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Taxonomic appraisal of *Fagraea ceilanica* (Gentianaceae), and description of a new tree species from the Bird's Head Peninsula, western New Guinea

Yee Wen Low, Jimmy F. Wanma, Bazilah Ibrahim, Charlie D. Heatubun & Victor A. Albert

Abstract

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A new rainforest understorey tree, *Fagraea christinae* Y.W. Low & V.A. Albert (Gentianaceae), is described here based on three collections from the Bird's Head Peninsula, western New Guinea. The new species was previously included in the species complex *F. ceilanica* Thunb. s.l. *Fagraea christinae* is superficially similar to *F. annulata* Hiern and *F. berteriana* A. Gray ex Benth. in having stamens inserted upon a fleshy ring on the inner surface of the corolla tube, but differs from those two taxa in having crenate bracteoles and calyx lobes. The new species is provided with line drawings, field photographs and a distribution map.

Keywords

GENTIANACEAE – *Fagraea* – Malesia – Southwest Papua Province – Vogelkop Peninsula – Endemic – Taxonomy

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Introduction

Fagraea Thunb., a genus of the gentian family (Gentianaceae), consists of shrubs, trees, hemi-epiphytes and lithophytes occurring in tropical and subtropical regions from the Indian subcontinent to mainland Indochina, Taiwan, the Malay Archipelago, through to Australia and into the Pacific Islands (STRUWE et al., 2002). Its centre of species diversity lies in Malesia, a well-known biogeographical region located within Southeast Asia (VAN STEENIS, 1950; LEENHOUTS, 1962a; STRUWE et al., 2002) and also one of the important biodiversity hotspots in the world (MYERS et al., 2000). Thunberg dedicated the genus to the Swedish naturalist Jonas Theodor Fagraeus (1729–1797), and it is typified by *F. ceilanica* Thunb., a shrub known for its long trumpet-like, showy and scented flowers (THUNBERG, 1782; PHILCOX, 1996). *Fagraea ceilanica* was described by Thunberg based on a flowering shrub he discovered when botanising between Colombo and the fort city of ‘Gale’ [Galle], ‘Ceilon’ [Ceylon; now Sri Lanka] (THUNBERG, 1782). Sri Lanka was Thunberg’s final stopover before he returned to Europe after his maiden voyage to Japan (THUNBERG, 1791; SVEDELIUS, 1944). Accompanying Thunberg’s protologue of *F. ceilanica* there was an illustration, Tab. IV, featuring a flowering branch and a cross-section of a fruit of the new genus and new species (Fig. 1A).

When *Fagraea* was revised for *Flora Malesiana* (LEENHOUTS, 1962a), *F. ceilanica* was interpreted in the broadest sense as a highly polymorphic species under the concept *Rassenkreis*, a German term for ring-species or species with several geographical subspecies (GOLDSCHMIDT, 1933; MEIKLE, 1957; LEENHOUTS, 1962b; MAYR, 1963). Based on morphological evidence gathered from herbarium specimens, multiple interbreeding neighbouring populations or local forms of *F. ceilanica* were interpreted to occur from the Indian subcontinent to mainland Southeast Asia, Taiwan, across the Malay Archipelago and into the Pacific Islands (LEENHOUTS, 1962a, 1962b). In addition, several interspecies hybridisations were also believed to have taken place between *F. ceilanica* and other *Fagraea* species, such as in New Guinea with *F. berteriana* A. Gray ex Benth., which likely resulted in *F. annulata* Hiern (LEENHOUTS, 1962b). *Fagraea berteriana*, as defined at present, is yet another polymorphic species complex that occurs in New Guinea, Australia, to the archipelagos of the Pacific Ocean (LEENHOUTS, 1962a, b; CONN, 1995; MOTLEY, 2004). Under the broad species concept adopted for *F. ceilanica*, many distinct species across the Malesian region and its vicinities were synonymised (LEENHOUTS, 1962a, b). When *F. ceilanica* s.l. was re-evaluated for regional taxonomic studies of *Fagraea* conducted for Borneo (WONG & SUGAU, 1996) and the Malay Peninsula (WONG & SUGUMARAN, 2016), its species concept was found to be unsustainable, and subsequently reinterpreted in the strict sense. The outcome of these studies resulted in the recognition of distinct taxa previously synonymised (see LEENHOUTS, 1962a, b) being reinstated and new species described.

