

Spiradiclis karstana (Rubiaceae), a new species from Yunnan, China

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Abstract

Spiradiclis karstana, a new species of *Spiradiclis* (Rubiaceae) collected from Yunnan, China, is described for the first time. It is morphologically close to *S. jingxiensis*, but differs from the latter mainly by its inflorescences with 5–9 flowers, its 1.5–2.4 mm long peduncles, its stipules shorter than 1 mm and the 5–12 pairs of secondary veins. The conservation status is assessed as “Vulnerable” (VU) according to the IUCN Red List Categories and Criteria.

Keywords

Spiradiclis, Rubiaceae, taxonomy, karst, China

Introduction

Spiradiclis Blume, a small genus of Rubiaceae as currently circumscribed (Lo 1998, 1999), consists of two subgenera and ca. 50 species. Most of them are widely scattered in southern and south-western China and north-western India, but a few occur in the Indo-China Peninsula (Robbrecht 1988, Deb and Rout 1989, Lo 1999, Chen and Taylor 2011, Wu et al. 2015a, b, 2016, Wang 2016, Pan et al. 2016, Liu et al. 2017). Most representatives of the genus are narrowly distributed in karst regions, generally accompanied by ferns and *Begonia* L., *Elatostema* J.R.Forst. & G.Forst. and Gesneriaceae. During flowering, species of *Spiradiclis* are sometimes confused with

Ophiorrhiza L. (Wu et al. 2015a), but they can be distinguished from the latter and other related genera by the linear-oblong or subglobose capsules that dehisce with four valves when mature (Lo 1999, Wu et al. 2015b). In China, nearly 47 species have been found, of which ten species have been published in the last four years (Deng et al. 2014, Wu et al. 2015a, b, 2016, Wang et al. 2015, Wen et al. 2015, Wang 2016, Pan et al. 2016, Liu et al. 2017).

In 2017, a plant lover, Mr. Ming-Feng Long, found a population of *Spiradiclis* on the cliff of a karst hill in Malipo county, SE Yunnan and contacted the authors for the identification. The individuals were first identified as *Spiradiclis jingxiensis* R.J.Wang as they shared a similar habitat and morphological characters such as prostrate or decumbent habit, distylous and purple-reddish flowers with slender salverform corollas. After a further comparison of specimens, however, these individuals can be distinguished from *Spiradiclis jingxiensis* mainly by their puberulent to subglabrous stems, leaves, stipules, peduncles and calyces (vs. dense pubescence), their ovate-triangular stipules, shorter than 1 mm (vs. linear, 1.5–3.0 mm long), their elliptic to oblong leaf blades (vs. ovate to broadly ovate), their 5–12 pairs of secondary veins (vs. 4–5 pairs) and their inflorescences with 5–9 flowers (vs. 1–2 flowers). Therefore, the specimens are assumed to represent an undescribed new taxon, which is here described.

Materials and methods

Most materials are deposited at the herbarium of forest plants in the Central South University of Forestry and Technology (CSFI), only one residing at Guangxi Institute of Botany, Guangxi Zhuang Autonomous Region and Chinese Academy of Sciences (IBK). Morphological observations of the new species have been carried out, based on field observations as well as on dry specimens. The conservation status of the new species is evaluated in accordance with IUCN guidelines (2016).

Taxonomy

Spiradiclis karstana L.Wu, X.Li & Q.R.Liu, sp. nov.

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Figures 1, 2

Diagnosis. Similar to *S. jingxiensis*, but differing from this species by the ovate-triangular stipules less than 1 mm long (vs. stipules linear, 1.5–3.0 mm long), the elliptic to oblong leaf blades (vs. ovate to broadly ovate), the 5–12 pairs of secondary veins (vs. 4–5 pairs) and the inflorescences with 5–9 flowers (vs. inflorescences with 1–2 flowers).

Type. CHINA. Yunnan Province: Malipo County, Mali town, Luoshuidong village, 23°03'N, 104°43'E, 900 m alt., 11 Apr. 2018, *Ming-Feng Long & Lei Wu MLP0002* (holotype: CFSI; isotype: CFSI).

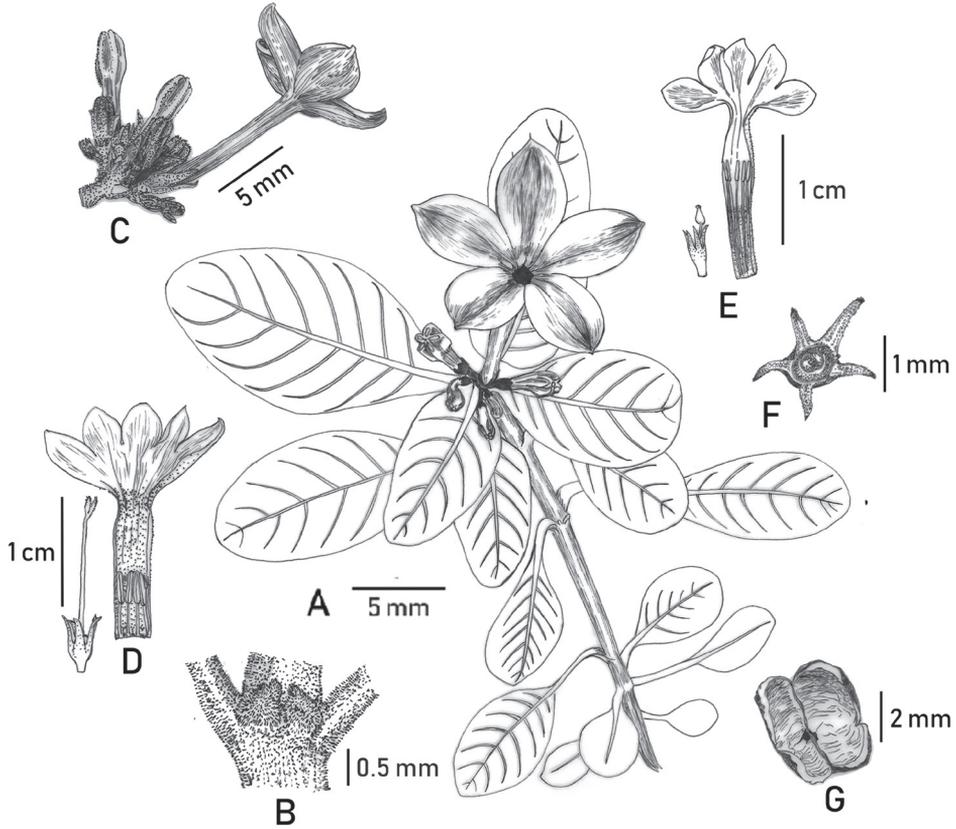


Figure 1. *Spiradiclis karstana* sp. nov. **A** habit **B** stipule **C** inflorescence, side view **D** long-styled flower **E** short-styled flower **F** calyx, frontal view, showing disc **G** remnant of dehiscent capsule, frontal view. Drawn by Xin-Yi Zeng.

Perennial herbs, up to 8 cm in height, prostrate or decumbent, usually rooting at nodes; stems terete, basal part usually woody, densely puberulent (trichomes white). Petiole 2–7 mm long; leaf blade elliptic to oblong, 0.8–4.5 × 0.5–1.6 cm, drying papery, adaxially green, abaxially yellowish-green, adaxially puberulent to subglabrous, abaxially puberulent, densely pubescent along principal veins on lower surface; base cuneate and somewhat decurrent, apex obtuse to acute; secondary veins 5–12 pairs, both midrib and secondary veins adaxially impressed, abaxially prominent; stipules ovate-triangular or sometimes 2-lobed, 0.2–0.8 mm long, densely puberulent outside, usually deciduous. Inflorescences terminal, cymose, 5–9-flowered, puberulent; peduncles short, 1.5–2.4 mm long, puberulent; bracts subulate, 0.5–1.5 mm long, puberulent. Flowers distylous; pedicels 1.0–2.5 mm long, puberulent. Calyx puberulent to subglabrous outside; hypanthium obconic, 1.2–1.7 mm long; calyx lobes equal, lanceolate to narrowly triangular, 2–2.5 mm long, acute at apex. Corolla 5-merous, slenderly salverform, purple-reddish, with a deep purple-reddish ring around the throat, glabrous outside; tube 15–25 mm

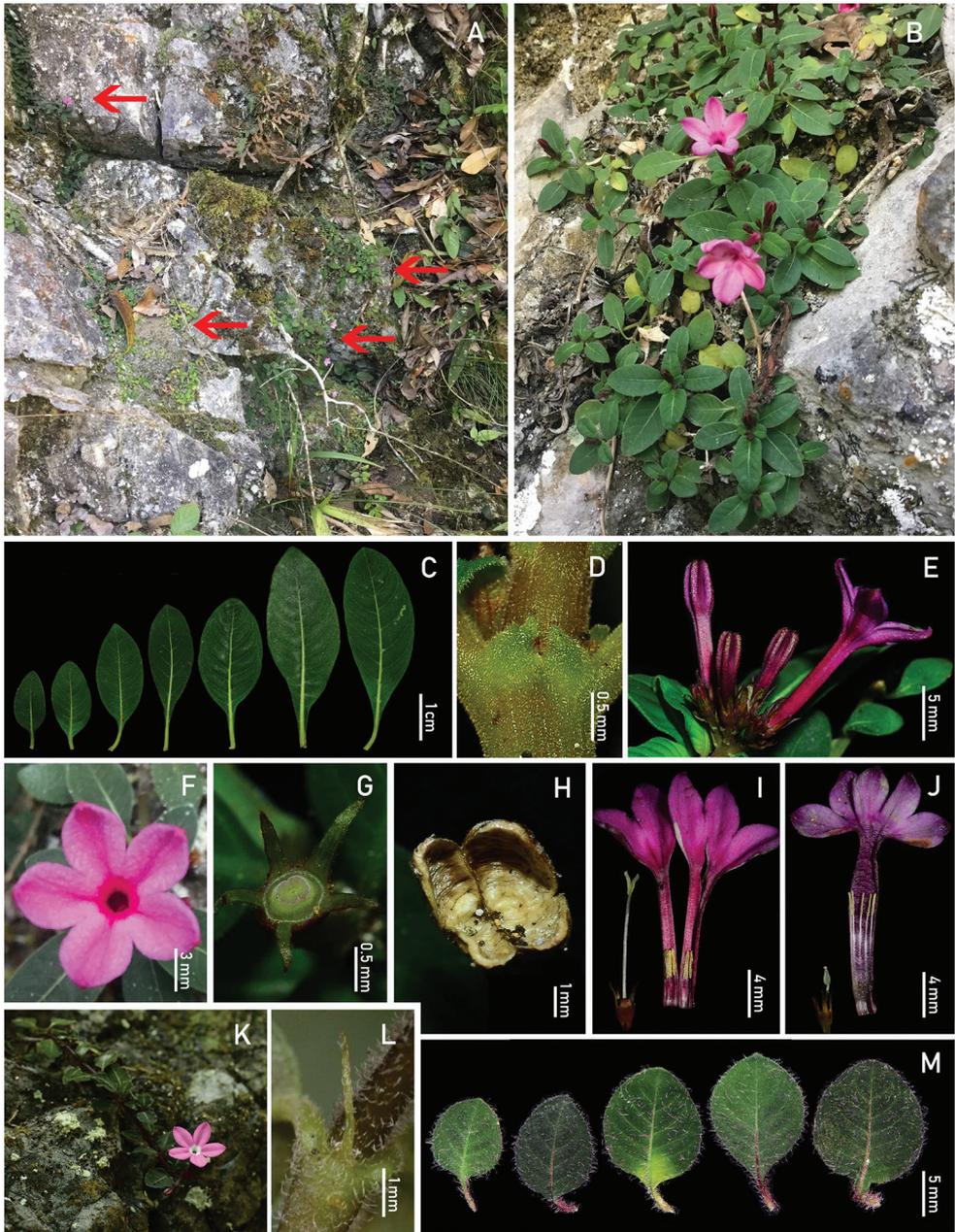


Figure 2. *Spiradiclis karstana* sp. nov. **A** habitat (The arrows show the places of growth) **B** habit **C** variation range of leaves **D** stipule **E** inflorescence, side view **F** long-styled flower, frontal view **G** disc and calyx **H** remnant of dehiscent capsule, frontal view **I** long-styled flower **J** short-styled flower. *Spiradiclis jingxiensis* **K** habit **L** stipule **M** variation range of leaves. Photos by Lei Wu, Ming-Feng Long and Xin-Xin Zhu.

long; lobes broadly ovate, 3.5–6.0 × 3.0–5.0 mm, apically rostrate-incurved; stamens completely included in the corolla tube at anthesis in both flower morphs; ovary 2-celled. Long-styled flowers: inside with a ring of hairs near the stamens; stamens inserted near

the base and stigma positioned a little below the throat of the corolla tube; anthers linear, ca. 2.0–2.4 mm long; stigma 2-lobed, lobes elliptic, ca. 1.2 mm long. Short-styled flowers: inside with sparse pubescence near the base of the corolla tube; stamens inserted above the middle and stigma positioned near the base of the corolla tube, anthers linear, ca. 2.5 mm; stigma 2-lobed, lobes ovate-lanceolate, ca. 1.5 mm long. Capsule obovoid, 2.5–3.5 mm long, subglabrous, opened at the top when mature. Seeds ca. 12 per capsule.

Phenology. Flowers and fruits were observed in April. We think flowering and fruiting may extend till May, because many flowers in April were still in bud.

Distribution and habitat. *Spiradiclis karstana* is known only from the crevices of forested cliffs at altitudes ranging from 800 to 1600 m in the karst area of SE Yunnan. This part of Yunnan is covered by evergreen rain forests that are highly similar to those in Indo-Malaysia (Zhu 2013) and are dominated by species from Magnoliaceae, Lauraceae, Dipterocarpaceae and Annonaceae.

Etymology. The specific epithet refers to the habitat of the new species.

Specimens examined (paratypes). CHINA. Yunnan Province. Malipo County, Mali town, Luoshuidong village, 25 Apr 2017, *Ming-Feng Long MLP 0001* (CFSI); Mengzhi city, Shuitian town, on a karst cliff, alt. 1650 m, 29 Apr 2017, *Meng-Qi Han et al. HMQ0001* (IBK).

Conservation status. So far, only two populations with about 300 individuals each have been found, notably near the towns of Mali and of Shuitian. The area of occupancy is estimated to be less than 4 km². Despite the fact that only two populations with relatively few individuals are known, the status of *Spiradiclis karstana* is not pessimistic. It may count on the strong adaptability of the species to the severe habitat where interference from humans is usually weak and where it is very hard for people to reach and the efficient government policy to protect the local vegetation (Lai et al. 2000, Sui and Chen 2006, Zhu et al. 2007). Considering all of the above, this species is therefore assigned a status of “Vulnerable” [VU B2ab(ii, iii, iv)] according to the IUCN criteria (2016).

Discussion

Karst ecosystems are known to be distinctive in vegetation and biodiversity and have an extreme and exceptional habitat that can provide the opportunity for speciation and radiation (Myers et al. 2000, Zhu 2007, Biswas 2009). As mentioned above, most representatives of *Spiradiclis* prefer this unique ecosystem. It may be the reason why this small genus shows fairly complex and diverse habit and morphology. Until now, 11 known species of *Spiradiclis*, viz., *S. danxiashanensis* R.J.Wang, *S. elliptica* Y.M.Shui & W.H.Chen, *S. glandulosa* L.Wu & Q.R.Liu, *S. guangdongensis* H.S.Luo, *S. hainanensis* H.S.Luo, *S. jingxiensis* R.J.Wang, *S. longanensis* R.J.Wang, *S. pauciflora* L.Wu & Q.R.Liu, *S. pengshuiensis* B.Pan & R.J.Wang and *S. umbelliformis* H.S.Luo, as well as this new one, are prostrate or decumbent herbs without erect stems and usually with roots at the nodes (Sui and Chen 2006, Chen and Taylor 2011, Wu et al. 2015a, 2015b, Wang et al. 2015, Wen et al. 2015, Wang 2016, Pan et al. 2016). The following key is provided to the prostrate or decumbent *Spiradiclis* species worldwide.

A key to the prostrate or decumbent species in *Spiradiclis*. This key was adapted from Chen and Taylor (2011)

- 1 Corolla tubes shorter than 10 mm 2
- Corolla tubes 10–25 mm 5
- 2 Leaf blades usually 2–10 cm long, second veins 7–9 pairs; corolla tubes 2–3 mm long 3
- Leaf blades 0.5–2 cm long, second veins 3–4 pairs; corolla tubes longer than 7 mm 4
- 3 Stem densely hairy; bracts linear *S. longanensis*
- Stem subglabrous; bracts oblong *S. elliptica*
- 4 Stipules shorter than 1 mm; inflorescences 3–7-flowered *S. pauciflora*
- Stipules 1.5–2.5 mm long; inflorescences 2–3-flowered *S. hainanensis*
- 5 Stipules 0.3–1.2 mm long, caducous 6
- Stipules 1.5–5 mm long, persistent 7
- 6 Stems and leaves densely pubescent; leaf blades ovate; calyx lobes 0.8–1.5 mm long *S. pengshuiensis*
- Stems and leaves puberulent; leaf blades elliptic to oblong; calyx lobes 2–2.5 mm long *S. karstana*
- 7 Calyx lobes 0.6–1.5 mm long 8
- Calyx lobes 2–6 mm long 9
- 8 Leaf blades 1.5–4 cm long; inflorescences 4–10-flowered... *S. umbelliformis*
- Leaf blades 0.3–1.1 cm long; inflorescences 1–2-flowered *S. jingxiensis*
- 9 Corolla glabrous outside, tubes 16–18 mm long *S. glandulosa*
- Corolla subglabrous outside, tubes 11–15 mm long; stigmas excluded in long-styled flowers 10
- 10 Corollas salverform; peduncles 1.3–2.8 cm *S. danxiashanensis*
- Corollas slenderly funnelform; peduncles shorter than 1 cm *S. guangdongensis*

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Imprecise descriptions of *Passiflora riparia* Martius ex Masters led to redundant descriptions as *P. emiliae* Sacco, *P. crenata* Feuillet & Cremers, *P. pergrandis* Holm-Nielsen & Lawesson and *P. fernandezii* Escobar

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Abstract

Passiflora riparia was incompletely described by Masters, who cited specimens of Martius and Spruce. While *Spruce 2191*, the unique syntype with an observable corona, exhibits a reduced outermost series of filaments, the accompanying iconography represents two equal outer series. Later descriptions have neither added significant information nor corrected the inconsistency in the corona description, so that four closely related species have been distinguished on the basis of traits not properly documented for *P. riparia*: *P. emiliae* (unequal outer series of filaments), *P. crenata* (bract color), *P. pergrandis* (flower size and sepal awn length), and *P. fernandezii* (hypanthium pubescence and shape). The present study compares (i) the descriptions of the above-mentioned taxa and (ii) 43 associated vouchers, as well as live specimens from two associated *P. crenata* populations. These and other specimens were georeferenced for a comparison of their distribution and habitat. Of the five *P. riparia* descriptions found in floras, only that of the Flora of Ecuador appears clearly divergent, corresponding in fact to *P. tolimana*. Those of the four other taxa only differ by unequal corona filaments (except for *P. crenata*) and the pubescence of floral parts. However, 22 vouchers associated with all these descriptions (including 16 for *P. riparia*), as well as the live specimens, share both these traits; the other 21 vouchers were uninformative and/or could not be assigned to any of the five species. The wider sample of 62 specimens indicates no significant differences in either geographic or in climatic distribution (lowlands of the Amazon basin), and a marked preference for riparian habitats. Thus, their very close morphology and ecology justify the placement of *P. emiliae*, *P. crenata*, *P. pergrandis* and *P. fernandezii* as synonyms of *P. riparia*, designating *Spruce 2191* as epitype. The most similar species, *P. ambigua* (20 specimens mapped), differs in corolla and bract color, as well as a distribution centered along the tropical Andes of South America and in Central America, in more diverse habitats.

Keywords

Passifloraceae, subgenus *Passiflora*, series *Laurifoliae*

Introduction

Five subgenera are currently recognized in the genus *Passiflora* L.: *Passiflora*, *Astrophea* (DC.) Mast., *Decaloba* (DC.) Rchb., *Deidamioides* (Harms) Killip and *Tetrapathea* (DC.) P. S. Green. Subgenus *Passiflora*, rich with more than 250 species, is characterized by large flowers with a corona made of several rows of filaments. Its supersection *Laurifoliae* (Cervi) Feuillet & J. M. MacDougal includes several series, organized around a clear morphological pattern (Rome and Coppens d'Eeckenbrugge 2017). In particular, series *Laurifoliae* Killip (1938) ex Cervi (1997) forms a very homogenous morphological group, with a very difficult taxonomy (Killip 1938, Holm-Nielsen et al. 1988). With the recently described *P. gustaviana* Ocampo & Molinari (Ocampo and Molinari 2017), it is composed of 25 species including glabrous to pubescent plants, whose stems are terete to angular and sometimes corky on old parts; leaves are unlobed, oblong to oblong-lanceolate, not peltate, with entire to glandular-serrulate margins, biglandular petioles; and stipules are setaceous or linear, and early deciduous. Their three bracts, free at base, with entire or serrulate-glandular margins, are more than 1 cm long. Their flowers are pendent, usually large and showy, often fragrant, with a short hypanthium and two campanulate series of long external filaments, and a variable number of series of reduced internal filaments (Rome and Coppens d'Eeckenbrugge 2017).

According to Killip (1938), *Passiflora riparia* Martius ex Masters appears to be the commonest representative of the series *Laurifoliae* in the upper and middle Amazon basin. Its original description by Masters (1872), in *Flora Brasiliensis*, refers to two syntypes: *Martius 3228*, from the mouth of the Madeira River in the Upper Amazonas, and *Spruce 2191* (the latter cited by Masters with an exclamation mark), collected from São Gabriel da Cachoeira, near the Rio Negro. The number of series of external corona filaments is not mentioned in Masters' description. In the accompanying botanical iconography, flowers appear to have one series of long filaments, whereas a schematic longitudinal section shows two equal series of external filaments. This detail has become problematic since the relative length of the two external filament series became an important diagnostic trait when Killip (1938) created the series.

Martius' specimen consists of two samples with much deteriorated flowers, which do not allow assessing the length of filament series. However, one of them holds a brief note in Latin handwritten by Martius, with incomplete information about the filaments: "Corona exterior serie simplici constat filorum alborum quae vittis quadratis violaceis picta sunt atque compressa; interior similis crassior". This indicates the existence of two outer series, the inner one with stronger filaments, but gives no direct information on their relative length. The flower of *Spruce 2191*, the specimen examined by Masters, has two very unequal series of external filaments, the outermost being reduced, with few short filaments. Thus, the illustration accompanying Masters'

description of *Passiflora riparia* reflects misinterpretation of the syntypes concerning an important diagnostic trait in the series. However, this anomaly was not corrected in the successive re-descriptions of the species (Killip 1938, Tillett 2003, Cervi 1997). The resulting confusion is responsible for the creation of several species that are closely similar or identical to the syntypes of *Passiflora riparia*.

Thus, in 1966, Sacco described *Passiflora emiliae* Sacco in the Boletim do Nacional Museum (Rio de Janeiro), from two Kuhlmann specimens that had been first determined as *P. riparia*. Indeed, as in *Spruce 2191*, the Kuhlmann specimens correspond to Masters' drawing of *P. riparia*, with the exception of their two unequal outer series of filaments. This is why Sacco (1966) provided a key where *P. riparia* is differentiated from *P. emiliae* by two subequal outer series of filaments.

Passiflora crenata Feuillet and Cremers (1984) was described as a French Guiana endemic, very similar to *P. riparia*. It was differentiated by the white color of its bracts (a trait not precisely described for *P. riparia*) and by its solitary flowers, in contrast to those of *P. riparia*, which are clustered on short lateral stems. The original description of *P. crenata* mentions two outer series of the same length as the sepals, however both the holotype and the illustration provided by Feuillet and Cremers (1984) show two very unequal outer series of filaments, the outermost appearing much shorter and thinner.

In the Flora of Ecuador, Holm-Nielsen et al. (1988: 116) designated *Martius 3228* as the lectotype of *P. riparia* and referred the other syntype, *Spruce 2191*, to *P. ambigua* Hemsl. With two glands placed above the middle of petiole (at the apex in the reference vouchers), their description of *P. riparia* is clearly different from the syntypes and the original description. Moreover, their description indicates a confusion between the innermost series of filaments and the operculum. Indeed, the authors describe “a nectar ring 0.5 cm long, recurved margin minutely sinuate to lobulate” and an “operculum 1 cm, erect, entire, borne just below corona”. In fact, the “nectar ring” corresponds to the operculum as observed in the series *Laurifoliae*; and the part named “operculum” by Holm-Nielsen et al. is the same innermost series of filaments, oriented towards the androgynophore and covering the entrance of the hypanthium, that exists in *P. tolimana* Harms, *P. kapiensis* Rome and Coppens, and other species of the series (Rome and Coppens d'Eeckenbrugge 2017). In the herbarium specimen *Knapp 6242* cited by Holm-Nielsen et al. (1988), these inner filaments appear more or less fused together, forming an erect tubular structure. On the next page, Holm-Nielsen et al. described *P. ambigua*, including *P. emiliae* as a synonym of this species. Furthermore, in their determination key, they distinguished *P. pergrandis* Holm-Nielsen and Lawesson (1987), another species of series *Laurifoliae*, from *P. riparia* by the awn of the sepal not exceeding its apex (vs. an awn exceeding the sepal apex). However, this trait is found in Spruce's syntype of *P. riparia* (which they assigned to *P. ambigua* instead of *P. riparia*).

In 1989, Escobar described *Passiflora fernandezii* Escobar as a close Bolivian relative of *P. riparia*: “*P. fernandezii* most closely resembles *P. riparia* [...], but differs from it by the pubescence and shape of the hypanthium. Both of these characters are variable in collections ascribed to that species [...] so that further study of the *Passiflora riparia* complex is needed.”

Here, we revise the different treatments of *P. riparia* and compare them with the descriptions and types of *P. emiliae*, *P. crenata*, *P. pergrandis*, and *P. fernandezii*, and re-examine the other vouchers associated to them by the different authors of these species. Thus, we can demonstrate that, based on the textual descriptions of *P. riparia* by Martius and Masters and the observation of both syntypes, *Martius 3228* and *Spruce 2191*, as well as the polymorphism observed on the reference vouchers mentioned in the different treatments, there is no ground for differentiating these five species. We also verify that none of these five taxa can be differentiated by its adaptation, using label information and a multivariate analysis of climates in their respective ranges, while observing that *P. ambigua* is marginally sympatric with them, less strongly related to riparian habitats, and adapted to a wider range of climates, particularly in tropical highlands. Consequently, we place *P. emiliae*, *P. crenata*, *P. pergrandis* and *P. fernandezii* in synonymy of *P. riparia*, and provide a more complete and precise description that takes into account the pan-Amazonian geographical distribution of this species and its attendant polymorphism.

Materials and methods

A first comparison confronts the descriptions of *P. riparia* by Masters (1872), Killip (1938), Cervi (1997), Tillett (2003), Holm-Nielsen et al. (1988), the original description of *P. emiliae* by Sacco (1966), that of *P. crenata* by Feuillet and Cremers (1984), that of *P. pergrandis* by Holm-Nielsen and Lawesson (1987), that of *P. fernandezii* by Escobar (1989). This comparison is focused on traits relative to stems, stipules, petiole, leaves, inflorescences, bracts, hypanthium, sepals, petals, corona (outer and inner series of filaments), operculum, androgynophore, ovary, and fruit. It has been extended to the description of the very similar *P. ambigua* by Hemsley (1902).

A second comparison bears on all available vouchers (43 specimens; see Table 2) associated with the descriptions of any of the first five species by these same authors, focusing on the following traits: petiolar gland position, presence of pseudoracemes, plant pubescence, bract size, color of bracts and perianth, when discernible or mentioned on the voucher label. We also include our own field observations of *P. crenata* in French Guiana, on living material collected from localities indicated in the original description.

Other 94 herbarium specimens have been observed and determined, for a comparative study of the habitat of the same taxa. Some sheets were studied from scans provided by the host herbaria. The complete list, comprising 137 materials initially classified under *P. riparia* or one of its four presumed synonyms or under *P. ambigua*, is listed in the appendix. For the distribution study, only fertile samples allowing unambiguous determination were retained, as well as other good quality reports (including photographs); the *P. crenata* sample from French Guiana was reduced to 11 specimens, to avoid an excessive weight for this taxon. When label information allowed, geographic coordinates were assigned to the voucher using Google Earth and gazetteers, the collecting sites were mapped and a distribution model was developed, using the MAXENT software and 19 bioclimatic variable layers from the Worldclim

database at a 2'30" grid resolution (corresponding roughly to 4.4×4.6 km at Equator; <http://www.worldclim.org/current>) (Hijmans et al. 2005). MAXENT identifies potential distribution areas based on their similarity in climatic conditions compared to those at the sites where the species has already been observed, hence modeling where conditions are suitable for their development. It infers the probability distribution of maximum entropy (i.e., closest to uniform) subject to the constraint that the expected value of each environmental variable (or its transform and/or interactions) under this estimated distribution matches its empirical average (Phillips et al. 2006). A logistic threshold value equivalent to the 10th percentile training presence was retained to separate climatically favorable areas from marginally fit areas. Thresholds of 33 and 67% training presence were used to discriminate “very good” and “excellent” climates.

Furthermore, 19 bioclimatic variables corresponding to the collection sites were extracted from the Worldclim database (Hijmans et al. 2005), and those variables that most contributed to the model were submitted to a Principal Component Analysis (PCA) for a comparative analysis of climatic adaptation.

Results

Comparative analysis of descriptions

Table 1 compares the descriptions of *Passiflora riparia* with those of its presumed synonyms. The cells highlighted in bold font correspond to the characters that differ from the descriptions of *P. riparia* by Masters (1872) and Killip (1938).

As Masters (1872) did not observe living specimens, his original description could not give indications about the size and color of several plant parts. Only the bracts are mentioned as colored, i.e., different from the usual chlorophyll green found in most passionflower species. Masters (1872) specified leaf size, as well as the length of sepals and petals, but gave no direct indication about the length of the outer series of filaments. He ignored Martius' considerations on the unequal width of the two series. The iconography seems very precise but it is confusing, as it shows a flower section with two equal series of filaments, whereas the other flowers exhibit only one series of long filaments protruding from the corolla.

Based on Peruvian and Brazilian herbarium specimens, the description by Killip (1938) completes that of Masters (1872) with the size of stipules, bracts, inner series of filaments and fruits, and expands the variability of leaves, sepals and petals. It mentions the reddish bract color but not the perianth color. It describes the species with two equal series of filaments.

The description of *P. riparia* by Cervi (1997), based on new specimens from Brazil, Peru and Ecuador is very similar to that of Killip. The only difference is that Cervi (1997) mentions the white color of petals. Another very similar description is that of Tillett (2003) in the Flora of the Venezuelan Guyana, with no mention of examined specimens. It expands further the variability of leaves, perianth color (pinkish white) and fruit size.

Table 1. Comparison of descriptions of *P. riparia*, *P. emiliae*, *P. arenata*, *P. pergrandis* and *P. ambigua*, with additional information from related iconography (*). Traits diverging from the original description of Masters are highlighted in bold font.

	<i>P. riparia</i> (Masters, 1872)	<i>P. riparia</i> (Killip, 1938)	<i>P. riparia</i> (Cervi, 1997)	<i>P. riparia</i> (Tillett, 2003)	<i>P. riparia</i> (Holm- Nielsen et al., 1988)	<i>P. emiliae</i> (Succo, 1966)	<i>P. arenata</i> (Feuillet & Cremers, 1984)	<i>P. fernandezii</i> (Escobar, 1989)	<i>P. pergrandis</i> (Holm-Nielsen & Lawesson, 1987)	<i>P. ambigua</i> (Hemsley, 1922)
Stem	terete to striate	terete	terete	–	–	terete, subangular or striate	terete to angular	angular to striate	terete to striate	terete to angular
Stipules	pubescence	glabrous	glabrous	–	glabrous	glabrous	glabrous	sparsely pubescent	glabrous	glabrous
	shape	setaceous*	linear	linear	setaceous	linear, acute	linear	linear	absent from the type	very slender
Petiole	pubescence	glabrous*	glabrous	–	glabrous	glabrous	glabrous	–	glabrous	glabrous
	size (cm)	–	0.3 to 0.4 long	0.3 to 0.4 long	0.4 long	ca. 1	1.5–2.0	ca 1 × 0.05	–	0.5–1.6 × 0.04–0.1
Leaves	length (cm)	1.35–2.25	1.5–2	1.5–2	3	1.5–2	1.5–2	1.2–1.8	2–3	2–6
	gland position	below middle	at middle	at middle	at middle	below middle	proximal half	at middle	below middle	at middle
Leaves	base	cordate to rounded	rounded, retuse or narrowed	rounded to retuse	truncate to obtuse	rounded	rounded, obtuse or slightly cuneate	rounded	obuse to truncate	rounded or cuneate
	apex	slightly acuminate	abruptly acuminate	abruptly acuminate	abruptly acuminate	acuminate, mucronate	acuminate, mucronate	abruptly acuminate	acuminate	acuminate cuspidately acuminate
Leaves	margin	entire to serrate	entire to minutely serrulate	entire to minutely serrulate	entire	entire	entire	entire	entire	entire to serrulate
	pubescence	glabrous*	glabrous	glabrous	glabrous	glabrous	glabrous	glabrous except for a few scattered trichomes at base on abaxial surface	glabrous	glabrous
Inflorescence	size (LxI, cm)	10.8–13.5 × 5.4–8.1	10–15 × 4.5–8	10–15 × 4.5–8	15–17 × 8–9	10.5–14.5 × 5.5–6.5	6–13 × 2.5–7	5–9.4 × 2.5–4.2	15–20 × 9–10	14–23 × 7.2–12
	type	axillary racemes	on short axillary branches, with no or reduced leaves	–	in axillary branches with or without reduced leaves, occasionally axillary to normal leaves	solitary	axillary, solitary or pseudoracemes*	axillary, aggregated at the end of stems	a distal bud developing to forming a conspicuous indeterminate inflorescence	solitary, axillary or in pseudoracemes

	<i>P. riparia</i> (Masters, 1872)	<i>P. riparia</i> (Killip, 1938)	<i>P. riparia</i> (Cervi, 1997)	<i>P. riparia</i> (Tillet, 2003)	<i>P. riparia</i> (Holm-Nielsen et al., 1988)	<i>P. emiliae</i> (Succo, 1966)	<i>P. ornata</i> (Feuillel & Cremers, 1984)	<i>P. fernandezii</i> (Escobar, 1989)	<i>P. pergrandis</i> (Holm-Nielsen & Lawesson, 1987)	<i>P. ambigua</i> (Hensley, 1972)
Bracts	color size (LxI, cm) pubescence	reddish 3-4 x 1.5-2 glabrous	- 3-4 x 1.5-2 glabrous	reddish 3-5 x 2-3 -	- 4.5 x 1 glabrous	- 2.5-3.5 x 1.4-2.2 pubescent	white 4-5 x 2-3 pubescent	- 1.9-2.4 x 1-1.4 pubescent	- 5 x 4 pubescent	green 3-6 x 3-4 pubescent
Hypanthium	pubescence shape/size	glabrous glabrous cylindric- campanulate	glabrous glabrous cylindric- campanulate	- broadly funnelform	glabrous 1-1.5 x 2 cm, broadly campanulate	pubescent cylindric- campanulate, 1.3 cm long	- 1 cm long	funnelform, 1.6-2 cm long, 2.4-2.9 cm wide at apex, 1-1.3 cm wide at base	pubescent campanulate, 1 x 2 cm	pubescent oblate, deeply intruded
Sepals	pubescence color size (LxI, cm)	glabrous - 4-5 x 2	glabrous - 4-5 x 2	- pinkish white shorter than sepals	glabrous lilac 4 x 1.5	pubescent white 3.5-4 x 1.3-1.8	pubescent greenish white 6 x 3	- - 2.6-3.1 x 1.5-2.1	pubescent - 6 x 3.5-4	pubescent white outside pink to dark purple inside 4-5 x 1.5-1.8
Petals	color size (LxI, cm)	- 4 x 0.8	white 4 x 0.8	pinkish white shorter than sepals	lilac 2.5 x 0.5-1	white 3-3.5 x 0.8-1	white 5 x 1-1.5	- ca 1.4 x 0.7	white 5.5-6 x 2	white strongly spotted with rose-purple 3-4 x 1
Outermost series of filaments	number shape	2 filamentose, camose, ca. 2 mm thick	2 filamentose, camose, ca. 2 mm thick	2 (rarely 1) the inner to 2 mm thick, filamentous, fleshy, forming a spherical cage around the androgynoscium, outer series more slender	2 filiform	2 the outermost filiform, the second serie ligulate	2 large and erected, enlarged at base	2 filamentous	2 outer series minutely sericeous, filaments of second series stout, ligulate	2 the outermost filiform, the second thicker
color	red striped	white banded with blue or violet	banded with blue or violet and white	banded red to purplish	-	white and red stripped	white and purple stripped	banded with purple	white and dark violet	white banded with red or purple
relative length	same length*	same length (4-5 cm)	subequal (4-5 cm)	same length (4-5 cm)	same length (6-7 cm)	outer series (1-1.3 cm) shorter than next one (2.5-3.5 cm)	both as long as sepals	the outer filaments ca 0.6 cm long, ca 0.4 mm wide, the inner ones 2.3-2.5 cm long, ca 1 mm wide	outer series 0.2 cm, second series 5 cm	the outermost shorter than the second series (sometimes atrophied)

	<i>P. riparia</i> (Mastre, 1872)	<i>P. riparia</i> (Killip, 1938)	<i>P. riparia</i> (Cervi, 1997)	<i>P. riparia</i> (Tillet, 2003)	<i>P. riparia</i> (Holm-Nielsen et al., 1988)	<i>P. emiliae</i> (Sacco, 1966)	<i>P. renata</i> (Fecullet & Cremers, 1984)	<i>P. fernandezii</i> (Escobar, 1989)	<i>P. pergrandis</i> (Holm-Nielsen & Lawesson, 1987)	<i>P. ambigua</i> (Hensley, 1972)
Inner series	many	many	many	2 or more series within the floral tube	5–6 series	many	4 (more or less distinct)	many	many	many
length	shorter than outer series, with intermediate series atrophied and the innermost slightly longer	irregular mass of tubercles covering about 6 mm of the height of the tube, the innermost filaments about 2 mm long	irregular mass of tubercles covering about 6 mm of the height of the tube, the innermost series filaments about 2 mm long	2 mm long	third series 0.5 cm, filiform, then 2 or 3 series 0.2–0.3 cm, filiform, irregularly arranged. The innermost 1 cm, erect, entire, borne just below corona.	shorter than outer series, with intermediate series atrophied and the innermost slightly longer	short	irregular rows of filaments 0.5–2 mm long in lower half of inner surface	third series close to operculum, minutely tuberculate 1–2 mm	intermediate series atrophied and the innermost slightly longer
Operculum	membranous, horizontal, margin recurved, fimbriate	membranous, horizontal, margin recurved, crenulate	membranous, horizontal, margin recurved, crenulate	horizontal, recurved margin with short, capitate filaments	0.5 cm, recurved, margin minutely sinuate to lobulate	membranous, horizontal, with margin recurved, crenulate	horizontal	horizontal, membranaceous, nonplicate	membranaceous, recurved, the margin with short fimbriate filaments	membranous, horizontal, with margin recurved, crenulate
Andro-gynophore	slightly longer than the flower tube.	–	–	–	–	1.5 cm	1 cm	–	–	1.5–2 cm
Ovary	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Fruit	globose	ovoid to globose	ovoid to globose	ovoid or globose	ovoid	–	ovoid	–	–	ovoid to oblong
size (LxI, cm)	larger than a cherry	3–4 × 2.5–3.5	3–4 × 2.5–3.5 cm	10 × 2.5–5	6 × 2.5	–	6 × 4	–	–	10–12 × 6–7

Although he maintains the presence of two equal series of corona filaments, he notes that the outer one is more slender and that the corona can be reduced to a single series of filaments.

Holm-Nielsen et al. (1988) were the first to mention *P. riparia* in Ecuador, referring to two specimens. Their description differs from the others in many traits: leaf size, the petiole gland position, the type of inflorescence, the color of the corolla, the size of the sepals, the length and shape of the two series of outer corona filaments, and finally the internal structure of the flower with the presence of an internal series of filaments closing the entrance to the nectar chamber. Thus, this description presents many more differences from the original description than those of the five other species examined here: *P. emiliae*, *P. crenata*, *P. pergrandis*, *P. fernandezii*, and even the much more anciently established *P. ambigua*. Its divergence can be visualized by the concentration of bold font in the corresponding column of Table 1. In contrast, the descriptions of *P. emiliae*, *P. crenata*, *P. fernandezii* and *P. pergrandis* are compatible with the earlier descriptions of *P. riparia*, except for pubescence of bracts, hypanthium and sepals, the relative length of the two outermost series of corona filaments, and their wider variation for quantitative traits (dimensions of stipules, leaves, sepals and fruits).

In 1966, Sacco described *P. emiliae* from Brazilian herbarium specimens hitherto classified under *P. riparia*. Holm-Nielsen et al. (1988) considered it as a synonym of *P. ambigua*. A comparison of both species shows that their flower structure is relatively similar, however the bract and perianth colors are clearly different (white bracts and perianth for *P. emiliae* vs. green bracts and dark purple perianth for *P. ambigua*). As compared with *P. riparia* description, that of *P. emiliae* differs by two unequal outer series of filaments (vs. two equal series), as well as pubescent bracts and sepals.

Feuillet and Cremers (1984) described *P. crenata* as an endemic species from French Guiana, distinguishing it from *P. riparia* by its white bracts and the type of inflorescence. Again, the two outer series of filaments are described as equal even though the drawing of the description shows only one outer series of filaments. Bracts and sepals are described as pubescent on their abaxial surface.

The description of *P. fernandezii* (Escobar, 1989), from one herbarium specimen, differs from that of *P. riparia* by two unequal outer series of filaments, a scattered pubescence on stems, leaf abaxial surfaces, and the funnellform hypanthium. It seems to have smaller leaves, bracts and perianth, as compared to the other species in Table 1. However, this difference in leaf size is more likely related to the origin of the specimens used for Escobar's description as they correspond to the terminal portion of floriferous branches, i. e., pseudoracemes, with shorter nodes and smaller leaves. In fact, the leaves at the base of the samples are about 9–12 cm long, which falls in the range of the other species descriptions.

The description of *P. pergrandis*, only based on the Ecuadorian type specimen, is closely similar to those of *P. crenata* and *P. emiliae*. The qualitative criteria, as leaf shape, the petiole gland position, the pubescence of different parts, the petal color, the hypanthium shape, and the disposition of inner filaments series are identical. The two outer series of filaments are very unequal, the outer elements being 2 mm long (vs. 50 mm

for the second series). The description does not mention the color of bracts and sepals. Flowers, leaves and bracts seem to be larger than in *P. crenata* and *P. emiliae*, but comparable with the observations of Tillett (2003) for *P. riparia*.

As compared to all species descriptions mentioned above, that of *P. ambigua* is only differentiated by the color of the bracts, petals and sepals.

Comparative analysis of herbarium and live specimens

Table 2 presents a comparison of the 43 herbarium specimens cited in the descriptions of *P. riparia* and its presumed synonyms, based on diagnostic traits. The observations of live specimens from two cited populations of *P. crenata* (Rome specimens) are also presented. Twenty-three herbarium specimens that do not match the syntype *Spruce 2191*, or that cannot be compared to it, are highlighted in bold font. Fourteen of them were assigned to other species of series *Laurifoliae*.

The two collections used in the original description of *P. riparia* provide complementary information. *Spruce 2191* is the most complete; on the sample conserved in Paris, the corona of its flowers has a single series of well-developed filaments (about 35 mm long), whereas the outermost series is severely reduced (slender filaments ca. 5–10 mm). Its bracts and the abaxial sepal surface are slightly pubescent. The bracts are reddish (confirmed by a handwritten note on the Kew specimen). Two samples belong to *Martius 3228*. The first one has very degraded flowers and it is impossible to see the series of external filaments and the internal structure. However, a handwritten note by Martius mentions the presence of two series of main filaments, the outermost being filiform and the second one thicker; the corolla is described as pink outside and white inside, and the bracts as pink to red, which is consistent with the reddish color of their dry remains. The second sample bears long peduncles, however the flowers themselves are lacking. In these samples, the bracts, hypanthium, peduncles, and the abaxial face of the sepals are pubescent.

Out of the 22 specimens mentioned by Killip (1938) in his description of *P. riparia*, six cannot be identified (including four of the five sterile specimens he collected himself) and seven differ from the original description and the syntypes by the position of petiolar glands, the color of perianth and bracts, the presence of cork on the stem, showing that they belong to other species of series *Laurifoliae*. Finally, only seven specimens could be maintained unambiguously in *P. riparia*. Whenever observable (five specimens), the outermost series of filaments is shorter than the second series. In *Williams 7876*, the outermost series is longer than in *Spruce 2191*, but still much reduced as compared to the second series. In the four other cases (*Williams 1440*, *Klug 4037*, *Klug 3897* and *Ducke 17338*), it is even absent. Three specimens present pubescence on floral parts. *Klug 3897* and *Williams 7996* also exhibit pubescence on the petioles of pseudoracemes. *Williams 7876* shows no pseudoraceme.

The description of *P. emiliae* is based on only two herbarium specimens (*Kuhlmann 1066* and *Kuhlmann 1064*) collected from the same locality (margins of Rio Arinos,

Table 2. Comparison of herbarium materials referenced in the descriptions of *P. riparia*, *P. emiliata*, *P. crenata*, *P. fernandezii*, *P. pergrandis* and *P. ambigua*. Two specimens of *P. crenata* from French Guiana have been replaced by field observations on populations at the collecting site. Question marks indicate that the trait could not be determined with confidence (e.g. pubescence on voucher scans). Dashes indicate that it could not be observed on the voucher (e.g. floral traits on sterile vouchers).

