

***Gastrodia queenslandica* (Gastrodieae, Epidendroideae, Orchidaceae) in Singapore and Thailand, first records in Asia**

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ABSTRACT. *Gastrodia queenslandica* Dockrill, a mycoheterotrophic orchid, was previously recorded from eastern Queensland, Australia. We recently encountered populations of *Gastrodia* R.Br. in Singapore and Thailand which appear to be conspecific with *G. queenslandica*. In 1889 Ridley collected this species in fruit from Singapore, but he incorrectly identified them as *Didymoplexis pallens* Griff. We present a comprehensive analysis including a detailed description, line drawing, colour plates, and notes on taxonomy and ecology. We assembled the plastome of *Gastrodia queenslandica* from Singapore, which is 29,498 bp in size, notably the smallest plastome recorded in the genus.

Keywords. Morphological diversity, Southeast Asia, species delimitation, taxonomy

Introduction

Gastrodia R.Br. is one of the largest genera of mycoheterotrophic plants (Hsu et al., 2016) comprising 109 accepted species to date (POWO, 2025). The genus is widely distributed from tropical Africa, Madagascar, other islands in the Western Indian Ocean, the Russian Far East to tropical Asia, Australia and New Zealand (Pridgeon et al., 2005). Most species are narrow endemics. With approximately 30 species of *Gastrodia*, Southeast Asia is a major centre of diversity for the genus (Cribb et al., 2010).

Classification relies primarily on flower structure (Suetsugu et al., 2018), but the taxonomy and classification of *Gastrodia* are challenging. Species of *Gastrodia* are often difficult to detect in the field: most of their growth takes place underground, and the plants only appear above ground when flowering and fruiting. Their inconspicuous habit and colouration, as well as their small flowers add to the difficulty. Moreover, their flowers are ephemeral and many collections contain only fruits.

Species diversity remains poorly documented in the genus, especially in Indonesia (Tsukaya & Hidayat, 2016; Metusala & Supriatna, 2017) and Madagascar (Martos et al., 2015; Huang et al., 2018; Hermans, 2020). No monographic work or systematic phylogenetic study on *Gastrodia* has been attempted so far, but regional floristic works continue to add new members to this species-rich genus. There have been attempts to divide the genus into multiple genera based for example on fruit characters and the level of tepal fusion (Clements & Jones, 2019), but *Gastrodia* is generally considered sensu lato; where a few small genera in Gastrodieae (*Auxopus* Schltr., *Didymoplexis* Griff., *Didymoplexiella* Garay and *Uleiorchis* Hoehne) are usually considered to be distinct.

Until recently, the only species of *Gastrodia* recorded from Singapore was *G. javanica* (Blume) Lindl. (Lok et al., 2009; Lindsay et al., 2022). During recent botanical surveys for the ongoing Flora of Singapore project, XYN and RCJL recorded a *Gastrodia* species in Bukit Timah Nature Reserve and MAN in Nee Soon Freshwater Swamp Forest, Singapore. Fruiting plants, which were first found, differed from *G. javanica* in infructescence structure and fruit elongation. Flowering plants were found during subsequent revisits to BTNR, which confirmed their morphological distinctiveness from other orchid species in Singapore. They were subsequently identified as *Gastrodia queenslandica* Dockrill previously only known from northeastern Australia (Dockrill, 1964, 1992).

In Thailand, where six species of *Gastrodia* have been reported previously (*G. fimbriata* Suddee, *G. phangngaensis* Suddee, Sirim. & Chamch. *G. javanica*, *G. verrucosa* Blume, *G. exilis* Hook.f. & *G. theana* Aver.), a population of an additional species was found by PP in 2017. This population was distinguished from other Thai species by its coralloid callus on the lateral sepals, but it conforms to the morphology of *Gastrodia queenslandica* as treated here.

We provide a detailed description, a line drawing, colour plates, and notes on the taxonomy and the ecology within the extended range of this species, as well as notes on the historical collections from Singapore.

Methods

Morphological measurements

We measured and photographed specimens at BKF, CNS, QRS and SING (see specimens examined and Appendix 1). To ascertain our identification, we conducted a thorough comparison of our materials to descriptions and illustrations of other species of *Gastrodia* with a callus on the lateral sepals.

