

A new species of *Cinnamomum* (Lauraceae) from the Bladen Nature Reserve, southern Belize

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Abstract

A new species in the Lauraceae, *Cinnamomum bladenense* S.W. Brewer & G.L. Stott, is described from the Bladen Nature Reserve in southern Belize. The new species is similar to *Cinnamomum brenesii* (Standl.) Kosterm., from which it differs by its much smaller, narrowly-campanulate flowers, its inner tepals glabrous abaxially, its shorter petioles, its minutely sericeous younger twigs, and its abaxial leaf surfaces not glaucous and with prominent secondary venation. A description, preliminary conservation assessment, and photographs of the species as well as a key to and notes on the *Cinnamomum* of Belize are provided.

Keywords

Cinnamomum, Lauraceae, Belize, Central America, Bladen Nature Reserve, Maya Mountains

Introduction

Cinnamomum Schaeff. currently contains c. 350 species (Rohwer 1993), primarily in tropical Asia, with approximately 47 species found in the Neotropics (Lorea-Hernández 1996). We follow Lorea-Hernández' (1996, 1997) use of leaf venation pattern, presence and distribution of domatia along midvein and secondary veins, pubescence type, inflorescence structure, pubescence of floral parts, hypanthium development and persistence of tepals in fruit as some principal features for distinguishing species in the genus. Lorea-Hernández' revision of the genus for the Neotropics (1996) recognized

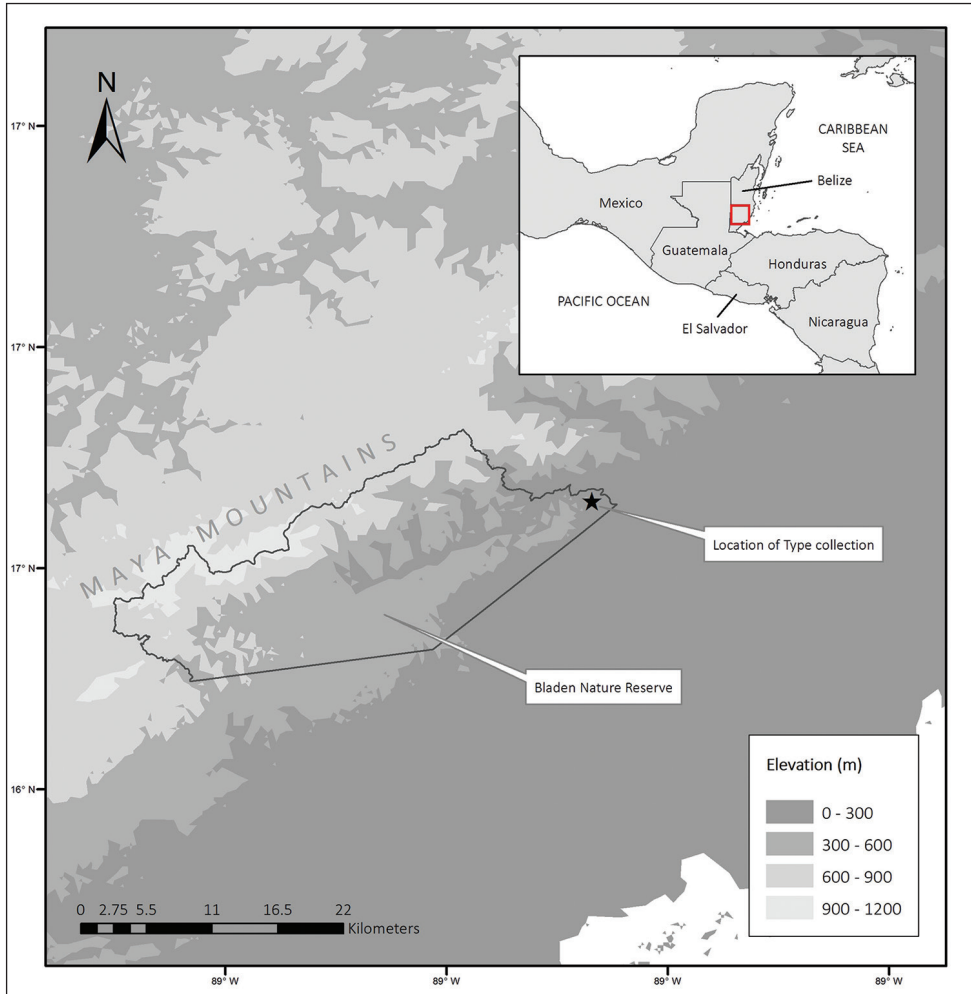


Figure 1. Elevation map of Belize with the type location (*) within the Bladen Nature Reserve.

only one species for Belize: *Cinnamomum triplinerve* (Ruiz & Pav.) Kosterm., a synonym of *Cinnamomum montanum* (Sw.) Bercht. & J. Presl (Rohwer 2014).

Floristic inventories in the Bladen Nature Reserve, Belize, Central America (Figure 1) from 2012–2014 resulted in the discovery of this species of Lauraceae. Fertile herbarium material collected from the type location was determined to be unique among any of the known species of *Cinnamomum* by comparing it with type and other herbarium specimens housed at MO, and online at F (<http://fm1.fieldmuseum.org/vrrc/>), HUH (http://kiki.huh.harvard.edu/databases/specimen_index.html), NY (<http://sweetgum.nybg.org/science/vh/>), US (<http://collections.nmnh.si.edu/search/botany/>), and JSTOR Global Plants (<https://plants.jstor.org/>). This plant is described here as a new species, and a key to and notes on the *Cinnamomum* of Belize are provided. Images of the

holotype and at least one isotype will be available on The Missouri Botanical Garden's electronic database TROPICOS (<http://www.tropicos.org>). Our examination of recent material of the genus in Belize confirms the presence of *Cinnamomum areolatum* (Lundell) Kosterm. for the country, as first reported by Standley and Steyermark (1946, as *Phoebe areolata* Lundell).

Taxonomic treatment

Cinnamomum bladenense S.W. Brewer & G.L. Stott, sp. nov.

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Type. BELIZE. Toledo District: Bladen Nature Reserve, c. 11 km north of Medina Bank, 16°33.14'N, 88°43.825'W, 320 m, 2 February 2016, S. W. Brewer & G.L. Stott 7529, (holotype, MO!; isotypes BM!, BRH!, CICY!, MO!, NY!, XAL)

Diagnosis. *Cinnamomum bladenense* is morphologically similar to *Cinnamomum brenesii* (Standl.) Kosterm. from which it differs by its much smaller (c. 2.1 vs. 3 mm long) and campanulate (vs. urceolate) flowers, its inner tepals glabrous abaxially (vs. pubescent), its shorter petioles (< 10 vs. > 10 mm), its moderately and minutely sericeous (vs. tomentose) younger twigs, and its abaxially matte green (vs. light-green glaucous) mature leaves with clearly prominent secondary venation abaxially (vs. venation nearly plane with the lamina).

Description. Tree 25 m tall, 26 cm DBH; bole round and mostly straight, with a low, narrow buttress of irregular-sized planks (Figure 2). Outer bark smooth, light-to-medium gray with a pinkish cast, occasional eye marks and rings, and lines of inconspicuous lenticels oriented lengthwise. Inner bark pinkish-brown with a moderately-pungent, chemical odor like that of bathroom cleaner (volatile, soapy).

Terminal buds moderately to densely sericeous with yellowish-white hairs. Twigs with slender, parallel, longitudinal grooves & low ridges (striate) to striate-angulate, less frequently laterally compressed and ridged-angulate, thinly to moderately-densely, minutely sericeous with silvery-white to yellowish, straight or weakly curved hairs 0.04–0.20 (0.3) mm long. Leaves alternate, thick-chartaceous to sub-coriaceous, ovate to ovate-elliptic, apex acute to shortly acuminate (rarely obtuse or rounded), base acute; within-branch leaf sizes highly variable, 11–31 mm wide × 35–86 mm long; petioles 3–9 mm, broadly and shallowly canaliculate, minutely sericeous. Venation mostly triplinerved, some subtriplinerved, the basal lateral nerves reaching c. ½ to ⅔ the length of the lamina; secondary veins 6–8; midvein and secondary veins immersed above, higher-order venation minutely impressed; midvein and secondary veins prominent below, higher order venation prominulous or minutely so. Inconspicuous domatia present in the form of barbellate axils of the basal-most pair of secondary veins, plane with the lamina, and usually present in one or two additional axils along the midrib, (rarely absent from a leaf). Laminae adaxially glossy, medium-dark green, glabrescent,



Figure 2. **A** Lower trunk and buttress of *Cinnamomum bladenense* **B** Bark and shallow trunk slash. Photos of same individual tree as *Brewer & Stott* 7529 by SW Brewer 18 March 2014.

with minute, mostly appressed to spreading, undulate to crisped, white to yellow-brown hairs on the basal portion of the midvein. Abaxial laminae light green, matte (to thinly and inconspicuously glaucous on young leaves), glabrescent or with very thinly-scattered, minute, subappressed and weakly undulate hairs; mid and lateral veins typically thinly minutely sericeous with appressed to subappressed hairs.

Inflorescences paniculate-cymose in leaf axils, 40–80 (130) mm, axes moderately covered in minute, mostly appressed (to spreading), straight to crisped hairs; bracts ligulate, mostly deciduous, to c. 5 mm long. Flowers narrowly campanulate, c. 2.0 mm long, on pedicels (2.0) 2.3–2.8 (–3.4) mm, drying dark brown to blackish-brown. Tepals 6, abscising nearly to the base in fruit, in flower spreading at shallow angles to the flower's long axis, glabrous abaxially, sericeous adaxially, the margins basally ciliolate, ovate to broadly elliptic, outer c. 1.9 mm and inner c. 2.3 mm × c. 1 mm. Stamens 9, 0.8–1.4 mm, all four-celled, filaments pubescent on both surfaces, inner three with sub-globose glands at the base; staminodia 0.8–0.9 mm, filaments pubescent, heads cordate, to 0.5–0.6 × 0.3–0.4 mm. Pistil 1.1–1.9 mm, the style c. 10% longer than the ovary. Hypanthium sericeous inside, glabrous outside. Immature fruits thinly-glaucous green or green, ellipsoid to 10.3 × 6.0 mm. Cupules to 4.5 × 3.8 mm, tepal remnants inconspicuous, to 0.26 mm above the bottom of the sinus between tepal remnants, pedicels partly turbinate in fruit (Figure 4).

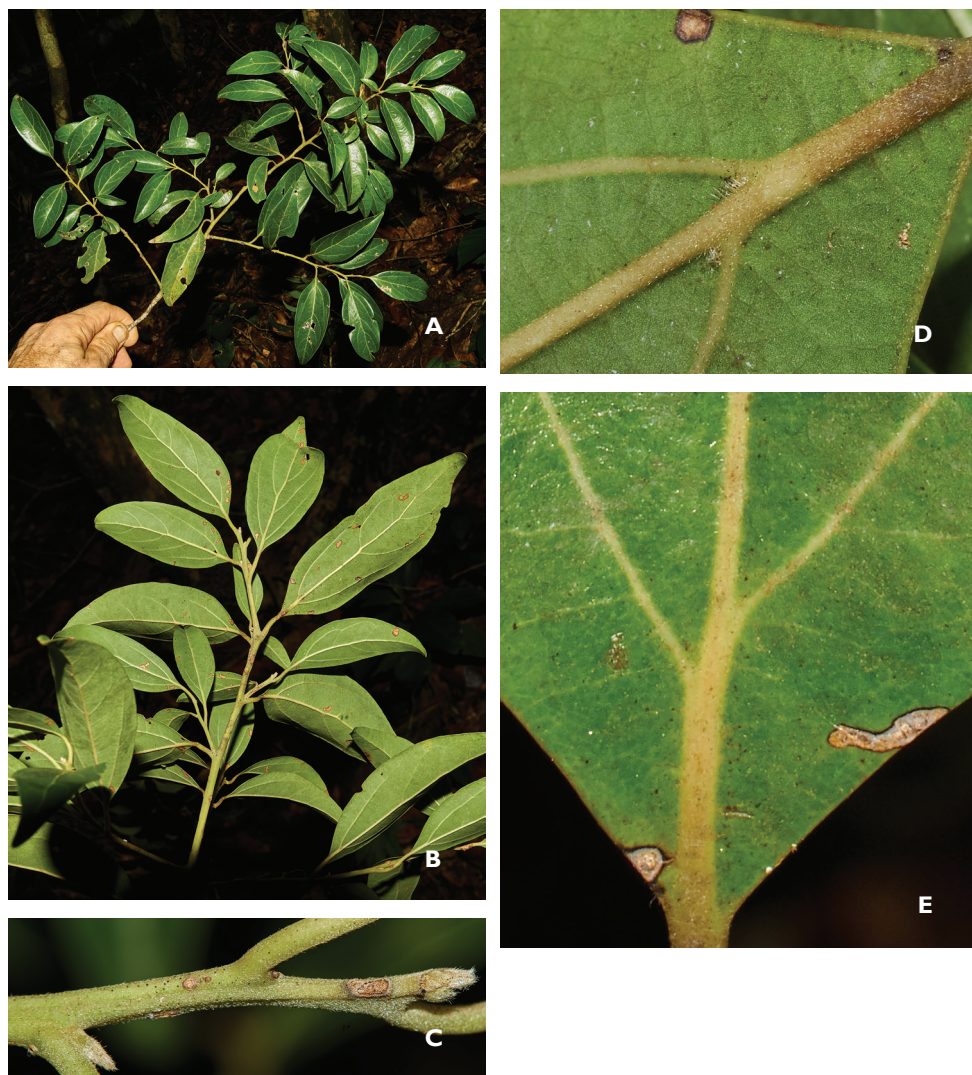


Figure 3. Diagnostic vegetative characters of *Cinnamomum bladenense* **A** Branch showing adaxial surface and variation of leaf sizes within branches **B** Abaxial surface of leaves showing matte green laminae and prominent midvein and secondary venation **C** Young twigs moderately and minutely sericeous with whitish buds **D, E** From the base of the same leaf lamina, respectively, adaxial surface of secondary vein axils not ampullous, abaxial surface of secondary veins barbellate and plane with the lamina surface. Photos from Brewer & Stott 7529 by SW Brewer 2 February 2016.

Other specimens examined. *Brewer & Stott 7148* (from the same individual as the type, in sterile condition, collected in March 2014), *Brewer & Stott 6815* (sterile tree 15 m tall, 12 cm DBH, collected in December 2012).

Etymology. The specific epithet honors the type location, the Bladen Nature Reserve, established in 1990 (IUCN Category 1a) to protect the watershed and the



Figure 4. Diagnostic and other fertile characters of *Cinnamomum bladenense* **A** Axillary inflorescences on dry branch with all but one leaf removed to show variation in size and degree of branching **B** Apical portion of inflorescence showing flowers in bud and anthesis **C** Leafy branch with infructescence **D** Immature fruits with cupules showing partially turbinate pedicels, remnants of tepals at summit of the cupule, cupules turning red. Photos from *Brewer & Stott 7529* by SW Brewer 2 February 2016.

unique flora and fauna of the Bladen branch of the Monkey River. The origin of the word “Bladen” is unknown.

Phenology and reproduction. Phenology data for this species are few; currently, flowering in this species is known to begin with the onset of the dry season, December–January, with fruits developing in January and February. The trees are not known to be fertile below 15 cm DBH and are not fertile every year.

Distribution and ecology. *Cinnamomum bladenense* is currently known only from fewer than 10 individuals on two limestone ridge-and-knoll systems south of the Bladen branch of the Monkey River, a few km upstream from where the Bladen descends into the coastal plain. This canopy tree species occurs in semi-evergreen forest c. 25 m high on very-well-drained, steep and rocky slopes on Cretaceous limestone. Similar habitat occurs southwest of the type location nearly to the Guatemala border, and northeast of the type location to the southeastern portion of the Cockscomb Basin, along the southeastern foothills of the Maya Mountains.

Preliminary conservation assessment. Population information is too limited to support an assessment of the extinction risk faced by *Cinnamomum bladenense*, and the category of Data Deficient (DD) is appropriate, according to IUCN (2012) criteria. The known habitat of the species is protected as part of a nature reserve, however anthropogenic fires and illegal logging in the area, including nearby potential habitat, are potential risks to the persistence of this species.

Discussion

Cinnamomum bladenense is unique for the genus in its relatively small flowers (< 2.3 mm from the base of the hypanthium to the apex of the tepals of dried specimens), and for its occurrence in the canopy of relatively tall-canopied (20–35 m) limestone slope forest. It has not been found on the adjacent apices of well-exposed ridges or on exposed rock outcrops, which are comparatively lower- and more open-canopied, much denser, of proportionately smaller-trees, and more unique floristically (Brewer et al. 2003). Limestone forests in the type location and nearby forests of similar vegetation have a high proportion of limestone specialists (Brewer unpubl. data), with soil properties significantly different than nearby soils on volcanic substrata (Winbourne et al. 2016). As far as we know, this new species appears to be unique among Neotropical species, perhaps along with *C. salicifolium* (Nees) Kosterm. from Mexico, by being associated exclusively with limestone. The latter species has abaxially pubescent tepals persistent in fruit, conspicuous and often dense and/or often spreading indument on the leaves and young twigs, villous filaments abaxially, and occurs in oak-pine forests.

In Lorea-Hernández’ (1996) revision of the Neotropical species of *Cinnamomum* Schaeff., specimens of Brewer & Stott 7529 key to *C. brenesii*, to which it is most similar (see diagnosis for differences), to *C. paratriplinerve* Lorea- Hernández (ined.), and, with considerable latitude in interpretation of indument, *C. hartmannii* (I.M. Johnst.)

Kosterm. *Cinnamomum brenesii* is a Costa Rican and Panamanian species most often collected in disturbed and open habitats such as pastureland, roadsides and trail edges (vs. closed-canopy limestone hill forests). *Cinnamomum paratriplinerve* differs from the new species in having external tepals glabrous adaxially, entirely turbinate pedicels (at least some) in fruit, hypanthium glabrous inside, and generally conspicuously longer leaves. It also is a species of Costa Rica and Panama in disturbed areas (pastureland, secondary forest) as well as “natural”, closed-canopy forest. *Cinnamomum hartmannii* is a species of northwestern Mexico, in the contact zone between dry, oak temperate forests and semi-deciduous to deciduous tropical forests. It has glabrous filaments, and mainly pinnate leaves villous-tomentose beneath when young, among other differences. All other known Neotropical species differ in one or more significant character states, including persistent or entirely-deciduous tepals, domatia absent or secondary domatia present, domatia of pocket-like depressions below and ampullous above, and indument of spreading to erect hairs.

The three species of *Cinnamomum* in Belize – *C. areolatum* (Lundell) Kosterm. *C. bladenense* S.W. Brewer & G.L. Stott, sp. nov., and *C. montanum* (Sw.) Bercht. & J. Presl – are easily separated in the field without fertile material. In Belize, *C. areolatum* is typically a small tree (usually < 10 m, < 10 cm DBH), treelet or colonial treelets/shrubs, on the tops and shoulders of ridges on very acidic and nutrient-poor, igneous substrate in somewhat open and low woody vegetation (woodlands or natural disturbances in low forest), dominated by or with a significant component of *Purdiaea belizensis* (A.C. Sm. & Standl.) J.L. Thomas, occasionally with *Cyrilla racemiflora* L. and sedges such as *Scleria* P.J. Bergius and *Rhynchospora* Vahl, and/or associated with areas of fire-dependent ferns [e.g., *Gleichenella pectinata* (Willd.) Ching, *Sticherus palmatus* (W. Schaffn. ex E. Fourn.) Copel., *Dicranopteris flexuosa* (Schrad.) Underw.]], and never on alluvium. Its canopy is somewhat scattered along the stem, not confined to the upper portion of the stem, with leaves that are < 5 cm wide, coriaceous to thick coriaceous, the upper surfaces smooth and plane, and the veins inconspicuously impressed above. The leaves have conspicuous, densely-prominent reticulum beneath, and domatia that are pocket-like below and ampullous above (at least some leaves) in the axils of the basal (or more) secondary veins. *Cinnamomum montanum* is found in ± closed canopy forest on rich alluvium or on acid substrata, never limestone, and is quite capable of exceeding 10 cm DBH and 20 m in height. It has the largest leaves of the three species, very often ≥ 5 cm wide, with at least some leaves > 10 cm long (often some much longer). It also has conspicuous ampullous and pocket-like domatia; however, its upper surface is not plane but “quilted” (coarsely bullate above, with long concave areas beneath) from the impressed midvein and secondary veins. *Cinnamomum bladenense* is found only on limestone slopes, has small leaves with short petioles, inconspicuous domatia not ampullous, and is a tree with a tight canopy at the top of the stem, even when small.

