.5±3.4)	9-11 (9.7±0.7)	19-25 (20.9±1.9)	2-5 (3.4±0.7)	psilate	Psilate

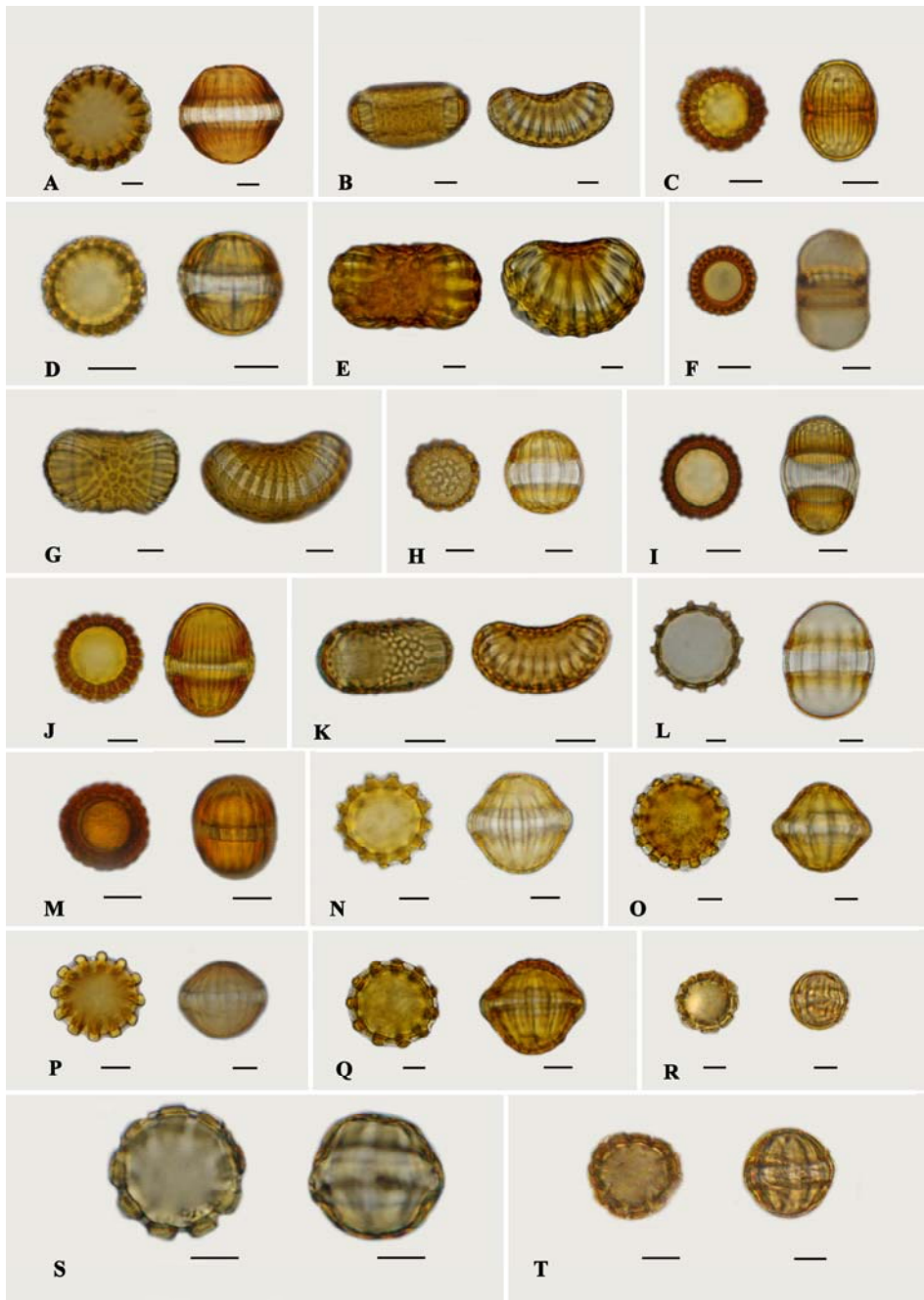
exine stratification is mostly obscure, 1 - 10 µm in thickness. The pollen has a psilate surface on the mesocolpium. Three exine sculpturing patterns at the apocolpium are present within the genera studied. All species in the *Polygala* section *Pseudosemeiocardium* and *P. karenium* have aperturoid depression, whereas psilate is found in all species of *P. arillata*, *P. chinensis*, *P. longifolia*, *P. triflora*, *P. venosa* and *Xanthophyllum*, and reticulate or reticulate-rugulate is found in most species of *Polygala* section *Polygala*. The pollen morphology is summarized in Table 1.

