



## Revision of *Cyrtandra tempestii* (Gesneriaceae) and the description of *Cyrtandra tuiwawai* from Taveuni, Fiji

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### Abstract

*Cyrtandra tempestii*, a species endemic to the southeast coast of Taveuni, Fiji, is reevaluated in light of recent field collections and a thorough examination of herbarium specimens. A revised description of this species based on observations and morphological measurements from the field is presented here. *Cyrtandra tuiwawai* *sp. nov.* was formerly included under *C. tempestii* based on similarities in floral morphology and is described here as a new species endemic to the montane forests of Taveuni. Habitat preference, as well as morphological characters, distinguish the two species from one another. The addition of *C. tuiwawai* brings the total number of *Cyrtandra* species in Fiji to 42, and supports the need for continued fieldwork in the region.

**Keywords:** conservation, island endemic, morphology, phylogeny, South Pacific

### Introduction

*Cyrtandra* Forster & Forster (1776: 5) (Gesneriaceae) is one of the largest and most widely distributed genera of angiosperms in the Pacific. Approximately 175 species occur across a region that extends from the Solomon Islands, east to the Marquesas, south to the Austral Islands and north to the Hawaiian Islands (Atkins *et al.* 2013). Members of the genus typically occur as understory shrubs or small trees in montane to lowland wet forest. A high degree of morphological similarity among Pacific species in terms of floral and fruit characters, as well as an apparent propensity to hybridize, has led to considerable taxonomic difficulty in the genus (see Gillett 1967, 1973, Wagner 1990, Smith 1991). Botanical explorations from 1840–1953 led to the description of 37 species of *Cyrtandra* in Fiji (Gillett 1967, Smith 1991), making it one of the largest concentrations of *Cyrtandra* species in the Pacific, second only to the Hawaiian Islands with ~60 species (Wagner 1990, Wagner *et al.* 2005). Recent field expeditions to the Fijian Islands of Vanua Levu and Taveuni in 2014 and 2015 resulted in the discovery and description of four additional *Cyrtandra* species (Johnson 2017), highlighting the need for further exploration of this floristically rich region.

The collection of a single *Cyrtandra* individual growing near sea level along the rugged coast of east Taveuni Island in 2014 piqued particular interest, given that *Cyrtandra* species rarely grow at such low elevations. A subsequent expedition to Taveuni in 2017 yielded collections of a species of *Cyrtandra* from a second coastal location further south with similar floral morphology to the individual collected in 2014. Examination of herbarium specimens and study of the taxonomic treatment of Fijian *Cyrtandra* by Gillett (1967) led to the conclusion that these plants were *C. tempestii* Horne ex Clarke (1883: 273), which was described in 1878 by John Horne based on a specimen from about three km northeast of the Salialevu estate on the southeast coast of Taveuni at a place called “Salialailai”. After this initial collection, all subsequent collections of plants identified as *C. tempestii* had been from mountainous regions of Taveuni above 660 m elevation. Further examination of these later collections suggested that, instead, they represent a distinct species based on considerable morphological differences. In this study, I present a revised description of *C. tempestii* and also describe *Cyrtandra tuiwawai* *sp. nov.* endemic to the high-elevation forest of Taveuni, Fiji.

## Methods

Diagnosis of the new species and the revision of *Cyrtandra tempestii* are based on morphological traits and differences in their geographic distribution. Morphological measurements were taken from herbarium specimens and supplemented with measurements from live plants in the field, as many characters essential to *Cyrtandra* identification are lost upon drying (particularly floral characters). Information was also taken from liquid-preserved flowers and fruit, as well as from digital photographs. Comparisons were made with all described species (Gillett 1967, Smith 1991) and specimens housed at BISH, GH, K, NY, PTBG, RSA, SUVA, UC, and US. Samples representing the newly described species were included in a recent molecular phylogeny of the Pacific clade of *Cyrtandra* based on five loci and a dense taxon sampling of 121 species (including 30 Fijian species; Johnson *et al.* 2017). Results of this study were evaluated to identify the closest relatives of the new species based on shared phylogenetic history. Conservation status was assessed in accordance with IUCN Red List Category criteria (IUCN Standards and Petitions Subcommittee 2017).

## Taxonomic Treatment

*Cyrtandra tempestii* Horne ex Clarke (1883: 273)

