Phytotaxa 24: 11–18 (2011)
www.mapress.com/phytotaxa/

Article

ISSN 1179-3155 (print edition)
PHYTOTAXA
ISSN 1179-3163 (online edition)

An amended description of *Rafflesia leonardi* and a revised key to Philippine *Rafflesia* (Rafflesiaceae)

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Abstract

The taxonomic identity of *Rafflesia banaoana* from Kalinga Province in northern Luzon (Philippines) and its affinity with *R. leonardi* of the adjacent Cagayan Province are discussed. Both taxa share a unique combination of morphological characters pertaining to the color and shape of the perigone lobes, their warts, the diaphragm aperture, the size and number of disk processes, and anther number. The only notable difference between *R. banaoana* and *R. leonardi* is flower size and characters correlated with size. Because *Rafflesia* species show large intraspecific variation in flower size, and because *R. banaoana* and *R. leonardi* share a number of other morphological features, we conclude that these two taxa are conspecific. The name *R. banaoana* should therefore be considered a synonym of the earlier name *R. leonardi*. Here, we present an amended description of *R. leonardi*. An updated key to all ten known species of Philippine *Rafflesia* is also provided.

Key words: Cagayan, Kalinga, Luzon, parasitic plant, Philippines, *Rafflesia banaoana*

Introduction

Rafflesia Brown (1821: 207; Rafflesiaceae) is a genus of holoparasitic plants that are exclusively dependent on their liana host *Tetrastigma* (Miquel 1863: 72) Planchon (1887: 423; Vitaceae). In his comprehensive review, Nais (2001) discussed all 18 *Rafflesia* species known at that time, two of which, *R. schadenbergiana* Göppert ex Hieronymus (1885: 3) and *R. manillana* Teschemacher (1844: 65) were reported for the Philippines. Since 2001, however, 12 additional names have been published for the Philippines (summarized in Barcelona *et al.* 2009a, 2009b, Balete *et al.* 2010). Of these, we recognize eight as distinct species. One of these new Philippine *Rafflesia* species was described by Malabrigo (2010) from a population discovered by staff of the Resources, Environment and Economic Center for Studies, Inc. (REECS) in the Kalinga Province of northern Luzon. Malabrigo named it *R. banaoana* Malabrigo (2010: 140), in honor of the Banao tribe.

In discussing its affinity, Malabrigo (2010) compared *R. banaoana* (Fig. 1A) to other Philippine species and concluded that it resembles *R. baletei* Barcelona & Cajano (Barcelona *et al*. 2006: 232) (Fig. 1C) of the Bicol Region (southern Luzon) in the shape and density of the perigone warts and the color and morphology of its ramenta. We, however, disagree with these observations. *Rafflesia banaoana* has perigone warts that are

Accepted by B. van Ee: 2 May 2011; published: 26 May 2011

smaller, less embossed, and, as visible in Fig. 1, more regularly and distantly spaced from each other than those of *R. baletei*. In addition, *R. banaoana* has warts of two distinct sizes: large elliptic or roundish warts interspersed with tiny ones, whereas *R. baletei* has warts that are irregular in shape and size and cannot readily be assigned to two size classes. Instead, the warts of *R. banaoana* most closely resemble those of *R. leonardi* Barcelona & Pelser (Barcelona *et al.* 2008a: 224) (Fig. 1B). Furthermore, in *R. banaoana*, the short, reddish-brown ramenta that are nearly evenly distributed in the perigone tube are much more similar to those of *R. leonardi* than to those of *R. baletei*.

Malabrigo (2010) also stated that *R. banaoana* is similar in size with *R. speciosa* Barcelona & Fernando (2002: 648) (Fig. 1E) of Panay and *R. mira* Fernando & Ong (2005: 267) (Fig. 1F) of Mindanao. Furthermore, he claimed that like *R. leonardi* from Cagayan Province (northern Luzon) and *R. manillana* of Samar and Luzon (Fig. 1D), *R. banaoana* has widely spaced perigone lobes and that it resembles *R. baletei*, *R. leonardi*, *R. lobata* Galang & Madulid (2006: 2), and *R. manillana* in perigone color. Finally, his photographs show that *R. banaoana* shares the wide diaphragm aperture of *R. leonardi*, *R. lobata*, and *R. manillana*. A comparison of *R. banaoana* photos and illustration with those of the aforementioned species, however, clearly shows that *R. banaoana* can only be confused with *R. leonardi* (Fig. 1A–F).