In alphabetic order of epithets, we compared the material to the following literature for flower details: *Gastrodia agnicellus* Hermans & P.J.Cribb from Madagascar (Hermans, 2020), *G. callosa* J.J.Smith from Java (Smith, 1931) and Taiwan (Hsu & Kuo, 2010), *G. crassiseppala* L.O.Williams from New Guinea (Williams, 1942), *G. holttumii* Carr from Peninsular Malaysia (Ong & O’Byrne, 2012; Ong, 2015), *G. queenslandica* from NE Australia, Singapore and Thailand (Dockrill, 1964, 1992), *G. isabelensis* T.C.Hsu from the Solomon Islands (Hsu et al., 2016), *G. madagascariensis* H.Perrier ex Martos & Bytebier from Madagascar (Martos et al., 2015), *G. maliauensis* Suetsugu, Suleiman & Tsukaya from Borneo (Suetsugu et al., 2018), *G. pubilabiata* Sawa from Japan and Taiwan (Lin & Wang, 2014), *G. sabahensis* J.J.Wood & A.Lamb from Borneo (Wood, 2008; Hroneš et al., 2024), *G. solomonensis* T.C.Hsu from the Solomon Islands (Hsu et al., 2016), *G. sui* C.S.Leou, T.C.Hsu & C.R.Yeh from Taiwan (Yeh et al., 2011), *G. tembatensis* P.T.Ong & P.O’Byrne from Peninsular Malaysia (Ong, 2015), and *G. umbrosa* B.Gray from Australia (Gray & Low, 2017).

Conservation assessment

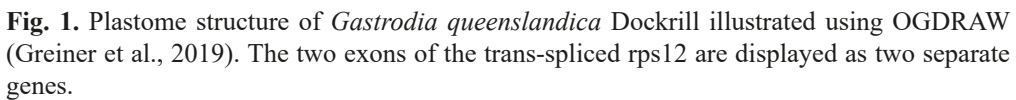
We conducted a global conservation assessment using the criteria set out by IUCN Standards and Petitions Committee (2024), and performed national conservation assessments for the two new populations using the criteria for regional assessment in IUCN Standards and Petitions Committee (2024) for Thailand and Davison et al. (2024) for Singapore.

DNA extraction and sequencing

Genomic DNA was extracted from flash-frozen infructescence tissue of *Gastrodia queenslandica* Dockrill collected in Singapore (Voucher: Ng et al. SING2023-109) using the DNeasy Plant Mini Kit (Qiagen) with two ethanol washes. DNA library preparation and sequencing was done by Novogene-AIT (Singapore) using paired end Illumina sequencing with 150 bp read length.

Plastome assembly and annotation

We used 20 million genome skimming raw reads for the plastome assembly. The reads were mapped to a reference plastome (*Gastrodia crispa* J.J.Sm.; NCBI GenBank accession NC_066062) using Geneious Prime v.11.1.14.1 (Biomatters Ltd, New Zealand). Assembly errors were manually corrected, and gaps were filled by iterative mapping. The completed plastome was annotated with Geneious Prime v.11.1.14.1, using the same reference plastome of *G. crispa* (NC_066062). The annotations were manually checked; no adjustments were necessary.



Morphological studies

Molecular studies

The plastome of *Gastrodia queenslandica* is 29,498 bp in size and highly similar in structure to that of *G. crisper* (NC_066062), showing no rearrangements. The plastome is very reduced (Fig. 1), lacking an inverted repeat, both characteristics typical of myco-

heterotrophic plants, and well-documented in all Gastrodieae sequenced so far (Wen et al., 2022). The number and order of genes was fully conserved in relation to *Gastrodia crispata*. The plastome of *Gastrodia queenslandica* represents the smallest plastome known so far in the genus. To our knowledge, the only published orchid plastomes that are smaller than this are *Epipogium* J.G.Gmel ex Borkh. (Schelkunov et al., 2015) and *Pogoniopsis* Rchb.f. (Klimpert et al., 2022), which are both mycoheterotrophic as well.

Taxonomic treatment

Gastrodia queenslandica Dockrill, N. Queensland Naturalist 32(136): 6 (1964). – *Demorchis queenslandica* (Dockrill) D.L.Jones & M.A.Clem., Orchadian 14 (8: Scientific Suppl.): xiii (2004). – TYPE: Australia, Queensland, Cook Pastoral District, Little Mulgrave River, 6 January 1962, A. Dockrill s.n. (holotype BRI [BRI-AQ0279600]). (Figs 2–6)

[The description of *Gastrodia queenslandica* is based on Singapore material with notes on material from Thailand for characters that differ.]

