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Morphological Characterization of Pollen Collected by *Apis dorsata* from a Tropical Rainforest

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Abstract: *Apis dorsata* is one of the important honeybee species in tropical and subtropical regions that forage on various plants including herbs, grasses, forest trees and plantation trees. However, information on the favored bee plants in terms of identity and quantity is lacking. The objectives of this study were: (1) to identify the pollen sources of *Apis dorsata* and (2) to develop a pollen atlas for selected plants foraged by *Apis dorsata*. Pollen cell samples from twenty one different colonies of *Apis dorsata* combs were collected, identified and quantified based on several reference materials. A total of twelve different pollen sources were identified in the samples. Pollen sizes were 8-9×38-40 μm, comprising five different shape classes. Inaperturate granulum pollen grains were observed in *Ceiba pentandra* and *Garcinia hombroniana* while rugulate grains were found in *Mangifera indica*. Pantoporate, syncolpate and pericolpate pollen grains with reticulum to microreticulate exine patterns occurred in *Acacia auriculiformis, Melaleuca cajuputi* and *Ixora congesta*. *Elaeis guineensis* showed trichotomosulcate pollen grains with a microreticulate sexine. Pantocolpate areola pollen was found in *Mimosa pudica* while granulum pollen was observed in *Cocos nucifera*. *Anacardium occidentale* showed a disulcate grain with a striate sexine pattern. Pollen grains of *Averrhoa carambola* and *Dimocarpus longan* were tricolpate and fossulate perforate to striate perforate. This work shows that *Elaeis guineensis* and *Mimosa pudica* were the most commonly found pollen sources. A pollen atlas of selected plants foraged by *Apis dorsata* in the tropical rainforest of Marang, Terengganu was developed.

Key words: *Apis dorsata*, pollen characterization, pollen atlas, tropical rainforest

INTRODUCTION

Bee foraging occurs on several different types of plants, including wild and cultivated plants which can continuously produce nectar and provide pollen. In general, tropical *Apis* sp. obtains large quantities of pollen from grasses and wind-pollinated plants (Roubik, 2005).

Ruttner (1988) found that *Apis dorsata* forages only on a few species. According to Kiew (1997), *Apis dorsata* have a surprising degree of diet specialization because they tend to forage on trees rather than herbaceous species, especially on papilionaceous flowers and on species of the Bombacaceae family.

Apis dorsata often visit the male flowers of large palm inflorescences while shunning the female flowers and this makes them floral parasites or thieves (Kiew, 1993). They often collect their nectar from large, open flowers that are easily accessible; for example *Durio* sp., *Eugenia* sp., *Elaeocarpus* sp. and other trees including species belonging to Dipterocarpaceae and Sapotaceae (Roubik, 2005).

In Marang, Terengganu, honey hunting is an important economic activity among the rural people. Honey hunting generates high returns because the price of honey is high, ranging from RM15-RM18 kg^{-1} during peak season. Typically, *Acacia* sp. and *Melaleuca* sp., have been a source of pollen and nectar, respectively (Kiew and Muid, 1991), providing ample food for bees. Nevertheless, *Apis dorsata* is known to have a wide range of food source, insinuating that there could be other plants acting as food source. At present, there is limited information about pollen collected by *Apis dorsata* colonies within Marang, Terengganu.

Pollen analysis is an important step in identifying plants that are preferred by *Apis dorsata* as its food source (Louveaux *et al*., 1978) because pollen morphology

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is species-specific. The numerous pollen types commonly found on honey combs shows that bees travel a considerable distance to collect nectar and pollen for honey production (Ebenezer and Olugbenga, 2010).

The conservation of natural forest that comprises plant species important for the sustenance of *Apis dorsata* is a priority in Terengganu, a state that has been declared as Malaysia's honey hub. This study was aimed at (1) identifying the pollen sources of *Apis dorsata* and (2) developing a pollen atlas for selected plants foraged by *Apis dorsata*. Findings from this study will provide stakeholders with strategic information about the plant species that can be sustained or planted within the foraging distance of *Apis dorsata*, in order to increase honey production.

MATERIALS AND METHODS

This study commenced in April of 2009 and was conducted for a duration of one year in Marang district, located in the state of Terengganu at the north eastern part of Peninsular Malaysia (Fig. 1) between upper left of

Fig. 1: Location of study area

5 21'N, 102 58' E and lower left of 4 49' N, 102 51''E with a total area of 43972 ha. The dominant tree species in the study area are *Melaleuca cajuputi*, *Acacia* sp., *Hevea brasiliensis* and *Cocos nucifera* (Saberioon *et al*., 2010).

Preparation of pollen cell samples: Pollen cell samples from twenty one different colonies of *Apis dorsata* combs were collected within the Marang area. For light microscopy, the samples were treated with glacial acetic acid and centrifuged at 1500 rpm for 3 min. After decanting the acetic acid, the sediment was acetolyzed (Erdtman, 1943). One part of the concentrated sulfuric acid was added drop by drop to nine parts of acetic anhydride and warmed in a water bath at 70°C for 10 min. After cooling, the mixture was centrifuged at 1500 rpm for 2 min. The supernatant liquid was decanted off. The sediment was then treated with glacial acetic acid and then centrifuged at 1500 rpm for 3 min, followed by sediment rinse and then centrifuged at 1500 rpm for 3 min. 50% aqueous glycerin prepared in distilled water was added and centrifuged for 3 min at 2500 rpm. The supernatant was decanted off and the pollen sediment was transferred to a glycerin jelly on slides. The slides were warmed slightly and the pollen sediment was covered by a glass cover. Nail varnish was applied to the edges of the cover glass to make the slides permanent. For scanning electron microscopy, pollen samples were mounted to a smooth surface of an adhesive tape pasted onto an aluminium stub. The stubs were coated with gold in a sputter coater (JEOL JFC–1600 Sputter Coater) for 4 min and finally examined using JEOL-JSM 5610 L. Pollen grains were observed using light and scanning electron microscopy and their morphology characterized using guidelines and descriptions made by Kiew and Muid (1991). Pollen grain numbers were quantified following the technique by Moar (1985). Results were expressed as frequency classes using the method suggested by Louveaux *et al.* (1978). The frequency classes comprised the following: "predominant pollen" (more than 45% of the pollen grains counted), "secondary pollen" (16-45%), "important minor pollen" (3-15%) and minor pollen" (less than 3%).