Specimen	Origin	Authors' determination	Petolar gland position	Pseudo-raceme	Pubescence	Bracts size	Bract color	Perianth color	Outer series of filaments	Observations
Martius (1872); <i>P. riparia</i> Spruce2191 (ST)	Brazil	<i>P. riparia</i>	middle	yes	peduncle - bracts - hypanthium - exterior of sepals	3 × 2 cm	reddish	white	Unequal, the outermost filiform and short, next one thicker and longer	
Martius 3228 (LT, IT)	Brazil	<i>P. riparia</i>	below middle	yes	bracts - ovary - fruit	3 × 2 cm	reddish pink	pink inside, white outside	"the outermost filiform, the second one thicker" (Latin handnote from Martius)	
Killip (1938); <i>P. riparia</i> Ducke 175338	Brazil, Para	<i>P. riparia</i>	middle	yes	?	4 × 2 cm	reddish	white	One, the outermost being completely atrophied	corona banded white and violet, androgynophore white
Ducke 24044	Brazil, Amazonas	<i>P. cf. laurifolia</i>	apex	no	?	–	green	violet	Two unequal	no inner filaments, fruit acuminate
Killip 26307	Peru	impossible	middle	–	–	–	–	–	–	sterile plant, <i>P. riparia</i> or <i>P. ambigua?</i>
Killip 26683	Peru	<i>P. riparia</i>	below middle	–	–	–	–	–	–	"flowers blue and white" (label)
Killip 28214	Peru	impossible	near apex	–	–	–	–	–	–	sterile plant
Killip 28940	Peru	impossible	middle	–	–	–	–	–	–	sterile plant, <i>P. riparia</i> or <i>P. ambigua?</i>
Killip 29012	Peru	impossible	middle	–	–	4 × 2 cm	–	–	–	fruit orange, <i>P. riparia</i> or <i>P. ambigua?</i>
Klug 3897	Peru	<i>P. riparia</i>	middle	yes	peduncle - bracts - calyx - petioles of pseudocarp	2 × 1.5 cm	reddish	white	one, the outermost being completely atrophied	
Klug 4037	Peru	<i>P. riparia</i>	middle	yes	?	–	–	grayish	one, the outermost being completely atrophied	
Spruce 1172	Brazil	<i>P. cf. laurifolia</i>	apex	no	peduncle	–	–	–	–	
Spruce 1394	Brazil	<i>P. laurifolia</i>	apex	no	?	–	green	red	two unequal	no inner filaments
Spruce 3390	–	<i>P. phellos</i>	apex	no	?	1.5 × 0.5 cm	green	red	two unequal	corky stems
Swallen 3390	Brazil, Para	<i>P. laurifolia</i>	apex	no	?	–	green	purple	two unequal	
Williams 1392	Peru	impossible	below middle	–	–	–	–	–	–	sterile plant, <i>P. riparia</i> or <i>P. ambigua?</i>
Williams 1440	Peru	<i>P. riparia</i>	middle	yes	–	–	reddish	white	one, the outermost being completely atrophied	
Williams 3126	Peru	impossible	middle	no	fruits - peduncles	–	–	–	–	<i>P. riparia</i> or <i>P. ambigua?</i>
Williams 5637	Peru	<i>P. venusta</i>	apex	no	?	4 × 2.2 cm	green	purple red	–	triangular sepals and petals, coriaceous leaves
Williams 5848	Peru	<i>P. cf. venusta</i>	below apex	no	–	–	green	–	–	coriaceous leaves

Specimen	Origin	Authors' determination	Petolar gland position	Pseudoraceme	Pubescence	Bracts size	Bract color	Perianth color	Outer series of filaments	Observations
Williams 6300	Peru	impossible	below apex	–	–	–	–	–	–	sterile plant, <i>P. riparia</i> or <i>P. ambigua?</i>
Williams 6378	Peru	<i>P. venusta</i>	near apex	no	ovary	–	green	–	two unequal series	
Williams 7876	Peru	<i>P. riparia</i>	middle	no	ovary - peduncle - bracts	3 × 1.5 cm	reddish	white	Unequal, the outermost filiform and short, next one thicker and longer	
Williams 7996	Peru	<i>P. riparia</i>	below middle	yes	peduncle - bracts - stipule and petioles of pseudoraceme	3.5 × 2 cm	reddish	–	–	
Sacco (1966): <i>P. emiliae</i>										
Kühlmann 1066 (HT)	Brazil, Mato Grosso	<i>P. riparia</i>	below middle	yes	ovary - peduncle - bracts - hypanthium - petioles of pseudoraceme	2.5–3.5 × 1.5–2.5 cm	white	white	Unequal, the outermost filiform and short, next one thicker and longer	short inner series (1–2 mm) in the hypanthium
Kühlmann 1064 (PT)	Brazil, Mato Grosso	<i>P. riparia</i>	below middle	yes	ovary - peduncle - bracts - hypanthium - petiole of pseudoraceme	2.5–3.5 × 1.5–2.5 cm	white	white	Unequal, the outermost filiform and short, next one thicker and longer	short inner series (1–2 mm) in the hypanthium
Feuille et Cremers (1984): <i>P. crenata</i> - vouchers										
Feuille 573	French Guiana	<i>P. riparia</i>	middle	yes	peduncles - calyx - bracts - petioles of pseudoraceme	4–5 × 2–3 cm	white	white	Unequal, the outermost filiform and short, next one thicker and longer	
Prevost 563	French Guiana	<i>P. riparia</i>	below middle	yes	peduncle - bracts - fruit	5–6 × 4 cm	–	–	–	fruit green with white spots
Feuille et Cremers (1984): <i>P. crenata</i> - live specimens from originally collected populations										
Rome specimens	French Guiana	<i>P. riparia</i>	below middle	yes	peduncles - calyx - bracts - petioles of pseudoraceme	4.5–6.2 × 2.7–4.3 cm	white to pink	white to greenish white	Unequal, the outermost filiform and short or absent, the second one thicker and longer	intermediate series atrophied and the innermost slightly longer; operculum membranous, horizontal, with margin recurved, crenulate
Holm-Nielsen et al. (1988): <i>P. riparia</i>										
Holm-Nielsen 1040	Ecuador	<i>P. tolimana</i>	below apex	no	?	1.5 × 0.5 cm	reddish	ilac	two subequal series	bracts short and acute
Knapp 6242	Ecuador	<i>P. tolimana</i>	apex	no	?	1.5 × 0.4 cm	reddish	pinkish lavender	two subequal series	bracts short and acute, inner series oriented towards the androgynophore, covering the entrance to the hypanthium
Cervi (1997): <i>P. riparia</i>										
Schultes 9900	Brazil, Amazonas	<i>P. pibellos</i>	apex	–	?	3 × 1 cm	green	–	–	corky stems
Spruce 1394	Brazil, Amazonas	<i>P. laurifolia</i>								see above, among materials cited by Killip (1938)

Specimen	Origin	Authors' determination	Petolar gland position	Pseudoraceme	Pubescence	Bracts size	Bract color	Perianth color	Outer series of filaments	Observations
Spruce 1172	Brazil, Amazonas	<i>P. cf. laurifolia</i>								
Spruce 3390	Brazil, Para	<i>P. phellos</i>								
Ducke 17338	Brazil, Para	<i>P. riparia</i>								
Allen 3340	Colombia	<i>P. laurifolia</i>	apex	no	?	3 × 1.5 cm	green	lavender	two unequal series	—
Jativa 439	Ecuador	<i>P. ambigua</i>	middle	yes	ovary	4.5 × 2.5 cm	green	petals white outside, pink inside	—	—
Warush BBAE86	Ecuador	impossible	below middle	no	fruits - peduncles	—	—	—	—	<i>P. riparia</i> or <i>P. ambigua</i> ?
Holm-Nielsen 1040	Ecuador	<i>P. tolimana</i>								
Smith 3157	Guyana	<i>P. laurifolia</i>	apex		bracts - peduncles	3.5 × 2 cm	green	red	two unequal series	fruit with a uniform color, could be <i>P. ambigua</i>
Ancuash 506	Peru	impossible	middle	yes	fruits - peduncles	—	—	—	—	—
Schunke 907	Peru	<i>P. riparia</i>	below middle	yes	?	2.5 × 1.5 cm	reddish	—	one, the outermost being completely atrophied	—
Revilla 241	Peru	<i>P. riparia</i>	below middle	yes	peduncles - bracts - calyx - fruit	2.5 × 1.5 cm	reddish	white	Unequal, the outermost filiform and short, next one thicker and longer	long peduncles
Klug 3897	Peru	<i>P. riparia</i>								
Schunke 3555	Peru	<i>P. riparia</i>	middle	yes	?	1.5 × 1 cm	purple	—	Unequal, the outermost filiform and short, next one thicker and longer	fruit pale green, with white spots
Schunke 3579	Peru	<i>P. riparia</i>	middle	yes	?	2.5 × 1.5 cm	reddish purple	—	one, the outermost being completely atrophied	immature fruits green with white dots
Schunke 2112	Peru	<i>P. riparia</i>	middle	yes	?	3 × 1.5 cm	violet	—	one, the outermost being completely atrophied	—
Holm-Nielsen and Lawesson (1987): <i>P. pargandis</i>										
Hartling 13771	Ecuador	<i>P. riparia</i>	middle	yes	?	3.5-4.5 × 3-4 cm	violet	more or less white	one, the outermost being completely atrophied	inner series of filaments reduced, filaments cross-stripped in white and dark violet
Escobar (1989): <i>P. femandezii</i>										
Fernández Casas 3341	Bolivia	<i>P. riparia</i>	middle	yes	peduncles - bracts - calyx - petioles of pseudonaceme (some trichomes on leaves of pseudonacemes)	2.5 × 1.5 cm	white	white	Unequal, the outermost filiform and short, next one thicker and longer	—

Mato Grosso). They are very similar to Spruce's syntype of *P. riparia*, with the exception of bract color (white vs. reddish in the syntype). As indicated in Sacco's description, the outermost corona filaments are shorter than in the second series. As in three specimens cited in Killip's description, the ovary, peduncles, bracts and petioles of pseudoracemes are pubescent.

In the description of *P. crenata*, Feuillet and Cremers (1984) refer to four herbarium specimens. The holotype (*Feuillet 573*) is similar to specimens of *P. emiliae* with white bracts again. It shows flowers gathered in pseudoracemes; pubescence on the peduncle, calyx, bracts, pseudoraceme petioles; and, contrary to the description of Feuillet and Cremers, two unequal series of filaments, with a shorter outermost series. *Prevost 563* only shows leaves with two glands below the petiole middle and a green fruit with white dots, while *Cremers 4294* and *Grenand 1825* were not available for examination. However, the corresponding localities mentioned in the publication, near the Cacao village and on the Regina road, were prospected. There, we observed several specimens with pink bracts in populations where the white bract phenotype dominates. This situation compares with that observed by Rich Hoyer, whose photographs document such polymorphism in Brazilian populations of *P. riparia* (Figure 1). Our field observations in French Guiana also confirm that *P. crenata* produces pseudo-racemes of flowers with large and pubescent sepals and show that its corona has two series of external filaments of different length, with an outer series that can even be absent (Figure 1 and Table 2). Field measures display a wide variability for quantitative traits in general.

Both specimens mentioned by Holm-Nielsen et al. (1988) in their description of *P. riparia*, *Holm-Nielsen 1040* and *Knapp 6242*, correspond to *P. tolimana*. This species can be easily distinguished from other Andean species of series *Laurifoliae* by its petiole with two glands at apex (or just below), very short and acute bracts, light pink to lilac perianth, two subequal series of corona with very slender filaments, and the innermost series that closes the entrance of the nectary chamber.

Out of the 20 herbarium specimens cited in the description of *P. riparia* by Cervi (1997), nine are misidentified and correspond to other species of series *Laurifoliae* (*Schultes 9900*, *Spruce 1394*, *Spruce 1172*, *Spruce 1394* and *Spruce 3390*, *Allen 3340*, *Jativa 439*, *Holm-Nielsen 1040* and *Smith 3157*), two cannot be identified (*Warush BBAE86*, *Ancuash 506*), as they are reduced to a stem with a few leaves and collected in areas where several closely related species coexist. *Pires 14246*, *Mathias 3982* and *Archer 3309* could not be verified. Contrary to Cervi's description of *P. riparia*, *Ducke 17338*, *Schunke 907*, *Schunke 3576*, *Schunke 2112*, and *Klug 3897* exhibit only one outer series of filaments, the outermost one being completely absent, while *Revilla 241* and *Schunke 3555* show two unequal outer series of filaments (the outermost filiform and short, the second thicker and longer).

On *Harling 13771*, the holotype of *P. pergrandis*, the leaves bear two glands below the middle of petiole. Flowers, surrounded by three violet bracts, are gathered in pseudoracemes. They have a white perianth with one outer series of long filaments (the outermost filaments being vestigial), cross-stripped in white and dark violet. The inner series are reduced (2–3 mm long). The pubescence of the plant could not be observed.

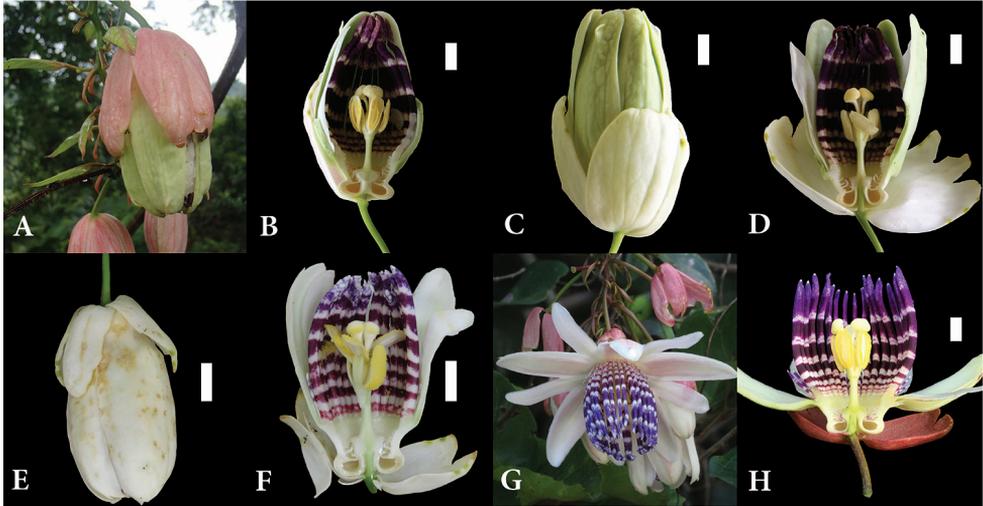


Figure 1. Comparison between flowers of *P. riparia* and *P. crenata*. **A–C** flowers of *P. riparia* from Alta Floresta, Mato Grosso, Brazil (photo: Rich Hoyer) **D** flower of *P. riparia* from Marituba, Para, Brazil (photo: Luis Otavio Adão Teixeira) **E–H** flowers of *P. crenata* from Cacao village, French Guiana. Flower size is indicated by 1 cm white bars.

Thus, *Harling 13771* belongs to *P. riparia*, as assessed from all the traits presented above: submedian petiolar glands, the occurrence of pseudo-racemes, colored bracts, white perianth, and a reduced outermost series of corona filaments.

Wide variation was observed for bract dimensions within the sets of specimens used by the different authors for the different taxa (see also bract size variation within populations in Figure 1), so this variation could not be related to any particular taxon.

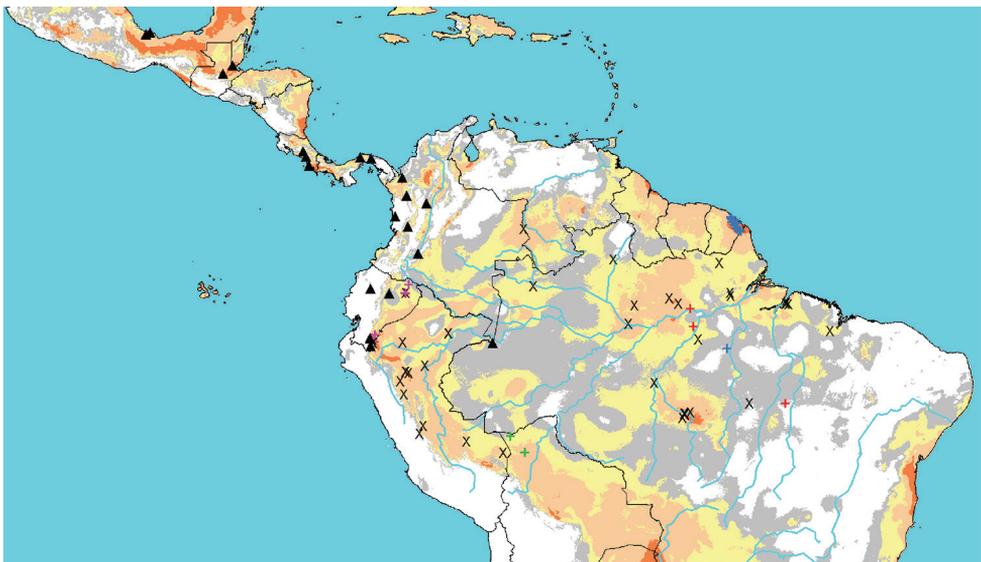
Analysis of distribution

A total of 83 specimens and live populations were georeferenced, 62 for *P. riparia* and its presumed synonyms, and 20 for *P. ambigua* (Table 3). In 59 cases of the former group, label information or precise location allowed inferences on the habitat corresponding to the collection. For their large majority, this habitat appears clearly humid (in the vicinity of flooded areas or water courses; 46 cases), and even frankly riparian in 32 cases (52%). The proportion of riparian collection sites was very similar for *P. riparia* and its four presumed synonyms. In comparison, 22% of examined *P. ambigua* specimens occupy a riparian habitat.

Figure 2 presents the geographic distribution of these collections and the bioclimatic distribution model obtained with the MAXENT software. The predicted range of *P. riparia* and its presumed synonyms includes the Guianas and the basins of the Amazon and southern Orinoco. The examined specimens broadly cover most of this range, except for the western Guianas (Suriname and Guyana) and most

Table 3. Distribution of the georeferenced sample used for Ecological Niche Modeling and habitat information retrieved from voucher labels and aerial photographs (when geographic coordinates are very precise).

Species	Specimens/obs.	Ecological info.	Humid habitat	Riparian habitat
<i>P. riparia</i>	38	35	28	19
<i>P. emiliae</i>	3	3	2	2
<i>P. crenata</i>	12	12	8	5
<i>P. fernandezii</i>	2	2	2	1
<i>P. pergrandis</i>	7	7	6	5
Total	62	59	46	32
<i>P. ambigua</i>	20	18	5	4

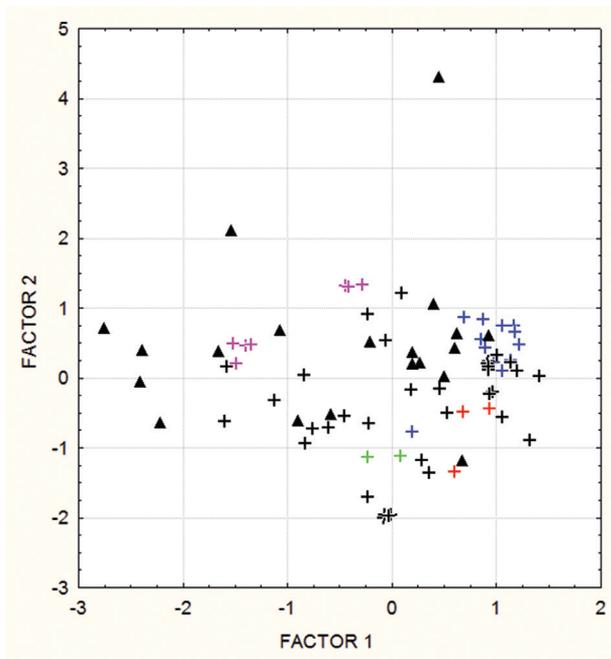
**Figure 2.** Distribution of examined specimens of *P. riparia* (X), *P. emiliae* (red cross), *P. crenata* (blue cross), *P. fernandezii* (green cross), *P. pergrandis* (purple cross), and the bioclimatic distribution model, highlighting climates that are marginal (grey), favorable (light yellow), very favorable (light orange) or excellent (bright orange). Black triangles represent distribution of examined specimens of *P. ambigua*.

of northeastern Bolivia. *Passiflora riparia* has not been reported in regions covered by other great drainage systems, as the Magdalena/Cauca rivers in Colombia and the Paraguay/Paraná rivers in southern Brazil, although the latter seems to offer considerable extensions of favorable habitats. In contrast, *P. ambigua* is mostly present in the smaller drainage systems of the South American and Central American Andes. Only one of the specimens examined for this species was collected in the Amazon basin, near the triple border between Brazil, Peru and Colombia. Thus, the two taxa appear marginally sympatric.

Table 4 and Figure 3 present the result of the PCA on the bioclimatic factors that contribute to the model with useful information that is not present in the other vari-

Table 4. Principal component analysis on the bioclimatic variables contributing to the MAXENT distribution model of *P. riparia*, *P. emiliae*, *P. crenata*, *P. fernandezii*, and *P. pergrandis*. Factor loadings.

Bioclimatic variable	Factor 1	Factor 2	Factor 3
2-Mean diurnal range	-0.45	-0.68	-0.17
5-Max. temp. of warmest month	0.71	-0.48	-0.28
6-Min. temp. of coldest month	0.85	0.33	-0.33
8-Mean temp. of wettest quarter	0.86	-0.12	-0.36
13-Precipitation of wettest month	0.55	0.40	0.63
14-Precipitation of driest month	-0.26	0.85	-0.33
15-Precipitation seasonality	0.51	-0.56	0.61
18-Precipitation of warmest quarter	-0.35	0.57	0.21
19-Precipitation of coldest quarter	0.52	0.67	0.09
Explained variance	3.19	2.80	1.28
Proportion of total	0.35	0.31	0.14

**Figure 3.** Representation of the climatic envelopes of *P. riparia* and its presumed synonyms in the principal plane of the PCA (same color code as for Figure 2). *Passiflora ambigua* collections are represented by black triangles.

ables, according to the MAXENT jackknife test. Figure 3 presents the dispersion of the examined specimens in the principal plane, where factor 1 is more positively correlated with temperatures and factor 2 with precipitations (Table 4). The parallelism between the climatic and geographic spaces suggests that the climatic parameters that affect *P. riparia* and its presumed synonyms vary rather regularly across Amazonia. Thus, at first

sight, *P. crenata* and *P. pergrandis* may appear relatively marginal, in both the geographical and climatic distributions. However, there is a clear continuity in the environmental space, and, compared to *P. riparia* specimens, these two taxa present no exceptional values in the bioclimatic principal plane. The bioclimatic envelope of *P. ambigua* appears much wider than that of *P. riparia* and its presumed synonyms. On one hand, it encompasses most of the *P. riparia* envelope, presenting very similar characteristics for precipitation, except for an outlier that corresponds to a specimen collected in the extreme conditions of the Colombian Chocó, under ca. 7 m annual rainfall. On the other hand it extends to habitats with cooler temperatures (to the left of the principal plane), which correspond to collecting sites at elevations above 1000 m in the Andes.

Discussion

Most of the confusion in the definition of *P. riparia* has arisen from the incomplete description by Masters (1872), in the very difficult context of the highly uniform series *Laurifoliae*, and from the mention of two equal series of outer corona filaments by Killip (1938), which was reproduced in the following descriptions of Cervi (1997) and Tillett (2003) (although the latter mentioned the occasional loss of the outermost series). This ‘two equal outer series’ problem originated from the ambiguous iconography accompanying the description of Masters (1872), which is inconsistent with the syntype *Spruce 2191*, and all other interpretable specimens mentioned in the literature. Indeed, our study of the specimens examined by Killip (1938) and Cervi (1997) shows that, whenever the relative length of outer corona filaments is observable, i.e. in 12 of them, their outer series is reduced, or even absent in nine of them. This clearly indicates that Killip (1938) and Cervi (1997) had not observed themselves the combination of two equal series of outer filaments with multiple series of very short inner filaments and other typical traits as white to red bracts and white corollas.

In 1966, Sacco realized the inconsistency between Killip’s description of *P. riparia* and two Kuhlmann specimens of this species where he could observe the reduction of the outermost series of filaments. But he used them as types for the description of a new species, *P. emiliae*, logically differentiated from *P. riparia* by the outer corona structure. It seems that this new species description remained confidential and only attracted the attention of Cervi, who reclassified a few other exemplars from *P. riparia* to *P. emiliae*, such as *Ducke 21311*, *Kuhlmann sn (R136313)*. Later, in 1997, he changed his mind and followed Holm-Nielsen et al. (1988) in considering it a synonym of *P. ambigua*. Table 1 shows that the description of *P. emiliae* only differs from those of *P. riparia* by the pubescence of the flower; however, this trait is also found in many examined specimens of *P. riparia*, including the syntypes (Table 2), as well as in the other presumed synonyms, *P. crenata*, *P. fernandezii* and *P. pergrandis*.

Originally, *P. crenata* was described as an endemic of French Guiana, distinguished from *P. riparia* by its white bracts and the type of inflorescence. However, bract color at anthesis varies between white and deep red in populations from French Guiana and from Brazil (Figure 1, Table 2) and the type specimens of *P. emiliae* also present white

bracts. In the examined specimens from Ecuador and Peru, bract color varied from red to purple and violet. The presence of single axillary flowers or of pseudoracemes is also a variable trait, even at the intra-individual level, as noted in the descriptions of *P. riparia* by Tillett (2003), *P. emiliae* by Sacco (1966), and observed by ourselves in *P. crenata*. Furthermore, other species of series *Laurifoliae* present both solitary flowers and pseudoracemes, as *P. ambigua*, *P. popenovii* Killip, *P. gabrielliana* Vanderpl., *P. caparidifolia* Killip, *P. killipiana* Cuatrec., *P. pbellos* Feuillet, *P. laurifolia*. Thus, no traits allow distinguishing *P. crenata* from *P. riparia* and *P. emiliae*.

The two more recent descriptions of *P. pergrandis* and *P. fernandezii* did not present new variations in any of the characters discussed above. Finally, we can conclude that the differences in the descriptions of *P. riparia*, *P. emiliae*, *P. crenata*, *P. pergrandis* and *P. fernandezii* are either related to the confusion introduced by the iconography associated with the original description or with the imprecisions related to the initial observation of two dry specimens. More details and variation have logically been documented after the examination of specimens from a wider geographic range, as well as the direct observations on living materials. The variations observed among specimens of *P. riparia* encompass the variations between this taxon on one hand and *P. crenata*, *P. emiliae*, *P. fernandezii* or *P. pergrandis* on the other hand. Furthermore, most specimens from the latter taxa have been collected under very similar habitats, dominated by lowland tropical climates in riparian habitats (Table 3, Figure 3), further justifying their placement as synonyms of *P. riparia*. Only the description of *P. riparia* in the Flora of Ecuador is clearly different, as it includes the mention of a lilac corolla, two extremely long series of outer filaments and the presence of an inner series of 1 cm erect filaments, a trait combination indicating that Holm-Nielsen et al. (1988) described *P. tolimana* instead of *P. riparia*.

Passiflora ambigua appears very similar to *P. riparia*, mostly differing in the color of bracts (green) and the corolla (lilac), but its distribution and ecology are different, with a much lesser frequency of riparian habitats and a capacity to thrive at much higher elevations, up to hillsides in the Andes of tropical South America and Central America.

Gathering *P. riparia*, *P. crenata*, *P. emiliae*, *P. fernandezii* and *P. pergrandis* into a single species imposes a new description, taking into account the reduction of the outermost series of corona filaments and variation observed in other traits, on our whole sample. In the following treatment, the lectotype and isotype chosen by Lawesson are logically retained, however, as its damaged flowers do not allow the observation of the corona structure, we choose as epitype the syntype *Spruce 2191*, i.e., the much better-preserved specimen that was observed by Masters for the original description.

Taxonomic treatment

***Passiflora riparia* Mart. ex Mast. in Martius, Fl. Bras. 13(1): 599. 1872**

Passiflora emiliae Sacco, Boletim do Museu Nacional de Rio de Janeiro. Botanica 32: 1–5. 1966. Type: Brazil. Mato Grosso, Rio Arinos, Dec. 1914, *Kuhlmann 1066* (holotype, R!), *Kuhlmann 1064* (paratype, R!).

Passiflora crenata Feuillet & Cremers, Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series C: Biological and Medical Sciences 87(4): 378. 1984. Type: French Guiana. Road between Roura and the Kaw mountain, 24 Jan. 1983, *Feuillet 573* (holotype, CAY!; isotype, BR, P!, U, US).

Passiflora pergrandis Holm-Nielsen & Lawesson, Annals of the Missouri Botanical Garden 74(3): 501, f. 4. 1987. Type: Ecuador. Zamora-Chinchipe: Zamora –Gualaquiza road, 5 km N of Cumbaraza, 900 m, 20 Apr. 1974, *Harling 13771* (holotype, GB!; isotype, AAU)

Passiflora fernandezii L. K. Escobar, Phytologia 66(1): 80–81. 1989. Type: Bolivia. Pando: Nicolas Suarez: between Porvenir and Cachuelita, along the trail, 19 Jan 1983, *F. Javier Fernández Casas 8341* (holotype, NY; isotypes, MO!, NY).

Type. Brazil. Forest near mouth of Madeira River, Brazilian state of Amazonas (in silvis prope ostium fluvii “Madeira”), March 1819, *Martius 3228* (lectotype, M! designated by Holm-Nielsen et al. (1988); isotype, M!). São Gabriel da Cachoeira, Amazonas, April 1852, *Spruce 2191* (epitype, P!, isoepitypes M!, K!, designated here).

Woody liana. Stem terete to subangulate, glabrous to slightly pubescent (on young parts or pseudoracemes), and green; internodes 4–48 cm. Tendrils glabrous, green. Stipules setaceous to narrow linear, generally aristate, yellow green to brown purple, eglandular to glandular (1–2 nectaries), 8.8–18.1 × 0.2–1.4 mm (including an arista 0–2.7 mm), early deciduous. Petiole 1.3–3.8 cm long, green to dark green, slightly canaliculate adaxially, glabrous (pubescent on pseudoracemes), bearing two conspicuous oval sessile glands (about 1 mm long), at or below the middle (0.4–1.3 cm from petiole base). Leaves simple, unlobed, 10.5–21 × 5.5–11 cm, glabrous throughout, green to dark green, adaxial surface lustrous, cordate to rounded at base, obtuse to acute at apex, mucronate and acuminate; margin entire (rarely glandular-serrulate). Inflorescence axillary, sessile, 1-flowered. Peduncles terete, green, pubescent, 1.9–2.8 mm in diameter, 1.4–3.5 cm long; pedicel 6.5–10 mm long. Bracts deciduous (at fruit maturity), pubescent on both sides, white to dark purple or white and more or less pink-purple veined, concave, free to base, 2.5–6.2 × 1.4–4.3 cm, with 3–7 marginal sessile green nectaries in distal half. Flowers axillary, pendulous, 2.8–3.4 cm long (from the base of nectary chamber to the ovary apex), solitary or presented in clusters on pseudoracemes (short internode branches). Nectary chamber pubescent externally, white greenish outside and white inside, 14.8–20.3 mm in diameter, 4.5–11.9 mm in depth. Hypanthium campanulate, pubescent, white greenish outside and white inside, 15–20 mm long and 18–21 mm in diameter at the base of sepals. Sepals pubescent, oblate, 4.2–6.4 × 1.8–2.8 cm, adaxial surface white to slightly pink, abaxial surface white to white greenish, slightly keel-shaped in distal half with a short awn (3–5 mm long). Petals glabrous, oblate, 4.2–5.4 × 1.2–1.6 cm, white. Corona filaments in 6–9 series, banded white and purple to dark purple; two major outer series, slightly curved, unequal: outer series 0–18 mm, second series 43.9–55.4 mm; inner series 1–2 mm, curved filiform, white with purple tip, covering the interior of the hypanthium. Staminal filaments 8–11 mm long, white greenish. Ovary pubescent, white, 8–9 mm long; three styles, white, 9–12 mm long, stigmas white to cream. Androgynophore glabrous, greenish white, 14–17 mm long

with an enlarged base about 10 mm wide. Operculum membranous, 4–5 mm long, recurved, shortly fimbriated at margin. Fruit obovoid, round in transversal section, pubescent, 3.6–7.3 cm long, about 2.5–4.8 cm in diameter; pericarp 0.5–1 cm thick; immature fruits green with fine white dots; mature fruits light orange, white spotted, with a sweet translucent pulp. Seeds obovoid, flat, with retuse apex, about 1 cm long.

Conclusion

Following our morphological and ecological analyses, *P. emiliae*, *P. pergrandis*, *P. fernandezii* and *P. crenata* are placed as synonyms of *P. riparia*, which reduces the current number of species belonging to series *Laurifoliae* to 21. Like *Passiflora nitida*, *P. laurifolia* or *P. ambigua*, *P. riparia* is a new example of a very widely distributed species in this series. In fact, its variability appears relatively limited in the context of its wide distribution.

The description of *P. riparia* in the Flora of Ecuador corresponds to *P. tolimana*; *Holm-Nielsen 1040* and *Knapp 6242* are the only known specimens from Ecuador for this species, hitherto considered endemic to Colombia. The determination of *Spruce 2191* under *P. ambigua* by Lawesson, endorsed by Holm-Nielsen et al. (1988), cannot be accepted, given that this specimen has white petals and sepals (vs. red to purple in *P. ambigua*).

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Appendix

Examined specimens

P. ambigua

BRAZIL. Amazonas: Esperança, mouth of Javari River, non-flood forest, 4-2-1942, *Ducke* 878 (MO). **COLOMBIA. Antioquia:** San Luis, 26 Jul. 1981, *Hoyos* 132 (JAUM). Municipality of Frontino, Las Orquídeas National Park, 31 Jan. 1995, *Pipoly* 18177 (JAUM). Municipality of Turbo, road of Tapón del Darién, 28 Feb. 1984,

Brand 947 (JAUM). **Chocó:** area of Baudó, 4 Feb. 1967, *Fuchs 21744* (COL). **Huila:** Municipality of Gigante, farm of Adonai Moreno, 20 Dec. 1976, *Escobar 435* (MO). **Meta:** Río Bravo village, La Cristalina stream, El Pital, 4 Mar. 1986, *Devia 1121* (MO). **COSTA RICA. Puntarenas:** Osa Península, 6 Jan. 1994, *Aguilar 2974* (CR). **Cartago:** Orosi, Navarro del Muñeco, 12 Apr. 1998, *Blanco 805* (USJ). **San José:** Vicinity of El General, Jan. 1939, *Skutch 3037* (US). **ECUADOR. Esmeraldas:** El Timbre, near Esmeraldas, 6 Aug. 1962, *Jativa 439* (US). **Napo:** Road Hollín-Loreto-Coca, Chaluayacu Community, 23 Dec. 1988, *Cerón 5772* (MO). **Pichincha:** Alluriquin, 19 Oct. 1921, *Werling 458* (QCA). **Zamora-Chinchipec:** Municipality of Zamora, Road Zamora-Loja, 29 Oct. 1991, *Palacios 8811* (MO). Palanda, Río Vergel Valley, 14 Nov. 2006, *Werff 22075* (MO). **GUATEMALA. Secanquim,** 14 May 1914, *Cook 79* (US). **HONDURAS. Machaca,** 8 Feb. 1934, *Schipp 1302* (F). **MEXICO. Veracruz:** Biological station of Los Tuxtlas, 7 Apr. 1971, *Calzada 230* (MEXU). Municipality of San Andrés Tuxtla, south of Ebitrolotu, 30 Apr. 1973, *Villegas Herrera 112* (MEXU). **PANAMA. Colón:** Santa Rita Ridge, east of transisthmian highway, 16 Dec. 1972, *Gentry 6561* (MO). **Panamá:** just before la Eneida along new trail which begins exactly beside López House, 8 March 1968, *Correa 825* (PMA). El Llano-Carti Road, 18 Apr. 1981, *Sytsma 4027* (MO). **PERU. Loreto:** Maynas, near Iquitos, in 1996, *Grandez 7837* (MO).

P. laurifolia

BRAZIL. Bahia: Barra, *Spruce 1394* (P). **Pará:** Santarem, 19 Jan. 1934, *Swallen 3309* (US). **COLOMBIA. Vaupés:** Vicinity of Mitú, Río Vaupés, 22 Feb. 1945, *Allen 3340* (US). **GUYANA. Western extremity of Kanuku Mountains,** in drainage of Takutu River, 4 March 1938, *Smith 3157* (U).

P. phellos

BRAZIL. Amazonas: Uanadona, near mouth of Río Dimiti, 10 May 1948, *Schultes 9900* (K). **VENEZUELA. Río Pacimini,** Feb. 1854, *Spruce 3390* (K).

P. riparia

BOLIVIA. La Paz: Prov. Iturrealde, Siete Cielos, Río Manupare, 4 June 1987, *Solomon 16923* (MO). **BRAZIL. Acre:** Municipality of Plácido de Castro, Río Abunã, 10 Jan. 1995, *Figueiredo 506* (NY). **Amapá:** National park of Tumucumaque, Río Jari, 21 Feb. 2013, *Hopkins 2284* (INPA). Municipality of Monção, basin of the Río Turiaçu, Ka'apor Indian Reserve, 12 Feb. 1985, *Balée 794* (MO), *Balée 810* (MO). Amazonas: Presidente Figueredo, Nazaré locality, Río Uatumã between Río Pitinga and Río Uatumã, 18 March 1986, *Ferreira 6808* (NY). **Amazonas:** Mouth of Río Madeira, *Martius 3228* (M). São Gabriel da Cachoeira near the Río Negro, Apr. 1852, *Spruce 2191* (P). **Pará:** Ruropolis Presidente Medici, 9 Feb. 1976, *Bamps 5341* (K). Municipality of

Almeirim, Mte. Dourado, road Mte Dourado-Munguba, 10 Feb. 1986, *Pires* 784 (INPA), Mt. Dourado, 20 June 1988, *Pires* 2227 (NY). Banks of Rio São Manoel, 14 Jan. 1952, *Pires* 3931. Belem, 29 Dec. 1922, *Ducke* 17338 (US). Rio Xingu, Island of Piracui, 22 Oct. 1986, *Souza* 449. **Goias:** ca. 2 km S. of Guar, 19 March 1968, *Irwin* 21451 (NY). **Mato Grosso:** Rio Arinos, Dec. 1914, *Kuhlmann* 1066 (R), *Kuhlmann* 1064 (R). Novo Mundo, Forest Reserve of Rio Cristalino, 11 Feb. 2008, *Zappi* 1194, margin of Rio Cristalino, 29 Nov. 1996, *Dubs* 2335 (K). Alta floresta, private property of environmental preservation, 10 Nov. 2006, *Sasaki* 1087 (K), 13 Dec. 2006, *Sasaki* 1199 (INPA), 23 Jan. 2007, *Sasaki* 1390 (INPA). **COLOMBIA. Guaina:** confluence of Ros Guaviare, Atabapo and Inirida, 23 Aug. 1975, *Garca-Barriga* 20929 (COL). **ECUADOR. Sucumbios:** Cuyabena faunistic reserve, Rio Cuyabeno from outlet of Laguna Grande and 5 km upstream, 2 Apr. 1989, *Balslev* 84715 (QCA). **Orellana:** National park Yasun, south of Ro Napo, 31 Jan. 1998, *Burnham* 1628 (QCA), Ro Tivacuno, 0.5 km upstream of confluence with Ro Tiputini, 24 March 1998, *Burnham* 1690 (QCNE). National Park Yasun, 16 Feb. 2002, *Perez* 392 (QCA). **Zamora-Chinchipe:** Road Zamora-Gualaquiza, ca 5 km north of Cumaraza, 20 Apr. 1974, *Harling* 13771 (GB). Nangaritza, Ro Tzenganga, 6 June 2005, *Quizhpe* 1201 (MO). Hill about 2 km downstream from Campamento Shaime along Ro Nangaritza, 15 Feb. 1994, *Werff* 13084 (QCNE). **FRENCH GUIANA.** Road to Montsinery, 7 March 2017, *Rome* 567 (P). Road between Cayenne and Cacao, 25 Feb. 2017, *Rome* 559 (P). Road to Rgina, 17 May 2008, *Rome* 118 (LYJB), *Rome* 119 (LYJB), *Rome* 120 (LYJB), *Rome* 121 (LYJB), *Rome* 122 (LYJB). Road between Rgina and St Georges, 10 Apr. 2008, *Rome* 45 (LYJB), 19 May 2008, *Rome* 129 (LYJB), *Rome* 136 (LYJB), *Rome* 138 (LYJB), *Rome* 142 (LYJB). Road of Kaw Mountain, 24 Nov. 2009, *Rome* 201 (LYJB), *Rome* 202 (LYJB), 29 Jan. 2013, *Rome* 400 (LYJB). Road to Tonnegrande, 30 Jan. 2013, *Rome* 405 (LYJB), *Rome* 406 (LYJB), *Rome* 407 (LYJB), *Rome* 408 (LYJB), *Rome* 409 (LYJB). Kotika mount, 21 Feb. 2005, *Granville (de)* 16896 (CAY). Municipality of Saint-Georges, Oyapock basin, 15 Aug. 1997, *Berton* 250 (CAY). Kamuyene Kamuyene, 12 Apr. 2005, *Bourdy* 3128 (CAY). Road of Kaw mountain, 24 Jan. 1983, *Feuillet* 573 (CAY), 1 Jan. 1986, *Feuillet* 2975 (CAY), 25 Aug. 2009, *Feuillet* 17078 (CAY). Path between Roura and the Gabrielle Creek, 21 Apr. 1979, *Prevost* 563 (CAY). Road to Rgina, near Camp Hervo, 14 March 2009, *Vanderplanck* 1605 (CAY). **PERU. Hunuco:** Prov. Pachitea, region of Pucallpa, western part of the “Sira montains” and adjacent lowland, 31 July 1988, *Wallnofer* 12-31788 (MO). Along Ro Pachitea, 12 July 1967, *Schunke* 2112 (US). **Junn:** Chanchamayo prov., El Bocaz, 20 Nov. 1982, *Vargas* 64 (USM). **Loreto:** in lower forest at Neshuya, 2 Oct. 1965, *Schunke* 907 (US). **Madre de Dios:** National Park Manu, Ro Manu, 1 Oct. 1986, *Foster* 11539 (F), *Foster* 11558 (F). Tambopata prov., Las Piedras, Cusco Amaznico, 7 Oct. 1991, *Timan* 2457 (MO). **San Martn:** Mariscal Cceres, mouth of Ro To-cache, 6 Nov. 1969, *Schunke* 3579 (US). San Martn, Boca Toma del Shicayo, N of Tarapoto along Ro Shilcayo, 27 May 1986, *Alcorn* 10 (MO). Juan Jui, Alto Ro Hual-laga, Oct. 1934, *Klug* 3897 (MO). Chazuta, Ro Huallaga, March 1935, *Klug* 4037 (K). Mariscal Cceres, Canyon of Huaquisha, right margin of Ro Huallaga, 30 June

1974, *Schunke* 7083 (MO). **Amazonas:** between Uchpayaco and Rimachi, banks of Río Pastaza, 30 July 1979, *Díaz* 1283 (MO). **Pasco:** Oxapampa, Puerto Bermúdez, 14 July 1929, *Killip* 26683 (US). Oxapampa, ca. 1 km from division of Villa Rica-Pto. Bermúdez road and Villa Rica-Palcazu road, on Palcazu branch, 15 Aug. 1984, *Knapp* 6633 (MO). **Loreto:** Maynas, Iquitos, July 1929, *Williams* 1440 (US), March 1930, *Williams* 7996 (US). Yurimaguas, lower Río Huallaga, March 1930, *Williams* 7876 (US). Maynas, district of Iquitos, Caserío, 25 Feb. 1976, *Revilla* 241 (MO), Río Nanay near Astoria, 15 March 1973, *Rimachi* 126 (USM). Tarapoto, Nov. 1902, *Ule* 6547 (K). **Ucayali:** Pucapanga, margin of Río Ucayali, 20 Aug. 1965, *Sagástegui* 5739 (HUT). **SURINAME.** Sipaliwini, vicinity of airstrip along Ulemari river, 1 May 1998, *Evans* 2971 (MO).

P. sp. (impossible or doubtful identification)

BRAZIL. Amazonas: Lake of Aleixo, in riparian forest, 3 Apr. 1932, *Ducke* 24044 (US). Bahia, Barra, March 1851, *Spruce* 1172 (P). **ECUADOR. Morona Santiago:** Shuar Pampants center, 10 Sept. 1986, *Warush RBAE86* (QCNE). **PERU. Amazonas:** Río Cenepa, 2 June 1973, *Ancuash* 506 (US). **Junín:** Junín, Puerto Yesup, 10 July 1929, *Killip* 26307 (US). **Loreto:** Alto Amazonas, Yurimaguas, lower Río Huallaga, 22 Aug. 1929, *Killip* 28214 (US). Near Iquitos, July 1929, *Williams* 1392 (US). La Victoria on the Amazon River, Aug. 1929, *Williams* 3126 (US). Santa Rosa, Lower Río Huallaga below Yurimaguas, 1 sept. 1929, *Killip* 28940 (US). Wooded banks of lower Río Huallaga, 5 Sept. 1929, *Killip* 29012 (US). **San Martín:** Alto Río Huallaga, Dec. 1929, *Williams* 6300 (US). Tarapoto, Alto Río Huallaga, Dec. 1929, *Williams* 5848 (F).

P. tolimana

ECUADOR. Napo: 2 km W of Archidonia, 27 June 1968, *Holm-Nielsen* 1040 (AAU). **Morona-Santiago:** ca. 32.5 km S. of Gualaquiza on road to Zamora, 4 Feb. 1984, *Knapp* 6242 (US).

P. venusta

PERU. San Martín: Lamas, Dec. 1929, *Williams* 6378 (US). Tarapoto, Alto Río Huallaga, Dec. 1929, *Williams* 5637 (F).

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Senyumia granitica (Gesneriaceae) from Johor, Malaysia, the second species of *Senyumia*

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Abstract

The genus *Senyumia* was previously known from a single species, *S. minutiflora* (Ridl.) Kiew, A. Weber & B.L. Burtt, from a limestone karst, Gunung Senyum, in Pahang, Malaysia. *Senyumia granitica* Kiew, here described and illustrated, is the second species of the genus. It differs from *S. minutiflora*, not only in its habitat, but also in its shorter leaves, larger, non-resupinate or only partially resupinate flowers and smaller seeds. It is known from a small, fragmented population from a low range of hills. Therefore, under the IUCN Red List Categories & Criteria, it is assessed as Critically Endangered.

Keywords

New species, *Senyumia granitica*, *Senyumia minutiflora*, ecology, conservation

Introduction

While investigating the granite cliffs of Bukit Belading in Johor State, the site at which the new species of cycad, *Cycas cantafolia* Jutta, K.L. Chew & Saw, has recently been discovered (Jutta et al. 2010), an unusual species of Gesneriaceae was found that did not match any known species. However, it was clearly closely similar morphologically to *Senyumia minutiflora* (Ridl.) Kiew, A. Weber & B.L. Burtt in habit, leaf shape, texture and indumentum, white flowers and twisted fruits, but it differs in its larger flowers that are not or are only partially resupinate. *Senyumia minutiflora* is unique amongst Peninsular Malaysian and indeed amongst Asian gesneriads in its resupinate flowers. Previous to this discovery, *Senyumia* was a monotypic genus, its single species being known from Gunung Senyum, Pahang, an isolated limestone karst hill. With

the discovery of this new species, the resupinate flower can no longer be considered a diagnostic character for the genus.

Morphologically, the genus *Senyumia* Kiew, A.Weber & B.L.Burtt most resembles another Malaysian monotypic genus, *Spelaeanthus* Kiew, A.Weber & B.L.Burtt, that is restricted to karst limestone (Kiew et al. 1998). They share thin, pale green leaves with a toothed margin, small, white flowers and short (less than 10 mm long), twisted capsules. Molecular analysis also places *Senyumia* in a well-supported subclade together with *Spelaeanthus* and the Australian species of *Boea* Lam. (Puglisi et al. 2016). *Senyumia* is distinct from *Spelaeanthus* in its larger leaves, corolla that has a very short, straight-sided, slightly dilating tube and the lobes that are in the upper position being strongly reflexed, the anthers are large and project beyond the corolla tube and the capsule that is distinctly twisted. In contrast, *Spelaeanthus* (represented by a single species, *S. chinii* Kiew, A.Weber & B.L.Burtt), has smaller leaves, a corolla with a longer, broadly inflated tube, the upper lobes are not reflexed, the stamens are included within the corolla tube and the capsule is scarcely twisted. On-going molecular work confirms that this new taxon from Johor belongs to *Senyumia* and is distinct from *Senyumia minutiflora* (C. Puglisi, pers. comm.).