***Polygala*:** The pollen grains are mostly oblate or subprolate, less frequently oblate-spheroidal, prolate or suboblate, P = 13 - 64 µm; E = 20 - 78 µm. The number of

apertures varies from 11 - 30 with 5 - 40 µm long colpi and 1 - 10 µm thick exines (Fig. 1A - L).

***Salomonina*:** The pollen grains are mostly oblate-spheroidal, rarely subprolate, P = 27 - 48 µm; E = 23 - 50 µm. The number of apertures is 10 - 23 with 17 - 33 µm long colpi and 3 - 9 µm thick exines (Fig. 1M - Q).

***Xanthophyllum*:** The pollen grains are oblate-spheroidal, suboblate or prolate-spheroidal, P = 22 - 33 µm; E = 23 - 37 µm. The number of apertures is 7 - 11 with 16 - 25 µm long colpi and 2 - 5 µm thick exines (Fig. 1R - T).



**FIGURE 1.** LM micrographs showing Polygalaceae pollen in polar view and equatorial view. A) *P. arillata*, B) *P. cardiocarpa*, C) *P. chinensis*, D) *P. erioptera*, E) *P. karenium*, F) *P. longifolia*, G) *P. malesiana*, H) *P. persicariifolia*, I) *P. polifolia*, J) *P. triflora*, K) *P. umbonata*, L) *P. venosa*, M) *S. cantoniensis*, N) *S. ciliata*, O) *S. kradungensis*, P) *S. longiciliata*, Q) *S. thailandica*, R) *X. ellipticum*, S) *X. gesinkii*, T) *X. lanceatum*. Scale bars = 10  $\mu$ m.

## DISCUSSION AND CONCLUSION

The present study shows that the main characteristic features of pollen of *Polygala*, *Salomonina* and *Xanthophyllum* are isopolar, radially symmetric, suboblate to subprolate in shape, a zonocolporate aperture in all genera, with a variable number of apertures between and within species. The exine sculpturing pattern is psilate on the mesocolpium and with or without depression at the poles. These characters agree well with those reported earlier for Polygalaceae (Erdtman, 1966; Paiva & Santos Dias, 1990 and Furness & Stafford, 1995). Furthermore, a heteropolar grain, bilateral symmetry, oblate or prolate in shape and reticulate or reticulate-rugulate sculpturing pattern at apocolpium are additional informative characters that have never been reported previously

The pollen shape of all species studied was mostly circular in polar view and oblate-spheroidal in equatorial view, but subprolate, suboblate, prolate or prolate-spheroidal shapes can also be found in a few species.

Two pollen groups can be established on the basis of the polar type and pollen symmetry.

**Group I:** This group has heteropolar grain and bilateral symmetry. The pollen morphology of this group is represented in all species of the *Polygala* section *Pseudosemeiocardium* (*P. cardiocarpa*, *P. malesiana* and *P. umbonata*) and *P. karensium* in the section *Chamaebuxus* (Fig. 2A - D),  $P = 13 - 46 \mu\text{m}$ ,  $E = 30 - 78 \mu\text{m}$ . The smallest size was found in *P. umbonata* ( $P = 13 - 20 \mu\text{m}$ ,  $E = 30 - 37 \mu\text{m}$ ), and the largest in *P. karensium* ( $P = 34 - 46 \mu\text{m}$ ,  $E = 58 - 78 \mu\text{m}$ ). The number of apertures varied

from 19 to 29, the exine is  $1-5 \mu\text{m}$  thick with a psilate sculpturing pattern on the mesocolpium but a reticulate sculpturing pattern with depression at the apocolpium.