Preparation of pollen atlas: Pollens were collected from various plant species located within the vicinity of the bee hive. Reference materials of pollen from all possible forage plants of *Apis dorsata* were prepared for identification and confirmation of pollen in the comb. The generic and species name of each plant species were identified and each pollen was described for each plant species. Light and scanning electron microscopy were performed using the procedures described earlier.

Pollen characteristics were recorded in the following sequence: pollen class, apertures, exine, ornamentation, outlines and measurements (Hesse *et al*., 2009). Photographs illustrating the pollen types were taken via a light microscope (MT5000; Meiji Techno Co. Ltd.; Japan) fitted with an Olympus E-420 SLR camera.

RESULTS

Morphological identification of pollen sources: Pollen morphology of various plant species found in the twenty one samples of *Apis dorsata* combs collected in Marang during the period May to September of 2009 is shown in light micrographs (Fig. 2) and scanning electron micrographs (Fig. 3). Twelve different pollen types were identified from the samples. The pollen types identified comprised the following: *Acacia* sp., *Durio zibethinus*, *Elaeis guineensis*, *Ixora* sp., *Cocos nucifera*, *Moringa pterygosperma*, *Mikania cordata*, *Mimosa pudica*, *Melaleuca cajuputi*, *Garcinia hombroniana*, *Mimusops elengi* and *Avicennia alba*. Description of pollen morphology is summarized below:

- ***Elaeis guineensis* (Palmae):** The pollen size ranges from 31 μm to about 32 μm. The shape is triangular with rounded angles and 3-slit aperture
- ***Mimosa pudica* (Fabaceae):** This is the smallest pollen among the pollen species (9×9 μm). The pollen grain occurs in tetrads with spheroidal shape. It is a pantocolpate pollen grain
- ***Acacia* sp. (Fabaceae):** This is a polyad consisting of 16 cells; 8 forming a cube and the other 8 in a ring encircling the central cells. The pollen size ranges from 37 μm to about 38 μm.
- ***Cocos nucifera* (Palmae):** The pollen grain is from dwarf hybrids. This grain is spheroidal in shape with diameter of about 19 μm. It is a heteropolar pollen with pantocolpate aperture
- ***Melaleuca cajuputi* (Myrtaceae):** This grain is peroblate in shape with a diameter of about 14 μm. This grain is similar to *Elaeis guineensis* in shape but with smaller dimension and its aperture is syncolpate
- ***Garcinia hombroniana* (Clusiaceae):** The pollen grain is suboblate in shape with a diameter size of 30 μm. It is a triporate pollen with clavate sculpture
- ***Durio zibethinus* (Bombacaceae):** This is the biggest pollen among the pollen species (68×69 μm). The pollen grain occurs in triporate with spheroidal shape
- ***Mikania cordata* (Compositae):** The pollen grain is spheroidal in shape. The pollen size ranges from 19-22 μm. It has a tricolporate aperture. The special characteristic of this pollen is the presence of small echinate

