

Rafflesia sharifah-hapsahiae (Rafflesiaceae), a new species from Peninsular Malaysia

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Abstract: A new species of the genus *Rafflesia*, *Rafflesia sharifah-hapsahiae*, is described, with illustrations. A key to 2 related species of *Rafflesia* of Peninsular Malaysia is also provided. A discussion on its differences and similarities with *Rafflesia azlanii* and *Rafflesia hasseltii* is presented.

Key words: Malaysia, tropical rainforest, *Rafflesia*, parasite

1. Introduction

Rafflesia R. Brown is a holoparasitic flowering plant of the tropical rainforests of South-east Asia. It is exclusively dependent on the host vine plant for its protection, nutrition, and survival. The vegetative parts of *Rafflesia* are reduced to thread-like structures, and huge flowers are produced externally on the root and stem surfaces of the host plant, with a diameter of up to 150 cm in *Rafflesia arnoldii* R. Brown (Nais, 2001). The biggest flower ever recorded for Peninsular Malaysia was 95 cm in *Rafflesia su-meiae* M. Wong, Nais & F. Gan (Wong et al., 2009). Not all flowers of *Rafflesia* are gigantic in size, and 5 of the known *Rafflesia* species measure between 15 and 20 cm in diameter (Nais, 2001).

Rafflesia has many vernacular names, including bunga pakma, bunga pecah belah, bunga kobis, bunga akar, kerubut, kekuanga, yak-yak, wusak, tumbuakar, bunga matahari, devil's betel box, cendawan matahari, sun mushroom, dai huang hua, monarch flower, sun toadstool, corpse flower, and stinking corpse lily.

Our field observation from 2011–2012 showed that *Rafflesia cantleyi* Solms-Laubach and *Rafflesia kerrii* Meijer in Peninsular Malaysia bloom regularly throughout the year, particularly during the wet season. Similarly, Nais (2001) found that flowers of *Rafflesia keithii* Meijer, *Rafflesia pricei* Meijer, and *Rafflesia tengku-adlinii* Mat-Salleh & Latiff of Sabah in Borneo bloom throughout the year. *Rafflesia* flowers are dioecious and unisexual, which means an individual plant produces either a female or male

flower. However, there are 2 species in the Philippines, *Rafflesia baletei* Barcelona & Cajano and *Rafflesia verrucosa* Balet, Pelser, Nickrent & Barcelona, that have bisexual flowers (Barcelona et al., 2009; Balet et al., 2010).

For pollination to occur, a pollinator must transfer pollen from the anthers of male flowers to the stigmas of female flowers. The flowers are brightly coloured ranging from orange, reddish brown, and maroon, mimicking the colour of meat and emitting a faint to strong odour depending on the species, which attracts pollinating agents. In other words, flowers of *Rafflesia* attract potential pollinators by providing primary attractant such as yellow sticky masses of pollen, brooding places in the perigone tubes, and secondary attractants such as odour and visual (Beaman et al., 1988). Previous authors have reported species of carrion flies as possible pollinators of *Rafflesia*. Species of flies mentioned by previous authors include *Lucilia papuensis* Macquart, *Lucilia porphyrina* Walker, *Hypopygiopsis tumrasvini* Kurahashi, *Chrysomyapinguis* Walker, *Chrysomya vileneuvei* Patton, *Chrysomya rufifacies* Macquart, *Calliphora* spp., *Sarcophaga* spp., and *Lucilia* spp. (Beaman et al., 1988; Banziger, 1991; Zuhud et al., 1998; Nais, 2001, 2004). Nais (2001) noted that reproductive success in *Rafflesia* is low due to their rarity, low percentage of buds reaching maturity, very short anthesis period, a large gender disparity, and rare occurrence of simultaneously blooming of both male and female flowers.

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Female *Rafflesia* flowers will form fruit upon successful pollination and fertilisation of gametes. Normally, about 10 days after blooming the perigone lobes and perigone tubes will disintegrate, whereas the central column and the disc will become hardened and swollen, and increase in size. The fruits need 6 months to mature in *Rafflesia arnoldii* R. Brown (Bouman & Meijer, 1994), about 8 months in *Rafflesia gadutensis* Meijer (Meijer, 1997), and 6–8 months in *Rafflesia keithii* Meijer (Nais, 2001). A *Rafflesia* fruit produces numerous tiny seeds. A single fruit of *Rafflesia keithii* Meijer produces about 270,000 viable and nonviable seeds (Bouman & Meijer, 1994).