Both taxa share a unique combination of morphological characters, namely, elliptic or roundish powdery white warts on the perigone's upper surface, a wide diaphragm aperture, and short, reddish-brown ramenta. Moreover, both *R. banaoana* and *R. leonardi* have relatively few disk processes (up to 16; Barcelona *et al.* 2008a, Malabrigo 2010) compared to other similar-sized *Rafflesia* species (e.g., *R. mira*, 38–40, and *R. speciosa*, 17–31). Also, the reddish orange, orbicular to broadly orbicular perigone lobes with slightly auriculate bases are unique characters of *R. banaoana* and *R. leonardi*. Finally, both taxa overlap in anther number (*R. banaoana*, 18–22 and *R. leonardi*, 20 or 21). The only distinguishing characters that the author explicitly mentions for *R. banaoana* are "the number and structure of the processes that are very few (14–16) [and] concentrated in the center of the disc but irregularly scattered" (Malabrigo 2010: 145). In comparison, the processes of *R. leonardi* are lacking or few and poorly developed. Observations of other *Rafflesia* species, however, show that the number of processes is strongly correlated with flower size (e.g., Barcelona *et al.* 2009b). It is, therefore, not surprising that these are more numerous and better developed in *R. banaoana*, which has larger flowers (40–50 cm diam.) than *R. leonardi* (25.5–34 cm diam.). This is further supported by the observation that small *R. leonardi* flowers entirely lack processes, whereas up to 10 processes have been reported for larger flowers of this species (Barcelona *et al.* 2008a). Thus, the only true difference between the taxa is flower size. Limited sample size may be a reason for the pronounced difference in flower size between *R. banaoana* and *R. leonardi*. When studying the flower size of *R. leonardi*, we measured ca. 10 fresh specimens of newly opened or early senescent flowers on ca. five different host plants. It is not clear from Malabrigo (2010) how many flowers of *R. banaoana* were measured, as only the holotype was cited. This holotype specimen was not available for examination at LBC.

Rafflesia species demonstrate substantial variation in flower size both between and within populations, and large variation can even be observed in flowers growing on a single host plant. Our field observations in different *Rafflesia* populations reveal that flower size may depend on the number of flowers and buds that are present on a single host as well as the size, health, and age of the host plant. The large variation in flower size is perhaps best exemplified by the largest flower in the world, *R. arnoldii* Brown (1821: 207), which has flowers that range from a little more than half a meter to a meter and a half when fully expanded—a three-fold size difference (Nais 2001). Likewise, in *R. schadenbergiana*, flowers from a single host plant have been measured from 52 to 70 cm in diameter (Barcelona *et al.* 2008b, 2009b) while the largest flower reported for this species is 80 cm (Hieronymus 1885, '1884'). Also, *R. manillana* shows large differences in flower size. For instance, flowers on one of the host plants in Basey, Samar are substantially larger (20–23 cm diam.) than flowers growing on other host plants in the area (15–17 cm diam.; pers. obs. by JFB). Because of the large intraspecific differences in flower size observed in *Rafflesia*, flower diameter is not suitable as the sole criterion for species delimitation. In view of this, and after examining the original description of *R. banaoana*, we therefore conclude that Malabrigo's (2010) *Rafflesia* and *R. leonardi* are conspecific and that the name *R.*

leonardi has priority. In the absence of access to the type specimen, we feel that sufficient morphological characters were illustrated in Malabrigo (2010) for us to make comparisons and be confident in our taxonomic conclusion.