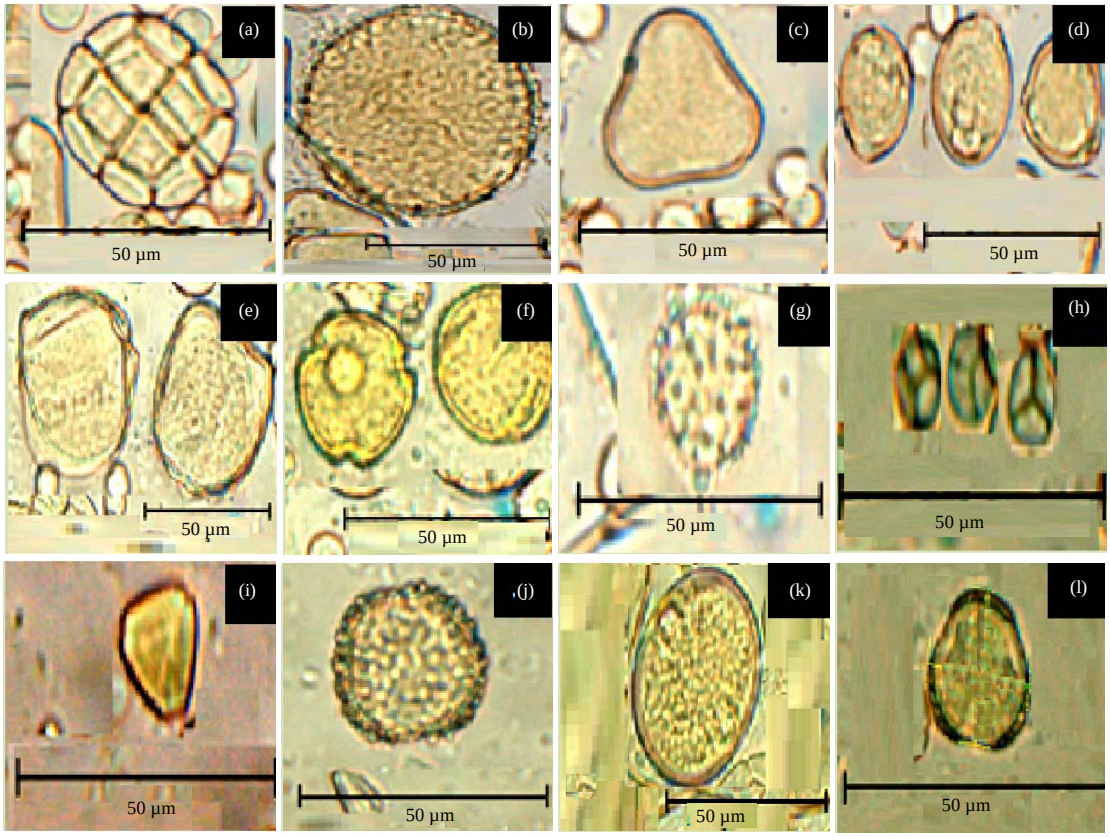

Fig. 2(a-l): Pollen sources identified from *Apis dorsata* pollen cells using light microscopy, (a) *Acacia* sp., (b) *Durio zibethinus*, (c) *Elaeis guineensis*, (d) *Ixora* sp., (e) *Cocos nucifera*, (f) *Moringa pterygosperma*, (g) *Mikania cordata*, (h) *Mimosa pudica*, (i) *Melaleuca cajuputi*, (j) *Garcinia hombroniana*, (k) *Mimusops elengi* and (l) *Avicennia alba*

- ***Avicennia alba* (Avicenniaceae):** The pollen grain is tricolporate and spheroidal in shape. The pollen size ranges from 18-19 µm
- ***Mimusops elengi* (Sapotaceae):** This grain is dicolporate and prolate in shape with a diameter of about 38 µm
- ***Moringa pterygosperma* (Moringaceae):** This grain is tricolporate and spheroidal in shape with a diameter of about 31 µm
- ***Ixora* sp.:** The pollen grain is pericolpate and suboblate in shape. The pollen size ranges from 23 µm to about 25 µm

Quantification of pollen collected by *Apis dorsata* over time: Pollen analysis results are given in Table 1. The highest percentage of pollen contained in pollen combs from May-September, 2009 was that of *Elaeis guineensis* at 98%, indicating that oil palm is the favourite source of pollen. From May-June, 2009 the pollen combs contained mainly pollens of *Mimosa pudica*. Although *Elaeis guineensis* and *Mimosa pudica* were the main sources of pollen, *Apis dorsata* was found to forage on *Melaleuca cajuputi* (56%) and *Acacia* sp. (39%) in mid June of 2009. The bees also foraged on other seasonal plants such as *Garcinia hombroniana*, indicating that their foraging is species-diverse.

Quantitatively, the samples collected between August 14 and August 25 of 2009 were more diverse in pollen sources than those of other samples. Samples collected on July 21, August 12 and August 18 of 2009 had a lower number of pollen source.

All samples, except for those sampled on August 28, 2009, showed a dominant type with pollen frequency exceeding 45%. The dominant pollen sources were *Elaeis guineensis*, *Mimosa pudica* and *Melaleuca cajuputi*. *Elaeis guineensis* was the most dominant pollen source in fourteen of the twenty one samples with a pollen count

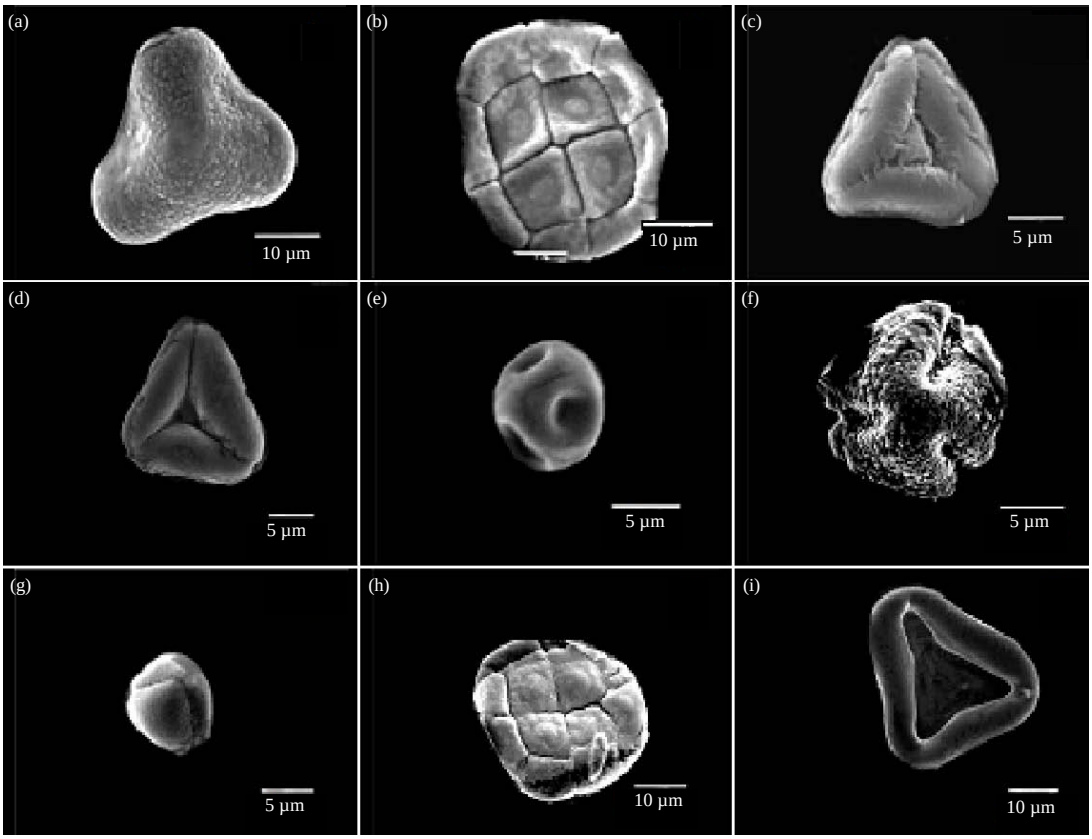

Fig. 3(a-i): Pollen sources identified from *Apis dorsata* pollen cells using scanning electron microscopy, (a), (i) *Elaeis guineensis*, (b), (h) *Acacia* sp., (c), (d) *Melaleuca cajuputi*, (e), (g) *Mimosa pudica* and (f) *Ixora* sp.

ranging from 42.8-98%. *Mimosa pudica* pollen dominated in six of the twenty one samples with a pollen count ranging from 58-91.8% while *Melaleuca cajuputi* was present in one of the twenty one samples with a pollen count of 56.4%.