A terrestrial, leafless mycoheterotrophic herb. **Roots** few, slender, often extending from apex of rhizome. **Rhizome** tuberous, fleshy, irregularly fusiform or sub-oblong, up to 4.5 cm long (3–9 cm in Thailand), 3–10 mm diam. (5–8 mm in Thailand), yellowish brown, densely nodular, covered with numerous scales and unicellular hairs; **scales** poorly preserved but possibly amplexicaul, deeply lobed to resemble multiple verticillate scales, lobes lanceolate, 1–2 mm long, pale yellow-brown. **Stem** (or underground part of the inflorescence) 2–4 mm long, 2–3 mm diam., covered by 2 or 3 scale-like sterile bracts. **Inflorescence** 8–14 cm long (10–20 cm in Thailand), 1–3-flowered, sub-umbellate, glabrous. **Peduncle** erect, 7–12 cm long, 1.5–3 mm diam., pale brown and glabrous at base, turning dark brown and slightly warty towards apex, 4–6-noded, with tubular, membranous sterile bracts, c. 4 × 5 mm. **Rachis** 3–6 mm, bearing 1–3 flowers, dark brown; **floral bracts** membranous, ovate to ovate-oblong, 2–4 mm × 1–3 mm, pale brown (5–8 mm long in Thailand; punctate outside, acute, caducous). **Pedicel and ovary** 8–12 mm long; **pedicel** glabrous, dull cream-white to pale brown, elongating up to 40 cm long in fruit; **ovary** verrucose, dark brown, 2–3 mm diam. **Flowers** resupinate, fleshy, ovoid, slightly nodding, not widely opening to campanulate (latter in Thai specimens), brown, with a smoky fragrance, lasting one day. **Sepals and petals** forming a perianth tube, 1.2–1.5 cm long, 0.8–1 cm wide, sepals and petals connate to c. 1/2 length of sepals, lateral sepals connate to c. 1/2 their length (almost free in Thai specimens). **Sepals** abaxially sub-angular and verrucose, yellow-brown at base, turning dark brown towards apex, obtuse to acute, cymbiform (acute and less distinctly cymbiform, with apex spreading in Thai specimens); **dorsal sepal** 1–1.3 cm long, free portions straight, ovate-deltoid, c. 6 × 5.5 mm, apex hooded, obtuse to acute, margins slightly irregular, inner surface

with a pale orange callus towards apex, adaxially cream-white in lower half, turning pale brownish-orange towards apex; *lateral sepals* slightly longer than the dorsal one, 1.2–1.5 cm long, hooded, free portions straight, ovate-deltoid, c. 7×6 mm, margins entire, apex obtuse to acute, on the adaxial surface with dull brick red coralloid patches of calli, occupying $2/3$ length of each lateral sepal. **Petals** 6–7 mm long, free portions obovate, c. 2.5×2 mm (slightly smaller, $2\text{--}2.5 \times 1.5\text{--}2$ mm in Thailand), margins slightly revolute, undulate, apex obtuse, pale orange, turning orange towards apex. **Lip** adnate to the tip of column-foot (which is also adnate to perianth tube), abaxially pale orange, turning orange to orange-red towards margins and apex, adaxially orange-red, $4.5\text{--}5.5 \times 3.8\text{--}4.5$ mm ($5\text{--}6 \times 3.5\text{--}5$ mm in Thailand), claw conspicuous; *hypochile* c. 1.2 mm long, white, at base with two elliptic yellow-orange calli c. 1 mm diam.; *mesochile* and *epichile* not distinguishable, together approximately cordate, c. 3×4.5 mm, orange, apex slightly arched downwards, obtuse, with two cream-white apical ridges c. 1×0.5 mm. **Column** straight, winged, 4–4.5 (5–6 mm in Thailand) $\times$ c. 2.5 mm, ivory-white, margins and wings red; *lateral wings* parallel to column, apex with a pair of stelia c. 1 mm long, deltate, approximately equal in length to anther cap; *column foot* present; *rostellum* well-developed; *stigma* located near base. **Anther** hemispherical, c. 0.9×1 mm, pollinia 2. **Capsule** ellipsoid, slightly warty, $1.6\text{--}3 \times 0.5\text{--}1$ cm ($2.8\text{--}3 \times 0.8\text{--}1.2$ cm in Thailand), with a much-elongated pedicel (variable but often 20–40 cm), erect. **Seeds** fusiform, 1.2–2 mm long.