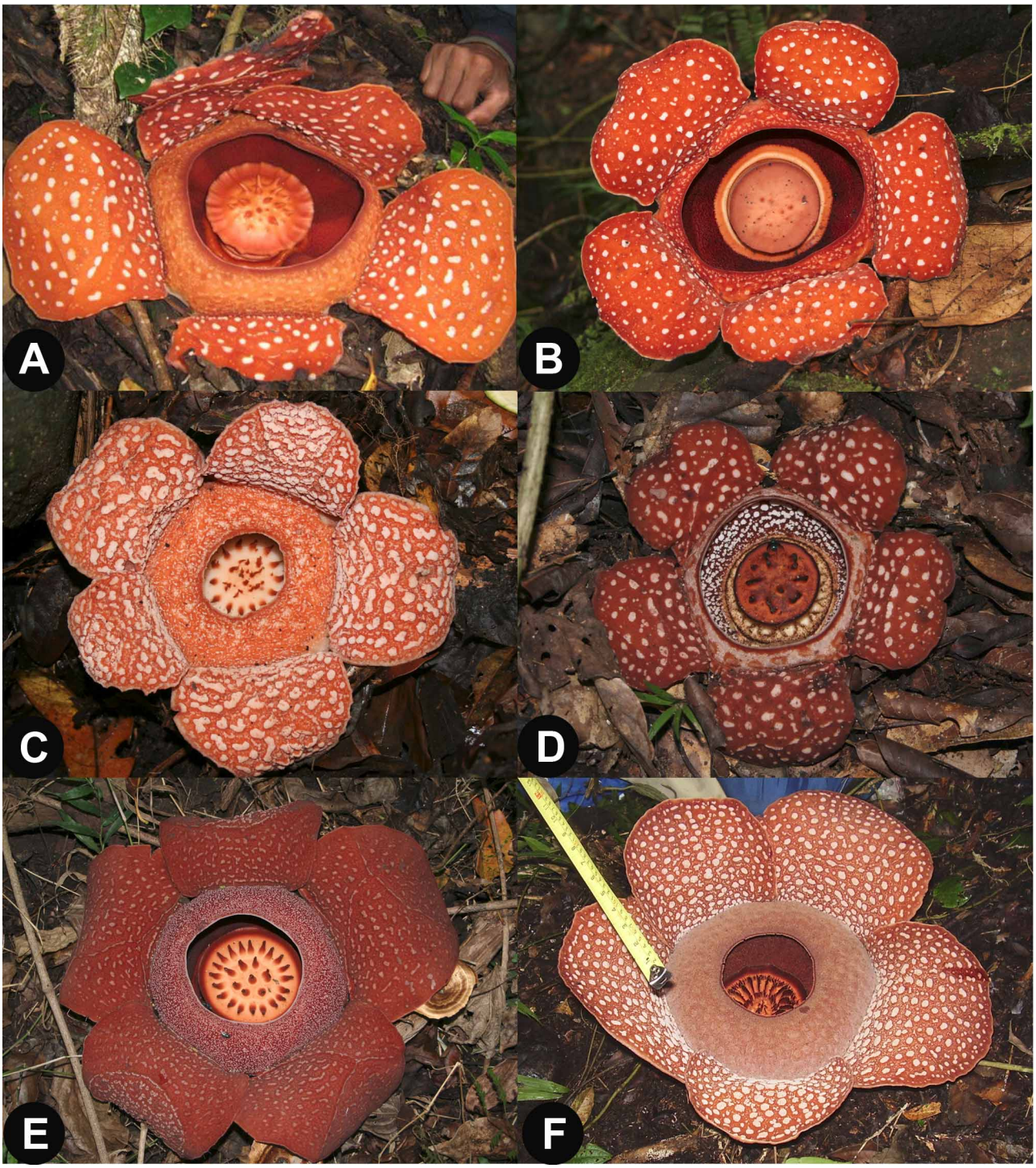

FIGURE 1. *Rafflesia banaoana* and species compared to it by Malabrigo (2010). **A.** *R. banaoana* Malabrigo (= *R. leonardi*). **B.** *R. leonardi* Barcelona & Pelser. **C.** *R. baletei* Barcelona & Cajano. **D.** *R. manillana* Teschem. **E.** *R. speciosa* Barcelona & Fernando. **F.** *R. mira* Fernando & Ong. Photo credits: **A.**—P. Malabrigo, courtesy of Asia Life Sciences, **B–E.** —J.F. Barcelona, **F.** —courtesy of Fuentes-Maestre, Department of Tourism Region XI.