Nais (2001) showed that agamospermy occurs in *Rafflesia keithii* Meijer and *Rafflesia tengku-adlinii* Mat Salleh & Latiff but the seeds may all be nonviable. Several early publications have also indicated the possibility of agamospermy in *Rafflesia* (Teijsmann, 1850; Motley, 1857; Beccari, 1875), as reviewed by Meijer (1997). Meijer (1997) further noted that the seeds produced agomerspermy are viable.

When the fruits mature, the seeds must be dispersed to a suitable host vine, *Tetrastigma* (Vitaceae), then germinate and form a new plant. The dispersal of seeds to the host plants has been the subject of some speculation. Among the proposed dispersal agents were squirrels, ants, pigs, and even elephants.

Previous authors have recorded 7 species of *Tetrastigma* (Vitaceae) that were known to be infected by *Rafflesia* (Nais, 2001, 2004). These species were *Tetrastigma curtisii* (Ridley) Suesseng, *Tetrastigma diepenhorstii* Miquel, *Tetrastigma glabratum* (Blume) Planch, *Tetrastigma leucostaphylum* (Dennst.) Alston., *Tetrastigma papillosum* (Blume) Planch, *Tetrastigma quadrangulum* Gapnep. & Craib, and *Tetrastigma scortechinii* (King) Gapnep.

Rafflesia is a small genus, represented by 30 species. These species are found in the South-east Asia region, distributed from Isthmus of Kra in Thailand (1 species), through Western Malesia: Peninsular Malaysia (4), Sumatra (5), Java (4), Borneo (9), and the Philippines (10) (Nais, 2004; Wong et al., 2009; Balet et al., 2010). They grow in lowland and hill primary forest, over-logged forest, and old secondary forest from lower altitude at about 300 m from sea level to higher altitude up to 1600 m from sea level (Nais, 2001).

Rafflesia sharifah-hapsahiae is the fifth species to be described from Peninsular Malaysia (Figures 1 and 2). The other species known from Peninsular Malaysia are *Rafflesia azlanii* Latiff & M. Wong (Figure 3), *Rafflesia cantleyi* Solms-Laubach, *Rafflesia kerrii* Meijer, and *Rafflesia su-meiae* M. Wong, Nais & F. Gan.

Rafflesia cantleyi was the first species to be described from Peninsular Malaysia (Solms-Laubach, 1910). It is only found in Peninsular Malaysia.

Rafflesia kerrii was originally described for Thailand by Meijer (1984). Meijer (1984) noted that this species was closely related to *Rafflesia cantleyi* from the Malay Peninsular but is distinct by larger average size of the flower, larger aperture and the different pattern of the warts on the perigone lobes, and less swollen apices of the ramenta. This species in Peninsular Malaysia was recorded from Mount Tepuh, Mount Chamah, Mount Stong, Lojing Highlands, Betis River Forest Permanent Reserve in Kelantan, and Pengkalan Hulu in Perak (Nais, 2001, 2004; Wong & Gan, 2008; Wong et al., 2009).

Rafflesia azlanii was discovered from Peninsular Malaysia by Latiff and Wong in 2003. *Rafflesia azlanii* is found growing in primary and logged over lowland dipterocarp forest in Peninsular Malaysia. Field observations by our research group in 2012 recorded the presence of this species from logged over primary lowland forest in Bersia River, Gerik, Perak. We have collected the voucher specimen bearing collection number Akmal 1 (SBP2B15).

Rafflesia su-meiae was described by Wong et al. in 2009 from Peninsular Malaysia. This species grows on the host vine of *Tetrastigma rafflesiae* (Miquel) Planchon in primary lowland and hill dipterocarp forest at 600–1200 m altitude (Wong et al., 2009).