Secondary pollen sources (frequency between 16% and 45%) identified from the twenty one samples were *Acacia* sp., *Elaeis guineensis* and *Mimosa pudica* while important minor pollen sources (frequency between 3% and 15%) were *Acacia* sp., *Moringa pterygosperma*, *Melaleuca cajuputi*, *Elaeis guineensis*, *Garcinia hombroniana*, *Mimosa pudica*, *Avicennia alba* and *Mikania cordata*. Meanwhile, *Moringa pterygosperma*, *Melaleuca cajuputi*, *Cocos nucifera*, *Garcinia hombroniana*, *Acacia* sp., *Avicennia alba*, *Ixora* sp., *Mimosa pudica*, *Durio zibethinus*, *Mikania cordata*, *Mimusops elengi* and *Elaeis guineensis* were categorized as minor pollen sources (frequency less than 3%). Seemingly, *Moringa pterygosperma, Cocos nucifera, Avicennia alba*, *Ixora* sp., *Durio zibethinus*, *Mikania cordata* and *Mimusops elengi* were collected by *Apis dorsata* in a random manner from the air.

Among the samples analyzed, the highest number of pollen source identified from a single pollen comb was 490 which was recorded from samplings dated August 9 and 18 of 2009 while the lowest number of pollen source was one (recorded from samplings dated July 28 and 29, August 9, 14, 15, 18, 25 and 29 and September 10, 16 and 24 of 2009). Clearly, *Elaeis guineensis* is of great importance to *Apis dorsata*, as displayed by its abundance in the pollen samples.

Development of pollen atlas: Pollen characteristics of selected bee plant species are given in Table 2. Scanning electron micrographs of the pollen grains under study are shown in Fig. 4 while the corresponding surface ornamentation of each pollen grain is illustrated in Fig. 5. Light micrographs of the pollen grains are given in Fig. 6. In general, pollen grains are typically free but often united in polyads and tetrads. Samples showed that surface ornamentation varied from striate to microreticulate. However, granulum was the more common type of surface ornamentation. Shape class varied from oblate to prolate-spheroidal and was rarely spheroidal.

Table 1: Pollen frequency classes in *Apis dorsata* pollen cell samples

Date of collection (Year 2009)	Pollen source			
	Predominant pollen (>45%)	Secondary pollen (16-45%)	Important minor pollen (3-15%)	Minor pollen (<3%)
May 17	*Mimosa pudica* (85.4%)	-	*Acacia* sp. (10.8%)	*Moringa pterygosperma* (2.4%), *Melaleuca cajuputi* (1.2%)
May 23	*Mimosa pudica* (68.6%)	*Acacia* sp. (17%)	*Moringa pterygosperma* (7.8%), *Melaleuca cajuputi* (4.6%)	*Cocos nucifera* (1.6%) *Garcinia* sp. (0.4%)
June 10	*Melaleuca cajuputi* (56.4%)	*Acacia* sp. (39%)	*Moringa pterygosperma* (4%)	*Garcinia* sp. (0.6%)
July 21	*Elaeis guineensis* (93%)	-	*Melaleuca cajuputi* (4.8%)	*Acacia* sp. (2.2%)
July 27	*Elaeis guineensis* (70.4%)	-	*Garcinia* sp. (12.8%), *Mimosa pudica* (12.4%), *Acacia* sp. (4.2%)	-
July 28	*Elaeis guineensis* (86%)	-	*Mimosa pudica* (11.6%)	*Melaleuca cajuputi* (2.2%), *Avicennia alba* (0.2%), *Garcinia* sp. (0.2%), *Acacia* sp. (0.2%)
July 29	*Mimosa pudica* (58%)	*Elaeis guineensis* (32%)	*Melaleuca cajuputi* (7%)	*Garcinia* sp. (2.8%), *Acacia* sp. (0.2%)
August 6	*Elaeis guineensis* (93%)	-	-	*Acacia* sp. (2.6%), *Melaleuca cajuputi* (2.4%), *Ixora* sp. (2.2%)
August 9	*Elaeis guineensis* (98%)	-	-	*Melaleuca cajuputi* (1%), *Mimosa pudica* (0.6%), *Garcinia hombroniana* (0.2%), *Acacia* sp. (0.2%)
August 12	*Elaeis guineensis* (78%)	*Mimosa pudica* (20.6%)	-	*Melaleuca cajuputi* (1.4%)
August 14	*Elaeis guineensis* (86%)	-	*Melaleuca cajuputi* (6.4%), *Mimosa pudica* (3%)	*Ixora* sp. (2%), *Durio zibethinus* (1.2%), *Acacia* sp (0.8%), *Avicennia alba* (0.4%), *Mikania cordata* (0.2%)
August 15	*Elaeis guineensis* (83%)	-	*Mimosa pudica* (12%), *Melaleuca cajuputi* (4.8%)	*Acacia* sp. (0.2%)
August 18	*Elaeis guineensis* (98%)	-	-	*Melaleuca cajuputi* (1.8%), *Acacia* sp (0.2%)
August 25	*Elaeis guineensis* (71%)	-	*Mimosa pudica* (8.6%), *Moringa pterygosperma* (6%), *Avicennia alba* (5.8%), *Mikania cordata* (4.4%), *Melaleuca cajuputi* (3.6%)	*Garcinia hombroniana* (0.8%), *Acacia* sp. (0.2%)
August 28	*Elaeis guineensis* (42.8%)	*Mimosa pudica* (33.6%), *Acacia* sp. (22%)	-	*Garcinia hombroniana* (1%), *Moringa pterygosperma* (0.8%)
August 29	*Elaeis guineensis* (89%)	-	*Mimosa pudica* (5.4%), *Melaleuca cajuputi* (4.8%)	*Mimusops elengi* (0.4%), *Acacia* sp. (0.4%), *Garcinia hombroniana* (0.2%)
September 10	*Mimosa pudica* (91.8%)	-	*Avicennia alba* (5%), *Melaleuca cajuputi* (3%)	*Acacia* sp. (0.2%)
September 15	*Mimosa pudica* (66.8%)	-	*Melaleuca cajuputi* (15%), *Acacia* sp. (12.2%), *Avicennia alba* (6.2%)	-
September 16	*Mimosa pudica* (85%)	-	*Garcinia hombroniana* (6.8%), *Acacia* sp. (4.6%)	*Melaleuca cajuputi* (2.6%), *Avicennia alba* (0.8%), *Elaeis guineensis* (0.2%)
September 21	*Elaeis guineensis* (97%)	-	-	*Melaleuca cajuputi* (1.2%), *Acacia* sp. (1.2%), *Mimusops elengi* (0.6%)
September 24	*Elaeis guineensis* (70%)	*Acacia* sp. (28%)		*Mimosa pudica* (1.6%), *Garcinia hombroniana* (0.2%), *Moringa pterygosperma* (0.2%)