Despite our taxonomic differences with Malabrigo (2010), we acknowledge the significance of the contribution of his work to our current knowledge of the distribution and morphology of *R. leonardi* in particular, and patterns of diversity of the genus *Rafflesia* in general. We now know that *R. leonardi* has flowers that range from 25.5 to 50 cm in diameter and that this species grows in the montane forests (up to 1361 m elevation) of Kalinga, as well as in the lowland evergreen forests (270–300 m elevation) of Cagayan Province of northern Luzon. The presence of *R. leonardi* in Kalinga is particularly interesting, because Merrill (1923: 121) reported *Rafflesia* from this province. Although Merrill referred to this species as *Rafflesia manillana*, it is possible that it was, in fact, *R. leonardi*.

Taxonomy

Rafflesia leonardi Barcelona & Pelser in Barcelona *et al.* (2008a: 224).—Type: *Barcelona et al. 3355* (holotype PNH!; isotypes L!, PUH!, US! CAHUP!).

= *Rafflesia banaoana* Malabrigo in Malabrigo (2010: 140). —Type: *Malabrigo 605* (holo LBC, n.v.).

An updated key to Philippine *Rafflesia*

Presented below is an updated identification key to all known Philippine *Rafflesia* that includes two species not described in the overview paper by Barcelona *et al.* (2009b): *R. aurantia* Barcelona, Co & Balete from Quirino Province of Luzon (Barcelona *et al.* 2009a: 18) and the recently described *R. verrucosa* Balete, Pelser, Nickrent & Barcelona from Mindanao (Balete *et al.* 2010: 50). This key now includes updated information on the morphology of *R. leonardi* following the observations of Malabrigo (2010). An updated character comparison (see Barcelona *et al.* 2009b) of all Philippine *Rafflesia* is also provided (Table 1). This includes additional measurements of *R. manillana* flowers from various localities.

1. Diaphragm aperture wide, more than ½ of the diaphragm diameter, fully exposing the disk inside (if otherwise, plants from Basey, Samar) 2
1. Diaphragm aperture narrow, less than ½ of the diaphragm diameter, only partially exposing the disk inside 4
2. Windows/white blotches absent from the inner surface of the diaphragm and perigone tube; processes when present, with reddish-orange tips; anther cavities on the floor of the perigone tube absent; flowers more than 25 cm diam. —Luzon ..... *R. leonardi*
2. Windows/white blotches present on the inner surface of the diaphragm and perigone tube, processes with blackish tips; anther cavities on the floor of the perigone tube prominent; flowers less than 25 cm diam 3

3. Diaphragm lobed, almost snow-white in newly opened flowers.—Panay ..... *R. lobata*
3. Diaphragm usually entire (irregularly lobed in some populations in northern Luzon), cream-colored with round or elliptic, reddish-orange blotches or reddish-orange background with cream-colored or whitish variously-shaped and sometimes coalescent blotches. – Luzon and Samar ..... *R. manillana*

4. Fully expanded flowers 40 cm or more in diam 5
4. Fully expanded flowers less than 40 cm diam 7

5. Disk processes polymorphic, larger ones laminar or plate-like, erose; perigone warts round or elliptic; rim of aperture darker than diaphragm. —Mindanao ..... *R. mira*
5. Disk processes monomorphic, conical; perigone warts elongated; rim of aperture whitish or paler than the diaphragm 6

6. Fully expanded flowers 52–80 cm diam, reddish maroon; diaphragm rugose, larger perigone warts 1 cm or more wide, sometimes coalescent or reticulate; disk processes more than 40 in number. —Mindanao . *R. schadenbergiana*
6. Fully expanded flowers 45–56 cm diam, rusty- or reddish brown; diaphragm generally smooth; larger perigone warts less than 5 mm wide, free; disk processes less than 40 in number. —Panay and Negros ..... *R. speciosa*

7. Flowers uniformly orange in color including warts; ramenta up to 1 cm —Luzon ..... *R. aurantia*
7. Flowers reddish orange, maroon or rusty brown, warts whitish or paler than the rest of the perigone tissue; ramenta up to 7 mm 8

