

Research Article

Tetrastigma diepenhorstii (Miq.) Latiff (Vitaceae), a New Host of *Rafflesia tuan-mudae* Becc. (Rafflesiaceae) in Borneo

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Rafflesia tuan-mudae Becc. (Rafflesiaceae) is endemic to Borneo and was recorded from Sarawak and probably Kalimantan. Previous records showed that *Tetrastigma rafflesiae* (Miq.) Planch. (Vitaceae) is the only host plant for *R. tuan-mudae*. In this study the host plants were collected each time *R. tuan-mudae* was observed or collected. Out of 20 *Tetrastigma* specimens collected infected by *R. tuan-mudae*, 14 were identified as *T. diepenhorstii* (Miq.) Latiff while 6 belonged to *T. rafflesiae*. Therefore, a new host for *R. tuan-mudae* is recorded and descriptions for each host are presented.

1. Introduction

Rafflesiaceae is a plant family that consists of eight genera *Apodanthes* Poit., *Bdallophytum* Eichler, *Cytinus* L., *Mitrastema* Makino, *Pilostyles* Guillemin, *Rafflesia* R. Br. ex Gray, *Rhizanthus* Dumort., and *Sapria* Griffith with about 55 species recorded. All members in this family are obligate parasites and rootless and have no chlorophyll and therefore are dependent on the host plants for water, nutrients, and survival [1]. Currently, the genus *Rafflesia* consists of about 34 species and is distributed in the Southeast Asian region [1–6].

Some species of the genus *Tetrastigma* (Miq) Planch. (Vitaceae), a woody vine, are the host plants for *Rafflesia* species [1]. *Tetrastigma* is distributed mainly in the Asian tropics, ranging from India to China, across Southeast Asia, eastward towards Fiji and extending towards subtropical Australia [7]. The species climb using tendrils, which develop opposite the leaf [8]. There are a few that have been reported

as the host plant for many *Rafflesia* species, namely, *T. curtisii* (Ridl.) Suess., *T. diepenhorstii* (Miq.) Latiff, *T. glabratum* Planch., *T. papillosum* Planch., and *T. rafflesiae* Planch. [1, 9–11]. However, the latter is the host plant for most *Rafflesia* species and also for *Rhizanthus zippelii* (Blume) Spach [1, 9]. Establishing the identity of the host plants is difficult mainly because they were usually not collected together with the *Rafflesia* [1]. Observations of 771 herbarium specimens from various herbaria such as BO, KEP, SAN, SAR, SING, SNP, and UKMB showed that there were only two records of *Tetrastigma* as the host. An example is shown by *R. keithii* (Coll. number SNP4088) where *T. diepenhorstii* is mentioned. Moreover, the hosts that were collected were sterile with no fruits or flowers, thus making reliable identification virtually impossible [1]. An ongoing study by Wan Nuur Fatiha Wan Zakaria is in progress to identify the sterile *Tetrastigma* species using molecular tools.

Rafflesia tuan-mudae Becc., commonly known as *Pakma* by the locals [12], is one of the *Rafflesia* species endemic to

Borneo [1]. The type specimen was collected from Mount Pueh, Sematan, Sarawak, and was described by Beccari in 1868 [1]. It is reported that *T. rafflesiae* is the host for *R. tuan-mudae* [1]. The *Rafflesia* is distributed in other parts of Sarawak such as Gunung Gading National Park, Mount Rara, and Mount Penrissen. Possibly it can be found in Cagar Alam Gunung Raya Pasi near Singkawang, around Pontianak, and the upper Kayan River in Kalimantan [1]. It inhabits lowland and hill dipterocarp forests and can be found at up to about 900 m above sea level. Based on Wildlife Protection Ordinance 1998, all *Rafflesia* species in Sarawak are totally protected. In this study, a new host plant for *R. tuan-mudae* is recorded based on sampling from several populations in western Sarawak.

2. Materials and Methods

The study was carried out at Gunung Gading National Park (Lundu), Mount Pueh (Sematan), Tapak Rafflesia Kampung Temurung (Padawan), and Batang Ai National Park (Sri Aman). The host plants were collected together with the blooming flowers and young buds of *R. tuan-mudae* each time a collection or observation was made. The morphology of each *Tetrastigma* species was observed and measured in the field. This included growth habit, stem and stem lenticels, vegetative characteristics, and reproductive characteristics [8]. Collections were prepared as complete herbarium specimens and deposited at the Sarawak Herbarium (SAR), the Forest Research Centre, and the herbarium of Universiti Malaysia Sarawak.