Distribution and ecology. *Gastrodia queenslandica* occurs in Australia (Queensland), Singapore and Thailand. This unusual, disjunct distribution could be due to a lack of flowering vouchers of *Gastrodia* from Indonesia, as there are many fruiting vouchers of *Gastrodia* from there which appear identical to those observed in Singapore, but in the absence of flowers or DNA data none can be attributed to this species with certainty. In Australia, the species has been collected at a few localities near Cairns. In Singapore, it has been collected from Bukit Timah Nature Reserve, Central Catchment Nature Reserve (Nee Soon Freshwater Swamp Forest), Western Water Catchment (“Bajau” or “Bajan”, in reference to the area around Kampong Ayer Bajau; this locality is likely lost as the area has been partially submerged in a water reservoir since the 1970s), and Seletar (now an urban area). Recent collections are from Bukit Timah and Nee Soon. In Thailand, the species is only known from one locality in Trang.

The species inhabits primary rainforest (in Singapore lowland dipterocarp rainforest) and freshwater swamp forest, favouring well-drained wet soil with leaf litter, typically along trails or streams. In Singapore, flowering and fruiting seem to peak from late March to June. A few plants have been seen in flower or fruit from November to January. In Queensland, the species flowers in January, whilst in Thailand it flowers in April. The pollinators remain unknown, though the smoky fragrance of the Singaporean plants suggests possible involvement of animals attracted to burning or resin. Autogamy has not been observed. In one collected flower, minute, unidentified larvae were observed; these larvae consumed the base of the tepals within a few hours of collection, causing the tepaline tube and labellum to detach from the column.