2. Materials and methods

The description of the new species from Mount Benom Forest Reserve in Raub, Pahang, is based on the holotype of the male flower and paratypes of male and female flowers, and supplemented by data taken from the type locality in 2011–2012. We refrained from collecting many specimens mainly due to rarity, protective, and conservation reasons. The floral morphology of *Rafflesia azlanii* for comparative study is based on the female flower collected by our research group from Bersia River in 2012 (Akmal 1 SBP2B15; blooming on 28 August 2012), information from the original publication of the species by Latiff and Wong (2003), and the species description by Nais (2004) and Nery et al. (2007). Species-differentiating characters used in this study to delimit distinction between species includes flower size, pattern of perigone lobes, pattern of diaphragm, pattern of window, size of aperture, number of processes, ramenta, and number of anthers. The application of flower differences have been widely used to differentiate between species in other groups of flowering plants for example in Magnoliaceae (Chen & Zeng, 2013), Hyacinthaceae (Uzunhisarcıklı et al., 2013), and Orobanchaceae (Zare & Dönmez, 2013).

3. Species description

3.1. Taxonomic treatment

Rafflesia sharifah-hapsahiae Adam, Mohamed, Aizat-Juhari & Wan sp. nova (Figures 1 and 2).

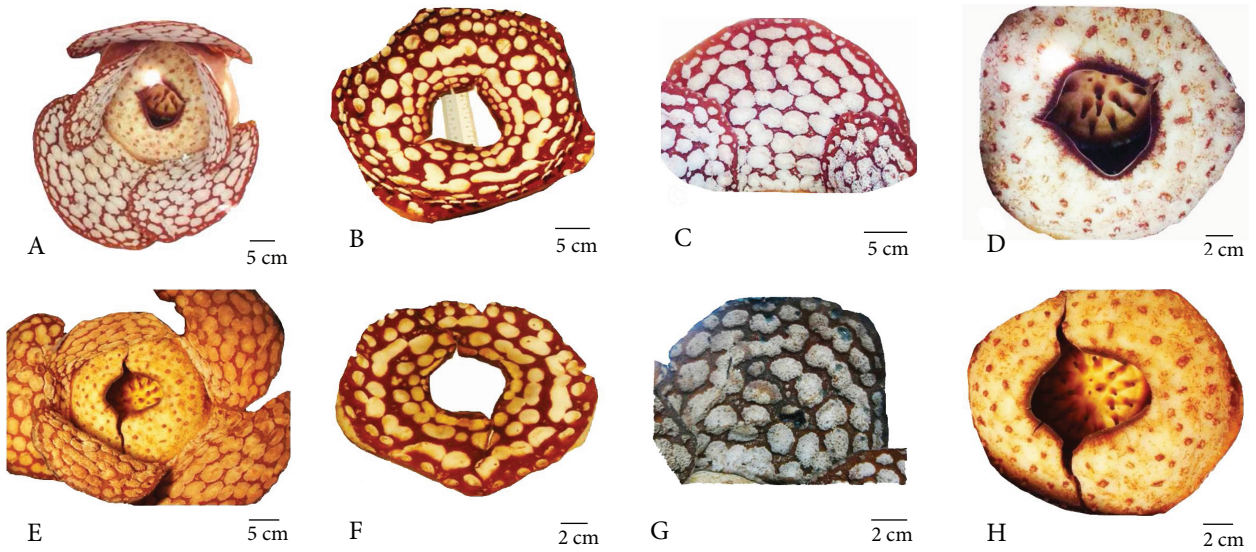


Figure 1. *Rafflesia sharifah-hapsahiae*. A- Male flower (Nik Nadira Farhana 4- CAP1B6; Holotype), B- Window pattern of male flower, C- Perigone lobe of male flower, D- Diaphragm of male flower with reddish dots, E- Female flower (Nik Nadira Farhana 5- CAP1B14; Paratype), F- Window of female flower, G- Perigone lobe of female flower, H- Diaphragm of female flower.