The absence of a nectary and the short corolla tube with large protruding anthers are characters of a pollen flower (Weber 2004). Ong Poh-Teck, Forest Research Institute Malaysia, observed the stingless bee, *Trigona laeviceps* Smith, visiting flowers of *Senyumia minutiflora* and collecting pollen (Fig. 1J). Weber (2004) suggested that extremely small flowers and the production of plentiful capsules and seeds in the wild, as is the case in *Senyumia minutiflora*, may be indicative of autogamy. However, in the Herbarium Nursery at the Forest Research Institute Malaysia, plants grown in an enclosure where insects were excluded, regularly flowered but did not produce fruits (P.T. Ong, pers. comm.) but neither did those flowers visited by the trigona bees that were grown outside the enclosure, suggesting that the trigona bees were pollen thieves rather than pollinators. The role of the resupinate position in *S. minutiflora* is not understood but the three larger basal lobes raised above the flower may serve to make the minute flower more conspicuous to the pollinator (Fig. 1F). The resupinate position does not appear to play a role in access to the flower by the pollinator because the fine pedicel does not support the weight of an insect like trigona. The flower is in a hanging position as the insect removes the pollen (Fig. 1J). However, the great difference in corolla size between the two species suggests that different pollinators are probably involved and the degrees of resupination may be an adaptation to these different pollinators.

Methods

Materials used for the description of the new species are based on living collections grown in the Herbarium Nursery at the Forest Research Institute Malaysia. However, measurements were made on dried herbarium specimens. Characters of the new species were compared with those of herbarium specimens of similar species in BM,

E, K, KEP, KLU, SING and UKMB (herbarium codes from *Index Herbariorum* at <http://sweetgum.nybg.org/ih>) and living specimens of the new species, *Senyumia minutiflora* and *Spelaeanthus chinii*. The conservation status of the new species is assessed by the Malaysian regional evaluator, LSL Chua, Forest Research Institute Malaysia, using the standard IUCN Categories and Criteria (IUCN 2012).

Taxonomy

Senyumia Kiew, A. Weber & B.L. Burtt.

Senyumia Kiew, A. Weber & B.L. Burtt. Beitr. Biol. Pflanzen 70 (1998 [1997]) 400; Weber, Fam. & Gen. Vasc. Pl. 7 (2004) 148.

Type species. *Senyumia minutiflora* (Ridl.) Kiew, A. Weber & B.L. Burtt.

Revised generic description. Short herb. **Stem** wiry, woody, to 20 cm long, 4–5 mm diameter, with a terminal rosette of many leaves. Indumentum pilose, of dense, long uniseriate hairs, intermingled with glandular hairs that make the lamina sticky to touch. **Leaves** opposite; petiole long, slender; lamina very thin, membranous, soft, pale green, broadly lanceolate to elliptic, 4–15 × 4–7.5 cm, margin toothed, teeth blunt, base not cordate, often unequal; veins 6–8 pairs. Inflorescences axillary, pair-flowered dichasial cymes, 9–17 cm long; pedicels very fine, 9–11 mm long. **Flowers** small; calyx divided to base into five narrowly lanceolate lobes, 1.5–2 mm long; corolla white, sometimes tinged pink, tube very short, straight-sided, slightly dilating, 1.2–3 mm long, limb bilabiate, lobes in upper position densely studded with short glandular hairs internally, in non- or partially resupinate flowers, two lobes of the upper lip are strongly reflexed, in resupinate flowers, the lower three lobes held in the upper position are strongly reflexed; stamens 2, anthers large, 1.5–2 mm long, ellipsoid, cohering, yellow, exerted; nectary absent; ovary small, 2–3 mm long, ovoid; style 2–5 mm long, protruding; stigma punctiform. **Capsules** orthocarpic, 4–10 mm long, glabrous, strongly twisted, opening on the dorsal and ventral sides, valves becoming spiral after dehiscence. **Seeds** numerous, minute, 104–117 × 29–31 µm or 350 × 210 µm.

Distribution. Two species, both endemic in Peninsular Malaysia.

Ecology. Lithophytic, growing in cracks and crevices in light shade either on quartz derived from granite or on limestone rocks.

Senyumia granitica Kiew, sp. nov.

urn:lsid:ipni.org:names:60478018-2

Figure 1

Diagnosis. This new taxon resembles *Senyumia minutiflora* in its wiry, woody stem; tufted leaves with an elliptic lamina with a non-cordate base; small, white flowers and

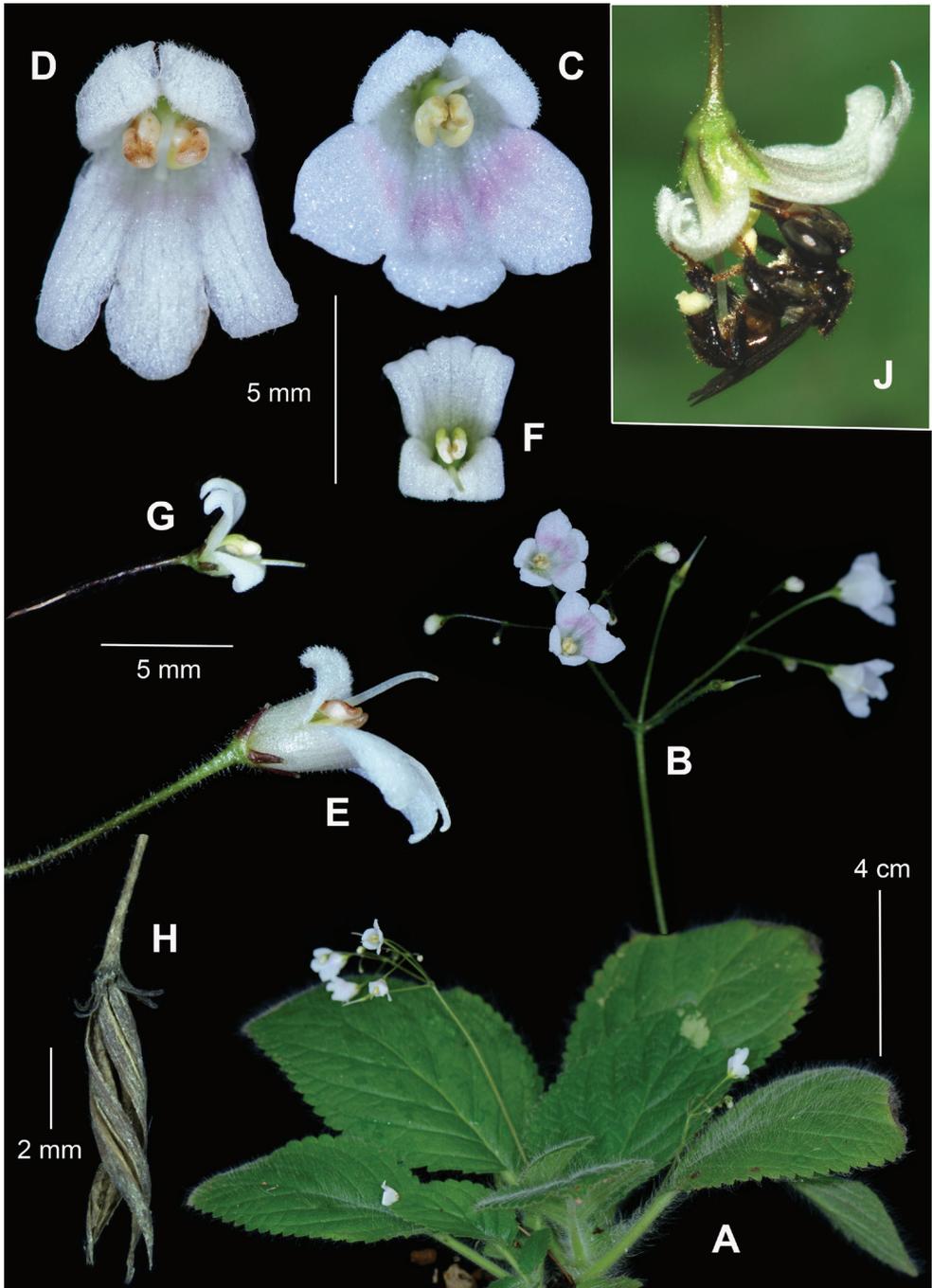


Figure 1. *Senyumia granitica* Kiew, sp. nov. **A** habit **B** Inflorescence showing partially resupinate flower **C** front view of a flower from Bukit Tukai population **D** front view of a flower from Bukit Reban Kambing population **E** side view of **D**; *Senyumia minutiflora* (Ridl.) Kiew et al. **F** resupinate flower **G** side view of flower (upside down for comparison with **E**) **H** fruit of *S. granitica* **J** *Trigona laeviceps* on *S. minutiflora*, note full pollen baskets. (photographs by PT Ong).

orthocarpic, strongly twisted capsule. However, the new species differs from *Senyumia minutiflora* in its shorter leaves that are less than 1.5 times longer than wide, flowers that are not resupinate or are partially resupinate, have a longer corolla tube and lobes of the lower lip that are flat and not reflexed and the much smaller seeds (Table 1).

Type. Peninsular Malaysia. Johor, Ledang District, Bukit Tukau, 10 Dec 2009, *Lau KH et al. FRI 68518* (holotype KEP!; iso.: K!, L!).

Description. Perennial herb. Stem wiry, woody, ca. 4–12 cm tall, erect, 3.5–5 mm diameter. Indumentum densely woolly with long soft uniseriate, whitish hairs, dense on petiole, on lamina on upper surface and veins on lower surface, ca. 2 mm long interspersed with glandular hairs, lamina sticky to touch. **Leaves** opposite pairs spaced up to 6.5–8 cm apart; petiole fleshy, densely hairy, hairs 2–6 mm long, pale green, ca. 2 cm long in upper leaves, lengthening in lower leaves to 10.5 cm long; lamina broadly lanceolate to ovate, 4–6(–10) × (3–)7–7.5 cm, in life soft, light green above with long hairs ca. 2 mm long interspersed with glandular hairs, making the lamina sticky to touch, whitish-green beneath, base rounded, slightly to strongly unequal, apex acute, margin deeply crenate or serrate, teeth ca. 3 × 4 mm, to rounded to acute, tipped by a hair; lateral veins 6–8 pairs, deeply impressed above, prominent beneath and covered in long hairs ca. 2 mm long interspersed with glandular hairs, intercostal veins scalariform, ascending. **Inflorescences** 5–12(–17) cm long, with wispy long glandular hairs, a pair-flowered dichasium three times branched with 6–10 to many flowers; peduncle 3–9 cm, lateral branches short 1–2 cm long; pedicels erect, very fine, 8–13 mm long. **Flowers** not resupinate or partially resupinate; sepals pale green, divided almost to base, narrowly lanceolate, ca. 2 × 0.75 mm, densely glandular hairy, hairs ca. 0.5 mm long; corolla pure white, scintillating, sometimes tinged pink, ca. 7–13 mm long, outside with minute glandular hairs, tube short, not pouched, 2–3 × 2.5–4 mm, upper lip 2-lobed, 2–4 × 2.5 mm, erect, margin strongly reflexed, inner surface densely studded with short glandular hairs; lower lip glabrous, flat (not recurved) with 3 more-or-less isomorphic lobes, either lip more-or-less longer than broad, 5–9 × 6–7 mm with oblong lobes (Bukit Reban Kambing population, Fig. 1D, E) or broader than long, 4–7 × 6.5–8 mm and lobes rounded (Bukit Tukau population, Fig. 1B, C); stamens 2, filaments white, sinuous, 2–3 mm long; anthers large, pale yellow, 1.5–2 × 0.5 mm, cohering, protruding ca. 1.5 mm beyond the corolla tube; nectary absent; ovary pale green, glabrous, 2–3 × 1 mm; style white 2–5 mm, projecting beyond the corolla tube; stigma punctiform. Infructescence curling and positioned below the leaves. **Capsules** strongly twisted, 4–7.5(–10) mm long, ca. 1.5 mm diameter. **Seeds** numerous, minute, 80–117 × 29–31 µm.

Distribution. Peninsular Malaysia, Johor, Ledang District, endemic on Bukit Reban Kambing and Bukit Tukau, on an isolated low range of granite hills from 200–500 m elevation, west of the southern tip of Gunung Ledang (formerly known as Mt Ophir).

Etymology. From its habitat, it grows in cracks in quartz rocks derived from the granite bedrock, in contrast to *Senyumia minutiflora* that is restricted to growing on limestone rocks.

Table 1. Characters that distinguish *Senyumia granitica* from *S. minutiflora*.

Character state	<i>S. granitica</i>	<i>S. minutiflora</i>
Leaf lamina size (cm)	4–6(–10) × (3–)7–7.5	9–13 × 4–7
Ratio leaf lamina width: length	0.9–1.3	1.9–2.2
Flower position	partially or not resupinate	resupinate
Dimensions of corolla tube (mm)	2–3 × 2.5–4	1.2 × 1
Length of lower lip (mm)	4–9	2.5–3
Position of lobes of lower lip	flat (not recurved)	strongly reflexed
Length of filaments (mm)	2–3	1.5
Length of anthers (mm)	1.5–2	1.5
Capsule length (mm)	4–7.5(–10)	4–6
Seed dimensions (µm)	80–117 × 29–31	350 × 210

Conservation status. Critically Endangered B2a,biii. The total population probably amounts to less than 250 fertile individuals and is vulnerable because of its small and fragmented population. It is severely threatened by habitat disturbance and degradation. The forested ridge lies outside the network of Totally Protected Areas and is surrounded by oil palm plantations. The Bukit Tunku area has been logged and is currently the site of an active quarry. The area is being considered as an extension to the Gunung Ledang State Park to protect the Critically Endangered *Cycas cantafolia*.

Ecology. In hill dipterocarp forest on ridges at 320–505 m elevation, below the tree canopy in light shade, on low cliff faces or vertical rocky outcrops of sedimentary rocks with quartzite inter-bedded with slate that has eroded to leave horizontal cracks where this species grows. It is a rare species known only from about four small populations, each with a few to about 60 fertile plants. From the many seedlings, it is apparently regenerating freely from seed. Plants with flowers and fruits were collected in July and December but in March and October only fruiting plants with abundant fruit were found. In March 2016 after a drought, its leaves were completely wilted and dried. It is not known if these plants can recover or whether the population will regenerate from seed. The woody stem shows that they are perennial plants.

Notes. There is some variation between populations. The populations on Bukit Reban Kambing have flowers that are never resupinate, are pure white and are slightly larger, the lower lip measuring 5–9 × 6–7 mm (Fig. 1D, E) compared with flowers from the Bukit Tunku population that, in some flowers, are partially resupinate (Fig. 1B), the lower lip is proportionally broader, measuring 4–7 × 6.5–8 mm and, in some individuals, the corolla is tinged pale pink (Fig. 1C). Otherwise, they are the same in calyx, corolla tube, stamen and carpel characters. It is tempting to suggest that these two forms should be given taxonomic recognition. However, very few flowers from the Bukit Tunku population were available to study variation in this population. Indeed, further investigation of the two populations may result in the recognition of two separate taxa, perhaps at an infraspecific rank.

Other specimens examined. Peninsular Malaysia. Johor: Ledang District, Bukit Tunku (2°20.04'N, 102°32.3'E), 30 Oct 2009, *Lau et al.* FRI 68516 (KEP!, SING!);

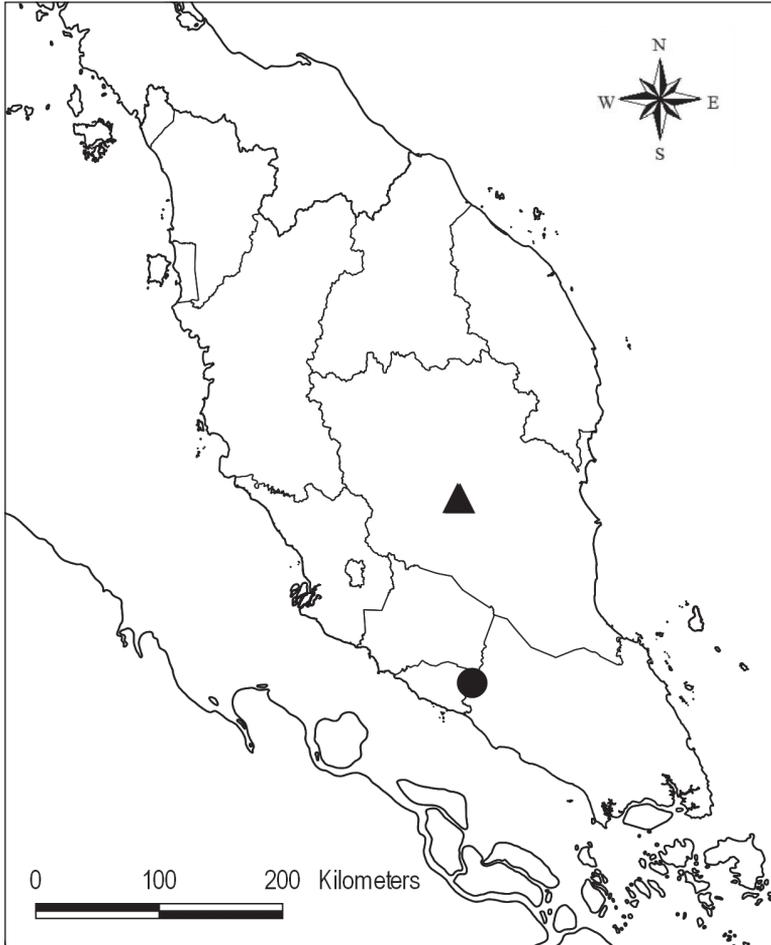


Figure 2. Distribution of *Senyumia granitica* (●) and *S. minutiflora* (▲).

ibidem, 27 July 2010, *Lau et al. FRI 68524* (KEP!); Ledang District, Bukit Reban Kambing (2°20.04'N 102°32.46'E), 8 March 2016, *Fakrul et al. FRI 85653* (KEP!); ibidem, 10 March 2016, *Fakrul et al. FRI 85672* (KEP!).

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Taxonomic revision of *Mcvaughia* W.R.Anderson (Malpighiaceae): notes on vegetative and reproductive anatomy and the description of a new species

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Abstract

A taxonomic revision of *Mcvaughia* is presented, including the description of a new species from the state of Piauí, Brazil, and notes on wood, secondary phloem, leaf, and floral morpho-anatomy. We present a key to the species, full morphological descriptions, a distribution map, and notes on distribution, ecology, etymology, and conservation status for each species.

Keywords

Atlantic Forest, Brazil, Caatinga, Malpighiales, Neotropical flora

Introduction

Mcvaughia W.R.Anderson is a genus of Malpighiaceae comprising three species endemic to the Atlantic Forest and Caatinga domains in northeastern Brazil (Anderson 1979; Amorim and Almeida 2015), one of which is described here for the first time. The genus can be easily recognized by its shrubby habit, anterior petals nestled inside one another, horseshoe-shaped anthers, and drupes with the epicarp twisted in a 180° angle (Anderson 1979; Amorim and Almeida 2015; this study). The genus was first described almost 40 years ago as monospecific, based on collections from the northern state of Bahia, Brazil (Anderson 1979). At that time, *Mcvaughia* was placed in the subfamily Byrsonimoideae by Anderson (1979), due to its habit, subulate styles with minute stigmas, tricolpate pollen grains, and chromosome numbers of 6 to 12 (Anderson 1977). Within this subfamily, the genus was morphologically related to *Burdachia* A.Juss. and *Glandonia* Griseb., sharing characteristics such as the posterior petal bearing glandular margins (Anderson 1981).

The first phylogenetic studies for Malpighiaceae demonstrated that a clade comprising the genera *Burdachia*, *Glandonia*, and *Mcvaughia* made the Byrsonimoideae paraphyletic (Cameron et al. 2001; Davis et al. 2001; Davis and Anderson 2010). Since then, those genera have been placed in the so-called Mcvaughoid clade, one of the three early diverging lineages of Malpighiaceae: Byrsonimoids, Acridocarpoids, and Mcvaughoids (Davis and Anderson 2010). The Mcvaughoid clade comprises eight species distributed in three genera: *Burdachia*, *Glandonia*, and *Mcvaughia* (Anderson 1981; Reis e Silva 2007; Amorim and Almeida 2015; Guesdon et al. 2018). About three decades later the description of *Mcvaughia*, the second species of the genus was discovered and described for the restinga vegetation and coastal dunes from the northern state of Sergipe, Brazil (Amorim and Almeida 2015).

During recent visits to Brazilian herbaria, we found a third species of *Mcvaughia* endemic to seasonally dry forests from the state of Piauí, Brazil. We present a taxonomic revision of *Mcvaughia*, including full morphological descriptions, a distribution map, illustrations, and notes on conservation, distribution, and etymology of all species accepted in the genus. Additionally, we present a detailed anatomical description of wood, bark, leaves, and flowers for the genus. This is the first of a series of joint studies focusing on the biosystematics of Malpighiaceae by the Malpighiales Biosystematics Working Group (GEBIM 2018).

Methods

Taxonomy

Morphological and phenological data were based on herbaria samples (ALCB, ASE, CEN, CEPEC, F, FLOR, G, HST, HUEFS, K, MBM, MICH, NY, P, RB, SP, TEPB, U, UB, US, and VIC; herbaria acronyms according to Thiers, continuously

updated). The indumentum terminology follows Anderson (1981), structure shapes follow Radford et al. (1974), the inflorescence terminology and morphology follows Weberling (1965, 1989), and fruit terminology follows Spjut (1994) and Anderson (1981). Wood and bark anatomical descriptions follow the recommendations of the IAWA Committee for hardwoods and barks (IAWA Committee 1989, Angyalossy et al. 2016). The conservation status was proposed following the recommendations of IUCN Red List Categories and Criteria, Version 3.1 (IUCN 2012). GeoCAT (Bachman et al. 2011) was used for calculating the Extent of Occurrence (EOO) and the Area of Occurrence (AOO). Maps were elaborated using ArcGIS 9.3 software (ESRI 2010), and geographical coordinates were obtained from herbaria specimens and the literature (Anderson 1979; Amorim and Almeida 2015).

Anatomy

Fresh samples of leaves, inflorescence, and stems were fixed in the field with FAA (formaldehyde, acetic acid and 50% ethyl alcohol; 1:1:18, by volume) for 48h (Johansen 1940) and vouchers deposited at HUEFS, and VIC herbaria (acronyms according to Thiers 2018, continuously updated). Additional herborized specimens were sampled for leaf and floral anatomy: *Mcvaughia bahiana* [D. Cardoso 57 (CEPEC), M. L. Guedes 12148 (CEPEC), I. Silva-Guesdon 300, 301(VIC)], *M. sergipana* [I. Silva-Guesdon 305, 306 (VIC)], and *M. piauiensis* [R. Barros 2922 (HUEFS)]. Herbarium samples were rehydrated according to Smith and Smith (1942), dehydrated in an ethanol series and stored in 70% ethanol. Leaves and petals were also submitted to clearing following Vasco, Thadeo, Conover, Daly (2014, modified), to dissociation techniques (Franklin 1945), and mounted in glycerin jelly (Johansen 1940). Samples stored in ethanol were then embedded in methacrylate resin (Historesin Leica; Leica Microsystems, Heidelberg, Germany) and sectioned using an automatic rotary microtome (Leica RM2265, or USA Leica RM2155, Deerfield, USA). Longitudinal and cross-sections were stained with toluidine blue at pH 4.7 (O'Brien and McCully 1981) and mounted in resin (Permount, Fisher Scientific, NJ, USA).

For wood and bark anatomy, *Mcvaughia sergipana* stems [specimen Amorim 8393 (HUEFS)] were boiled in water and glycerin for a month to soften its extremely stiff wood (Angyalossy et al. 2016), being subsequently embedded in polyethylene glycol 1500 (PEG 1500; Rupp 1964), and sectioned in a sliding microtome with a permanent hard steel knife type "C" (Barbosa et al. 2018) with the aid of a Styrofoam resin (Barbosa et al. 2010). The sections were double stained in Safrablau (Bukatsch 1972 modified by Kraus and Arduin 1997) and mounted in Canada balsam. Imaging was performed using a light microscope (AX70TRF; Olympus Optical, Tokyo, Japan) equipped with a digital camera (AxioCam HRc; Zeiss, Göttingen, Germany). Anatomical analyses of leaves and flowers were conducted at the Plant Anatomy Laboratory – UFV and wood and bark anatomy at the Plant Anatomy Laboratory of the Smithsonian Natural History Museum (SI-NMNH).

SEM analysis

Micromorphological data were obtained using a scanning electron microscope (SEM) at the Center for Microscopy and Microanalysis, Universidade Federal de Viçosa. Fixed samples were dehydrated in an ethanol series, submitted to the critical point technique (CPD 020; Bal-Tec, Balzers, Liechtenstein), sputter coated with gold (Bozzola and Russell 1992), and observed and photographed using a Leo 1430VP SEM (Zeiss, Cambridge, United Kingdom). The anatomical patterns of secretory structure were described as sessile when the secretory epidermis covered all the projected area; subsessile when the secretory epidermis is surrounded by non-secretory epidermis; and stalked when a short stalk is present.

Results

Mcvaughia W.R.Anderson, *Taxon* 28: 157. 1979

Type species. *Mcvaughia bahiana* W.R.Anderson

Description. *Shrubs* to subshrubs, perennial, growing in sandy soils. *Branches* cylindrical, densely sericeous or lanate-velutinous, generally glabrescent at age. *Stipules* epipetiolar, completely connate, persistent. *Leaves* opposite; petiole eglandular; blade bearing 2–many glands abaxially. *Thyrsi* terminal, pedunculate, many-branched; cincinni alternate to subopposite, 1–14-flowered; bracts persistent; bracteoles persistent, one of them 1-glandular, the other eglandular, gland green in bud turning yellow in anthesis. *Flowers* zygomorphic; floral buds slightly flattened at middle; pedicel stout, straight in bud. *Sepals* leaving petals exposed in pre-anthesis, all 2-glandular. *Petals* bright to golden yellow, glabrous, the anterior two remaining cupped one inside the other; lateral petals with the margin erose; posterior petal bearing several marginal glands. *Stamens* 7–8, staminodes 2–3 (stamens opposite the posterior-lateral sepals and the posterior petal); filaments glabrous, those opposite the posterior-lateral petals slightly curved towards the apex; connectives inconspicuous; anthers horseshoe-shaped, glabrous, outer locules confluent at apex, reduced to antherodes in staminodes. *Ovary* 3-carpellate, 3-locular, 2 locules ± anterior, apparently collapsed lacking ovules, 1 locule almost posterior, fertile, 1-ovulate; styles 3, slender, truncate to uncinatate at apex; stigma minute, lateral. *Drupes* rugose, twisted, asymmetric, 1-locular, proximal chamber thick-walled, 1-seeded, distal chamber thin-walled, filled with a viscous secretion (allowing the fruit to float and to be dispersed by water).

Etymology. The epithet pays tribute to Dr. Rogers McVaugh (*1909–2009†), an American botanist, expert in the Mexican flora.

Distribution. *Mcvaughia* is restricted to sandy soils within sedimentary basins of Northeastern Brazil, with different species being endemic to each sedimentary basin: *Mcvaughia bahiana* – Tucano basin, *M. piauihensis* – Parnaíba basin, and *M. sergipana* – Sergipe-Alagoas basin (Amorim and Almeida 2015). Sedimentary basins represent

conspicuous phytogeographic zones within the Caatinga domain, with a distinct biota from other areas of Caatinga over crystalline shield, holding endemism records for some angiosperm families (Cardoso and Queiroz 2007; Almeida et al. 2018; Silva and Souza 2018).

Biogeography. *Mcvaughia* is the sister-group of *Burdachia* and *Glandonia*, comprising a lineage (*Mcvaughia* clade) of early diverging Malpighiaceae with water-dispersed fruits, most commonly found growing along wetland floodplains and upland forest throughout the Amazon Basin (Anderson 1981). Davis et al. (2014) estimated that the ancestor of this clade might have arisen around 38.0–33.9 Myr, and its extant lineages diversified from 25 to 15 Myr. The description of *M. piaubiensis* corroborates the hypothesis of Amorim and Almeida (2015) that extant lineages of *Mcvaughia* have probably experienced recent radiations along the caatingas and restingas of Northeastern Brazil. This inference is based on the fact that all three *Mcvaughia* species occur along current or past courses of the São Francisco river (SFR): *M. piaubiensis* occurs to the west, and *M. bahiana* and *M. sergipana* occur to the east near the SFR's delta (Fig. 11). During the upper Pliocene, the SFR flowed to the equatorial Atlantic Ocean via the Piauí or Canindé Rivers, in the Parnaíba river basin, state of Piauí (King 1956; Nascimento et al. 2013). However, the rising of the Grande and Ibiapaba Ridges in northwestern Ceará state during the Pliocene/Pleistocene boundary would have abruptly interrupted the SFR's course (King 1956; Mabesoone 1994; Nascimento et al. 2013; Almeida et al. 2018). By this time, the ancestor of *Mcvaughia* might have already been established in this area, and its populations might have been isolated from each other by the formation of several lakes in northwestern Bahia, due to the interruption of the river flow (King 1956; Mabesoone 1994; Nascimento et al. 2013). It was not until the Mindel glaciation (ca. 450,000 years ago) that the SFR found its way to the eastern Atlantic Ocean, bordering the states of Alagoas and Sergipe (King 1956; Mabesoone 1994; Nascimento et al. 2013), thus, paving the way for recent vicariant cladogenesis events within these populations.

Wood Anatomy of *Mcvaughia sergipana*. Heartwood and sapwood indistinct light brown; grain straight to slightly wavy. In anatomical sections, the heartwood appears with abundant cell contents (bottom of Fig. 1A–B) in vessels and other cell types. The contents stain in blue with safrablau (Fig. 1A–B). Growth ring boundaries are distinct (Fig. 1A–B), marked by a line of axial parenchyma (Fig. 1B) and thicker walled, radially narrow fibers (Fig. 1A–B). Wood is diffuse-porous (Fig. 1A). Vessels are narrow, $34 \pm 9 \mu\text{m}$, generally arranged in radial multiples of 4 or more (Fig. 1A), abundant, 244 ± 57 vessels/ mm^2 , and with a mean length of $365 \pm 73 \mu\text{m}$. Some solitary vessels and shorter radial multiples are also present (Fig. 1A–B). Perforation plates are simple. Intervessel pits are alternate, minute, $4 \mu\text{m}$, vestured. Vessel ray-pitting with distinct borders; similar to intervessel pits in size and shape. Fibers very thick-walled (Fig. 1A–B), with simple to minutely bordered pits. Axial parenchyma paratracheal, scanty and forming a discontinuous line at the growth ring limits (Fig. 1A–B), 3–4 cells per parenchyma strand (Fig. 1C). Rays with 1–3 cells wide (Fig. 1C), lower than 1 mm (Fig. 1C), heterocellular mixed, with procumbent, square and upright cells mixed throughout

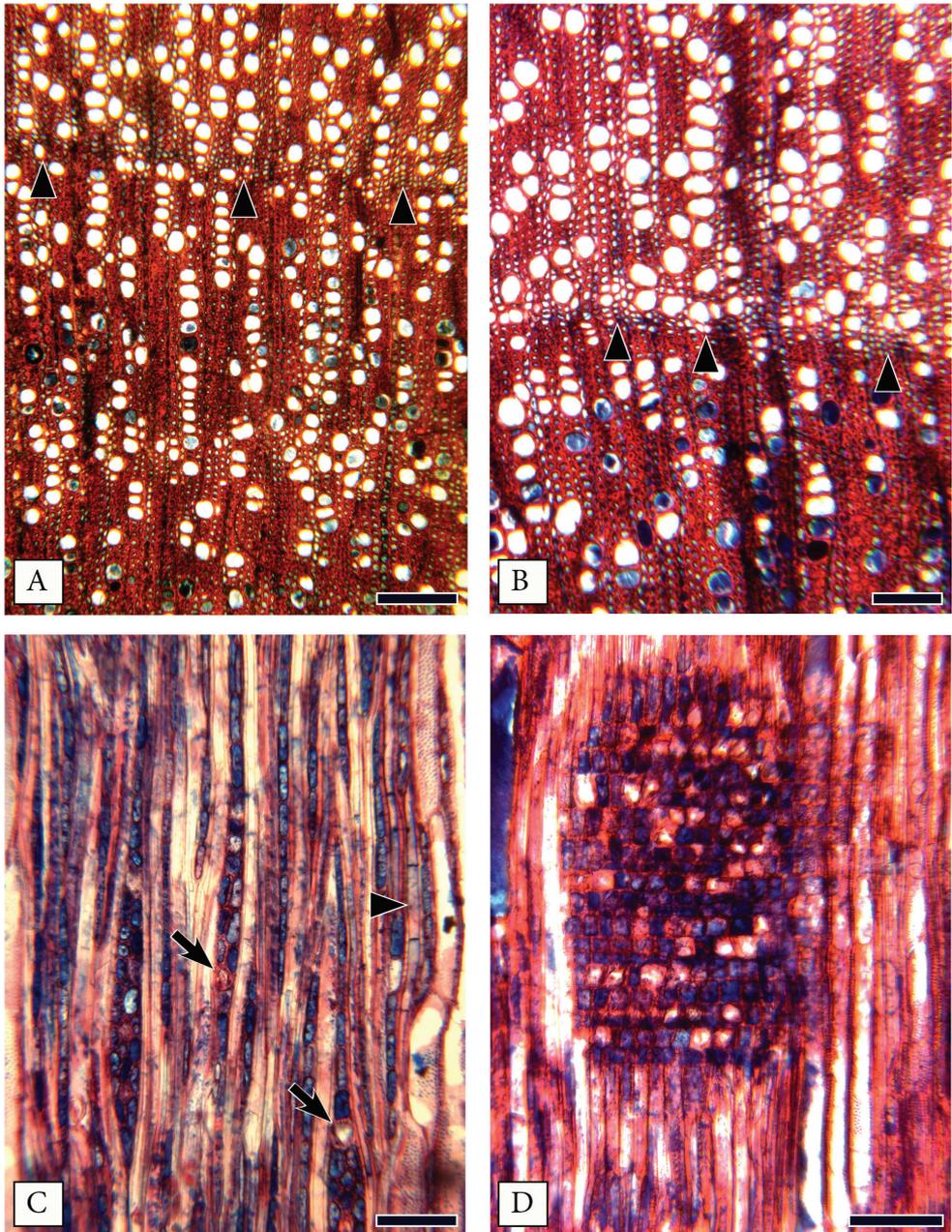


Figure 1. Wood anatomy of *Mcvaughia sergipana*. **A–B** transverse sections: Growth rings marked by radially narrow fibers (arrowheads) and a discontinuous line of axial parenchyma (in B); vessels are narrow and abundant, arranged in radial rows of 4 or more cells; some solitary vessels present; parenchyma rare, paratracheal scanty or at the growth ring limits; heartwood vessels in the bottom with content **C** radial section: Rays 2–3 cells wide, non-storied; prismatic crystals present in ray cells (arrows); parenchyma with 3 cells per strand (arrowhead) **D** ray heterocellular with procumbent, square and upright cells mixed throughout the ray. Scale bars: 150 μm (**A**), 100 μm (**B–C**), 60 μm (**D**).

the ray (Fig. 1C). Perforated ray cells common, non-storied (Fig. 1C). Large prismatic crystals in enlarged ray cells (Fig. 1C) of the body and margins.

Secondary phloem anatomy of *Mcvaughia sergipana*. Growth rings are indistinct, phloem non-stratified (Fig. 2A–C). Conducting phloem represents a narrow band of 11–12 cells away from the cambium. Nonconducting phloem is marked by the collapse of the sieve tubes, a more significant dilatation of the axial and ray parenchyma (Fig. 2A–B), and belated sclerosis of some scattered ray cells. Sieve tubes are diffuse (Fig. 2C), solitary or in radial multiples of 2 cells (Fig. 2C), sieve plates are simple, slightly inclined, $441 \pm 71 \mu\text{m}^2$ in area ($24 \pm 2 \mu\text{m}$ in diameter). Sieve tube elements length is $243 \pm 45 \mu\text{m}$. Slime plug always evident at the sieve plates. One to two companion cells per sieve tube element, as seen in transverse section. When two companion cells are present, one lies on each side of the sieve tube. Dilatation due to cell expansion and division is evident in the rays, axial parenchyma, and the cortex (Fig. 2A–B). Axial phloem parenchyma constitutes the ground tissue (Fig. 2A–C), four cells per parenchyma strand. Axial parenchyma with druse crystals appears as diffuse-in-aggregate lines (Fig. 2A–C, E), giving a stratified appearance to the phloem, clear both in transverse and radial section (Fig. 2A–C, E). Rays with a straight course, slightly dilated (funnel-shaped). Ray width, height, and composition equal to those of secondary xylem (Fig. 2D–E). Sclerenchyma is represented by scattered bulky fiber-sclereids (Fig. 2A–C) and a few sclerified ray cells in the nonconducting phloem (Fig. 2B). Phloem elements are non-storied. Druses are abundant, present in absolutely all parenchyma cells (Fig. 2C). Crystals are present both in chambered axial parenchyma cells (Fig. 2C) and in individual axial and ray parenchyma cells of the phloem (Fig. 2D) and cortex.

Leaf anatomy. The leaf anatomy in the species of *Mcvaughia* is quite similar. The vascular system of petioles is arranged as a curved arc with two conspicuous accessory bundles. The most distinctive leaf character is the distribution pattern of glands (Fig. 3A–C). These glands are distributed at the base and throughout the leaf blade, varying in number from two to eight basilar glands and from few to several distal laminar glands. The basilar and laminar leaf glands were identified as short-stalked (Fig. 3D–E), except in *M. sergipana* which were recognized as sessile and partially set in the mesophyll (Fig. 3F). Based on the anatomical arrangement, these leaf glands are composed of a palisade-like secretory epidermis and vascularized parenchyma (Fig. 3F). The laminar glands in *M. sergipana* are conspicuous (Fig. 3G, I), while in *M. bahiana* (Fig. 3H) and *M. piauiensis* (Fig. 3J) these glands are inconspicuous, and difficult to see with the naked eye. The leaf blade anatomy revealed a dorsiventral mesophyll with a single layer of palisade parenchyma and a variable number of spongy parenchyma layers. In *M. sergipana* the spongy parenchyma has several layers (Fig. 3K), while in *M. bahiana* and *M. piauiensis* fewer layers were observed (Fig. 3L). Idioblasts containing druses are commonly observed in the mesophyll (Fig. 3L). Malpighiaceae trichomes were observed in the epidermis of both surfaces (Fig. 3M–O), being more abundant abaxially and in young leaves. The outline of the anticlinal epidermal cell walls adaxially is straight (Fig. 3M–N), while abaxially may vary from straight to sinuous (Fig. 3P–Q),

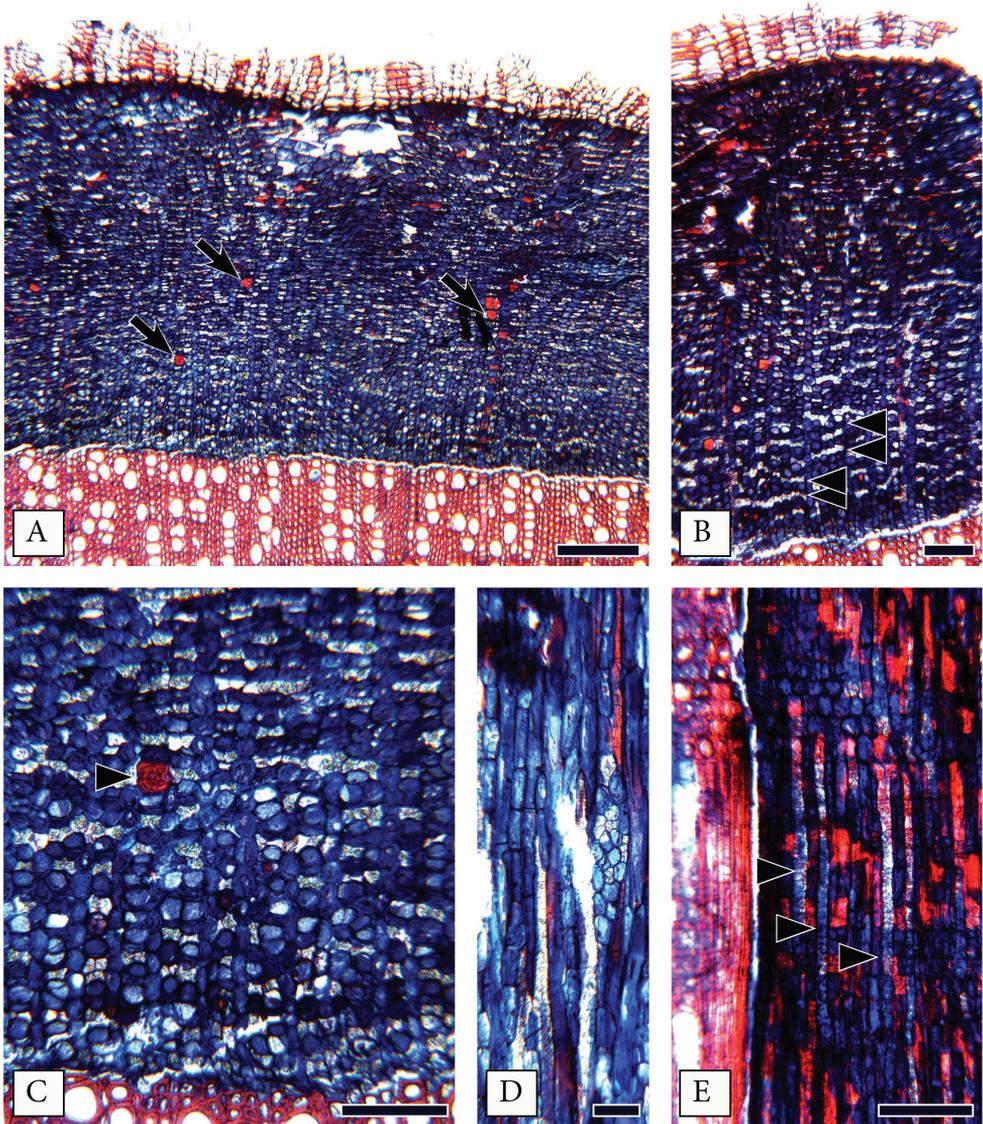


Figure 2. Secondary phloem of *Mcvaughia sergipana*. **A–C** Transverse section: **A** Phloem non-stratified, with scattered fiber-sclereids (arrows); Rays dilating slightly **B** Crystalliferous axial parenchyma arranged in diffuse-in-aggregate narrow bands (arrowhead) **C** Crystalliferous axial parenchyma with druse crystals, forming diffuse in aggregate bands, isolated fiber-sclereids present (arrowhead) **D** A ray 3 cells wide, fiber-sclereids and axial parenchyma in tangential section **E** Bands of crystalliferous parenchyma with druses evident also in radial section; Rays heterocellular mixed. Scale bars: 200 μm (**A**), 100 μm (**B–C, E**), 50 μm (**D**).

being exclusively straight in *M. sergipana*. All species of *Mcvaughia* show hypostomatic leaves (Fig. 3K–L), with paracytic stomata (Fig. 3P–Q).

Floral anatomy. Observations during field trips revealed that sepal and petal glands are yellow in *M. sergipana* and *M. bahiana* (Fig. 4A–B). The bracteole gland is

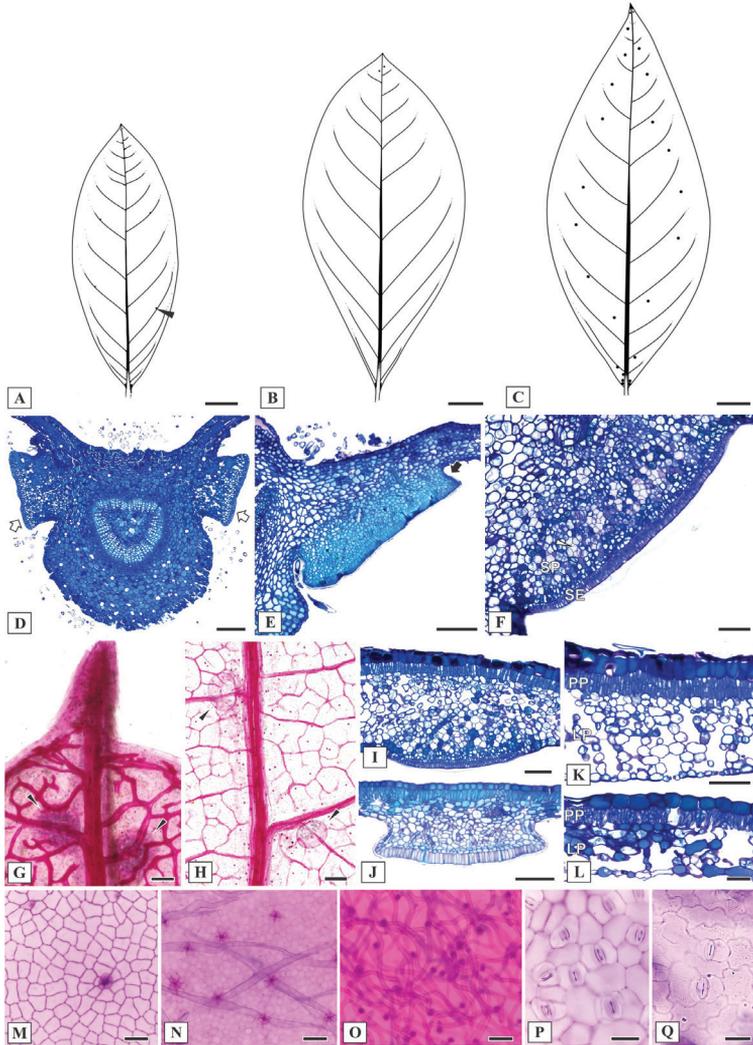


Figure 3. Leaf morphoanatomy of *Mcvaughia* species. **A** patterns of leaf glands distribution on the abaxial leaf surface of *M. bahiana* **B** patterns of leaf glands distribution on the abaxial leaf surface of *M. piaubiensis* **C** patterns of leaf glands distribution on the abaxial leaf surface of *M. sergipana* **D** transverse section of leaf base showing the basilaminar pair of stalked glands (white arrows) **E** basilaminar leaf gland with a stalk (black arrow) in *M. piaubiensis* **F** basilaminar gland in *M. sergipana* showing a sessile position (SE= anatomical arrangement with secretory epidermis, SP= vascularized secretory parenchyma) **G–H** laminar glands on the apex of cleared leaves of *M. sergipana* and *M. bahiana* respectively, note the apical tooth (**G**) **I** sessile laminar glands in *M. sergipana* **J** stalked laminar gland in *M. piaubiensis* **K–L** transverse sections of the leaf blade; mesophyll with uniserial palisade-like parenchyma and spongy parenchyma composed by several or few layers in *M. sergipana* and *M. bahiana*, respectively; note the idioblast with druse crystals at the mesophyll (white arrow) and the stomata distribution at the abaxial leaf surface (black arrow) **M–N** adaxial epidermis surface of *M. piaubiensis* and *M. sergipana*, showing scars of malpighiaceus trichomes **O** abaxial epidermis surface of trichomes abundance in *M. bahiana* **P–Q** outline of the anticlinal epidermal cell walls: straight in *M. sergipana* (**P**) and sinuous in *M. bahiana* (**Q**). Laminar scale bars: 1 cm (**A–C**), 100 μ m (**D, F–K, N–O**), 150 μ m (**E**), 50 μ m (**L–M, P–Q**).