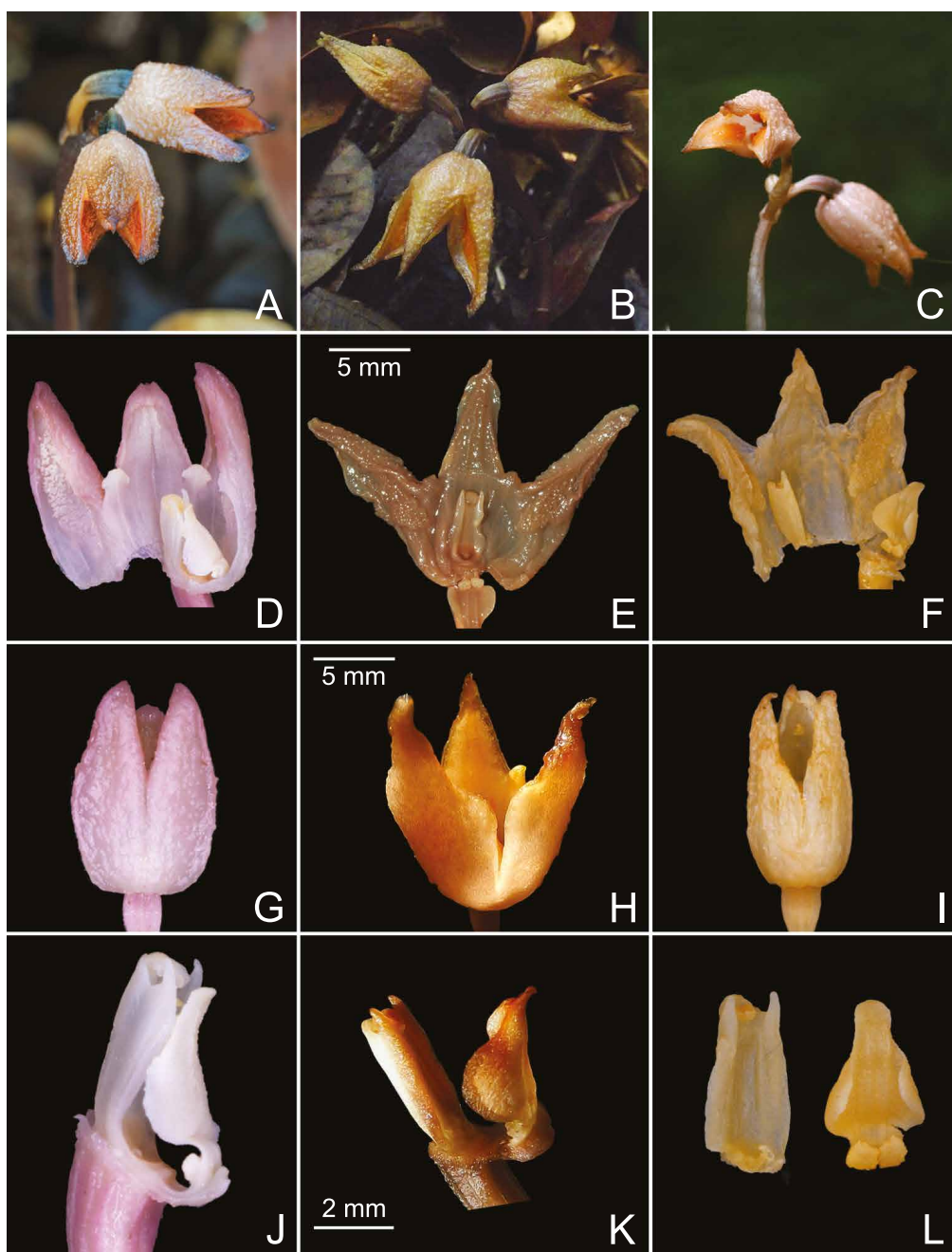


Fig 2. Comparison of *Gastrodia queenslandica* Dockrill in Singapore (Hu *et al.* SING2023-122; left), Thailand (Po-aim 07; middle) and Australia (Gray 9697; right). **A–C.** Photographs of flowering plants in situ. **D–F.** Perianth spread out, dissected between lateral sepals. **G–I.** Intact perianth, ventral view. **J–L.** Column and labellum. D–I and J–L are to the same scale. (Photos: A, M.A. Niissalo; B, P. Phoiain; C, B. Gray; D–L, A.Q. Hu)