Figs. 1, 2

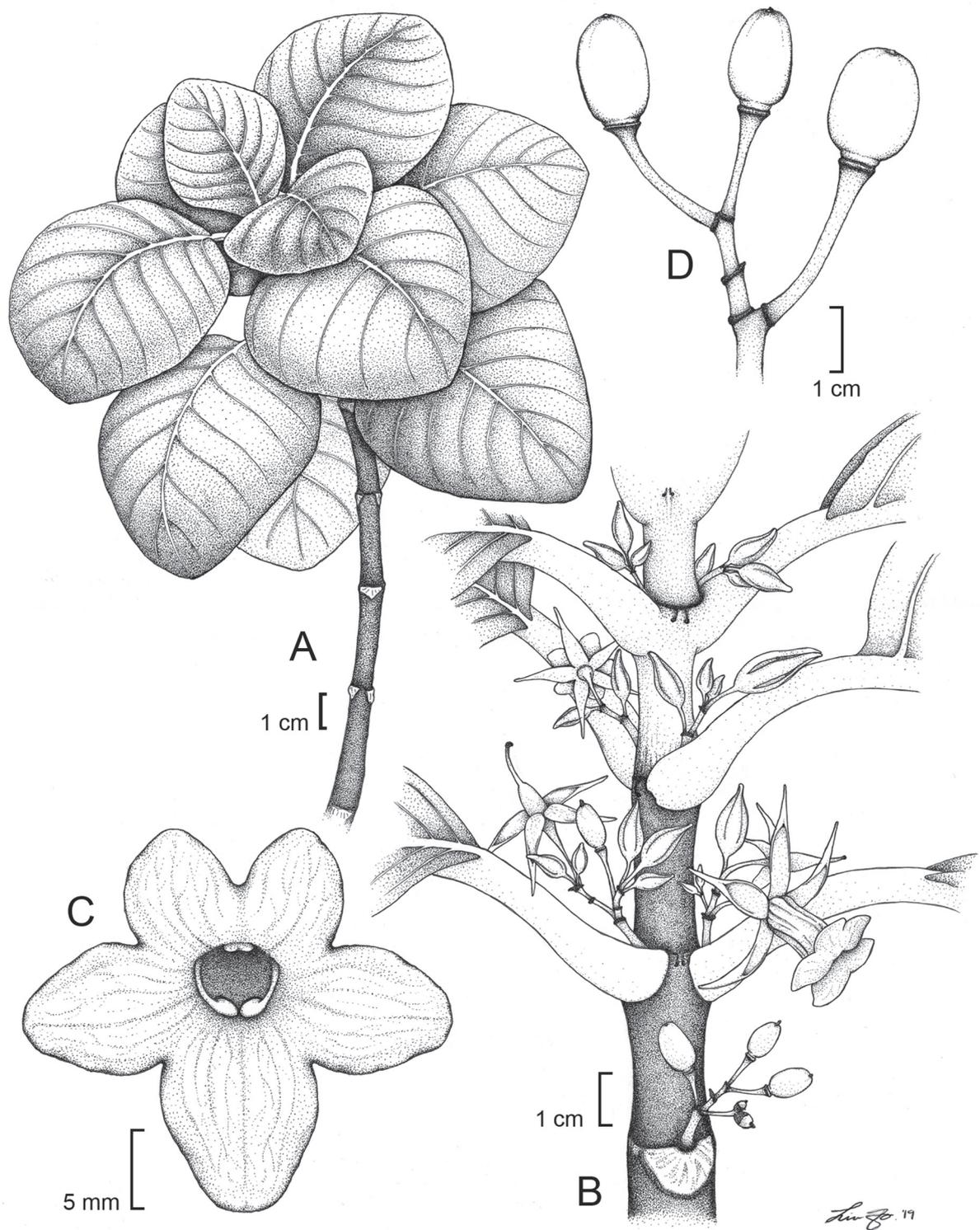
Type:—FIJI. Taveuni: In woods near the sea at Salialailai, September 1878, *Horne 1136* (holotype K!, isotype GH!).

**Diagnosis:**—*Cyrtandra tempestii* is similar to *C. rotumaensis* St. John (1970: 457) but differs in its longer pedicels (to 20 mm *vs.* 10 mm), calyces with linear lanceolate lobes (*vs.* calyces with narrowly ovate lobes with lanceolate tips), and larger corolla (to 20 mm long *vs.* to 11.5 mm long). It also shares affinities with *C. samoensis* Gray (1862: 39), but differs in its smaller leaves (to 43 × 17 cm *vs.* 91 × 36 cm), longer bracts (4 mm *vs.* 2 mm), longer pedicels (to 20 mm *vs.* 12 mm), white calyces with equally cleft linear lanceolate lobes (*vs.* pale green calyces with unequally cleft lanceolate lobes), and white corolla (*vs.* corolla greenish yellow to white with yellow coloration at the mouth of the tube).

**Description:**—Shrub up to 2 m tall; stems unbranched or few branched near the base with appressed brown pubescence. Leaves opposite, borne on upper 2–5 nodes, internodes 2–3 cm long, blades elliptic to elliptic obovate or ovate, 29–43 cm long and 12–17 cm wide, upper surface green and strigillose with univariate multicellular trichomes, lower surface light green, pubescent, 5–7 secondary veins on each side, margins serrulate to crenulate, apex acute to rounded or obtuse, base oblique to aequilateral and cuneate to rounded, petioles 5–7 cm long, pale green with sparse to moderately dense brown pubescence; inflorescence an axillary cyme, 9–17 flowers, cymules 1–3 flowered, peduncle 15–29 mm long, terminated by lanceolate bracts, to 4 mm long, deciduous after anthesis, pedicels 10–20 mm long; calyx pale green to white, outer surface sparsely pilose with brown trichomes, inner surface glabrous, lobes linear lanceolate and equally cleft nearly to the base, 11–13 mm long, deciduous; corolla white, tube funnellform, slightly curved, 18–20 mm long and 6–7 mm wide, outer surface glabrous, inner surface with short glandular trichomes near the mouth of the tube and covering the lobes, upper lobes to 7 mm long and 6 mm wide, lower lobe to 10 mm long and 8 mm wide; stamens 2, filaments white with an orange spot near the base, to 2 mm long, anthers apically connate; staminodes 3, 1–2 mm long, adnate 1–2 mm below filaments and opposite the posterior sinuses; nectary disc annular, cupulate, to 2 mm high, drying to a pelviform structure, persistent in mature fruit; gynoecium (ovary, style, stigma) to 15 mm long, ovary and style glabrous, stigma applanate, bilobed; berries ellipsoid to ovoid, to 16 mm long and 10 mm wide, glabrous, turning white at maturity.