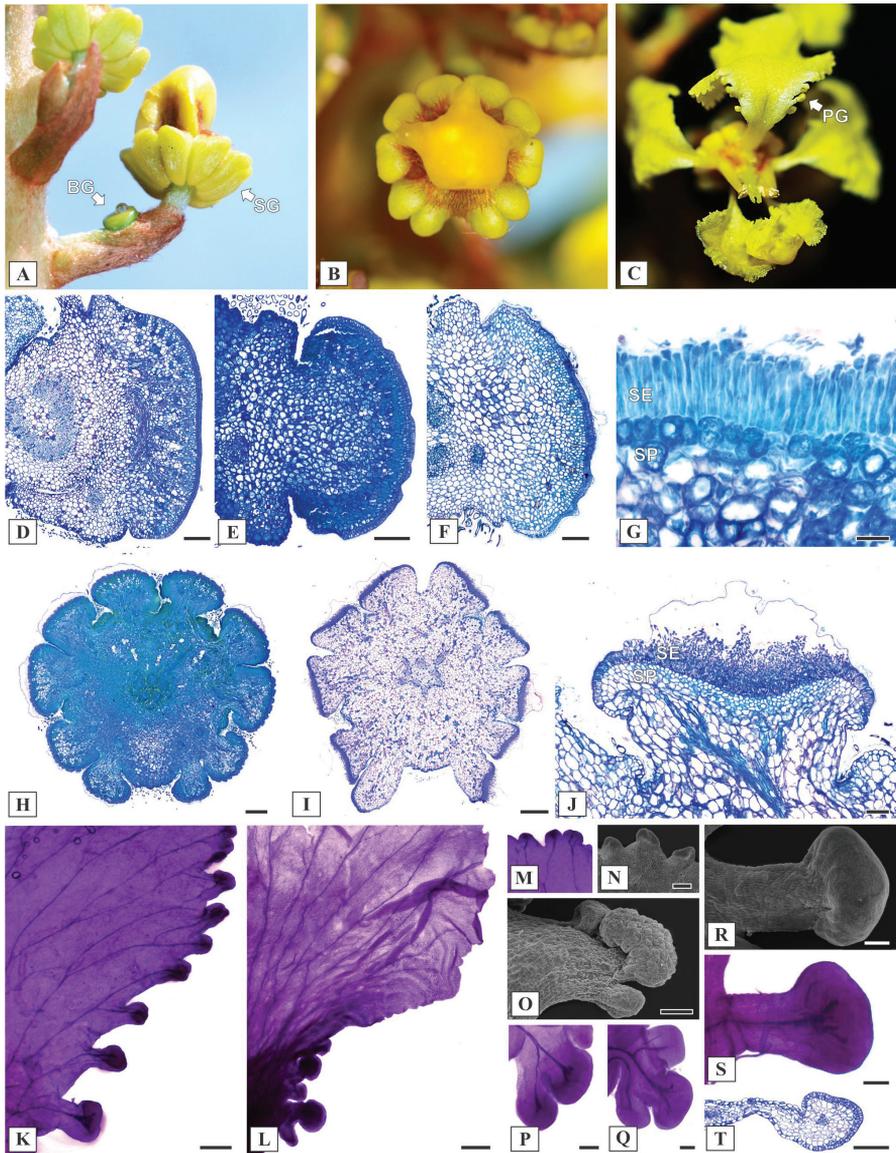


Figure 4. Reproductive morphoanatomy of *Mcvaughia* species. **A** inflorescence during development, showing a bracteole gland (BG) and Sepal glands (SG) **B** ten sepal glands encircling the calyx **C** Petal glands (PG) along the margin of posterior petal **D–F** transverse section of bracteole glands in *M. sergipana*, *M. bahiana* and *M. piauiensis*, respectively **G** anatomical arrangement of bracteole gland, with a palisade-like secretory epidermis (SE) and secretory parenchyma (SP) **H–I** transverse section of floral bud and anthesis flower in *Mcvaughia bahiana* and *M. sergipana*; calyx gland pair displaced at the anterior sepal **J** calyx gland structure, showing a secretory epidermis (SE) and vascularized secretory parenchyma (SP) **K–L** petal glands on the margin of petals in *M. sergipana* and *M. bahiana* respectively **M–N** detail of the petal glands at the apex of the petal limb in *M. sergipana*, cleared and in SEM image **O–Q** petal glands positioned at the base, *M. bahiana* on SEM image, *M. bahiana* and *M. piauiensis* cleared **R–T** conspicuous and stalked petal glands at the base of *M. sergipana*, in SEM image, cleared and longitudinal section. Scale bars: 200 μm (**D**), 150 μm (**E–F**), 50 μm (**G**), 500 μm (**H–I**), 100 μm (**J, P–S**), 300 μm (**L–M**), 200 μm (**N, T**).

initially green (Fig. 4A) turning yellow during anthesis. The secretory surface of the bracteole gland may vary from flattened (Fig. 4D) in *M. sergipana* to convex in the other two *Mcvaughia* species (Fig. 4E–F). The bracteole glands show an anatomical arrangement similar to that of the leaf glands, with palisade-like secretory epidermis and a vascularized secretory parenchyma (Fig. 4G). The calyces are particularly zygomorphic, due to the lateral displacement of glands in the anterior sepal (Fig. 4H–I). The bracteole glands are subsessile (Fig. 4D–F), while the sepal glands are short-stalked (Fig. 4J). Petal glands were recorded throughout the limb margin of the posterior petal in *M. sergipana* (Fig. 4K) and distributed only at the base in *M. bahiana* (Fig. 4L) and *M. piauihensis*. In *Mcvaughia sergipana* the petal glands at the apex region are sessile (Fig. 4M–N). The basal petal glands in *M. bahiana* (Fig. 4O–P) and *M. piauihensis* are sessile to slightly subsessile (Fig. 4Q), while in *M. sergipana* are stalked (Fig. 4R–S). The petal glands show the same anatomical composition as the leaf, bracteole, and sepal glands (Fig. 4T).

Key to the species of *Mcvaughia*

- 1 Leaf blades sericeous, margins revolute, several conspicuous and sessile glands near the midvein, straight outline of the wall in anticlinal epidermal cells, mesophyll with more than 4 layers of spongy parenchyma; cincinni 1–2-flowered; margins of posterior petal entirely glandular, staminode opposite the posterior petal with stout filament; restinga and coastal dunes ..
..... *Mcvaughia sergipana*
- Leaf blades tomentose to lanate-velutinous, margins plain, conspicuous and stalked glands only near base and apex, sinuous outline of the wall in anticlinal epidermal cells, mesophyll with fewer than 4 layers of spongy parenchyma; cincinni (2–)3–7-flowered; margins of posterior petal glandular at base only, staminode opposite the posterior petal with slender filament; inland caatinga 2
- 2 Shrubs 1–3 m tall; leaf blades tomentose; flowers 1–1.2 cm diam., staminode opposite the posterior petal shorter than fertile stamens, apex of styles truncate; state of Bahia *Mcvaughia bahiana*
- Subshrubs ca. 50 cm tall; leaf blades lanate-velutinous; flowers 1.5–2 cm diam., staminode opposite the posterior petal as long as fertile stamens, apex of styles uncinatate; state of Piauí.....*Mcvaughia piauihensis*

1. *Mcvaughia bahiana* W.R.Anderson, *Taxon* 28: 157. 1979

Figs 5–6, 11

Type. BRAZIL. Bahia: Conceição do Coité, road from Coité, 12 km to Santaluz, fl. Fr., 6 Mar 1976, W.R. Anderson 11740 (holotype: MBM barcode MBM59835!; isotypes: F barcode F0062743F!, G barcode G00352842!, K barcode K000426948!;

MICH barcode MICH1102251!, NY barcode NY00067680!, P barcode P02429273!, RB barcode RB00540751!, SP barcode SP000249!, U barcode U0003826!, UB barcode UB1950!, US barcode US00108758!).

Description. *Shrubs* 1–3 m tall. *Branches* densely sericeous, glabrescent at age. *Stipules* 2.5–5 mm long, adaxially glabrous, abaxially sericeous. *Leaves* opposite; leaf blades 4.5–8.8 × 2–5 cm, chartaceous to subcoriaceous, elliptic to obovate, base cuneate to rotund, margins plain, entire, apex acute to apiculate, adaxial side initially tomentose, glabrous at age, abaxial side densely tomentose, a pair of conspicuous glands at base abaxially, on each side of the midrib, a few inconspicuous glands scattered over the blade, with 1–3 glands near the apex; petiole 0.3–0.7 cm long, canaliculate, densely tomentose, eglandular. *Thyrsi* of 2–7-flowered cincinni; rachis 3–10 cm long, smooth, densely tomentose, with brown hairs; lateral cincinni 12–24, subopposite; bracts 2–7 mm long, narrowly-triangular, appressed to the peduncle, eglandular, tomentose; peduncle 1.5–4.5 mm long, tomentose; bracteoles 1.5–2.5 mm long, narrowly triangular, opposite, appressed to the peduncle, tomentose, one of each pair bearing a conspicuous gland at base, 1–1.2 mm long. *Flowers* 1–1.2 cm diam. at anthesis, floral buds 3–3.2 mm long, pedicel 0.5–1.7 mm long, tomentose. *Sepals* 2–3 × 1.5–2.5 mm, straight, keeled, covering most of the androecium, apex acute, margin glabrous, adaxial side glabrous, abaxial side tomentose, glabrescent near the margin; 10-glandular, glands 1.5–2.5 × 0.7–0.8 mm, yellow, elliptic. *Petals* yellow, both sides glabrous, soon deciduous; anterior lateral petals orbicular, cucullate, nested inside one another, limb 3–3.3 × 4.5–4.7 mm, margin denticulate, 2-glandular at base, claws 1.2–1.5 × 0.2–0.25 mm, glabrous; posterior lateral petals obovate, spreading, limb 5.5–6.5 × 6–7 mm, margin erose, 2-glandular at base, claws 1.8–2 × 0.3–0.35 mm, glabrous; posterior petal obovate to orbicular, erect, limb 6–7 × 7–8 mm, margin erose, 3–5 pairs of rounded glands at the base of limb, proximal pair larger, claws 3–4 × 0.7–0.9 mm, both sides glabrous. *Stamens* free at base, filaments 2–3 × 0.2–0.4 mm, cylindrical, thicker at base; connective inconspicuous, glabrous; anthers 0.7–1 × 0.4–0.45 mm; staminodes opposite the posterior-lateral sepals covered by sepals, filaments ca. 1 mm long, long-triangular, anthers ca. 0.2 mm long, oblong, locules lacking; staminode opposite the posterior petal not covered by sepals, exerted, diverging from styles, filament 2–2.1 × 0.2–0.4 mm long, anther 0.25–0.3 mm long, oblong, locules reduced. *Ovary* 1–1.3 × 1–1.3 mm, ovoid, densely sericeous; styles 3, erect, ca. 2.5–2.7 × 0.5–0.6 mm, cylindrical, parallel, glabrous, apex truncate, anterior style slightly smaller than posterior ones; stigma lateral, circular. *Drupes* 7–8.5 × 4–5 mm, cylindrical, slightly twisted, apex with persistent styles, sparsely tomentose, with two chambers, proximal chamber containing the seed, distal chamber containing an oily substance; seed globose, smooth. *Embryo* not seen.

Specimens seen. **BRAZIL.** **Bahia:** Itiúba, 20 km de Camaleão para Cansanção, 330 m, fl., 26 Feb 2000, A.M. Giullietti 1827 (CEN, FLOR, HUEFS, RB, UB); 20 Km East Camaleão, Rod. Itiúba/Cansanção, 21 Feb 1974, fl., R.M. Harley 16465 (CEPEC, MICH, NY, P, RB). Monte Santo, Fazenda Bom Jesus, fl. fr., 11 Oct 2000, C.M.L. Aguiar 17, 18, 19, 27, 28, 30, 31 (HUEFS); fl. fr., 12 Jan 2006, M.L. Guedes



Figure 5. *Mcvaughia bahiana*. **A** shrub habit **B** subshrub habit **C** inflorescence showing glandular bracts **D** inflorescence showing flowers in anthesis **E** inflorescence showing immature and mature fruits **F** detail of mature fruits **G** drupe indumentum **H** glabrescent drupe. **A, D–H** by W.R. Anderson **B–C** by I.R. Guesdon.

12148 (ALCB). Quijingue, Serra das Candeias, 5 Km W povoado Quixabá do Mandacaru, near Tucano, fl. fr., 15 May 2005, D. Cardoso 529 (HUEFS); fl. fr., 8 Jul 2006, D. Cardoso 1311 (HUEFS). Tucano, povoado Bizamum, 23 km from Tucano, fl. fr., 6 Jun 2004, D. Cardoso 57, 99 (HUEFS, SP); povoado Marizá, 13 km from Tucano, fl. fr., 6 Jan 2006, D. Cardoso 958 (HUEFS, RB); distrito de Caldas do Jorro, estrada entre Caldas do Jorro e rio Itapicurú, fl. fr., 1 Mar 1992, A.M. Carvalho 3863 (CEPEC, HUEFS, MBM, NY, SP); fl., 15 March 2008, G. Costa 341 (HST, HUEFS); povoado Bizamum, fl., 6 Feb 2004, L.P. Queiroz 9017 (HUEFS); povoado Bizamum, fl. fr., 22 Sep 2015, I.R. Guesdon 300, 301 (VIC).

Distribution, habitat, and phenology. *Mcvaughia bahiana* is known only from sandy caatingas (seasonally dry forests) within northeastern state of Bahia, Brazil (Fig. 11). Flowering and fruiting throughout the year.

Conservation status. *Mcvaughia bahiana* shows an extent of occurrence of 2,527 km², and an area of occupancy of 16.000 km² within the northeastern state



Figure 6. Photograph of the isotype of *Mcvaughia bahiana*.

of Bahia, Brazil. Its restricted distribution associated with an accelerated habitat degradation categorizes it as Endangered (EN). *Mcvaughia bahiana* is the only species in the genus not protected within the limits of a conservation unit.

Etymology. The epithet refers to the distribution of *M. bahiana*, which is restricted to the state of Bahia, Brazil.

Anatomical notes. Leaf glands are distributed throughout the leaf blade. Two basilaminar glands are typically positioned in pairs and visible to the naked eye (Fig. 3A). However, the anatomical study revealed a few additional glands distributed distally and difficult to see with the naked eye, two or three of them positioned subjacent to the apical leaf tooth. Anatomically, the basilaminar and laminar glands are short-stalked (Fig. 3D, J). The section of the bracteole and sepal glands revealed a subsessile anatomical structure (Fig. 4E). Malpighiaceae trichomes and their scars are frequent on the leaf, especially on the abaxial surface (Fig. 3O). On mature leaves, the indumentum along the middle and secondary veins and the apical leaf tooth is typically tomentose. The outline of the anticlinal walls is straight on the adaxial surface and sinuous on the abaxial (Fig. 3Q). Field observations revealed that the leaf glands are yellow, while the bracteole and sepal glands are green becoming yellow in blooming. The glands on the posterior petal are restricted to the proximal portion of the limb, where ca. 5 marginal glands were observed on each side of the petal limb (Fig. 4L, O–P).

2. *Mcvaughia piaubiensis* R.F.Almeida & Guesdon, sp. nov.

urn:lsid:ipni.org:names:60478019-2

Figs 7–8, 11

Diagnosis. *Mcvaughia piaubiensis* differs from *M. sergipana* Amorim & R.F.Almeida due to its leaf blades abaxially lanate-velutinous (versus sericeous), margins plain (versus revolute), conspicuous and stalked glands only near base and apex (versus throughout the leaf blade), cincinni 3–7-flowered (versus 2-flowered), margins of posterior petal glandular at base only (versus entirely glandular), and staminode opposite the posterior petal with slender filament (versus with stout filament). It also differs from *M. bahiana* W.R.Anderson due to its subshrub habit (versus shrub habit), leaf blades lanate-velutinous (versus tomentose), flowers 1.5–2 cm diam. (versus 1–1.2 cm diam.), staminode opposite the posterior petal as long as fertile stamens (versus shorter than fertile stamens), and the apex of styles uncinat (versus truncate).

Type. BRAZIL. Piauí: Guaribas, Parque Nacional da Serra das Confusões, Barreiro, fl., 28 Mar 2007, R. Barros 2922 (holotype: HUEFS barcode HUEFS135774!; isotype: CEPEC!, TEPB!).

Description. *Subshrubs* ca. 50 cm tall. *Branches* densely lanate-velutinous, glabrescent at age. *Stipules* 4–4.5 mm long, adaxially glabrous, abaxially densely lanate-velutinous. *Leaves* opposite; leaf blades 6–11 × 3–6 cm, chartaceous to subcoriaceous, elliptic to obovate, base cuneate, margins plain, entire, apex acute to apiculate, adaxial side light green *in sicco*, initially lanate-velutinous to glabrescent, abaxial side dark

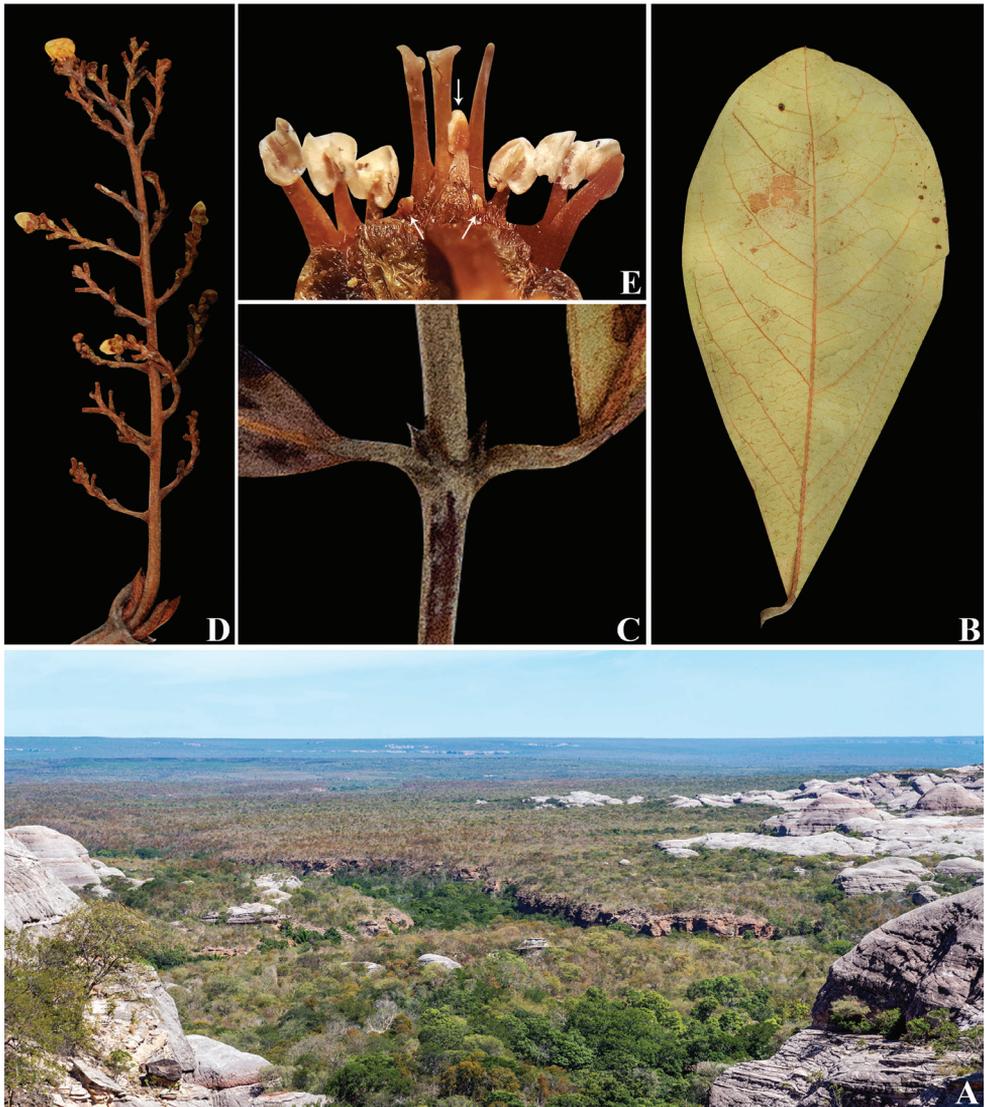


Figure 7. *Mcvaughia piauiensis*. **A** seasonally dry forests from Serra das Confusões, Piauí, Brazil **B** abaxial surface of a leaf **C** detail of epipetiole stipules **D** inflorescence **E** rehydrated flower showing the stamens (white arrows= reduced stamens) and styles. **A** by S.E. Martins **B–E** by R.F. Almeida.

green *in sicco*, initially lanate-velutinous to glabrescent, except from midvein at base, a pair of conspicuous glands at base abaxially, on each side of the midrib, a few inconspicuous glands scattered on the blade, with 2 conspicuous glands near apex; petiole 0.8–1 cm long, canaliculate, densely lanate-velutinous, eglandular. *Thyrsi* of 5–8-flowered cincinni; rachis 6.5–7 cm long, smooth, densely tomentose-velutinous, with rusty hairs; lateral cincinni 14–15, alternate; bracts 1.5–2.5 mm long, triangular, appressed to the peduncle, eglandular, tomentose-velutinous; peduncle 3–4 mm long,

tomentose-velutinous; bracteoles 1.5–2 mm long, triangular, subopposite, appressed to the peduncle, tomentose-velutinous, one of each pair bearing a conspicuous gland at base, 1.3–1.8 mm long. *Flowers* 1.5–2 cm diam. at anthesis, floral buds 3–3.5 mm long, pedicel 2–3 mm long, tomentose-velutinous. *Sepals* 2–2.5 × 1–1.3 cm, straight, keeled, covering most of the androecium, apex rounded, margin short ciliate, adaxial side glabrous, abaxial side tomentose, glabrescent near the margin; 10-glandular, glands 1–1.2 × 0.7–0.8 mm, yellow, elliptic. *Petals* yellow, soon deciduous; anterior lateral petals orbicular, cucullate, nested inside one another, limb 2.9–3.2 × 4–4.3 mm, margin erose, eglandular, claws 1–1.2 × 0.2–0.25 mm, glabrous; posterior lateral petals obovate, spreading, limb 4–5 × 4–4.5 mm, margin erose, eglandular, claws 1.5–2 × 0.3–0.35 mm, glabrous; posterior petal obovate to orbicular, erect, limb 5–5.5 × 5–5.5 mm, margin erose, 2–3 pairs of reniform glands at the base of limb, proximal pair larger, claws 2.5–3 × 0.6–0.8 mm, adaxially pubescent. *Stamens* free at base, filaments 2–3 × 0.2–0.4 mm, cylindrical, thicker at base; connective inconspicuous, glabrous; anthers 0.3–0.45 × 0.4–0.45 mm; staminodes opposite the posterior-lateral sepals covered by sepals, filaments ca. 1 mm long, long-triangular, anthers ca. 0.2 mm long, oblong, locules lacking; staminode opposite the posterior petal not covered by sepals, exerted, diverging from styles, filament 2–2.1 × 0.2–0.4 mm long, anther 0.25–0.3 mm long, oblong, locules reduced. *Ovary* ca. 1 × 1 mm, ovoid, densely tomentose; styles 3, erect, ca. 3 × 0.5 mm, cylindrical, parallel, tomentose at base, uncinata at apex, anterior style slightly smaller than posterior ones; stigma lateral, circular. *Drupes* (immature) 5–6 × 2–3 mm, cylindrical, slightly twisted, apex with persistent styles, rusty tomentose, with two chambers, proximal chamber containing the seed, distal chamber containing an oily substance; seed (immature) globose, smooth. *Embryo* not seen.

Distribution, habitat, and phenology. *Mcvaughia piauiensis* is known only from sandy caatingas (seasonally dry forests) within Serra das Confusões National Park in state of Piauí, Brazil (Fig. 11). Flowering in March.

Conservation status. *Mcvaughia piauiensis* is known only from a single population within the limits of the Serra das Confusões National Park in state of Piauí, Brazil. Until additional fieldwork can be done in seasonally dry forests from Piauí, this species is best categorized as data deficient (DD).

Etymology. The epithet refers to the distribution of *M. piauiensis*, which is restricted to the state of Piauí, Brazil.

Anatomical notes. This new species resembles *M. bahiana* in several aspects. The distribution pattern of leaf glands is quite similar, with both showing only one pair of conspicuous glands at base and a few conspicuous glands scattered over the blade (Fig. 3B). The basilar and laminar glands correspond to short-stalked glands (Fig. 3E, J). The sinuous outline of the anticlinal epidermal cell walls recorded on the abaxial leaf surface in *M. bahiana* (Fig. 3Q) was also observed in *M. piauiensis*. On both surfaces of *M. piauiensis*, the malpighiaceae hairs are less frequent (Fig. 3M), when compared with *M. bahiana* and *M. sergipana*, but the indumentum is clearly lanuginose-velutinous in young leaves. The distribution pattern of glands on the posterior petal is the same observed in *M. bahiana*, as ca. 5 short-stalked glands



Figure 8. Photograph of the holotype of *Mcvaughia piauhiensis*.

on the proximal portion of the petal limb margin (Fig. 4Q). Although no recent field observations have been recorded, we believe that the color of the glands and the color of the flower are the same observed in *M. bahiana*.

3. *Mcvaughia sergipana* Amorim & R.F.Almeida, *Systematic Botany* 40(2): 534. 2015
Figs 9–11

Type. BRAZIL. Sergipe: Pirambu, estrada para lagoa redonda, restinga sobre tabuleiro, 10°41'79"S, 36°50'90.2"W, 96 m, fl. fr., 7 Oct 2013, A.M.A. Amorim et al. 8393 (holotype: CEPEC barcode CEPEC142146!; isotype: ASE barcode ASE0035770!, HUEFS barcode HUEFS226853!, MBM!, NY barcode NY02859382!, MICH!, P barcode P01168074!, RB barcodes RB01190994!, RB01191408!, RB01191409!, SP barcode SP003291!).

Description. *Shrubs* 1.5–2 m tall. *Branches* densely lanate-velutinous, glabrescent at age. *Stipules* 3–5 mm long, adaxially glabrous, abaxially sericeous. *Leaves* opposite; leaf blades 8.4–12 × 2.7–6.5 cm, chartaceous to subcoriaceous, elliptic to ovate to elliptic-lanceolate, base acute to cuneate, margins slightly revolute, entire, apex acute to slightly acuminate, adaxial side green *in sicco*, initially sericeous to glabrescent, abaxial side metallic green *in sicco*, densely sericeous to glabrescent, 1–4 pairs of conspicuous glands at base abaxially, on each side of the midrib, with many conspicuous glands scattered distally; petiole 0.3–1.5 cm long, canaliculate, densely sericeous to glabrous at age, eglandular. *Thyrsi* of 1–2-flowered cincinni; rachis 6.5–11.4 cm long, striated, densely sericeous, with brown hairs; lateral cincinni 15–30, opposite to subopposite; bracts 5–6.5 mm long, lanceolate, spreading, eglandular, sericeous; peduncle 4–5 mm long, sparsely sericeous; bracteoles 2.5–3 mm long, triangular, subopposite, spreading to the peduncle, sericeous, one of each pair bearing a conspicuous green gland at base, 1.3–1.8 mm long. *Flowers* 1.5–2 cm diam. at anthesis, floral buds 3–3.5 mm long, pedicel 2–3 mm long, tomentose-velutinous. *Sepals* 2–2.5 × 1–1.3 cm, straight, keeled, covering most of the androecium, apex rounded, margin short ciliate, adaxial side glabrous, abaxial side tomentose, glabrescent near the margin; 10-glandular, glands 1–1.2 × 0.7–0.8 mm, yellow, elliptic. *Petals* yellow, soon deciduous; anterior lateral petals orbicular, cucullate, nested inside one another, limb 2.9–3.2 × 4–4.3 mm, margin erose, eglandular, claws 1–1.2 × 0.2–0.25 mm, glabrous; posterior lateral petals obovate, spreading, limb 4–5 × 4–4.5 mm, margin erose, eglandular, claws 1.5–2 × 0.3–0.35 mm, glabrous; posterior petal obovate to orbicular, erect, limb 5–5.5 × 5–5.5 mm, margin glandular, 2–3 pairs of stalked reniform glands at the base of limb, proximal pair larger and with many sessile glands scattered distally at the margin, claws 2.5–3 × 0.6–0.8 mm, adaxially pubescent. *Stamens* free at base, filaments 2–3 × 0.2–0.4 mm, cylindrical, thicker at base; connective inconspicuous, glabrous; anthers 0.3–0.45 × 0.4–0.45 mm; staminodes opposite the posterior lateral sepals covered by sepals, filaments ca. 1 mm long, long-triangular, anthers ca. 0.2 mm long, oblong, locules lacking; staminode opposite the posterior petal not covered by sepals, exerted, diverging from styles, filament 2–2.1 × 0.2–0.4 mm

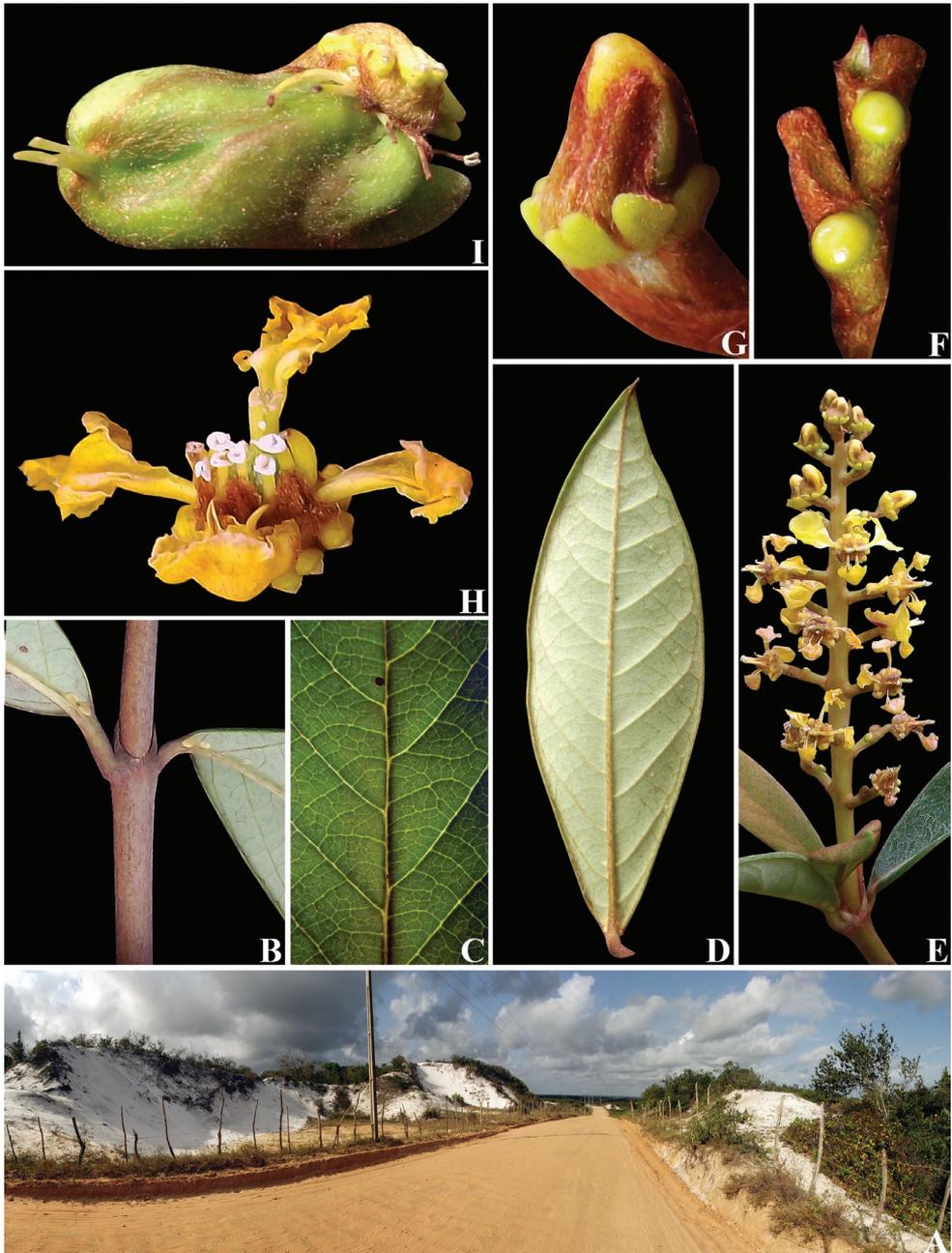


Figure 9. *Mcvaughia sergipana*. **A** sandy dune where *M. sergipana* occurs **B** detail of epipetiole stipules **C** detail of leaf venation patterns **D** abaxial surface of a leaf **E** inflorescence showing buds and flowers **F** detail of glandular bracts **G** floral bud **H** flower in frontal view **I** fruit in side view. Photos by R.F. Almeida.

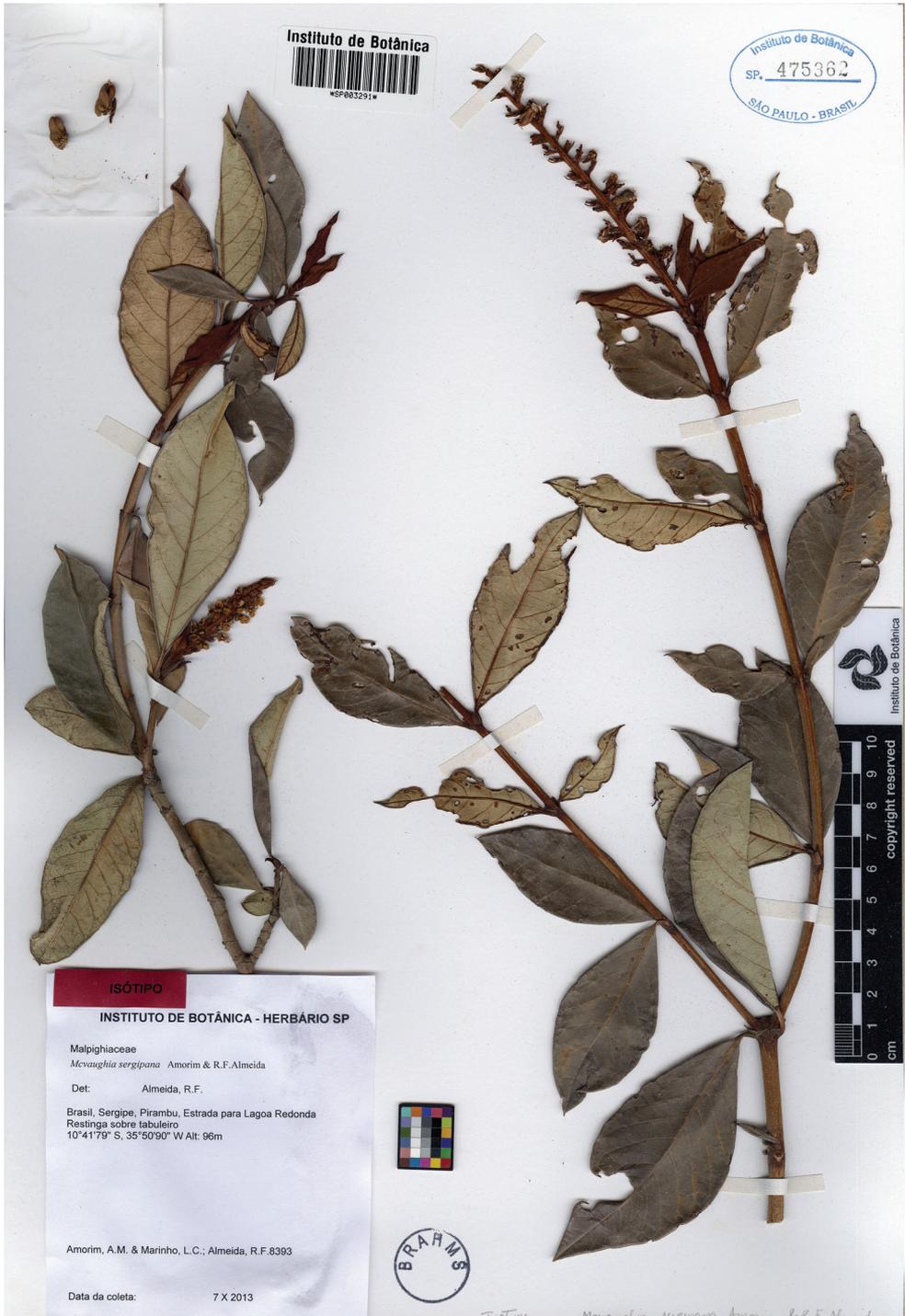


Figure 10. Photograph of the isotype of *Mcvaughia sergipana*.

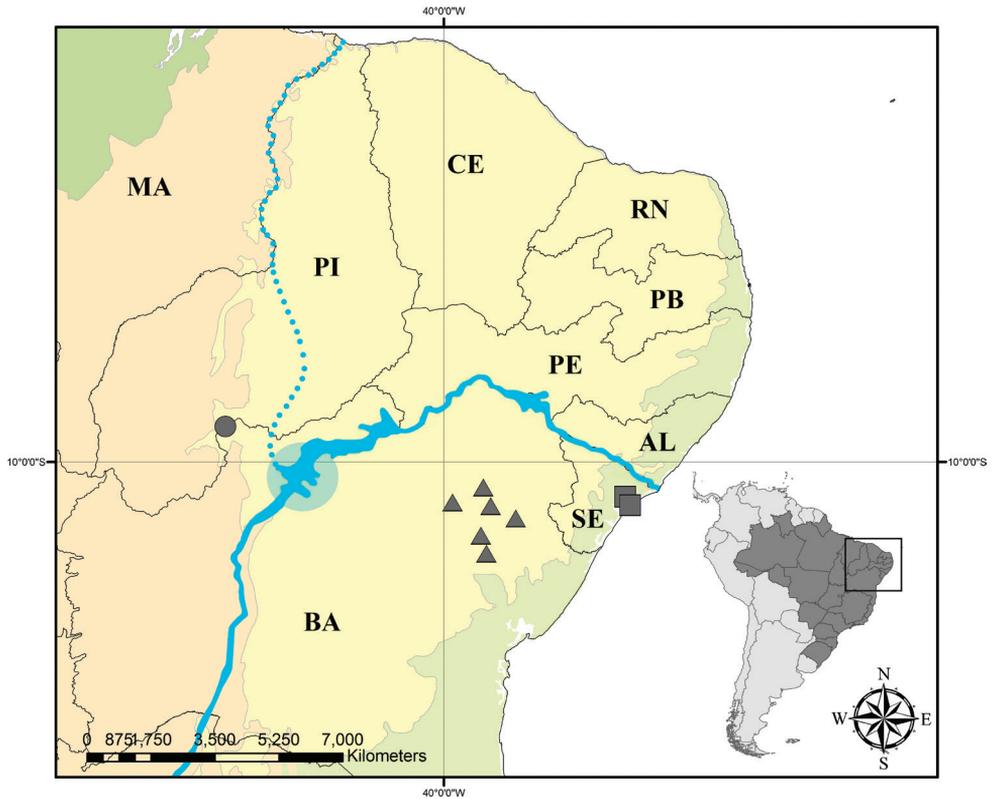


Figure 11. Distribution map of *Mcvaughia*: triangle – *M. bahiana*, circle – *M. piauiensis*, and square – *M. sergipana*. Solid blue line in the center represents the São Francisco River today. Dotted blue line represents the past course of São Francisco River. Blue circle represents the São Francisco paleo lake. Light green – Atlantic Forest domain, dark green – Amazon Forest domain, orange – Cerrado domain, and yellow – Caatinga domain. AL – state of Alagoas, BA – state of Bahia, CE – state of Ceará, MA – state of Maranhão, PB – state of Paraíba, PE – state of Pernambuco, PI – state of Piauí, RN – state of Rio Grande do Norte, and SE – state of Sergipe.

long, anther 0.25–0.3 mm long, oblong, locules reduced. *Ovary* ca. 1 × 1 mm, ovoid, densely tomentose; styles 3, erect, ca. 3 × 0.5 mm, cylindrical, parallel, tomentose at base, uncinata at apex, anterior style slightly smaller than posterior ones; stigma lateral, circular. *Drupes* 5–6 × 2–3 mm, cylindrical, slightly twisted, apex with persistent styles, rusty tomentose, with two chambers, proximal chamber containing the seed, distal chamber containing an oily substance; seed globose, smooth. *Embryo* not seen.

Specimens seen. BRAZIL. Sergipe: Japarutuba, povoado Sambaíba, fl. fr., 9 Sep 2013, B.C.A. Lima 37 (ASE); povoado Bonito, fl. fr., 24 Nov 2014, S.A. Damasceno 73 (ASE). Pirambú, estrada para Lagoa Redonda, fl. fr., 20 Dec 1978, M.R. Fonseca s.n. (ASE671); fl. fr., 17 May 2011, Santana 911 (ASE); fl. fr., 1 Nov 2011, E.A. Melo 13 (ASE); fl. fr., 9 May 2013, G.M.A. Matos 270 (ASE, CEPEC); fl. fr., 24 Sep 2015, I.R. Guesdon 305, 306 (VIC).

Distribution, habitat, and phenology. *Mcvaughia sergipana* is known only from sandy restingas and coastal dunes within the Atlantic Forest Domain in the state of Sergipe, Brazil (Fig. 11). Flowering and fruiting from September to December.

Conservation status. *Mcvaughia sergipana* shows an extent of occurrence of 49.735 km² and an area of occupancy of 12.000 km². Its restricted distribution and accelerated degradation of habitat categorizes it as Critically Endangered (CR). Even though the populations of *M. sergipana* are scattered within two municipalities in the state of Sergipe, Brazil, some of them are located within the limits of Santa Isabel Biological Reserve.

Etymology. The epithet refers to the distribution of *M. sergipana*, which is restricted to the state of Sergipe, Brazil.

Anatomical notes. This species has an unusual distribution pattern of leaf glands (Fig. 3C), in which all conspicuous glands are scattered throughout the leaf blade and visible to the naked eye. The basilar glands are generally positioned in pairs, varying from 2–8 glands. Several laminar glands are distally scattered throughout the blade, and one pair is positioned subjacent to the apical leaf tooth (Fig. 3G). The outline of the anticlinal epidermal cell walls is straight on both adaxial and abaxial surfaces (Fig. 3N, P). Leaf glands are yellow, and bracteole glands are green in secretory stage (Fig. 4A), turning yellow at blooming. The basilar and laminar leaf glands were anatomically identified as sessile (Fig. 3F, K), while the bracteole gland was recognized as subsessile (Fig. 4D) and the sepal gland as short-stalked (Fig. 4I). The bracteole gland shows a flattened secretory surface. Another important character that distinguishes *M. sergipana* is the distribution pattern of glands on the posterior petal. About five marginal petal glands are present on the proximal portion of the posterior petal in other *Mcvaughia* species, but only in *M. sergipana* do these glands extend the entire length of the petal margin (Fig. 4K, M–N). The proximal petal glands are stalked, in contrast to the small glands distributed distally that are sessile (Fig. 4R–T).

Discussion on the anatomical characters

Mcvaughia can be characterized by very hard woods, narrow vessels in a radial arrangement, scanty axial parenchyma, heterocellular mixed rays, and large prismatic crystals in ray cells. The bark can be characterized by scattered fiber-sclereids, axial parenchyma in lines filled with druse crystals, intercalating with sieve tubes. *Mcvaughia* has various features similar to other Malpighiaceae, such as the narrow vessels in radial arrangement, simple perforation plates and simple sieve plates, minute vestured pits, parenchyma strands of 2–4 cells, heterocellular rays, and prismatic crystals in wood and druse crystals in the bark (Solleder 1908, Metcalfe and Chalk 1950, Amorim et al. 2017, Cabanillas et al. 2017, Pace et al. 2018). It is unique within the family because of its very scanty axial parenchyma, making it similar mainly to *Byrsonima*, which can also have a shrub habit (Solleder 1908, Metcalfe and Chalk 1950). However, *Byrsonima* has shorter radial vessel chains, the rays are wider and heterocellular with body procumbent

and square to upright marginal cells (Sonsin et al. 2014), as opposed to *Mcvaughia*, which has heterocellular mixed rays. *Byrsonima* also has abundant septate fibers, which are absent in *Mcvaughia*. From the two genera sister to *Mcvaughia*, namely *Burdachia* and *Glandonia*, only a few aspects are described in Solereder (1908), and Metcalfe and Chalk (1950) and these genera seem to diverge from *Mcvaughia* in having simple pits in the vessel-ray parenchyma interface, and *Burdachia* is described as having abundant paratracheal confluent parenchyma. The presence of heterocellular mixed rays is also unusual in this genus, since these types of rays are more common in lianas than in shrubs or trees (Amorim et al. 2017, Cabanillas et al. 2017, Pace et al. 2018). In the phloem, *Mcvaughia* is unique for the low abundance of sclerenchyma, which is generally quite abundant, at least in the nonconducting phloem of Malpighiaceae (Amorim et al. 2017, Cabanillas et al. 2017, Pace et al. 2018).

Glandonia species also show leaf glands varying from two to four basilaminar and a few to several laminar glands, which can be conspicuous or inconspicuous to the naked eye (Guesdon et al. 2018). Stalked glands have been recorded in the literature for *Banisteriopsis* (Araújo and Meira 2016; Nery et al. 2017), and *Stigmaphyllon* (Almeida and Mamede 2016); as well, sessile glands are known in *Diplopterys pubipetala* (Possobom et al. 2010), and sessile to immersed glands in *Amorimia* (Mello et al. in press.) and *Glandonia* species (Guesdon et al. 2018). Dorsiventral mesophyll with a single layer of palisade parenchyma and paracytic stomata are quite similar in all the three genera and commonly found in Malpighiaceae species, as reported by Araújo et al. (2010), Almeida et al. (2017), and Guesdon et al. (2018). The bracteole color observed in the field, could be used to distinguish the Mcvaughioide genera, being typically white in *Glandonia* (Guesdon et al. 2018), pink in *Burdachia* (Guesdon et al. unpubl. data) and green turning yellow in all *Mcvaughia* species. The secretory surface variation of the bracteoles glands in *Mcvaughia* provides diagnostic characters, as in species of *Glandonia* species (Guesdon et al. 2018). The short-stalked sepal glands recorded in species of *Mcvaughia* are also recorded in *Glandonia* (Guesdon and Meira unpubl. data), while subsessile sepal glands were reported in *Banisteriopsis* (Araújo and Meira 2016), and *Diplopterys pubipetala* (Possobom et al. 2015). The stalked and sessile petal glands found in *Mcvaughia* were also observed in *Burdachia* (Guesdon et al. unpubl. data), being only previously reported in *D. pubipetala* (Possobom et al. 2015). Leaf and bracteole glands have been described as true nectaries (Possobom et al. 2010; Araújo and Meira 2016, Nery et al. 2017; Guesdon et al. 2018). The sepal and petal glands have been identified as elaiophores on the sepals and as osmophores on the petals (Possobom et al. 2015; Araújo and Meira 2016; Guesdon and Meira unpubl. data). The anatomical similarity observed among all these glands support their homology, as suggested by molecular phylogenies (Castro et al. 2001; Davis and Anderson 2010).