Fagraea ceilanica sensu Leenhouts in New Guinea

The ring-species hypothesis proposed for a species complex of *Fagraea ceilanica* recognised 14 forms or ‘races’, four of which occur in New Guinea: ‘angienensis’, ‘gardeniaeflora’, ‘litoralis’ and ‘ternatana’ (LEENHOUTS, 1962a, b). The ‘litoralis’ form is the most widespread throughout the distribution range of *F. ceilanica* s.l. It is defined in having (i) small- to medium-sized elliptical leaves, (ii) a pair of small bracteoles inserted in the middle along the length of the pedicel, and (iii) a cup-shaped calyx not constricted in the mouth (LEENHOUTS, 1962a, b).

The ‘angienensis’ and ‘ternatana’ forms share the following characteristics: (i) calyx constricted in the mouth, and (ii) a pair of small bracteoles inserted slightly above the middle along the length of the pedicel (LEENHOUTS, 1962a, b). The former is distinguishable from the ‘ternatana’ form in having slightly obovate leaves (LEENHOUTS, 1962a, b). On the other hand, the ‘gardeniaeflora’ form is distinct from the other three forms in New Guinea by having a pair of large bracteoles inserted just below the calyx and forming a cupule or a cup tightly clasping around the base of the calyx (LEENHOUTS, 1962a, b). Later, in the taxonomic treatment of *Fagraea* for Papua New Guinea, Leenhouts’ forms recognised in New Guinea were grouped into two primary forms, the ‘*F. gardeniaeflora*’/‘*F. archboldiana*’ form and the ‘*F. litoralis*’/‘*F. ternatana*’ form (CONN, 1995).

Morphologically, these four New Guinean forms proposed in LEENHOUTS (1962a, b) are distinct from *Fagraea ceilanica* s.s., and we believe they are worthy of taxonomic recognition. A similar conclusion was also made by CONN (1995). Nevertheless, we do not attempt to solve this taxonomic puzzle here as it requires a thorough and systematic evaluation of all the 14 *F. ceilanica* forms or ‘races’ proposed by Leenhouts across its distribution range, including all the synonyms.

Our taxonomic perspective

The first comprehensive taxonomic account of New Guinean *Fagraea* s.l. was by LEENHOUTS (1962a), who prepared it for the *Flora Malesiana* and recorded 13 species. In the flora of mountainous regions of New Guinea, *F. salticola* Leenh. is the only species enumerated to occur above 3,000 m elevation (CONN, 1983). Later, when a review of the *F. gracilipes* A. Gray complex sensu Leenhouts was carried out for Australia and New Guinea, five distinct taxa previously synonymised were reinstated (CONN & BROWN, 1993). A flora account for Papua New Guinea, a sovereign state occupying the island’s eastern half, enumerated 16 species of *Fagraea* s.l. (CONN, 1995). A recent checklist of New Guinean vascular flora (CÁMARA-LERET et al., 2020) listed 11 species of *Fagraea* s.s., with one species transferred to *Cyrtophyllum* Reinw. and the other to *Picrophloeus* Blume following an approach based on molecular



Fig. 1. – *Fagraea ceilanica* Thunb. **A.** Reproduction of the illustration, tab. IV (THUNBERG, 1782); **B.** Lectotype (Thunberg s.n. [UPS-THUNB4308]); **C.** Flowering plant from Rahathangala, Sri Lanka.
 [Photos: **A:** Biodiversity Heritage Library (contributed by the Natural History Museum Library, London); **B:** reproduced with kind permission from the Museum of Evolution, Uppsala University, Sweden; **C:** Himesh D. Jayasinghe]

phylogenetic studies conducted on West Malesian *Fagraea* s.l. (SUGUMARAN & WONG, 2012; WONG & SUGUMARAN, 2012). *Utania* G. Don was unfortunately overlooked in CÁMARA-LERET et al. (2020) but was accounted for in *Trees of Papua New Guinea* (CONN & DAMAS, 2019) and *Trees of New Guinea* (UTTERIDGE & JENNINGS, 2021).