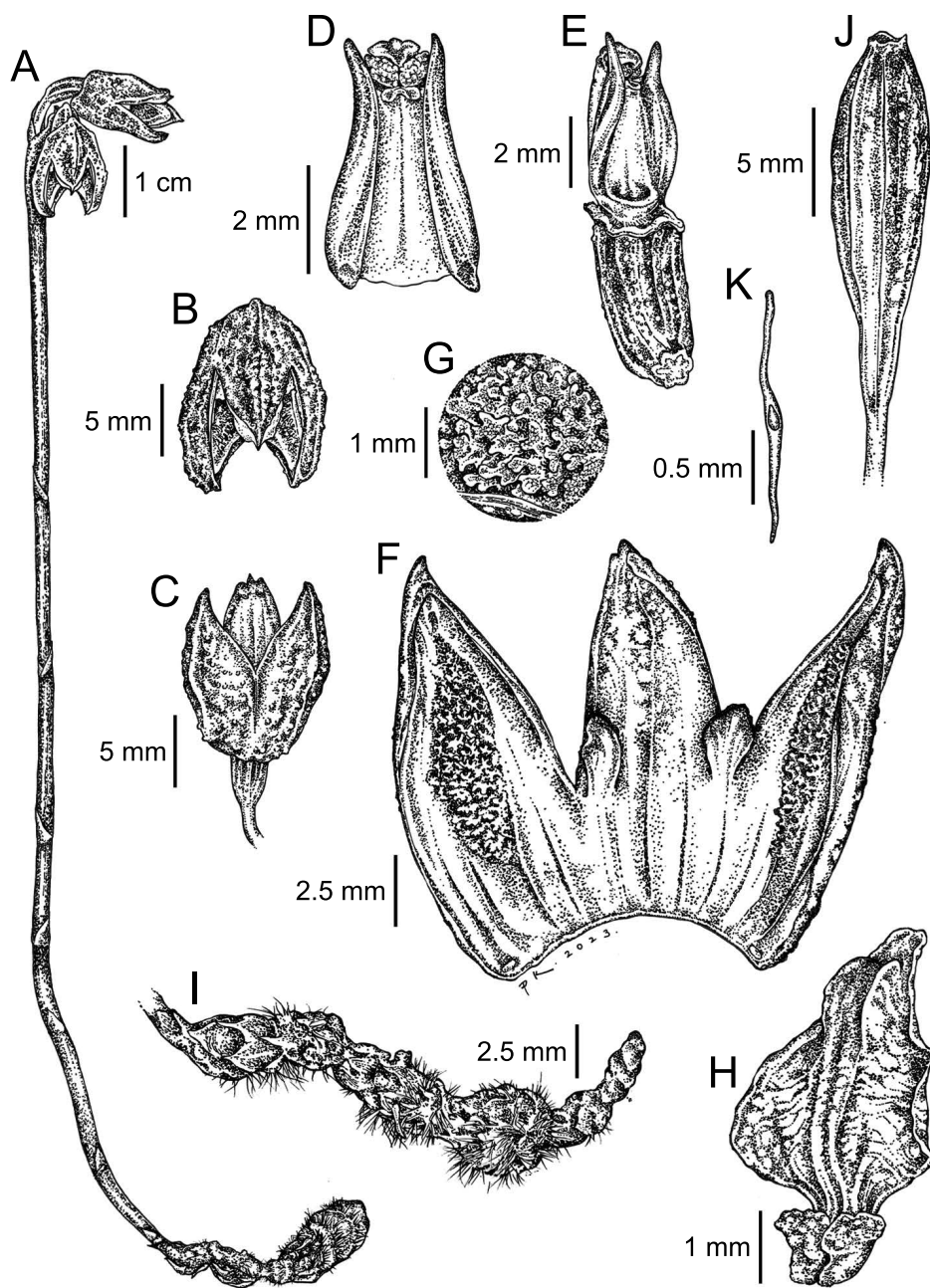


Fig. 3. Line drawing of *Gastrodia queenslandica* Dockrill. **A.** Flowering habit. **B.** Flower, dorsal view. **C.** Flower, ventral view. **D.** Column. **E.** Column and ovary, showing the basal position of the stigmatic surface. **F.** Perianth tube, cut open between the fused lateral sepals. **G.** Detail of calli on the surface of the lateral sepals. **H.** Lip. **I.** Tuberous rhizome. **J.** Capsule, excluding the elongated base of the fruit. **K.** Seed. From Hu *et al.* SING2023-122. Drawn by Cheng Puay Koon.



Fig. 4. Photographs of *Gastrodia queenslandica* Dockrill in Singapore. **A.** Habit of a flowering plant, showing perianth abscission after flowering. **B.** Details of flowers. **C.** Detail of capsule. **D.** A plant with a mature fruit and a full-size inflorescence in bud, showing the extent of fruit elongation. A from Hu *et al.* SING2023-117; B–D from Hu *et al.* SING2023-122. (Photos: M.A. Niissalo)