Table 2: Pollen characteristics of selected bee plant species in Marang, Terengganu

Family	Species	P	E	P/E ratio	Shape	Sexine surface ornamentation	Projection type	Aperture type	Outline
Anacardiaceae	*Anacardium occidentale*	10	34	0.29	Peroblate	Striate	Absent	Disulcate	Elliptic
Anacardiaceae	*Mangifera indica*	17	23	0.74	Oblate	Rugulate	Absent	Inaperturate	Triangular
Bombacaceae	*Ceiba pentandra*	12	34	0.35	Peroblate	Granulum	Striato reticulate	Inaperturate	Triangular
Clusiaceae	*Garcinia hombroniana*	20	24	0.83	Suboblate	Granulum	Clava	Inaperturate	Circular
Fabaceae	*Acacia auriculiformis*	11	35	0.31	Peroblate	Reticulum	Absent	Pantoporate	Elliptic
Fabaceae	*Mimosa pudica*	8	9	0.89	Oblate spheroidal	Areola	Absent	Pantocolpate	Circular
Myrtaceae	*Melaleuca cajuputi*	6	18	0.33	Peroblate	Granulum	Absent	Syncolpate	Triangular
Oxalidaceae	*Averrhoa carambola*	21	20	1.05	Prolate spheroidal	Fossulate perforate	Absent	Tricolpate	Circular
Palmae	*Cocos nucifera*	38	40	0.95	Oblate spheroidal	Granulum	Absent	Pantocolpate	Heteropolar
Palmae	*Elaeis guineensis*	18	24	0.75	Suboblate	Microreticulate	Absent	Trichotomo-sulcate	Quadrangular
Rubiaceae	*Ixora congesta*	20	25	0.80	Suboblate	Microreticulate	Absent	Pericolpate	Quadrangular
Sapindaceae	*Dimocarpus longan*	15	18	0.83	Suboblate	Striate, Perforate	Absent	Tricolpate	Circular

P: Polar axis, E: Equatorial diameter

Pollen grains from the samples exhibited different sizes, shapes, apertures and ornamentation. On the basis of apertural types, eight distinct pollen types recognized were: tricolpate, pantocolpate, disulcate, pantoporate, syncolpate, trichotomosulcate, pericolpate and inaperturate.