8. Diaphragm warts thick, prominently raised, laminar, fringing the aperture rim giving it an erose appearance; disk processes anastomosing laminar plates, forming an interconnected system. —Mindanao ..... *R. verrucosa*
8. Diaphragm warts thin, slightly raised, not laminar, not fringing the aperture rim; disk processes solitary and conical or variously branched but not anastomosing laminar plates nor forming an interconnected system 9

9. Disk creamy white centrally, becoming reddish brown towards the periphery, undersurface (corona) whitish, tan peripherally; processes monomorphic, mostly solitary, in two concentric rings; ramenta nearly uniformly distributed from the base of the perigone tube to the diaphragm; diaphragm aperture round; windows absent; flowers often bisexual. —Luzon ..... *R. baletei*
9. Disk yellowish centrally, maroon towards the periphery, undersurface uniformly maroon; processes polymorphic, sometimes anastomosing, flattened horizontally, radially disposed; ramenta polymorphic, scattered, more or less solitary and less-branched in the perigone tube, clustered, larger, stouter and dense inside the diaphragm; diaphragm aperture usually oval; windows present in larger flowers; flowers strictly unisexual. —Luzon..... *R. philippensis*

TABLE 1. Character comparison for Philippine *Rafflesia*. This is an updated version of the table published in Barcelona *et al*. (2009b).

Characters	*R. baletei*	*R. verrucosa*	*R. aurantia*	*R. lobata*	*R. manillana*	*R. philippensis*	*R. leonardi* (including *R. banaoana*)	*R. speciosa*	*R. mira*	*R. schadenbergiana*
Position of flowers on host	on roots	on roots	on roots	on roots and climbing shoots	on roots and climbing shoots	on roots	on roots and climbing shoots	on roots and climbing shoots	on roots	on roots
Flower diameter (cm)	9–22	14.5–16	ca. 20	11–21	14–23	17.5–27(–32)	25.5–50	45–56	45–60	52–80
Perigone color	orange	reddish orange or cinnamon	orange	reddish orange	reddish orange	red, less often reddish orange	reddish orange	reddish orange to red	reddish orange to red	reddish orange to maroon
Perigone wart / ornamentation shape	round or elliptic	prominently raised, solitary, irregular in shape, usually roundish, less often rod-like to narrowly elongated, white-tipped	sharp-edged, areoles-forming	round or elliptic	round or elliptic	elliptic or slightly elongated	round or elliptic	elongated	mostly round or elliptic	elongated to reticulate
Diaphragm rim	entire	erose	entire	lobed	entire (rarely lobed)	entire	entire	entire (rarely lobed)	entire	entire
Diaphragm rim color vs. diaphragm color	darker	concolorous	concolorous	concolorous	white	white	concolorous	concolorous or white	red	white

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TABLE 1 (continued)

Characters	*R. baletei*	*R. verrucosa*	*R. aurantia*	*R. lobata*	*R. manillana*	*R. philippensis*	*R. leonardi* (including *R. banaoana*)	*R. speciosa*	*R. mira*	*R. schadenbergiana*
Diaphragm surface	reticulate	densely covered with prominently raised, pleated, plate-like, white-tipped warts	sharp-edged, areoles-forming	smooth	smooth or slightly rugose	rugose	smooth	smooth	smooth	rugose
Ratio diaphragm / aperture diameter	2.3–2.5	1.75–2.25	3.3–2.8	up to 1	1.33–1.8 (–2.33)	2–2.2	1.2–1.5	1.8–2 (–2.4)	ca. 2	1.8–2.2
Diaphragm aperture shape	round	round, sometimes irregularly so	round	round	round	oval	round	round	round	round
Disk processes number	19–26	indefinite	indefinite	7–14	8–30	up to ca. 25	absent or up to 16	17–31	38–40	30–63
Disk processes arrange-ment / disposition	regular concen-tric rings	irregular, inter-connected system	centrally disposed, horizon-tally oriented in females?, vertically oriented in males?	irregular concentric rings	irregular concentric rings	irregular, not in rings	irregular concen-tric rings	regular concen-tric rings	irregular concentric rings	regular concentric rings
Disk processes maximum length (cm)	1	1.1	1	0.5	0.55	1.5	1.2	2.3	1	3
Disk processes types	monomor phic, conical or slightly laterally com-pressed, often branched	tightly packed, laminar plates with erose margins	poly-morphic, flattened, peri-pheral ones narrowly lanceo-late, spinose, tuber-culate, tips tufted with golden brown hairs	monomor-phic, conical or slightly laterally com-pressed, unbran-ched	mono-morphic, conical or slightly laterally com-pressed, unbran-ched, tips tufted with black hairs	dimorphic, promi-nently flattened laterally and branched, interspersed with tuberculate ones	almost absent, when present mono-morphic, conical, un-branched	mono-morphic, conical, often un-branched	poly-morphic in 4 zones: conical central ones followed by blades perpen-dicular to each other, then outermost ones reduced	mono-morphic, conical, often un-branched