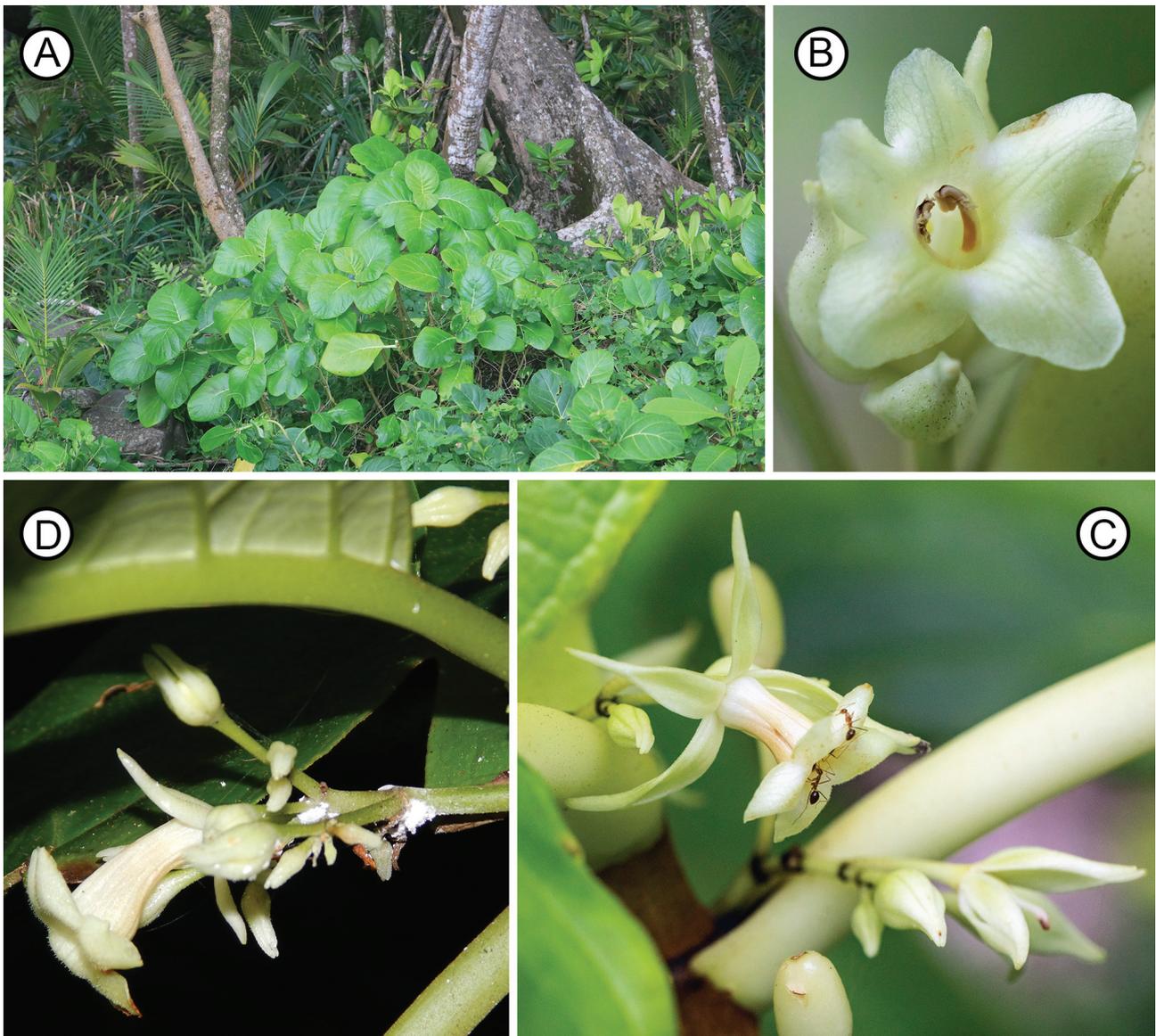
**Distribution and ecology:**—*Cyrtandra tempestii* is only known with certainty from a single small population in the coastal forest of Salialailai, southern Taveuni, Fiji (Fig. 3). The individual collected further north at Lavena shares the coastal habitat preference that is characteristic of *C. tempestii* and also has a similar floral morphology with this species (see Fig. 2D), but the leaf shape of this individual is more strongly elliptic. Additional molecular work is required (see below) to determine if this lone individual is in fact *C. tempestii* or if it represents a hybrid (*C. ciliata* Seemann (1866: 182) and *C. gregoryi* Johnson (2017: 87) both grow nearby but have only been observed at elevations above 30 m).

**Phenology:**—Individuals of this species have been observed to flower and fruit in August and October.



**FIGURE 1.** *Cyrtandra tempestii* Horne ex C.B.Clarke **A** Habit **B** Stem and inflorescences **C** Corolla, anterior view **D** Mature fruits. Drawn by Liv-Monique Johnson from field photographs by J. Game.

**Phylogenetic placement:**—Material from the type locality at Saliailalai was not available for inclusion in the phylogenetic analysis by Johnson *et al.* (2017), thus precluding placement of *Cyrtandra tempestii*. However, the individual collected from Lavena, here referred to as *C. aff. tempestii*, was placed with strong support (85 BS, 100 PP) in a clade comprised of 13 species from eight geographic regions in the Pacific (Samoa, Fiji, Vanuatu, Society Islands, Micronesia, Tonga, Wallis & Futuna, and the Loyalty Islands; Fig. 4). The closest relatives of this individual remain unknown, as it forms a polytomy with two other clades. Gillett (1967) proposed that *C. denhamii* Seemann (1866: 182) (endemic to Gau, Fiji) and *C. rarotongensis* Cheeseman (1901: 290) (endemic to Rarotonga, Cook Islands) were closely related to *C. tempestii* based on similar habit, leaves, inflorescence, and calyx morphology, as well as the presence of a nectiferous annular disc. St. John (1970) suggested that the closest relative of *C. tempestii* is *C. rotumaensis* (endemic to Rotuma, ~460 km north of the Fijian archipelago), with its coastal habitat preference and similar leaf morphology. The most notable difference between these two species is the floral morphology, with *C. rotumaensis* having smaller flowers and narrowly ovate as opposed to linear lanceolate calyx lobes (St. John 1970, J. Game pers. comm.). Unfortunately, *C. denhamii*, *C. rarotongensis* and *C. rotumaensis* have not been included in a phylogenetic analysis to date. *Cyrtandra tempestii* also appears similar to *C. samoensis* (endemic to Samoa, Tonga, and Niue) in terms of overall morphology and coastal habitat preference, and *C. tuiwawai sp. nov.* in terms of calyx morphology. Both *C. samoensis* and *C. tuiwawai* are supported as belonging to the larger clade within which *C. aff. tempestii* is placed.