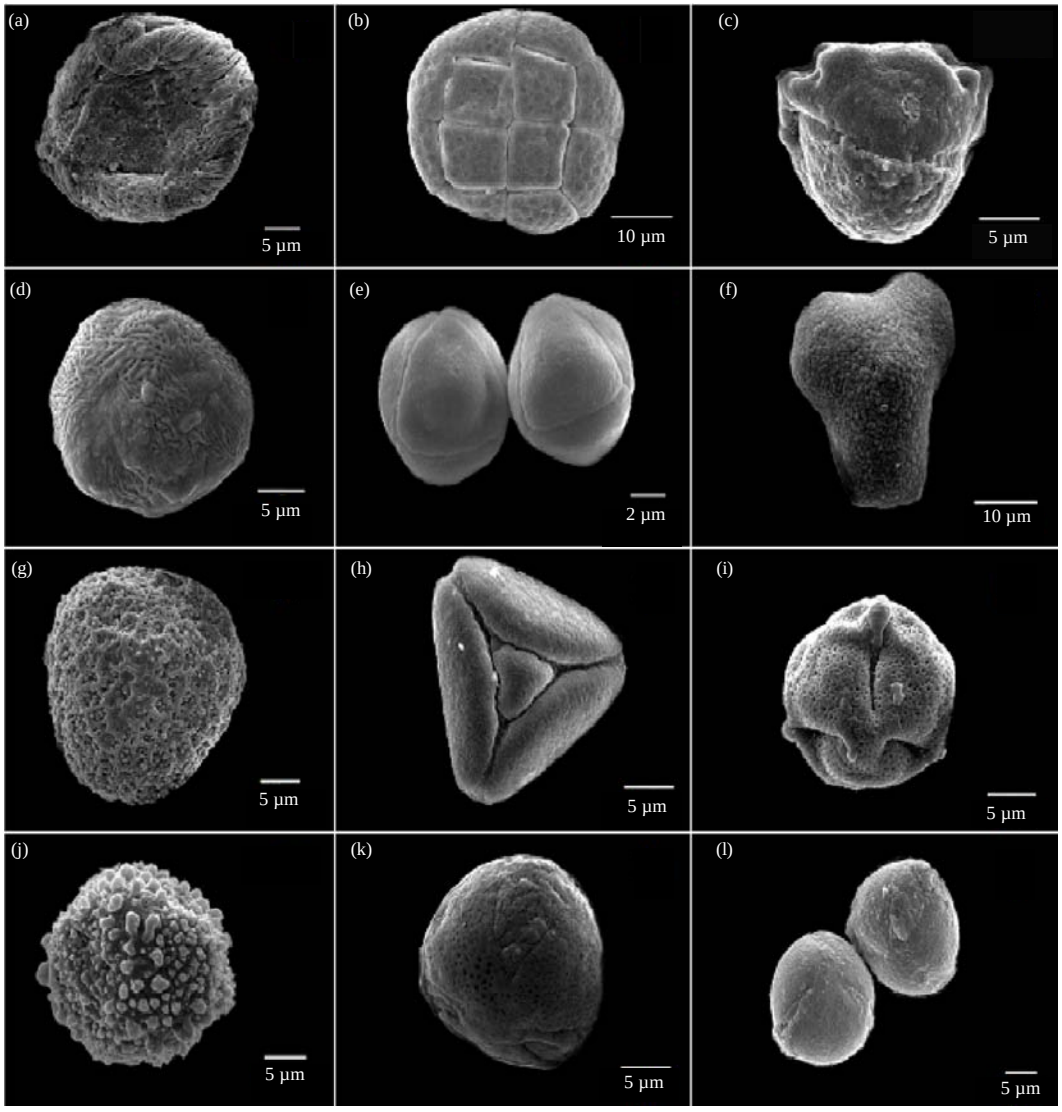

Fig. 4(a-l): Pollen grains of (a) *Anacardium occidentale*, (b) *Acacia auriculiformis*, (c) *Cocos nucifera*, (d) *Mangifera indica,* (e) *Mimosa pudica*, (f) *Elaeis guineensis*, (g) *Ceiba pentandra*, (h) *Melaleuca cajuputi*, (i) *Ixora congesta*, (j) *Garcinia hombroniana*, (k) *Dimocarpus longan* and (l) *Averrhoa carambola*

Colpate pollen is easily delimited. Pollen grains were tricolpate in *Averrhoa carambola* (Oxalidaceae) and *Dimocarpus longan* (Sapindaceae) while pollen grains were pantocolpate in *Mimosa pudica* (Mimosaceae) and *Cocos nucifera* (Palmae), syncolpate in *Melaleuca cajuputi* (Myrtaceae) and pericolpate in *Ixora congesta* (Rubiaceae). Porate pollen is easily recognized and was found to be present in *Acacia auriculiformis* (Mimosaceae).

In terms of pollen units, both *Acacia auriculiformis* and *Mimosa pudica* showed polyads and were separated from each based on the number of cells, whereby *Acacia auriculiformis* exhibited 12-celled polyads while *Mimosa pudica* exhibited 4-celled polyads.

Sulcus pollen is recognized by distally-situated elongated apertures. Disulcate pollen was found in *Anacardium occidentale* (Anacardiaceae) while trichotomosulcate pollen which refers to the three radiate sulci, was found in *Elaeis guineensis* (Palmae). Inaperturate pollen grains are easily recognized by the non-aperturate pollen. This pollen type was found in *Mangifera indica* (Anacardiaceae), *Ceiba pentandra* (Bombacaceae) and *Garcinia hombroniana* (Clusiaceae).