In 2019, a flowering and fruiting *Fagraea* specimen was collected around Ayamaru Lakes in the central region of the Bird's Head Peninsula (comprising the current Indonesian provinces of Southwest Papua and West Papua). Based on the *Fagraea* s.l. identification key in the *Flora Malesiana* account (LEENHOUTS, 1962a), we managed to key out the Ayamaru taxon as *F. ceilanica* s.l., but with much dissatisfaction considering it is a species with a broad species concept as discussed in CONN (1995) and WONG & SUGAU (1996). While reviewing images of herbarium specimens of *Fagraea* s.l. from New Guinea at the Naturalis BioPortal website [https://bioportal.naturalis.nl], we came across two collections from Ayamaru, Vink BW15226 and Vink BW15361, that were a perfect match to our own Ayamaru collection. These Vink collections bear determination slips of Leenhouts, with Vink BW15226 determined as *F. ceilanica* 'angiensis' form and Vink BW15361 as *F. ceilanica* 'ternatana' form. As we disagree with these determinations for the two Vink collections, we decided to examine this western New Guinean taxon more carefully.

Firstly, we affirmed that the three Ayamaru collections, Wanma et al. MAN-SING45, Vink BW15226 and Vink BW15361 are identical and belong to the same taxon. Separately, a collection from the vicinity of Ayamaru (Polak 923) that represents the unnamed Ayamaru taxon was brought to our attention by Timothy Utteridge (pers. comm.). We are convinced that the Ayamaru taxon is distinct from all 14 *Fagraea ceilanica* forms or 'races' recognised by Leenhouts, as the former has distinctly crenate bracteoles and calyx lobes. In contrast, the 14 *F. ceilanica* forms or 'races' of Leenhouts have entire bracteoles and calyx lobes margin (LEENHOUTS, 1962a, b). We further believe that the Ayamaru taxon is morphologically most similar to taxa that share the diagnostic morphological character of having stamens inserted upon a fleshy ring around the mid-portion of the inner surface of the corolla tube. In contrast, the fleshy ring is absent in *F. ceilanica* s.s. (PHILCOX, 1996). As we are unable to match the Ayamaru taxon to any named New Guinean, Australian or Malesian *Fagraea* species (LEENHOUTS, 1962a, b; CONN, 1995; CONN et al., 1996; WONG & SUGAU, 1996; WONG & SUGUMARAN, 2016; CÁMARA-LERET et al., 2020), we hereby describe it as a new species, *F. christinae* Y.W. Low & V.A. Albert, endemic to the Bird's Head Peninsula.

Material and methods

A survey of *Fagraea ceilanica* s.l., with an emphasis on Sri Lankan and New Guinean materials, was conducted based on herbarium specimens, protologues and monographs (LEENHOUTS, 1962a, b; CÁMARA-LERET et al., 2020). All measurements were taken from dried herbarium specimens held at BO, K, L, SING and UPS. Photographs of flowering and fruiting *Fagraea* species were taken in the field, from which herbarium materials were then gathered. Type images of Australian and Malesian *Fagraea* s.s. available on the JSTOR Global Plants website [http://plants.jstor.org], as well as images of herbarium specimens of L, U and WAG on the Naturalis BioPortal website were accessed and examined.

The extent of occurrence (EOO) and area of occupancy (AOO) were calculated using GeoCAT (BACHMAN et al., 2011; BACHMAN & MOAT, 2012) to assess the risk of extinction according to the IUCN Red List Categories and Criteria (IUCN, 2012). Data used for the assessment are based on herbarium records kept at BO, BRI, K, L, MAN, SING and WAG.

Taxonomic treatment

Fagraea christinae Y.W. Low & V.A. Albert, **sp. nov.** (Fig. 2, 3).

Holotypus: INDONESIA. Prov. West Papua: Maybrat Regency, Ajamaru [Ayamaru], [1°16'31"S 132°11'44"E], 240 m, 7.III.1962, Vink BW15226 (L [L.2687803] image!; iso-: K!, WAG [WAG.1807281, WAG.1807284, WAG.1807285] images!).

Fagraea christinae Y.W. Low & V.A. Albert is morphologically similar to *F. annulata* Hiern in having stamens inserted upon a fleshy ring around the mid-portion of the corolla tube but differs in having the margins of bracteoles and calyx lobes distinctly crenate (vs. entire in *F. annulata*).