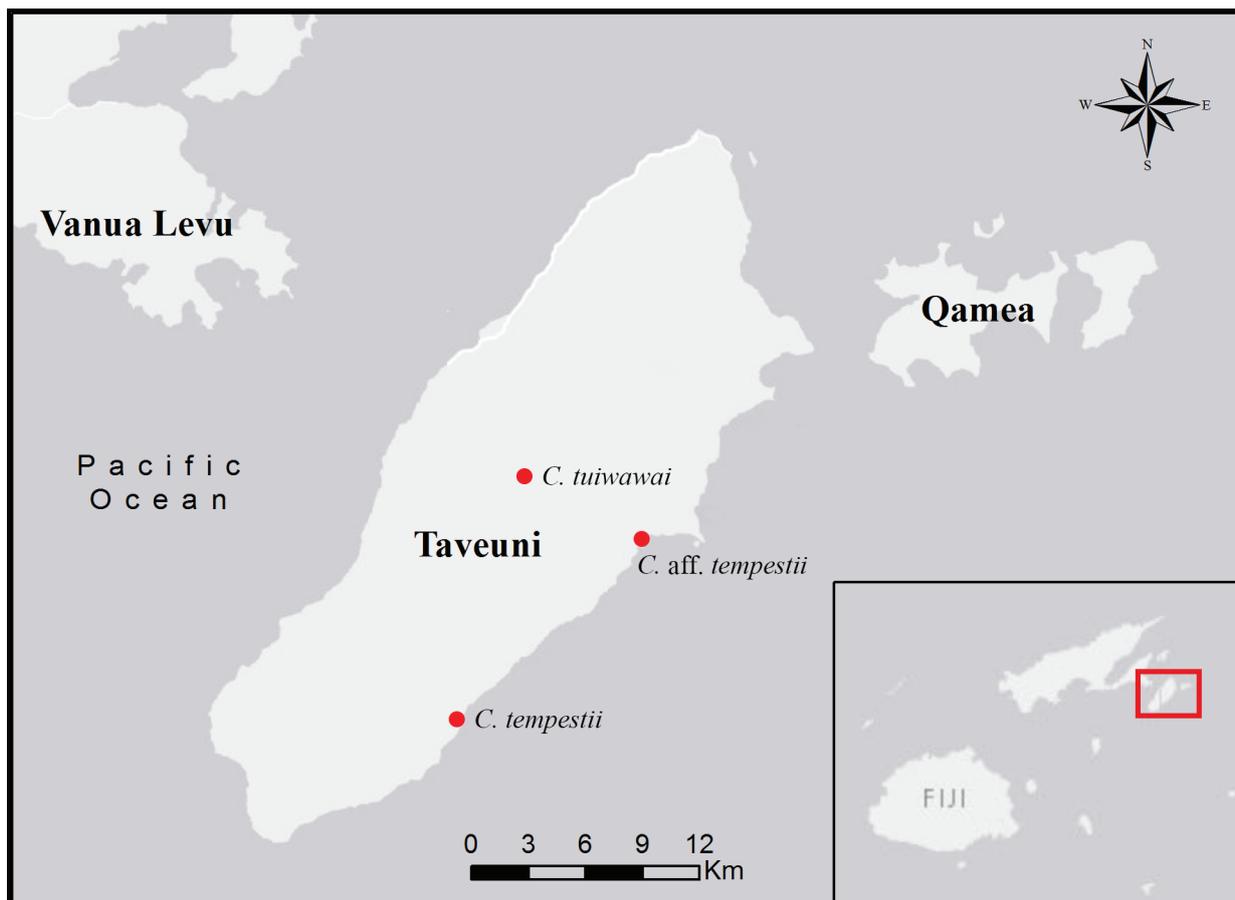


**FIGURE 2.** *Cyrtandra tempestii* Horne ex C.B. Clarke from Saliailalai and *C. aff. tempestii* from Lavena **A** *C. tempestii* shrub habit **B** *C. tempestii* corolla, anterior view **C** Lateral view of *C. tempestii* flower, buds and mature fruit **D** *C. aff. tempestii* axillary cyme inflorescence with calyces cleft to base. Photos A–C taken in the field by J. Game, photo D taken in the field by M.A. Johnson.