Key to Belizean *Cinnamomum*

- 1 Tepals abaxially glabrous, deciduous in fruit. Flowers small, < 2.3 mm long from the base of the hypanthium to the apex of the tepals. Domatia plane with the leaf surface, inconspicuous. Trees on limestone soils, to 25 m and 25+ cm DBH *C. bladenense*
- Tepals abaxially pubescent or not, persistent in fruit. Flowers > 2.3 mm long. Domatia ampullous above (at least in some leaves), conspicuous. Trees on igneous substrata and/or alluvium.
- 2 Small trees, treelets, or low clumps of a few stems. Tepals abaxially glabrous in flower. Inflorescence axes and/or pedicels and flowers glaucous when young. Abaxial minor leaf venation dense and prominulous, leaves < 5 cm wide *C. areolatum*
- Trees, occasionally > 15 m and > 10 cm DBH. At least some tepals abaxially pubescent. Inflorescence axes and/or pedicels and flowers not glaucous. Abaxial minor leaf venation essentially flat, not dense, at least some (often most) leaves > 5 cm wide *C. montanum*

Acknowledgements

This species was discovered during the establishment of permanent sample plots in the Bladen Nature Reserve. Plots were demarcated and enumerated by a team from Ya'axché Conservation Trust (co-managers of the reserve) between 2012 and 2014, as part of ongoing biodiversity monitoring efforts. Funding was provided by the Protected Areas Conservation Trust (Belize), the Oleg Polunin Memorial Fund (UK), and the Percy Sladen Memorial Fund (UK). Additional equipment was provided by Idea Wild (USA). We are grateful to Henk van der Werff (MO) for his valuable comments and review of an earlier version of this manuscript. We thank reviewers Jens Rohwer and Pedro Luís Rodrigues de Moraes for their helpful corrections and comments on the manuscript submitted for publication. Teri Bilsborrow, Mary Merello, and James C. Solomon are gratefully acknowledged for their logistical herbarium support at the Missouri Botanical Garden.

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Flora of Nam Kading National Protected Area I: a new species of yellow-flowered *Strobilanthes* (Acanthaceae), *S. namkadingensis*

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Abstract

A new species of Acanthaceae, *Strobilanthes namkadingensis* Soulad. & Tagane from Nam Kading National Protected Area, Bolikhamxay Province, central Laos, is described and illustrated. It is characterized by long spicate inflorescences consisting of 6–32 flowers, yellow corolla, the absence of long white hairs on the bracts and 4–6 seeds per capsule. Three DNA barcode regions of the partial genes for the large sub-unit ribulose-1,5-bisphosphate carboxylase oxygenase (*rbcL*) and maturase K (*matK*) and internal transcribed spacers (ITS) are also provided.

Keywords

DNA barcoding, Indochina, Laos, *Sericocalyx*, taxonomy

Introduction

Strobilanthes Blume, consisting of ca. 400 species is one of the largest genera in the family Acanthaceae (Hu et al. 2011). The genus is characterized by plietesial flowering pattern, homomorphic calyx lobes (sometimes partially fused to form a bipartite or tripartite calyx), 4 monadelphous stamens in which usually 2 filaments are distinctly longer than the other 2, 2-locular ovary with 2(-8) ovules per locule, and bifurcate stigma with unequal branches (Hu et al. 2011). The species of *Strobilanthes* are widely distributed from lowlands to high mountains in subtropical to tropical areas in Asia. In Laos, 14 species with one subspecies have been recorded (Benoist 1935, Deng et al. 2007, Newman et al. 2007, Wood and Scotland 2009).

Here, we describe a new species of *Strobilanthes* from Nam Kading National Protected Area, Bolikhamxay Province, central Laos. The national park covers an area of 169 ha, with an elevation gradient from 138 m in the lowland to 1,514 m at the summit of Phou Pa Paek and is bisected by the Nam Kading River. The climate is most strongly influenced by the south-west monsoon from April to October that brings 90 percent of the annual precipitation. Temperature in the lowland of Bolikhamxay Province varies between 20°C and 30°C, but in the high altitude areas of Nam Kading Protected Area it may drop to as low as 5°C during dry season from December to February (Hallam and Hedemark 2013). The vegetation of Nam Kading Protected area contains mixed deciduous forest, grasslands, wetlands and limestone karst (Strindberg et al. 2007, Hallam and Hedemark 2013). The only floristic survey of the Area was made near human settlements by Electrowatt (1995) who reported 256 plant species including 2 rare species namely, *Lagerstroemia balansae* Koehne (synonym of *L. cochinchinensis* Pierre ex Laness.) and *Justicia gendarussa* Burm.f.

During a botanical survey in Nam Kading National Protected Area in December 2016, a wild, yellow-flowered species of *Strobilanthes* was collected in the semi-shaded understory of semi-evergreen forest. To determine its identity, we made a morphological comparison to closely related species based on dried specimens at herbarium (BKF, FOF, FU, RUPP and SAR), digital images of specimens on the webpages of JSTOR Global Plants [<https://plants.jstor.org/> (accessed 22 Feb. 2017)], K [<http://apps.kew.org/herbcat/navigator.do> (accessed 22 Feb. 2017)] and P [<https://science.mnhn.fr/institution/mnhn/collection/p/item/search> (accessed 22 Feb. 2017)], and the relevant literature of surrounding countries including Cambodia, China, Japan, Laos, Thailand and Vietnam (e.g. Benoist 1935, Deng et al. 2007, Newman et al. 2007, Wood and Scotland 2009, Hu et al. 2011).

The purpose of this paper is to describe and illustrate this as a new species, *Strobilanthes namkadingensis* Soulad. & Tagane accompanying with DNA barcodes of the three DNA barcode regions, the partial genes for the large subunit ribulose-1,5-bisphosphate carboxylase oxygenase (*rbcL*) and maturase K (*matK*) (CBOL Plant Working Group 2009) and the internal transcribed spacer region of the nuclear ribosomal DNA (ITS). DNA sequencing for *rbcL* and *matK* followed to the published protocols (Kress et al. 2009, Dunning and Savolainen 2010) and for ITS according to Rohwer et al. (2009) and Chen et al. (2010) using the two primer pairs (ITS18-F, ITS26-R and, ITS2-S2F and ITS2-S3R).

Taxonomy

Strobilanthes namkadingensis Soulad. & Tagane, sp. nov.

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Figs 1, 2

Diagnosis. *Strobilanthes namkadingensis* is distinguished from all the previously known species of Laos and its surrounding countries including China, Cambodia, Thailand and Vietnam clearly by a combination of 6–32 flowered spikes up to 10.5 cm long, yellow corolla, the absence of long white hairs on the bracts and 4–6-seeded capsule. In the region, *S. namkadingensis* is similar to *Strobilanthes squalens* S.Moore of Vietnam and *Sericocalyx thailandicus* Bremek. of Thailand in having yellow corolla and long-beaked floral bracts, but distinguished by its long spikes (vs. less than 3 cm long), broader floral bracts (obovate-elliptic to broadly elliptic vs. lanceolate to ovate-lanceolate), smaller corolla (1.9–2.1 cm long vs. less than 1.7 cm long), and the absence of long white hairs on the bracts.

Type. LAOS. Bolikhamxay Province, Nam Kading National Protected Area, in semi-evergreen forest, beside a dried rocky stream, 18°12'17.9"N, 104°33'34.5"E, alt. 146 m, 26 Dec. 2016, with flowers and fruits, Tagane S., Yahara T., Zhang M., Okabe N., Souladeth P., Sengthong A., Chayer S. L426 (holotype-HNL!, isotypes-FOF!, FU!, K, KYO!, P).

Description. Anisophyllous shrub, 1.5 m tall. Stem terete, densely covered with white hairs, pale yellow green when dried. Leaves slightly unequal in each pair, petiolate; blade broadly elliptic, ovate-elliptic, (0.7–)5.5–11 × (0.2–)2.2–4.5 cm, apex acuminate, base cuneate, briefly decurrent onto petiole, margin shallowly crenate, chartaceous, pale yellow green adaxially, light pale yellow green abaxially, sparsely strigose and scabrous on both sides, densely covered with cystoliths adaxially; midrib prominent on both surfaces, secondary veins 6–8 pairs, prominent on both surfaces, tertiary veins scalariform-reticulate, faintly visible to invisible; petiole 0.5–1.3 cm long, scabrid adaxially, glabrous abaxially, margin ciliate. Inflorescences spicate, terminal and axillary, (2–)3–10.5 cm long, 6–32-flowered; outer (inflorescence) bract narrowly elliptic-ovate, 1.4–2.1 × 0.4–0.5 cm, apex acute to acuminate, sessile, shortly puberulent adaxially, sparsely with short stiff hairs at margins and on midveins on both surfaces; floral bracts obovate-elliptic to broadly elliptic, ca. 1.7 × 0.7 cm long, apex caudate, acumen up to 0.8 cm long, persistent, pale yellow green, sparsely pilose with glandular hairs adaxially, shortly puberulent, with grand-tipped hairs abaxially, margin ciliate with large-celled white hairs; bracteole 2, linear, 5–7 mm long, glandular hairy. Calyx lobes 5, linear, ca. 5–9 mm long, apex acute, slightly accrescent in fruit, upper three and lower two calyx lobes are fused ca. 2 mm from the base, covered with cystoliths adaxially, glandular hairy abaxially. Corolla yellow, funnel-shaped, 1.9–2.1 cm long, 0.8 cm in diam., membranaceous, hairy with short erect hairs outside, pilose with long white hairs inside of tube, corolla lobes 5, elliptic to suborbicular, ca. 3.8 × 3.1–3.8 mm, apex rounded. Stamens 4, didynamous; the shorter pairs of filaments ca. 1.5 mm

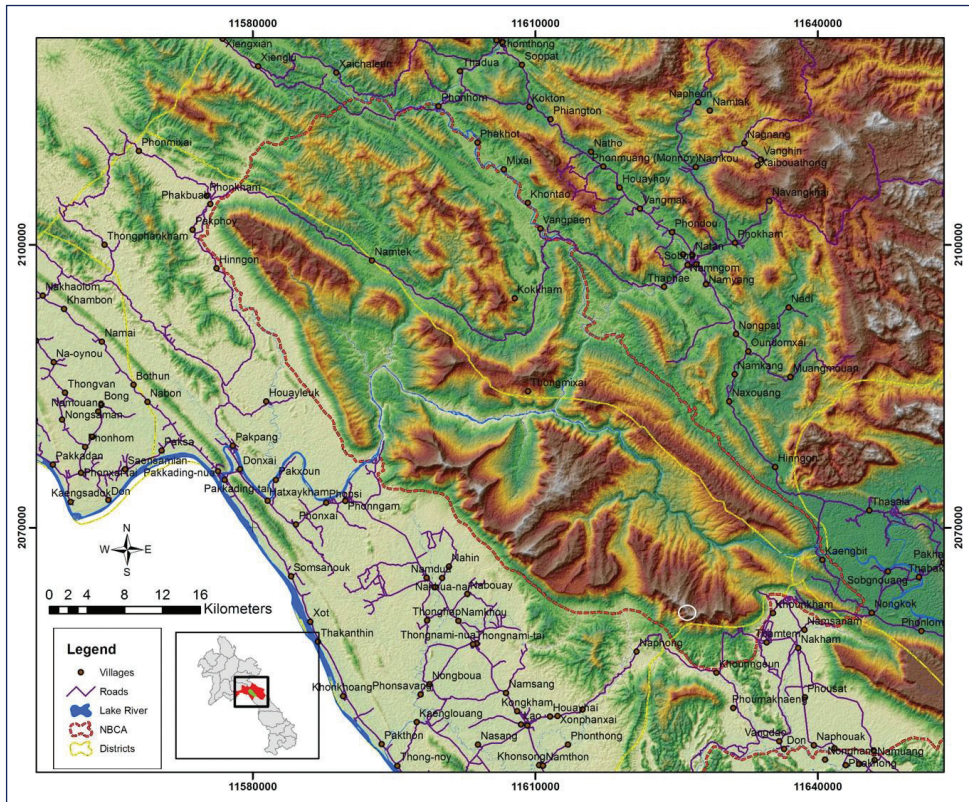


Figure 1. Locality of Nam Kading National Protected Area. White circle indicates where we found *Strobilanthes namkadingensis* Soulad. & Tagane.

long, with a few white hairs; the longer ones 5–6.5 mm long, pilose with long white hairs except upper 2/5, base of filaments adnate to corolla tube; anthers ca. 2–2.2 mm long, dorsifixed, attached lower 1/3 part of anther (monadelphous). Style 1.2 cm long, sparsely pilose, stigma ca. 2 mm long, glabrous. Capsule narrowly ellipsoidal, 8.4–10 mm long, ca. 2.8 mm in diam., glandular hairy, 4–6-seeded. Seeds spirally arranged on free-central placenta, suborbicular, 2 mm height, 1.8 mm width, 0.2 mm thick, strongly flattened, light yellow brown, glabrous.

Distribution. Laos, Bolikhamxay Province (so far known only from Nam Kading National Protected Area).

Habitat and ecology. *Strobilanthes namkadingensis* is found in semi-shaded under-story of semi-evergreen forest beside a dried stream; at alt. 146 m. The flowering and fruiting specimen was collected in December.

GenBank accession no. Tagane et al. L426: LC257983 (*rbcL*), LC257984 (*matK*) and LC257953 (ITS).

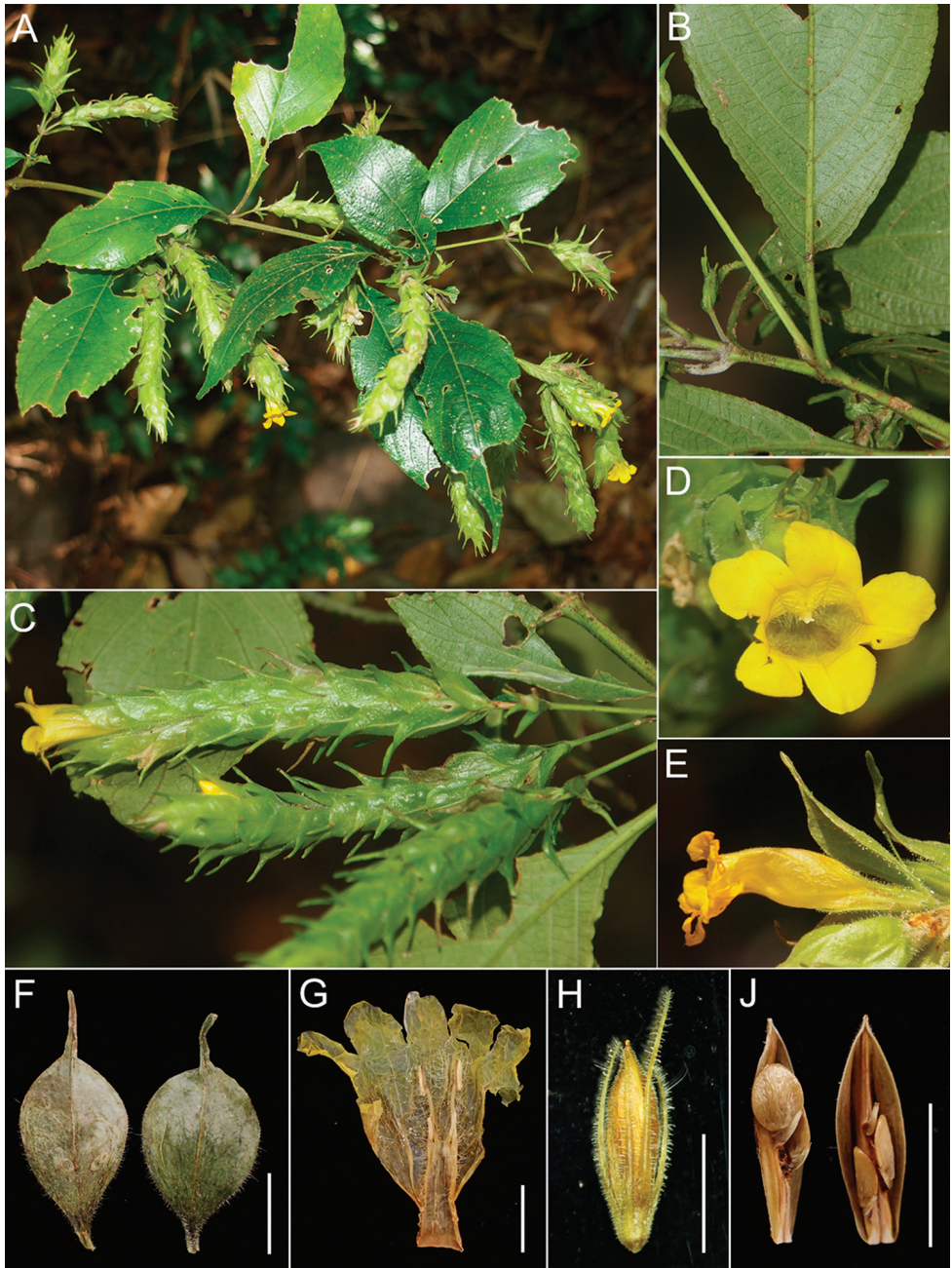


Figure 2. *Strobilanthes namkadingensis* Soulad. & Tagane. **A** flowering branch **B** abaxial leaf surface **C** inflorescence **D** flower **E** side view of corolla **F** floral bracts **G** corolla opened out **H** fruit with calyx **J** longitudinal section of capsule showing seeds (from Tagane *et al.* L426, FU). All scale bars: 5 mm.

Etymology. This specific epithet *namkadingensis* refers to the type locality.

Primary conservation assessment. Data Deficient (DD) (IUCN 2012). Only one individual was found along a dried rocky stream beside road. The individual grows in a protected area of Nam Kading National Protected Areas, but the habitat is close to a road and can be easily affected by human disturbance from the road. Further intensive field surveys are needed to evaluate its conservation status.

Note. Bremekamp (1944) treated the species having a yellow corolla and 4–8 seeded capsule as *Sericocalyx* Bremek. and the new species belongs to this group. However, Moylan et al. (2004) demonstrated that *Sericocalyx* is polyphyletic in the subtribe Strobilanthisae, based on phylogenetic analyses using ITS and *trnL-F* sequences and morphology. Therefore a single monophyletic *Strobilanthes s.l.* is accepted (Moylan et al. 2004, Deng et al. 2006) and the new species is here described as a species of *Strobilanthes*. The BLAST similarity search based on the ITS sequence of *S. namkadingensis* resulted in homology as high as 543/562 bp (including 17 gaps) and 532/562 bp (including 19 gaps) with the sequence of *S. chinensis* (Nees) J.R.I. Wood & Y.F. Deng (synonym, *Sericocalyx chinensis* (Nees) Bremek.) (GenBank accession no. AY489384) and *Sericocalyx crispus* (L.) Bremek. (AY489383) respectively in the DNA database, supporting that the new species is genetically closely related to the *Sericocalyx* group. *Strobilanthes namkadingensis* is distinguished from *S. chinensis* by having more secondary veins of lamina (6–8 pairs vs. 5 pairs), longer spikes (3.5–10 cm long as opposed to *S. chinensis* up to 3 cm long), and 4–6 seeds per capsule (vs. 8-seeds).

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The authors are grateful to the managers and staff of Nam Kading National Protected Area for supporting our botanical inventory in the protected area. We thank curators of the herbaria BKE, FOF, FU, RUPP and SAR for their specimens accessible, and Mariko Akama (Kyushu University) and Keiko Mase for their help in DNA sequencing. The editors of the journal and two anonymous reviewers are also sincerely thanked for their useful and constructive comments. This study was supported by the Environment Research and Technology Development Fund (4-1601) of the Ministry of the Environment, Japan, JSPS KAKENHI (15H02640).

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Key to *Syagrus* identification using leaflet margin anatomy: Supplement to “A revision of *Syagrus* (Arecaceae)”

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Abstract

Presented here is an alternative method of identification for species of the Neotropical palm genus *Syagrus*. It makes use of anatomical characters found in the leaflet margins and can be used for identification when few other vegetative or reproductive morphological characters are available. This anatomical study demonstrates the vast diversity found in a single palm genus and may also help to gain understanding of some possible relationships within the genus.