Tree to 10 m tall, trunk to 12 cm diam., glabrous throughout; bark smooth, dark grey-brown. Petioles (6–)10–15 mm long, to 3 mm wide, petiolar sheaths present and not fused along the interpetiolar median. Leaves lamina elliptic to obovate, (4–)6–12 × (2–)3–6 cm, thin-leathery; base cuneate, slightly decurrent, without auricles; apex acute to short acuminate; margin entire; midrib flat to sunken above, prominent below; secondary veins 4–9 pairs, distinct to faintly visible (rarely inconspicuous) on upper side, inconspicuous on lower side; tertiary venation inconspicuous on both sides. Inflorescences terminal, a solitary to 3-flowered branched cyme, up to 5 cm long. Pedicels up to 3 mm long, up to 4 mm diam.; floral bracts broadly triangular, up to 1 cm long, apex ± acute to obtuse, margin crenate, inserted below the calyx. Calyx 25–30 mm long, sparsely glandular on

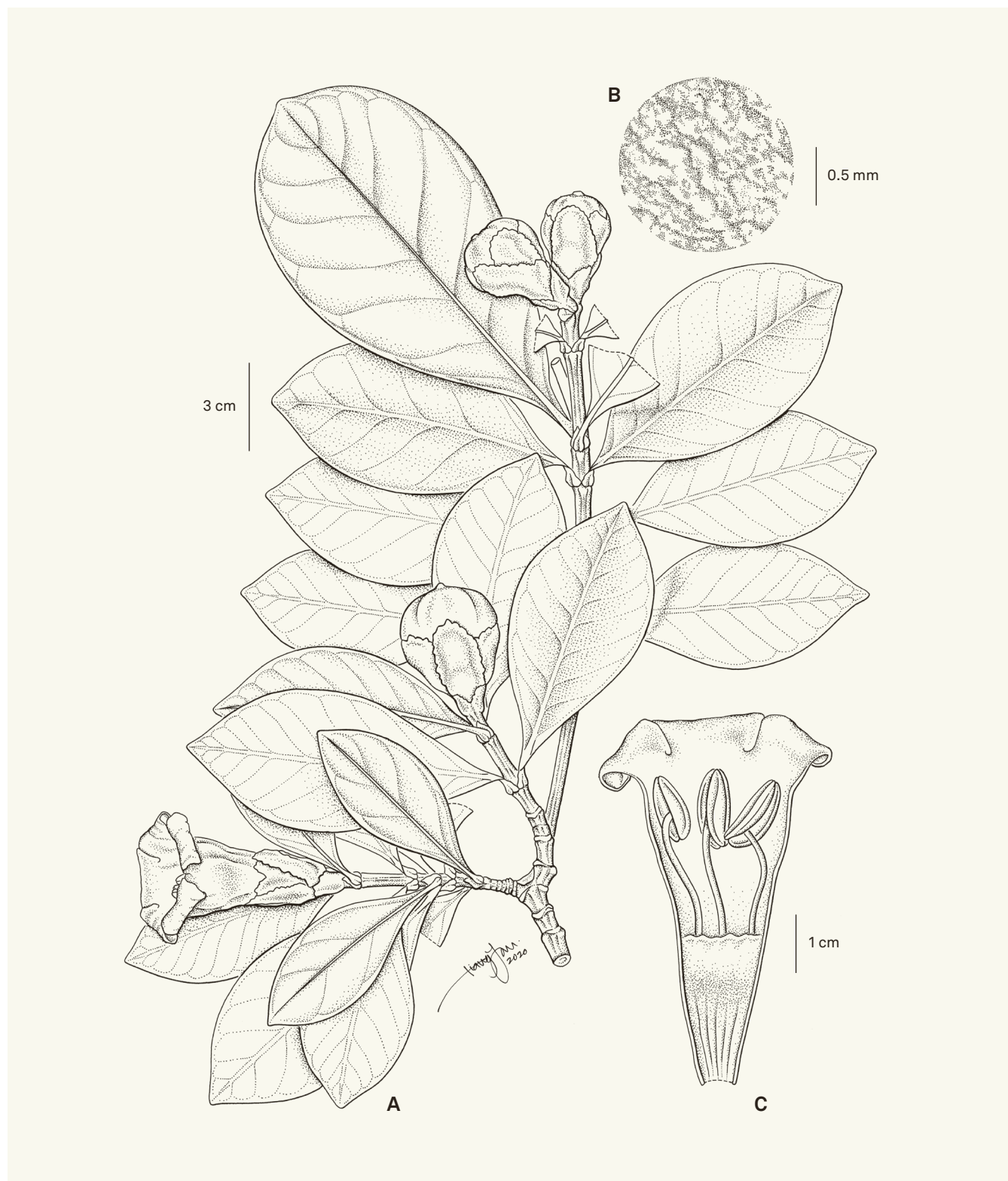


Fig. 2. – *Fagraea christinae* Y.W. Low & V.A. Albert. **A.** Habit of a flowering and fruiting branch; **B.** Close-up of calyx lobes outer surface showing warty or verrucose texture; **C.** Half of a longitudinal section of an open flower; note the stamens are inserted upon a thickened wall (forming a thickened ring in complete flower).

[A–C: Wanma et al. MAN-SING45] [Drawings: X.Y. Loh]



Fig. 3 – *Fagraea christinae* Y.W. Low & V.A. Albert. **A.** Habit; **B.** Close-up of flower buds enclosed by calyx lobes and a pair of bracteoles with distinctive crenate margins; **C.** Side view of an open flower showing curled corolla lobe margins; **D.** Top view of an open flower with stamens clearly seen inserted upon a fleshy ring; **E.** Close-up of pink, mature fruits; fruit on the right artificially cut opened to reveal numerous small and black kidney-shaped seeds.

[A–E: Wanma et al. MAN-SING45] [Photos: Y.W. Low]

outer surface; calyx mouth up to 15 mm diam.; calyx lobes 5, broadly elliptic, 15–20 × 12–17 mm, margin crenate. *Corolla* salver-shaped, green on outer surface, white on inner surface; tube up to 50 mm long, up to 9 mm wide at the mid-portion, up to 23 mm wide at the throat; lobes 5, broadly obovate, c. 8 × 12 mm, left-contorted at bud stage. *Stamens* 5, inserted upon a fleshy ring around the mid-portion of the corolla tube, dorsifixed, included inside the corolla tube; filaments up to 14 mm long; anthers up to 7 mm long. *Style* up