3. Results and Discussion

A total of 20 *Tetrastigma* samples were collected. Of these, 14 were identified as *T. diepenhorstii* while six belonged to *T. rafflesiae*. Table 1 shows a list of species names, collection numbers, collection dates, localities, and collectors of the *Tetrastigma* species collected from four different populations.

It was reported that *T. rafflesiae* would be the only host for *R. tuan-mudae* [1]. However, this study showed that *T. diepenhorstii* is also a host making it the second host plant recorded for *R. tuan-mudae*. Descriptions of both *Tetrastigma* species observed and collected in this study are presented.

Tetrastigma rafflesiae (Miq.) Planch. (Figure 1). In DC., Monog. Phan. 5,2 (1887) 443; Suesseng. in Engler & Prantl, Natur. Pflanzenfam. ed. 2, 20d (1953) 325. *Basionym*. *Vitis rafflesiae* Miq., Ann. Mus. Bot. Lugd. Bat. 1 (1863-64) 76. *Lectotype*: Sumatra, s. loc., Korthals s.n. xi/63 (L); *T. tuberculatum* (Blume) Latiff, Folia Malays. 2 (2001) 186; *Cissus tuberculata* Blume, Bijdr. 1 (1825) 189 - *Type*: Java, s.l. Blume s.n. (L) *nom. superfl.*; *T. lanceolarium* (Roxb.) Planch. in DC. Monog. Phan. 5,2 (1887) 423; Suessenguth in Engler & Prantl, Natur. Pflanzenfam. ed. 2, 20d (1953) 322; Backer & Bakhuizen v.d. Brink, Fl. Java 2 (1965) 89; Latiff, Gard. Bull. Sing. 36,2 (1983) 222; Keng, Conc. Fl. Sing. (1990) 119. *Cissus lanceolaria* Roxb., Fl. Ind. 1 (1820) 430; *Vitis lanceolarium* (Roxb.) Wall. in Wight & Arn., Prod. Fl. Ind. Orient. 1 (1834) 128; Miq., Fl. Ind. Bat. Suppl. 1 (1860-61) 603 et Ann. Mus. Bot.

Lugd. Bat. 1 (1863-64) 75; King, J. As. Soc. Beng. 65,2 (1896) 395; Backer, Schoolfl. Java (1911) 254; Ridley, Fl. Mal. Penin. 1 (1922) 475, *nom. illeg.* (include type of *Cissus leucostaphylla*). *Type*: Plants of Bengal, Vallia-tsujori-Valli, Rheede p. 430; *T. mutabile* (Blume) Planch. in DC., Monog. Phan. 5,2 (1887) 440; Suesseng. in Engler & Prantl, Natur. Pflanzenfam. ed. 2, 20d (1953) 323; Backer & Bakhuizen van den Brink, Fl. Java 2 (1967); *Cissus mutabilis* Blume, Bijdr. 1 (1825) 190; Miq., Fl. Ned. Indie 1,2 (1959) 605; *Vitis mutabilis* (Blume) Miq., Ann. Mus. Bot. Lugd. Bat. 1 (1863) 75. *Holotype*: Java, s. loc., Blume s.n. (L); *T. encephalosperrum* Ridl., Bull. Misc. Inform. Kew (1926) 62. *Type*: Sumatra, Mentawai, Sipora Is., Boden Kloss SF 14643 (K, SING); Suesseng. in Engler & Prantl, Natur. Pflanzenfam. ed. 2, 20d (1953) 322; *T. kunstleri* (King) Craib, Fl. Siam Enum. 1 (1926) 313; Suessenguth in Engler & Prantl, Natur. Pflanzenfam. ed. 2, 20d (1953) 325. *Vitis kunstleri* King, J. As. Soc. Beng. 65,2 (1896) 396; Ridley, Fl. Mal. Penin. 1 (1922) 475. *Holotype*: Peninsular Malaysia, Perak, Larut, King's Collector 8027 (K, SING).

Vernacular Name. Akar engkarana (Iban name).