The members of this group are also supported by anatomical studies. Piwpuan (2007) reported that the leaf surface of this group has a unicellular trichome which is spine-like, but this does not agree well with the morphological classification.

**Group II:** This group has an isopolar grain and radial symmetry, and can also be divided into 2 types based on the sculpturing pattern at the apocolpium.

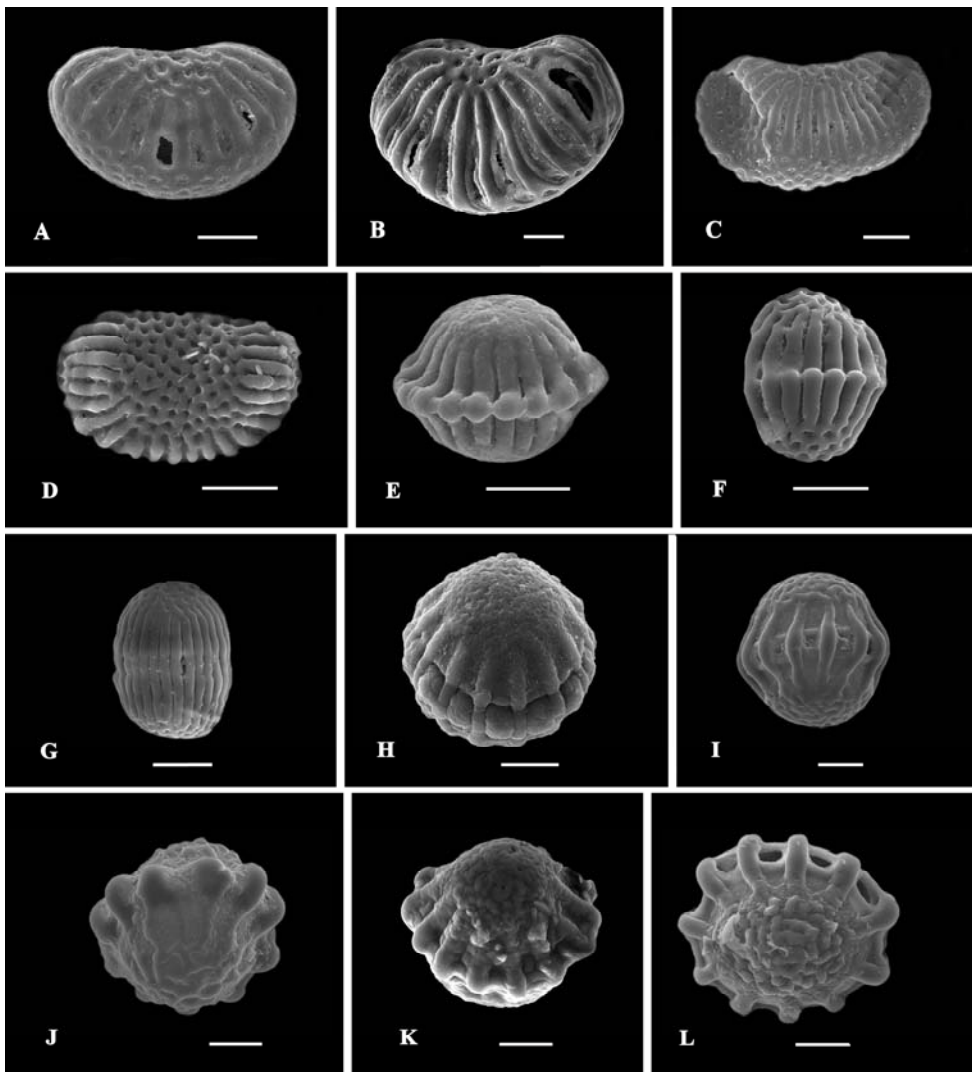
**Type I:** This type is characterized by a reticulate or a reticulate-rugulate apocolpium. The pollen is oblate-spheroidal to prolate in shape ( $P = 19 - 48 \mu\text{m}$ ,  $E = 20 - 50 \mu\text{m}$ ). The number of apertures varies from 10 to 30 with a  $3 - 9 \mu\text{m}$  thick exine that has a psilate sculpturing pattern on the mesocolpium and a reticulate or reticulate-rugulate pattern at the apocolpium. *P. polifolia* tends to have more apertures than the other members of this type (25-30 vs 10-23).