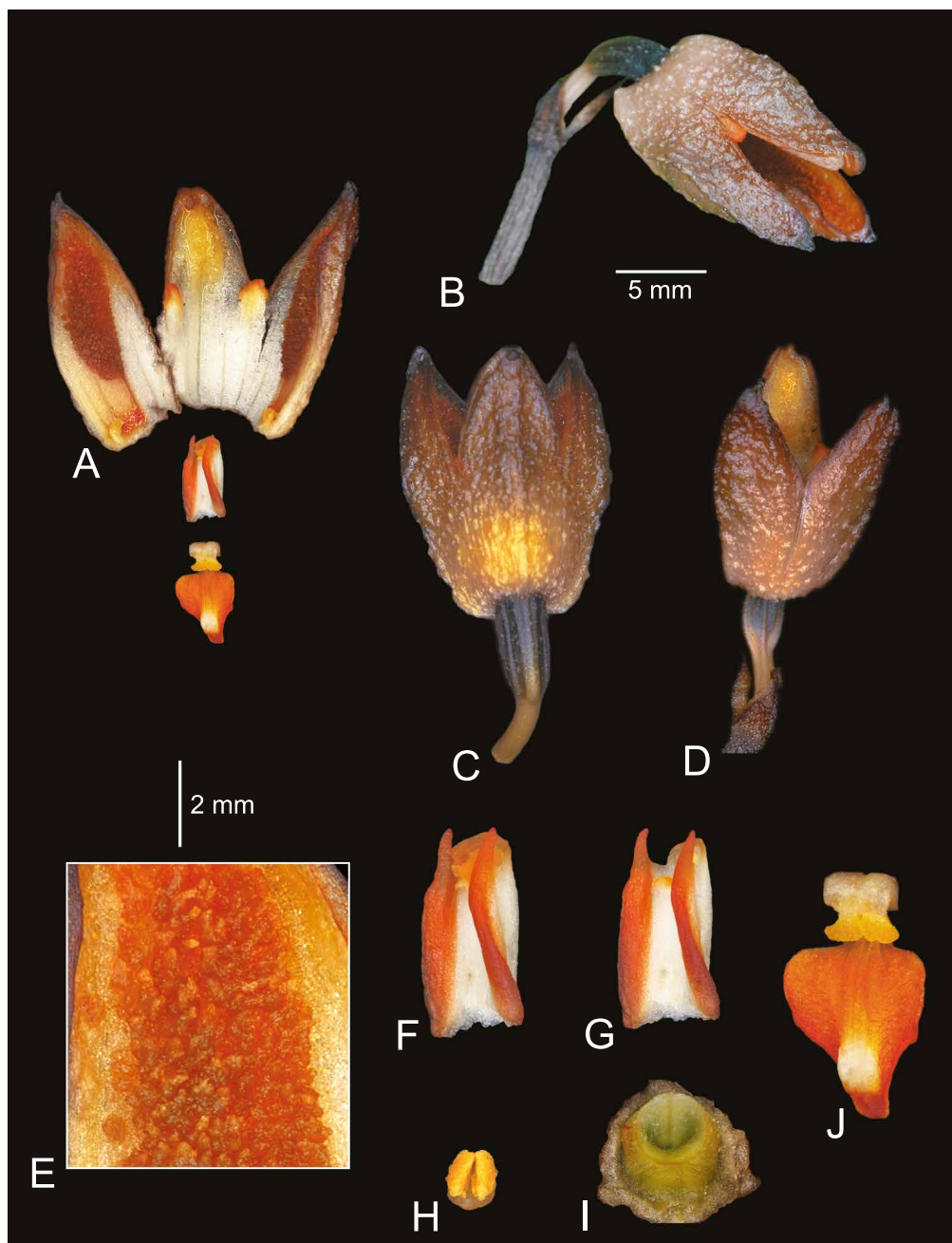


Fig. 5. Photographs of the floral parts of *Gastrodia queenslandica* Dockrill in Singapore. **A.** Perianth tube, cut open between the fused lateral sepals. **B.** Flower, oblique front view. **C.** Flower, dorsal view. **D.** Flower, central view. **E.** Detail of calli on the surface of the lateral sepals. **F.** Column. **G.** Column showing rostellum by removing the anther cap. **H.** Anther cap with two pollinia. **I.** Stigma. **J.** Lip. From Hu *et al.* SING2023-122. A–D and E–J are to the same scale respectively. (Photos: A.Q. Hu)



Fig. 6. Two over-a-century-old collections of *Gastrodia queenslandica* Dockrill in Singapore, collected by H.N. Ridley and deposited at SING. **A.** Ridley s.n. [SING0056033]. **B.** Ridley s.n. [SING0056032].

Provisional IUCN Conservation assessment. The new populations we report here expand the known range of the species, and currently the extent of occurrence (EOO) of 1,300,000 km² is extensive and area of occupancy (AOO) of 24 km² is small (Bachman et al., 2011, calculated using <https://geocat.iucnredlist.org/>); as there is no evidence of recent decline in population size, these do not affect the conservation assessment. The population size is very poorly known. Only a small number of individuals have been observed globally, but especially the Australian range has been little surveyed. The area of suitable habitat in Australia is extensive, and all the known populations, including the ones reported here, are in protected areas. The known localities have not experienced significant habitat loss since the 1970s, which is likely longer than three generations (however, nothing is currently known of the generation time of this species), but there is much uncertainty if this represents the total range of the species. As the total population size and population trends and history of global habitat loss

are not known, the species is best treated globally as Data Deficient. In Singapore, *Gastrodia queenslandica* has a population of c. 40 flowering/fruiting individuals, mostly in Bukit Timah Nature Reserve. As there are fewer than 50 individuals in Singapore, it should be considered nationally Critically Endangered using the national criteria set out by Davison et al. (2024). In Thailand this species should also be considered Critically Endangered (CR D) as the known population is fewer than 50 individuals (IUCN Standards and Petitions Committee, 2024). No immigration events are expected between the known populations due to the long distances between them.