Keywords

Syagrus, Arecaceae, anatomy, key, identification

Introduction

The following is meant to be a supplement to a revision of *Syagrus* (Noblick 2017). Palm leaflet anatomy has been useful in identification and has been used to suggest systematic relationships in the family. Tomlinson (1961) examined and described the leaflet anatomy of some 250 species of palms in 137 genera and suggested systematic relationships among genera. Horn et al. (2009) took it a step further and mapped lamina anatomy on the phylogenetic tree for the palm family based on plastid sequence data (Asmussen et al. 2006) in order to understand the evolution of lamina anatomy. Tomlinson’s brief survey (Tomlinson 1961) inspired Glassman to examine anatomy of

the genus and its closely related genera in greater detail (Glassman 1972, 1987). Glassman (1972) emphasized that his survey of the genus was “based on mostly one collection for each taxon.” However by the time Glassman (1987) completed his revision, slides of two or more specimens were made for most taxa. His key was written as a convenient tool for identification and was not intended to show relationships. I produced a key based on leaflet anatomy to aid in the identification of 25 difficult to taxonomically distinguish *Syagrus* species with short, subterranean stems and was able to infer some relationships (Noblick 2013) that had been previously resolved by a molecular analysis (Meerow 2009). The key included herein has been completely rewritten and is meant to aid in the identification of all known 65 species and two subspecies of *Syagrus*.

Meerow et al. (2009) showed how leaflet anatomy supported the molecular relationships between *Allagoptera*, *Parajubaea* and *Polyandrococos* (now a synonym of *Allagoptera*).

Tomlinson et al. (2011) expanded his original 1961 work and presented information on 183 palm genera (out of 185 now recognized) and suggested relationships based on anatomy and the use of modern phylogenetic approaches.

Glassman (1972) emphasized various anatomical characters, several of which this paper makes use of, such as: (1) location of larger veins, (2) frequency and location (adaxial, abaxial, or in the middle) of intermediate and minor veins, (3) relative abundance, shape and location (adaxial and abaxial, or adaxial only) of clusters of nonvascular fibers, called fiber bundles (Tomlinson et al. 2011, Noblick 2013), (4) relative size of fiber bundles and veins at extremities of leaflets.

Tomlinson et al. (2011) only showed two *Syagrus* cross-sections in their publication: *S. orinocensis* and *S. weddelliana* (formerly *Lytocaryum*). However he suggested many anatomical features that vary in *Syagrus*, but the only ones used in this current study are: (1) the presence of trichomes, (2) the abundance and location of adaxial non-vascular fibers, varying from an almost continuous layer within the hypodermis to few fibers, (3) the extent and location of abaxial non-vascular fibers, (4) the extent to which the minor abaxial veins are in contact with the abaxial hypodermis, (5) the degree to which the inner sheath of major veins develop fibrous extensions to the upper surface layers.

Materials and methods

Plants examined

Both fresh and preserved (herbarium) material were used in this project. Dried material can be sectioned after rehydrating in a 5% solution of Contrad 70® (Decon Labs, King of Prussia, PA, U.S.A.) for a period of 24 hours (Tomlinson et al. 2011), though better results are obtained with fresh material.

The living material used in this study came mainly from the collections at Montgomery Botanical Center (MBC, Miami, FL) and the Jardim Botânico Plantarum

(Nova Odessa, São Paulo, Brazil). A few were collected from Fairchild Tropical Botanic Garden (Coral Gables, FL). The dried material was often from air-dried specimens made while doing fieldwork, from the herbarium at Jardim Botânico Plantarum (HPL, Novo Odessa, São Paulo, Brazil), and from the Fairchild Tropical Botanic Garden herbarium (FTG, Miami, FL). A few specimens were from the following herbaria: G, IBGE, IPA, K, MO, NY and US.

Anatomical preparation

There are a number of ways to hand section leaflet margins and most of these are covered in Noblick (2013). This type of research neither requires expensive hardware or use of chemicals and dyes. To start with, the leaflet sampled should always be collected from the same place on the plant. In this study, leaflets were sampled from the middle of a central leaflet. The following equipment was used: a hand microtome, a sharp knife, a straight razor, a double sided razor blade, a small artists brush (one of the smallest ones), a dropper bottle of water, a watch glass, a stone or plate to sharpen the straight razor blade, and a carrot (Figure 1A). The hand microtome was purchased from a home schooling site (Homesciencetools.com, Billings, MT, U.S.A.) for about \$45. The traditional straight razor I use can be purchased from an online shaving store, though the one I purchased from no longer exists. One of the cheapest pre-sharpened stainless steel straight razors for beginners will probably do fine, and they can be purchased for as little as \$14 from Jet.com (Hoboken, NJ, U.S.A.). I use a Dovo hollow ground stainless steel straight razor, which is available online for about \$80. I prefer the traditional straight razor blade over those with replacement blades. Finally, to keep a razor-sharp edge, one needs a sharpening stone. The Dia-sharp 3 micron 8000 mesh (DMT D8EE 8" Extra Extra Fine Diamond Stone) (DMTsharp.com or Diamond Machining Technology, Marlborough, MA, U.S.A) was found to be an excellent choice. Using it frequently between sectionings will maintain the sharpness required for making clean, thin sections.

Preparing the section

Using a small sharp knife, a piece of carrot is cut into a small cube that will fit in the hand microtome (Figure 1B, C). A perpendicular, vertical slit is cut in the top of the cube with the double-sided razor blade, but not all the way through. A piece of the palm leaf margin is placed into the vertical carrot slit and the carrot cube is clamped into the hand microtome. The carrot cube is adjusted down until it is barely showing above the microtome plate. The first cut is made across the carrot to cut off the excess leaf material and carrot. The blade is re-sharpened using the Diamond Stone and water (Figure 1D). Lubricate the surface of the carrot with a drop of water and slide the straight razor across the microtome in a horizontal slicing movement, while pressing the side of the blade firmly against the plate (Figure 1E). If at first, it does not cut anything, adjust the hand

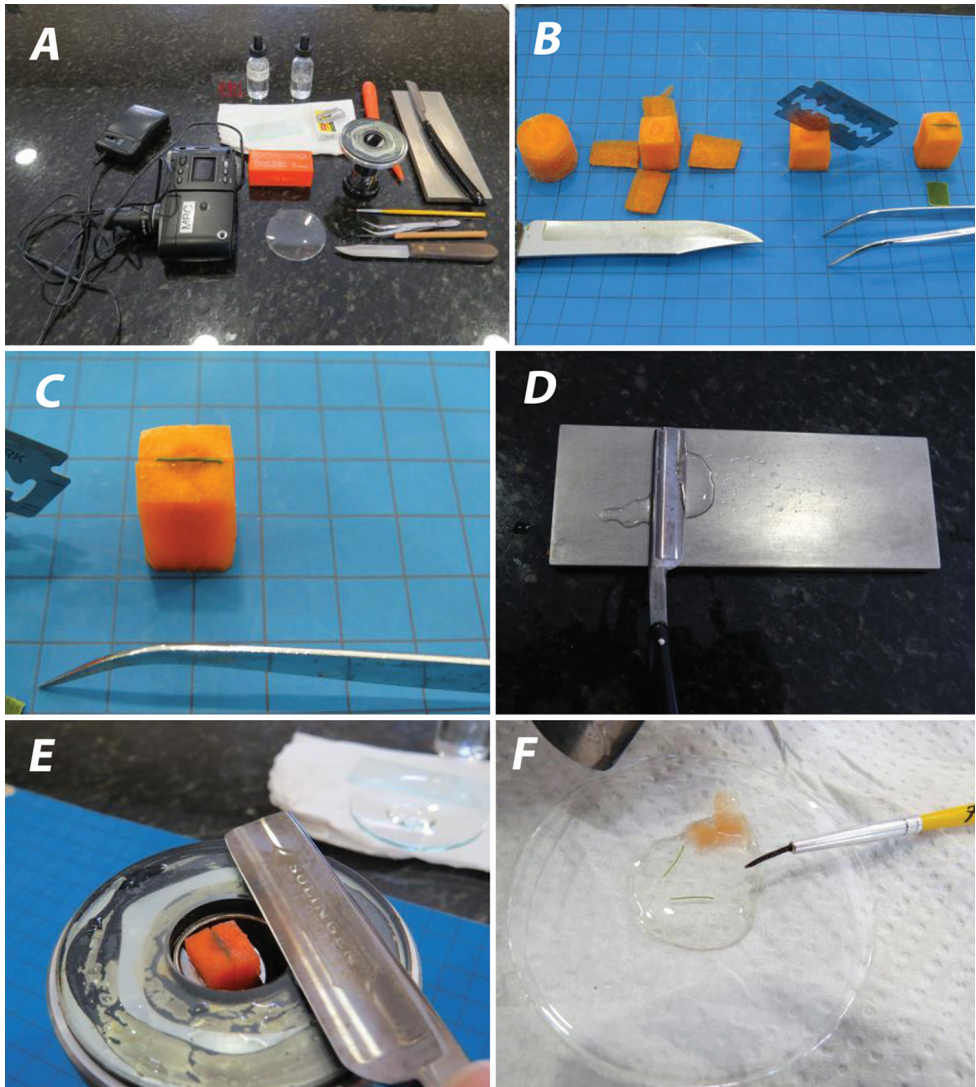


Figure 1. Materials and methods. **A** Materials used in making leaflet sections **B** Cutting carrot into a cube, slitting the cube and inserting the leaflet margin **C** Leaflet margin inserted in carrot cube ready for sectioning **D** Sharpening the straight razor on the wet stone **E** Clamping the carrot cube with leaflet margin into the hand microtome and preparing to section with the straight razor **F** Leaflet sections teased from the carrot into a watch glass with water.

microtome up about a $\frac{1}{4}$ of a turn and try again. Always keep the specimen lubricated with water using the eye dropper. After obtaining a section, tease the carrot away from the section or drop the section with attached carrot into a watch glass with water and tease the carrot from the section using the narrow artist brush, leaving the section in the watch glass (Figure 1F). After several sections have been successfully made, examine the sections in the watch glass under a dissecting microscope.

Preparing the slide

To prepare the slide, some glass slides, glass cover slips, artist brush, a bottle of 1:1 glycerin and water solution, and a dissecting needle are needed. Glass slides with frosted glass along one side to write on are preferred. The glass slide and glass cover slip should always be cleaned with distilled water or 70 % alcohol before using. Label the frosted portion of the slide and spread a drop or two of the 1:1 glycerin and water solution on the slide. While looking through the dissecting microscope, select the thinnest sections from the watch glass with the narrow artist brush and place them into the 1:1 glycerin droplet on the slide. After placing a number of the sections on the slide (ca. 6), then cover the sections with the glass cover slip. The best way to insure that no bubbles are left behind under the cover slip is to use a dissecting needle. Place one edge of the cover slip at the edge of the glycerin droplet with the sections and begin gently lowering it into place over the sections. By placing the dissecting needle tip on its side under the other edge of the cover slip, while slowly pulling out the needle as the cover slip lowers into place, most of the air bubbles should exit from under the cover slip on the side of the exiting needle.

Photography

The glass slide is now placed under a compound light microscope and photographed under the 10× objective (100× magnification). Images were taken with a Nikon Coolpix 4500 digital camera with a Leitz periplan 10 x/18 eye piece adapter. The camera was powered by a Powerline Universal AC adapter so there was no need to rely on battery power. The camera was set to P mode, white balance was adjusted to the light source of the microscope, and the lens was set to Fisheye 2. The images were cleaned of background spots, adjusted for brightness and contrast, and sharpened if necessary using Adobe Photoshop. Two adjacent images near the tip were photo merged using Adobe Photoshop. A stage micrometer was used to apply a scale to each image and replaced by a scale bar to aid in assembling these into a plate, while maintaining the scale.

Characters defined

This paper is focused mainly on characters of the more easily sectioned leaflet margin and not on the more difficult to section midrib. Epidermis and dark staining idioblasts (tanniniferous cells) were also not examined. Characters assessed during this study follow some of Glassman's and Tomlinson's characters as listed above in the introduction. Figure 2 clarifies much of the terminology for characters used in this paper. To be clear, in each leaflet cross-section the upper or superior side of the lamina is called the adaxial surface. The lower or inferior side is called the abaxial (Dransfield et al. 2008, Esau 1977).

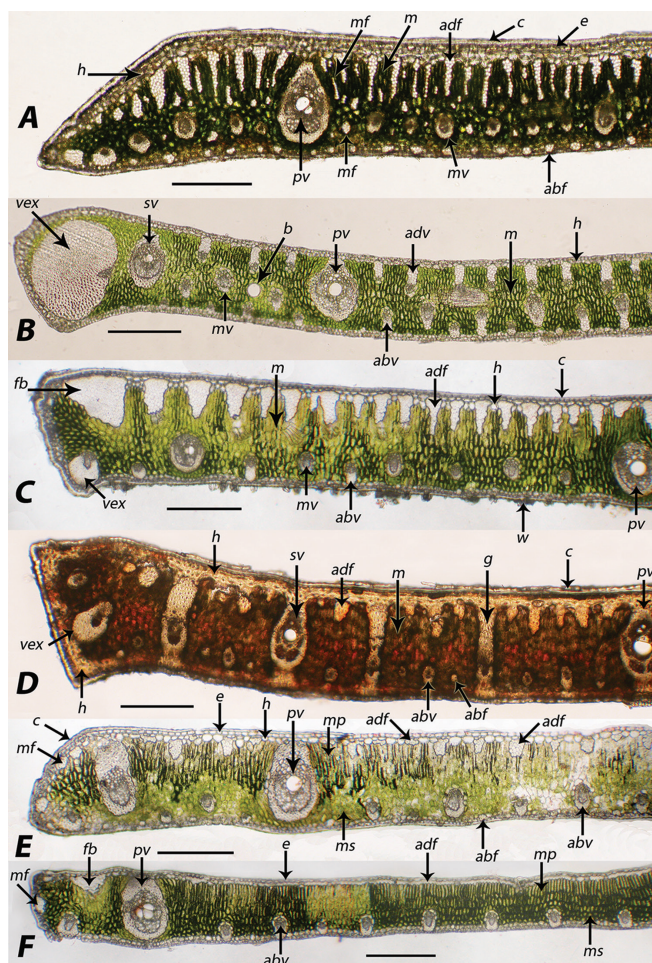


Figure 2. Characters. **A** *Syagrus vagans* with large adaxial fiber bundles reaching nearly $\frac{1}{2}$ across the mesophyll, fiber bundles scattered throughout the mesophyll, mesophyll minor veins, abaxial fibers and a primary vein that is nearly connected to the hypodermis **B** *S. lilliputiana* showing a large marginal vein with an exaggerated fibrous sheath, adaxial minor veins, and an air bubble artifact **C** *S. coronata* with a large marginal fiber bundle, large adaxial fiber bundles, a small vein with an exaggerated fibrous sheath, and unattached primary vein **D** *S. harleyi* with a sclerenchymous hypodermis on the margin and along the adaxial surface, along with adaxial fiber bundles and abaxial minor vein symmetry (mirrored anatomy) and fibrous extensions from minor veins forming a girder **E** *S. orinocensis* with a mesophyll differentiated into palisade and spongy layers, marginal vein with fibrous sheath noticeably thickened adaxially, many fiber bundles along the adaxial surface, many of which are only one-cell thick and others reaching less than $\frac{1}{5}$ across the mesophyll, also note very small abaxial fiber bundles often alternating with abaxial minor veins **F** *S. vermicularis* with an adaxial fiber bundle forming a continuous single layer of fiber cells in the hypodermis. **abf** = abaxial fiber bundle **adf** = adaxial fiber bundle **abv** = abaxial minor vein **adv** = adaxial minor vein **b** = trapped air bubble artifact **c** = cuticle **e** = epidermis **fb** = larger fiber bundle **g** = girder vein **h** = hypodermis **hf** = fibrous hypodermis **m** = mesophyll **mf** = marginal fiber bundle **mp** = palisade mesophyll **ms** = spongy mesophyll **mv** = mesophyll minor vein **p**v = primary vein **sv** = secondary vein **vex** = vein with exaggerated fibrous sheath **w** = wax. Bar scale = 0.25 mm.

The outer most layer of the leaf is the cuticle (Figure 2, c), a non-cellular waxy layer produced by the epidermis (Dransfield et al. 2008). The cuticle is followed by the epidermis, “outer skin” (Figure 2, e), followed by the hypodermis, “under skin” (Figure 2, h), which is finally followed by the mesophyll or “middle leaf” region (Figure 2, m). The mesophyll can be undifferentiated (m) or differentiated into a distinct palisade mesophyll (mp) and spongy mesophyll (ms). The palisade mesophyll near the adaxial surface is composed of vertically linear cells; the spongy mesophyll near the abaxial surface is composed of round cells and intercellular spaces of various sizes. Within the mesophyll are veins of various sizes, which are also known as vascular bundles or fibro vascular bundles (Tomlinson et al. 2011). In this paper they will be referred to as primary veins (Figure 2, pv), secondary veins (Figure 2, sv), and minor veins, which, depending on their location, are called mesophyll veins (Figure 2, mv), adaxial minor veins (Figure 2, adv) or abaxial minor veins (Figure 2, abv). Some primary and secondary veins are often attached to the adaxial hypodermis and sometimes to both adaxial and abaxial surfaces by fibrous sheath extensions. If the attachment extends to both surfaces via a narrow fibrous sheath extension, the vein appears girder-like and is indeed referred to as a girder (Tomlinson et al. 2011) (Figure 2D, g). In some veins the fibrous sheath becomes so enlarged with fibers that they are referred to as veins with exaggerated fibrous sheaths (Tomlinson et al. 2011) (Figure 2B, C, D, vex). Some veins have exaggerated sheaths both adaxially and abaxially as in *S. guimaraesensis* (Figure 5) or *S. pimentae* and *S. procumbens* (Figure 7). In addition to the veins, the laminal tissues are supported by nonvascular fibers or fiber bundles of various sizes. Some have large fiber bundles adjacent to or near their margins (Figure 2C, fb). Many fiber bundles are adaxial and may reach close to 1/3 to 1/2 or more across the mesophyll (Figure 2A, C, adf). Minor, intermediate and major (large) fiber bundles can be found adaxially (Figure 2A, C, D, E, adf). Many minor fiber bundles are mainly abundant abaxially (Figure 2A, C, D, E, abf). Occasionally minor fiber bundles are scattered throughout the mesophyll (Figure 2A, mf).

Terminology defined

Mirrored anatomy—anatomy in which the abaxial surface is identical or similar to the adaxial surface. One surface appears to be reflected in the other. In this study, this term is not used exactly in the classical sense, where adaxial veins are exactly opposite other abaxial veins or adaxial fiber bundles are opposite abaxial fiber bundles (again, one surface reflected in the opposite surface). Here the term is used to describe the situation where structures are lined up perfectly opposite each other as if in a reflection. For example, adaxial fiber bundles may lie exactly opposite from abaxial veins or adaxial veins are opposite abaxial fiber bundles as in *S. mendanhensis* (Figure 6) or *S. pleioclada* (Figure 7). Again it is a reflection, but not necessarily of the same structures. This arrangement is not common in *Syagrus*.

Dorsiventral anatomy — anatomy in which the adaxial surface is very different from the abaxial surface. This is the anatomy most commonly seen in most *Syagrus* species.

Characters utilized

The following characters were examined and used in this key:

Veins

- Presence/absence of adaxial minor veins
- Presence/absence of abaxial minor veins
- Presence of both adaxial and abaxial minor veins
- Quantity of adaxial minor veins (many, few)
- Adaxial minor veins (paired or opposite) abaxial minor veins
- Paired adaxial and abaxial minor veins (nearly touching or not)
- Presence/absence of abaxial vein with an exaggerated fibrous sheath
- Quantity of abaxial minor veins (many, few)
- Presence/absence of large marginal vein with exaggerated fibrous sheath
- Presence/absence of large marginal vein with exaggerated fibrous sheath on both adaxial and abaxial side
- Presence/absence of mesophyll minor veins
- Most mesophyll veins with or lacking abaxially thickened fibrous sheaths
- Location of mesophyll veins (middle, upper half, lower half)
- Presence/absence of primary or secondary vein (near or not near) the tip of the margin
- Primary, secondary or minor veins (attached, unattached)
- Surface to which the veins are attached (adaxial side only, both sides)
- Manner in which veins are attached (broadly attached, by one narrow fibrous extension, by two narrow fibrous extensions or girder-like)
- Order of arrangement of veins near the margin (secondary vein – minor veins – primary vein, primary vein – minor veins)
- Abaxial minor veins alternating with abaxial fiber bundles (or no such pattern).