This type comprises all members of *Salomonina* and three species of *Polygala*, *P. erioptera*, *P. persicariifolia* and *P. polifolia* (Fig. 2E - L).

**Type II:** This type is characterized by a psilate apocolpium. The pollen is suboblate to prolate in shape ( $P = 22 - 64 \mu\text{m}$ ,  $E = 22 - 57 \mu\text{m}$ ). The number of apertures is 7 - 27 and the exine is  $2 - 10 \mu\text{m}$  thick. Two subtypes can be established based on the number of apertures.

**Subtype A:** This subtype has 16 - 27 apertures and contains *P. arillata*, *P. chinensis*, *P. longifolia* and *P. triflora*. *P. longifolia* has the shortest colpi which ranges from  $5 - 10 \mu\text{m}$  (Fig. 3A-D).

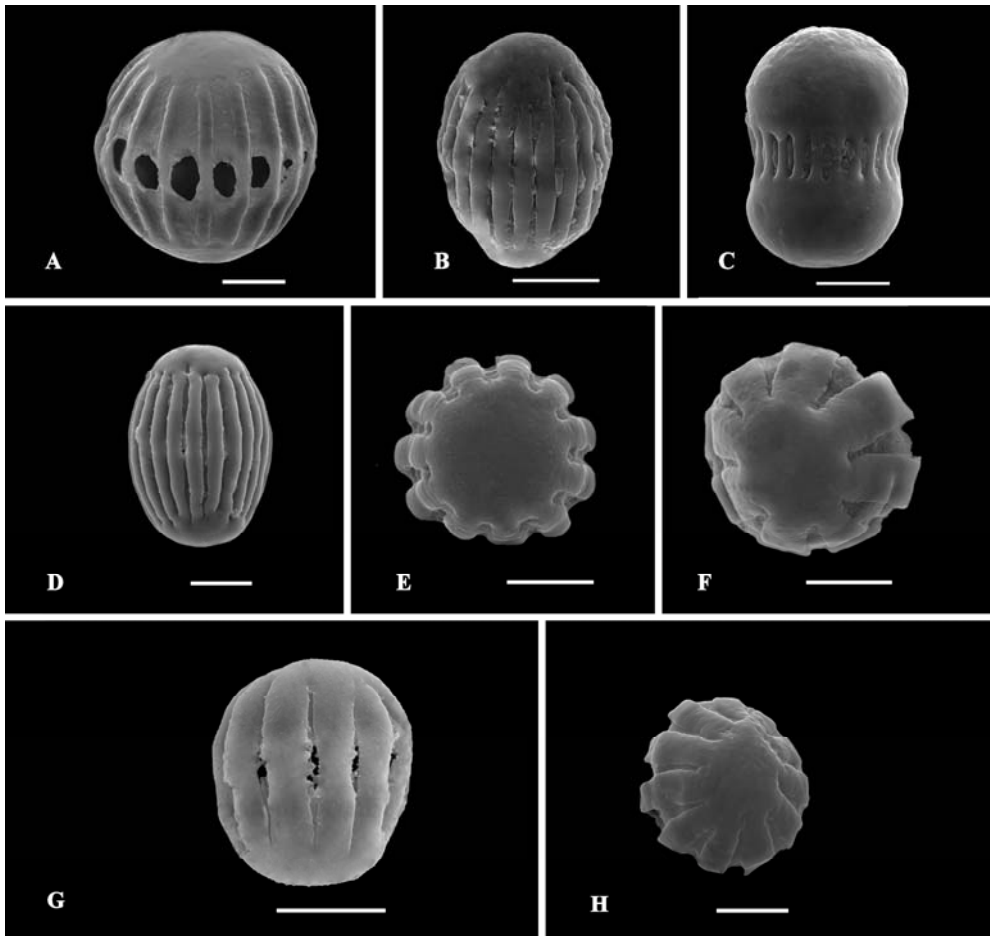
**Subtype B:** This subtype has a small number of apertures, 7 - 14, and contains all



