



A new species of *Gastrodia* (Gastrodieae, Epidendroideae, Orchidaceae) from the Maliau Basin Conservation Area, Sabah, Borneo

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Gastrodia Brown (1810: 330; Gastrodieae, Epidendroideae) comprises mycoheterotrophic orchids from throughout the temperate and tropical regions of Asia, Oceania, Madagascar and Africa (Chung & Hsu 2006, Cribb *et al.* 2010, Tan *et al.* 2012). The genus is characterized by fleshy tubers, as well as the absence of normal leaves, union of sepals and petals and two mealy pollinia that lack caudicles. Furthermore, many *Gastrodia* species within section *Codonanthus* (Schlechter 1911, Tuyama 1967) produce inflorescences that are only 3–15 cm in length at flowering (Chung & Hsu 2006) and, owing to their short flowering seasons and dwarf habits, are seldom noticed when flowering (Tuyama 1982, Suetsugu *et al.* 2012). The identification of *Gastrodia* species requires detailed observation of floral features, such as lip and column morphology, that are hidden within the perianth tube.

Although the species taxonomy of section *Codonanthus* remains to be revised, several studies have recently re-examined the diversity of *Gastrodia* (section *Codonanthus*) species from various countries in Asia (Chung & Hsu 2006, Meng *et al.* 2007, Hsu & Kuo 2010, 2011, Yeh *et al.* 2011, Hsu *et al.* 2012, 2016, Tan *et al.* 2012, Ong & Byrne 2012, Ong 2015, Suetsugu 2013, 2014, 2016, 2017, Hu *et al.* 2014, Huang *et al.* 2015, Pelsner *et al.* 2016, Tsukaya & Hidayat 2016). Consequently, the genus has been updated to comprise more than 90 acceptable species, making it the largest mycoheterotrophic genus among all vascular plants (Hsu *et al.* 2016, Suetsugu 2017).

Borneo is one of the most biodiverse regions of the world, particularly with respect to mycoheterotrophic plants, and harbors ca. 70 mycoheterotrophic species, which is more than the number documented in the whole of tropical Africa (Merckx *et al.* 2013). A high rate of endemism in Borneo is particularly pronounced in the mycoheterotrophic Burmanniaceae sensu APG (2016; Thismiaceae of other authors) and Orchidaceae, with all 16 *Thismia* species and at least 18 mycoheterotrophic orchids endemic (Sochor *et al.* 2017, 2018; Suetsugu *et al.* 2017, 2018; Tsukaya *et al.* 2017). Even though recent botanical surveys have uncovered many previously undescribed mycoheterotrophs in Borneo (Sochor *et al.* 2017, 2018; Suetsugu *et al.* 2018; Tsukaya *et al.* 2017), only four *Gastrodia* species have been reported: *G. javanica* (Blume, 1825: 421.) Lindley (1840: 384), *G. spathulata* (Carr, 1935: 180) Wood (in Wood *et al.* 2011: 355), *G. sabahensis* Wood & Lamb (in Wood 2008: 139), and *G. grandilabris* Carr (1935: 179). However, the continued discovery of new species and distribution records for mycoheterotrophs in Borneo suggest that a large number of undescribed species remain hidden. Indeed, as anticipated, a *Gastrodia* species, with floral morphology that differs from that of other known species, was discovered in the Maliau Basin Conservation Area of Malaysian Borneo.

Many *Codonanthus* species are pollinated by fruit flies, which are trapped in the space between the labellum and column of the flowers (Martos *et al.* 2015, Suetsugu 2018). Martos *et al.* (2015) demonstrated that the trap chamber can filter out fruit fly species for which body sizes differ from the dimensions of the trapping apparatus (Martos *et al.* 2015). Therefore, differences in lip and column morphology can indicate pollinator-mediated reproductive isolation.

Gastrodia maliauensis Suetsugu, M.Suleiman & Tsukaya, *sp. nov.* (Figs. 1–2)

Type:—MALAYSIA. Sabah: Maliau Basin Conservation Area, from Ginseng Camp (N4°44'44"; E116°55'05", 680 m alt.) to Maliau Falls (N4°46'06", E116°55'05", 440 m), 16 August 2017, Tsukaya, Suetsugu & Anthony TSA-5 (holotype: BORH; isotype: TNS, a flower in the spirit collection).