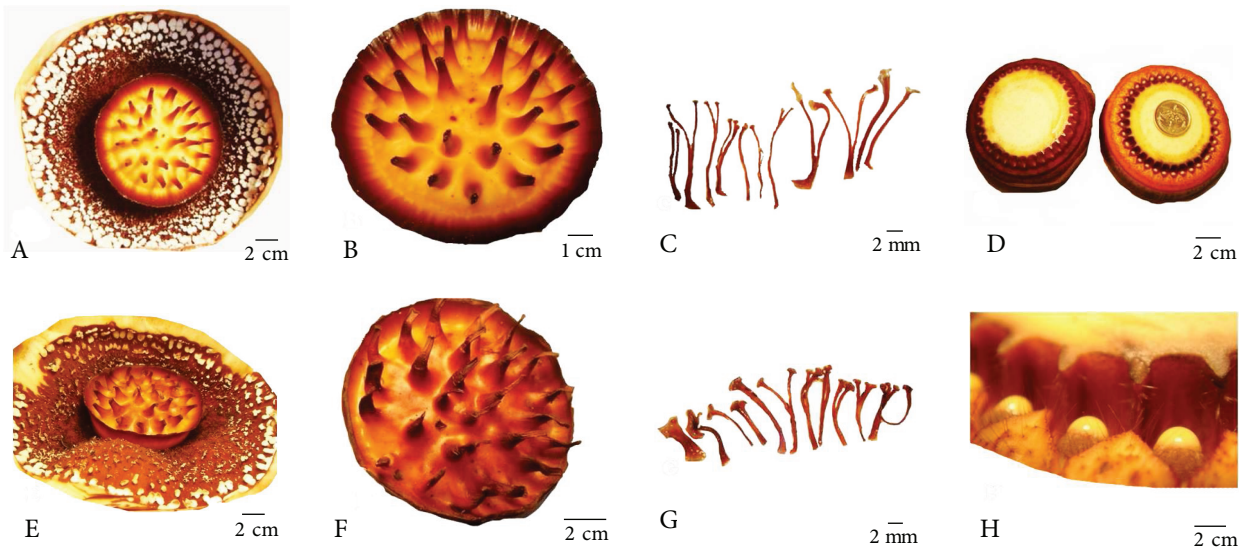


Figure 2. *Rafflesia sharifah-hapsahiae*. A- Inner perigone tube of male flower, B- Processes arranged in 3 rings of 2 + 9 + 15 in male flower, C- Ramenta on inner perigone tube of male flower, D- Numerous anthers (28) on lower surface of disc, E- Inner perigone tube of female flower, F- Processes arranged in 3 rings of 4 + 8 + 15 in female flower, G- Ramenta on inner perigone tube of female flower, H- Disc undersurface of male flower.

Type: Malaysia, Pahang, Raub District, Ulu Dong Province, Mount Benom Forest Reserve, 562 m, on gentle hill slope of after-logged primary lowland dipterocarp forest, 13.03.2011, 03°55'13.4"N, 102°0'00.5"E, Nik Nadira Farhana 4 (CAP1B6♂). [Holotype: UKMB]

Diagnoses: This species is similar to *Rafflesia azlanii* by the perigone lobes covered by rows of coalesced white warts. It is different from *Rafflesia azlanii* by the absence of marginal ring of white warts on the periphery of the

window, more rows of coalesced white warts on the perigone lobes, higher number of concentric rings of white warts on the window, larger number and rings of circular dots on the diaphragm, larger number and rings of processes on the upper surface of the disc, and more anthers (see Table).

Description: Male flower. Mature flower buds 25 cm diameter. Flower medium size, 47–49.5 cm diameter. Weight 1.8–3.3 kg. The flower perigone lobes 5, variable

Table. Comparison between *Rafflesia sharifah-hapsahiae*, *Rafflesia azlanii*, and *R. hasseltii*.

Characters	<i>R. sharifah-hapsahiae</i>	<i>R. azlanii</i>	<i>R. hasseltii</i>
Flower diameter	46–59 cm	38–50 cm	38–50 cm
Length of perigone lobes (PL)	11–19.5 cm	9.5–12 cm	11.5–13 cm
Width of PL	13–25 cm	12–16 cm	15–17 cm
Number of rows of coalesced white warts on PL	7–9	4–6	3
Arrangement of rows of coalesced white warts on PL	rows well-spaced, partly covering PL	coalesced, merging, almost covering PL	well-spaced rows of coalesced warts
Diaphragm width	20–23 cm	11.2–18 cm	7 cm
Number of circular spots on diaphragm	73–113	19–25	25
Number of rings of circular spots on diaphragm	3–5	1–2	1
Aperture size	5.6–9.5 cm	4.7–8 cm	9–10 cm
Number of circular rings on windows	5–7	4	1
Marginal ring on window	absent	present	present
Ramenta structure and length	branching, 3–13 mm	branching, 4–11 mm	linear, 4–11 mm
Number of processes	25–31	15–17	15–24
Arrangement of processes	3 rings	2 rings	2 rings
Number of anthers	29–33	20	20