**FIGURE 2.** SEM micrographs of pollen. Group I (A-D) and Group II Type I (E-L): A) *P. cardiocarpa*, equatorial view showing reticulate with depression at apocolpia and apertures. B) *P. karenium*, subequatorial view showing reticulate with depression at apocolpium and apertures. C) *P. malesiana*, equatorial view showing reticulate with depression at apocolpia and apertures. D) *P. umbonata*, subpolar view showing reticulate with depression at apocolpium and apertures. E) *P. erioptera*, subequatorial view showing reticulate apocolpium and apertures. F-G) Equatorial view showing apertures and reticulate apocolpia and apertures, F) *P. persicariifolia*. G) *P. polifolia*. H) *S. cantoniensis*, subpolar view showing reticulate-rugulate apocolpium. I) *S. ciliata*, equatorial view showing apertures and reticulate-rugulate apocolpium. J-L.) Subpolar view showing reticulate-rugulate apocolpium and apertures, J) *S. kradungensis*, K) *S. longiciliata*, L) *S. thailandica*. Scale bars = 10  $\mu$ m.

the examined species of *Xanthophyllum* plus *P. venenosa*. (Fig. 3E - H). The presence of sclereid cells on the ground tissue of the

stem and a similar pattern of the vascular tissues in the floral part supports the



**FIGURE 3.** SEM micrographs of pollen. Group II Type II subtype A (A-D) and Group II Type II subtype B (E-H): A) *P. arillata*, subequatorial view showing psilate apocolpia and apertures. B-C) Subequatorial view showing psilate apocolpia and apertures, B) *P. chinensis*, C) *P. longifolia*. D) *P. triflora*, equatorial view showing psilate apocolpia and apertures. E) *P. venenosa*, polar view showing psilate apocolpium. F) *X. ellipticum*, subpolar view showing psilate apocolpium. G) *X. gesinkii*, equatorial view showing apertures and psilate at apocolpia. H) *X. lanceatum*, subpolar view showing psilate apocolpium. Scale bars = 10  $\mu$ m.

grouping of *P. venenosa* and *Xanthophyllum* (Piwpuan, 2007; Eriksen, 1993).

The palynological and anatomical studies suggest that *Xanthophyllum* should be treated as a genus within Polygalaceae. However, more taxa need to be examined and alternative techniques, such as perhaps molecular systematic approaches, are needed to clarify the infrageneric taxa of this family.

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## APPENDIX

## SPECIMENS EXAMINED

The species are enumerated in alphabetical order. All specimens examined are deposited at Khon Kaen University Herbarium (KKU); *Polygala arillata* Buch.-Ham. ex D.Don, Narumol 24. -*P. cardiocarpa* Kurz, Narumol 101. -*P. chinensis* L., Narumol 21. -*P. erioptera* DC., Narumol 97. -*P. karensium* Kurz, Narumol 19. -*P. longifolia* Poir., Narumol 23. -*P. malesiana* Adema, Narumol 60. -*P. persicariifolia* DC., Narumol 95. -*P. polifolia* C.Presl, Narumol 61. -*P. triflora* L., Narumol 81. -*P. umbonata* Craib, Narumol 90. -*P. venenosa* Juss. ex Poir., Narumol 42. -*Salomonina cantoniensis* Lour., Narumol 26. -*S. ciliata* (L.) DC., Narumol 59. -*S. kradungensis* H. Koyama, Narumol 88. -*S. longiciliata* Kurz, Narumol 22. -*S. thailandica* H.Koyama, Narumol 80. -*Xanthophyllum ellipticum* Korth. ex Miq., Narumol 50. -*X. gesinkii* Meijden, Narumol 37. -*X. lanceatum* (Miq.) J.J.Sm., Narumol 36.

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