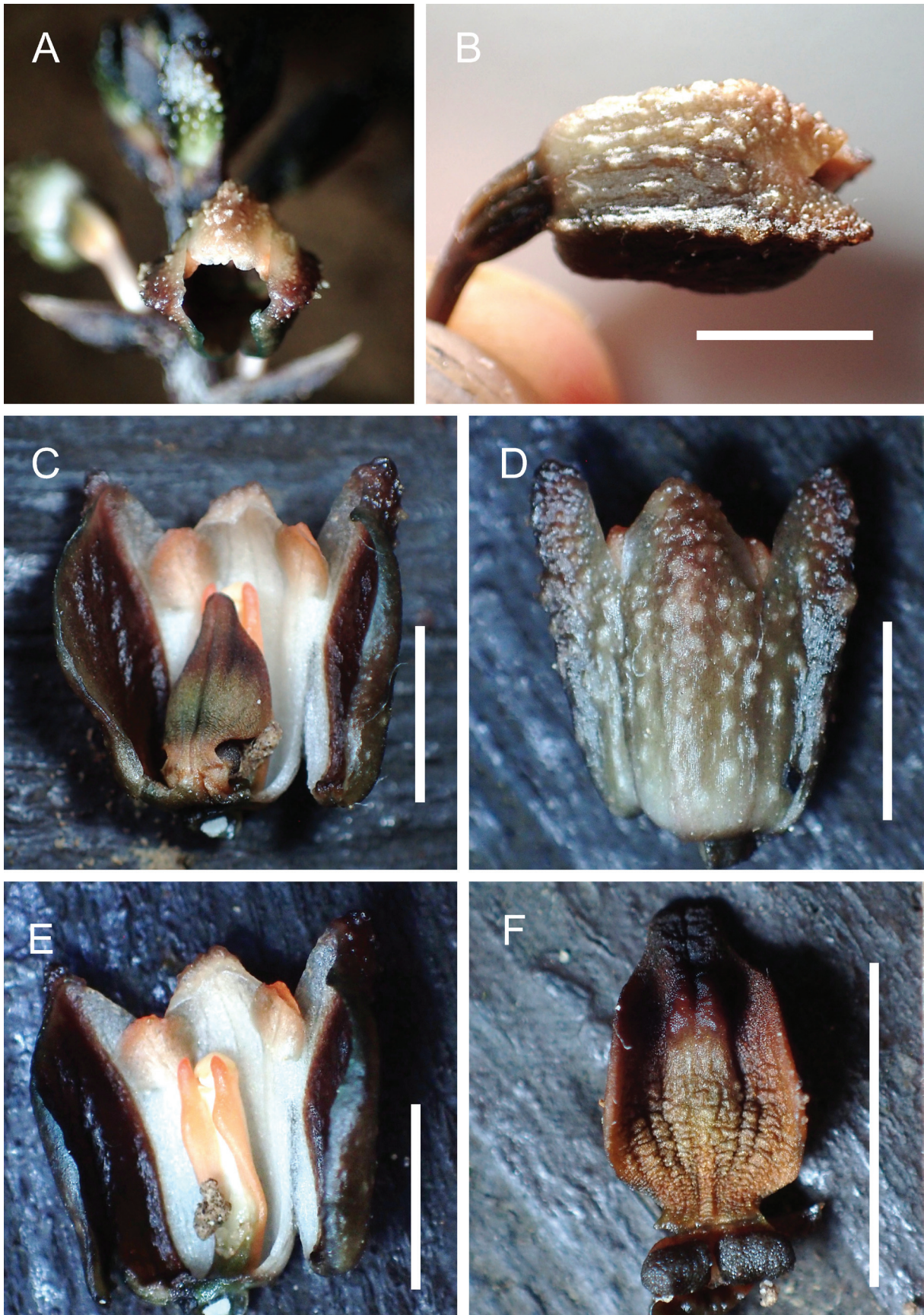


FIGURE 1. *Gastrodia maliauensis* (photos of the holotype). A. Flowers. B. Flower, side view. C. Dissected flower. D. Flattened perianth tube. E. Flattened perianth tube, with column. F. Lip. B–E. Bar = 5 mm. F. Bar = 1 mm.