The glands of the posterior petal provide promising floral characters for taxonomic studies in Malpighiaceae (Guesdon pers. com.). Previous studies in *Mcvaughia* (Anderson 1979; Amorim and Almeida 2015) have mentioned the presence of glands only at the proximal region of the posterior petal, and details about number, shape, and size are imprecise. Anatomic studies helped to elucidate the distribution of those structures, revealing not only the stalked glands on the proximal portion of the posterior

petal, but also the sessile glands distally distributed exclusively in *Mcvaughia sergipana*. Additionally, the presence of glands on the lateral petals of *Mcvaughia bahiana* mentioned by Anderson (1979) was not confirmed in this study. However, this might be a result of intraspecific variation. The petal glands have also been taxonomically useful to distinguish species of *Glandonia* (Guesdon et al. 2018).

Conclusions

The results presented in this study are the second step towards a complete taxonomic revision of the Mcvaughioid clade using several additional methods in biosystematics, initiated by Guesdon et al. (2018). Additionally, this is the first record of scanty sclerenchyma in the secondary phloem in Malpighiaceae, and of a shrub with heterocellular mixed rays, long radial rows of narrow vessels and scanty axial parenchyma in the wood. The macro and micromorphological data presented here are promising for future taxonomic and phylogenetic studies focusing on understanding the morphological evolution in the Mcvaughioid clade, and in Malpighiaceae, as well.

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Hedychium ziroense (Zingiberaceae), a new species of ginger lily from Northeast India

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Abstract

We describe *Hedychium ziroense* **sp. nov.** from Northeast India (NE India) which was discovered during one of our recent botanical explorations in Arunachal Pradesh. We provide detailed morphological comparison of this species with four other *Hedychium* species (*H. griersonianum* R.M.Sm., *H. ellipticum* Buch.-Ham. ex Sm., *H. gomezianum* Wall. and *H. yunnanense* Gagnep.), with which it shares some morphological similarities. The new species is characterised by a dense cylindrical spike, pubescent rachis, folded bracts, 2–3 flowers per cincinnus, deeply cleft labellum and a distinctive late monsoonal flowering phenology from August to September.

Keywords

Apatani, Arunachal Pradesh, *Hedychium*, taxonomy, Ziro

Introduction

The genus *Hedychium*, comprising more than 80 species (Sanoj 2011), is distributed in the tropical, subtropical and warm-temperate Asia (Indian subcontinent, China and Southeast Asia) and Madagascar (Siriruga 1991, Newman et al. 2004, Newman and Pullan 2007, Tanaka et al. 2016, Ding et al. 2018, WCSP 2018). Based on inflorescence type and bract structure, Wallich (1853) recognised four subgeneric divisions within *Hedychium*: *Coronariae* (spikes with more or less tightly imbricate bracts), *Spicatae* (spikes with distant, spreading bracts), *Siphonium* (characterised by stemless habit and crested anther) and *Brachyphilum* (characterised by an exceedingly small la-

bellum). Based on the relative lengths of stamen and labellum, Horaninow (1862) divided the genus into three groups: *Gandasulium* (species with shorter stamen compared to labellum), *Macrostemium* (species with stamen length equal to or exceeding the labellum length) and *Brachychilum*. Later, Baker (1892) treated *Gandasulium* (to be corrected as *Hedychium*, as it includes the type of the genus, *M. Newman* pers. com.) and *Macrostemium* as two different sections within the genus *Hedychium*. Finally, based on the shape of the inflorescence and concealment of the inflorescence rachis, Schumann (1904) divided *Hedychium* into two subgenera: *Gandasulium* (to be corrected as *Hedychium*, mentioned above; characterised by wide, ellipsoid or ovoid inflorescence, dense imbricate bracts and hidden rachis) and *Eosmianthus* (characterised by longer than wide inflorescence, spreading bracts and exposed rachis). However, the molecular phylogeny of *Hedychium* by Wood et al. (2000) revealed that the morphologies referred to by Wallich (1853), Horaninow (1862), Baker (1892) and Schumann (1904) were not synapomorphic with any of the subgeneric groups and therefore the subgeneric groups were not supported. Instead, four distinct clades were now identified in the phylogenetic tree based on their biogeographic pattern; clade 1 - mostly Peninsular Malaysian taxa, clade 2 - Chinese and high elevation Himalayan taxa, clade 3 - *Hedychium acuminatum* and clade 4 - mostly Indian and Burmese (Myanmar) taxa. Interestingly, the number of flowers per cincinnus was the only morphological character that correlated with the clades wherein clade 2 was represented only by the species with 1-flowered cincinnus.

In India, *Hedychium* is the most diverse genus in the family Zingiberaceae and it is represented by at least 44 taxa (31 species and 13 varieties) from NE India and the Western Ghats (Sanoj 2011). Taxonomic revisions and explorations in the last few decades have resulted in the discovery of several new *Hedychium* (species as well as varieties) from the NE India and the Western Ghats (Sanoj et al. 2010, Sanoj and Sabu 2011, Thomas et al. 2015, Odyuo and Roy 2017). However, the total species count of *Hedychium* in India remains ambiguous due to the lack of detailed taxonomic studies, incomplete geographical sampling caused by difficult terrain and political disturbances (Srivastava 1984, Sarangthem et al. 2013, Sarangthem 2015, Ashokan and Gowda 2017). Northeast India consists of eight states, out of which Arunachal Pradesh (previously known as NEFA or North-East Frontier Agency) holds a major share of the Eastern Himalayan biodiversity hotspot (Mani 1974, Paul et al. 2005). It is second highest (20 species) in *Hedychium* diversity in India, next to Meghalaya (28 species, pers. obs.). Three *Hedychium* species (*H. radiatum*, *H. raoii* and *H. robustum*) are known to be narrow endemics to Arunachal Pradesh and they are known only from their respective type localities (Rao and Hajra 1974, Pal and Giri 1998, Sanoj 2011).

Here we describe a new species of *Hedychium*, characterised by more than 1-flowered cincinnus in each bract, from Arunachal Pradesh. The new species shares some morphological features with *H. griersonianum* R.M.Sm., *H. ellipticum* Buch.-Ham. ex Sm., *H. gomezianum* Wall. and *H. yunnanense* Gagnep. *H. griersonianum* is known so far from only its type locality in Bhutan (Fig. 1, Table 1). *H. ellipticum* is one of the widely distributed species with a large variation in its morphology. *H. gomezianum* is

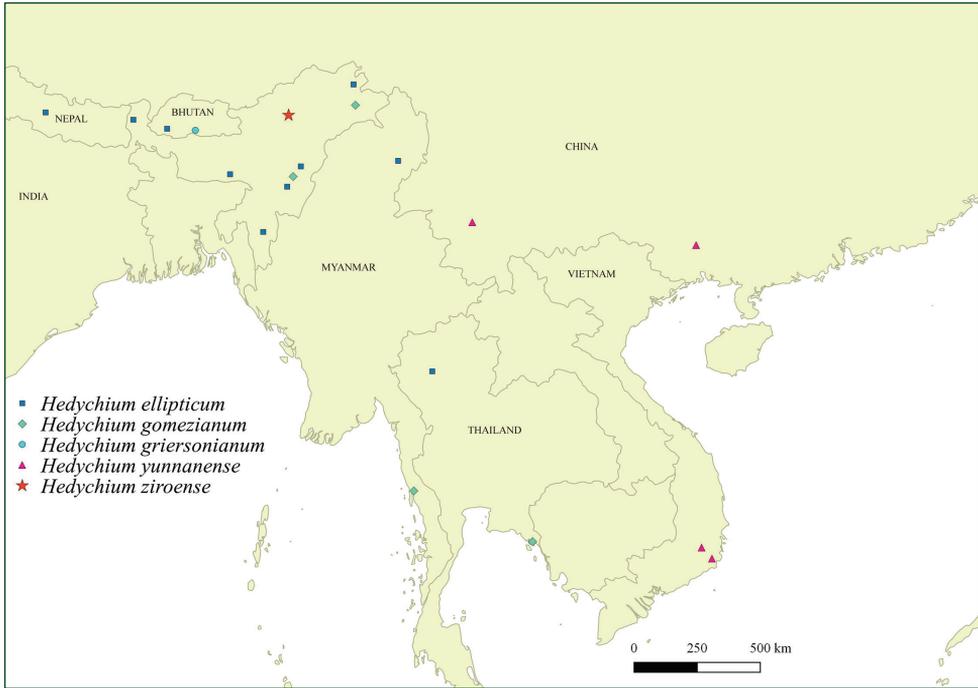


Figure 1. Distribution of *Hedychium ellipticum*, *H. gomezianum*, *H. griersonianum*, *H. yunnanense* and *H. ziroense* sp. nov. in the Indian subcontinent, China and Southeast Asia.

distributed in Myanmar, NE India and Thailand. *H. yunnanense* is native to Southwest China and Vietnam. All the aforementioned species are characterised by 1-flowered cincinnus in each bract (scarcely two flowers appearing per bract even though the whole inflorescence never completely deviates from the 1-flowered cincinnus structure).

Materials and methods

Field collection trips were planned and conducted in August and September 2017 in selected regions within the state of Arunachal Pradesh. Metadata collection included scoring of morphological, phenological as well as ecological characters. Morphological measurements were taken using both ruler and digital calipers. Collections included herbarium and spirit samples and leaf tissues in silica for further molecular studies.

All *Hedychium* protologues were examined including monographs and revisions; Koenig 1783, Smith 1811, Roscoe 1828, Wallich 1853, Horaninow 1862, Baker 1892, Schumann 1904, Naik and Panigrahi 1961, Rao and Verma 1969, Srivastava 1984, Smith 1991, Sirirugsa and Larsen 1995, Wu and Larsen 2000, Sanoj 2011, Wongsuwan and Picheansoonthon 2011, Thomas 2015). Herbarium collections, including type specimens, were consulted at ARUN, ASSAM, BHPL, BO, BSA, BSHC, BSI, CAL, MH, QBG, SING, TBGT and in online databases (Global Plants: <https://>

plants.jstor.org/; Kew Herbarium Catalogue: <http://apps.kew.org/herbcat/>; Muséum national d'Histoire naturelle: <https://science.mnhn.fr/>; Smithsonian Institution: <https://www.si.edu/>; The Linnean Collections: <http://linnean-online.org/>; Zingiberaceae Resource Centre: <http://padme.rbge.org.uk/ZRC/>; see Appendix 1).

The conservation status for the new species was evaluated according to the International Union for Conservation of Nature (IUCN) guidelines (2017).

Taxonomic treatment

Hedychium ziroense V.Gowda & Ashokan, sp. nov.

urn:lsid:ipni.org:names:60478024-2

Fig. 2

Diagnosis. Based on inflorescence shape and floral characters such as flower colour, relative length of filament to the labellum, relative length of corolla lobes to lateral staminodes and labellum, *Hedychium ziroense* V.Gowda & Ashokan, sp. nov. is morphologically similar to *H. griersonianum* R.M.Sm., *H. ellipticum* Buch.-Ham. ex Sm., *H. gomezianum* Wall. and *H. yunnanense* Gagnep., but it can be easily distinguished from the aforementioned species by lamina length (up to 60 cm long in *H. ziroense* vs. 40 cm or less in *H. griersonianum*, *H. ellipticum*, *H. gomezianum* and *H. yunnanense*), bract length (4 cm or more in *H. ziroense* and less than 4 cm in *H. griersonianum*, *H. ellipticum*, *H. gomezianum* and *H. yunnanense*), number of flowers per cincinnus (2–3 flowered in *H. ziroense* vs. 1-flowered in *H. griersonianum*, *H. ellipticum*, *H. gomezianum* and *H. yunnanense*), relative lengths of bract and calyx (bract always longer than calyx in *H. ziroense* vs. bract length equal or less compared to calyx in *H. griersonianum*, *H. ellipticum*, *H. gomezianum* and *H. yunnanense*) and anther colour (orange in *H. ziroense* vs. crimson in *H. griersonianum*, orange-red in *H. ellipticum*, red in both *H. gomezianum* and *H. yunnanense*), (Figs 2, 3 and 4; Table 1).

Type. INDIA. Arunachal Pradesh, Lower Subansiri District, about 5 km before Ziro town along the Itanagar-Ziro road. Terrestrial herbs on the edge of sub-tropical broad-leaved evergreen forest, 27°32'13.19"N, 93°47'35.70"E, 1717 m a.s.l., A. Ashokan, VG2017-AR1989, 08 September 2017 (flowering). Holotype: BHPL!; isotypes: ARUN!, BHPL!, CAL!. Fig. 2.

Description. Terrestrial, rhizomatous herb up to 1.6 m tall; rhizome branching parallel to leaf distichy, pale brown externally, creamy white internally; leafy shoot slanting with an erect inflorescence; basal sheath pinkish-red. Leaves subsessile; sheath purplish-red; ligule 1.8–2.3 cm wide, ovate, glabrous, purplish-red; lamina 35–60 × 13–17 cm, elliptic-lanceolate, glabrous, dark green (adaxial) and pale green (abaxial); acumen 1.5–3.0 cm long, ends in a small caducous appendage; base rounded, red protrusion at the junction of ligule and leaf base. Inflorescence 16 × 8 cm, dense-spike, erect, cylindrical; rachis pubescent, remains more hidden due

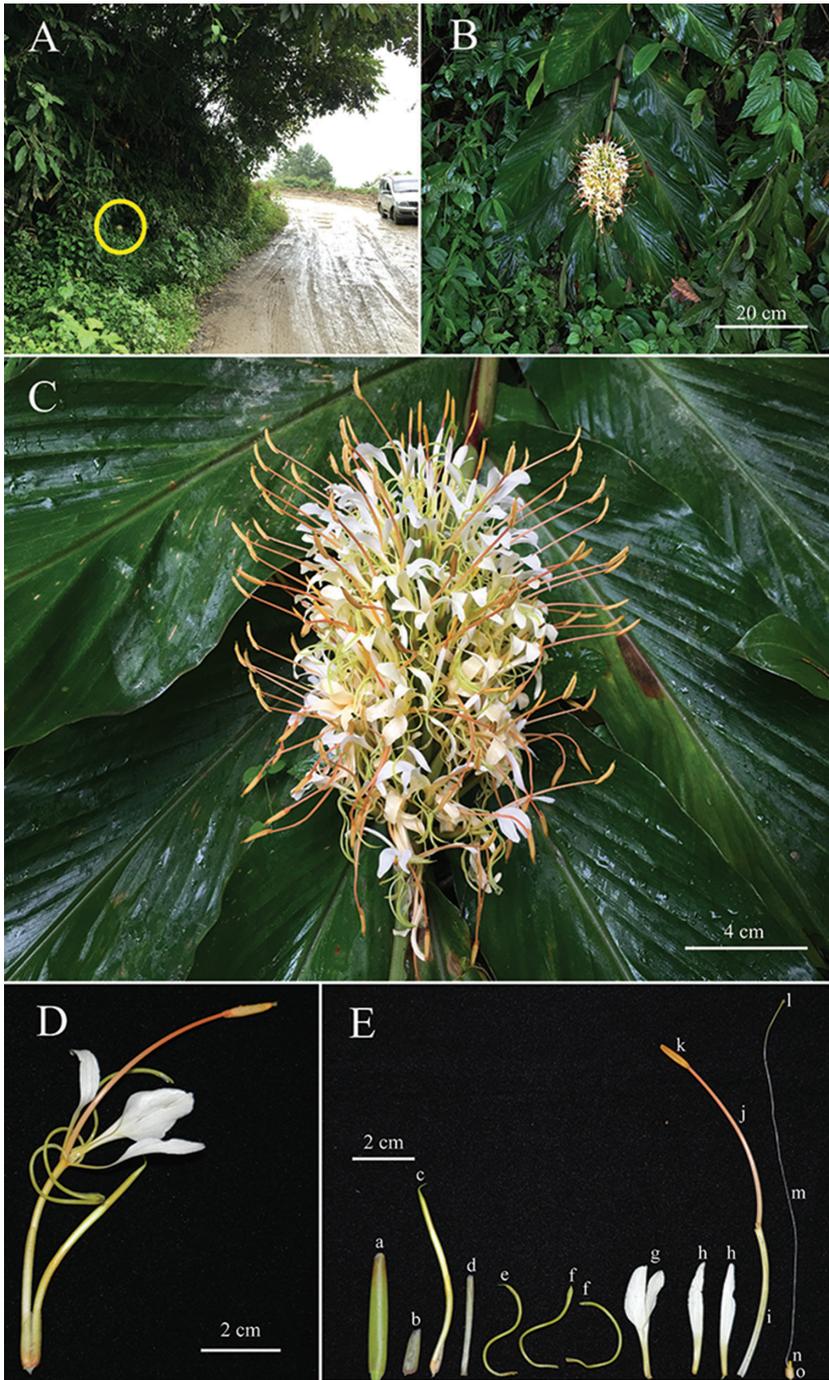


Figure 2. *Hedychium ziroense* V.Gowda & Ashokan, sp. nov. **A** Habitat **B** Habit **C** Inflorescence **D** Flower **E** Floral dissection **a** Bract **b** Bracteole **c** Unopened bud **d** Calyx **e** Dorsal corolla lobe **f** Lateral corolla lobe × 2 **g** Labellum **h** Lateral staminode × 2 **i** Floral tube **j** Filament **k** Anther **l** Stigma **m** Style **n** Epigynous nectary × 2 **o** Ovary. Photographed by Ajith Ashokan.

Table 1. Morphological similarities and dissimilarities of *Hedychium ziroense* sp. nov. with *H. griersonianum*, *H. ellipticum*, *H. gomezianum* and *H. yunnanense*. Amongst the five species, characters that are diagnostic for *H. ziroense* sp. nov. are shown in bold.

Attributes	<i>Hedychium ziroense</i> sp. nov.	<i>H. griersonianum</i> R.M.Sm.	<i>H. ellipticum</i> Buch.-Ham. ex Sm.	<i>H. gomezianum</i> Wall.	<i>H. yunnanense</i> Gagnep.
Literature source for morphological characters	This paper	Smith (1991, 1994)	Smith (1811), Sanoj (2011)	Wallich (1853), Sirirugsa (1991), Sanoj (2011), Wongsuwan and Picheansoonthon (2011)	Gagnepain (1907), Wu and Larsen (2000), MNHN (2018)
Plant height (m)	1.6	1	0.6–1.1	0.5–1.2	0.5–1.0
Lamina size (cm)	35–60 × 13–17	30–35 × 8–10	24–39 × 7–15	34–37 × 5.5–7.5	20–40 × 10
Inflorescence type	cylindrical	elongate spike; elliptical	elliptical	cylindrical	cylindrical
Inflorescence density	dense	dense	dense	lax	lax
Inflorescence length (cm)	16	12	4–10	5–20	15–20
Bract type	folded; involute	imbricating	imbricating	folded; involute	folded; involute
Bract shape	elliptic	oblong	elliptic	elliptic	lanceolate
Bract indumentum (adaxial)	absent	absent	absent	present	absent
Bract size (cm)	4.0–4.5 × 1.0–1.2	1.0–2.0 × 0.5–0.8	1.5–3.2 × 1.0–3.0	2.8–3.1 × 0.9–1.1	1.5–2.5
Bracteole size (cm)	1.0–1.5	1.0	0.9–1.2	1.0–1.3	1.2–1.8
Number of flowers per cincinnus	2–3	1	1	1	1
Calyx length (cm)	2.8–3.2	2.0–2.5	1.7–3.2	2.7–3.0	1.7–2.8
Floral tube length (cm)	4.7–5.0	3.5–4.0	4.0–7.0	3.0–4.8	3.5–5.0
Corolla lobe length (cm)	4.0–4.5	2.5–3.5	2.8–5.6	4.0–4.5	2.5–3.0
Lateral staminode shape	narrowly oblanceolate	narrowly elliptic	spatulate	narrowly oblanceolate	oblong-linear
Lateral staminode length (cm)	3.5–4.0	1.5–1.8	2.5–5.0	3.1–3.2	2.2–2.9
Labellum shape	elliptic	elliptic	spatulate	oblanceolate	obovate
Labellum length (cm)	3.5–4.0	1.0–1.3	2.1–4.0	2.6–2.7	2.0–2.5
Labellum sinus depth	½ or more the length of labellum	⅓ the length of labellum	less than ⅓ the length of labellum	less than ½ the length of labellum	½ the length of labellum
Filament length (cm)	5.5–6.0	2.5–3.0	4.0–7.0	3.5–4.0	3.5–4.2
Anther colour	orange	crimson	orange-red	red	red
Anther length (cm)	0.9–1.2	0.6–1.0	1.6–1.8	1.0–1.5	1.0–1.2
Flowering	August–September	June–July	June–August	July–August	July–September
Elevation (m)	>1700	1100	305–2440	500–1700	2000–3000
Distribution	Arunachal Pradesh	Bhutan	Nepal, Bhutan, NE India, China, Myanmar	NE India, Myanmar, Thailand	China, Vietnam

to overcrowding of bracts and flowers; bracts 4.0–4.5 × 1.0–1.2 cm, elliptic, glabrous, green, tinged with red, folded, involute, 2–3 flowered; bracteoles 1.0–1.5 cm long, tubular, pubescent, greenish-red. Flowers 11.5–12.5 cm long, ascending, white (when fresh), turn creamy white the next day, many flowers open simultaneously, mildly fragrant in the daytime and strongly fragrant at night; calyx 2.8–3.2 cm long, tubular, translucent, 3-toothed, slightly hairy at tip; floral tube 4.7–5.0 cm long, glabrous, curved, greenish-yellow; corolla lobes linear, curled, orientated downwards, glabrous, light green; dorsal lobe 4.2–4.5 cm long, linear, curled, glabrous, beaked at tip, embracing the filament and anther in the bud stage, light green; lateral lobes 4.0–4.3 cm long, linear, curled (single curl), non-beaked at tip, glabrous, light green; lateral staminodes 3.5–4.0 cm long, widest part 0.5 cm, narrowly oblanceolate, one edge linear, obtuse, unguiculate, upper halves reflexed backwards, positioned acute (< 70°) with respect to labellum, white, light yellow towards base; labellum 3.5–4.0 × 1.0–1.5 cm, elliptic, glabrous, white with light yellow blotch, deeply bilobed, canaliculate, gradually clawed; lobes acute, upper halves reflexed backwards; sinus 1.5–2 cm deep; claw 1.0–1.3 × 0.2–0.3 cm; filament 5.5–6.0 cm long, slightly arching, deeply grooved on one side, pale orange, bright orange towards tip; anther 0.9–1.2 cm long, linear, basifixed, orange; thecae 2, split longitudinally; connective 0.1–0.2 cm long, bright orange; stigma 0.1 cm wide, cup-shaped, hairy at tip, exerted from the anther by at least 0.1 cm, green; style 11.5–12 cm long, filiform, white, greenish towards tip; epigynous nectaries 0.2–0.25 cm long, glabrous, yellow; ovary 0.3–0.4 × 0.2–0.4 cm, barrel-shaped, pubescent, creamy orange externally; placentation axile; ovules spherical, creamy white. Fruit not seen.

Distribution and habitat. This species is known only from collection along road banks on the Itanagar-Ziro road, Lower Subansiri District, Arunachal Pradesh at an elevation of more than 1700 m.

Phenology and ecology. Flowering from August to September. Flowers mildly fragrant during the day and prominently fragrant at night indicating that this species may be pollinated by nocturnal pollinators.

Sub-tropical broad-leaved evergreen forest; canopy partially shaded; soil black, clay loam; Average temperature: 25 ± 2 °C; Humidity: > 98%; Average rainfall: ~3000 mm.

Other *Hedychium* in the vicinity: *H. coccineum* Buch.-Ham. ex Sm., *H. speciosum* var. *gardnerianum* (Ker Gawl.) Sanj and M.Sabu, *H. stenopetalum* Lodd. and *H. wardii* C.E.C.Fisch. Except for some *H. speciosum* var. *gardnerianum*, all other *Hedychium* were fruiting at the time of collection.

Etymology and vernacular name. The specific epithet, “*ziroense*”, is derived from the type locality ‘Ziro’, the closest town to where the species was found. The town of Ziro is the headquarters of Lower Subansiri District, Arunachal Pradesh. *Ziro* is also the name of the native tribal inhabitants of the valley much before the arrival and subsequent colonisation of Apatani tribe (Ngunu Ziro pers. com.). In Apatani language, members of *Hedychium* are known by the common name “papi” (Bouchery 2016).

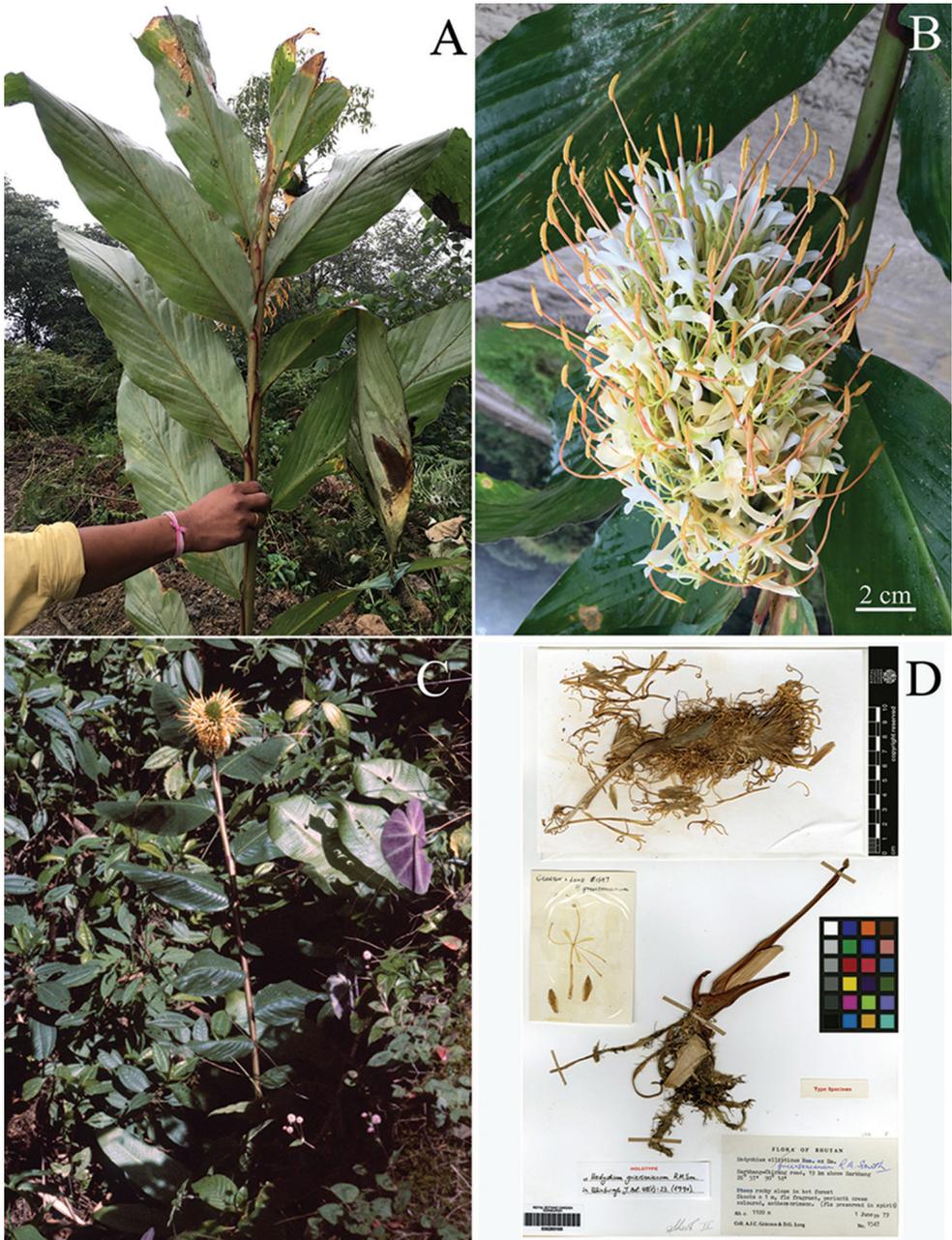


Figure 3. Comparison of *Hedychium ziroense* and *H. griersonianum*. **A, B** Shoot and inflorescence of *H. ziroense* sp. nov. **C** *H. griersonianum* **D** Holotype of *H. griersonianum* R.M.Sm. Photo Credits: **A, B** Ajith Ashokan **C** Andrew Grierson. © Royal Botanic Garden Edinburgh 2018; **D** <http://data.rbge.org.uk/herb/E00265100> © Royal Botanic Garden Edinburgh 2018.

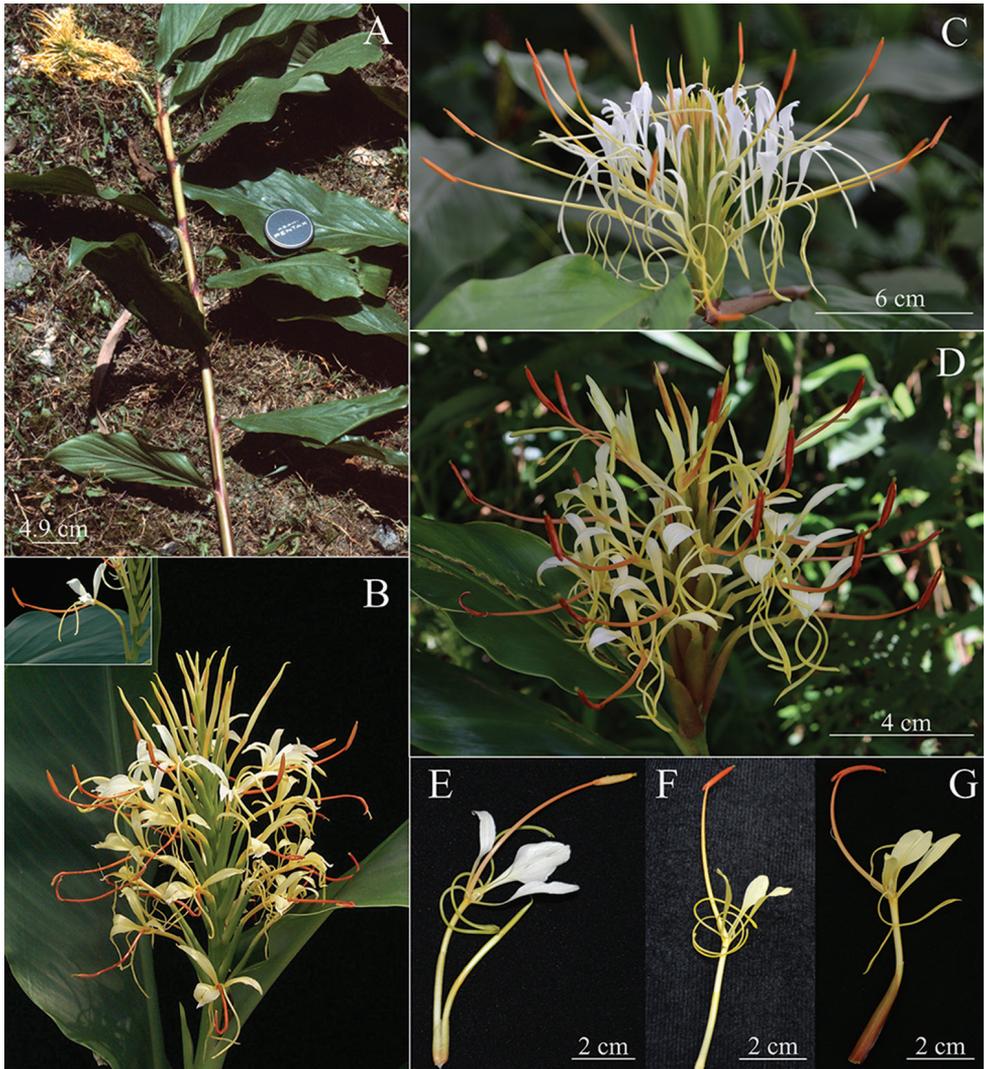


Figure 4. **A** *Hedychium griersonianum* **B** Inflorescence of *H. yunnanense* (flower in the inset) **C** Inflorescence of *H. ellipticum* **D** Inflorescence of *H. gomezianum* **E** Flower of *H. ziroense* **F** Flower of *H. ellipticum* **G** Flower of *H. gomezianum*. Photo Credits: **A** Andrew Grierson. © Royal Botanic Garden Edinburgh 2018; **B** Leslie Brothers. © United States National Herbarium (US); **C, E, A** Ajith Ashokan; **D, F, G** Preeti Saryan.

Conservation status and IUCN preliminary assessment. At the time of collection, the area comprising this population was under threat due to the ongoing resurfacing and widening of the Ziro-Hapoli-Yazali-Kimin road. As this species is known only from the type locality, we categorise it as data deficient (DD) following the IUCN guidelines (IUCN Standards and Petitions Subcommittee 2017).

Acknowledgements

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Appendix I

List of specimens examined for *Hedychium ziroense* sp. nov., *H. griersonianum*, *H. ellipticum*, *H. gomezianum* and *H. yunnanense*. Specimens from the Royal Botanic Garden Edinburgh (E), Royal Botanic Gardens, Kew (K), Linnean Society of London (LINN) and Muséum national d'Histoire naturelle (P) refer to high-resolution digital images of specimens that were examined in this study.

Species	Specimen(s) examined with collector and collection information.
<i>Hedychium ziroense</i> V.Gowda & Ashokan, sp. nov.	INDIA. Arunachal Pradesh, Lower Subansiri District, about 5 km before Ziro town along the Itanagar-Ziro road, 27°32'13.19"N, 93°47'35.70"E, 1717 m a.s.l., A.Ashokan VG2017-AR1989, 08 September 2017; 27°31'57.97"N, 93°47'43.35"E, 1782 m a.s.l., A.Ashokan VG2018007, 25 August 2018 (BHPL).
<i>H. griersonianum</i> R.M.Sm.	BHUTAN. Sarbhang, 01 June 1979, A. J. C. Grierson & D. G. Long 1547 (E, K); Chukka, 03 July 1914, R. E. Cooper 1152 (E).
<i>H. ellipticum</i> Buch.-Ham. ex Sm.	NEPAL. Narainhetty, 28 July 1902, F. Buchanan-Hamilton 8.31 (LINN); INDIA. Arunachal Pradesh, Lower Subansiri District, Jara, 17 September 1983, G. D. Pal 591 (ARUN!); Meghalaya, Khasi & Jaintia Hills, Barapani, 3500 ft., 28 June 1922, U. Kanjilal 7731 (ASSAM!); Manipur, Senapati District, Taphou Hills, 23 July 2016, N. Sarangthem VC2016c (BHPL).
<i>H. gomezianum</i> Wall.	MYANMAR. Mergui, N. Wallich 6543 (K); THAILAND. Peninsular: Khao Khlong Yang at Khao Phra Mi, 06 July 1979, K. Larsen 30649 (E); Ranong, Pra Part Beach, 18 July 1979, C. Niyomdham 349 (E); INDIA. Arunachal Pradesh, Anjaw District, Pomagam, 1500 m., 20 October 2010, R. Gogoi 21543 (ARUN!); West Kameng District, Tenga Valley, 05 September 2017, A. Ashokan VG-AR1971 (BHPL); Manipur, Senapati District, Taphou Hills, 01 August 2017, P. Saryan VG-MN1751 (BHPL); Ukhrul District, 25 August 2017, A. Ashokan VG-MN1926 (BHPL); Nagaland, Kohima, 31 August 2017, A. Ashokan VG-AR1949 (BHPL).
<i>H. yunnanense</i> Gagnep.	CHINA. Yunnan, 24 July 1902, J. Beauvais 1284 (P); Yunnan, July 1912, G. Forrest 8708 (E); Yunnan, E. E. Maire 659 (E); VIETNAM. Dalat, 15 July 1924, F. Evrard 1039 (P); Tonkin, km 15 du col de Lô Qui Hô près Chapa, 28 July 1926, E. Poilane 12637 (P).

Dacar Cas/Somali Red Aloe: a new species of *Aloe* (Asphodelaceae) from Somaliland

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Abstract

A new species of *Aloe* (*Asphodelaceae*) is described from Somaliland. It differs from other species in forming large clumps and in having sap that is initially yellow but quickly turns bright red and then dark red or reddish-brown, paniculate red-flowered inflorescences and uniformly coloured leaves with red teeth. Its recognition raises the number of species known from the combined area of Somaliland and Somalia s.s. from 31 to 36. A map portraying species density of *Aloe* by country, as that genus is now interpreted, shows that *Aloe* has its highest density on islands in the Indian Ocean but that, within Africa, the greatest density is in countries along the eastern highlands. The data also reinforce the importance of field botanists in determining a country's known plant diversity.

Keywords

Asparagales, species density, Africa

Introduction

The genus *Aloe* L. (*Asphodelaceae*) includes over 600 species, all native to Africa, islands in the western Indian Ocean or the Arabian Peninsula (Newton 2004; Carter et al. 2011; Klopper and Smith 2013). Its members are succulent plants with densely packed, spirally arranged leaves. They vary from stemless to having horizontal or vertical stems. The inflorescences vary from racemes to panicles with branches bearing spirally arranged pedicellate flowers that vary from being well-spaced to densely packed and distally concentrated.

The flowers have a tubular perianth that is usually red to pink or scarlet but may be yellow, yellow-green or almost white. There are six stamens and a single gynoecium composed of three united carpels with many ovules. In most species, the fruits are capsules but a few form berries. Almost all species are considered to have medicinal and/or cosmetic value, but a few are poisonous. Only one, *A. vera* L., is widely cultivated. Because the species are often important to local people, there is considerable interest in the relationship among their use, distribution and phylogenetic relationships. This has resulted in publication of revisionary (Sebsebe and Nordal 2010; Klopper et al. 2012; Ruch et al. 2013; Klopper 2015; Cole and Forrest 2017) and phylogenetic (Grace et al. 2015) studies of the genus, plus development of an international database (Aloes of the World 2018) that enables easy visualisation of the distribution of the species richness by country.

Somaliland, which declared its independence from Somalia s.l. in 1991, lies along the south side of the Gulf of Aden. Its flora is treated in the "Flora of Somalia" (Thulin 1993, 1995, 1999, 2006) which was begun in 1988 (Thulin 1993, preface), before the breakdown of the central Somali government. In volume 4 of the "Flora of Somalia", Lavranos (1995) recognised 31 species of *Aloe*, all of them collected before 1990. In 1988, the unrest that eventually led to the breakdown of the central Somali government made botanical exploration challenging but, after its unilateral declaration of independence, Somaliland achieved a degree of peace and stability that, among other things, encouraged renewed exploration of its flora and fauna. This resulted in the addition of three previously undescribed species of *Aloe* to the country's flora [*A. orlandi* Lavranos (Orlando 2003), *A. rubrodonta* T.A.McCoy & Lavranos and *A. kahinii* T.A.McCoy & Lavranos (McCoy and Lavranos 2007)] which were included in the appendices of the final two volumes of the flora to be published (Thulin 1999, 2006). A fourth species, *A. nugalensis* Thulin, was described later (Thulin 2012) based on plants grown from seeds collected in 1985. In this paper, we describe a fifth species, so far known only from Somaliland, locally known as "Dacar Cas" or "Red Aloe" but which we refer to, in English, as the Somali Red Aloe to distinguish it from the species currently associated with the English name "Red Aloe", *A. cameronii* Hemsl. We also re-examined the distribution of *Aloe*, being interested in the extent to which recent discoveries have modified the information provided by Newton (2004).

Materials and methods

In 2014, Awale noticed an *Aloe* growing alongside a road near Alala Adka (Alaala Cadka) [Names are shown in English, followed by the Somali name in parentheses], Marodi Jeh (Maroodi Jeex) Region, Somaliland, that was unlike other native species in the area in forming large, dense patches (Fig. 1). They also differed from other *Aloe* species in the region in having leaves with reddish teeth and, when cut, an exudate that rapidly turns from yellow to bright red. Local people had also noticed the plants, referring to them as "Da'ar As (Dacar Cas), or Red Aloe, to distinguish them from other Aloes in the region, such as Da'ar Buduk (Dacar Budhuq), the name used locally for *A. retrospiciens* Reynolds.



Figure 1. *Aloe sanguinalis* at Alala Adka showing the largest clump in October 2016.

In October 2016, Awale and Barkworth visited the Alala Adka site to take photographs and make measurements. The location is a treeless plain in the Oogo ecological zone (Ibrahim 2010), dominated by shrubs and showing signs of overgrazing (Fig. 1). Unfortunately, no flowers were present. Despite this, they attempted to determine the scientific name of the plants using "Flora of Somalia" (Lavranos 1995; Thulin 1999, 2006) but none of the descriptions fitted, nor did those of other publications consulted, such as Ruch et al. (2013). They sent images of the plants to Mats Thulin, the late John Lavranos and Tom McCoy, three individuals highly respected for their knowledge of the region's flora, Lavranos and McCoy being the second and third most prolific describers of *Aloe* species (Klopper and Smith 2013). All stated that the images sent were not of a species with which they were familiar and advised returning when the plants were in flower, partly to enable preparation of a complete description, but also to investigate the possibility that the plants were hybrids.

In May 2017, Awale and Barkworth revisited the site and found flowers. They prepared specimens, recorded measurements and took photographs both in the field and in the herbarium (Fig. 2). Awale also collected cuttings to grow and observe in Hargeisa. The flowers were protandrous, forming plump, well-filled anthers that matured before the styles had fully elongated. Both the anthers and the styles appeared fully functional. These observations made it unlikely that the plants were hybrids.

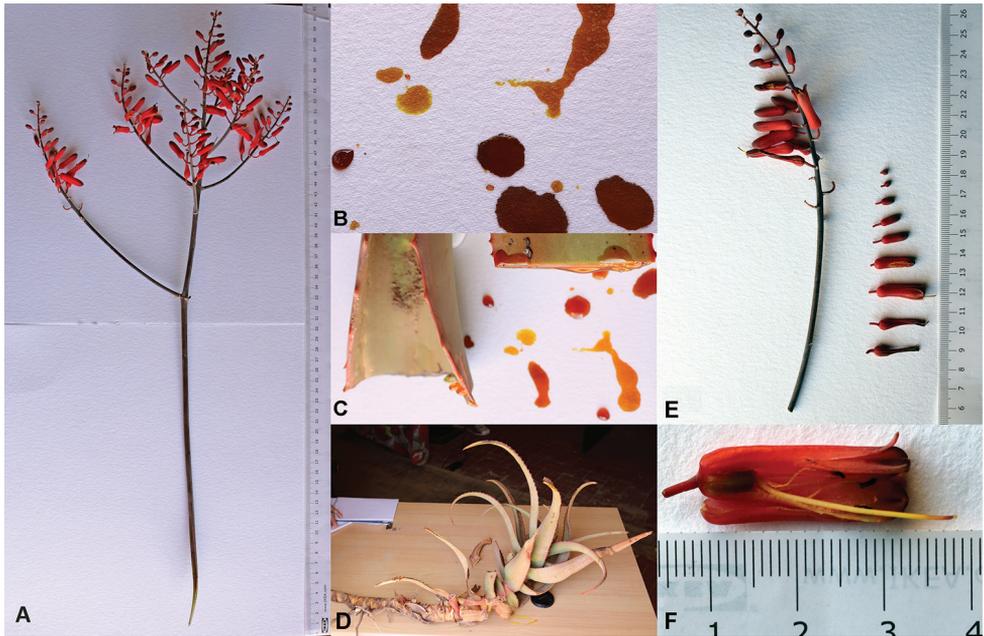


Figure 2. *Aloe sanguinalis* from Alala Adka, June 2017. **A** Whole inflorescence, including peduncle **B** Sap, showing color after 10–15 minutes **C** Leaves freshly cut near their base showing color of sap when fresh **D** Decumbent offset, showing roots from some nodes **E** Inflorescence branch and flowers from another branch, arranged from top to bottom of the branch **F** Flower after maturation of style.

In January 2018, Awale discovered another population growing near Lafarug (Lafaruug), in Sahil (Saaxil) Region, alongside the road to Hiin-Weyne village. Later that month, Barkworth and Awale revisited the location to learn more about the plants there and to make measurements. Lafarug is in the subcoastal area below the Golis escarpment and has sandy soil with semi-desert vegetation that includes *Vachellia tortilis* (Forssk.) Galasso & Banfi, *Dobera glabra* (Forssk.) Poir., *Salvadora persica* L., *Indigofera sparteola* Chiov. and *Commiphora* Jacq. (Fig. 3A). There were no flowering inflorescences in January but some old ones were collected and examined for seeds. Awale revisited the site in June 2018, at which time the plants were in flower (Fig. 3B), and again in August 2018. During the August trip, he collected seeds.

Most capsules collected in January at Alala Adka had no seeds; none had more than 3. Capsules collected from the Lafarug population in August 2018 had several seeds. A total of about 50 seeds from the Lafarug area were planted in a pot and kept moist. By November 2018, 12 had germinated and one had developed three leaves (Fig. 4).

Based on the comments by Thulin, Lavranos and McCoy and the apparent functionality of the anthers and styles, we proposed recognising the Somali Red Aloe as a new species in July but, at the urging of the reviewers, Barkworth reviewed all the *Aloe* images made available by the Royal Botanical Gardens, Kew (Kew 2018), specimens in the herbarium of the Missouri Botanical Garden and, together with Gelle, those in the East African Herbarium of National Museums, Kenya. Because many of the distinguish-

ing features of Aloes are poorly preserved in herbarium specimens, we also reviewed the species descriptions for specimens that could not, based on the herbarium specimens seen, readily be distinguished from the Somali Red Aloe. These studies supported our earlier conclusion that the Somali Red Aloe should be described as a new species. In preparing the description, we have used terminology that is consistent with Klopper et al. (2013) but avoided use of the term “raceme” because of inconsistencies in how it is used [compare, for example, Klopper et al. 2013 with Harris and Harris (2001) and Beentje (2016)].

To examine current knowledge about the distribution of species richness in Aloe, we updated Newton’s table with data from multiple sources [(Reynolds 1954; Klopper et al. 2012; Ruch et al. 2013; Rakotoarisoa et al. 2014; Klopper 2015; Rakotoarisoa and Grace 2017; Cole and Forrest 2017; Aloes of the World (2018)] and calculated the number of species per km². In doing so, we used the current interpretation of *Aloe* which excludes *Aloidendron* (A. Berger) Klopper & Gideon F. Sm., *Aloiampelos* Klopper & Gideon F. Sm. and other small genera previously included in it.