Fibers

- Presence/absence of adaxial fiber bundles
- Size of the adaxial fiber bundles (reaching $1/3$ to $1/2$ across mesophyll, reaching less than $1/3$, reaching less than $1/5$ across mesophyll)
- Shape of adaxial fiber bundles (long and fat, long and skinny, elliptical, oblong, wedge-shaped, fat or skinny icicle-shaped, short and fat, irregular, rounded)
- First adaxial fiber bundle (the largest, ca. same size as others)
- Quantity of adaxial fiber bundles (many, occasional to none or few)
- Alignment of adaxial fiber bundles across from abaxial minor veins (aligned and opposite or not aligned)
- Mirrored versus dorsiventral anatomy (as defined above)
- Small adaxial fiber bundles alternating with larger adaxial fiber bundles
- Adaxial fiber bundles opposite abaxial veins (opposite each other, no such arrangement)
- Presence/absence of large to extra-large fiber bundle at or near the margin

- Presence/absence of abaxial fiber bundles
- Quantity of abaxial fiber bundles (many, few to none)
- Presence/absence of marginal minor fiber bundles (several, few to absent)
- Presence/absence of minor mesophyll fiber bundles
- Location of minor mesophyll fiber bundles (upper half, lower half, scattered throughout)

Other non-fiber, non-vein characters

- Differentiated or undifferentiated mesophyll
- If differentiated mesophyll, then the number of palisade layers (2 or 3 versus one)
- Cuticle layer (thick, thin)
- Adaxial hypodermis layer (sclerenchymous with thickened walls, near continuous one layer thickness of fibers, discontinuous layer of fibers, round bubble-like shaped cells, small rectangular shaped cells).
- Presence/absence of tiny fibers in the abaxial hypodermis layer
- Presence/absence of trichomes on the exterior abaxial surface
- Lamina thickness (<0.25 mm or 0.25 mm or more)

Non-anatomical characters used in the key

- Stem size (short underground [acaulescent], taller aerial stem)
- Stem number (solitary, in pairs or clustering)
- Leaf orientation (procumbent, spreading)
- Abaxial pubescence, tomentum or trichome color (brown, silvery) on the leaflets
- Leaf color (silver blue, green to dark blue-green)
- Middle leaflet measurements
- Leaf rachis length measurements

This key was designed for use in the field using simple tools and simple methods, which means using minimal equipment, no staining, low magnification (no higher than 100×), and the use of simple characters. Refer to the characters in the methods and Figure 2 for clarification. By using the methods listed above and following many of the simple techniques mentioned by Tomlinson et al. (2011), rapid results can be achieved in a laboratory provided with only the simplest of equipment.

Results

This key contains headings, which will aid the reader to move through the key more rapidly. The headings refer back to the couplet that was responsible for bringing the reader to this section of the key. The number of the couplet that brought the reader to this section of the key is enclosed in parentheses following the heading. Besides aiding

the reader to move more quickly through the key, the headings show the major subsections of the key. It is a way for the reader to understand where the major branches are in the key and which character separates species in that section of the key.

Key

- 1 Adaxial fiber bundles reach more than 1/3 to 1/2 across the mesophyll **2**
- Adaxial fiber bundles absent or reach less than 1/3 across the mesophyll... **37**

Adaxial fiber bundles large (1)

- 2 No or few mesophyll minor veins (usually present only at the tip) **3**
- Mesophyll minor veins present (usually present throughout) **18**

No or few mesophyll minor veins (2)

- 3 Large marginal vein with exaggerated fibrous sheath occupying most of the margin **4**
- No such vein or vein with exaggerated fibrous sheath occupying less than 1/2 the margin **10**

Large marginal vein with exaggerated sheath (3)

- 4 Both abaxial and adaxial minor veins present **5**
- Only abaxial minor veins present and adaxial minor veins usually absent.... **7**
- 5 Minor abaxial fiber bundles usually absent or if present not alternating with minor abaxial veins ***S. allagopteroides***
- Minor abaxial fiber bundles present and alternating with abaxial minor veins **6**
- 6 Adaxial minor veins common ***S. cerqueirana***
- Adaxial minor veins occasional to none..... ***S. minor***
- 7 Mesophyll fibers or fiber bundles restricted to the upper half of the mesophyll ***S. campestris***
- Mesophyll fibers or fiber bundles absent in the upper half of the mesophyll... **8**
- 8 Adaxial fiber bundles linear, like skinny icicles ***S. romanzoffiana***
- Adaxial fiber bundles fat and elliptical or oblong..... **9**
- 9 Large adaxial fiber bundles abundant ***S. cataphracta***
- Larger adaxial fiber bundles occasional..... ***S. deflexa***

No large marginal vein with exaggerated sheath (3')

- 10 Adaxial and abaxial minor veins present **11**
- Adaxial minor veins absent **12**
- 11 Adaxial minor veins many and usually attached by a large fibrous extension ...
..... ***S. cerqueirana***
- Adaxial minor veins few and attached by a relatively small fibrous extension ...
..... ***S. yungasensis***

- 12 Lamina thin, less than 0.25 mm thick.....*S. macrocarpa*
 – Lamina thicker, 0.25 mm or thicker **13**
 13 Primary vein attached to adaxial but not abaxial surface..... **14**
 – Primary vein attached to both surfaces..... **15**
 14 Large to medium-sized first adaxial fiber bundle near the margin, most other
 adaxial fiber bundles elliptical or oblong in shape *S. lorenzoniorum*
 – Very large first adaxial fiber bundle near the margin, most other adaxial fiber
 bundles wedge-shaped, like fat icicles..... *S. caerulescen*
 15 Secondary and minor veins attached to both surfaces forming narrow ‘gird-
 ers’ *S. campylospatha*
 – Minor veins attached to the abaxial surface only, not forming narrow ‘gird-
 ers’ **16**
 16 Small adaxial fiber bundles alternating with larger adaxial fiber bundles.....
 *S. graminifolia* subsp. *graminifolia*
 – Fiber bundles all the same size **17**
 17 Secondary vein with a short narrowing adaxial fibrous extension like a vase..
 *S. graminifolia* subsp. *cabraliensis*
 – Secondary vein with longer narrow adaxial fibrous extension like a wine bot-
 tle *S. graminifolia* subsp. *glazioviana*

Mesophyll minor veins present (2')

- 18 Scattered mesophyll fibers or fiber bundles absent..... **19**
 – Scattered mesophyll fibers or fiber bundles present **32**

No Mesophyll fibers (18)

- 19 Abaxial fibers, abaxial fiber bundles or abaxial minor veins none or only
 weakly visible, abaxial veins present with little abaxial thickening and alter-
 nating with larger mesophyll veins **20**
 – Many Abaxial fiber, abaxial fiber bundles and/or abaxial minor veins present
 and obvious, minor abaxial veins usually thickened abaxially and not alternat-
 ing **27**
 20 Adaxial fiber bundles opposite abaxial minor veins, mirrored anatomy **21**
 – Adaxial fiber bundles and abaxial minor veins not necessarily opposite each
 other, dorsiventral anatomy..... **22**
 21 One minor adaxial fiber bundle-abaxial minor vein pair between primary and
 secondary veins..... *S. mendanbensis*
 – Three minor adaxial fiber bundle-abaxial minor vein pairs between primary
 and secondary veins *S. pleioclada*
 22 Weakly visible abaxial veins alternating with larger mesophyll veins *S. comosa*
 – No abaxial veins present..... **23**
 23 No extra-large adaxial fiber bundles on or near the margin *S. gouveiana*
 – Extra-large adaxial fiber bundles on or near the margin..... **24**
 24 Primary veins attached to the adaxial surface..... **25**
 – Primary veins unattached..... **26**

- 25 Hypodermal cells rounded or bubble-like, especially between the adaxial fiber bundles, no tiny fibers in the abaxial hypodermis.....*S. duartei*
 – Hypodermal cells smaller, rectangular, especially near the adaxial fiber bundles, small, almost indistinguishable fibers in the abaxial hypodermis
 *S. evansiana*
- 26 Adaxial fiber bundles short and fat, irregular-shaped to rounded.... *S. kellyana*
 – Adaxial fiber bundles long and fat, mostly wedge-shaped, like skinny or fat icicles.....*S. coronata*
- 27 Marginal hypodermis with thick sclerenchymous walls, secondary and tertiary veins attached to the adaxial surface via long narrow fibrous sheath extensions*S. harleyi* (high elevation form)
 – Marginal hypodermis without sclerenchymous walls, secondary and tertiary veins unattached or fibrous sheath extensions wider than 2 or 3 cells28
- 28 Abaxial minor veins clearly alternating with abaxial fiber bundles *S. petraea*
 – Mostly abaxial minor veins along the abaxial surface, abaxial fiber bundles infrequent and not alternating as above.....29
- 29 Palm develops an aerial stem.....*S. glaucescens*
 – Palm develops only short, underground stem.....30
- 30 Few (3–8) attached abaxial minor veins and abaxial fiber bundles between larger veins, sometimes with a large fiber bundle near the margin, but frequently lacking*S. glazioviana*
 – Many (9–12+) abaxial minor veins and abaxial fiber bundles between larger veins, always with a large fiber bundle near the margin31
- 31 Primary veins attached, silvery-blue leaves with middle leaflets 24–34 × 2–3 cm *S. rupicola*
 – Primary veins unattached, gray-blue leaves with shorter, narrower middle leaflets 10–20 × 0.7–1.2 cm.....*S. longipedunculata*

Mesophyll fibers present (18')

- 32 Abaxial fiber bundles or fibers absent or nearly so or not readily apparent.... 33
 – Abaxial fiber bundles or fibers present and very obvious.....34
- 33 First adaxial fiber bundle the largest.....*S. microphylla*
 – First adaxial fiber bundle smaller or not much larger than the second
*S. werdermannii*
- 34 Primary veins clearly attached and some of the first adaxial fiber bundles larger, elliptical to rounded and oblong and the rest like fat icicles, mesophyll fibers few*S. ruschiana*
 – Primary veins clearly unattached or nearly so, first adaxial fiber bundles smaller or more angular in shape and the rest like skinny icicles, mesophyll fibers more abundant35
- 35 Primary veins sometimes nearly attached*S. vagans*
 – Primary veins obviously unattached36

- 36 Large fiber bundle and veins with exaggerated fibrous sheaths near the margin *S. santosii*
 – Large fiber bundle absent, adaxial minor veins sometimes present near the margin, much smaller marginal minor veins with exaggerated fibrous sheath present *S. schizophylla*

Adaxial fiber bundles small to none (1')

- 37 Mesophyll minor veins present or at least several near the margin 38
 – Mesophyll minor veins absent 46

Mesophyll minor veins present (37)

- 38 Very large marginal vein with exaggerated fibrous sheath adaxially and abaxially 39
 – No such marginal vein 40
 39 Most mesophyll veins with abaxially thickened fibrous sheaths, medium to dark green leaves procumbent, leaf rachis 2.4–13 cm long *S. procumbens*
 – Most mesophyll veins lacking abaxially thickened fibrous sheaths, silvery bluish-green leaves spreading, leaf rachis 44–65 cm long *S. pimentae*
 40 Minor adaxial veins present 41
 – Minor adaxial veins absent 42
 41 Large marginal vein with exaggerated fibrous sheath present .. *S. lilliputiana*
 – No such large marginal vein present, but a large vein with thickened sheath is present a short distance from the margin *S. guimaraesensis*
 42 Few to no adaxial fiber bundles present, lamina less than 0.25 mm thick
 *S. pompeoi*
 – Adaxial fiber bundles always present even if small, lamina thicker than 0.25 mm 43
 43 Mesophyll minor veins located in the mid to upper half of the mesophyll, mesophyll undifferentiated, short palm with an underground stem *S. pleiocladoides*
 – Mesophyll minor veins located in the lower half of the mesophyll, the latter differentiated into palisade and spongy mesophyll cells, palms with aerial columnar stems 44
 44 Cuticle layer, very thick, first adaxial fiber bundle the largest *S. kellyana*
 – Cuticle layer, very thin, not obvious, first adaxial fiber bundle not always the largest 45
 45 Large primary vein near the margin, stems solitary *S. oleracea*
 – Only secondary or minor veins near the margins, stems often in pairs or clustering *S. cearensis*

No Mesophyll minor veins (37')

- 46 Large marginal vein with exaggerated fibrous sheath 47
 – No such marginal vein present 51

Large marginal vein with exaggerated sheath (46)

- 47 Mesophyll fibers present in the upper half of the mesophyll.... *S. itacambirana*
- No mesophyll fibers present 48
- 48 No adaxial minor veins *S. loefgrenii*
- Adaxial minor veins present and often paired with abaxial minor veins 49
- 49 Adaxial minor veins and abaxial minor veins paired and opposite each other, but never nearly touching *S. angustifolia*
- Several minor adaxial veins paired and nearly touching abaxial minor veins 50
- 50 A few adaxial and marginal minor fiber bundles present *S. menzeliana*
- Adaxial and marginal minor fiber bundles absent..... *S. emasensis*

No large marginal vein with exaggerated sheath (46')

- 51 Hypodermis with thickened sclerenchymous walls especially on the margin, adaxial fiber bundles are usually opposite abaxial minor veins 52
- Hypodermis lacking thick sclerenchymous walls, adaxial fiber bundles not usually opposite adaxial minor veins 53
- 52 Sclerenchymous hypodermis continues along the adaxial surface, all adaxial minor veins are usually attached..... *S. harleyi* (low elevation form)
- Sclerenchymous hypodermis only on the margin, every other abaxial minor vein (mesophyll vein) is unattached *S. harleyi* (high elevation form)
- 53 Most veins attached to both surfaces of the leaflet and/or leaflet with hairy trichomes on the abaxial surface..... 54
- Most veins attached to either the adaxial or abaxial surface but not to both and lacking hairy trichomes 57
- 54 Most veins attached only to the abaxial surface or attached adaxially only by a very short fibrous extension, palm with short underground stem..... *S. itapebiensis*
- Most veins attached to both surfaces and to the adaxial surface by a very narrow fibrous extension, palm with aerial stem..... 55
- 55 Mesophyll differentiated into palisade and spongy mesophyll cells..... *S. weddelliana*
- Mesophyll undifferentiated 56
- 56 Leaf rachis 140–155 cm, leaflet with brownish pubescence abaxially ... *S. boehnei*
- Leaf rachis less than 99 cm, leaflet with silvery pubescence abaxially *S. insignis*
- 57 Mesophyll undifferentiated 58
- Mesophyll differentiated 60
- 58 Primary veins clearly unattached *S. picrophylla*
- Primary veins attached adaxially or nearly so..... 59
- 59 First fiber bundle the largest, leaf rachis ca. 100 cm long..... *S. elata*
- First fiber bundle ca. same size as the others, leaf rachis 167–440 cm long.... *S. romanzoffiana*

- 60 Two or three layers of palisade mesophyll cells on the adaxial surface, lamina usually 0.25 mm thick or more.....61
- One layer of palisade mesophyll cells on the adaxial surface, lamina usually less than 0.25 mm thick.....70
- 61 Abaxial fiber bundles alternating with abaxial minor veins62
- Abaxial fiber bundles absent or with only an occasional one present67
- 62 Large vein near the tip of the margin63
- No large vein near the tip of the margin.....65
- 63 Marginal vein with fibrous sheath not noticeably thickened and adaxial fiber bundles very obvious..... *S. amara*
- Marginal vein with fibrous sheath noticeably thickened, abaxial fiber bundles very small and sometimes difficult to distinguish64
- 64 Marginal vein with fibrous sheath noticeably thickened both abaxially and adaxially.....*S. stenopetala*
- Marginal vein with fibrous sheath noticeably thickened only adaxially.....
..... *S. orinocensis*
- 65 Marginal fiber bundles not present or not very large*S. stratincola*
- Marginal fiber bundles fairly large, especially on the adaxial surface.....66
- 66 A nearly continuous single layer of fiber cells in the adaxial hypodermis and fiber bundles along the adaxial surface, Amazonas.....*S. inajai*
- Occasional fiber cells in the adaxial hypodermis and fiber bundles often lacking, Atlantic Forest*S. botryophora*
- 67 Secondary vein near the tip, followed by several minor veins and the primary vein.....68
- Primary vein near the tip, followed by several minor veins69
- 68 Many fibers or fiber bundles along the adaxial surface, adaxial vein with an exaggerated fibrous sheath absent or very small.....*S. cocoides*
- No or very few fibers or fiber bundles along the abaxial surface, an abaxial vein with an exaggerated fibrous sheath is often present near the margin
.....*S. flexuosa*
- 69 Nearly continuous one layer of fibers in the adaxial hypodermis
.....*S. vermicularis*
- Interrupted layer of fibers and fiber bundles in the adaxial hypodermis.....
.....*S. pseudococos*
- 70 Primary vein unattached, abaxial fiber bundles appearing flattened*S. smithii*
- Primary vein attached adaxially, abaxial fiber or fiber bundles, if present, small and rounded71
- 71 Adaxial fibers and fiber bundles form a continuous layer in the hypodermis, abaxial fiber fibers and fiber bundles occasionally present.....*S. sancona*
- Adaxial fibers and fiber bundles forming a discontinuous layer in the hypodermis, abaxial fibers and fiber bundles absent *S. cardenasii*

Discussion

Variation

I have examined several specimens for each species. However, I make no claim that this has been an exhaustive study. In making use of this key the user must allow for slight variation due to environmental and population differences from the published images. As more specimens were sampled, I expected to see more variation, but was surprised to see how many species stayed true to their basic arrangement of veins and fiber bundles, as well as agreed with previous work done by Glassman (1972, 1987). Nonetheless, a few do vary and for this reason more than one image is used to represent some species. Examples of this are seen in *Syagrus cerqueirana* (Figure 3) where the marginal vein with the exaggerated fibrous sheath varies in size along with the number of adaxial and abaxial minor veins and fiber bundles. Another example is *S. cocoides* (Figure 3), where the marginal tip shape varies, along with the quantity and frequency of adaxial fiber bundles. *Syagrus glazioviana* (Figure 4, 5) is an extreme example of variation. The variation seen in this species either represents true variation within a single species or it is revealing a complex of several closely related species. Environment definitely plays a part in this variation as seen in *S. harleyi* (Figure 5) where the low elevation form has a sclerenchymous hypodermis on the margins and along the adaxial surface making it more drought resistant, while the high elevation form has a sclerenchymous margin, but has less sclerenchymous tissue along the adaxial surface. The variation seen in *S. hoehnei* (Figure 5) represents two different populations (Harri Lorenzi, pers. comm.). *Syagrus minor* also represents two specimens separated by over 100 km with one having adaxial veins, which are nearly absent in the other. The variation seen in *Syagrus vagans* (Figure 8) clearly demonstrates the futility of trying to use marginal shape for species determination, at least in *Syagrus*.

Molecular clades versus phenetic (key) branch similarities

Although I was not attempting to show close relationships in his key, nevertheless, certain relationships are suggested based on how these species resolved in the key. Such relationships can only be confirmed further by an in depth phylogenetic molecular analysis of the genus.