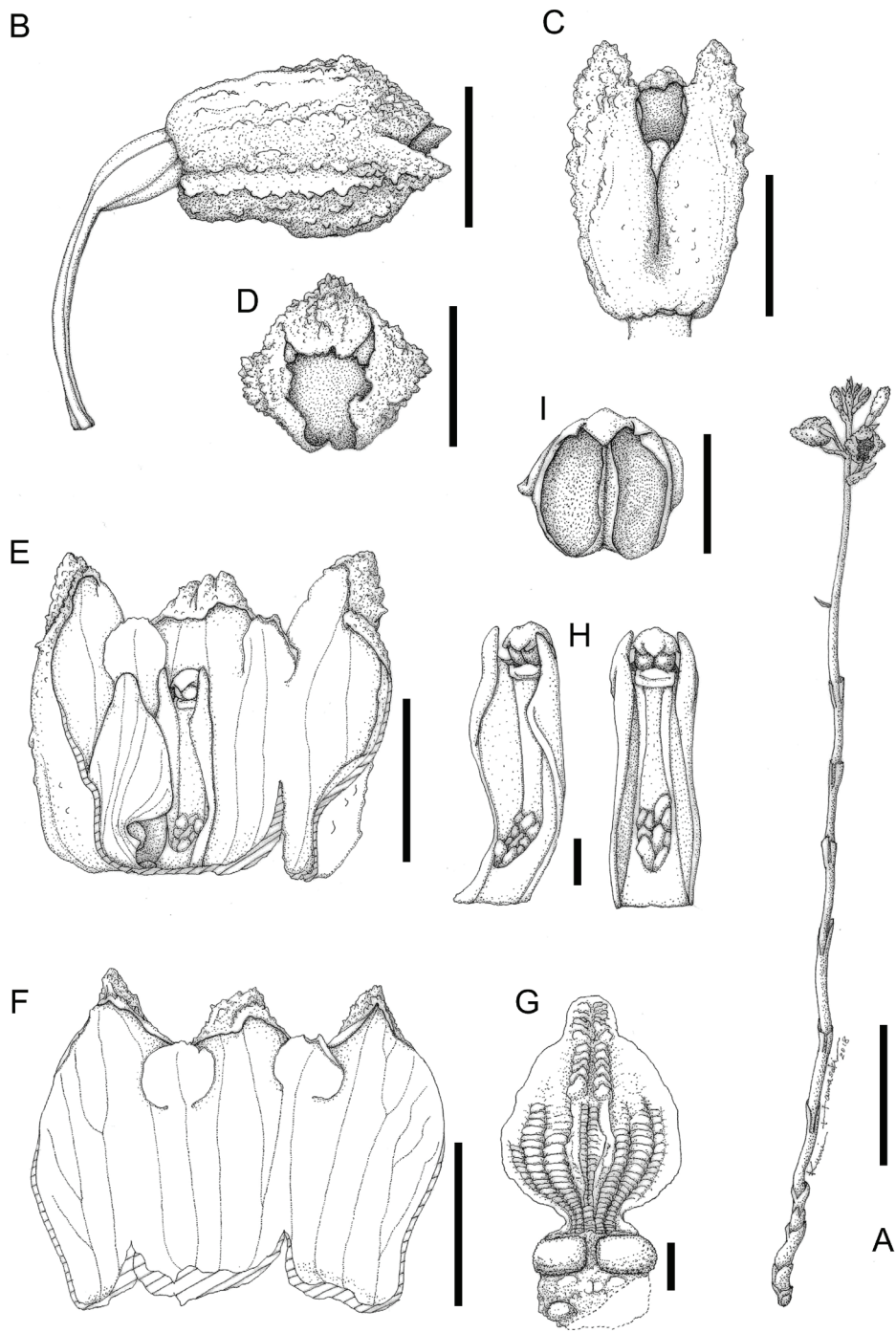


FIGURE 2. *Gastrodia maliauensis* (drawn from the holotype). A. Habit. B. Flower, side view. C. Flower, bottom view. D. Flower, front view. E. Dissected flower. F. Flattened perianth tube. G. Lip. H. Column. I. Anther cap. A. Bar = 3 cm. B–F. Bar = 5 mm. G–I. Bar = 1 mm.