Notes for Table: Floral characters of *Rafflesia azlanii* and *Rafflesia hasseltii* listed in the Table above are adapted from Latiff and Wong (2003), Nais (2004), Nery et al. (2007), and the specimen collected by our research group from Bersia River in Perak (Akmal 1 – SBP2B15). The number of circular rings on windows and arrangement of processes on disc for *Rafflesia hasseltii* are taken from Nery et al. (2007).

in sizes between lobes, 13.5–19.5 cm long and 15–24 cm wide; upper surfaces covered by white warts with brick red background. White warts on perigone lobes consist of 8–9 well-spaced rows of coalesced white warts. Basal row of warts on perigone lobes consist of 6–7 warts, merging across the perigone lobes. Number of warts on each perigone lobe varies, ranging from 18 to 65. Warts sizes also vary from 2 to 36 cm long and 1–2 cm thick. Diaphragm aperture is small and circular, 5.6–7.5 cm wide. Diaphragm 20–22.5 cm diameter across; upper surface cover 94–113 red spots or reddish ring of white spots; the red spots are arranged in 4–5 circular rings; lower surface of diaphragm or window cover 6–7 concentric rings of coalesced and discrete white warts. Number of processes 25–26, 3 concentric rings, 15 in the outer ring, 9 in the middle ring, and 1–2 in the inner ring, 0.7–1 cm wide and 2.2–3 cm long. The disc 8.5–10.5 cm diameter and 1.9 cm thick raised rim 1.9 cm high; covered numerous bristles

on lower surface of the disc. There are 2 types of ramenta namely fugacious and nonfugacious ramenta covering inner surface of perigone tube. Nonfugacious ramenta makeup of simple or branch and with capitate apices, the length varies from 3 to 13 mm long. Branched ramenta are branching from 2 different levels of ramenta axis from lower half, lower two-thirds, and towards the apex. Anthers are numerous, 29–33. Annulus rings 2. Annulus grooves 29–33.

Female flowers. Mature flower buds 25–28 cm diameter. Flower medium size, 46–59 cm diameter. Weight of flower about 3.1 kg. Perigone lobes 5, variable in sizes between lobes, 11–19.5 cm long and 13–25 cm wide, upper surfaces covered by white warts with brick red background. White warts on perigone lobes consisting of 7–8 well-spaced rows, warts commonly coalesced across the perigone lobes. Basal row of warts on perigone lobes consist of 5–7 warts, merging across the perigone lobes. Number of

warts in each perigone lobe varies, ranging from 16 to 53. Warts vary in sizes, 1.8–30 cm long and 1.2–3.5 cm thick. Diaphragm aperture is small and circular, about 8–9.5 cm wide. Diaphragm 22.5–23 cm diameter across; upper surface covered by 73–79 red spots or reddish ring white spots, the red spots are arranged in 3–4 concentric rings, windows are covered by 5–6 concentric rings of coalesced and discrete white warts. Window white, extended fully of the inside space. Processes about 28–31, arranged in 3 concentric rings, 16–18 in the outer ring, 8–9 in the middle ring, and 4 in the inner ring, 0.4–1 cm wide and 0.3–2 cm long. Disc 9.5–11 cm diameter and 2–2.5 cm thick, raised rim 2–2.5 cm high, smooth, white and without bristles on lower surface of the disc. Inner surface of perigone tube is covered with 2 types of rameta namely fugacious and nonfugacious rameta. Nonfugacious rameta are made up of simple and branch and with capitates apices; the length varies from 3–13 mm long. Branched rameta are branching from 2 different levels of rameta axis from lower half, lower two-thirds, and towards the apex. Annulus 2 and 30–31 annulus grooves.

Paratypes: Malaysia, Pahang, Raub District, Ulu Dong Province, Mount Benom Forest Reserve, 562 m, on gentle hill slope of after-logged primary lowland dipterocarp forest, collected from the type locality but from different host plant, 13.03.2011, 03°55'13.4"N, 102°03'00.5"E, Nik Nadira Farhana 5 (CAP1B14♀) & Nik Nadira Farhana 6 (CAP1B35♀). [Paratypes: UKMB]; *ibid.*, 24.06.2012, Alia 1 (CAP1B56♂). [Paratype: UKMB].

Host plant: Observation. *Tetrastigma rafflesiae* (Miquel) Planch. (Vitaceae), woody vine. Synonym: *Tetrastigma leucostaphyllum* (Dennst.) Alston ex Mabb. (Veldkamp, 2007).