An outline of the key is presented (Figure 9, 10) to allow one to more clearly visualize the branches of the key and is not meant to depict a phylogenetic analysis. This is not a cladogram. An interesting, but unintentional consequence of producing this key has been to discover how species might be related based on their anatomical phenetics, i.e. possible relationships based on their overall similarity in anatomy or the organization of their anatomical characters. It must be emphasized that this is not an actual phenetic analysis using some kind of distance coefficient. In some cases, branches of the key contain species that had been previously shown to be related by molecular analyses (Meerow et al. 2009,

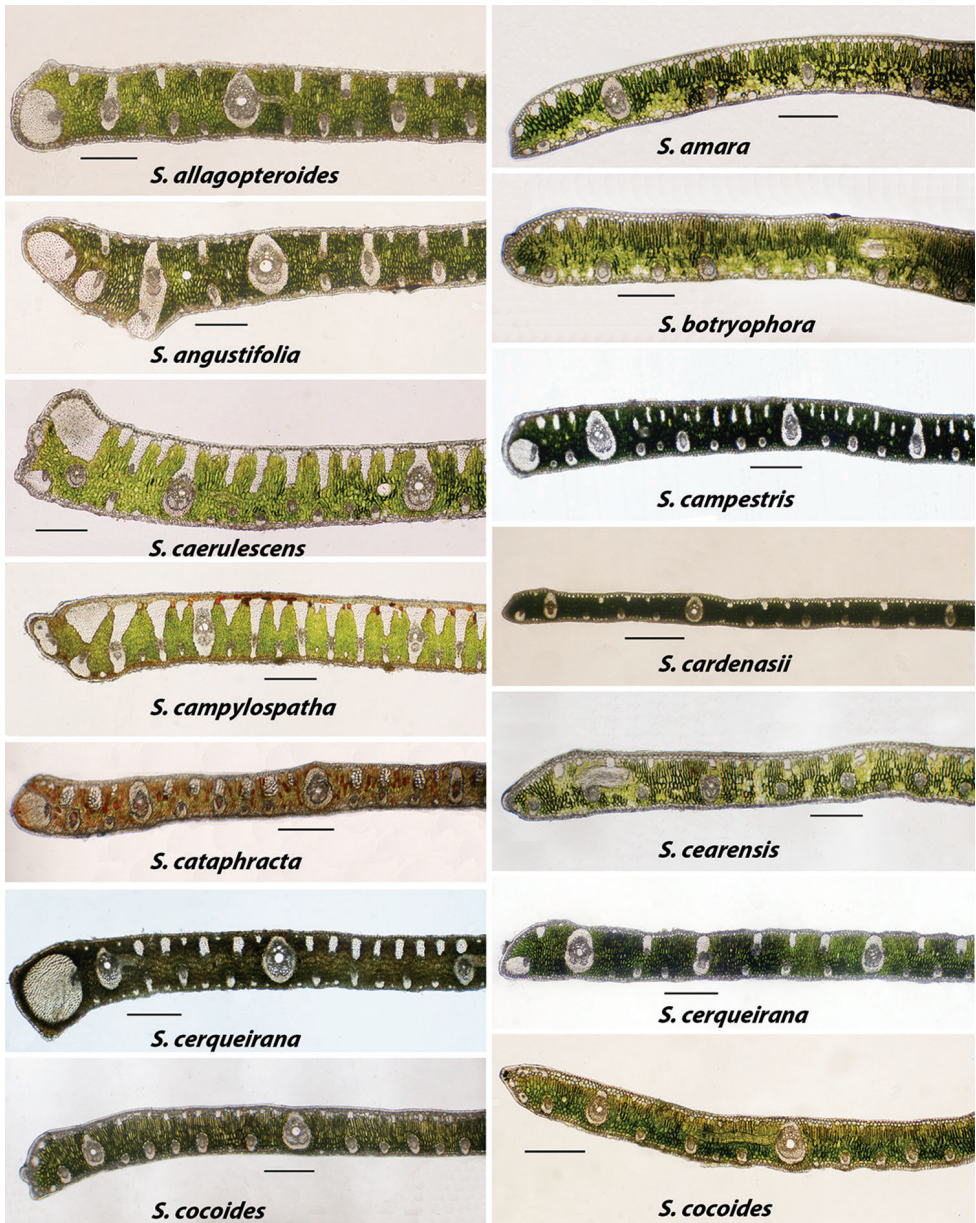


Figure 3. Alphabetically arranged marginal leaflet transections. *Syagrus allagopteroides* to *S. cocoides*. Bar scale = 0.25 mm.

2014). As demonstrated in Table 1, species of the former genus *Lytocaryum* all resolve in the same branch of the key (Figure 10, branch 53) as they did in the molecular analysis of those analyzed. Species of the strongly supported Rain Forest clade (Meerow 2009, 2014) all emerge together in a branch of the key containing mostly Amazonian, Caribbean, An-



Figure 4. Alphabetically arranged marginal leaflet transections. *Syagrus comosa* to *S. glazioviana*. Note variation in *S. glazioviana*. Bar scale = 0.25 mm.



Figure 5. Alphabetically arranged marginal leaflet transections. *Syagrus glazioviana* to *S. itapebiensis*. Note variation in *S. harleyi* and *S. hoehnei*. Bar scale = 0.25 mm.



Figure 6. Alphabetically arranged marginal leaflet transections. *Syagrus kellyana* to *S. petraea*. Note variation in *S. minor*. Bar scale = 0.25 mm.



Figure 7. Alphabetically arranged marginal leaflet transections. *Syagrus picrophylla* to *S. schizophylla*. Note variation in *S. romanzoffiana*. Bar scale = 0.25 mm.



Figure 8. Alphabetically arranged marginal leaflet transections. *Syagrus smithii* to *S. yungasensis*. Note variation in *S. stenopetala* and *S. vagans*. Bar scale = 0.25 mm.

dean and few Atlantic forest species (Figure 10, branch 60). The Eastern Brazilian species of the molecular analyses are not as neatly grouped, but of the few species analyzed, they emerge in two portions of the key, but usually among other Eastern or Central-Western Brazilian species (Table 1, Figure 9, branches 18 and 43'). Cluster stemmed species mostly emerge in the same branch of the key (Table 1, Figure 9, branch 3').

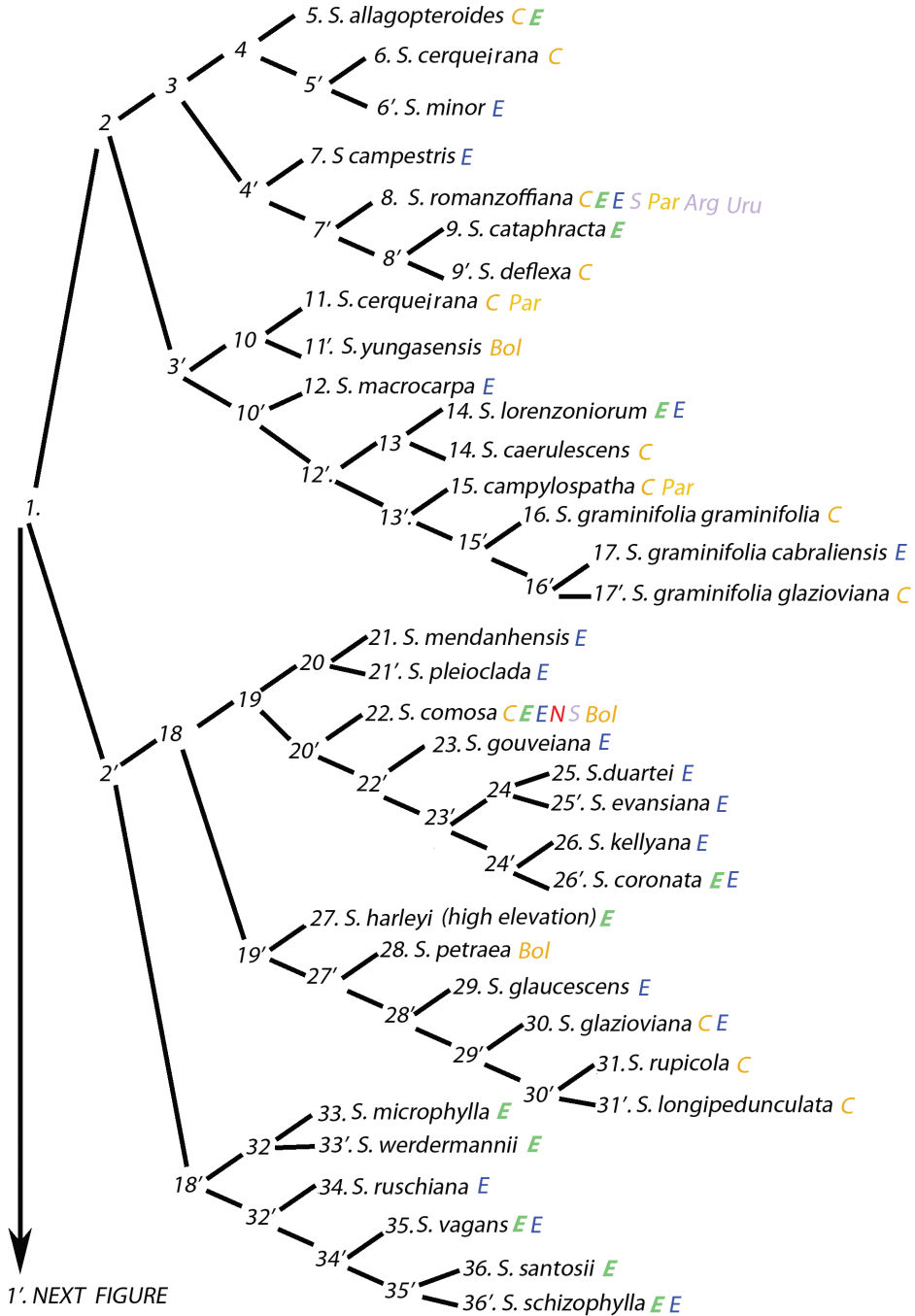


Figure 9. Diagram of the anatomical key to *Syagrus*. Branch 1. Colored letters represent regions of distribution for that species. For regions of Brazil: **Orange C** = Central-West **Green bold italic E** = Northeast **Blue E** = Southeast **Red N** = North and **Violet S** = South. For other countries: **Arg** = Argentina **Bol** = Bolivia **Par** = Paraguay and **Uru** = Uruguay.

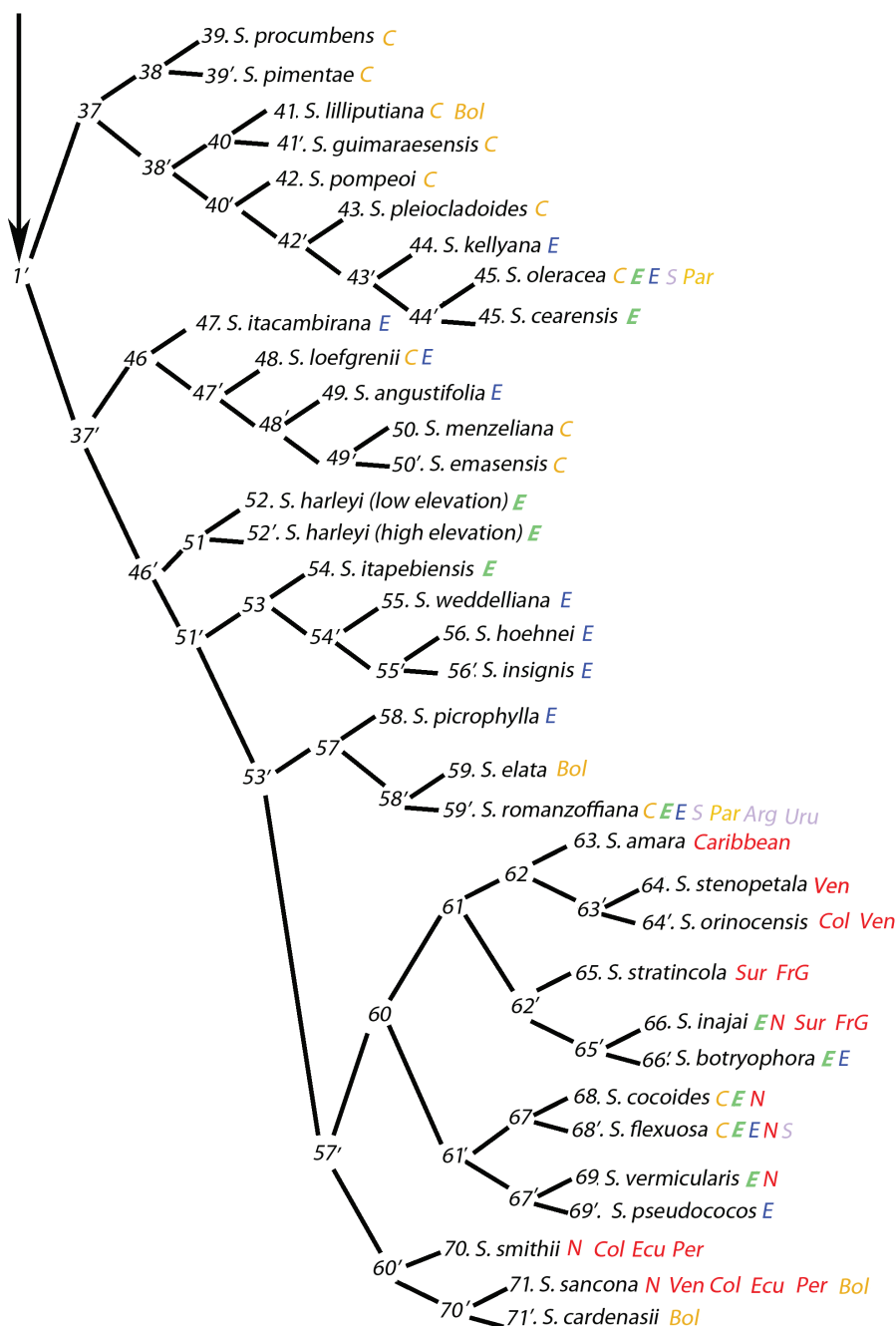


Figure 10. Continuation of the diagram of the anatomical key to *Syagrus*. Branch 1'. Colored letters represent regions of distribution for that species. For regions of Brazil: **Orange C** = Central-West **Green bold italic E** = Northeast **Blue E** = Southeast **Red N** = North and **Violet S** = South. For other countries: **Arg** = Argentina **Bol** = Bolivia **Col** = Colombia **Ecu** = Ecuador **FrG** = French Guyana **Par** = Paraguay **Per** = Peru **Sur** = Surinam **Uru** = Uruguay and **Ven** = Venezuela.

Table 1. Comparison of molecular clades and key branches. Meerow et al. (2009) designated three clades based on nuclear DNA sequences in *Syagrus*: Rain Forest, Eastern Brazilian, and Cluster stemmed. Taxa with an asterix (*) in column 4 were part of the original molecular analysis (Meerow et al. 2009).

Name of Clade or Region	Molecular Clade (Meerow 2009)	Key Branch	Species found in similar Branch of Key	Geographical Region
Rain Forest/ <i>Lytocaryum</i>	<i>L. itapebiensis</i> <i>L. weddelliana</i>	53	<i>S. itapebiensis</i> * <i>S. weddelliana</i> * <i>S. hoehnei</i> <i>S. insignis</i>	Atlantic Forest Atlantic Forest Atlantic Forest Atlantic Forest
Rain Forest	<i>S. amara</i> <i>S. orinocensis</i> <i>S. stenopetala</i> <i>S. botryophora</i> <i>S. cocoides</i> <i>S. vermicularis</i> <i>S. sancona</i> <i>S. ruschiana</i>	57'	<i>S. amara</i> * <i>S. orinocensis</i> * <i>S. stenopetala</i> * <i>S. inajai</i> <i>S. botryophora</i> * <i>S. stratincola</i> <i>S. cocoides</i> * <i>S. flexuosa</i> * <i>S. vermicularis</i> * <i>S. pseudococos</i> <i>S. smithii</i> <i>S. sancona</i> * <i>S. cardenasii</i>	Caribbean Amazon Amazon Amazon Atlantic Forest Amazon Amazon Central Brazil Amazon Atlantic Forest Amazon Andes/Amazon Andes
Eastern Brazilian	<i>S. cearensis</i> <i>S. coronata</i> <i>S. glaucescens</i> <i>S. kellyana</i> <i>S. oleracea</i>	18	<i>S. mendanhensis</i> <i>S. pleioclada</i> <i>S. comosa</i> <i>S. gouveiana</i> <i>S. duartei</i> <i>S. kellyana</i> * <i>S. coronata</i> * <i>S. harleyi</i> <i>S. petraea</i> <i>S. glaucescens</i> * <i>S. glazioviana</i> <i>S. rupicola</i> <i>S. longipedunculata</i>	Eastern Brazil (MG) Eastern Brazil (MG) E. & Central Brazil Eastern Brazil (MG) Eastern Brazil (MG) Eastern Brazil (MG) Eastern Brazil Eastern Brazil (BA) Bolivia Eastern Brazil (MG) E. & Central Brazil Central Brazil (GO) Central Brazil (GO)
Eastern Brazilian		43'	<i>S. kellyana</i> * <i>S. oleracea</i> * <i>S. cearensis</i> *	Eastern Brazil E. & Central Brazil Eastern Brazil
Clustered stemmed	<i>S. campylospatha</i> <i>S. cerqueirana</i> <i>S. macrocarpa</i> <i>S. flexuosa</i>	3'	<i>S. cerqueirana</i> * <i>S. yungasensis</i> <i>S. macrocarpa</i> * <i>S. lorenzoniorum</i> <i>S. caerulescens</i> <i>S. campylospatha</i> * <i>S. graminifolia</i>	C. Brazil /Paraguay Andes (Bolivia) Eastern Brazil (MG) Eastern Brazil (MG) Central Brazil (GO) C. Brazil /Paraguay C. Brazil (GO, MG)

Species from the same or neighboring geographic regions

Frequently, neighboring species key out in the same branch (Figure 9, 10). Branch 2 contains species primarily from the Central-West region of Brazil. *Syagrus allagopteroides* and *S. minor* are from adjacent areas of Goiás and Minas Gerais (branch 4). All of

the three subspecies of *S. graminifolia* (as defined by Noblick, 2017) fall out together in the key (branch 15') and while they are from two different geographic regions of Brazil (Southeast and Central-west), they are really only from the neighboring states of Goiás and Minas Gerais, which just happen to form the boundary between these two regions.

Branch 19 contains species that can all be found in the state of Minas Gerais, Brazil. *Syagrus mendanhensis* and *S. pleioclada* (branch 20) are from the neighboring areas of the Serra Diamantina and Serra do Cipó in Minas Gerais as are *S. gouveiana*, *S. duartei*, and *S. evansiana* (branch 19). In that same branch, *Syagrus kellyana* grows in the neighboring Serra do Mar region of Minas Gerais closer to the coast, while *S. coronata* can be found growing in the northeastern part of the same state adjacent to its Bahian distribution.

Species of branch 19', with one exception, come from the Central-West or adjacent Southeastern region of Brazil. *Syagrus glazioviana*, *S. rupicola* and *S. longipedunculata* (branch 29') can all be found in the state of Goiás with *S. rupicola* and *S. longipedunculata* restricted to the Serra dos Veadeiros in the northern part of Goiás while *S. glazioviana* is more widespread.

Several Bahian species emerge in branch 18'. *Syagrus microphylla* and *S. werdermannii* grow in the mountainous interior of Bahia. *Syagrus vagans* tolerates the dry caatinga habitat in and between the mountains and the coast of Bahia. Finally, the rare, recently discovered *S. santosii* and more common *S. schizophylla* flourish near the coast.

With few exceptions most of the species in branch 37 grow in Brazil's Central-West region, Mato Grosso, Mato Grosso do Sul, and Goiás (*S. procumbens*, *S. pimentae*, *S. lilliputiana*, *S. guimaraesensis*, *S. pompeoi*, *S. pleiocladoides*, *S. oleracea*). However, the *S. oleracea* distribution overlaps with *S. cearensis* from Brazil's Northeast region and at one time they were considered to be the same species (Glassman 1987, Noblick 2004, 2017).

Branch 46 contains cerrado species from the adjacent Central-West and Southeast regions of Brazil. *Syagrus emasensis* and *S. menzeliana* are neighboring species (branch 49') with the first growing in the southwestern corner of Goiás in the Parque Nacional das Emas and the other growing just south of the park.

It is not surprising to see both forms of *S. harleyi* key out in branch 51. However, the high elevation form also may key out earlier in branch 19 as some of the abaxial minor veins can be interpreted as being mesophyll veins.

All of the former *Lytocaryum* species (branch 53) grow in Atlantic Forest of Eastern Brazil from Brazil's Northeast region and the eastern hills of Bahia (*S. itapebiensis*), through Brazil's Southeast region including the Serra do Mar mountains of Espírito Santo (*S. insignis*), Rio de Janeiro (*S. weddelliana*), and into the state of São Paulo (*S. hoehnei*).