Taxonomic treatment

Aloe sanguinalis Awale & Barkworth, sp. nov.

urn:lsid:ipni.org:names:60478025-2

Figures 1–4

Type. SOMALILAND. Marodi Jeh (Maroodi Jeex), Hargeysa, Alala Adka, 15–20 km west of the town of Da’ar Buduk (Dacar Budhuq). Elevation 950 m, 9.8705N, 44.3761E (WGS84), 24 May 2017, *Mary E. Barkworth S17.001*, *Ahmed Ibrahim Awale*, *Garrett Billings* and *Helen Pickering* (holotype: HARG).

Diagnosis. *Aloe sanguinalis* differs from other species of *Aloe* in its combination of sap that is initially yellow but quickly turns bright red, drying to dark red or brownish-red, strong clump-forming habit, red teeth and paniculate inflorescence of well-spaced glabrous, red flowers.

Description. Plants with decumbent stems, rooting at the lower nodes, forming clumps 1–10(–40) m long in their longest direction; stems leafy, the terminal 50–100 cm vertical. Leaves 30–40 cm long, 5–8 cm wide at the base, lanceolate, evenly blue-green on both surfaces when young, becoming suffused with reddish colouration at the margins and the distal portion of their upper surfaces with age, crescent-shaped in cross-section when dry; margins with sharp red teeth 4–6 mm long spaced 1–3 cm apart near the base of the leaves, closer together towards the leaf tips; sap yellow when fresh, rapidly becoming bright red, drying to dark red or brownish-red, without a noticeable odour. Inflorescences paniculate, 70–120 cm long (including peduncle), 20–75 cm long (excluding peduncle), lower primary branches (15–)23–50 cm long, ascending to arcuate, often with 1(–2) secondary branches, flowers confined to the distal 1/2–3/4 of the branches, pedicellate and spirally arranged, not secund, distance between lowest flowers 5–11 mm; bracts subtending the pedicels 5–9 mm long, narrowly triangular; pedicels about 10 mm long, not elongating in fruit; perianths (including lobes) 20–25 mm long,



Figure 3. *Aloe sanguinalis* at Lafarug. **A** One of the larger clumps, with Awale, in January 2018 **B** Inflorescence of *Aloe sanguinalis* at Lafarug, June 2018.

red, glabrous; outer perianth lobes 10–15 mm long, slightly recurved distally, with narrow, hyaline, minutely erose margins; stamens 6, the anthers versatile, ca. 2 mm long, extending about 1 mm beyond the perianth at anthesis but the perianth extending 3–5 mm beyond the anthers as the style matures; ovary superior, with many ovules, stigma exerted 5–9 mm beyond the perianth at maturity. Capsules 15–20(–25 mm) long, 13–20 in diameter, ovoid, woody; seeds winged, 5–11 mm across (including the papery wing), triangular-pyramidal, outer surfaces ca. 1 mm across.

Distinguishing features. *Aloe sanguinalis* caught Awale’s attention by the large size of its clumps but its most distinctive feature appears to be the colour of its sap (Fig. 2) which is yellow, quickly turning bright red, then drying dark red or brownish-red. The difficulty is that none of the descriptions in the "Flora of Somalia" refer to sap colour. Carter et al. (2011) mention sap features, usually colour, but for only 186 of the 517 species treated. In most species, the colour is described as some variant of yellow, but *A. rabaiensis* Rendle has sap described as “yellow, drying red” and *A. volkensii*, sap described as “yellow, drying dark reddish”. *Aloe rabaiensis* is a shrubby aloe which differs from *A. sanguinalis* in having flowers in “sub-capitate to capitate” clusters (Carter et al. 2011, p. 633). It extends from Tanzania to southern Somalia s.s. *Aloe volkensii* Engl. is a tree aloe described as having densely flowered, “subcapitate to cylindrical-conical” flower clusters. It is known from south-eastern Kenya and north-eastern Tanzania (Carter et al. 2011, p. 691).

There were 16 other species described as having sap that dries purplish or reddish-brown. Of them, none is known from Somaliland, but *A. gillettii* S. Carter grows in Puntland, Somalia “on limestone with *Juniperus* in open *Commiphora* bushland” (Lavranos 1995, p. 40), a different habitat from that of *A. sanguinalis*. *Aloe gillettii* also differs from *A. sanguinalis* in having “dark grey-green leaves with very numerous white spots” and “white, cartilaginous teeth to 1 mm long” (loc. sic). The other species would also be ruled out by the description given.

There are other clump-forming species in Somaliland and Somalia but none, so far as we are aware, that forms such large clumps. Again, the difficulty is that existing descriptions merely refer to forming small or large clumps.



Figure 4. Seedling of *Aloe sanguinalis*, grown from seeds collected at Lafarug in August 2018.

Distribution. *Aloe sanguinalis* is currently known from only two locations, the type locality near Alala Adka and a more northern locality at 9.9840N, 44.8195E near the village of Lafarug. Larajasse (1897, p. 25), a Catholic missionary based in Berbera from 1888–1903, stated that “da’ar” refers to bile or an “aloe about three feet high, red and orange varieties, broad spiked fleshy leaves, spreading out from the ground; is a favorite food of elephants.” It seems probable, considering the species known from the area, that he was referring to *A. sanguinalis*. Elephants have not been seen in Somaliland since 1958.

Habitat and ecology. The two known locations of *Aloe sanguinalis* are open plains with sandy soils in which, among other species, *Salvadora persica* and *Indigofera sparteola* grow. The Alala Adka location is treeless but there are scattered *Vachellia tortilis* trees at the Lafarug site.

Phenology. Flowering time in *Aloe sanguinalis* is probably determined by the timing of the spring rains which fall between late March and early June. The optimum time for seed collection has not been determined, but it is likely to be July to September.

Etymology. The epithet is derived from *sanguineus*, Latin for blood, and refers to the colour of the sap which distinguishes it from all other species in the region.

Comments

Conservation status

The two known populations of *Aloe sanguinalis* do not appear to be under immediate threat. Both areas are used for livestock (goats, camels) grazing but there was no indication that *A. sanguinalis* was being eaten, nor was there any indication that leaves were being over-harvested. Some clumps appear to have been split in two, possibly by grazing animals. Once a path through a clump is established, it is likely to become permanent as the soil will be compacted making seedling and offset establishment more difficult.

At both Alala Adka and Lafarug, there are multiple clumps of *Aloe sanguinalis*. There were some markings on the leaves suggesting that insects might be piercing their surface but otherwise, the plants seemed undamaged. All the plants appeared to be growing on slight mounds in the sandy soil, probably because they protect the soil from being blown away. Offsets from both sites have been planted successfully in Hargeisa.

The largest clumps of *Aloe sanguinalis* were those at the first site, Alala Adka, the largest being about 40 m long and 10 m wide. We estimated that it was composed of about 2500 stems. The clumps at Lafarug were considerably smaller, none that we saw being more than 5 m long in its longest dimension. We do not know what proportion of the vertical stems within a clump represents new individuals rather than established offsets. It seems probable, given the obstacles drought and grazing present to seedlings, that most growth is vegetative. Time constraints precluded a detailed survey of the two sites.

The biggest threat to the species may be the increasing frequency of drought which makes establishment of new plants, whether from seed or offsets, difficult. We saw no seedlings at either location but did not conduct a deliberate search for them within the clumps nor underneath other shrubby vegetation, the locations where they are most likely to become established. Because so little is known about the distribution, phenology, pollination, seed set and reproductive success of *Aloe sanguinalis*, we recommend it be regarded as “data deficient”.

Herbarium studies

Aloe tends to make very poor herbarium specimens. Both leaves and flowers tend to lose their colour, making it essentially impossible to tell from most specimens whether, in life, the leaves were evenly coloured and what colour the leaf margins and teeth had been. Moreover, in many instances, the preserved leaves were much smaller than indicated in the descriptions, collectors tending to collect leaves, or portions of leaves, to fit herbarium sheets. In a few instances, the label contained colour information and notes about the size of the plants and the leaves, but such specimens were exceptional. Despite these restrictions, the images provided by the Royal Botanic Gardens, Kew (Kew 2018) were invaluable. Unfortunately, records from the other herbaria likely to have substantial holdings of *Aloe* from Somaliland and other parts of the Horn of Africa (EA, ETH and UPS; codes from Thiers 2018) are not yet

available on line. In future, we encourage individuals collecting aloes to supplement their specimens with images of the living plants, a suggestion that digital technology has made feasible, and that herbaria mobilise their specimen records using software (for example, Symbiota 2018) that can accommodate multiple images per specimen.

Distribution of species density

Updated information on the number of *Aloe* species present in different countries (Table 1) shows 96 more records than in Newton (2004). although the numbers for a few countries have decreased, probably because of the exclusion of *Aloidendron*, *Aloiampelos* and a few other small genera. The overall increase reflects both recognition of new species and the discovery of known species in additional countries. The highest species densities (Table 1, Fig. 5) are on ocean islands and in countries that are so small that, even if only 1 species is present, the species density is high. Within Africa, the

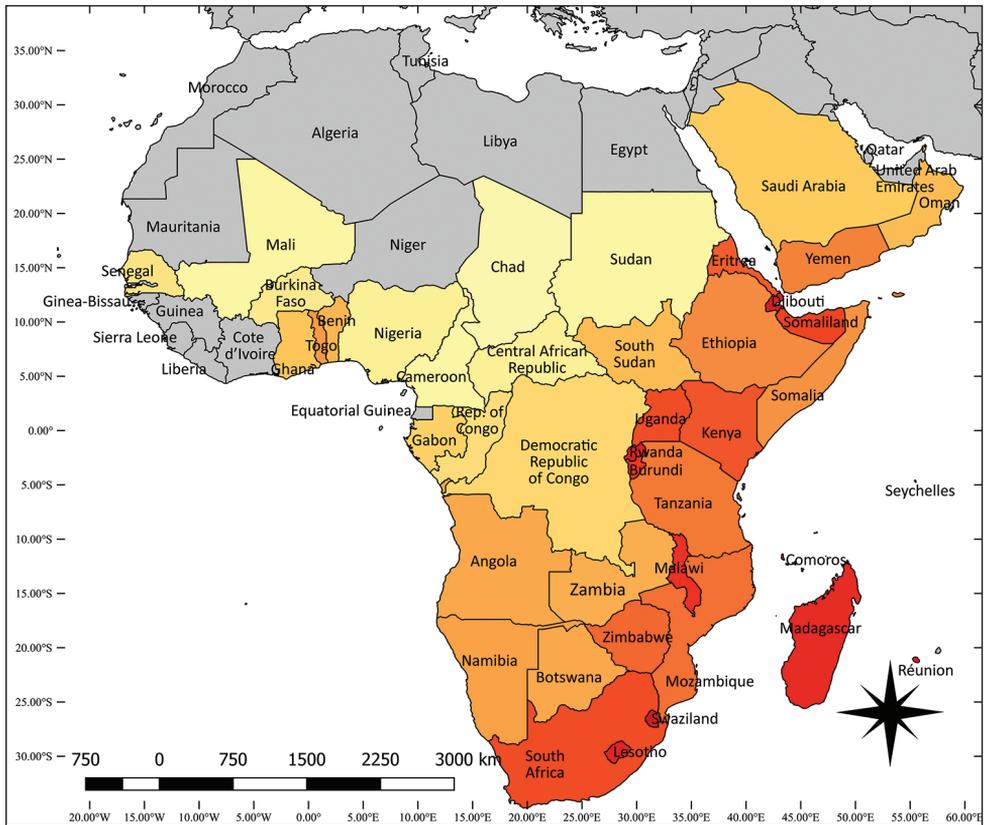


Figure 5. *Aloe* species density by country. Lowest density pale yellow (Chad), deep red (as in Réunion); highest densities are for islands too small to show on map; grey – no species known. See Table 1 for data.

Table 1. *Aloe* L. species richness and density. ND: no data.

Country or Area	Area in km ²	Species Newton (2004)	Species Current	Species Density (species/km ²)
Aldabra	155	1	1	0.006435
Angola	1246799	24	29	0.000023
Benin	110622	3	2	0.000018
Botswana	566730	8	13	0.000023
Burkina Faso	273800	1	1	0.000004
Burundi	25680	1	5	0.000195
Cameroon	472710	1	1	0.000002
Central Africa Republic	622984	ND	2	0.000003
Chad	1259200	ND	1	0.000001
Comoros	2235	1	2	0.000895
Djibouti	23180	ND	7	0.000302
Democratic Republic of Congo	2267048	13	15	0.000007
Eritrea	101000	8	10	0.000099
Ethiopia	1000000	34	45	0.000045
Gabon	257667	ND	2	0.000008
Ghana	227533	3	3	0.000013
Côte d'Ivoire	318003	ND	1	0.000003
Kenya	569140	55	63	0.000111
Lesotho	30355	8	8	0.000264
Madagascar	581540	77	129	0.000222
Malawi	94080	17	19	0.000202
Mali	1220190	3	3	0.000002
Mauritius	2030	2	3	0.001478
Mozambique	780380	25	45	0.000058
Namibia	823290	26	24	0.000029
Nigeria	910768	3	3	0.000003
Oman	309500	5	5	0.000016
Pemba	988	2	2	0.002024
Republic of Congo	341500	ND	2	0.000006
Réunion	2512	1	1	0.000398
Rodrigues	108	1	1	0.009259
Rwanda	24668	4	7	0.000284
Saudi Arabia	2149690	22	23	0.000011
Senegal	192530	ND	1	0.000005
Seychelles	455	1	3	0.006593
Socotra	3665	3	5	0.001364
Somalia s.s.	451217	17	19	0.000042
Somaliland	176120	23	27	0.000153
South Africa	1214470	119	136	0.000112
South Sudan	644329	ND	10	0.000016
Sudan	1861484	ND	4	0.000002
Swaziland	17204	18	29	0.001686
Tanzania	885800	40	50	0.000056
Togo	54385	1	2	0.000037
Uganda	197100	16	22	0.000112
Yemen	527968	26	29	0.000055
Zambia	743398	19	16	0.000022
Zanzibar	1464	2	1	0.000683
Zimbabwe	386847	27	33	0.000085

highest species densities belong to countries of the eastern highlands and coast. The general distribution of species richness is similar to that in Grace et al. (2015), in which the information is related to the genus' phylogenetic history.

Table 1 and the citations used to update it demonstrate that aloes are more likely to be discovered in countries where they are the focus of field botanists fascinated by the genus. This point was brought out even more clearly by Crouch et al. (2013) in their analysis of species discovery, collecting effort and collectors in southern Africa. They conclude that "Further new descriptions are likely to flow from active fieldwork in rugged environments." (Crouch et al. 2013 p. 195). We agree concerning the higher probability of making new discoveries in rugged environments but, as this paper and that describing *A. orlandi* (Lavranos 2006) demonstrate, there are still discoveries to be made in easily accessible habitats. To facilitate research on Somaliland's species, the University of Hargeisa and Somaliland Biodiversity Foundation have established an *ex situ* conservation site in front of the university's Biodiversity Museum. Those interested in collecting aloes and other species in Somaliland should contact the Ministry of Environment and Rural Development to obtain a collecting permit before applying for a visa and well in advance of their planned visit.

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Revision of *Polygonatum* (Asparagaceae, Nolinoideae, Polygonateae) of Taiwan

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Abstract

Polygonatum is widely distributed in the northern hemisphere, especially in eastern Asia. There has been no comprehensive taxonomic study of Taiwanese taxa for some time, and researchers could not agree on a consistent treatment of the genus. Therefore, we revised the genus by literature review and type specimen examination along with comparison of morphology, karyotype and pollen characteristics. Only one species *P. arisanense* Hayata was recognized in this study. *P. chingshuishanianum* Ying and *P. formosanum* (Hayata) Masamune & Simada are regarded as varieties of *P. arisanense* and are here presented as two new combinations, *P. arisanense* var. *chingshuishanianum* and *P. arisanense* var. *formosanum*.

Keywords

new combination, *Polygonatum*, plant taxonomy, Taiwan

Introduction

The genus *Polygonatum* comprises ca. 60 species, distributed in the northern hemisphere, mainly from southwest China to Japan (Chen et al. 2000). Some species, such as *P. sibiricum* Redoute and *P. odoratum* (Mill.) Druce have been cultivated as medical or horticultural crops (Wujisguleng et al. 2012, Tang et al. 2018).

The diagnostic characters of the genus include the presence of rhizomes, single and often arching stem, alternate, opposite, or whorled phyllotaxis, axillary inflorescences with one to several flowers, perianth tubes longer than segments, and berries (Wang et al.

1978; Chen et al 2000; Ying 2000). The basic chromosome number was $x=9-11$ (sect. *Polygonatum*), 12 (sect. *Sibirica*), 13–15 (sect. *Verticillata*) (Floden and Schilling 2018).

The taxonomy of *Polygonatum* on Taiwan has varied significantly depending on the authors since their earliest collections. The first collection of *Polygonatum* in Taiwan was made by Matsumura and Hayata (1906) who reported it as *P. officinale* All. var. *maximowiczii* Franch. & Sav. This record was followed by Hayata (1908) and Kawakami (1910). Later, Hayata (1915) described a new species *P. alte-lobatum* Hayata. These taxa were listed in the plant list of Hayata (1917). Later, Hayata (1920) described two new taxa *P. arisanense* Hayata and *P. officinale* All. var. *formosanum* Hayata, and the earlier record of *P. officinale* var. *maximowiczii* was a misidentification of *P. officinale* var. *formosanum*. Sasaki (1928) followed the example of Hayata (1920) but applied a different name *P. japonica* C. Morren & Decne. var. *formosanum* Hayata. Masamune and Simada (1936) upgraded *P. officinale* var. *formosanum* to species level as *P. formosanum* (Hayata) and this was followed by Masamune (1954). Ying (1969) treated *P. arisanense* and *P. formosanum* as synonyms of *P. cyrtonema* Hua, and described a new species *P. daitonense* Ying in his master's thesis, but without formal publication afterwards. Liu and Ying (1978) listed *P. alte-lobatum* and *P. cyrtonema* in the Flora of Taiwan, 1st edition. Wang et al. (1978) listed three Taiwanese species of *Polygonatum*: *P. alte-lobatum*, *P. arisanense*, and *P. odoratum* (Mill.) Druce. This treatment was followed by Chen et al. (2000). Jeffery (1980) treated *P. arisanense* as a synonym of *P. cyrtonema*. Ying (1988) described a new species *P. chingshuishanianum* Ying from eastern Taiwan. Ying (1990) revised the genus and catalogued three taxa in Taiwan: *P. alte-lobatum*, *P. chingshuishanianum*, and *P. odoratum* (Mill.) Druce var. *pluriflorum* (Miq.) Ohwi. This treatment was also followed by Ying (2000) and Boufford et al. (2003). Wang (1997) studied the karyotype of Polygonateae of Taiwan and recorded two species, *P. altelobatum* and *P. cyrtonema*. The aforementioned *P. chingshuishanianum* was treated as a synonym of *P. altelobatum*. Based on morphological data, Chao et al. (2013) transferred *P. alte-lobatum* to *Heteropolygonatum* M. N. Tamura and Ogisu as a new combination: *H. alte-lobatum* (Hayata) Y. H. Tseng, H. Y. Tzeng and C. T. Chao.

From the history outlined above, it is clear that almost every author proposed their own treatment, and no comprehensive revision has been published. Some taxa, like *P. chingshuishanianum*, were poorly known; very few specimens could be examined in herbaria, and the available specimens, including the type specimen, all lacked floral parts. Therefore, it was deemed that a modern review of *Polygonatum* of Taiwan was necessary. The aims of this study were to elucidate the taxonomic status and circumscription of each taxon, together with their nomenclature and distribution in Taiwan.

Methods

Study materials

The study materials were from herbaria and field collections with at least 3 individuals cultivated for each population. Living materials were cultivated in the greenhouse

of the Department of Forestry, National Chung Hsing University. Voucher specimens (include living ones) were deposited in the herbarium of the National Chung Hsing University (TCF). The following herbaria were examined: CHIA, HAST, KYO, NTUF, PPI, TAI, TAIE, TAIF, TCF, TI, TNM, and TNU. We also retrieved type specimen images of *Polygonatum* from the website of the Muséum National d'Histoire Naturelle (P). Pollen observation and karyotype analysis materials are listed in Table 1.

The floral morphology is important in the taxonomy of *Polygonatum*, and therefore we had to check the flower morphology of living plants, especially *P. chingshuishanianum*, whose floral part was lacking on the type specimen. In order to do this, we visited the type population of *P. chingshuishanianum* for several years, and were only able to capture two anthesis individuals.

Pollen morphology

The pretreatment of the anther followed the method of Halbritter (1998). The anther was dried with a critical point dryer (Quoram E3100). The pollen was taped on to the stub with copper tape, after sputter-coating with gold (Quoram SC7620) and observed by SEM (Hitachi S-3400N). The terminology and description of pollen morphology were in accordance with Punt et al. (2007) and Hesse et al. (2009) while the aperture type classification followed the procedure of Halbritter and Hesse (1993).

Karyotype analysis

Plant materials for karyotype analysis were cultivated in the greenhouse of the Department of Forestry. Root tips were collected in the morning on a sunny day and preserved in 0.002M 8-hydroxyquinoline solution below 10 °C for eight hours. Afterwards, the roots were fixed in Carnoy's solution (glacial acetic acid: 99.5% EtOH, 1:3) at 4 °C overnight. The fixed roots were stained with acetic-orcein overnight, squashed and observed under a light microscope (Accu-Scope 3025 Series). Cells showing good chromosome spreading were photographed with a CCD camera (ProgRes C14 Plus). Karyotype analysis was done according to the procedures of Levan et al. (1964) and Stebbins (1971).

Distribution and conservation rank evaluation

The distribution maps were made by the location of herbaria specimens and our field work. Older specimens were geo-referenced using the study of Huang et al. (1993), and points proximal to written locality were mapped. Classification of geographical climatic regions and altitudinal vegetation zones followed the guidelines of Su (1984, 1985). We used the protocol of the red list of vascular plants of Taiwan, 2017 (editorial committee of red list of vascular plants of Taiwan, 2017) for evaluation of conservation ranks.

Results

Diagnostic characteristics of *Polygonatum*

Leaf

Leaf morphology is an important character for identification of intrageneric taxa of *Polygonatum* (Chen et al. 2000). The leaf shape of *P. arisanense* var. *chingshuishanianum* is lanceolate to oblong lanceolate with obtuse apex (Fig. 7C, D), whereas the leaves of *P. arisanense* var. *arisanense* and *P. arisanense* var. *formosanum* are ovate to ovate-lanceolate with acute and obtuse apexes respectively (Fig. 6C, D, 8C, D). The texture also differs among these taxa. The leaf of *P. arisanense* var. *arisanense* is chartaceous, whereas *P. arisanense* var. *chingshuishanianum* and *P. arisanense* var. *formosanum* have chartaceous to coriaceous leaves.

Rhizome

The Taiwanese taxa all have tuberous rhizomes that are similar in appearance to one another, rather than the terete rhizomes found in *P. odoratum* (Fig. 6B, 7B, 8B).

Inflorescence

The inflorescences of *Polygonatum* species are solitary to multi-flowered umbels, axillary and often pendulous. The three taxa of Taiwan have similar inflorescence forms, but can be distinguished by the number of flowers within an inflorescence. The inflorescences of *P. arisanense* var. *chingshuishanianum* have only one or two flowers, while *P. arisanense* var. *arisanense* and *P. arisanense* var. *formosanum* have (3–)5–7 and 2–3(–5) flowers, respectively (Fig. 6E, 7E, 8E).

Flower

The flowers of the three taxa are typical for *Polygonatum*. The perianth tube of *P. arisanense* var. *chingshuishanianum* is smaller (6–8 mm × 4–5 mm) than the others. Besides, two forms of perianth tube are found among the taxa of Taiwan. The first one is found in *P. arisanense* var. *arisanense*, which have an acute base (less than 90°) (Fig. 6F). The second type is found in *P. arisanense* var. *chingshuishanianum* and *P. arisanense* var. *formosanum*, which have an obtuse to truncate base (more than 90°) (Fig. 7E, 8F).

Pollen morphology

The pollen grains of Taiwanese *Polygonatum* are monosulcate monads of medium size, spheroidal, simple-sulcate aperture type, and the proximal polar view is perforate. The widths of the lumina and the muri are similar among the three taxa. No conspicuous difference is found among them (Table 2, Fig. 1).

Karyotype analysis

The chromosome number of the three taxa is determined to be $2n = 2x = 22$, and the asymmetry type is 2B. The chromosomes exhibited centromeres at the median (m), submedian (sm), and terminal (t) positions. The numbers of each type were slightly

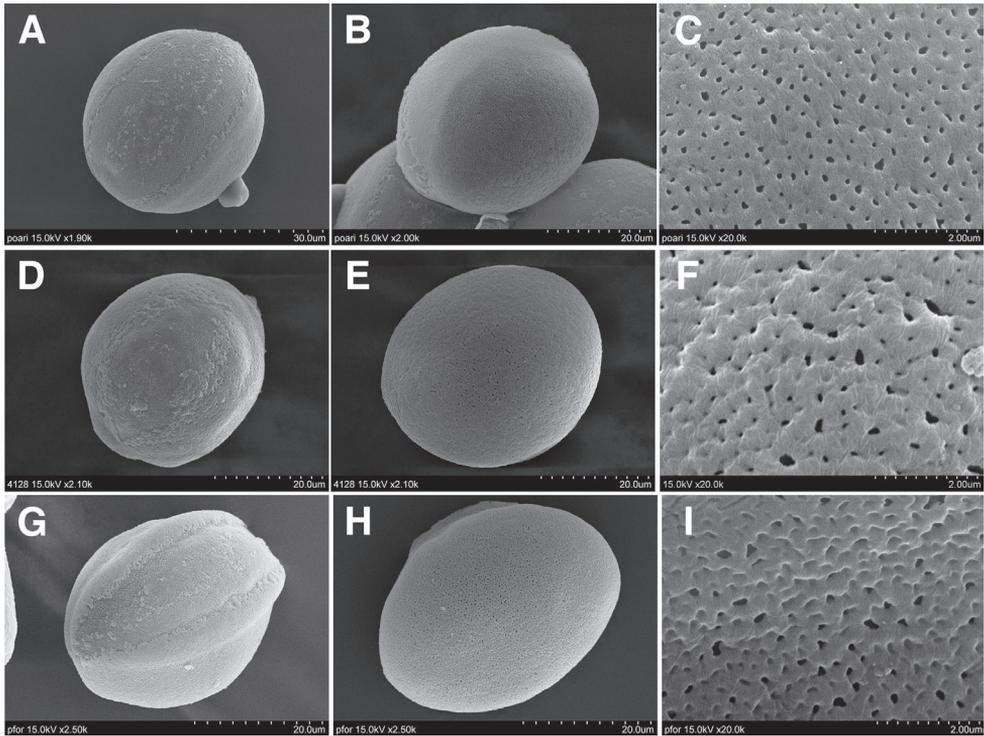


Figure 1. Pollen morphology of *Polygonatum* of Taiwan. **A–C** *P. arisanense* var. *arisanense* **D–E** *P. arisanense* var. *chingshuishanianum* **G–I** *P. arisanense* var. *formosanum* **A, D, G** proximal polar view **B, E, H** distal polar view **C, F, I** sculpture.

Table 1. Materials of pollen and chromosome observation in this study.

Taxa	Location	Coll. no.
<i>Polygonatum arisanense</i> var. <i>arisanense</i>	Nantou county: Hsinyi township, Mt. Chungtashan	Chao 4131
	Pingtung county: Wutai township	Chao 4019
<i>P. arisanense</i> var. <i>chingshuishanianum</i>	Hualien county: Hsiulin township, Mt. Chingshuishan	Chao 4128
<i>P. arisanense</i> var. <i>formosanum</i>	Taipei city: Yangmingshan national park, Mt. Tatun main peak	Chao 4105

different among the varieties, and no secondary constriction was observed. The karyotype formula of *P. arisanense* var. *arisanense* is $2n = 22 = 10m+9sm+3^{st}$, *P. arisanense* var. *chingshuishanianum* is $2n = 22 = 9m+12sm+2^{st}$, and *P. arisanense* var. *formosanum* is $2n = 22 = 10m+10sm+2^{st}$ (Table 3, Fig. 2).

Distribution

The taxa of *Polygonatum* of Taiwan are all endemic, and were found from low to medium altitude in mountainous regions. Compared to other varieties, *P. arisanense* var. *arisanense* has the widest distribution. It grows in most geographical climate zones except for the Lanyu region, the Southeast, the south section of the East region, and oth-

Table 2. Pollen morphology of *Polygonatum* taxa of Taiwan.

Taxa	Equatorial axis (μm)	Polar axis (μm)	P/E	Shape	Size rank	Aperture	Sculpture
<i>P. arisanense</i> var. <i>arisanense</i>	28.03 \pm 0.66	24.07 \pm 0.83	0.86	spheroidal	medium	simple-sulcate	perforate
<i>P. arisanense</i> var. <i>chingshuishanianum</i>	38.03 \pm 3.03	32.81 \pm 3.37	0.86	spheroidal	medium	simple-sulcate	perforate
<i>P. arisanense</i> var. <i>formosanum</i>	40.87 \pm 0.26	31.34 \pm 2.00	0.77	spheroidal	medium	simple-sulcate	perforate

Table 3. Karyotype of *Polygonatum* of Taiwan.

Taxa	Chromosome number	Karyotype formula	Asymmetry type
<i>P. arisanense</i> var. <i>arisanense</i>	22	10m+9sm+3 st	2B
<i>P. arisanense</i> var. <i>chingshuishanianum</i>	22	9m+12sm+2 st	2B
<i>P. arisanense</i> var. <i>formosanum</i>	22	10m+10sm+2 st	2B

er coastal areas. The vertical distribution of this variety is from ca. 300 m up to 2000 m, lower in the northern part of Taiwan. This region is located in the *Ficus-Machilus* zone to lower *Quercus* zone of the altitudinal vegetation zone classified by Su (1984), which had more precipitation and higher relative humidity (Fig. 3). The habitats are often shady with high moisture, under, or in the margin, of a forest.

In contrast, *P. arisanense* var. *chingshuishanianum* and *P. arisanense* var. *formosanum* have very narrow distributions, especially the former. *P. arisanense* var. *chingshuishanianum* is only found in one location, near the summit of Mt. Chingshuishan in Hualien county of eastern Taiwan (Fig. 4). The plants are growing on a limestone slope with full sunlight and thin soil. On the other hand, *P. arisanense* var. *formosanum* is only found in the region of Yangmingshan National Park, a volcanic area in northern Taiwan (Fig. 5). The populations were found from the exposed roadside to the forest habitat.

Conservation rank

In the red list of vascular plants of Taiwan 2017 (editorial committee of the red list of vascular plants of Taiwan, 2017), the conservative rank of *P. chingshuishanianum* (= *P. arisanense* var. *chingshuishanianum*) and *P. odoratum* var. *pluriflorum* (= *P. arisanense* var. *arisanense* and *P. arisanense* var. *formosanum*) was evaluated as data deficient (DD) and of least concern (LC). Here we reevaluate three taxa of *Polygonatum* of Taiwan. As a result, *P. arisanense* var. *arisanense* is evaluated at LC rank. The population was still large in the island and the plants are common, so there is no immediate threat to this taxon. *Polygonatum arisanense* var. *chingshuishanianum* is ranked as critical endangered (CR)(A1(a), B1(bii+biii), D1), because there are few fertile individuals and there is a hiking trail that crosses the population area. *Polygonatum arisanense* var. *formosanum* is evaluated as near threatened (NT)(C, C1). This variety is only found in Yangmingshan National Park, but there are more than ca. 10,000 fertile individuals and they are regenerating well. However, considering the narrow distribution and the fact that some of the populations are near places of human activity, we evaluate the conservative rank as near threatened.

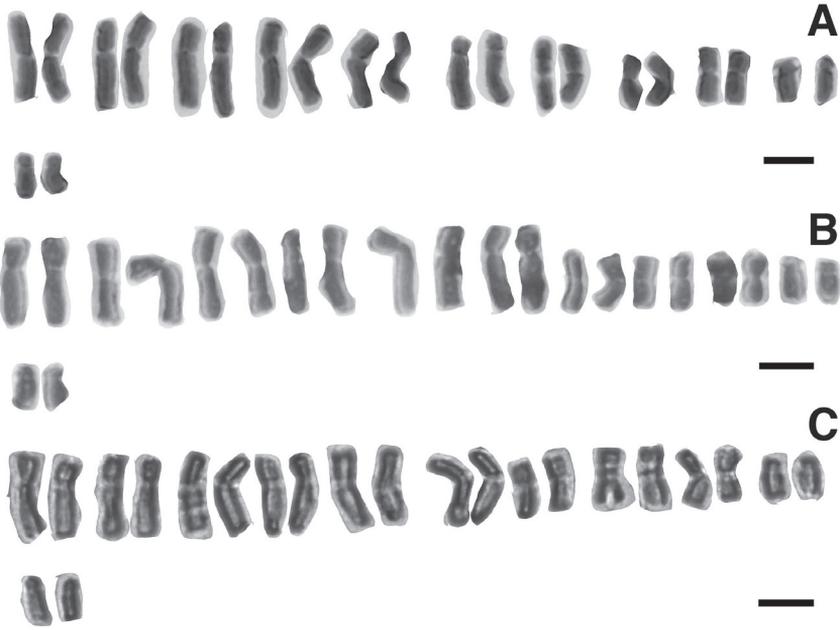


Figure 2. Chromosome of *Polygonatum* of Taiwan. **A** *P. arisanense* var. *arisanense* **B** *P. arisanense* var. *chingshuishanianum* **C** *P. arisanense* var. *formosanum*. Scale bar: 5 μ m.

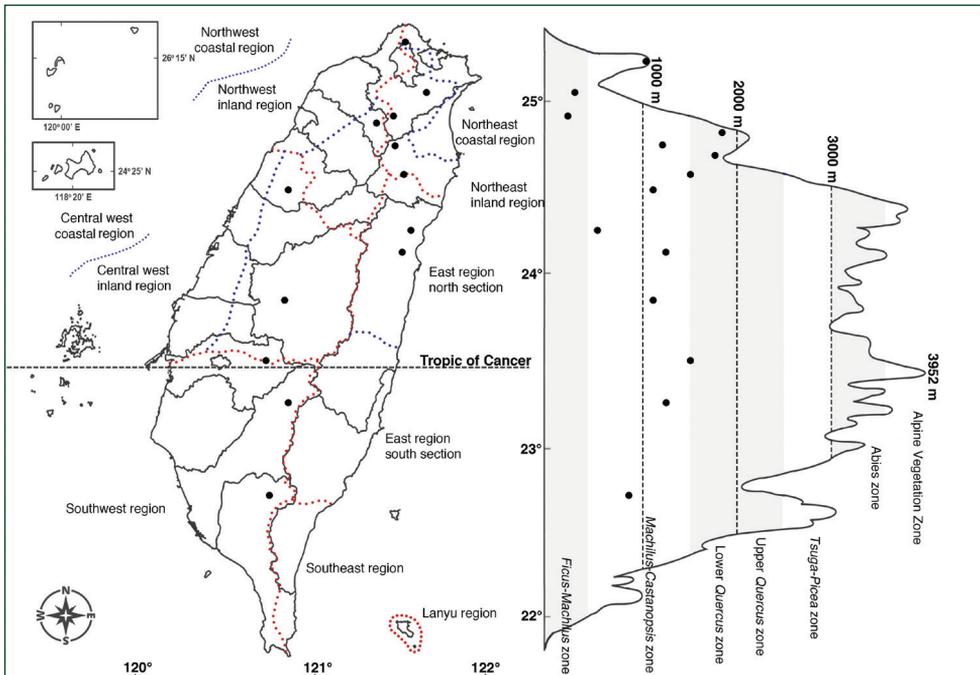


Figure 3. Distribution map of *Polygonatum arisanense* var. *arisanense*.

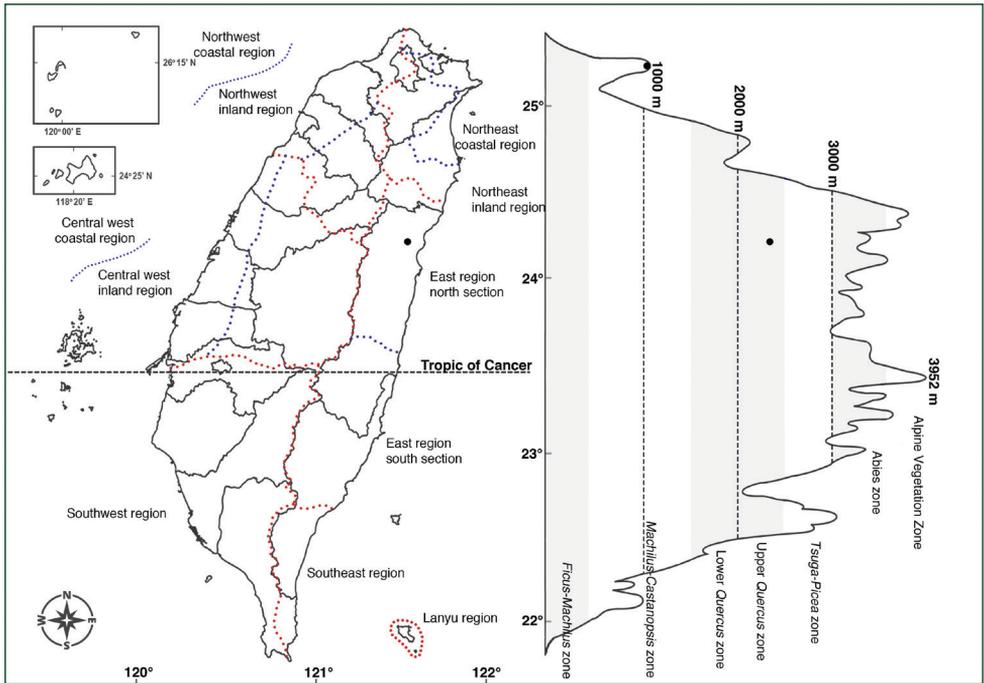


Figure 4. Distribution map of *Polygonatum arisanense* var. *chingshuishanianum*.

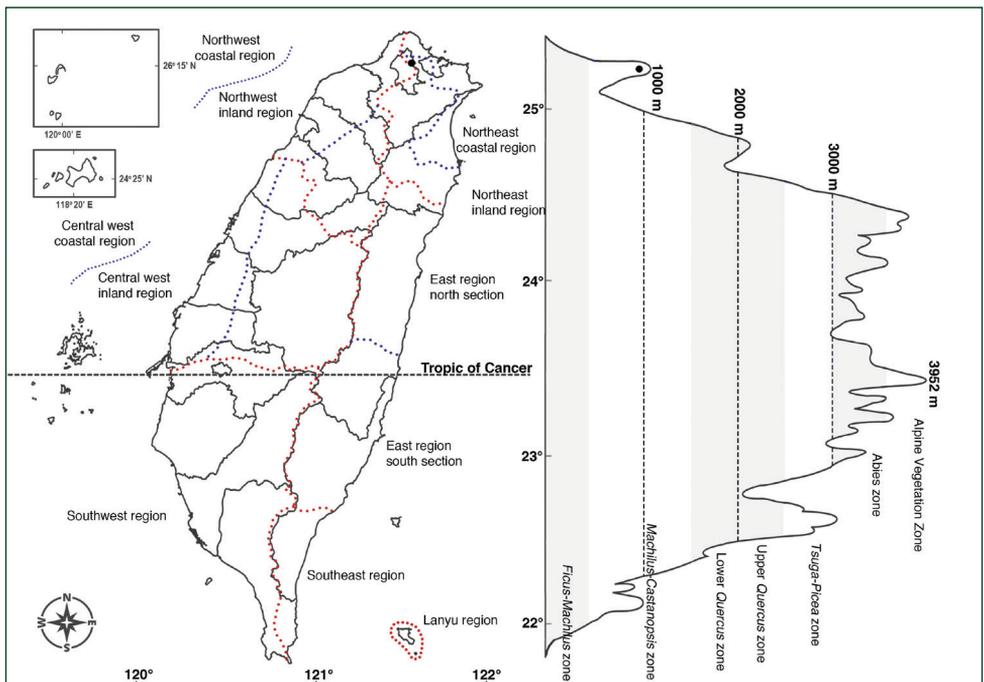


Figure 5. Distribution map of *Polygonatum arisanense* var. *formosanum*.

Discussion

Here we present evidence that leads us to conclude that there is but one species and three taxa of *Polygonatum* of Taiwan. These are enumerated below.

The differences between *Polygonatum arisanense* and related taxa

Polygonatum arisanense were identified as *P. odoratum*, *P. odoratum* var. *pluriflorum* or *P. cyrtoneura* by several authors (Ying 1969, 1990, 2000; Wang et al. 1978; Jeffery 1980; Wang 1997; Boufford et al. 2003). These species all have similar appearances with alternate leaves, pendulous axillary inflorescences, white perianth tubes, and purplish berries. Identification of species often relies on the rhizome and stamen morphology (Tamura 1993; Chen et al. 2000), but such parts are often neglected when collecting the samples, or are hard to observe in herbarium sheets. The morphology of the rhizome provides significant value in determining the taxonomy of *Polygonatum*, but this character is usually lacking on the herbarium specimens, even on the type specimens. Different forms can be recognized among the taxa; for example, *P. hookeri* Baker has terete rhizomes, while *P. franchetii* Hua and *P. filipes* Merr. ex C. Jeffery & McEwan have moniliform ones. Tuberous rhizomes are found in all Taiwanese taxa, and are different from the terete rhizomes of *P. odoratum*. Therefore, misidentification is relatively common in *Polygonatum* species. According to literature review, and examination of living and herbarium materials, *P. arisanense* is distinguished from *P. odoratum* by having tuberous rhizome, which is terete in the latter. On the other hand, *P. arisanense* was distinguished from *P. cyrtoneura* by its filaments being adnate to the middle of the perianth tube, and the anther being without spurs, whereas the filaments are adnate near the apex of the perianth, and the anthers are spurred in the latter. Such a result was also supported by the molecular study (Floden and Schilling 2018) The fact that the chromosome number of *P. odoratum* was $2n = 20$ (Tamura 1990), and of *P. arisanense* was $2n = 22$, revealed that the difference between them was not only on the morphological, but also on the genetic level (Table 4). Besides, Hsu (1971) also recorded a tetraploid individual ($2n = 44$) of *P. arisanense* from Taitung county, implying that the polyploidy events may be found in some populations. Such events were often found in the populations of *Polygonatum* (Therman 1950; Tamura 1990). Further study of the distribution and frequency of polyploidy event of *P. arisanense* population is needed.

The taxonomic status of *P. chingshuishanianum* and *P. formosanum*

In order to determine the taxonomic status of *P. chingshuishanianum*, the floral morphology is the key character due to the lack of type specimen. The observed flower morphology was generally identical to that of Ying (1988, 2000), and the morphol-

Table 4. Comparison of *Polygonatum arisanense* and related species.

	<i>P. arisanense</i>	<i>P. cyrtonea</i>	<i>P. odoratum</i>
Rhizome	tuberous	moniliform or tuberous	terete
Stamen	not spurred	spurred	not spurred
Chromosome number	2n=22	2n=18, 20, 22	2n=20

Table 5. Comparison between *Polygonatum arisanense* and its varieties.

	var. <i>arisanense</i>	var. <i>chingshuishanianum</i>	var. <i>formosanum</i>
Leaves shape	lanceolate to wide lanceolate	lanceolate to oblong lanceolate	ovate to ovate lanceolate
Texture	chartaceous	chartaceous to thinly coriaceous	thick chartaceous to coriaceous
Flowers per inflorescence	5–7	1 or 2	3–5
Flowers perianth tube size (cm)	1.5–2 × 1	1–1.5 × 0.8	2–3 × 0.5–1
Base of perianth tube	acute	flattened	flattened

ogy of other parts matched those of the type specimen. Therefore, the plant we found was identified as *P. chingshuishanianum*, and was the first record of floral morphology after the original publication of Ying (1988). Generally, the floral morphology was similar to *P. arisanense*, but minor distinctions included the fact that there were few-flowered inflorescences, smaller flowers, truncate to obtuse perianth tube base, dwarf plant size and thicker leaves. These were all different from typical *P. arisanense*. The morphology of the pollen and karyotype were also similar to *P. arisanense*, but the floral morphology was distinct from the lower altitude population of *P. arisanense* var. *arisanense*. Moreover, the habitat of this taxon was on the limestone region of eastern Taiwan, which had abundant endemic species found in this region, such as *Dianthus seisuimontanus* Masamune (Caryophyllaceae), *Berberis chingshuiensis* T. Shimizu (Berberidaceae), and *Rhamnus chingshuiensis* T. shimizu (Rhamnaceae). Such a unique geological environment may lead to unique evolution events. Therefore, we treated this taxon as a variety of *P. arisanense* rather than an independent species as Ying (1988, 2000)(Table 5).

Polygonatum officinale var. *formosanum* was originally described by Hayata (1920). and elevated to *P. formosanum* Masamune and Simada (1936). From nearly that time henceforth it has been treated as a synonym of *P. odoratum*, *P. odoratum* var. *pluriflorum*, or as *P. cyrtonea* (Liu and Ying 1978; Wang 1997; Chen et al. 2000; Ying 2000). After careful observation of the types and living plants from the type locality, this taxon was found to be more similar to *P. arisanense* rather than the species and taxa mentioned above. This taxon differs from var. *arisanense* by having thicker leaves, larger flowers, basal flattened perianth tubes, and fewer-flowered inflorescences, but the pollen morphology and karyotype are similar to those of *P. arisanense*, so we prefer to treat this taxon as a variety of *P. arisanense* (Table 5).

Taxonomic treatment**Key to *Polygonatum arisanense* and its varieties**

- 1 Leaves lanceolate to ovate; flowers usually 3–7 per inflorescence **2**
 – Leaves lanceolate to oblong-lanceolate; flower solitary or 2 per inflorescence....
 ***P. arisanense* var. *chingsbuisbanianum***
 2 Leaves lanceolate to wide lanceolate, chartaceous; perianth tube base slightly
 acute ***P. arisanense* var. *arisanense***
 – Leaves ovate to lanceolate-ovate, thick chartaceous to coriaceous; perianth
 tube base flattened ***P. arisanense* var. *formosanum***

1. *Polygonatum arisanense* Hayata var. *arisanense*, *Icones Plantarum Formosanarum*. 9:140. 1920. Type: Taiwan, Chiayi County, Arisan, Kodensho, leg. S. Sasaki, May 1913. (Lectotype designated by Jeffery (1980): TII; isotype: TII)

Fig. 6
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P. cyrtoneura sensu auct. Liu & Ying non. Hua in *Journal de Botanique (Morot)* 6 (21): 393–394. 1892.

P. odoratum sensu auct. Chen et al. non. Druce in *Annals of Scottish Natural History* 60: 226. 1906.

P. odoratum (Mill.) Druce var. *pluriflorum* sensu auct. Ying non. Ohwi in *Bulletin of the Natural Science Museum* 26: 7. 1949.