Specimens examined. AUSTRALIA: **Tropical North Queensland:** Cooper Creek, 28 Jan. 2004, fruiting, Gray 8882 (QRS [QRS126356]); Mossman Gorge National Park, 2 Jan. 2016, flowering, Gray 9697 (CNS [CNS144480]).

SINGAPORE: **Bukit Timah:** 1902, fruiting, Ridley s.n. (SING [SING0056033]); ibidem, 30 Mar. 2023, fruiting, Ng et al. SING2023-109 (SING [SING0291189]); ibidem, 6 Apr. 2023, flowering, Hu et al. SING2023-117 (SING [spirit material SING0323513]); ibidem, 7 Apr. 2023, flowering, Hu et al. SING2023-122 (SING [SING0291188; spirit material SING0323512]); ibidem, 4 May 2023, flowering, Hu et al. SING2023-143 (SING [spirit material SING0323514]). **Nee Soon:** Nee Soon Swamp Forest, 1889, fruiting, Ridley s.n. (SING [SING0056032]); ibidem, 7 Nov. 2022, fruiting, Niissalo et al. SING2022-1004 (SING [SING0361981]). **Seletar:** Apr. 1889, fruiting, Ridley s.n. (SING [SING0056034]). **Western Water Catchment:** 1892, fruiting, Ridley s.n. (SING [SING0056031]).

THAILAND: **Trang:** Yan Ta Khao District, Thung Khai Botanical Garden, 24 Apr. 2017, *Phoaiam 07* (BKF).

Notes. There are minor morphological differences between the three populations of *Gastrodia queenslandica*. The Singapore population has cymbiform, incurved, obtuse to acute sepals. The Thai and Australian specimens display acute to acuminate sepals, which are not cymbiform, but rather curved outwards to form a constricted campanulate flower. Lateral sepal fusion also differs: Singaporean and Australian populations show fusion for c. 1/2–2/3 of their length, whereas in Thai specimens they are almost free to the base. The pedicels in Australian plants are usually shorter than the Singaporean ones but this is not consistent, and the length of pedicels could be related to soil moisture (AQH, MAN & BG, pers. obs.). Nothing is known of variation in flower morphology within the populations.

Fruiting specimens of *Gastrodia queenslandica* may be confused with other *Gastrodia* species that display elongated pedicels, as well as with members of the genus *Didymoplexis*. Fruiting specimens collected from Singapore between 1889 to 1902 were identified by Ridley (1896) as *Didymoplexis pallens* Griff., a classification that has persisted in recent plant catalogues (e.g., Chong et al., 2009; Lindsay et al., 2022). Even though the infructescences of Gastrodieae cannot be identified with complete certainty, these specimens fully agree with *Gastrodia queenslandica* based on their short rachides with 1–2 fertile bracts. The specimens we have seen of *Didymoplexis pallens* have longer rachides with 4–20 flowers, with the rachis contributing nearly half the inflorescence length when in fruit (Comber, 1990; Appendix 1). Consequently, all the Singaporean material cited by Ridley as *Didymoplexis pallens* is here treated

as *Gastrodia queenslandica*, and *D. pallens* should no longer be considered native to Singapore. The misidentification of fruiting *Gastrodia* specimens with *Didymoplexis* appears to be common (Martos et al., 2015), suggesting that numerous specimens labelled as *Didymoplexis* at K, L and P (and likely other herbaria) may represent *Gastrodia* species. A thorough examination of these specimens, complemented by field collection of flowering specimens, would likely lead to a better understanding of the diversity and distribution of *Gastrodia*.

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Appendix 1. Specimens of *Didymoplexis pallens* Griff. examined for morphological comparison.

MYANMAR: **Southern Myanmar:** Taninthayi NR, 24 Mar. 2012, *Saw et al. TNRO 58* (SING [SING0388221]).

PENINSULAR MALAYSIA: **Kedah:** Kedah Peak, Jun. 1893, *Ridley s.n.* (SING [SING0137516]). **Penang:** Barat Daya, Pulau Betong, 6 Feb. 1903, *Curtis s.n.* (SING [SING0137514]). **Johor:** Layan-Layang, 21 Apr. 1935, *Holttum 29354* (SING [SING0137517]).