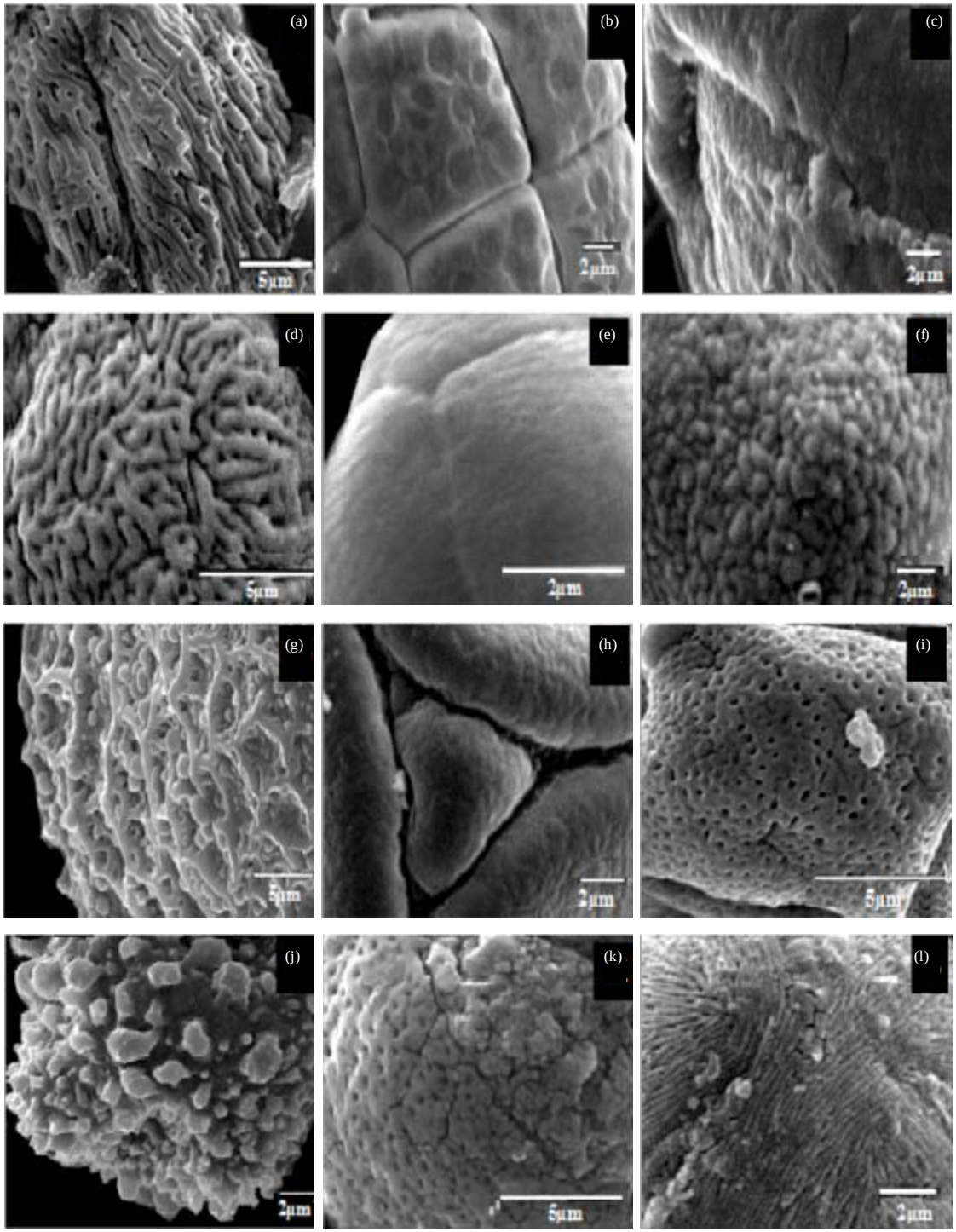

Fig. 5(a-l): Surface ornamentation of (a) *Anacardium occidentale*, (b) *Acacia auriculiformis*, (c) *Cocos nucifera*, (d) *Mangifera indica*, (e) *Mimosa pudica*, (f) *Elaeis guineensis*, (g) *Ceiba pentandra*, (h) *Melaleuca cajuputi*, (i) *Ixora congesta*, (j) *Garcinia hombroniana*, (k) *Dimorcarpus longan* and (l) *Averrhoa carambola*

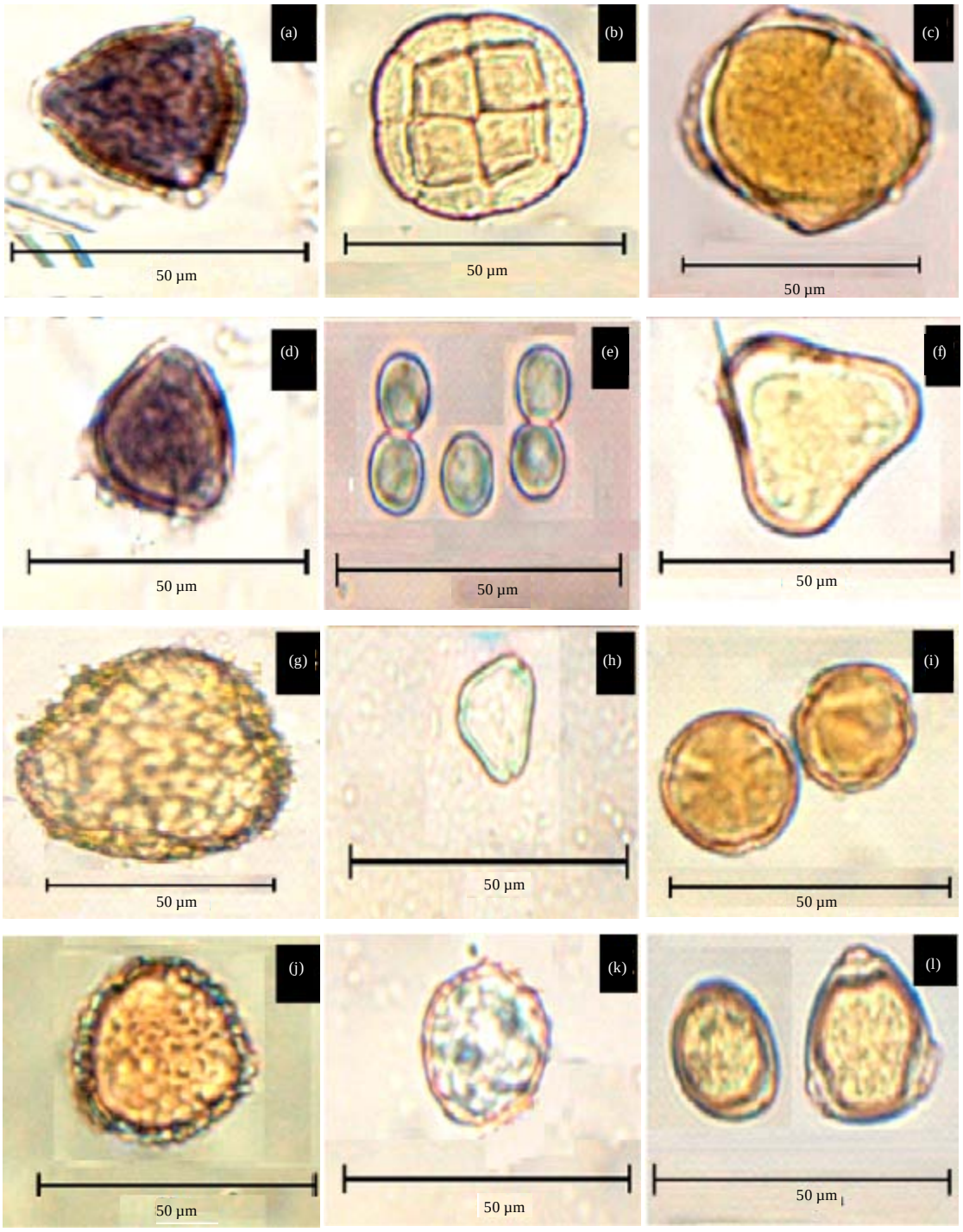

Fig. 6(a-l): Light micrographs of (a) *Anacardium occidentale*, (b) *Acacia auriculiformis*, (c) *Cocos nucifera*, (d) *Mangifera indica*, (e) *Mimosa pudica*, (f) *Elaeis guineensis*, (g) *Ceiba pentandra*, (h) *Melaleuca cajuputi*, (i) *Ixora congesta*, (j) *Garcinia hombroniana*, (k) *Dimorcarpus longan* and (l) *Averrhoa carambola*

The shapes of pollen grains were also different. In general, there were five different pollen shapes recorded which are: prolate to spheroidal, oblate, sub oblate, oblate to spheroidal and peroblate. Prolate to spheroidal and oblate shapes were found in *Averrhoa carambola* (Oxalidaceae) and *Mangifera indica* (Anacardiaceae), respectively. Sub oblate-shaped pollen was found in *Garcinia hombroniana* (Clusiaceae), *Elaeis guineensis* (Palmae), *Ixora congesta* (Rubiaceae) and *Dimocarpus longan* (Sapindaceae). *Mimosa pudica* (Fabaceae) and *Cocos nucifera* (Palmae) both showed oblate to spheroidal-shaped pollen. Peroblate-shaped pollen was observed in *Anacardium occidentale* (Anacardiaceae), *Ceiba pentandra* (Bombacaceae), *Acacia auriculiformis* (Fabaceae) and *Melaleuca cajuputi* (Myrtaceae).