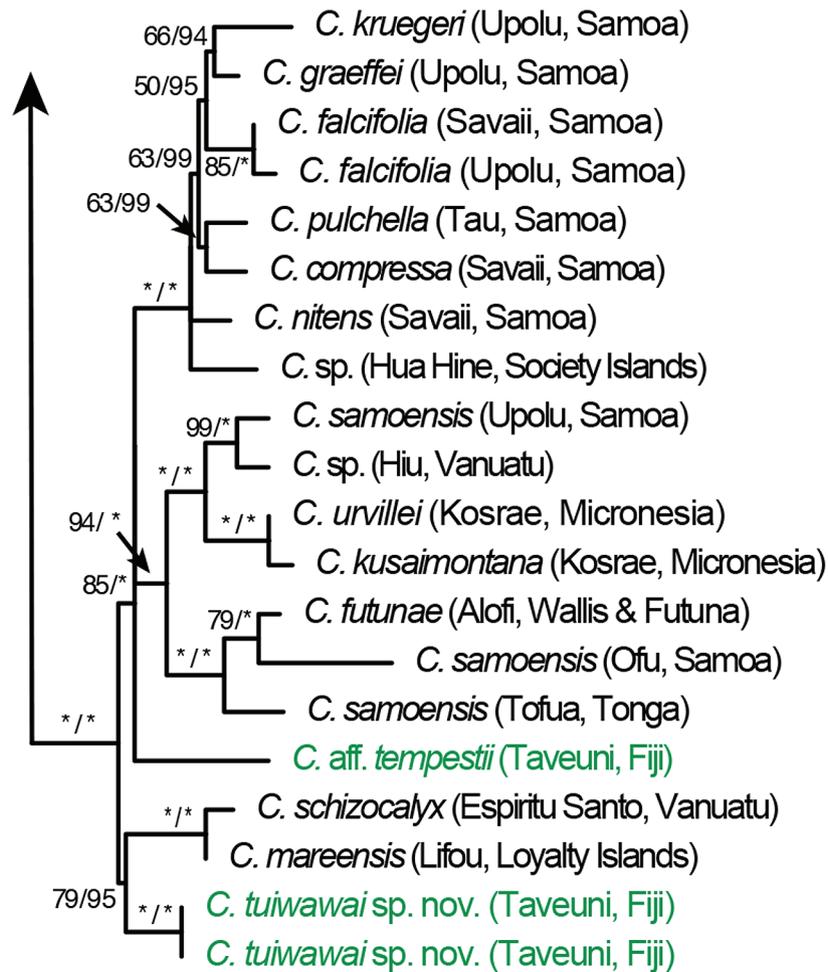
**Conservation status:**—Proposed IUCN Red List Category: Critically Endangered (CR) based on an estimated area of occupancy of < 500 km<sup>2</sup> (criterion B2), known to exist at no more than five locations (B2a), projected decline in extent of occurrence, area of occupancy (B2bii), and area, extent, and/or quality of habitat (B2biii), and population size estimated to number fewer than 50 individuals (D). Threats to this species include the clearing of coastal forest for agricultural crops, invasive species that can compete for resources (M. Johnson, pers. obs.), and damage caused by high winds and storm surges during tropical cyclones. An indirect effect of agricultural practices in areas where *Cyrtrandra tempestii* occurs is a proliferation of crop pests such as mealybugs (Pseudococcidae), which were found in dense populations on the underside of leaves and around the inflorescences of the specimen collected in Lavena (Fig. 2D). Mealybug infestation can lead to leaf drop, and the insects can act as vectors for a number of plant diseases. Additional surveys of the coastal forests of Taveuni are warranted to better characterize the distribution and demographics of this species, and will also aid in future conservation assessments.

**Additional specimens examined:**—FIJI: Taveuni: growing along the Lavena coastal walk, ca. 3 km W of Lavena Village, 17 m elev., 16°52.43' S, 179°54.14' W, 03 August 2014, *M.A. Johnson 103* with G.J. Hora (RSA!); Salialailai, growing at the mouth of a stream in *Barringtonia edulis* dominant coastal forest, two streams before the Ravilevu Nature Reserve, ~2 m elev., 05 October 2017, *M. Tuiwawa 5087* and *5088* (SUVA), *J.C. Game loc.cit* 16°57.23' S, 179°59.54' W (WGS84) *17/073* (UC!).

**Notes:**—A single individual with floral affinities to *Cyrtrandra tempestii* was observed on the coast at Lavena (Fig. 3). No other *Cyrtrandra* species were observed in the immediate vicinity, although *C. gregoryi* was collected 0.64 km to the NW. The population of *C. tempestii* at Salialailai comprised several individuals, with no other conspecifics observed in the area (Fig. 3).



**FIGURE 3.** Distribution of *Cyrtrandra tempestii* Horne ex C.B.Clarke and *C. tuiwawai* M.A.Johnson on Taveuni, Fiji. The location of the single individual referred to as *C. aff. tempestii* collected from Lavena is also noted.



**FIGURE 4.** A portion of the Maximum Likelihood phylogram from Johnson *et al.* (2017) based on three nuclear (ITS, ETS, *Cyrt1*) and two chloroplast (*psbA-trnH*, *rpl32-trnL*) loci. Support values shown for each branch are bootstrap (BS) and posterior probabilities (PP) when  $\geq 50\%$  and  $\geq 0.50$ , respectively. An asterisk indicates 100% BS or 1.0 PP; a dash indicates that the branch was not supported.