Distribution and habitat: Peninsular Malaysia: Pahang, Raub District, Mount Benom Forest Reserve. It is growing on gentle hill slopes in primary lowland dipterocarp forest, 562 m altitude. The existence of logging roads indicated these forests have been logged. Further study covering the distribution range may alter the current distribution of the species in Peninsular Malaysia.

4. Discussion and conclusion

This study shows that *Rafflesia sharifah-hapsahiae* of Peninsular Malaysia is related to *Rafflesia azlanii* by rows of large coalesced white warts covering the surface of the perigone lobes. However, the former species distinctively differs from the latter in many other floral characters as listed in the Table.

This study shows that *Rafflesia sharifah-hapsahiae* of Peninsular Malaysia is related to *Rafflesia azlanii* (Figures 1 and 3) and *Rafflesia hasseltii* of Sumatra by rows of large coalesced white warts covering the surface of the perigone lobes. However, the former species distinctively differs

from the latter in many other floral characters as listed in the Table.

Rafflesia sharifah-hapsahiae can be distinguished immediately from the related species by the absence of a marginal ring of white warts on the periphery of the window (Figure 1). Another species of the genus reported to have a marginal ring of white warts on the window is *Rafflesia hasseltii* of Borneo and Sumatra (Nais, 2001). The other floral characters that also differentiate it from *Rafflesia azlanii* are as follows: it has larger flowers attaining a maximum diameter of 59 cm; it has longer and wider perigone lobes; it has more rows of coalesced white warts on the perigone lobes (Figure 1), with these rows of coalesced white warts well-spaced they do not totally cover the background of the perigone lobes; it has a wider diaphragm, measuring 22–23 cm across; it has a larger number of circular spots that are arranged in 3–5 rings on the diaphragm (Figure 1) but in 1–2 rings in *Rafflesia azlanii*; and it has more rings of circular white warts on the window. Latiff and Wong (2003) noted the resemblance of *Rafflesia azlanii* with *Rafflesia hasseltii* of Sumatra and Borneo, particularly the character of coalesced warts on the perigone lobes and presence of marginal ring of white warts on the periphery of the window (Figure 1) but it differed in many other floral characters (see Table). They also reported the absence of *Rafflesia hasseltii* from Peninsular Malaysia (Latiff & Wong, 2003). The presence of a marginal ring of white warts on the periphery of the window of *Rafflesia azlanii* and *Rafflesia hasseltii* was also noted by Nery et al. (2007). It differed distinctively from *Rafflesia hasseltii* and *Rafflesia azlanii* in many other characters (Table). *Rafflesia sharifah-hapsahiae* also differed from the 2 related species in having branched rameta, higher numbers of processes on the disc, processes arranged in 3 rings, and higher number of anthers. The differences in its floral characters thus strongly supported the separation of *Rafflesia sharifah-hapsahiae* from *Rafflesia azlanii* and *Rafflesia hasseltii*.

For the convenience of researchers, a key to presently known related species from Peninsular Malaysia is given below.

Key to the related species of *Rafflesia*

- 1- Marginal ring of white warts on the periphery of the window absent; anthers 29–33; processes 25–31 and distributed into 3 rings **R. sharifah-hapsahiae**
- 1- Marginal ring of white wart on the periphery of the window present; anthers 20; processes 15–17 and distributed into 2 rings **R. azlanii**

Etymology: Named after Professor Tan Sri Dato' Seri Dr. Sharifah Hapsah Syed Hasan Shahabudin, the Vice Chancellor of Universiti Kebangsaan Malaysia for her commitment and support in this project and her concern on conserving the biodiversity, particularly *Rafflesia* in Malaysia.