Climbing shrubs, climb up to 15 m high, large. Young stems terete, 2.6–4.1 cm in diameter, old stems terete, ca. 10 cm in diameter, or strap-like, 2.6–4.1 cm wide, ca. 2 cm thick, pustulate, young stems pustulate, terete. Leaves 3-foliolate to pedately 5- to 7-foliolate, coriaceous, glabrous on both surfaces, the adaxial surface nerves quite conspicuous, the abaxial surface nerves prominent, the petioles 6.7–11.6 cm long; terminal leaflets 13.6–20.5 × 4.2–9.4 cm, lanceolate, acuminate, acute at base, obscurely dentate, the petiolules 0.6–3.3 cm long; lateral leaflets 5.8–13.4 × 2.6–6.7 cm, lanceolate, rounded at base, the apex and margin as in terminal leaflets, the petiolules 0.4–2.5 cm long. Inflorescence a dichotomouscymes, peduncles 0.5–2.1 cm long. Staminate flowers ca. 2 mm long, ovoid. Pistillate flowers ca. 5 mm long, oblong, the staminode ca. 0.5 mm, the stigma-lobe rounded, ciliolate. Berries 1.5–2.0 cm in diameter, globose, 1-2-seeded; seeds 1.2 × 0.6 cm, oblong, the testa rugulose, the endosperm M-shaped in cross-section.

Specimens Examined. BORNEO. Sarawak. Mount Pueh, Sematan, KP4, 12 November 2014; KP15, 24 October 2015; KP16; KP17, 24 October 2015; Tapak Rafflesia Kampung Temurung (Padawan), KT2, 10 November 2015.

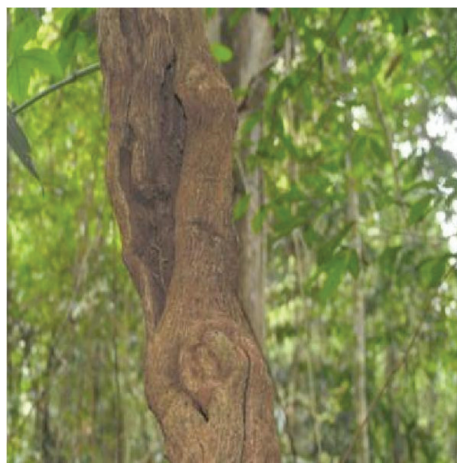
Distribution. India, Myanmar, Thailand, Vietnam, Sarawak, Sabah and Kalimantan.

Ecology and Habitat. It is mostly found on the margin of lowland dipterocarp forests, frequently on limestone outcrops and hill dipterocarp forests. In Sarawak, the species is recorded to inhabit on yellow sandy clay soil, near the river bank, and frequently on lowland *kerangas* forests. It is found in the mixed dipterocarp forests to lower montane forests. As far as it is known this is the host species for all the species of *Rafflesia* in Malesia except for *R. keithii* and *R. kerrii*.

Observations. It is recognised by its lanceolate, nondentate leaflets, and globose berries. In Peninsular Malaysia the

TABLE 1: List of species names, collection numbers, collection dates, localities, and collectors of *Tetrastigma* species collected from four different populations.