*Cyrtandra tuiwawai* M.A.Johnson, *sp. nov.*

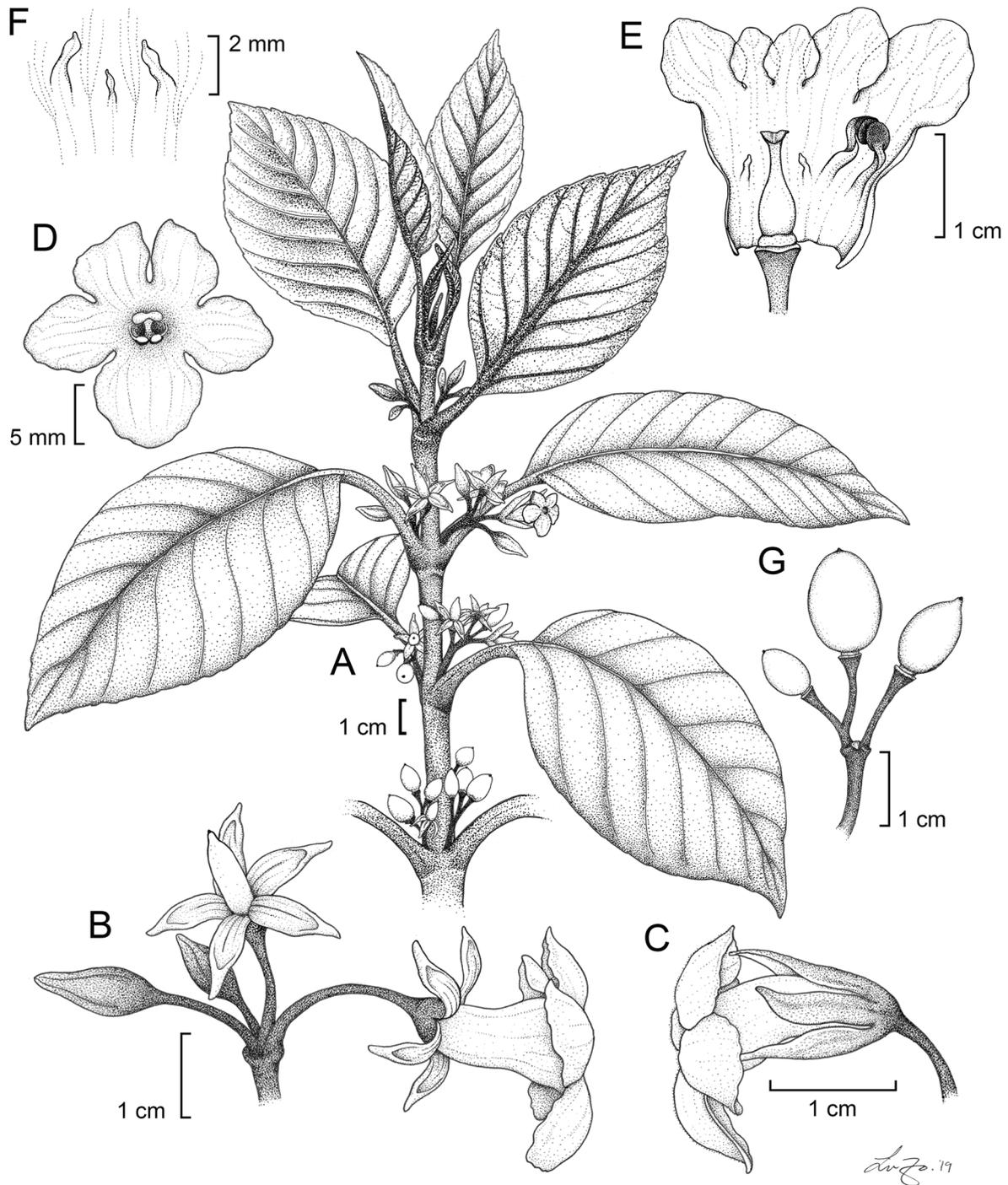
Figs. 5, 6

Type:—FIJI. Taveuni: Des Voeux Peak, along the road to the summit, 1036 m elev., 16°50.24' S, 179°58.30' W, 13 July 2014, M.A. Johnson 83 with G.J. Hora (holotype RSA!, isotype RSA!, SUVA!).

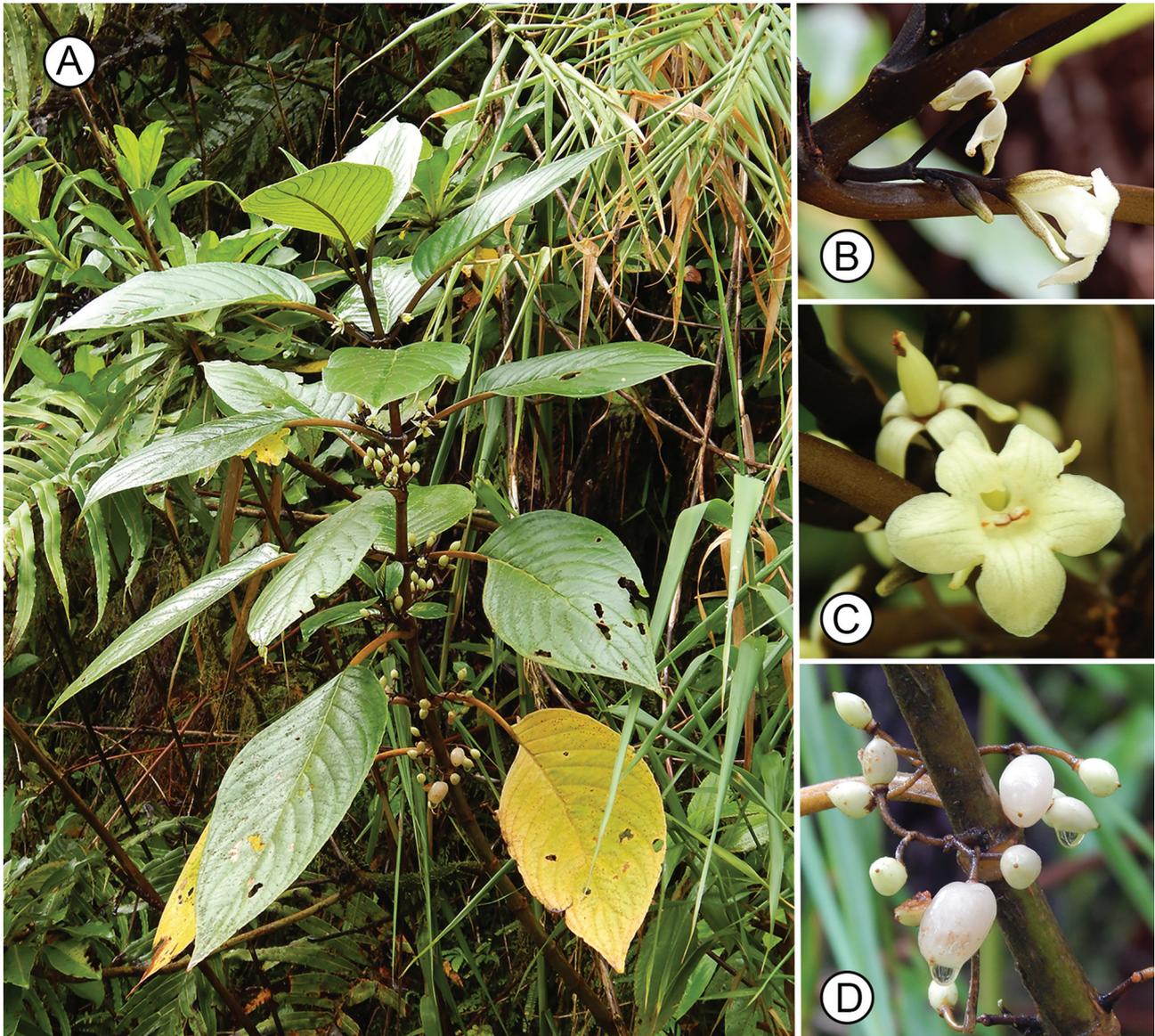
**Diagnosis:**—*Cyrtandra tuiwawai* differs from *C. tempestii* in having dense, appressed, purplish-black pilose trichomes on younger structures (*vs.* sparse brown pilose trichomes on younger structures), dark green, glabrous leaves to 25 × 11 cm (*vs.* green pubescent leaves to 43 × 17 cm), fewer flowers per cyme (1–8 *vs.* 9–17), calyx with moderately dense purplish-black pilose trichomes on outer surfaces (*vs.* sparsely brown pilose trichomes), and corolla yellowish-white, the tube 14–17 mm long and 5–8 mm wide (*vs.* corolla white, the tube 18–20 mm long and 6–7 mm wide).