Most of the species found in branch 57' are from the Caribbean, northern part of South America, the Amazon or the Andes. *Syagrus amara* from the Caribbean logically falls out in branch 62 next to *S. stenopetala* (Venezuela) and *S. orinocensis* (Venezuela, Colombia), the next closest *Syagrus* species. In branch 60, *S. stratincola* and *S. inajai* co-exist in the rain forests of Suriname and French Guyana of northern South America. *Syagrus inajai*, which is found throughout much of the Amazon basin also emerges near *S. botryophora* of the Atlantic Forest, an Amazonian connection that was

also resolved in the molecular analyses (Meerow 2009, 2014). A similar Amazonian/ Atlantic Forest connection pops up in branch 67' between the pre-Amazonian species of *S. vermicularis* and the Atlantic Forest species, *S. pseudococos*. This Amazonian connection shown both here and in the molecular analyses offers further evidence that the two forests were connected at one time. Finally, several Andean species emerge in branch 60' with *S. smithii* (Colombia, Ecuador, and Peru), *S. sancona* (Venezuela to Bolivia), and *S. cardenasii* (Bolivia).

Conclusion

As demonstrated in the figures, there is a great deal of diversity in the leaflet anatomy of the genus *Syagrus*. This key has made use of this diversity to create a valuable and easy tool for the identification of *Syagrus* species using anatomical characters found in leaflet margin cross-sections. It will especially be found to be useful when the palms have not yet produced any reproductive material and little else is known about the palm under study. It can also be used to help confirm identifications.

The key can be seen as a crude means to infer certain relationships within the genus. The anatomical key based on phenetics, not only repeated some of the same groupings or clades that were seen in the molecular analyses, but also grouped the species geographically as well. Only further, more inclusive, molecular analyses will determine if the relations found here are substantiated by the DNA sequences.

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Five new species of *Syzygium* (Myrtaceae) from Sulawesi, Indonesia

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Abstract

Following ongoing ecological research on the tree diversity of the Indonesian island of Sulawesi, we describe five new species of *Syzygium*. These are the first descriptions of *Syzygium* species from the island since Blume (1850, *Jambosa celebica* and *J. cornifolia*), highlighting the significant lack of taxonomic research on the genus for the region. The five species proposed as new are *Syzygium balgooyi* **sp. nov.**, *Syzygium contiguum* **sp. nov.**, *Syzygium devogelii* **sp. nov.**, *Syzygium eymae* **sp. nov.**, and *Syzygium galanthum* **sp. nov.** All species are illustrated and information on their distribution, ecology, and conservation status is given.

Keywords

Indonesia, Lore Lindu National Park, Myrtaceae, Sulawesi, *Syzygieae*, *Syzygium*, taxonomy, Wallacea

Introduction

The botanical diversity of the Indonesian island of Sulawesi is poorly known and remains one of the least studied in Southeast Asia (de Vogel 1989, Cannon et al. 2007). The "Checklist of woody plants of Sulawesi" by Kessler et al. (2002), the most comprehensive taxonomic work for the island, highlighted how numerous taxonomic groups

were in need of specialist systematic work. Myrtaceae and the largest genus in the family, *Syzygium* P.Browne ex Gaertner (1788, 166), were in particular emphasised because only four species of *Syzygium* were recorded in the checklist while approximately 350 un-named collections were listed. Several species now accepted as belonging to *Syzygium* were listed under other generic names in the checklist, such as *Acmena* de Candolle (1828, 262) and *Eugenia* Linnaeus (1753, 470), which further underscores the complex history of the genus.

Syzygium is the most - species rich genus of woody plants in Southeast Asia with around 1000 species but little is known of the genus in Wallacea, the biogeographically important transition zone between the Asian and Australian continental areas. As in the other Wallacean regions, the Maluku Islands and Lesser Sunda Islands, the *Syzygium* species of Sulawesi have never been revised or monographed so there is no robust baseline data of which species occur in the region. The last *Syzygium* species to be described from Sulawesi were by Blume (1850) under the generic name *Jambosa*: *J. celebica* Blume and *J. cornifolia* Blume. The occurrence of other, mostly widespread species of *Syzygium*, have been noted over time and resulted in 14 species recorded from Sulawesi at present (WCSP 2016). This number is unrealistically low when considering *Syzygium* diversity in neighbouring regions: Java holds c. 60 species; Borneo, the Philippines, and New Guinea c. 200 species each (WCSP 2016). In fact, recent extensive examination of herbarium material suggests that Sulawesi harbours > 100 species, the great majority of them yet unnamed (SYZWG 2016).

Species of *Syzygium* are present in virtually all ecosystems of Sulawesi, and are often important components of the biological communities (van Balgooy and Tantra 1986, Whitten et al. 1987, Milliken and Proctor 1999, Culmsee et al. 2010), so the lack of taxonomic resolution presents a serious impediment for a better understanding of ecological processes as well as for conservation efforts on the island.

In 2006–2007 and 2011–2012, the University of Göttingen, Germany, and Tadulako University, Palu, Indonesia conducted ecological fieldwork campaigns in Lore Lindu National Park (LLNP), Central Sulawesi. Difficulties in the identification of *Syzygium* specimens collected during these surveys motivated us to take a closer look at the taxonomy of the genus. Fortunately, the area of LLNP had been visited before by other botanists (Bloembergen 1940, Meijer 1983, van Balgooy and Tantra 1986), so good fertile collections for comparison were available in herbaria. Five species could not be matched with previously published taxa and are here proposed as new. This is the first time in > 165 years that species of *Syzygium* are described from Sulawesi.

Methods

Morphological observations

The specimens collected during our ecological fieldwork in LLNP (HC, 2006–2007; HC and FB, 2011–2012) were the starting point for this study. Duplicates of relevant

specimens, including types, were deposited in L and the Indonesian herbaria BO and CEB (herbarium acronyms follow Thiers continuously updated). To identify our specimens, all *Syzygium* specimens from Sulawesi at A, B, BM, BO, E, GH, K, L, M and U were examined and all matching specimens sorted into morphospecies. We then attempted to identify our morphospecies using keys and floristic treatments from regions around Sulawesi: the Malay Peninsula (Henderson 1949), Borneo (Merrill and Perry 1939, Ashton 2011), Java (Amshoff 1963), the Philippines (Robinson 1909, Elmer 1914, Merrill 1915, 1921, 1951, Pelser et al. 2011), New Guinea (Diels 1922, 1924, Merrill and Perry 1942, Hartley and Perry 1973), and Australia (Hyland 1983). Because *Syzygium* is such a species-rich genus, we had to repeat this process several times to make sure we did not miss any species our specimens could be matched with. All specimens examined by us are marked with an exclamation mark. We recorded morphological characters of all cited specimens to produce the species descriptions using the package *monographaR* (Reginato 2016) in R (R Core Team 2015).

Photographs in the field were taken using a Canon EOS 500D camera with a Tamron AF 18–200mm f/6.2–3.8 lens, for later photographs of dried material we used the same camera with a Tamron SP 90mm F/2.8 MACRO lens. Colours of dried specimens were compared to Munsell Soil-Color Charts (Munsell Color 2010) and colour names used accordingly.

Wood density (oven-dry mass per fresh volume) was determined from wood cores extracted with increment borers. The samples' fresh volume was measured by Archimedes' principle and weight was noted from the same samples after oven-drying for 48h at 105°C.

For the descriptions, flowers and fruits were boiled in dilute detergent for 5 minutes and dissected thereafter. Dimensions were measured using a ruler with 0.5 mm accuracy. All colours and measures given refer to dried and pressed material unless otherwise stated. We measured the distance of intramarginal veins from leaf margin in the proximal 2/3 of the blade; it usually decreases towards the apex. Likewise, we measured the distance of secondary veins in the central 1/2 of the leaf; it decreases near the base. Dimensions of flower buds are given including the anthopodium, those of the hypanthium excluding the anthopodium (if present).

Terminology

Terminology for organs in *Syzygium* has been varied and often confusing, with authors using different terms for the same structures or similar terms for different structures.

We here adopt the detailed concepts of Briggs and Johnson (1979) on inflorescence structure but use more common terms instead of their rather technical vocabulary: bract instead of *pherophyll* and bracteole instead of *prophyll/metaxyphyll*. We follow Briggs and Johnson (1979) in using the term *anthopodium* for the internode between the flower and its subtending bracteoles. This structure has been referred to as pseudopedicel (Schmid 1972) or pseudostalk (Henderson 1949), but Briggs and

Johnson (1979) convincingly argued that it is indeed the last internode below the flower and coined the term anthopodium to avoid further confusion. The concept has been adopted by Hyland (1983) who, however, used the more common term pedicel. The anthopodium may be elongated or not; in the latter case the flowers are sessile, although they may appear stalked when arising from elongated higher-order axes of the inflorescence. Otherwise we follow the terminology of Beentje (2012) and Hyland (1983) except for using *hypanthium* instead of *calyx tube*.

Presentation of data

Since several specimens found in herbaria contained very limited information about the respective collecting localities, we interpreted the locality data of all specimens cited in this paper and translated it into a common format. The format contains approximate coordinates in WGS 84 (if not given on the label), the nearest village, and the administrative divisions in descending order: Province, Kabupaten (Kab., Regency), and Kecamatan (Kec., District).

Specimens collected in Sulawesi by the Forest Research Institute Buitenzorg (Bogor), also called Boschproefstation or Boschbouwproefstation (van Steenis-Kruseman and van Welzen 2014), often bear confusing information about the respective collectors. The original herbarium labels for these collections (usually deposited in BO) give the actual collector with a personal collection number and in addition the institutional *bb*- or *Cel*-number. Duplicate labels usually only contain the institutional number and either read Neth. Ind. For. Service or Boschproef station as collector. We cite these specimens as NIFS (Netherlands' Indies Forest Service) with the respective institutional number.

In the diagnoses, we give floral formulas for each species, following the format and recommendations of Prenner et al. (2010). Furthermore, we apply Appropriate Citation of Taxonomy (Seifert et al. 2008) throughout the manuscript.

Under Distribution and Habitat, we characterised the forest stands of the species which were found primarily in our (FB and HC) inventory plots by mentioning the families with the five highest family importance values (FIV). The FIV is an objective measure of importance of a family in a stand taking into account the number of individuals, number of species, and basal area of that family and comparing them to the stand total (see Mori et al. 1983 for detailed description of the method).

Conservation Assessment

We used GeoCAT (Bachman et al. 2011) to calculate the extent of occurrence (EOO) and area of occupancy (AOO) of each species as basis for the conservation assessments following the recommendations of IUCN Standards and Petitions Subcommittee (2014).

Results

All species here described are glabrous in all parts and possess flower characters placing them in the broadly defined *Syzygium* subg. *Syzygium* (Craven and Biffin 2010): anther sacs parallel and opening by longitudinal slits, placentation axile-median. The species of which we have seen fruiting material furthermore have seeds without intrusive tissue interlocking the cotyledons and free cotyledons, conforming with subgenus *Syzygium* as well. These characters are not mentioned again in the species descriptions.

1. *Syzygium balgooyi* Brambach, Byng & Culmsee, sp. nov.

urn:lsid:ipni.org:names:60474721-2

Figures 1, 2, 8

“*Eugenia* spec. BB“ (Koorders 1898, 173, 459, Koorders-Schumacher 1914, 95).

„Myrtaceae sp. 10“ p.p. (Culmsee and Pitopang 2009, see also 2017 (Erratum), Culmsee et al. 2011).

Diagnosis. *Syzygium balgooyi* is characterised by long, elongate-clavate flowers, a character otherwise only known from the morphologically similar *Syzygium schumannianum* (Nied.) Diels (1922, 402) from New Guinea and the Maluku Islands. *Syzygium balgooyi* differs from that species by its smooth (vs prominently longitudinally ridged) hypanthium and fruit and by the hypanthium rim which remains entire after anthesis (vs apically splitting into 4 recurving lobes). Floral formula $B1 \ Bt2 \ K4^* \ C4^* \ A\infty^* \ \hat{G}(2) \mid V_{x\infty}$.

Type. INDONESIA. South Sulawesi (Sulawesi Selatan), Kab. Luwu Timur, Kec. Nuha, Between Soroako and Nickel plant site, c. 2°33'S, 121°22'E, 500 m, 10 Jul 1979: *van Balgooy* 3956 (flowers; holotype L [L.2517558]! [spirit collection L 0771145] [wood sample L 0708624], isotype A [A01143212]!).

Description. **Trees**, up to 37 m tall, diameter at breast height ≤ 65 cm, trunk straight, ≤ 20 m tall, often fluted and with buttresses ≤ 3 m tall and 1 m out. Outer **bark** pale brown to bright red, peeling off in small or large sheets, inner bark dark red, usually paler towards inside, sometimes with little watery red sap, wood very hard and heavy, sapwood cream, clearly separated from the dark reddish brown heartwood. Young **branchlets** 1–2 \times 1.5–4 mm, strongly flattened, the flat sides usually with two lateral, rounded ridges leading to the petioles and one central ridge continuing into the next internode, often resinous when dry, epidermis green, drying dusky red to reddish black and usually smooth; becoming terete, bark drying red to dark reddish brown, finely flaking and with conspicuous flaking remnants of epidermis.

Leaves (sub-)opposite. Petioles 2–12 \times 1–3.5 mm, flat and sometimes narrowly winged above, rounded or keeled beneath, drying reddish black and smooth. Blades (4–) 7–11.5 (–16) \times (1.5–) 3–5 (–9) cm, ratio (1.2–) 1.8–2.7 (–5), (narrowly) elliptic, obovate, or oblanceolate, base cuneate and attenuate at the very base or obtuse

to rounded, apex usually rounded or obtuse, sometimes emarginate or acute, margin slightly to strongly revolute; (thick-)coriaceous, purple, pink, or reddish when young, fresh to dark glossy green above, paler glossy green beneath, drying dull to shiny, often resinous after drying, reddish brown to reddish black above, reddish brown to very dusky red beneath. Midrib channelled above, prominent and rounded or keeled, drying reddish black and smooth beneath. Secondary vein pairs (9–) 11–14 (–16), 4–12 (–15) mm apart, \pm faint and lighter red than the lamina above, \pm prominent and darker than the lamina beneath; intersecondary veins present. Tertiary veins sup-parallel near the midrib, reticulate towards the margins, \pm faint above, faint or prominulous and darker than the lamina beneath. Inner intramarginal vein 1–5 mm from the leaf margin, \pm looping; outer intramarginal vein < 1 mm from the leaf margin, often seemingly absent from leaf margin.

Inflorescences terminal and often in axils of distal leaf pair, rather dense panicles, 5–10 cm long, peduncles 1–6 cm long, axes subangular or rounded, flattened, resinous after drying. Bracts c. 3 mm long, linear, pellucid-dotted, caducous; bracteoles 2 per flower, sometimes seemingly 4 (by contraction of the ultimate inflorescence axes?), 1 mm long.

Flowers 5–15 per inflorescence, within the panicles in monads or clusters of 2–4, 4-merous, anthopodium absent, c. 20–30 mm in diameter at anthesis, mature buds 20–30 \times 3–6 mm. Hypanthium 20–30 \times 5–7 mm, elongate-clavate, yellowish green, drying smooth black, hypanthium rim 15 mm long, glandular inside. Calyx lobes c. 2 \times 2 mm, claw- or hood-shaped. Petals c. 4 \times 3 mm, \pm obovate, pale green. Stamens c. 100, filaments 10–20 mm long, pale green, anthers c. 0.5–0.8 mm long, ellipsoid, yellow. Ovary bilocular, locules surrounded by spongy tissue, ovules c. 15–20 per locule, ascending, \pm arranged in 2 longitudinal rows. Style 25–35 mm long, pointed.

Fruits 1–2-seeded, 27–33 \times 12–16 mm, ampulliform, yellowish green (immature?), drying black, smooth or slightly warty, pericarp c. 1 mm thick, leathery when fresh, \pm woody when dried, hypanthium rim 8–12 mm long, 4–5 mm in diameter.

Seeds 13–15 \times 9–10 mm, ellipsoid, testa cartilaginous, attached to the pericarp, cotyledons free from the testa, \pm half-globose, minutely verrucose, facing surfaces undulate.

Etymology. The species is named after Max Michael Josephus van Balgooy (*1932), botanist and authority on Southeast Asian plant taxonomy, identification, and biogeography. He collected over 900 specimens during a Dutch-Indonesian expedition to Sulawesi in 1979, among them the type specimen of this species. We enjoyed the privilege of learning from Max during several stays at the herbarium in Leiden and receiving his help with the identification of our specimens collected in Central Sulawesi.

Phenology. Flowering specimens have been encountered throughout the year without any apparent association with geography or climate. Fruiting specimens have been recorded in May (*de Vogel* 5413) and September (sight record by FB).

Distribution and habitat. *Syzygium balgooyi* is restricted to Sulawesi and widespread across the island (Figure 2). The species occurs on a variety of geological substrates, namely volcanic rocks on the Northern Peninsula, acid plutonic rocks and

schists in the Central Sulawesi Mountains (see Brambach et al. 2016 for definition), alluvial deposits at the base of the Southern Peninsula, and ultramafic rocks on the Eastern and Southeastern Peninsulas. According to the information on specimen labels it grows in primary forests, both virgin and disturbed, over a wide elevational range (c. 100–2000 m). There, it forms part of the canopy layer, sometimes co-dominant (van Balgooy and Tantra 1986), but usually with scattered individuals (Culmsee et al. 2011, Brambach et al. in press).

Conservation status. The AOO of 64 km² would place *Syzygium balgooyi* in the category “Endangered” (EN), despite its wide distribution in Sulawesi (Figure 2) as reflected by the estimated EOO of 94 451 km². The species has been found in a wide variety of habitats, including montane forests at different elevations, with scattered individuals or even co-dominant at times (see Distribution and Habitat above). We have no reason to believe that it is scarce throughout its range. Rather, we argue that the small estimated AOO is an artifact due to the generally low collection rate in Sulawesi and the real geographic distribution does not meet criterion B for any of the “threatened” categories of IUCN (2012). However, although we lack real evidence about possible changes in population size over time, using the Global forest change website (Hansen et al. 2013), we detected deforestation activities at or near five of the 18 collection localities (28%) of *S. balgooyi*. Given that the species is only recorded from old-growth forest habitats, we consider this a loss of suitable habitat, slightly below the 30% threshold for the “Vulnerable” category. Notably, all deforestation took place in places with relatively easy access and at low elevations. Thus, given (1) the relatively large EOO of *S. balgooyi*, (2) its apparent wide ecological niche, (3) its frequency of occurrence, (3) the low collection rates in Sulawesi, and (4) the loss of suitable habitat, we propose a preliminary extinction risk assessment of “Near Threatened” (NT) following the IUCN Red List Categories and Criteria (IUCN 2012).

Vernacular names. Cenke hutan (= forest clove, Indonesian, *de Vogel* 2651), Jambu (general name for *Syzygium*, Indonesian, *NIFS bb* 33081), Rokobako (*NIFS Cel.III*-385), Tambeanitu (Bahasa Behoa, *Brambach et al.* 1047, 1083, 1290, 1316), Wawahuling (Bahasa Tondano, *Koorders* 18251, see *Koorders* 1898, 173, 459).

Notes. Among *Syzygium* species of Sulawesi, *S. balgooyi* can be recognised in the field by its tall stature (Figure 1a), the bright red bark that peels off in thin sheets (Figure 1d, g) and the rather thick, usually obovate or oblanceolate leaves with ± rounded tips (Figure 1b–c, 8a–e). Dry specimens are recognisable by the dark reddish brown twigs bearing thick black flakes of the peeling epidermis and the very dark upper leaf surface with contrasting paler veins.

Leaf size and thickness are quite variable (Figure 8a–e), as can be expected for a species with such a wide ecological distribution. Small leaves are usually found at higher elevations, whereas thick leaves seem to be associated with ultramafic soils. While the extreme forms suggest that several distinct species are involved, when taking into account all the available material, intermediate states connecting the extremes appear. We therefore prefer to treat this as one species with the vegetative parts morphologically variable.