Perennial herbs. Rhizome tuberous. Stem arching, 30–150(–200) cm long, green or purplish green, glabrous, sometimes covered with white powder, base covered with scale leaf, caducous. Leaf deciduous, alternate, chartaceous, 3-multiple nerved, lanceolate to wide lanceolate, 15.0–18.5 cm long, 5.5–8.0 cm wide, apex acuminate, base attenuate, petiole short, 3–5 mm long, often reddish or purplish. Inflorescences umbel with 5–7 flowers, peduncle longer than pedicels, ca. 3 cm long, glabrous, inflated, articulated close to flowers, bracteoles very minutely, caducous. Flowers pendulous, perianth tube 1.5–2.3 cm long, ca. 1 cm in diam., white with pale green veins, base acute, perianth segments 6, arranged into 2 whorls, each 3, 5–10 mm long, ca. 5 mm wide, green with dark green strip, ovate to triangle, apex obtuse, floccose. Stamen 6, filaments slender, base expansion and flattened, papillose or short cottony, inserted at middle of perianth tube, ca. 1 cm long, anthers ca. 3 mm long, 2-loculed, introrse and longitudinally dehiscent. Ovary superior, 3-loculed, ovate to oblong, covered with white powder, 3.0–4.5 mm long, 2.0–3.5 mm in diam., apex obtuse; style filiform, 1.3–1.5 cm long, stigma entire, pubescent. Fruits berry, purplish black. Seeds numerous. $2n=22$.

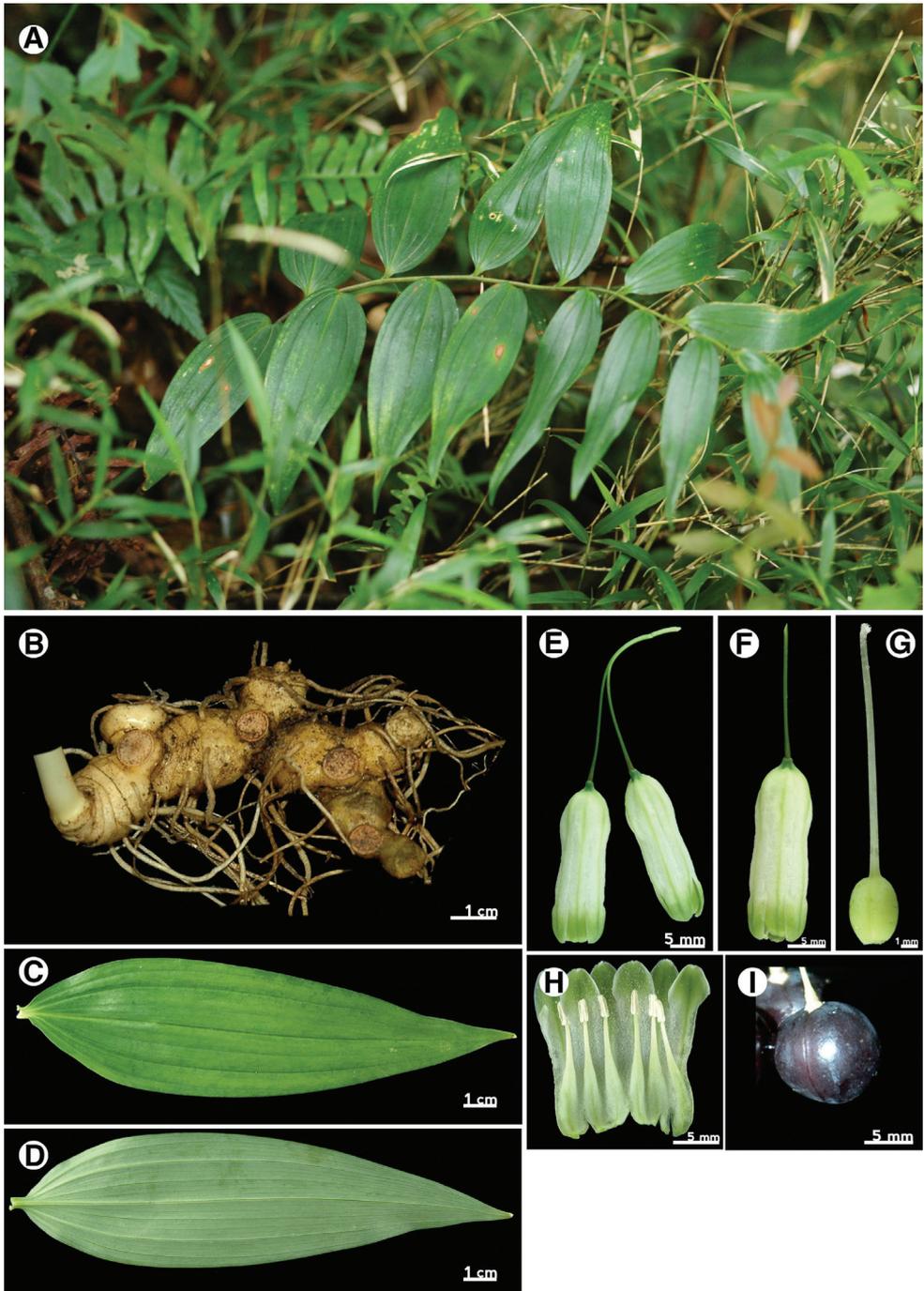


Figure 6. *Polygonatum arisanense* var. *arisanense*. **A** habit **B** rhizome **C** leaf adaxial surface **D** leaf abaxial surface **E** inflorescence **F** flower **G** pistil **H** expanded perianth tube with stamens **I** fruit.

Endemic. Distributed from low to ca. 2000 m mountains through the island (Fig. 3).

Specimen examined. Taipei city: Nankangshan, 30 m, 20 May 1987, S. M. Chaw 419 (HAST); **New Taipei city:** Wuliaochien, 500 m, 20 Aug 2004, C. M. Wang et al. 7627 (TNM); In silvis inter Sauken et Hyarawa, T. Suzuki 7047 (TAI); tonroku ridge of kahoyama, 11 May 1935, Fukuyama ST19237 (TAI); rarayama, 1200 m, 7 Sep. 1934, T. Suzuki 11733 (TAI); Lo-pei-shan, Y. B. Cheng & T. S. Hsieh 1182 (TAI); Mt. Wuliaochien, 300–500 m, 26 Apr 2014, T. C. Hsu 6959 (TAIF); Mt. Peichatienshan, 1500 m, 10 Oct 1984, C. I Peng 7466 (HAST); Tachienchih, 700 m, 24 Mar 2001, Y. Y. Huang 280 (HAST); Shihting, 400 m, 28 Feb 1993, H. W. Lin et al. 106 (TNU); **Ilan county:** Chiaping logging trail, 1000–2000 m, 7 Aug 2006, C. H. Chen et al. 7442 (TNM); ca. 8 km of no. 100 logging trail of Chilan, ca. 1300 m, 27 Apr 2007, C. F. Chen et al. 2501 (TNM); Tatung, T. Y. A. Yang et al. 13664 (TNM); Mt. Taiheizan, Jul. 1929, S. Suzuki 1072 (TAI); Mt. Taiping, 27 Aug. 1962, Chuang et al. 4795 (TAI); Shi-yen-ya-ko, C. S. Kuoh 1789 (TAI); Mt. Taiping, C. C. Chuang et al. 4689 (TAI); Mingchih, Liao et al. 10531 (CHIA); Taipingshan logging trail, 29 Apr 2007, P. F. Lu 13696 (TAIF); Ssuchi logging trail, 1400–1700 m, 9 May 2011, T. C. Hsu 3977 (TAIF); Mt. Poluo, 1300 m, 17 Apr 2014, C. T. Chao 3375 (TCF); near Chilan, on provincial road sign between 67 km to 69 km, 1200 m, 14 Aug. 1997, J. C. Wang & C. H. Chen 10525 (TNU); 710 logging track, 1000–1100 m, 22 Sept 1996, Y. C. Chen 65 (TNU); **Taoyuan county:** Mt. Lala, 1500 m, 7 May 1986, S. Y. Lu 19144 (TAIF); same loc., ca. 2 Jul 2009, C. T. Chao 785, 786, 787 (TCF); same loc., 26 Sep 2009, C. T. Chao 1033, 1034, 1035, 1036 (TCF); on the way from Lalashan forest recreation area to Fushan, 1500–1600 m, 11 May 1997, S. M. Kuo 82 (HAST); Pafu ancient trail, 1500 m, 14 Apr 2014, C. T. Chao (TCF); from Lalashan forest recreation area to Fushan, 1500–1600 m, 11 May 1997, S. M. Kuo et al. 82 (TNU); **Hsinchu county:** Yuanyanghu, 1700 m, 9 May 1995, H. Y. Shen et al. 778 (TNM); same loc., Y. F. Wang 1043 (TAI); same loc., 1700 m, 28 Jun 1985, S. Y. Lu 16589 (TAIF); same loc., 1670 m, 8 May 1995, H. Y. Shen 746 (HAST); Malo to Shangyulao, ca. 1000 m, 14 May 2004, C. M. Wang & C. P. Lu 7371 (TNM); Taikeigun, Tamankei no minamoto, T. Suzuki & T. Nakamura ST 18228 (TAI); Chenhsipao, ca. 1800 m, 26 Jul 2000, Summer Collecting Team 11595 (TAIF); same loc., 1640 m, 10 May 2000, C. H. Lin 289 (HAST); Mt. Litung, ca. 1800 m, 17 May 2008, P. F. Lu 15952 (TAIF); same loc., 1510 m, 3 Jul 2002, C. H. Chen 4374 (TAIE); Ssumakussu, 1500 m, 23 May 2012, T. C. Hsu 5757 (TAIF); Taohsia to Shangyulao, 1300 m, 2 Jun 2012, T. C. Hsu 5789 (TAIF); Kuanwu, Talu forest road 20–26 km, 2000 m, 20 May 1994, J. C. Wang 9214 (HAST); the north line of Loshan logging trail, 1440 m, 9 Jun 2004, C. C. Wu 677 (HAST); Chienshih, ca. 1000 m, 20 Jan 2010, C. T. Chao 1271 (TCF); Tlungtan, 2000 m, 17 Apr 2016, C. T. Chao 4095 (TCF); Matai ancient trail, 500 m, 7 Dec 2014, C. T. Chao 3622 (TCF); Kuanwu, Talu forest road 20–26 km, 2000 m, 20 May 1994, J. C. Wang et al. 9214 (TNU); **Miaoli county:** Talu logging trail, C. H. Yu 950 (TAI); Mt. Henglung ancient trail, ca. 1550 m, 25 Apr 2010, P. F. Lu 20163 (TAIF); Kuantaoshan, 700 m,

C. T. Chao 1287 (TCF); Hennungshan, 1000 m, 8 Jan 1997, M. Y. Shen 1277, 1278 (TAIE); Hoununghsi, 5 Jun 1997, M. Y. Shen 1727 (TAIE); Malabanshan, 1402 m, 22 Mar 2006, M. Y. Shen 4318 (TAIE); Ta-lu logging tract east line, 2000 m, 8 Jul 1998, J. C. Wang & summer collection team 10662 (TNU); **Nantou county**: Hakku-Musha, 14 Jul. 1930, G. Masamune 1349 (TAI); Shanlinhsi, K. C. Chang 137 (CHIA); Chitou, 15 Feb 1960, T. I. Chuang 3167 (HAST); same loc., 1150 m, 5 Feb 2010, C. T. Chao 1326 (TCF); Renlun logging track, 1638 m, 27 Jun 2017, M. Y. Shen 5393 (TAIE); Tungpu to kuankao, 1700 m, 14 Apr 1996, K. C. Yang 4692 (TNU); Hsitou recreation area, 1200–1500 m, 14 Feb 1997, S. M. Kuo et al. 71 (TNU); **Chiayi county**: Hsiting, K. C. Yang 5646 (TNM); Bunkiko, U. Faurie s. n. (TD); Mt. Chiananyun, ca. 1600 m, 29 Mar 2012, T. C. Hsu 5525 (TAIF); Tatungshan, 1700 m, 19 Oct 1998, T. W. Hsu 9244 (TAIE); **Yunlin county**: Shihpishan, 1500 m, 13 Mar 2009, C. T. Chao 476, 478 (TCF); **Tainan city**: Tatungshan, T. C. Huang & S. F. Huang 15995 (TAI); en route from Chietung Villa to Tienyunshan, 1300 m, 1 Nov 1985, C. I Peng 8805 (HAST); **Hualien county**: Hoping logging trail 27–27.5 km, ca. 1200 m, 6 May 2000, S. T. Chiu et al. 6163 (TNM); Hoping logging trail 39.7 km, near the working cabin of Forest Bureau, ca. 2000 m, 7 May 2006, S. T. Chiu et al. 6274 (TNM); Hoping logging track, 26–39 km, 800–1800 m, 22 Apr 2002, S. M. Kuo et al. 705 (NTNU); Tentyo cliff, C. H. Chen 7029 (TNM); Monte Taroko-taizan, 1800–2000 m, 14 Jun 1933, T. Suzuki 9494 (TAI); from Fong-shan Branch to no. 29 compt., Liu et al. 96 (TAI); Hoping, ca. 1300 m, 22 Apr 2002, S. M. Kuo et al. 705 (TAIF); Mt. Chienliyen, 1400 m, 17 Apr 2011, T. C. Hsu 3879 (TAIF); from peak of Chingshuishan to Shakatang forest road, 1500–2000 m, W. P. Leu 1804 (HAST); same loc., 1300 m, 30 Apr 2016, C. T. Chao 4110 (TCF); Lanshan, 1500 m, 1 Apr 1994, Y. C. Sun 220 (TAIE); Mt. Mukwashan forest, Halun station, 2000–2100 m, 23 Sep 1984, C. I Peng 7278 (HAST); **Kaohsiung city**: Mt. Hsiaokuan logging trail, 16 Apr 2009, M. J. Jung 3953 (TAIF); **Pingtung county**: Mt. Lili, 1000 m, 6 May 2012, T. C. Hsu 5656 (TAIF); same loc., 30 Apr 2013, T. C. Hsu 6543 (TAIF); on a hiking path near Wutai, 860 m, 26 Feb 2002, W. C. Leong 3019 (HAST); Wutai to Ali, 1100 m, 7 Dec 2015, C. T. Chao 4019 (TCF);

2. *Polygonatum arisanense* Hayata var. *chingshuishanianum* (S.S.Ying) C.T.Chao & Y.H.Tseng, comb. nov.

urn:lsid:ipni.org:names:77194987-1

Fig. 7

清水山黃精

Polygonatum chingshuishanianum S. S. Ying in Memoirs of the College of Agriculture, National Taiwan University 28(2): 42. 1988. Ying, Fl. Taiwan 5:61, 2000; Boufford et al., Fl. Taiwan 6:112, 2003. Type: Hualien county, Hsiulin township, Chingshuishan, 2300 m, 26 Jun 1988, S. S. Ying s.n. (holotype: NTUF!), **syn. nov.**

Polygonatum altelobatum sensu auct. Wang non Hayata, Icones Plantarum Formosanarum 5:229. 1915.

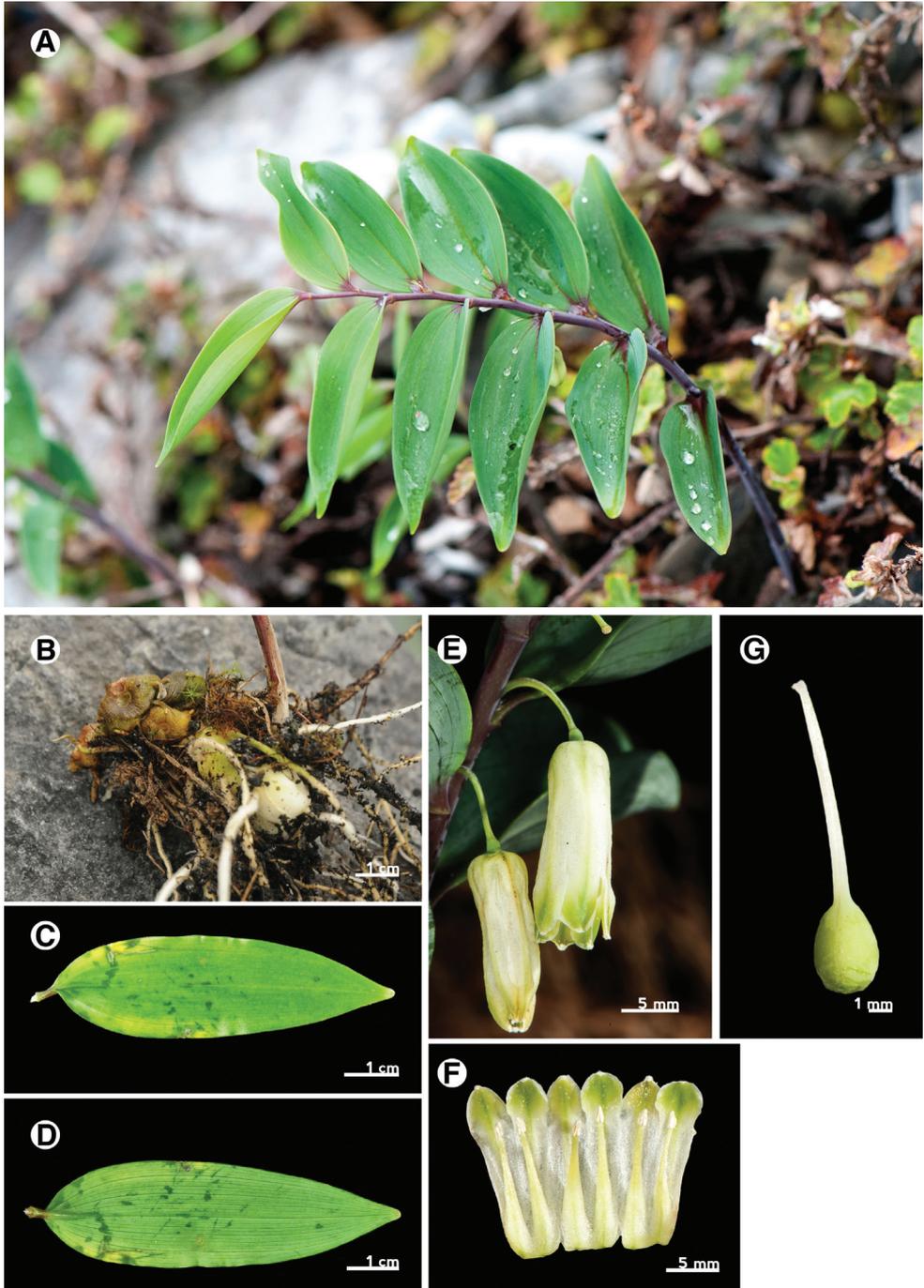


Figure 7. *Polygonatum arisanense* var. *chingshuishanianum*. **A** habit **B** rhizome **C** leaf adaxial surface **D** leaf abaxial surface **E** inflorescence **F** expanded perianth with stamens **G** pistil.

Perennial herbs. Rhizome tuberous, 1.5–1.8 cm in diam. Stem straight, 10–30 cm long, purplish-green, base covered with scale leaf, caducous. Leaves deciduous, alternate, chartaceous to thinly coriaceous, 3-nerved, lanceolate to oblong-lanceolate, 5.5–7.5 cm long, 1.5–2.5 cm wide, apex obtuse, base obtuse and decurrent to the petiole base, entire, glabrous on both surfaces, petiole ca. 3 mm long, glabrous. Inflorescences solitary or two flowers, peduncle ca. 1.3 cm long. Flowers pendulous, pedicels 5.0–6.5 mm long, glabrous, articulated close to the flower, perianth tube 1–1.5 cm long, ca. 8 mm wide, base flattened, perianth segments 6, arranged into 2 whorled, each 3, triangular, ca. 5 mm long, ca. 5 mm wide, green with dark green strip, apex obtuse, floccose. Stamens 6, base expansion and flattened, inserted at middle of perianth, filaments 5.5–6.5 mm long, anthers oblong-lanceolate, 1.5–2.0 mm long, ca. 1 mm wide. Ovary superior, globose, 4.5–5.5 mm long, 3.5–4.5 mm in diam., glabrous, style filiform, ca. 1 cm long, glabrous, stigma entire, pubescent. Fruits berry, globose, glabrous. $2n=22$.

Endemic. Known only from the summit of Mt. Chingshuishan, ca. 2300–2400 m, on exposed limestone slopes (Fig. 4).

Specimen examined. Hualien county: Hsiulin township, Mt. Chingshuishan, on the way from the entrance to the mountain peak, 2000–2400 m, 9 May 1997, C. H. Chen & S. D. Shen 2066 (TNM; TNU); Mt. Chingshuishan, near the summit, ca. 2200 m, 2 Jun 2010, C. T. Chao 1424 (TCF); same loc., 17 May 2014, C. T. Chao 3396 (TCF); same loc., 17 May 2015, C. T. Chao 3767 (TCF); same loc., 1 May 2016, C. T. Chao 4128 (TCF); Hsiulin township, 2400 m, 22 Aug 1996, C. H. Chen & C. T. Lu 64 (TNU).

3. *Polygonatum arisanense* Hayata var. *formosanum* (Hayata) C.T.Chao & Y.H.Tseng, comb. nov.

urn:lsid:ipni.org:names:77194988-1

Fig. 8

大屯黃精

Polygonatum officinale All. var. *formosanum* Hayata, *Icones Plantarum Formosanarum*. 9:140. 1920. Type: Taipei City, Taiton (Mt. Tatumshan), ad 1500 metra, U. Faurie 544 (holotype: KYO!).

Polygonatum formosanum (Hayata) Masam. & Simada, *Short Flora of Formosa* 271. 1936.

Polygonatum daitonense T. S. Liu & S. S. Ying *nom. nud.*

Perennial herbs. Rhizome tuberous. Stem straight to arching, 30–80 cm long, green or purplish, glabrous, covered with scale leaf at the base, caducous. Leaves deciduous, alternate, thick chartaceous to coriaceous, ovate to lanceolate ovate 3-multiple nerved, apex attenuate, base obtuse, 8.0–10.5 cm long, 3.5–5.5 cm wide, sessile or short-petioled, ca. 3 mm long, often purplish. Inflorescences axillary, solitary to umbels with 3–5 flowers, peduncle subequal to pedicels, 1.5–2.0 cm long, articulated close to the flower, bracteoles very minutely, caducous. Flowers pendulous, perianth tube, 2.5–3.5 cm long, 0.5–1.0 cm

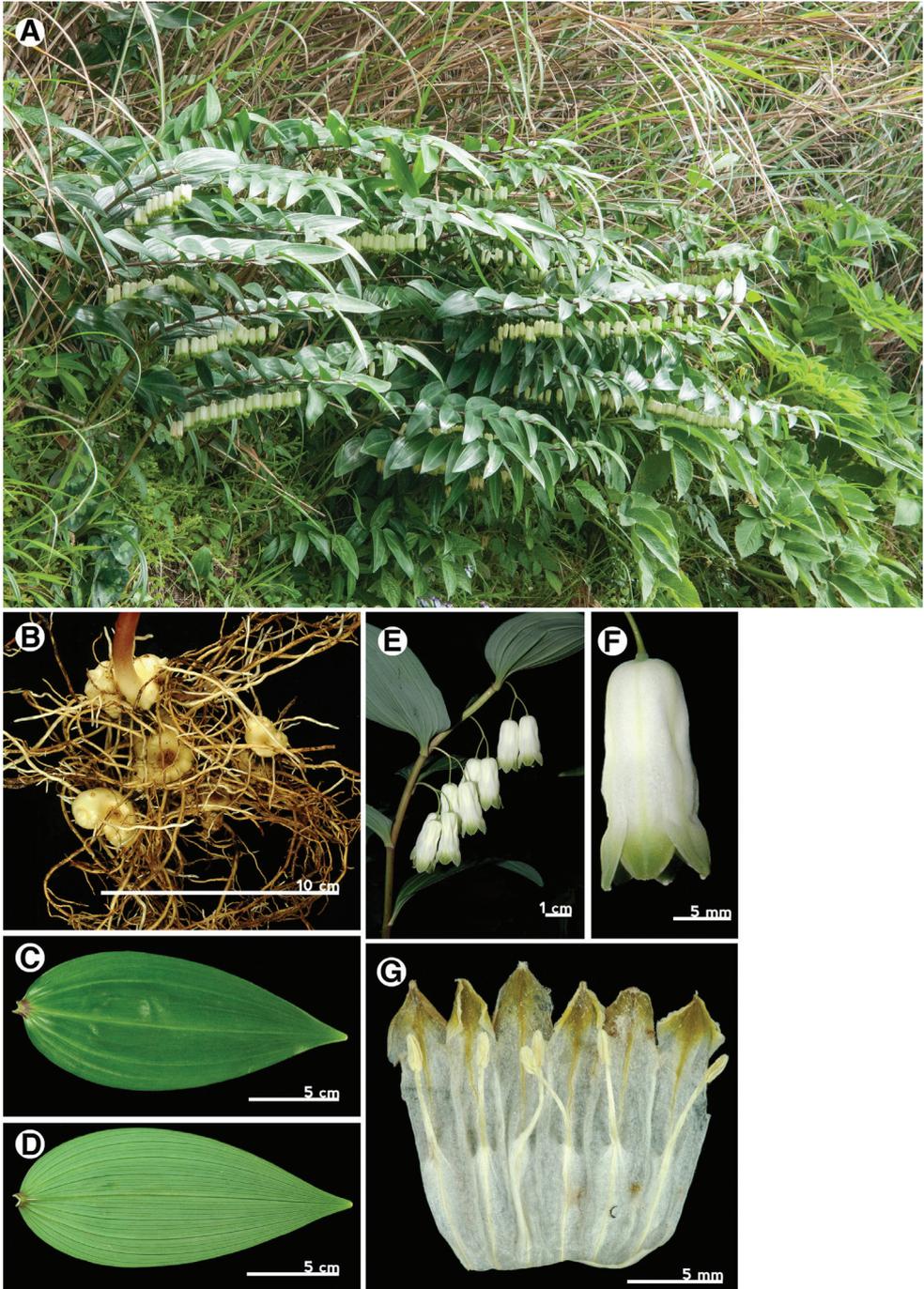


Figure 8. *Polygonatum arisanense* var. *formosanum*. **A** habit **B** rhizome **C** leaf adaxial surface **D** leaf abaxial surface **E** inflorescences **F** flower **G** expanded perianth with stamens.

wide, slight flattened at base, white with green strips, perianth segments 6, arranged into 2 whorls, each 3, 5.5–8.0 mm long, 5.5–8.0 mm wide, green with dark green strip, ovate to triangle, apex obtuse, floccose. Stamens 6, filaments slender, base expansion and inflated, papillose or short cottony, inserted at middle of perianth tube, ca. 5 mm long, anthers 1.5–2.0 mm long, 2-loculed, introrse and longitudinally dehiscent. Ovary superior, 3-loculed, ovate to oblong, covered with white powder, 3.5–4.0 mm long, ca. 3 mm in diam., style filiform, ca. 1.5 cm long, stigma entire, pubescent. Fruit berry, purplish black. $2n=22$.

Endemic. Only known from Yangmingshan national park, northern Taiwan (Fig. 5).

Specimen examined. Taipei city: Mt. Tatunshan, 26 Apr 1931, S. Sasaki 19 (TAI); same loc., 10 May 1936, H. Simada 1292 (TAI); same loc., 10 Apr 1981, Y. F. Chen 2025 (TAI); same loc., 8 May 2010, C. T. Chao 1416 (TCF); same loc., 1 May 2016, C. T. Chao 4105 (TCF); Tsaoshan to Chutzihu, 1931, Tanaka 1250 (TAI); Shiaokuangyingshan, 11 Apr 1937, H. Simada 1287 (TAI); same loc., 22 Apr 1937, H. Simada 1289 (TAI); Mt. Chihsingshan, 30 Jun 1937, H. Simada 1369 (TAI); same loc., 1 Nov 1968, M. Mizushima et C. C. Hsu 5082 (TAI); same loc., 14 Apr 1983, K. C. Yang 1367 (TAI); same loc., 25 Apr 1985, T. C. Wan & K. C. Yang 2004 (TAI); Chungshing Farm, 4 Apr 1988, T. C. Huang 13452 (TAI); Chutzuhu, 500 m, 24 Mar 1972, J. W. Tsai 88 (TAIF); Hsiantienhu, 800 m, 16 Sep 1985, S. Y. Lu 16890 (TAIF); Tsaiungkengshan, 850 m, 19 Aug 2001, P. F. Lu 1123 (TAIF); same loc., 26 Oct 2002, S. W. Chung 5943 (TAIF); same loc., 1 Apr 2006, P. F. Lu 11560 (HAST); same loc., 850 m, 14 Jul 1996, S. C. Wu et al. 877 (TNM, TNU); Yangmingshan, 700–800 m, 4 Apr 2008, P. F. Lu 15623 (HAST); Chungchengshan to Tatunshanfeng, 600–900 m, 3 Apr 1998, C. M. Wang 3005 (HAST, TNM); Palaka highway, close to Hsiaoyukeng, 700–800 m, 24 Feb 1997, S. M. Kuo & H. M. Shih 79 (TNU); on the top of Mt. Chihsing, 900–1000 m, 28 Apr 1997, S. M. Kuo & Y. C. Chen 81 (TNU); the path to Tsaiungkengshan, 700–800 m, 30 Mar 2007, Y. C. Huang 546 (TNU);

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Cirsium tatakaense (Compositae), a new species from Taiwan

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Abstract

A new species of *Cirsium*, *Cirsium tatakaense* Y.H.Tseng & C.Y.Chang, from central-southern Taiwan is described and illustrated. This species is similar to *C. kawakamii* Hayata in leaf shape, achene and chromosome number ($2n = 64$), but can be readily distinguished from *C. kawakamii* by the narrower leaf lobes, usually higher number of florets and phyllaries, the purplish-red corolla (vs. white) and larger pollen grains. A key to the species of *Cirsium* in Taiwan is also presented.

Keywords

New species, Chromosome number, *Cirsium tatakaense*, *Cirsium kawakamii*, Compositae, Taiwan

Introduction

Cirsium Mill. is a genus of Compositae and comprises approximately 250 species widely distributed throughout the world's temperate and subtropical zones (Kadota 2007). A total of 46 species are native to China (Shih and Greuter 2011), 64 to Japan (Iwatsuki et al. 1995) and 9 to Taiwan (Peng 2003).

Kitamura (1937) established the first infrageneric classification for East Asian *Cirsium*. In this classification, the Taiwanese species were placed in two of the sections, sect. *Pseudoeriolepis* (Nakai) Kitam. and sect. *Onotrophe* (Cass.) DC. and five subsections, subsect. *Arenicola* Kitam., subsect. *Australicirsium* Kitam., subsect. *Nipponocirsium* Kitam., subsect. *Sinocirsium* Kitam. and subsect. *Spanioptilon* Less. The latter subsection was subsequently raised to the rank of section (sect. *Spanioptilon* (Less.) Shih) by Shih (1984) and maintained by Iwatsuki et al. (1995).

Recently, we discovered a rare *Cirsium* growing in the high mountain areas of central-southern Taiwan. Based on the systems of Kitamura (1937) and Iwatsuki et al. (1995), this taxon belonged to section *Onotrophe* subsection *Nipponocirsium* and appeared to be similar to *Cirsium kawakamii* Hayata, sharing the longer leaf lobes, nodding bowl-shaped mature capitula and corolla lobes as long as the inflated part of the corolla tube.

Materials and methods

We compared the new species to the other two species of *Cirsium* sect. *Onotrophe* in Taiwan.

Herbarium examination

Materials primarily comprised fresh and dried specimens; voucher specimens were deposited in TCF, PPI and TNM. The herbaria referenced included HAST, KYO, PPI, TAI, TAIF, TCF, TI and TNM.

Pollen morphology

Pollen grains, all from fresh material, were directly mounted on a stub without any pretreatment and sputter coated with gold (Quorum SC7620) for observation with a scanning electron microscope (Hitachi S-3400N). The shape, size and exine ornamentation were studied following Erdtman (1952) and Hesse et al. (2009). Vouchers for the pollen material studied are provided in Table 1.

Table 1. Voucher material for the *Cirsium* Mill. pollen morphology.

Taxa	Location	Coordinate	Altitude	Date	Voucher
<i>C. tatakaense</i>	TAIWAN. Kaohsiung City Taoyuan District, Kuaiku to Yakou	23°16.03'N, 120°56.24'E	2600 m	21 Oct 2014	<i>C. Y. Chang</i> , 160 (TNM)
	TAIWAN. Nantou County Sinyi Township, Tataka	23°29.24'N, 120°52.71'E	2620 m	15 Nov 2014	<i>C. Y. Chang</i> 182 (TCF)
	TAIWAN. Nantou County Sinyi Township, Tataka to Shihshan	23°28.56'N, 120°52.74'E	2530 m	26 Oct 2015	<i>C. Y. Chang</i> , 842 (TNM)
	TAIWAN. Nantou County Sinyi Township, Tataka to Shihshan	23°29.24'N, 120°52.71'E	2631 m	22 Dec 2015	<i>C. Y. Chang</i> 1017 (TCF)
<i>C. kawakamii</i>	TAIWAN. Taichung City Heping District, Mt. Pintian to Mt. Dabajian	24°26.52'N, 121°15.83'E	2800 m	13 Aug 2014	<i>C. Y. Chang</i> 264 (TNM)
	TAIWAN. Taichung City Heping District, Mt. Syue Trail 8.9 km	24°23.53'N, 121°14.20'E	3500 m	3 Oct 2015	<i>C. Y. Chang</i> 774 (TCF)
	TAIWAN. Nantou County Ren'ai Township, Nengao cross-ridge historic trail 11 km	24°2.79'N, 121°15.77'E	2600 m	29 Jan 2018	<i>C. Y. Chang</i> 1605 (TNM)
<i>C. arisanense</i>	TAIWAN. Taichung City Heping District, Mt. Syue trail 8.9 km	24°23.60'N, 121°13.98'E	3450 m	3 Sept 2015	<i>C. Y. Chang</i> 756 (TCF)
	TAIWAN. Nantou County Ren'ai Township, Rueilan river pipes road 2 km	24°06.95'N, 121°11.96'E	2240 m	27 May 2016	<i>C. Y. Chang</i> 1275 (TCF)

Table 2. Voucher material for the *Cirsium* Mill. karyotype analysis.

Taxa	Location	Coordinate	Altitude	Date	Voucher
<i>C. tatakaense</i>	TAIWAN. Chiayi County Alishan Township, Tataka to Paiyun lodge	24°28.40'N, 120°54.23'E	2800 m	15 May 2016	<i>C. Y. Chang</i> 1269 (TCF)
<i>C. kawakamii</i>	TAIWAN. Taichung city Heping District, Mt. Syue trail 8.9 km	24°23.73'N, 121°13.94'E	3371 m	8 Nov 2015	<i>C. Y. Chang</i> 874 (TCF)
	TAIWAN. Taichung city Heping District, Mt. Syue trail 8.9 km	24°23.73'N, 121°13.94'E	3371 m	21 May 2016	<i>C. Y. Chang</i> 1271 (TCF)

Karyotype analysis

Karyotype analysis was performed by following the same procedure applied by Ozcan et al. (2011) and Yüksel et al. (2013). Root tips were collected on sunny mornings and preserved in 0.002 M 8-hydroxyquinoline solution below 10 °C for eight hours. This material was then fixed with Carnoy's solution (1 part acetic acid: 3 parts EtOH) for at least 24 hours at 4 °C. The fixed roots were then stained with acetic-orcein for 24 hours at room temperature, squashed and the slides examined using an stereo microscope (ACCU-ScoPE 3025). Voucher material is presented in Table 2.

Results and discussion

Morphological comparison

Following Kitamura (1937) and Iwatsuki et al. (1995), *Cirsium tatakaense* is placed in section *Onotrophe* together with *C. kawakamii* and *C. arisanense*. Amongst them, *C. arisanense* belongs to subsection *Australicirsium*, which is characterised by having rosette leaves, pot-shaped capitula which are erect or nodding when mature, corolla lobes equal in length to the inflated part of corolla tube and corona-like achene beaks. Both *C. tatakaense* and *C. kawakamii* belong to subsection *Nipponocirsium*, which is characterized by not having rosette leaves, larger bowl-shaped capitula which are nodding when mature, corolla lobes equal in length to the inflated corolla tube and tube-like achene beaks. In comparison with *C. kawakamii* (Table 3), *C. tatakaense* has purplish corolla (vs. white in *C. kawakamii*) (Figure 5[2]), usually more florets (136)161–308 (vs. (61)115–222 in *C. kawakamii*) (Figure 5[2]) and phyllaries 111–199 (vs. 79–123 in *C. kawakamii*) (Figure 5[2]) and narrower leaf lobes 7.3–11.9 mm (vs. 17.2–18.6 mm in *C. kawakamii*) (Figure 5[1]).

Chromosome number

The basic number of chromosomes amongst *Cirsium* species is often $2n = 34$ (Hsu 1970; Funk et al. 2009; Chen and Yeh 2010a; Chen and Yeh 2010b), including in *C. arisanense* (Peng and Hsu 1978). However, the chromosome number of *C. tatakaense* is $2n = 64$ (Fig. 6A), which is the same as that of *C. kawakamii* (Fig. 6B), indicating that

the two species are similar in this respect. Notably, other taxa of the same subsection in Japan are $2n = 68$ (Iwatsuki et al. 1995). These findings imply that subsect. *Nippono-cirsium* are tetraploids with aneuploid cells.

Palynological study

Cirsium tatakaense pollen has a larger diameter, up to 36–43 μm (vs. 32–35 μm in *C. kawakamii*) and its surface spines have broader bases of 4.2–5.6 μm (vs. 2.0–2.3 μm in *C. kawakamii*). The pollen grains of *C. tatakaense* are similar to *C. arisanense* (Fig. 7A, C). However, *C. kawakamii* (similar to *C. tatakaense* in macroscopic morphology) has the smallest pollen grains and spine in Taiwan (Fig. 7B). Pollen morphology is associated with pollination, thus implying reproductive isolation between the two species.

Comparison of the distribution between *C. tatakaense* and *C. kawakamii*

Compared with *C. tatakaense*, *C. kawakamii* occurs at higher altitudes (up to 3500 m); *C. tatakaense* is seldom discovered over altitudes of 3000 m. In addition, *C. kawakamii* is usually distributed in alpine gullies and valleys, whereas *C. tatakaense* often appears on spacious roadsides, seemingly with no preference for valley habitats. Therefore, we believe that *C. kawakamii* prefers shaded and moist environments, whereas *C. tatakaense* prefers open areas with higher drought tolerance. Some geographical segregation appears to exist in the distributions of *C. tatakaense* and *C. kawakamii*.

Table 3. Summary of characters between the species of *Cirsium* sect. *Onotrophe* in Taiwan.

Characters	<i>C. tatakaense</i>	<i>C. kawakamii</i>	<i>C. arisanense</i>
Leaf size (cm)	27.2–34.8 cm × 16.4–19.4 cm	27.5–30.6 cm × 17.8–20.2 cm	10.6–21.3 cm × 3.0–6.3 cm
Leaf shape	Elliptic to broadly elliptic	Elliptic to broadly elliptic	Narrowly elliptic to deltoid
Leaf margin	Mainly pinnatisect	Pinnatisect or bipinnatisect	Pinnatipartite or bipinnatipartite
Leaf lobes Size	6.4–7.5 cm × 7.3–11.9 mm	8.3–10.4 cm × 17.2–18.6 mm	0.7–2.9 cm × 6.6–16.0 mm
Pair of leaflobes	4–6	6–7	6–10
Mature Capitula	Nodding	Nodding	Erect or nodding
Involucre shape	Bowl-shaped (upper width ≥ base)	Bowl-shaped (upper width ≥ base)	Pot-shaped (upper width < base)
Corolla colour	Purplish-red	White	Yellow
Floret number	(136)161–308	(61)115–222	87–133
Phyllary number	111–199	79–123	93–114
Beak of achene	Tube-like	Tube-like	Corona-like
Pollen size (P/E)	34.2–42.6 μm / 35.2–44.7 μm	31.7–34.5 μm / 34.3–37.1 μm	41.7–51.0 μm / 44.7–49.3 μm
Pollen spine base width	4.2–5.6 μm	2.0–2.3 μm	2.8–4.8 μm
Chromosome number	$2n = 64$	$2n = 64$	$2n = 34$ (Peng and Hsu 1978)
Distribution	Endemic to Taiwan; open areas of fog forests at 2000–3000 m alt. central-southern Taiwan (Fig. 3)	Endemic to Taiwan; gullies and valleys at 1500–3500 m alt. central-northern Taiwan (Fig. 3)	Endemic to Taiwan; widely distributed in open areas of mountain area at 1500–3800 m alt. (Fig. 3)

Taxonomic treatment

Key to the species of *Cirsium* Mill. in Taiwan

- 1 Biennial herb; involucre tube-shaped (length 2 times than width); corolla lobes < 2.5 mm long ***C. ferum***
- Perennial herb; involucre pot or bowl-shaped (length approximates width), corolla lobes > 2.5 mm long..... **2**
- 2 All leaves cauline, basal rosette leaves absent..... **3**
- Leaves in both a basal rosette as well as cauline **5**
- 3 Leaves densely cobwebbed on abaxial surface; mature capitula erect, involucre pot-shaped (upper width shorter than base); apical parts of inner phyllaries inflated, obtuse; outer phyllaries lanceolate, apex acute without spine; corolla lobes obviously longer than the inflated part of corolla tube..... ***C. lineare***
- Leaves glabrous on both surfaces; mature capitula nodding, involucre bowl-shaped (upper width greater or equal to base); apical parts of inner phyllaries acute or acuminate; outer phyllaries elliptic with long spine at the apex; corolla lobes as long as the inflated part of corolla tube **4**
- 4 Corollas white; leaves pinnatisect or bipinnatisect, lobes > 15 mm wide
..... ***C. kawakamii***
- Corollas purple; leaves mainly pinnatisect, lobes < 12 mm wide
..... ***C. tatakaense***
- 5 Phyllaries narrowly ovate..... **6**
- Phyllaries subulate **7**
- 6 Corollas white; phyllaries lanceolate, inner and outer phyllaries similar in length; stems cauline, without rhizome ***C. brevicaule***
- Corollas purple; phyllaries narrowly ovate to ovate, inner and outer phyllaries distinct in length; stems both cauline and rhizomatous ***C. morii***
- 7 Apical prominently parts of phyllaries longer than 4 mm, blade-like; corolla lobes as long as the inflated part of corolla tube **8**
- Apical prominently parts of phyllaries shorter than 4 mm, spine-like; corolla lobes shorter than the inflated part of corolla tube **9**
- 8 Leaf abaxial surface pubescent; mature capitula erect or nodding
..... ***C. arisanense***
- Leaf abaxial surface densely cobwebbed; mature capitula nodding
..... ***C. hosokawae***
- 9 Leaf abaxial surface densely cobwebbed; mature capitula nodding
..... ***C. suzukii***
- Leaves surface pubescent; mature capitula erect **10**
- 10 Corollas purple; leaves surface shortly hairy ***C. japonicum* var. *australe***
- Corollas white; leaves surface glabrescent ***C. japonicum* var. *takaoense***

Species treatments

***Cirsium kawakamii* Hayata in J. Coll. Sci. Imp. Univ. Tokyo. 159. 1911.**

Figs 4B, 5B, 6B, 7B

Type. TAIWAN. Mt. Morrison, ca. 3000 m alt., 20 Oct. 1906. *T. Kawakami* & *U. Mori* 2279 (holotype: TI!; isotype: TAIF!).

Description. Perennial herbs, stems 0.5–1.8 m tall, without rosette leaves. Leaves pinnatipartite or pinnatisect, 27.5–30.6 cm long and 17.8–20.2 cm wide, U-shaped space between pinnae, smooth, elliptic to broadly elliptic, base truncate to cuneate, apex caudate, pinnae 8.3–10.4 cm long and 17.2–18.6 mm wide, space between pinnae 2.5–3.0 cm, 6–7 pairs. Capitula arranged into racemes or panicles, mature capitula nodding, involucre bowl shaped, 3.4–3.8 cm long and 1.5–2.0 cm wide. Involucre lacking abaxial appendages, inner phyllaries acute apically, outer phyllaries green with indistinct layers, 1.6–1.8 cm long and 1.8–2.4 mm wide, protrusion 6.0–11.0 mm. Florets with white corolla, 2.8–3.1 cm long, corolla lobes 5.2–6.0 mm long and 0.4–0.7 mm wide; 5 synantherous stamens, detached filaments with irregular protuberances, basal caudate extensions, white or brown, anthers 5.4–8.2 mm long, filaments 6.8–8.0 mm long. Stigmas bifid apically, style 2.0–3.4 cm long, ovaries 1.5–2.0 mm long. Achenes oblong, base acute, apex truncate, beige, 4.3–4.9 mm long and 1.7–1.8 mm wide, long tube-shaped beak apically. Pappus 1.3–2.1 cm long forming basal ring, easily shed.

Phenology. Flowering between September and October and fruiting between October and November.

Distribution. Endemic to central-northern Taiwan. Preference for gullies and valleys at 1500–3500 m alt. (Fig. 3).

Chinese name. Yu-shan-ji (玉山薊).

Chromosome number. $2n=64$ (Fig. 6B).

Palynology. Pollen grains are tricolporate, spheroidal, microreticulate and $31.7\text{--}34.5 \times 34.3\text{--}37.1 \mu\text{m}$ (P/E ratio: 0.9–1.0). The surface is densely covered with spines that are 2.5–3.2 μm long and 2.1–2.2 μm wide at the base. The distance between spines is 7.6–8.8 μm (Fig. 7B).

Additional specimen examined. TAIWAN. Taoyuan City, Fuxing District, Mt. Lalashan, 1550–1700 m alt., 25 Sept. 1991. *C. I Peng* 14628 (HAST!). Miaoli County, Tai'an Township, Tunnel of Mt. Shishihshan to Mt. Huoshihshan, 2480 m alt., 18 Sept. 1995. *C. M. Wang* 1728 (TNM!). Taichung City, Heping District, Mt. Syue to Mt. Chihchiayangdashan, 3300 m alt., 10 Sept. 2014. *C. Y. Chang et C. H. Liu* 68 (TNM); Mt. Pintian to Mt. Dabajianshan, 2800 m alt., 24°26.52'N, 121°15.83'E, 13 Aug. 2014. *C. Y. Chang* 264 (TNM); Mt. Syue Trail 8.9 km, 3500 m alt., 24°23.53'N, 121°14.20'E, 3 Oct 2015. *C. Y. Chang* 774, 1271 (TCF). Nantou County, Ren'ai Township, Nengao cross-ridge historic trail 11 km, 2600 m alt., 24°2.79'N, 121°15.77'E, 29 Jan 2018. *C. Y. Chang* 1605 (TNM); Chengkung lodge, 3140 m alt., 31 July 2015. *C. Y. Chang* 654 (TNM); Guandao river, 22 Oct. 1932. *S. Sasao s. n.* (CHIA!); Mt. Hohwanshan, 3300 m alt., 15 Oct. 1994. *Tunghai Collecting Team s. n.* (TNM!). Hualien County, Xiulin Township, Sungshielou lodge to Dayuling, 3 Aug. 1974. *C. N. Lin s. n.* (KYO!).