| Species name | Collection number | Date | Locality | Collectors |
|-------------------------|-------------------|-------------------|--|----------------------|
| <i>T. diepenhorstii</i> | GG19 | 5 December 2014 | Gunung Gading NP | WN Fatiha |
| <i>T. diepenhorstii</i> | GG23 | 31 December 2014 | Gunung Gading NP | WN Fatiha |
| <i>T. diepenhorstii</i> | GG26 | 30 April 2015 | Gunung Gading NP | WN Fatiha |
| <i>T. diepenhorstii</i> | GG28 | 22 June 2015 | Gunung Gading NP | WN Fatiha |
| <i>T. diepenhorstii</i> | GG32 | 9 July 2015 | Gunung Gading NP | WN Fatiha |
| <i>T. diepenhorstii</i> | GG34 | 1 August 2015 | Gunung Gading NP | WN Fatiha |
| <i>T. diepenhorstii</i> | GG36 | 20 September 2015 | Gunung Gading NP | WN Fatiha |
| <i>T. diepenhorstii</i> | GG38 | 22 October 2015 | Gunung Gading NP | WN Fatiha & M Muklis |
| <i>T. diepenhorstii</i> | BASP3 | 4 August 2015 | Batang Ai NP | Connie Geri |
| <i>T. diepenhorstii</i> | KP2 | 26 May 2014 | Mt Pueh | WN Fatiha |
| <i>T. rafflesiae</i> | KP4 | 12 November 2014 | Mt Pueh | WN Fatiha |
| <i>T. diepenhorstii</i> | KP5 | 12 February 2014 | Mt Pueh | WN Fatiha |
| <i>T. diepenhorstii</i> | KP10 | 24 October 2015 | Mt Pueh | WN Fatiha & M Muklis |
| <i>T. diepenhorstii</i> | KP11 | 24 October 2015 | Mt Pueh | WN Fatiha & M Muklis |
| <i>T. rafflesiae</i> | KP15 | 24 October 2015 | Mt Pueh | WN Fatiha & M Muklis |
| <i>T. rafflesiae</i> | KP16 | 24 October 2015 | Mt Pueh | WN Fatiha & M Muklis |
| <i>T. rafflesiae</i> | KP17 | 24 October 2015 | Mt Pueh | WN Fatiha & M Muklis |
| <i>T. diepenhorstii</i> | KT1 | 10 November 2015 | Tapak Rafflesia Kampung Temurang (Padawan) | WN Fatiha & M Muklis |
| <i>T. rafflesiae</i> | KT2 | 10 November 2015 | Tapak Rafflesia Kampung Temurang (Padawan) | WN Fatiha & M Muklis |
| <i>T. rafflesiae</i> | KT5 | 5 April 2016 | Tapak Rafflesia Kampung Temurang (Padawan) | WN Fatiha & M Muklis |



(a)



(b)

FIGURE 1: *Tetrastigma rafflesiae* collected from Mount Pueh, Sematan. (a) Older stem terete. (b) Pedately 5 leaflets.

species is most widely distributed, being recorded from various habitats throughout. In Sarawak, the species is mostly found at lower elevations. It is believed to be the host of the *Rafflesia* buds found in Ranau (Coll. number SP4308). It can climb up to the height of 7 m. The stem is black, peduncle and pedicel are green, and fruits are light green.

Tetrastigma diepenhorstii (Miq.) Latiff (Figure 2). *Tetrastigma diepenhorstii* (Miq.) Latiff, Folia Malays. 2(3): 185. — *Cissus diepenhorstii* Miq., Fl. Ind. Bat. Supp. 1 (1860-61) 515 — Type: Indonesia, Sumatera, Priaman, Diepenhorst s.n. (Isotype L !)

Synonym. *Tetrastigma trifoliolatum* Merr., Philip. J. Sci. 9,4 (1914) 370 et Enum. Philip. Fl. Plt. 3 (1923) 5; Suesseng. in

Engler & Prantl, Natur. Pflanzenfam. ed. 2, 20d (1953) 326 — Type: The Philippines, Leyte, C.A. Wenzel 544.

Vernacular Name. Pupus, Pumpaos (Dusun, Sabah), Akar engkaranda, Bulunka (Iban, Sarawak).

Climbing shrubs, large, climbs up to ca. 20 m long. Tendrils simple, glabrous. Stems 0.5–1.5 cm in diameter, striate, pustulate. Tendrils simple. Leaves 3-foliolate, coriaceous, glabrous, abaxial surface chocolate-coloured, the petioles 6.5–17.2 cm long; terminal leaflets 10.2–20.4 × 4.2–11.3 cm, elliptical, apex acuminate, base cuneate, margin subentire to grossly dentate, the petiolules 3–8.0 cm long; lateral leaflets 9–18 × 3.5–10.5 cm, ovate-elliptic, base obtuse,



FIGURE 2: *Tetrastigma diepenhorstii* collected from Gunung Gading National Park, Lundu. (a) Older stem rounded. (b) Three leaflets.

apex and margin as in terminal leaflets, the petiolules 0.4–2.7 cm long. Inflorescence a dichotomous cyme, ca. 4.5 cm across, ultimate axis umbelules, peduncles ca. 0.5–2 cm long, bracteate. Staminate flowers minutely pubescent, obovoid, ca. 2 mm long, pedicels ca. 1 mm long, calyx cupuliform, margin lobed, petals obovate, 1.8×0.7 mm, saccate, filaments ca. 0.6 mm, anthers oblong 1.0×0.8 mm. Berries ellipsoid, 1.0×0.7 cm, cerebriform or smooth, 1-seeded; Berries ellipsoid, 1.0×0.7 cm, cerebriform or smooth, 1-seeded; seeds 0.9×0.5 cm, broadly ellipsoid, the testa reticulate, the endosperm basically M-shaped in cross-section but with a few lateral growths.