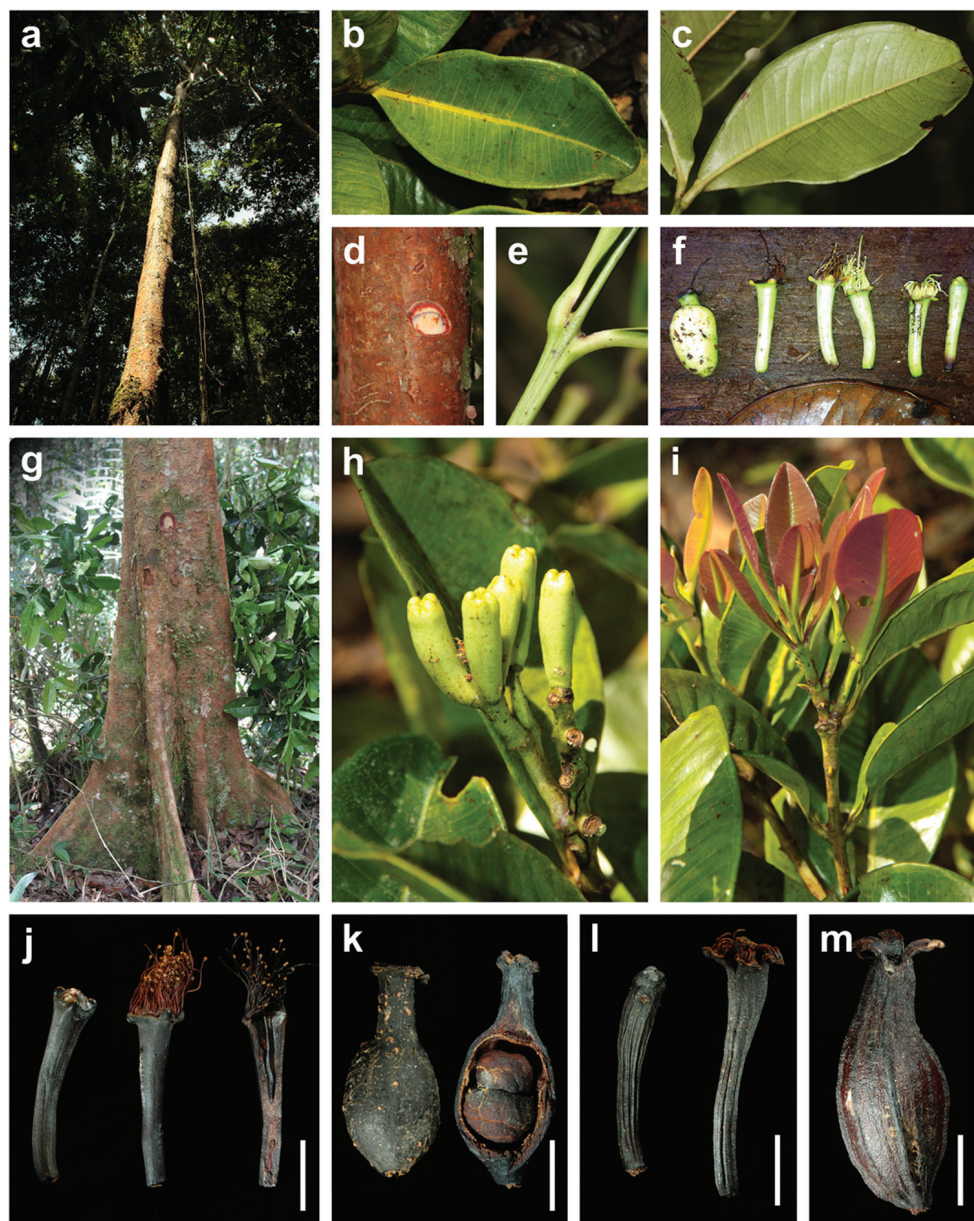


Figure 1. Morphological characters of *Syzygium balgooyi* and *S. schumannianum*. *Syzygium balgooyi* (**a–k**): **a** c. 20 m tall trunk **b** upper leaf surface; **c** lower leaf surface **d** bark with slash **e** ridged shoot apex with subopposite leaves **f** flowers at different stages during anthesis and fruit **g** trunk base with steep narrow buttresses **h** inflorescence with flower buds **i** shoot with young leaves **j** dried flowers before and during anthesis and longitudinal section of flower **k** dried fruit and longitudinal section of fruit showing two cotyledons. *Syzygium schumannianum* (**l–m**): **l** dried flowers before and during anthesis **m** dried fruit. **a–b** and **h–i** Brambach et al. 1564 **c** Brambach et al. 0861 **d–e** Brambach et al. 0628 **f** sighting on Mt Katopas by FB **g** Brambach et al. 0889; **j** holotype van Balgooy 3956 [L.2517558] **k** de Vogel 5413 [L.2517563] **l** Wiakabu et al. LAE 50571 [L.2535534] **m** Brass 13610 [L.2524420]. All scale bars: 1 cm.

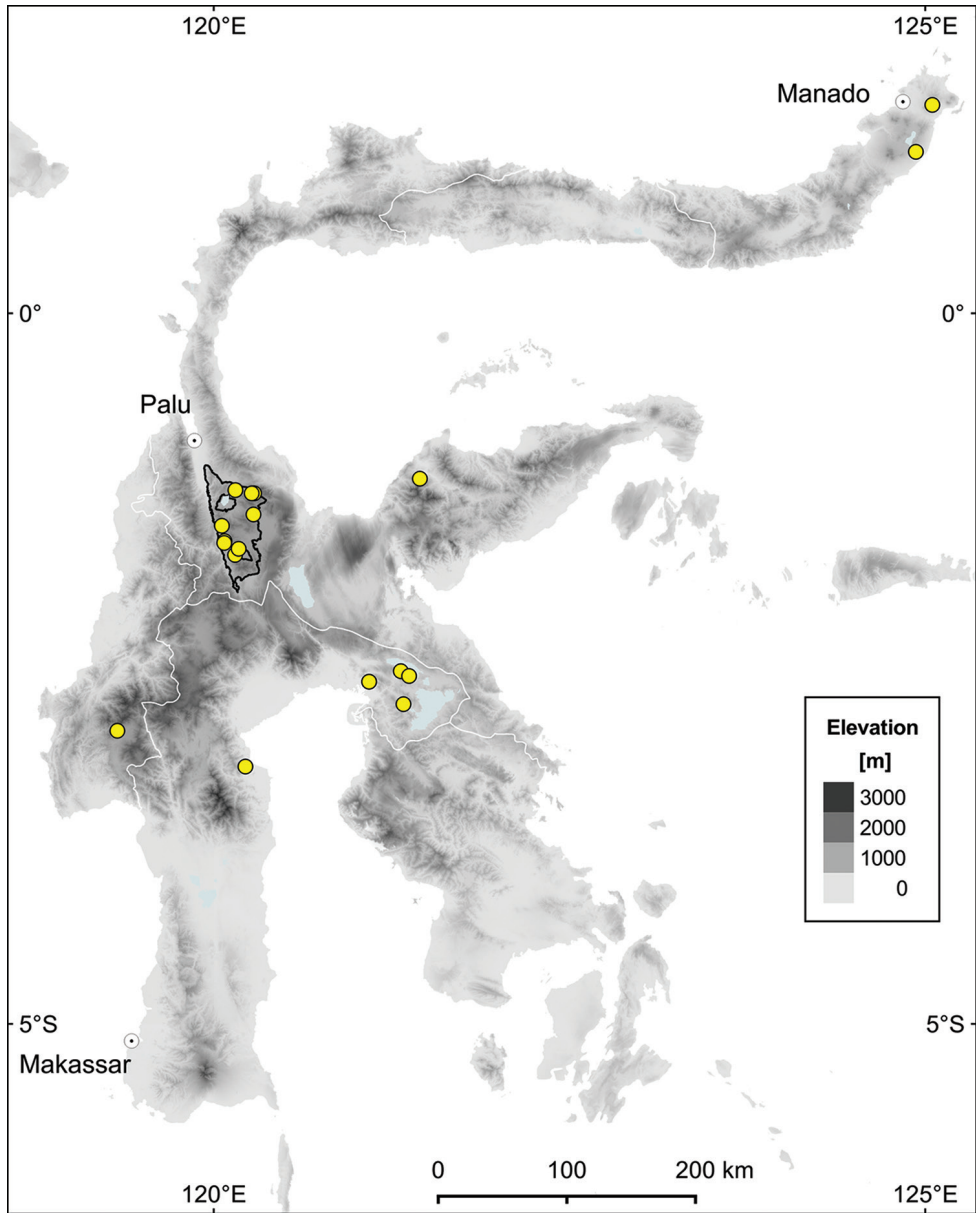


Figure 2. Distribution map of *Syzygium balgooyi* in Sulawesi. Collecting localities are shown as yellow dots; Lore Lindu National Park is indicated by a black line. Map created with QGIS (QGIS Development Team 2016) using the digital elevation model of Jarvis et al. (2008).

Syzygium balgooyi and *S. schumannianum* are difficult to separate in vegetative state. *S. balgooyi* usually has leaves with rounded, obtuse, emarginate, or acute tips, whereas they are shortly acuminate in *S. schumannianum*, but there are exceptions in both species. Flowers and fruits of the two species also share the same structure but there are

two important differences which we consider sufficient to warrant specific separation: Firstly, as indicated by the original name *Eugenia neurocalyx* Schumann nom. illeg. (in Schumann and Hollrung 1889, 90), the outer surface of the hypanthium in *S. schumannianum* bears prominent “nerves”, i.e. longitudinal ridges (Figure 1l–m). These ridges are already visible in young flower buds and remain present until the fruiting stage. Single, very faint ridges may appear in flowering specimens of *S. balgooyi* (seen in *de Vogel* 2651) but in the bulk of the material at our disposition, flower buds, flowers, and fruits are completely smooth (Figure 1j–k). Furthermore, in *S. balgooyi* the stamens are arranged in a ring along the upper margin of the hypanthium rim, which remains entire through the fruiting stage (Figure 1j–k). In *S. schumannianum*, the apical portion of the woody hypanthium rim splits into 4 outward-curving lobes and the stamens are arranged in a small area at the inside of each lobe near its tip (Figure 1l–m, Schumann and Hollrung 1889, Merrill and Perry 1942).

The wood of *S. balgooyi* is used for construction in North Sulawesi, but is not water-resistant (Koorders 1898, 173). Several collectors describe it as very hard and heavy. Mean wood density, as measured from 13 wood cores in LLNP was 0.74 g cm⁻³ (\pm 0.05 SD).

Additional specimens examined (Paratypes). INDONESIA. **North Sulawesi (Sulawesi Utara)**: Kab. Minahasa, Kec. Kakas, Old-growth forest Pinamorongan, c. 1°08'N, 124°56'E (“Noord-Celebes, Residentie Menado, Pinamorongangebergte bij Kakas”), 500 m, 30 Jan 1895: *Koorders* 18251 (sterile; L [L.2517502]! [L.2535743]!).

Kota Bitung, Kec. Ranuwulu, southern part of Wiau Forest Reserve (Hutan Lindung G. Wiau), base of Mt Klabat, c. 1°28'N, 125°03'E, 400 m, 1 Nov 1973: *de Vogel* EF 2651 (flowers; L [L.2535729]! [L.2535730]! [wood sample L 0204047]).

Central Sulawesi (Sulawesi Tengah), LLNP: Kab. Poso, Kec. Lore Utara, west slope of Mt Rorekautimbu, c. 1°16'S, 120°16'E, 1700 m, 15 May 1979: *van Balgooy* MMJ 3371 (sterile; L [L.2535697]!).

Kab. Poso, Kec. Lore Utara, west slope of Mt Rorekautimbu, c. 1°16'S, 120°17'E, 2000 m: 5 May 1979: *Tantra* IJM 1589 (sterile; L [L.2517457]!), & 1592 (sterile; L [L.2535672]!); *ibid.* loco, 17 May 1979: *de Vogel* EF 5413 (fruits; BO [BO-1686561], K [K001024419]!, L [L.2517562]! [L.2517563]!, [wood sample L 0708565]).

Kab. Poso, Kec. Lore Utara, 4 km E of Wuasa, c. 200 m N of Rumuku waterfall, tree-inventory plot Torongkilo, 1°24.9'S, 120°16.7'E, 1450 m, 6 Mar 2012: *Brambach* F, *Mangopo* H, *Firdaus*, *Faber* M, *Tiranda* R 1478 (sterile; BO [BO-1938440]!, CEB, L!) & 1564 (flower buds; BO [BO-1938441]!, CEB, K [K000993483]!) & 1583 (sterile; GOET [GOET020022]!).

Kab. Poso, Kec. Lore Tengah, 9 km NW of Bariri, 100 m E of climate tower, tree-inventory plot Bariri NE, 1°39.4'S, 120°10.5'E, 1400 m: Jul 2007: *Culmsee* H y896 (sterile; CEB, L!); *ibid.* loco, 21 Aug 2011: *Brambach* F, *Mangopo* H, *Firdaus*, *Faber* M, *Tiranda* R 0861 (sterile; BO [BO-1938438]!, CEB, GOET [GOET020025]!) & 0889 (sterile; BO [BO-1938439]!, CEB, L!) & 0907 (sterile; CEB, GOET [GOET020024]!, L!).

Kab. Poso, Kec. Lore Tengah, 9 km NW of Bariri, 80 m south of climate tower, tree-inventory plot Bariri S, 1°39.5'S, 120°10.4'E, 1400 m, Jul 2007: *Culmsee H 1459* (sterile; CEB, GOET [GOET020006]!) & *1495* (sterile; BO [BO-1938457]!, CEB); ibid loco, Jul 2007: *Culmsee H r808* (sterile; CEB, GOET [GOET020008]!).

Kab. Poso, Kec. Lore Tengah, 7 km WNW of Hanggira, E flank of Mt Dali, tree-inventory plot Pantakleabae, 1°42.0'S, 120°09.0'E, 1950 m: 3 Mar 2011: *Culmsee H, Brambach F, Mangopo H, Firdaus, Faber M, Tiranda R r2162* (sterile; CEB, GOET [GOET020021]!) & *r2254* (sterile; BO [BO-1927087], CEB, GOET [GOET020023]!); ibid. loco, 30 Mar 2011: *Brambach F, Mangopo H, Firdaus, Faber M, Tiranda R 0038* (sterile; BO [BO-1926965], CEB, GOET [GOET020027]!, K [K000993482]!, L!) & *0058* (sterile; BO [BO-1926969]!, [BO-1926970]!, CEB, GOET [GOET020033]!) & *0082* (sterile; BO [BO-1938382]!, CEB, GOET [GOET020030]!, L!) & *0097* (sterile; CEB, GOET [GOET020029]!, L!); ibid. loco., 23 Jan 2012: *Brambach F, Mangopo H, Firdaus, Faber M, Tiranda R 1333* (sterile; CEB, GOET [GOET020020]!, L!).

Kab. Sigi, Kec. Kulawi, 2.4 km ENE of Toro, NE edge of Pono Valley, tree-inventory plot Pono, 1°29.7'S, 120°03.4'E, 1050 m: 4 Aug 2006: *Culmsee 125* (sterile; BO [BO-1938456]!, CEB, L!) & *209* (sterile; CEB, K [K000993486]!); ibid. loco, Jul 2007: *Culmsee r211* (sterile; CEB, GOET [GOET020009]!).

Kab. Sigi, Kec. Kulawi Selatan, 4 km E of Watukilo, following footpath to Mt Tokepangana, tree-inventory plot Tokepangana, 1°36.9'S, 120°04.4'E, 850 m, 16 Apr 2011: *Brambach F, Mangopo H, Firdaus, Faber M, Tiranda R 0176* (sterile; BO [BO-1926967]!, CEB, GOET [GOET020028]!, L!) & *0206* (sterile; BO [BO-1926968]!, CEB) & *0283* (sterile; BO [BO-1926973]! [BO-1926974]!, CEB, GOET [GOET020032]!, K [K000993481]!, L!) & *0319* (BO [BO-1926934]!, CEB) & *0332* (BO [BO-1926966]!, CEB) & *0363* (BO [BO-1926919]!, CEB).

Kab. Sigi, Kec. Kulawi Selatan, 4 km ENE of Watukilo, 400 m N of Mboe River, tree-inventory plot Rantena, 1°36.2'S, 120°04.5'E, 700 m: 17 Jun 2011: *Brambach F, Mangopo H, Firdaus, Faber M, Tiranda R 0466* (sterile; BO [BO-1938383]!, CEB, GOET [GOET020031]!); ibid. loco, 21 Jun 2011: *Brambach F, Mangopo H, Firdaus, Faber M, Tiranda R 0628* (sterile; CEB, GOET [GOET020026]!, L!).

Kab. Sigi, Kec. Nokilalaki, 4.3 km SSW of Tongoa, NW flank of Mt Nokilalaki, ca. 400 m S of Shelter 2, tree-inventory plot Nokilalaki 2, 1°14.6'S, 120°09.1'E, 1850 m, Sep 2007: *Culmsee 2923* (sterile; CEB, L) & *3075* (sterile; BO [BO-1938463]!, CEB).

Kab. Sigi, Kec. Nokilalaki, 4.3 km SSW of Tongoa, NW flank of Mt Nokilalaki, ca. 500 m SSE of Shelter 2, tree-inventory plot Nokilalaki 1, 1°14.7'S, 120°09.2'E, 1900 m, Aug 2007: *Culmsee 2636* (sterile; CEB, L!) & *2641* (sterile; BO [BO-1938462]!, CEB, GOET [GOET020007]!) & *2721* (sterile; CEB, K [K000993487]!).

Kab. Tojo Una-una, Kec. Ulubongka, N slope of Mt Katopas, 1°9.8'S, 121°26.9'E, 1100 m, 4 Sep 2014: Sight record by F Brambach (photograph Figure 1f).

West Sulawesi (Sulawesi Barat): Kab. Mamasa. Kec. Mamasa, near Osango c. 2°56'S, 119°19'E ("Celebes en Ond. Boven Binoeang, ca. Osango"), c. 1500 m, 1 Jul 1939: *Netherland's Indies Forest Service (NIFS) bb 28293* (sterile; L [L.2529832]!).

South Sulawesi (Sulawesi Selatan): Kab. Luwu, Kec. Ponrang, near Kampung Tampa, c. 3°11'S, 120°13'E ("Celebes en Ond. Palopo, Bakka, Kampoenng Tampa"), c. 100 m, 15 Sep 1941: *NIFS bb 33081* (flowers; L [L.2535805]!).

Kab. Luwu Timur: Kec. Malili, Ussu, c. 2°36'S, 121°06'E ("Selebes, Malili, Oe-soe): c. 300 m, 13 Jul 1931: *NIFS Cel./III-385* (flower buds; L [L.2535679]!); *ibid.* loco, c. 400 m, 19 Jun 1934: *NIFS Cel./III-293* (sterile; L [L.2517541]!); *ibid.* loco, 100 m, 28 Mar 1941: *NIFS bb 32595* (sterile; BO [BO-1304600], L [L.2517463]!).

Kab. Luwu Timur, Kec. Wasuponda, Larona, c. 2°45'S, 121°20'E, 500–1000 m ("Celebes. Goud. Celebes, Ond. afd. Malili, nabij La Rona"), n.d.: *NIFS bb 1843* (sterile; L [L.2535842]!) & *bb 1895* (sterile; L [L.2535843]!).

Kab. Luwu Timur, Kec. Nuha, Hills W of Soroako, c. 2°31'S, 121°19'E, 550 m, 17 Jun 1979: *van Balgooy MMJ 3767* (old inflorescences; L [L.2535910]! [wood sample L 0708626]).

2. *Syzygium contiguum* Brambach, Byng & Culmsee, sp. nov.

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Figures 3, 4, 8

"Myrtaceae sp. 9" (Culmsee and Pitopang 2009).

Diagnosis. *Syzygium contiguum* is a species of treelets with slender, angular young branchlets and (sub-)sessile, chartaceous leaves with few (8–13), distinct secondary veins, two marginal veins, and conspicuous cordate bases; the basal lobes of opposed leaves often reach each other. The dense or lax panicle inflorescences are terminal or arise from the upper leaf axils and bear small (5–6 × 3–4 mm in mature buds) pyriform flowers with numerous white stamens. The species is similar to *Syzygium urdanetense* (Elmer) Merrill (1951, 420) from the Philippines but differs from that species by angular (vs usually terete) young branchlets and inflorescence axes, by smaller (usually 9–14 × 3.5–5 vs 18–35 × 6–11 cm), chartaceous (vs coriaceous) leaves with shorter (0–1.5 vs 3–5 mm) petioles and fewer secondary vein pairs (8–13 vs 17–35), and by gland-dotted (vs smooth) petals. It differs from *Syzygium paucipunctatum* (Koord. and Valetton) Merrill and Perry (1939, 169) from Sumatra, Java, and Borneo, in chartaceous (vs coriaceous), leaves with no or few gland dots (vs gland-dotted beneath) which dry dark reddish brown to very dusky red above and (dark) reddish brown beneath (vs. olive-green above and brownish beneath) and shorter (5–6 vs c. 9 mm long) mature flower buds. Floral formula $B1 \ Bt2 \ K4^* \ C4^* \ A\infty^* \ \hat{G}(2) \ + \ Vx-8$.