**Description:**—Shrub up to 3 m tall; stems branched near the base, with dense appressed purplish-black pilose trichomes when young. Leaves opposite, borne on upper 5–8 nodes, internodes 2–6 cm long, blades elliptic to elliptic ovate, 17–25 cm long and 8–11 cm wide, upper surface dark green and glabrous, lower surface light green and glabrate except veins densely purplish-black pilose, 7–9 secondary veins on each side, margins undulate to finely serrate, apex acute to acuminate, base strongly oblique, petioles 3–9 cm long with appressed brown pubescence; inflorescence an axillary cyme, appressed purplish-black pilose throughout, 1–8 flowers, peduncle 7–13 mm long, terminated by lanceolate bracts, 2–4 mm long, deciduous after anthesis, pedicels 11–15 mm long; calyx white, outer surface pilose with moderately dense purplish-black pilose trichomes, inner surface glabrous, lobes linear lanceolate and equally cleft nearly to the base, 9–15 mm long, deciduous; corolla yellowish-white, tube funnellform, slightly curved, 14–17 mm long and 5–8 mm wide, outer surface glabrous, inner surface with short glandular trichomes near the mouth of the tube and dense short white pubescence covering the lobes, upper lobes 5–8 mm long and 4–7 mm wide, lower lobe 8–11

mm long and 6–10 mm wide; stamens 2, filaments 4.8 mm long, white with an orange spot near the base, anthers 1.2 mm long, connate at the apex; staminodes 3, 1–2 mm long, adnate 1–2 mm below filaments and opposite the posterior sinuses; nectary disc annular, cupulate, to 2 mm high, drying to a pelviform structure, persistent in mature fruit; gynoeceium (ovary, style, stigma) 10–11 mm long, ovary glabrous, style sparsely pubescent with capitate glandular trichomes, stigma applanate, bilobed; berries ellipsoid to ovoid, 14–22 mm long and 9–13 mm wide, glabrous, turning white at maturity.



**FIGURE 5.** *Cyrtandra tuiwawai* M.A. Johnson **A** Habit **B** Inflorescence with buds, an older flower, and developing young fruit **C** Corolla and calyx of younger flower, lateral view **D** Corolla, anterior view **E** Dissected corolla, showing stamen insertion, details of the gynoeceium, and staminodes **F** Close-up of three staminodes **G** Fruits. Drawn by Liv-Monique Johnson from M.A. Johnson 83 (RSA, SUVA) and field photographs by M.A. Johnson.



**FIGURE 6.** *Cyrtandra tuiwawai* M.A.Johnson **A** Habit **B** Inflorescence, lateral view **C** Flower, anterior view **D** Young (green) and mature (white) fruits. All photographs taken in the field by M.A. Johnson.

**Distribution and ecology:**—*Cyrtandra tuiwawai* is only known with certainty from the cloud forest summit of Des Voeux Peak (1036–1210 m elevation) on Taveuni, Fiji (Fig. 3). Smith’s collection from “dense forest W of an old crater occupied by a swamp and small lake (660–900 m elevation)” was likely from an area 2–3 km W of the road to Des Voeux Peak (J. Game, pers. comm.).

**Phenology:**—Individuals of this species have been observed to flower and fruit in April, July, August, October and November.

**Etymology:**—This species is named for Marika Tuiwawa, Curator of the South Pacific Regional Herbarium at the University of the South Pacific in Fiji. For his dedication to the conservation of Fiji’s flora, his valuable insights into Fijian *Cyrtandra*, and his kind assistance with fieldwork logistics and permits in Fiji that made this publication possible, I gratefully extend him due recognition.