Gastrodia maliauensis is similar to *G. verrucosa* Blume (1856: 175) in possessing bell-shaped flowers with verruculose outer surfaces, sepals connate ca. 2/3 of their length and petals connate ca. 2/3 of their length. However, it differs from *G. verrucosa* in lacking globose processes just below the stigma (vs. having these processes), stelia with obtuse apices (vs. acute apices) and different ridges on the lip disc (two central ridges extending to apex and other ridges only extending to near the middle vs. all 6–8 ridges extending to apex).

Terrestrial, mycoheterotrophic herbs. Rhizome tuberous, fusiform or cylindrical, covered with numerous scales. Stem erect, dark brown, ca. 20 cm long, ca. 2.5 mm in diameter, nodes 10, with tubular, membranous scale leaves. Bracts ovate, up to 8 × 4 mm. Inflorescence racemose, rachis, ca. 3 cm long, densely 10 flowered. Pedicel and ovary up to 12 mm long. Flower, bell-shaped, slightly tilted upwards, resupinate, ca. 10 mm long, 6.4 mm in diameter. Sepals and petals united, forming a five-lobed perianth tube, outer surface pale greenish brown to dark brown, verruculose. Sepals subsimilar, ca. 10 mm long, adnate to petals for ca. 2/3 of their length; lateral ones connate ca. 2/3 of their length; inner surface of dorsal sepal ivory, smooth, margins entire; half of inner surface of lateral sepals in contact with dorsal sepal ivory, smooth, margins entire; half of inner surface of lateral sepals in contact with one another dark brown, smooth, margins entire; free portion of dorsal sepal straight, ovate-triangular, obtuse at apex, ca. 4.2 × 3.8 mm; free portions of lateral sepals, triangular, acute at apex, ca. 4 × 4 mm. Free portions of petals ovate or elliptic, ca. 1.8 × 2.2 mm, base contracted, margin slightly undulate. Lip adnate to column foot, dark brown, ca. 6.8 × 3.8 mm; hypochile with 2 elliptic calli; epichile ovate, base contracted, with 6–8 ridges on disc (two central ridges extending to apex and other ridges only extending to near the middle), margin slightly undulate, apex portion ligulate, ca. 1 mm wide. Column straight, semi-cylindrical, 6.1–6.3 × 1.9–2.0 mm, white; lateral wings (stelia) distinct, narrow, edges parallel to column, base slightly angled, reddish orange, apex obtuse; rostellum prominent; stigma located at base. Anther hemispheric, ca. 1.2 mm in diameter, pollinia 2. Fruits and seeds not seen.

Distribution and phenology:—To date, we found only one flowering individual in the Maliau Basin Conservation Area, Sabah, Borneo, Malaysia. Its habitat is the wet understory of a forest dominated by Dipterocarpaceae species.

Preliminary IUCN conservation status:—Critically Endangered on the basis of one location, a single mature individual and a single population. [CR: D].

Taxonomic notes:—*Gastrodia maliauensis* is similar to *G. verrucosa* in possessing bell-shaped flowers with verruculose outer surfaces, sepals connate ca. 2/3 of their length, and petals connate ca. 2/3 of their length. However, these characters are similar to those of other species that are morphologically similar to *G. verrucosa* (Suddee & Harwood 2009). This complex probably includes *G. appendiculata* Leou & Chung (1991: 138), *G. boninensis* Tuyama (1939: 2), *G. confusa* Honda & Tuyama (1939: 659), *G. confusoides* Hsu, Chung & Kuo (2012: 273), *G. nantoensis* Hsu & Kuo ex Lin in Lin *et al.* (2016: 99), *G. sabahensis* Wood & Lamb in Wood (2008: 139), *G. shimizuana* Tuyama (1982: 380), and *G. verrucosa*. However, the taxonomic identity of *G. verrucosa* has remained somewhat problematic, mainly due to the incompleteness of the original description.