***Cirsium tatakaense* Y.H.Tseng & C.Y.Chang, sp. nov.**

urn:lsid:ipni.org:names:77194985-1

Figs 1, 2, 4A, 5A, 6A, 7A

Diagnosis. Differs from *C. kawakamii* in having narrower leaf lobes (7.3–11.7 mm), usually more florets, (136)161–308 and phyllaries (111–199), a purplish-red corolla and larger pollen grains (34.2–42.6 × 35.2–44.7 μm).

Type. TAIWAN. Nantou County, Sinyi Township, Highway no. 18, Tataka to Shihshan, 2400 m alt., 23°28.52'N, 120°52.10'E, 3 October 2016. *C. Y. Chang 1444* (holotype: TCF; isotype: TNM, PPI).

Description. Perennial herbs, stems 0.5–1.5 m tall, without rosette leaves. Leaves pinnatipartite or pinnatisect, 27.2–34.8 cm long and 16.4–19.4 cm wide, U-shaped space between pinnae, smooth, elliptic to broadly elliptic, base truncate to cuneate, apex caudate, pinnae 6.4–7.5 cm long and 7.3–11.9 mm wide, space between pinnae 2.9–3.0 cm, 4–6 pairs. Capitula arranged into racemes or panicles, mature capitula nodding, involucre bowl-shaped, 3.9–4.0 cm long and 1.7–2.1 cm wide. Involucre lacking abaxial appendages, inner phyllaries acute apically, outer phyllaries reddish-purple with indistinct layers, 1.1–2.2 cm long and 1.8–2.4 mm wide, protrusion 6.3–13.0 mm. Florets with purplish-red corolla, 3.2–3.3 cm long, corolla lobes 4.3–5.3 mm long and 0.4–0.7 mm wide; 5 synantherous stamens, detached filaments with irregular protuberances, basal caudate extensions, light purple or brown, anthers 6.4–6.8 mm long, filaments 7.1–8.1 mm long. Stigmas bifid apically, style 3.0–3.2 cm long, ovaries 1.7–1.9 mm long. Achenes oblong, base acute, apex truncate, beige, 3.0–3.5 mm long and 1.4–1.6 mm wide, long tube-shaped beak apically. Pappus 1.6–1.8 cm long forming basal ring, easily shed.

Phenology. Flowering between August and October and fruiting between September and November.

Distribution. Endemic species of Taiwan. *Cirsium tatakaense* is located in open areas of cloud forests of vegetation zones from the *Quercus* to *Abies* forest zone at alt. 2000–3000 m in central-southern Taiwan (Fig. 3). Based on the geographical climatic regions and vegetation zones (Su 1984, 1985), *C. tatakaense* is distributed mainly in the central-west inland regions. *Cirsium tatakaense* has been discovered in sunny environments, such as roadsides and forest margins, concentrated on the upper portions of hills along Provincial Highway no. 18. *Miscanthus transmorrisonensis* Andersson (Poaceae), *Rubus taitoensis* Hayata (Rosaceae) and *Senecio nemorensis* L. var. *dentatus* (Kitam.) H. Koyama (Compositae) are often discovered with *C. tatakaense*. Sometimes, *C. arisanense* Kitam. and *C. ferum* Kitam. are found near to *C. tatakaense*; however, no hybrid individual between these species has been observed.

Chinese name. Ta-ta-jia-ji (塔塔加薊).

Etymology. The species epithet *tatakaense* derives from the type location Tataka in Nantou County.

Notes. This species has in the past been mistakenly identified as *C. kawakamii* (S. Saito 3477, KYO!; Yamazaki 945, KYO!; *C. I Peng* 8026, 8936, 11788, 14628, HAST!; *K. F. Chung* 1053, HAST!; *Kawakami & Sasaki s. n.*, TAIF!; *M. L. Weng* 1723, TAI!; *Y. Kudo*

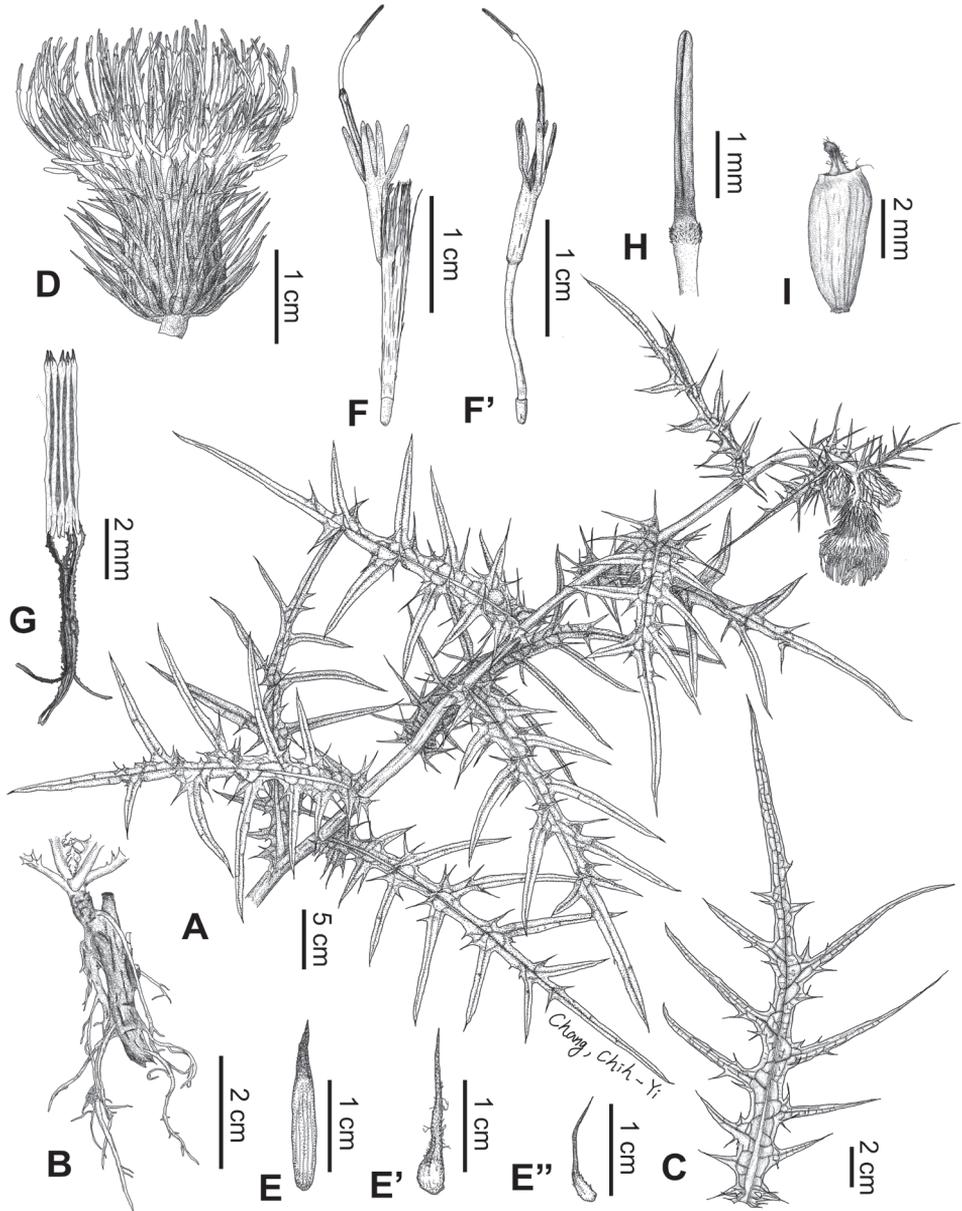


Figure 1. Line drawings of *Cirsium tatakaense* Y.H.Tseng & C.Y.Chang **A** habit **B** root **C** leaf **D** capitula **E** inner phyllary **E'** middle phyllary **E''** outer phyllary **F** floret **F'** floret (pappus removed) **G** synanthous **H** style branches **I** achene. Voucher: C. Y. Chang 1442 (TCF).

& S. Suzuki 300, TAI!; C. C. Hsu 4231, TAI!; C. I Peng 738, TAI!; C. T. Chao et al. 2534, TNMI!; C. S. Kuoh 15146, TNMI!) or less often as *C. arisanense* Kitam. (Yamamoto et al. 4142, TAI!; Y. J. Lin 169, PPI!). The earliest record of *C. tatakaense* was collected by T. Kawakami & S. Sasaki s. n. (TAIF!) at Mt. Morrison (alt. ca. 3000 m) on October 8, 1909.

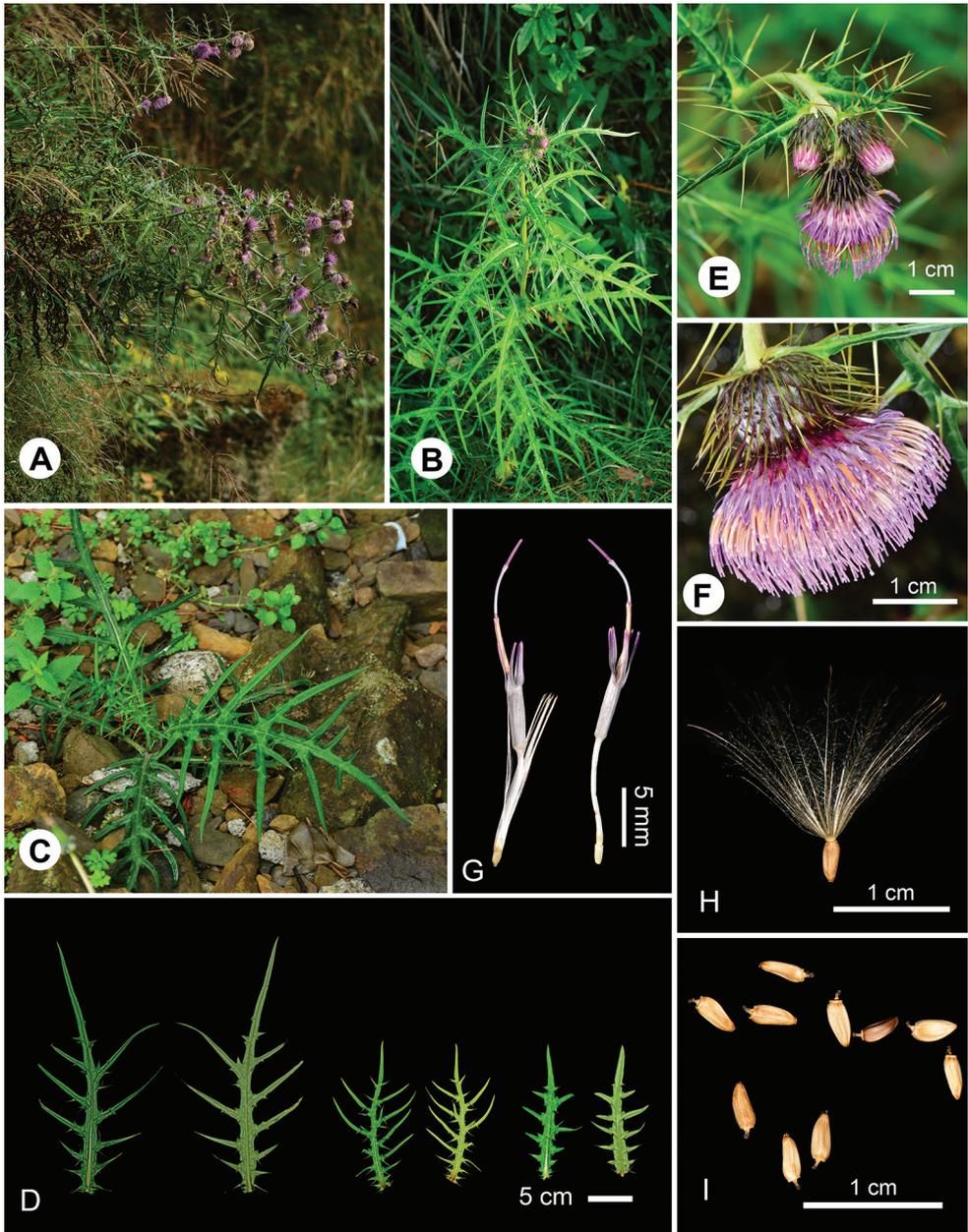


Figure 2. *Cirsium tatakaense* Y.H.Tseng & C.Y.Chang **A** habitat **B** habit **C** seedling **D** variations of leaves **E** inflorescences **F** capitula **G** floret; (right-side pappus removed) **H** achene with pappus **I** achene.

Other specimens collected from 1909–1930 were from Alishan (alt. ca. 2200 m). However, only a few populations remain in Alishan, with the largest population appearing along the Yushan Main Peak Trail from Tataka to Paiyun Lodge (alt. ca. 2800 m). We assume that use in herbal medicine as well as climate change have reduced the population of *C. tatakaense*.

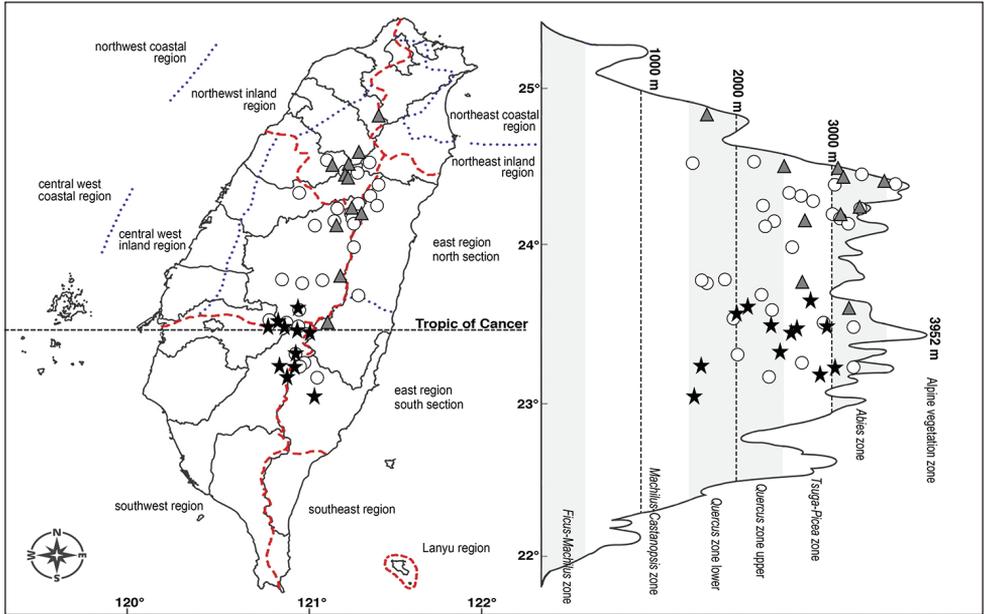


Figure 3. Distribution map of *Cirsium tatakaense* Y.H.Tseng & C.Y.Chang (star); *C. kawakamii* Hayata (triangle); and *C. arisanense* Kitam. (circle) of Taiwan.

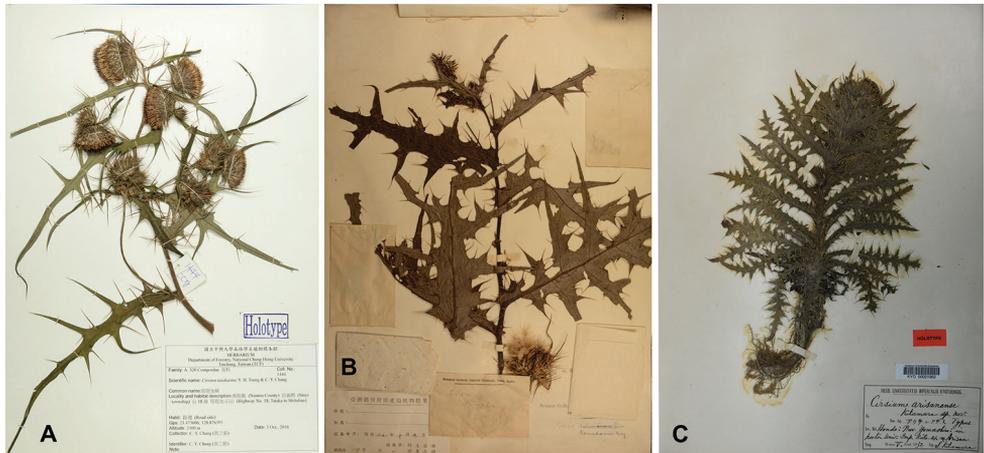


Figure 4. Holotypes of the three species of *Cirsium* sect. *Onotrophe* in Taiwan. **A** *C. tatakaense* Y.H.Tseng & C.Y.Chang 1444 (TCF) **B** *C. kawakamii* Hayata, T. Kawakami & U. Mori 2279 (TI!) **C** *C. arisanense* Kitam., S. Kitamura s.n. (KYO!).

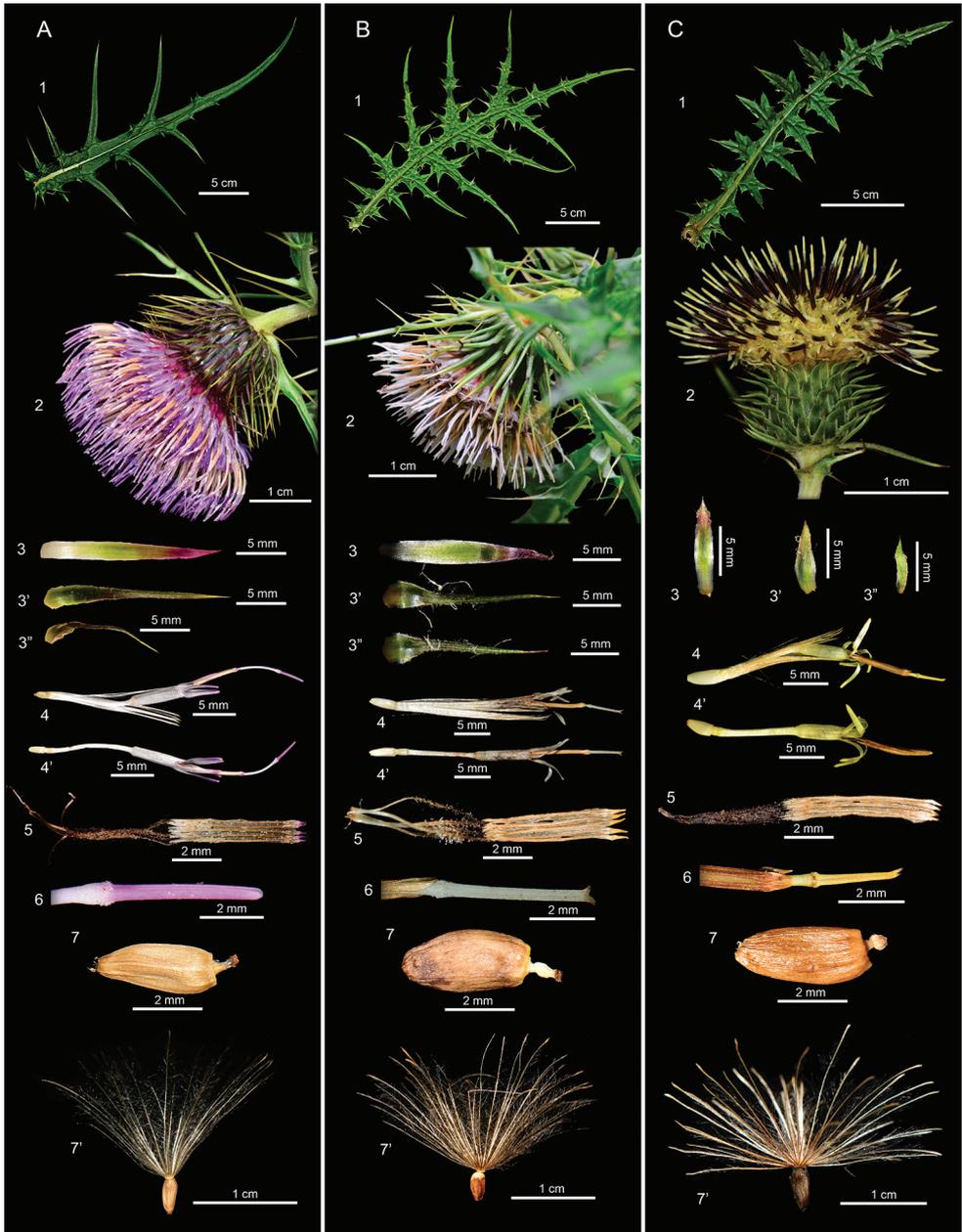


Figure 5. Comparison of the morphological characters amongst the species of *Cirsium* sect. *Onotrophe* in Taiwan. **A** *C. tatakaense* Y.H.Tseng & C.Y.Chang **B** *C. kawakamii* Hayata **C** *C. arisanense* Kitam.: 1 leaf 2 capitula 3 inner phyllary 3' middle phyllary 3'' outer phyllary 4 floret 4' floret (pappus removed) 5 synanthems 6 style branches 7 achene 7' achene with pappus.

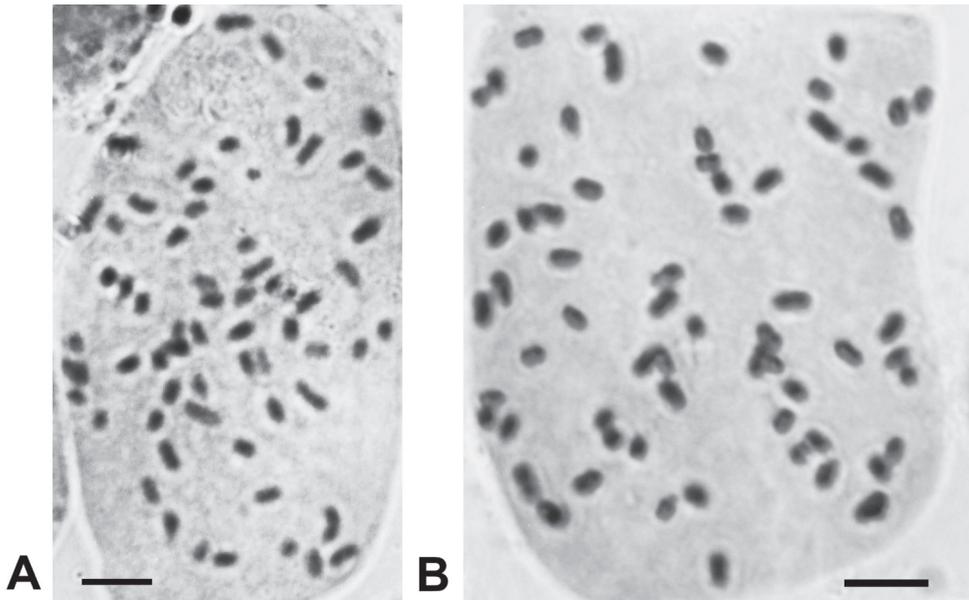


Figure 6. Chromosome number of the two species of *Cirsium* subsect. *Nipponocirsium* Kitam. in Taiwan. **A** $2n = 64$, *C. tatakaense* Y.H.Tseng & C.Y.Chang **B** $2n = 64$, *C. kawakamii* Hayata. Scale bar: 5 μ m.

Chromosome number. $2n = 64$ (Fig. 6A)

Palynology. Pollen grains are tricolporate, spheroidal, microreticulate and $34.2\text{--}42.6 \times 35.2\text{--}44.7 \mu\text{m}$ (P/E ratio: 0.9–1.0). The surface of the pollen is densely covered with spines that are $3.2\text{--}5.1 \mu\text{m}$ long and $4.2\text{--}5.6 \mu\text{m}$ wide at the base. The distance between spines is $7.5\text{--}10.6 \mu\text{m}$ (Fig. 7A).

Conservation status. *Cirsium tatakaense* is distributed in central-southern Taiwan, with a population of more than 1000 mature individuals. Its habitats are mainly located in high and sunny mountain areas and many of them are difficult to locate. Therefore, following the International Union for Conservation of Nature (IUCN) Categories and Criteria (IUCN 2014), we regard this species as Least Concern. However, long-term monitoring of its population is still required.

Additional specimens examined (paratype). TAIWAN. Nantou County, Sinyi Township, Highway no. 18, Tataka to Shihshan, 2400 m alt., $23^{\circ}28.52'N$, $120^{\circ}52.10'E$, 3 Oct. 2016. *C. Y. Chang 1442* (TCF); same loc., 3 Oct. 2016. *C. Y. Chang 1443* (TCF); same loc., 12 Sept. 2012. *C. T. Chao et al. 2534* (TNM!); Tunpu Hot Spring to Kuankao, 1300–2600 m alt., 3 July 1985. *C. I Peng 8026* (HAST!). Chiayi County, Alishan Township, Alishan, 25 Dec. 1928. *Y. Kudo & S. Suzuki 300* (TAI!); Tatachia saddle to Paiyunshanchuang, 2700–3000 m alt., 9 Nov. 1985. *C. I Peng 8931* (HAST!); Tatachia saddle to Mt. Yushanchienfu, 2700–3100 m alt., 11 Nov. 1990. *P. J. Wu et al. s. n.* (TNM!). Kaohsiung City, Taoyuan District, Kuaiku to Yakou, 2600 m alt., $23^{\circ}16.03'N$, $120^{\circ}56.24'E$, 21 Oct. 2014. *C. Y.*

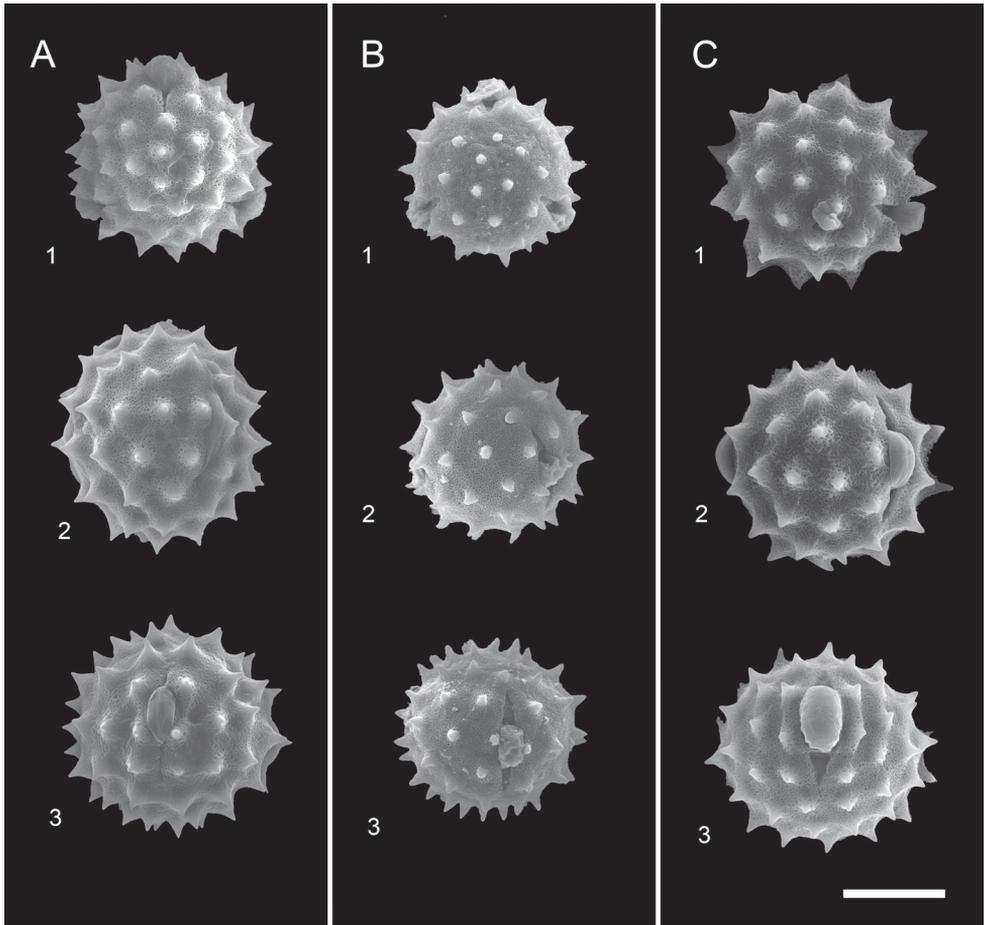


Figure 7. Comparison of the pollen morphology of the three species of *Cirsium* sect. *Onotrophe* in Taiwan. **A** *C. tatakaense* Y.H.Tseng & C.Y.Chang **B** *C. kawakamii* Hayata **C** *C. arisanense* Kitam.: **1** polar view **2** equatorial view **3** colporate view. Scale bar: 30 μ m.

Chang 160 (TNM); Gingzin bridge, 14 Sept. 1999. *C. S. Kuoh* 15146 (TAN!). Taitung County, Yanping Township, Yenping forest-road, 1500–1800 m alt., 2 July 2006. *Y. J. Lin* 169 (PPI!).

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Clematis mae (Ranunculaceae), a new species of *C. sect. Meclatis* from Xinjiang, China

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Abstract

Clematis mae Z.Z.Yang & L.Xie, a new species of Ranunculaceae from Xinjiang, China, is described and illustrated. The new species is morphologically similar to *C. orientalis* and *C. glauca* but can be distinguished for being a less hairy plant (hairy in *C. orientalis*), often 2-ternate leaves (1–2-pinnate for *C. orientalis* and *C. glauca*), lanceolate to linear-lanceolate leaflets (elliptic or ovate in *C. glauca*), larger flowers (smaller flower in *C. orientalis*) and narrowly lanceolate sepals with acute to slightly attenuate apex (narrowly oblong sepals in *C. orientalis* and ovate to broadly lanceolate sepals in *C. glauca*). The new species is endemic to the southern slope of North Tianshan Mountain in Central Xinjiang. The conservation status of the species is also discussed.

Keywords

Anemoneae, Asia, Eudicots, Ranunculales, vine

Introduction

Clematis L. is one of the three most widely distributed genera in Ranunculaceae (the other two being *Anemone* L. and *Ranunculus* L.; Ziman and Keener 1989), with approximately 300 species (Fang et al. 1980, Tamura 1987, 1995, Essig 1991, Johnson

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1997, Grey-Wilson 2000, Wang and Li 2005, Miikeda et al. 2006, Xie et al. 2011, Lehtonen et al. 2016, Jiang et al. 2017). The taxonomy of *Clematis* has attracted much attention due to its great horticultural value. Historically, this large genus had been subdivided into many infrageneric groups using different taxonomic levels by different authors (Spach 1839, Prantl 1887, Tamura 1987, 1995, Johnson 1997, Grey-Wilson 2000, Wang and Li 2005).

Clematis sect. *Meclatis* (Spach) Baillon also known as the *Orientalis* group (*sensu* Grey-Wilson 1989, 2000) is one of the taxonomically most difficult groups in the genus, with approximately a dozen yellow-flowered species that are widely distributed in Eurasia (Grey-Wilson 1989, Brandenburg 2000, Wang 2006). Species of *C.* sect. *Meclatis* are especially common in the highlands of central Asia and the Tibetan plateau. In his recent worldwide taxonomic revision of the section, Wang (2006) used leaf shape and colour, inflorescence type and position, sepal morphology and filament shape as key characteristics for species classification and accepted 13 species in *C.* sect. *Meclatis*. However, recent molecular phylogenetic analyses did not clearly resolve this morphologically defined section and showed that species of *C.* sect. *Meclatis*, *C.* sect. *Fruticella* and other species, like *C. barbellata* Edgew. and *C. pogonandra* Maxim., were nested together (Xie et al. 2011, Lehtonen et al. 2016). Many of *C.* sect. *Meclatis* species are widely distributed and also present a wide range of morphologic variation (e.g. *C. orientalis* L., *C. glauca* Willd., *C. tibetana* Kuntze and *C. tangutica* (Maxim.) Korsh.). There are also several narrowly distributed local species with very distinctive characteristics recognised by Wang (2006) (e.g. *C. sarezica* Ikonnikov, *C. caudigera* W.T. Wang and *C. corniculata* W.T. Wang). Recently, a new local species belonging to *C.* sect. *Meclatis* from Iran was also reported (Habibi et al. 2014).

During field investigations in Xinjiang, a distinctive population of *Clematis*, clearly belonging to sect. *Meclatis*, was discovered on the southern slope of North Tianshan Mountain. After carefully studying specimens of *C.* sect. *Meclatis* in Xinjiang and adjacent areas, we confirmed that this plant represents a distinctive taxonomic entity and thus describe it as a new species.

Methods

Field investigations were conducted in the type locality and other areas in Xinjiang; specimens of *C.* sect. *Meclatis* were collected from Xinjiang and Gansu for morphological comparison. Furthermore, specimens of *C.* sect. *Meclatis*, deposited in PE, KUN, IBSC, BJFC, HIMC, IBK, NAS, XJA, XJBI, K, US and E were widely checked and evaluated using the relevant literature (Grey-Wilson 1989, Brandenburg 2000, Wang 2006). Morphological comparison and measurement of the specimens were carried out under a YKT5300 stereomicroscope. Newly collected specimens have been deposited in the herbaria of Beijing Forestry University (BJFC).

Taxonomy

Clematis mae Z.Z. Yang & L. Xie, sp. nov.

urn:lsid:ipni.org:names:77194986-1

Figs 1, 2, 3A–C

Diagnosis. The new species is most similar to *C. orientalis* L. and *C. glauca* Willd. and it can be distinguished from the latter two species by the following combinations of characteristics. Plants of the new species are less hairy than *C. orientalis* and, in this respect, are similar to *C. glauca*. The leaves of the new species are often 2-ternate, with lanceolate to linear lanceolate leaflets. Its leaflets are larger than those of *C. orientalis*, but narrower than those of *C. glauca*. The flowers are also significantly larger than those of *C. orientalis* and slightly larger than those of *C. glauca*. The sepals of the new species are also less hairy than those of *C. orientalis* and similar to those of *C. glauca*. The shape of the sepal is lanceolate and the apex is acute to slightly attenuate. In *C. orientalis*, the sepals are often linear, oblong and reflexed. The sepals of *C. glauca* are often wider than those of the new species (Table 1, Fig. 3).

Type. CHINA. Xinjiang: Toksun, Yuer gou, alt. 2590 m, sandy bank along the river, 22 Aug. 2018, fl, fr, *M. Ma & Z.Z. Yang 99348* (holotype: BJFC; isotypes: 3 ex BJFC).

Description. Woody vine. Branches slender, shallowly 6 sulcate, very sparsely puberulous. Leaves pinnate to 2-ternate, very rarely ternate, up to 16 cm in length and 13 cm in width; living leaflets dry, green or sometimes grey-green, papyraceous to chartaceous, lanceolate to linear-lanceolate, 1.8–6.5 × 0.3–0.8 cm, glabrous on the upper side, sparsely puberulous on the lower side, usually 2–3-lobed to 2–3-sect, sometimes undivided, terminal lobe lanceolate to linear-lanceolate, 0.4–0.8 cm broad, margin entire, never dentate, midrib adaxially flat or slightly prominent, abaxially clearly prominent. Cymes all axillary, (1–2)–3-flowered; peduncles 2.5–3.0 cm long, slender; bracts petiolate, leaflet-like, up to 3.5 cm long; central flower of the 3 flowered cyme without bracteole, two lateral flowers bracteolate; bracteole petiolate and leaflet-like, up to 8 mm long. Flower 3.8–5.8 cm diam.; pedicel 2.8–5.2 cm long, puberulous, upper pedicel usually densely hairy. Sepals 4, pinkish-purple outside and yellow inside, ascending, lanceolate, 18–27 × 4–6.5 mm, puberulous on both surfaces, outside margin velutinous, apex acute to slightly attenuate. Stamens more than 30, 9–12 mm long; filaments lanceolate linear, widened in the lower part, pubescent; anthers linear to narrowly oblong, 3–4 mm long, glabrous, apex obtuse, minutely apiculate. Carpels numerous, up to 60 per flower; ovaries pubescent; styles 8–12 mm long, densely villous. Achenes laterally compressed, elliptic, ca. 3.9 × 2.1 mm, puberulous; persistent styles 6.5 cm long, plumose.

Specimens seen (paratypes). CHINA. Xinjiang: Toksun, Yuer gou, alt. 2600 m, 22 Aug. 2018 (fl, fr), *M. Ma & Z.Z. Yang 99349, 99355* (paratypes: BJFC).

Phenology. Flowering and fruiting time: July to September.

Distribution. Only known from its type locality, Yuer gou, Toksun, Xinjiang, China.

Vernacular name. Ming Tie Xian Lian (明铁线莲; new Chinese name)



Figure 1. Holotype specimen (*M. Ma & Z.Z. Yang 99348*, deposited in BJFC) of the new species, *Clematis mae* Z.Z. Yang & L. Xie, collected from Yuer gou, Toksun, Xinjiang, China.



Figure 2. Illustration of *Clematis mae* Z.Z.Yang & L.Xie. Drawn by S.F. Li

Habitat and conservation status. According to currently available data regarding *C. mae*, it occurs only in its type locality. The environment of the habitat is stable. We found about 200 individuals of the new species scattered along the river bank (elevation ca. 2500–2600 m) of Yuer Gou, Toksun Co. and we did not find individuals of this species outside this area. The herbarium investigation showed that several *C. sect. Meclatis* specimens were collected in Toksun Co., e.g. *AJ Li & JN Zhu 7288*,

Table 1. Morphological comparison of the new species to two closely related species.

Species	<i>C. mae</i>	<i>C. orientalis</i>	<i>C. glauca</i>
Hairs on plant	Present but hard to see	Hairs often dense	Present but hard to see
Leaf	Bluish-green, pinnate to 2-ternate	Grey green, 1–2-pinnate	Bluish-green to green, 1–2-pinnate
Leaflet	Thick papery, always lanceolate to linear lanceolate, margin entire	Thick papery to subcoriaceous, highly variable, sometimes lanceolate, margin entire or 1–2 dentate	Papery to herbaceous, variable, often elliptic or ovate, margin entire
Inflorescence	1–3-flowered cyme	1-many-flowered cyme, often panicle like	1–7-many-flowered cyme
Bracteole	Entire	Entire	Sometimes 3-lobed
Flower	3.8–5.8 cm diam.	1.4–2.8 cm diam.	3.5–3.8 cm diam.
Sepal	Ascending, not reflexed	Spreading, reflexed	Ascending, not reflexed
Sepal color	Pinkish-purple outside	Yellow	Pinkish-purple or yellow outside
Sepal shape	Narrowly lanceolate	Often narrowly oblong	Narrowly ovate to elliptic
Inside sepal	puberulous	puberulous	glabrous or very sparsely puberulous
Stamen	7–12 mm long	5–9 mm long	7–14 mm long



Figure 3. Field photographs of three closely related species of sect. *Meclatis*. **A–C** *Clematis mae* Z.Z. Yang & L. Xie. (photo taken by M. Ma & Z.Z. Yang) **A** Biternate leaf and flower buds **B** Ascending flower and its outside sepals **C** Flower inside **D–F** *Clematis orientalis* L. (photo taken at Shihezi, Xinjiang, China, by Z.Z. Yang) **D** Habitat and plants of *C. orientalis* **E** Flower showing spreading and reflexed sepals **F** Flower showing discernible hair on the inside sepals **G–I** *Clematis glauca* Willd. (photo taken at Liancheng, Gansu, China, by J. He and L. Xie) **G** Habitat and plant in flower **H** Cyme and leaves **I** Flower and young fruit.

7335 (PE) and *QR Wang et al. 4209* (PE); however, these specimens were collected at least 70 km from Yuer Gou and morphologically belong to *C. orientalis*. Based on currently available data, we considered the new species to be a local species endemic to a small area of Yuer Gou, Toksun Co. The open areas of the riverside, in which the new species occurs, may be threatened by settlements and agricultural activities. Therefore, we propose that the new species should be treated as Endangered (EN) in the International Union for Conservation of Nature (IUCN) categories system (IUCN 2012).

Etymology. The species epithet is chosen in honour of the collector, Ms. Ma Ming, who first noticed this new species and guided the last author to collect specimens.

Taxonomic notes. The new species clearly belongs to sect. *Meclatis* by its ascending sepals and pubescent and linear-lanceolate stamen filaments (Tamura 1995, Wang 2006) and is more similar to *C. glauca* than to *C. orientalis*. Observations of hairs, leaflets, flower size and shape and other characteristics clearly demonstrate that the new species is a taxonomic entity distinct from *C. orientalis*. *Clematis orientalis* is one of the most widely distributed species in its genus and has a wide range of morphological variation (Grey-Wilson 1989, Brandenburg 2000, Wang 2006). Both Grey-Wilson (1989) and Wang (2006) recognised seven varieties. The leaf shape of *C. orientalis* is strikingly variable (summarised by Grey-Wilson 1989) and may be similar to that of *C. mae*, but the leaves of *C. mae* are thinner than those of *C. orientalis*. Moreover, *C. orientalis* is often identified by its grey leaves, hairy stems and flowers and reflexed linear-oblong sepals. *Clematis mae* from central Xinjiang is less hairy than *C. orientalis* and has larger flowers with ascending lanceolate sepals (Fig. 3). The hair and floral characteristics of the new species are somewhat similar to those of *C. glauca*, another widely distributed species with wider leaflets and sepals. In comparison with *C. orientalis*, *C. glauca* has less hairy stems and flowers, much wider leaflets and sepals and non-reflexed sepals. The primary differences between the new species and *C. glauca* are their leaflet shape, sepal shape and flower shape and size. Furthermore, the bracteoles of *C. glauca* are sometimes 3-lobed, which is never the case in *C. mae*.

Additional specimen examined

Clematis orientalis L., Sp. Pl. 1: 543. 1753.

AFGHANISTAN. Kokcha-Tal, *D. Podlech 12732* (E). AZERBAIJAN. Caucasus, *Kolakovsky 1413* (MW). CHINA. Inner Mongolia, *Ejina, ZY Zhu & DS Wen 013* (HIMC); Gansu, Minqin, *YQ He 3332* (PE, WUK); Gansu, Jiuquan, *Qinghai-Gansu Exped. 2968* (PE), *ZJ Dong 270* (WUK). Xinjiang, Altay Shan, *RC Ching 2813* (PE); Xinjiang, Aqtau, *YC Wang Y172, Y180* (BJFC); Xinjiang, Gongliu, *Xinjiang Exped. Inst. Northwest Bot. 2667* (PE); Xinjiang, Hami, *RC Ching 122* (PE); Xinjiang, Hejing, Baluntai, *TY Zhou et al. 651335* (NAS), *T Zhang et al. 0443* (KUN); Xinjiang, Hettian, *Kelimu 106* (XJBI); Xinjiang, Korla, *AJ Li & JN Zhu 8641* (PE); Xinjiang, Qira, *Xinjiang Exped. 56-129* (PE); Xinjiang, Kunlun Shan, *ZQ Xie 25* (XJA); Xinjiang,

Shanshan, *AJ Li & JN Zhu* 6692 (PE); Xinjiang, Shihezi, *ZZ Yang* 0857, 0858 (BJFC); Xinjiang, Tian Shan, *TN Liou* 2689 (PE); Xinjiang, Toksun, *AJ Li & JN Zhu* 7288 (PE), *QR Wang et al.*, 4290 (PE); Xinjiang, Turpan, *ZM Zhang* 294 (PE); Xinjiang, Ürümqi, *TN Liou* 2891 (PE); Xinjiang, Yecheng, *Qinghai-Xizang Exped.* 87-764 (PE), Xinjiang, Kashi, *Abulimit* 258 (XJA); Xinjiang, Zhaosu, *Xinjiang Exped. Inst. Northwest Bot.* 2593 (PE). IRAN. Khorasan, *Koelz* 16822 (US). KAZAKHSTAN. Dzhambul, *Raikova* 2915 (PE); Western Tianshan, *Mekerov* 400 (PE); Issyk, *A. Regel* 498 (K). MONGOLIA. South-western Mongolia, *Ozypreeva s.n.* (MW). RUSSIA. Dagestan, *Клукова s.n.* (MW). TURKEY. Tortum, *Davis* 47565 (K); Oltu valley, *JC Archibald* 8281 (E). TURKMENISTAN. Ashabad, *P. Sintenis* 1055 (E). UZBEKISTAN. Tashkent, *Ellas, Murray & Newcomba* 9873 (PE).

***Clematis glauca* Willd., Berl. Baumz. 65. t. 4, fig. 1. 1796.**

CHINA. Gansu, Liancheng, *J He & L Xie* 2018GS009 (BJFC), *RF Huang* 2111 (HNWP); Gansu, Tianzhu, *RF Huang* 2601 (HNWP). Qinghai, Qilian, *collector unknown* 8532 (HNWP); Qinghai, Huzhu, *BZ Guo* 25547 (HNWP). Xinjiang, Altay Shan, *RC Ching* 2332 (PE); Xinjiang, Burqin, *YR Ling* 74-1008 (PE); Xinjiang, Ili, *XY Li YL* 96015 (XJBI); Xinjiang, Gongliu, *YC Wang* Y171 (BJFC); Xinjiang, Korla, *AJ Li & JN Zhu* 8642 (XJBI); Xinjiang, Ulatai, *KC Kuan* 3816 (PE); Xinjiang, Wenquan, *Hoch & J. R. Chen* 86-308 (PE). Xinjiang, Ürümqi, *RC Ching* 628 (PE). RUSSIA. Altai Mountain, Chuya River, *Elias, Weber, Tomb & Krasnoborov* 4411 (PE).

Key to the species of *Clematis* sect. *Meclatis*

- 1 Leaflet margin entire or with 1–2 teeth per side 2
- Leaflet margin regularly denticulate, dentate, serrate or crenate..... 9
- 2 Flowers solitary, terminal or also in lateral, axillary cymes 3
- Flowers usually in lateral, rarely also in terminal cymes, never solitary and terminal 4
- 3 Sepals inside glabrous, corniculate at apex *C. corniculata*
- Sepals inside puberulous, not corniculate at apex *C. tibetana*
- 4 Lateral cyme with one flower, sepals brown-purple, apex conrniculate *C. sarezica*
- Cyme with 1–3-many flowers, sepals yellow or tinged with purple, apex not coniculate 5
- 5 Leaflet blades narrowly elliptic or narrowly ovate, sepal inside glabrous or very sparsely puberulous *C. glauca*
- Leaflet blades lanceolate or linear-lanceolate 6
- 6 Sepal inside glabrous..... *C. intricata*
- Sepal inside puberulous 7
- 7 Sepal outside glabrous..... *C. ladakhiana*

- Sepal puberulous on both surfaces 8
- 8 Leaves grey green, 1–2 pinnate; sepal oblong, yellow outside, reflexed
..... *C. orientalis*
- Leaves bluish-green, often 2-ternate; sepal lanceolate, purple outside, not re-
flexed *C. mae*
- 9 Sepals inside glabrous..... 10
- Sepals inside puberulous 11
- 10 Leaf margin crenate *C. akebiooides*
- Leaf margin dentate or denticulate..... *C. tangutica*
- 11 Sepal with tail-like projection 3–6 mm long at apex; flowers only solitary and
terminal, never in axillary cymes *C. caudigera*
- Flowers usually in lateral, rarely also in terminal cymes, never solitary and
terminal 12
- 12 Sepals puberulous outside *C. hilariae*
- Sepals glabrous outside 13
- 13 Leaflets usually narrowly ovate or lanceolate, undivided, apex attenuate, mar-
gin serrate *C. serratifolia*
- Leaflets broadly ovate or ovate, 2–3-lobed, apex acute, margin irregularly
dentate..... *C. zandaensis*

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