Specimens Examined. BORNEO. Sarawak, Gunung Gading National Park, Lundu, GG19, 5 December 2014; GG23, 31 December 2014; GG26, 30 April 2015; GG28, 22 June 2015; GG32, 9 July 2015; GG34, 1 August 2015; GG36, 20 September 2015; GG38, 22 October 2015; Batang Ai National Park, BASP3, 4 August 2015; Mount Pueh, Sematan, KP2, 26 May 2014; KP5, 12 February 2015; KP10, 24 October 2015; KP11, 24 October 2015; Tapak Rafflesia Kampung Temurung (Padawan), KT1, 10 November 2015.

Distribution. Malesia: Sumatera, Borneo and The Philippines.

Ecology and Habitat. In Sumatra it is known to occur on sandy soil of depleted open secondary forests at ca. 20 m elevation. But in Sabah (Borneo) it is observed to occur from mangrove forest edge to the mountain ridges as high as 1100 m elevation at Mt. Kinabalu. It is also the known host for *Rafflesia keithii*, an endemic species to Borneo Coll. number SNP4088 [1, 11]. In Sarawak (Borneo) it was reported from the mixed dipterocarp to submontane forests at altitude ranging from 110 to 1100 m above sea level. It has also been reported that the local fishes, such as *Sema* and *Tengadak* are attracted to the berries when they fall into the river.

Observation. It is recognised by its coriaceous leaflets, secondary reticulation very conspicuous, the terminal petiolules about five times as long as the lateral ones, peduncles are very short, bracteate and the berries are ellipsoid. It is closely similar to *T. curtisii* in terms of its conspicuous nerves between the secondary venations.

During field samplings, some of the host plants were not able to be collected together with the *Rafflesia* due to several limitations. First, there were no climbing lianas around or near *Rafflesia tuan-mudae* when collections were made. This could be due to the growth habit of lianas of which the stems are very flexible and tend to grow and climb in all directions [13]. Second, the leaves of the host plant were too high in the canopy thus we were unable to collect materials for voucher specimens. This is possibly due to the presence of tendrils that are helical in shape and tend to coil to other nearby plants allowing the lianas to climb to sufficient height to catch the sunlight [1, 14]. Figure 3 shows the blooming flower of *R. tuan-mudae* and its host plants which were collected together.

4. Conclusion

This is the first detailed study reporting the host plants of *R. tuan-mudae* as both *T. rafflesiae* and *T. diepenhorstii* in Sarawak, Malaysia. This finding is therefore crucial in identifying a need to conserve both host plants of *R. tuan-mudae*, in order to preserve the population of *R. tuan-mudae*.

Competing Interests

The authors declare that they have no competing interests.



FIGURE 3: *Rafflesia tuan-mudae* and its host plant. (a) Flower of *R. tuan-mudae* collected at Gunung Gading National Park, Lundu. (b) Host plant, *T. diepenhorstii* (Coll. number GG34). (c) Flower of *R. tuan-mudae* collected at Mount Pueh, Sematan. (d) Host plant, *T. rafflesiae* (Coll. number KP4).

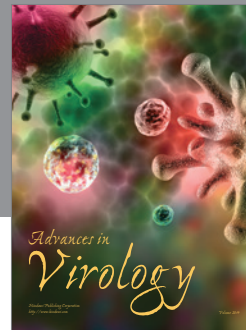
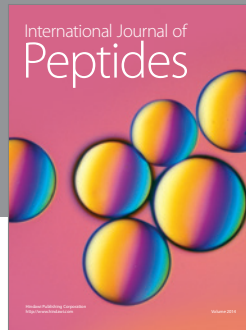
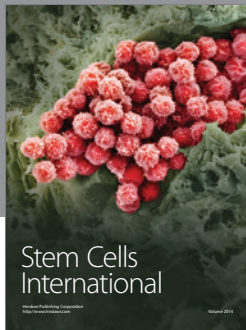
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