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TABLE 1 (continued)

Characters	*R. baletei*	*R. verrucosa*	*R. aurantia*	*R. lobata*	*R. manillana*	*R. philippensis*	*R. leonardi* (including *R. banaoana*)	*R. speciosa*	*R. mira*	*R. schadenbergiana*
Ramenta color relative to surrounding tissue	darker	white-tipped in newly opened flowers, otherwise concolorous	slightly darker?	white	white	darker	darker	darker	darker	darker
Ramenta length (mm)	up to 2	7	7–10	1–2	0.5–1	up to 3	up to 2	up to 2	5–10	4–10
Ramenta distribution on the perigone tube and diaphram	uniform	longer and denser at perigone tube floor, shorter and more widely spaced on the diaphragm, nearly absent near the aperture rim	sparse towards the aperture, becoming dense towards the base of the floral cavity	sparse at base, abundant towards the diaphragm	sparse at base, abundant towards the diaphragm	sparse at base, abruptly more abundant towards the diaphragm	abundant at base, gradually more sparse towards aperture	uniform	sparse at base, abundant halfway, less abundant towards aperture	sparse at base, abundant halfway, less abundant towards aperture
Ramenta size & shape	largest at base, slightly smaller towards aperture, not clustered	covered with clavate pustules, polymorphic, filiform to variously branched or cleaved apically, white-tipped in newly opened flowers	uniformly lanate, glabrous, slender, unbranched to furcate, tips swollen	smallest and solitary at base, larger and more clustered towards the aperture ('windows')	smallest and solitary at base, larger and more clustered towards the aperture ('windows')	smallest and solitary at base, abruptly larger and more clustered towards the diaphragm	solitary at base, more sparse and clustered towards aperture	largest and solitary at base, smaller and more clustered towards aperture	smallest at base and diaphragm, largest halfway up the tube, not clustered	smallest and solitary at base, largest, more clustered halfway up, smaller and more clustered towards aperture
Windows	absent	absent	absent	present	present	present only in large flowers	absent	absent	absent	absent
Anther number	11–14	20 or 21	12–14	10–11	10–18	14–16(–23)	18–22	19–24	10–22	26–40
Tetrastigma host	*Tetrastigma* sp.	*Tetrastigma sp.*	*Tetrastigma sp.*	*Tetrastigma sp.*	*T. leucostaphylum*, *T.* cf. *loheri*, *Tetrastigma* sp.	*Tetrastigma sp.* or *T. scariosum* (see Veldkamp, 2009)	*T.* cf. *loheri*	*Tetrastigma sp.*	*T. loheri*	*T. papillosum*
Distribution	Luzon	Mindanao	Luzon	Panay	Luzon and Samar	Luzon	Luzon	Panay and Negros	Mindanao	Mindanao

Acknowledgements

We dedicate this paper to four important Filipino botanists, namely, Mr. Leonardo L. Co, Drs. Prescillano M. Zamora, Daniel A. Lagunzad, and Cecilia B. Amoroso whose legacy in advancing Philippine Botany through training Filipino students, raising awareness about the importance of biodiversity conservation, and protecting the Philippines' precious forests and seas, will always be appreciated and remembered. We will sorely miss you. We thank Dr. Wiliam Sm. Gruezo, Chief Editor, Asia Life Sciences, for allowing us to reprint a photograph of *Rafflesia banaoana*.

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