**Phylogenetic placement:**—A recent phylogenetic study by Johnson *et al.* (2017) supported *Cyrtandra tuiwawai* as sister (79 BS, 95 PP) to a clade comprising *C. marensis* Däniker (1933: 78) (Lifou, Loyalty Islands) and *C. schizocalyx* Gillett (1974: 704) (Espiritu Santo, Vanuatu; Fig. 4). Like *C. tuiwawai*, *C. schizocalyx* also grows in high-elevation montane wet forest (Y. Pillon, pers. comm.), and shares the white calyces that also characterize *C. tuiwawai*. In contrast, *C. marensis* grows in coastal shrublands and on limestone cliffs (Y. Pillon, pers. comm.), and resembles *C. samoensis* in overall appearance. However, *C. marensis* shares several floral characters with *C. tuiwawai*, including deciduous white calyces that are equally cleft nearly to the base.

**Conservation status:**—Proposed IUCN Red List Category: Endangered (EN) based on an estimated area of occupancy of < 500 km<sup>2</sup> (criterion B2); known to exist at no more than five locations (B2a); projected decline in extent of occurrence; area of occupancy (B2bii); and area, extent, and/or quality of habitat (B2biii). Threats to this species include clearing along roadsides, invasive species (M. Johnson, pers. obs.), and damage from tropical cyclones. The montane forests of Taveuni remain relatively unexplored, exceptions being the forest along the road to Des Voeux Peak and the area surrounding Lake Tagimoucia. Additional surveys are needed to more fully characterize the distribution of this species and document threats to its continued survival.

**Additional specimens examined:**—FIJI: Taveuni: Hills E of Somosomo, W of old crater occupied by small swamp and lake, 660–900 m elev., 18 August 1953, *Smith 8388* (NY!, UC!, US!); summit of Des Voeux Peak in stunted ridge-top cloud forest, 1210 m elev., 22 April 1993, *Regalado & Vodo 585* (BISH!, GH!, NY!); beside Des Voeux Peak Rd., 1080 m elev., 18 November 2016, *Game 16/216* (PTBG!); near Des Voeux Peak Rd., 1191 m elev., 10 October 2017, *Game 17/170* (UC!).

**Notes:**—Four other *Cyrtandra* species were observed to grow sympatrically with *C. tuiwawai* on Des Voeux Peak (*C. ciliata*, *C. hispida* Johnson (2017: 92), *C. leucantha* Smith (1953: 41–42) and *C. chippendalei* Horne ex Clarke (1883: 230–231)). Although all five species were flowering simultaneously, no morphologically intermediate (i.e., inter-specific hybrid) individuals were observed. Individuals of *C. leucantha*, *C. tuiwawai* and *C. ciliata* appeared to occur with some frequency along the roadside, with *C. hispida* and *C. chippendalei* being less common in the area.

## Discussion

A new species of *Cyrtandra* that was previously lumped under *C. tempestii* was described here as *C. tuiwawai*. *Cyrtandra tempestii* was also revised to include morphological information that was recently acquired during field surveys on Taveuni. Prior to the field expedition conducted on Taveuni in 2017, *C. tempestii* had not been collected since Horne first described this unique species endemic to the coastal forests of Taveuni 136 years ago. The two species treated in the present study differ in habitat preference and a number of vegetative and floral characters. The Flora of Fiji published by A.C. Smith in 1991 included 37 species of *Cyrtandra*, all of which are endemic to the archipelago. Fieldwork on the islands of Vanua Levu and Taveuni resulted in four additional species (Johnson 2017), and with the description of *C. tuiwawai* the total number of Fijian *Cyrtandra* is brought to 42 species. Continued fieldwork is warranted in this floristically rich region of the South Pacific to improve our understanding of *Cyrtandra* taxonomy and evolution, as well as to generate more detailed conservation assessments for the many rare and endangered taxa that are ubiquitous across the Pacific islands.

## Acknowledgements

I am grateful to John Game for providing collection information and photographs of *Cyrtandra* individuals from the 2017 field expedition to Taveuni, which together with suggestions from Marika Tuiwawa ultimately led to the revision of *C. tempestii* presented here. I also thank Marika Tuiwawa, Alivereti Naikatini, Manoa Maiwaqa, Mereia Tabua, and Sarah Pene (South Pacific Regional Herbarium, The University of the South Pacific) for assistance with fieldwork logistics in Fiji. Collecting permits were granted by The Fiji Ministry of Education, export permits by Fiji Biosecurity, and import permits by the United States Department of Agriculture. I also thank my husband Gregory Hora for assistance in the field and for providing endless encouragement and moral support. This work would not have been possible without the kind peoples of Fiji, who offered their assistance, expertise and hospitality. The following herbaria graciously allowed the use of their collections for study: BISH, GH, K, NY, RSA, SUVA, UC, US, and WU. Funding for this project was provided by the following: Rancho Santa Ana Botanic Garden; Garden Club of America Award in Tropical Botany; American Philosophical Society Lewis and Clark Fund for Exploration and Field Research; The Gesneriad Society Nelly D. Sleeth Scholarship Endowment Fund; The Gesneriad Society Elvin McDonald Fund; Society of Systematic Biologists Graduate Student Research Award; Sigma Xi Grants-in-Aid of Research; American Society of Plant Taxonomists Graduate Student Research Grant; and Claremont Graduate University. Lastly, I am grateful to my sister, Liv-Monique Johnson, for the beautiful line drawings, and to Lucinda McDade and John Game for comments that greatly improved this manuscript.

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