As stated by Ong (2015), the protologue of *G. verrucosa* by Blume (1856) is brief and vague: “flowers pedicellate, perigonium lobes subequal-obtuse, warty externally, column with two erect stelia” and cannot be used to identify specimens. Therefore, the descriptions and illustrations of *G. verrucosa* by Smith (1905, 1906, 1908) provide the only detailed information of the species based on specimens collected from Java, the type locality. Comparing our material to descriptions and illustrations of *G. verrucosa* by Smith revealed that *G. maliauensis* can be easily distinguished from *G. verrucosa* by analyzing column shape (without globose processes just below the stigma vs. with globose processes just below the stigma), stelia (obtuse apex vs. acute apex), and pattern of ridges on the lip disc (only two central ridges extending to the apex and other ridges only extending to near the middle vs. all 6–8 ridges extending to the apex). In addition, *G. maliauensis* has a longer lip than *G. verrucosa* (>6 mm vs. <5 mm; Smith 1905, 1906, 1908). Moreover, quantitative differences are also recognized. The stem of *G. verrucosa* was reported to be ca. 7 cm long and bears 2 flowers (Smith 1905, 1906, 1908), while that in the new species is ca. 20 cm long and bears 10 flowers.

Seidenfaden & Wood (1992) noted that *G. verrucosa* occurs in Sumatra, Peninsular Malaysia, Java, and Japan by treating *G. holttumii* Carr (1929: 38), *G. confusa* Honda & Tuyama (1939: 659), and *G. boninensis* Tuyama (1939: 2) as synonyms of *G. verrucosa* and that the disjunct distribution pattern required further study. Suddee & Harwood (2009), who supported this view, also noted that the discovery of *G. verrucosa* in Thailand fills in part of the large distributional gap and that *G. shimizuana* Tuyama (1982: 380) is another synonym of *G. verrucosa*. However, owing to clear differences in lip and column morphology, which are key characters in *Gastrodia* taxonomy, we suggest that these species differ from both *G. verrucosa* and *G. maliauensis*. For example, the lips of both *G. verrucosa* and *G. maliauensis* bear 6–8 ridges that arise from the base of the epichile, whereas the lips of *G. boninensis*, *G. confusa*, *G. confusoides*, *G. sabahensis*, and *G. shimizuana* bear two longitudinal keels that arise from just below the ligulate apex, and those of *G. appendiculata* and *G. nantoensis* lack ridges altogether. In addition, both *G. verrucosa* and *G.*

maliauensis possess columns that are nearly uniform in width from the base to apex, whereas the other species possess columns that are arguably widest at about one third of the length from the base. Therefore, when compared to members of the *G. verrucosa* complex, the new species is most similar to *G. verrucosa*, although it differs as described above.

Intriguingly, although *G. holttumii* was treated as a synonym of *G. verrucosa* by Seidenfaden & Wood (1992), O'Byrne (2010) reported that a fresh specimen from the type locality (Peninsular Malaysia) of *G. holttumii* matched the description and illustration of *G. holttumii* by Car (1929) but not those of *G. verrucosa*. Accordingly, Ong (2015) rejected Seidenfaden & Wood's (1992) treatment of *Gastrodia holttumii* as a synonym of *G. verrucosa* and excluded Peninsular Malaysia from the distribution of *G. verrucosa*. Similarly, the specimens identified as *G. verrucosa* in other areas, such as Thailand (Suddee & Harwood 2009) and the Philippines (Pelser *et al.* 2011, Barcelona *et al.* 2013), may contain other undescribed species. However, because the precise identification of *Gastrodia* species requires the detailed analysis of floral organs that are concealed in the perianth tube, herbarium specimens will need to be re-analyzed to confirm the true identity of specimens previously attributed to *G. verrucosa*.

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