Sexine surface ornamentation also revealed distinct variation. There were eight different sexine surface ornamentations recorded which are: striate, rugulate, striate to perforate, granulum, microreticulate, reticulum, areola and fossulate to perforate. In *Anacardium occidentale* (Anacardiaceae) and *Mangifera indica* (Anacardiaceae), striate and rugulate ornamentations were found, respectively. Striate to perforate ornamentations were observed in *Dimocarpus longan* (Sapindaceae), whereas granulum ornamentation was found in *Ceiba pentandra* (Bombacaceae), *Garcinia hombroniana* (Clusiaceae), *Melaleuca cajuputi* (Myrtaceae) and *Cocos nucifera* (Palmae). Microreticulate ornamentation was observed in *Elaeis guineensis* (Palmae) and *Ixora congesta* (Rubiaceae). Sexine surface ornamentation in other species was as follows: reticulum, areola and fossulate to perforate in *Acacia auriculiformis* (Fabaceae), *Mimosa pudica* (Fabaceae) and *Averrhoa carambola* (Oxalidaceae), respectively.

DISCUSSION

Results clearly indicate that *Apis dorsata* foraged on a wide range of pollen grains. Ebenezer and Olugbenga (2010) and Olusola and Oluwatoyin (2009) reported that the pollen spectra of their samples indicated the presence of various plant species. Ige and Apo (2007) reported that the more the pollen source and pollen content, the more the source of nectar collection and greater the richness of the honey.

The dominance of *Elaeis guineensis* pollen in honey combs was also reported by Ebenezer and Olugbenga (2010) and Olusola and Oluwatoyin (2009). *Elaeis guineensis* is widely planted on a plantation scale and produce a massive number of male or female inflorescences throughout the year. According to Wilms *et al*. (1996), bees typically rely on mass flowering trees. The continuous flowering of *Elaeis guineensis* gives the opportunity for *Apis dorsata* to collect pollen and make it as a main source of pollen for all seasons. *Apis dorsata* frequently collects pollen from the sickly-scented (eugenol) male inflorescence. In the case of *Elaeis guineensis*, it has been shown that foraging bees frequented its flowers so long as the pollen was available. This explains why *Elaeis guineensis* is classified as a predominant pollen source. However, *Elaeis guineensis* is not recommended as a planted pollen source because honey contaminated by its pollen is reported to have an unpleasant odor and taste (Kiew and Muid, 1991).

Elaeis guineensis, *Mimosa pudica* and *Melaleuca cajuputi* were the most dominant pollen sources, indicating that their pollen and nectar are important substrates for *Apis dorsata* in Marang, Terengganu.

Gary (1975) observed that honeybees are very intelligent and have a high retentive ability. Therefore, if they have visited a flower possessing a particular color, they will return to the same flower repeatedly. Similarly, if a scent is presented to them for a very short time, it will be remembered for several months or even over their entire life. It is clear from these observations that when *Elaeis guineensis* or any other plant is flowering, *Apis dorsata* will continue to visit them for pollen and nectar.

Results indicate that *Apis dorsata* is not very selective in their feeding. The amount of pollen from a particular plant species present in the pollen samples would depend on the quantity produced at the time *Apis dorsata* visits and the frequency of such visits. The frequency of visiting the flower is strongly correlated with the importance of the species importance as a nectar or pollen source (Kiew and Muid, 1991).

Results clearly show that the foraging pattern of *Apis dorsata* was not strongly influenced by plant physical characteristics. The presence of species like *Mimosa pudica* (weed), *Ixora congesta* (shrub) and *Elaeis guineensis* (tree) represented the three categories of plant physical characteristics in these samples. Despite this stratification, honeybees in general prefer to visit plants that contain high quality nectar and/or significant floral attractiveness (Ige and Apo, 2007). In this study, the surrounding vegetation significantly affected pollen collection by *Apis dorsata*, both in terms of the amount and the number of pollen types collected.

CONCLUSION

There were twelve different pollen sources identified in this study. The pollen sources were *Acacia* sp., *Durio*

zibethinus, *Elaeis guineensis*, *Ixora* sp., *Cocos nucifera*, *Moringa pterygosperma*, *Mikania cordata*, *Mimosa pudica*, *Melaleuca cajuputi*, *Garcinia hombroniana*, *Mimusops elengi* and *Avicennia alba*. Several other sources of pollen were also stored in the pollen cells, indicating that *Apis dorsata* also seeks pollen from other types of plants. In terms of pollen quantity, *Elaeis guineensis* was the main contributor in the samples (54%), followed by *Mimosa pudica* (29%), *Acacia* sp. (6.7%) and *Melaleuca cajuputi* (5.7%). The remaining eight plant species were of insignificant composition.

Nine plant families in the Marang area were identified as the preferred pollen source of *Apis dorsata*. These plants contributed to the pollen atlas of *Apis dorsata*. From the nine families, twelve species were recorded and found to have different pollen characteristics. Eight distinct pollen types were recognized which are: tricolpate, pantocolpate, disulcate, pantoporate, syncolpate, trichotomosulcate, pericolpate and inaperturate.

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