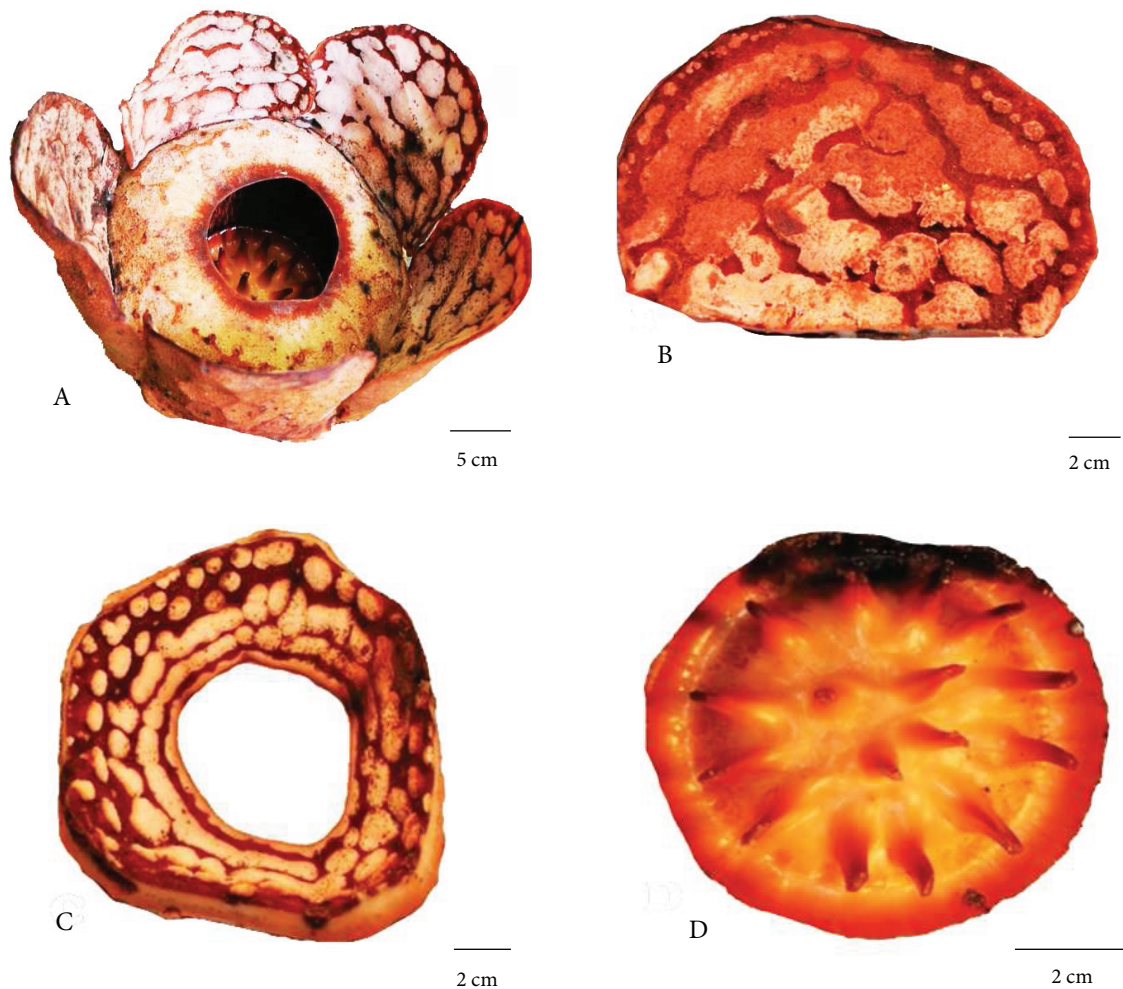


Figure 3. *Rafflesia azlanii*. A- Female flower, Akmal 1 (SBP2B15), B- 5 rows of coalesced white warts merging into one another almost covering up the perigone lobe surface, C- Window covered by 4 concentric rings of white warts with inclusive marginal ring on the periphery. D- Processes arranged in 2 rings 4 + 12 in female flower.

Vernacular: Bunga pakma, bunga pecah belah.

Based on the pattern of white warts on the perigone lobes, the known *Rafflesia* species of Peninsular Malaysia can be arbitrarily classified into 3 main groups: the *Rafflesia azlanii* group, the *Rafflesia cantleyi* group, and the *Rafflesia kerrii* group. Members of the *Rafflesia azlanii* group have their perigone lobes covered by rows of large coalesced white warts (Figure 3), members of the *Rafflesia cantleyi* group have their perigone lobes covered by rows of large discrete white warts, and members of the *Rafflesia kerrii* group have their perigone lobes covered by dispersed minute white warts. Based on this classification, the first group is represented by *Rafflesia azlanii* and *Rafflesia sharifah-hapsahiae*, the second group is represented by *Rafflesia cantleyi*, and the third group comprises *Rafflesia kerrii* and *Rafflesia su-meiae*.

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