to 40 mm long; stigma clavate with a shallow depression at the top, inserted in the corolla tube; ovary unknown. *Fruits* globose when mature, depressed globose and somewhat 4-lobed when immature, 25–30 × 25–30 mm; apex conspicuously beaked upon drying; base tightly clasped by the calyx lobes; surface in fresh mature specimens smooth (epidermis wrinkled conspicuously upon drying), green, maturing pinkish red. *Seeds* numerous, kidney-shaped, c. 1 × 0.5 mm; testa surface areolate.

Etymology. – This species is dedicated to Christina Soh Jeng Har (1955–2020) of the Singapore Botanic Gardens' library. Chris, as she was fondly known amongst patrons of the library, colleagues and friends, was the longest-serving librarian who played an important role in overseeing the expansion and modernisation of the Gardens' botanical literature for close to 40 years before she passed away in 2020 (Low, 2021). She was also one of the sponsors for YWL's doctoral scholarship from the National Parks Board, Singapore, to study *Syzygium* Gaertn. (*Myrtaceae*) in the Bird's Head Peninsula, New Guinea.

Distribution, ecology and phenology. – *Fagraea christinae* is endemic to the Ayamaru Lakes, Maybrat Regency in the Southwest Papua Province, Indonesia (Fig. 4), where it occurs in tall and moist primary rainforest to secondary forest on loam over uplifted ancient corallite limestone. Flower buds, open flowers, immature fruits and mature fruits have been collected in March.

Conservation Status. – *Fagraea christinae* is rare and known from four locations in primary rainforest to secondary forest around the Ayamaru Lakes, where its habitat is threatened by the rapid growth of settlements around the lakes (SOLOSSA et al., 2013). The extent of occurrence (EOO) of the species is estimated to be c. 156 km² (which falls within the 100 km² upper limit for CR status under the subcriterion B1), whereas its area of occupancy (AOO) is estimated to be 16 km² (which falls within the 500 km² lower limit for EN status under the subcriterion B2). Based on satellite data on forest cover obtained for Indonesian New Guinea between 2001 to 2019, GAVEAU et al. (2021) estimated that 83% (34.29 million hectares) of the region remains forested, with a predicted deforestation rate on an upward trend. Over 19 years, 2% (0.75 million hectares) of forest was cleared (GAVEAU et al., 2021).



Fig. 4. – Distribution of *Fagraea christinae* Y.W. Low & V.A. Albert in the Bird's Head Peninsula, New Guinea. Solid coloured area of the map reflects the West Papua Province (before the 2022 split into two separate provinces, Southwest Papua and West Papua), Indonesia.

As the over 4,000 km Trans-Papua Highway, a much-needed public infrastructure for social development in Indonesian New Guinea, is being completed in stages, an acceleration in development is predicted and if not planned carefully and sustainably, it will lead to severe deforestation as seen in Borneo (GAVEAU et al., 2014, 2016). *Fagraea christinae* is provisionally assessed as “Critically Endangered” [CR B1ab(iii,iv)] using the IUCN Category and Criteria (IUCN, 2012).

Notes. – An unpublished phylogenomic result of an ongoing study (Albert et al., in prep.) of Southeast Asian *Fagraea* s.s. including representatives from *Cyrtophyllum*, *Limnolobos* K.M. Wong & Sugumaran, *Picrophloeus* and *Utania*, places *Fagraea christinae* in one of the sister clades within *Fagraea* s.s. The robustly supported clade consists of New Guinean and Australian taxa with stamens inserted upon a fleshy ring, namely *F. berteriana*, *F. salticola* and *F. christinae*. In contrast, the other sister clade includes mostly West Malesian taxa with stamens inserted upon the inner surface of the corolla tube wall, such as *F. ceilanica* s.s. The preliminary finding of Albert et al. (in prep.) confirmed the topology of the ‘*Fagraea*’ clade proposed by SUGUMARAN & WONG (2012) but with robust support obtained for the two sublineages, including relationships between species.

Additional specimens examined. – **INDONESIA. Prov. West Papua:** Maybrat Regency, Tubun, North of Ajamaru [Ayamaru], 260 m, 12.III.1962, Vink BW15361 (K, L); west of Ayawasi, track to plot 6, 1°08'24"S 132°07'12"E, 9.XI.1995, Polak MP923 (K, L); Aitinyo, Athabu, 1°24'15"S 132°15'15"E, 359 m, 1.III.2019, Wanma et al. MAN-SING45 (BO, BRI, G, K, MAN, SING [2 sheets]).

Implications for future work

As demonstrated in previous studies (WONG & SUGAU, 1996; WONG & SUGUMARAN, 2016; VENUGOPAL et al., 2018) and the present work, the current broad circumscription of *Fagraea ceilanica* is unsustainable for species delineation, and it requires reappraisal throughout its distribution range. The first essential step is to interpret and define *F. ceilanica* in a strict sense based on the original protologue and the type specimen from Sri Lanka (see Fig. 1). Subsequently, a review of *F. ceilanica* sensu LEENHOUTS (1962a, b) based on morphological characteristics is to be carried out to (i) re-establish taxa with distinct morphological characters that were synonymised under it, and (ii) examine the 14 forms or ‘races’ proposed and describe novel taxa hidden under the broad species concept. Any population-level phylogenomics studies involving *F. ceilanica* s.l. should include all the 14 forms or ‘races’ proposed in LEENHOUTS (1962a, b), across its distribution range with involvement from local botanists, ecologists and naturalists to encourage diverse and inclusive scientific collaboration.

Species diversity of *Fagraea* is the highest in the Malesia region (POWO, 2023), and considering Borneo and the Malay Peninsula have been revised within the last 30 years (see WONG & SUGAU, 1996; WONG & SUGUMARAN, 2016). Immediate attention is required for a taxonomic reassessment of *F. ceilanica* s.l. for Java, the Lesser Sunda Islands, the Maluku Islands, New Guinea, the Philippines, Sulawesi and Sumatra. Without taxonomic clarity, conservation assessment carried out for *F. ceilanica*, a “widespread” artificial entity, will be misleading as real biological entities were concealed under the broad species concept. In contrast, an accurate taxonomic assessment of a taxon will highlight the actual conservation requirements of the species, if necessary, to ensure adequate protection and management strategies provided.

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