Type. INDONESIA. Central Sulawesi (Sulawesi Tengah), LLNP, Kab. Sigi, Kec. Kulawi, 2.4 km ENE of Toro, NW of Pono Valley, tree-inventory plot Pono, 1°29.7'S, 120°03.4'E, 1050 m, Jul 2006: *Culmsee H 535* (flowers; holotype L[L.3962133]!, isotype CEB).

Description. **Treelets**, up to 10 m tall, diameter at breast height ≤ 11 cm. **Bark** and wood not known. Young **branchlets** 0.5–1 × 1–2 mm, slender, rectangular in

cross section, sometimes narrowly winged, epidermis drying dark reddish brown, smooth; soon becoming terete with 4 ridges and eventually terete, bark pale or yellowish brown with flaking remnants of epidermis; with (1–) 2 (–4) pairs of ≤ 2 mm long, caducous cataphylls near the base of the current flush.

Leaves opposite, (sub-)sessile. Petioles 0–1.5 \times 1–2 mm, absent or very short and stout, drying very dusky red. Blades (6.5–) 9–14 (–19) \times (2.3–) 3.5–5 (–6.1) cm, ratio (1.9–) 2.5–3.2 (–3.6), narrowly elliptic or lanceolate, rarely oblanceolate, base distinctly cordate (or auriculate), basal lobes of opposed leaves often touching each other, apex (long-)acuminate or caudate, margin flat or sometimes minutely revolute; chartaceous, drying dull to satin, dark reddish brown to very dusky red above, (dark) reddish brown beneath; sometimes with scattered black gland dots. Midrib channelled above, prominent, rounded, and darker than the lamina beneath. Secondary vein pairs 8–12, (3–) 5–11 (–18) mm apart, slightly sunken or sometimes slightly prominent, rather inconspicuous above, very prominent and darker than the lamina beneath; some intersecondary veins usually present. Tertiary veins sub-parallel near the midrib to reticulate towards the margin, faint above, prominulous beneath. Inner intramarginal vein 3–7 mm from leaf margin, hardly looping; outer intramarginal vein 0.5–2 mm from leaf margin.

Inflorescences terminal and in the axils of 1–2 distal leaf-pairs, \pm lax panicles, (2.5–) 3.5–7.5 (–11) cm long, peduncles 1–3.5 cm long, axes (sub-)angular, flattened. Bracts c. 0.5–2 (–7) mm long, lowermost foliaceous, caducous, others deltate, keeled, \pm persistent; bracteoles 2 per flower, 0.5–1 mm long, similar to bracts.

Flowers ≤ 40 per inflorescence, within the panicles in monads or triads, 4-merous, anthopodium absent, c. 15 mm in diameter at anthesis, mature buds 5–6 \times 3–4 mm. Hypanthium 4–5 \times 3–5.5 mm, obconical to infundibuliform, gland-dotted or \pm smooth, hypanthium rim 2 mm long. Calyx lobes 0.5–1 \times 1–2.5 mm, deltate first, becoming broadly rounded and eventually splitting irregularly at anthesis. Petals 3–6 \times 3–6 mm, pseudocalyptrate, orbicular, gland-dotted. Stamens c. 80–100, filaments 6–10 mm long, white, anthers c. 0.5 mm long, ellipsoid. Ovary bilocular, locules subtended by spongy tissue, ovules c. 8 per locule, spreading. Style 6–8 mm long, pointed.

Fruits 2-seeded, 1.1–1.3 \times 1.8–1.9 cm, globose to oblate, drying smooth, pericarp c. 2 mm thick, hypanthium rim c. 5 mm in diameter.

Seeds 9–10 \times 12–13 mm, half-moon shaped.

Etymology. The specific epithet refers to the leaf bases of opposing leaves which, due to their cordate shape and the short petioles, often approach or touch each other.

Phenology. In Central Sulawesi a slight dry season usually lasts from May to September or October. Flowering was observed during the wet and dry seasons: in July 2016, January/February 2007, July 2007 in Pono and in April 1975 on Mt Nokilalaki.

Distribution and habitat. According to our present knowledge, the species is endemic to the province of Central Sulawesi. It has been recorded from only three localities in and around LLNP at 1000–1150 m elevation (Figure 4). Most of the specimens were collected in our (FB and HC) inventory plot in Pono Valley near the western border of LLNP.

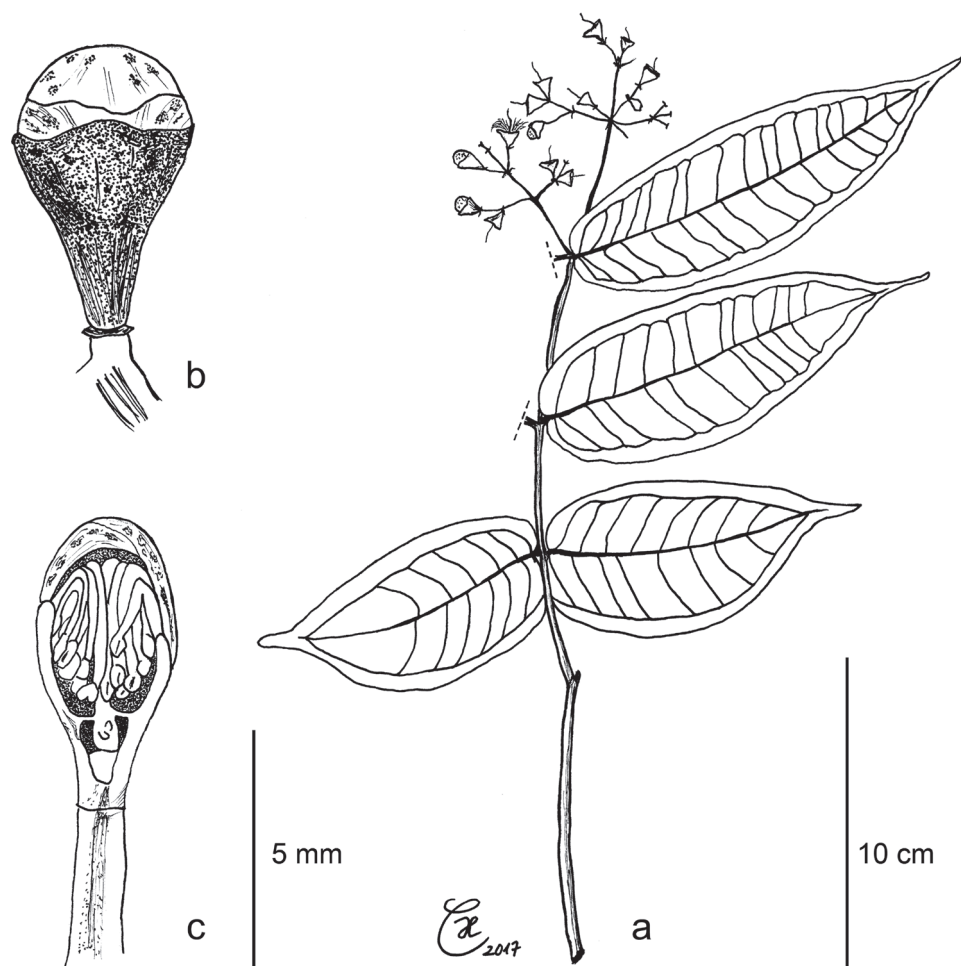


Figure 3. *Syzygium contiguum*: **a** leafy twig with flowers in different developmental stages **b** flower bud with gland-dotted petals and shallow calyx lobes **c** flower bud, longitudinal section. All from holotype Culmsee 535.

In the Pono inventory plot, the species was found in undisturbed submontane rainforest on flat terraces with Sideralic Cambisols (IUSS Working Group WRB 2014) developed from metamorphic rocks. The forest at Pono was dominated by Fagaceae, Lauraceae, Sapotaceae, Moraceae, and Rubiaceae species (families with top five FIV) and contained seven other species of *Syzygium*: *S. acuminatissimum* (Blume) de Candolle (1828, 261), *S. balgooyi*, *S. galanthum*, *S. lineatum* (DC.) Merrill and Perry (1938a, 109), *S. phaeostictum* Merrill and Perry (1942, 270), and two undetermined species (Brambach et al. in press). See Culmsee and Pitopang (2009) for more information on the floristics of the Pono valley plot. The collection locality of *Widjaja EAW 3502* in the almost entirely deforested Napu valley suggests remnant riparian forest as habitat.

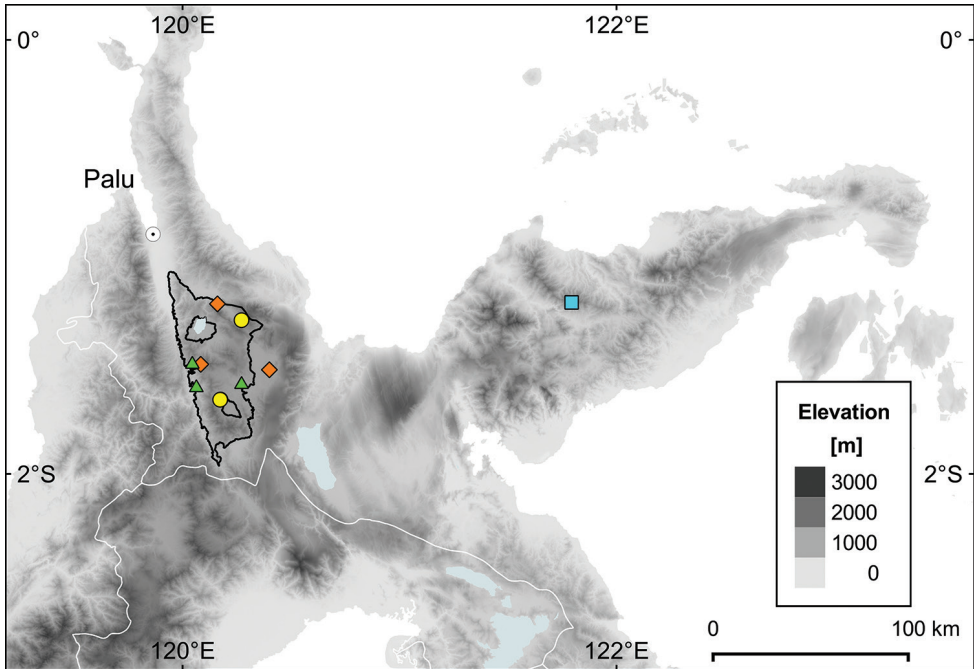


Figure 4. Distribution map of four species of *Syzygium* in Central Sulawesi: *Syzygium contiguum* (orange diamonds), *S. devogelii* (yellow dots), *S. eymae* (light blue square), and *S. galanthum* (green triangles). Lore Lindu National Park is indicated by a black line. Map created with QGIS (QGIS Development Team 2016) using the digital elevation model of Jarvis et al. (2008).

Conservation status. *Syzygium contiguum* has a limited geographical distribution (estimated EOO 557 km²) and seems to be restricted to submontane forest within a narrow elevational belt. We assume that the estimated AOO of 12 km² is unrealistically low, due to limited collection activities in Central Sulawesi. However, only the collection locality of *Meijer 9572* seems to be covered by intact forest habitat. The other two localities are small forest fragments (*Widjaja EAW 3502*) and forest with recent deforestation activities in close proximity (Pono inventory plots, detected using the Global Forest Change website, Hansen et al. 2013), possibly related to the establishment of cocoa plantations (Aiyen Tjoa, Tadulako University, personal communication, June 2015). Given the apparent narrow geographical and elevational distribution and the recommendation to use a precautionary attitude in conservation assessments (IUCN Standards and Petitions Subcommittee 2014) we propose a preliminary extinction risk assessment of “Endangered” (EN B1ab(i,ii,iii)).

Notes. *Syzygium urdanetense* (as *Eugenia urdanetensis*, Elmer 1914, 2356), the species most similar to *S. contiguum*, was originally described from Mt Masay (previously Mt Urdaneta) on the southern Philippine island of Mindanao and is widespread throughout the Philippines (Merrill 1951, Pelsner et al. 2011). The species is variable in vegetative characters such as leaf size, leaf base (usually rounded and only the very

base cordate, but sometimes distinctly cordate) and branchlet shape (usually terete, but rarely subangular). In addition to the characters mentioned in the diagnosis, there are differences in the tertiary venation, the veins being \pm ladder-like and perpendicular to the midrib in *S. urdanetense* whereas in *S. contiguum* they are \pm parallel to the secondary veins near the midrib and become reticulate towards the leaf margin (Figure 8f). While with the available material, *S. contiguum* can be clearly distinguished from *S. urdanetense* on morphological grounds, we do not discard the possibility that future collections, especially from the northern peninsula of Sulawesi, will uncover populations with intermediate characters. If so, *S. contiguum* may eventually have to be sunk into an expanded *S. urdanetense*. In light of the almost complete lack of taxonomic resolution for *Syzygium* in Sulawesi, we nevertheless consider it advisable to propose *S. contiguum* as a distinct species.

Two fruiting specimens collected at low elevations (200–300 m) on Sulawesi's Southeast Peninsula, *Prawiroatmodjo & Maskuri 1231* [L.2517450] and *1957* [L.2517547], are morphologically similar to *S. contiguum* as defined above except for the leaf tips which are not long-acuminate. In the absence of flowering material, and because of the different habitat and distribution, we prefer not to include them here at present, but future additional collections may prove otherwise.

We choose *Culmsee 535* as type specimen because it contains flowers in all stages of maturity although unfortunately, it was collected with only two duplicates (in CEB and L). Nevertheless, the more widely distributed paratypes collected by HC at the type locality all belong to the same population as the type.

Additional specimens examined (Paratypes). INDONESIA. **Central Sulawesi (Sulawesi Tengah), LLNP:** Kab. Poso, Kec. Nokilalaki, N slopes of Mt Nokilalaki. ("Celebes, central part, area of Mt. Nokilalaki, Loro Kalimata Reserve"), 1°13'S, 120°08'E, \pm 1000 m, 24 Apr 1975: *Meijer 9572* (flowers; L [L.2535817]!, US [US-2995269] photo!).

Kab. Poso, Kec. Lore Peore, Road to Napu from camp Dongi-dongi, 1°31.2'S, 120°22.4'E, 1127 m, 26 Dec 1988: *Widjaja EA EAW 3502* (fruits; BO [BO-1917489]! [BO-1917490]!, K! , L).

Kab. Sigi, Kec. Kulawi, 2.4 km ENE of Toro, NW of Pono Valley, tree-inventory plot Pono, 1°29.7'S, 120°03.4'E, 1050 m, Jul 2006: *Culmsee H 284* (flowers; GOET [GOET020010]!).

Kab. Sigi, Kec. Kulawi, 2.4 km ENE of Toro, NW of Pono Valley, tree-inventory plot "Pono", 1°29.7'S, 120°03.4'E, 1050 m, Jan 2007: *Culmsee H y410* (flower buds; BO [BO-1938450]! [BO-1938451]!, CEB, GOET [GOET020012]!, K [K000993488]!, L!); *ibid.* loco, Jul 2007: *Culmsee H r463* (flower buds; BO [BO-1938464]!, CEB, GOET [GOET020011]!, K [K000993489]!, L!) & *y503* (flower buds; CEB, GOET [GOET020013]!) & *y514* (flower buds; BO [BO-1938452]!, CEB) & *y581* (flower buds; CEB, L!) & *y582* (flower buds; CEB, K [K000993490]!) & *y592* (flower buds; BO [BO-1938453]! [BO-1938454]!, CEB) & *y595* (flower buds; CEB, GOET [GOET020014]!, L!).

3. *Syzygium devogelii* Brambach, Byng & Culmsee, sp. nov.

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Figures 4, 5, 8

„Myrtaceae sp. 10“ p.p. (Culmsee and Pitopang 2009, see also 2017 (Erratum)).

Diagnosis. *Syzygium devogelii* is a species of treelets characterised by slender, narrowly winged young branchlets, medium-sized narrowly elliptic leaves, straight and distinct secondary veins connected by an intramarginal vein impressed above and prominent beneath, small flowers (5 × 3 mm in bud) in terminal inflorescences that develop into rather large fruits (c. 20 × 25 mm), mature seeds lacking a testa, and cotyledons with echinate outer surfaces. The species is morphologically similar to *Syzygium perspicuinerivium* (Merr.) Masamune (1942, 537) but differs from that species in smaller leaves with fewer secondary veins and in flowers with distinct calyx lobes (vs calyx calyptrate). It is furthermore similar to *Syzygium valdevenosum* (Duthie) Merrill and Perry (1939, 182) but differs in lateral veins which are impressed above (vs prominent), much smaller inflorescences, and smaller, obconical (vs infundibuliform) flowers. Floral formula $B1\ Bt2\ K4^*\ C4^*\ A_{\infty}^*\ \hat{G}(2)+\ V_{\infty}$.

Type. INDONESIA. Central Sulawesi (Sulawesi Tengah), LLNP, Kab. Poso, Kec. Lore Utara, west slope of Mt Rorekautimbu, c. 1°17.5'S 120°16.3'E, 1350 m, 11 May 1979: *de Vogel EF 5293* (fruits; holotype L [L.2535665]! [L.2535666]!; isotype K!).

Description. **Trees**, up to 13 m tall, diameter at breast height ≤ 13 cm, trunk ≤ 7 m tall. Outer **bark** whitish to brown, mealy or peeling off in thin sheets, inner bark pale or dark red, wood cream-coloured. Young **branchlets** 1–2.5 × 2–3 mm, ± flattened, angular or oblong in cross section with 4 narrow wings, epidermis dark red when young, drying reddish or yellowish brown, smooth; becoming rounded with 4 ridges, bark (yellowish) brown, peeling off in thin sheets.

Leaves (sub-)opposite. Petioles 7–16 × 1–3 mm, channelled above, rounded beneath, epidermis drying smooth or with transverse cracks. Blades (12.5–) 14–19 (–22.5) × (4–) 4.5–7 (–8.5) cm, ratio (2.1–) 2.6–3.3 (–4), narrowly elliptic (or lanceolate), base cuneate or obtuse, apex acuminate, margin revolute; chartaceous or coriaceous, red or pink when young, above, beneath, drying dull to satin, variable in colour from greyish brown and olive grey to very dusky red above, dull to satin and, dark reddish brown beneath; pellucid dots rather few, visible or not on both sides. Midrib channelled above, very prominent, rounded, smooth and drying darker than the lamina beneath. Secondary vein pairs (9–) 11–14 (–17), 5–22 mm apart, channelled or impressed above, prominent and drying darker than the lamina beneath, straight or slightly arching from the midrib; intersecondary veins sometimes present. Tertiary veins dense, ± ladder-like and perpendicular to the midrib, faint above, prominent beneath. Inner intramarginal vein 2–9 mm from leaf margin, looping or not and prominent; outer intramarginal vein 0.5–1.5 mm from leaf margin, as prominent as tertiary venation.

Inflorescences terminal, dense metabotryoids, 2.5 cm long, peduncles 1 cm long, axes flattened, with 2 or 4 narrow wings, drying brown. Bracts c. 1.5 mm long, ovate, keeled, caducous; bracteoles 2 per flower, 1 mm long, similar to bracts.

Flowers c. 15 per inflorescence, within the inflorescence in triads, 4-merous, antheropodium absent, only known before anthesis, mature buds 5×3 mm. Hypanthium c. 4×3 mm, obconical, drying dark reddish brown, densely glandular-warty, hypanthium rim 2 mm long, glandular inside. Calyx lobes c. 1×2 mm, broadly rounded. Petals c. 3×3 mm, cucullate in bud. Stamens c. 100, filaments 2–3 mm long, anthers c. 0.4 mm long, ellipsoid. Ovary bilocular, surrounded by spongy tissue, ovules numerous per locule, ascending. Style 3–4 mm long, pointed.

Fruits 1-seeded, c. 20×25 mm, irregularly depressed globose, laterally compressed, green, drying black and, smooth, pericarp \pm woody, 1 mm thick, hypanthium rim 1–2 mm long, 5–9 mm in diameter.

Seeds c. 15×20 mm, transverse ellipsoid, testa adhering to the pericarp, spongy inside and adhering to the outer surface of the cotyledons, cotyledons \pm half-globose, facing surfaces undulate, outer surfaces densely echinate, protuberances obscured by spongy testa tissue.

Etymology. The species is named after Eduard Ferdinand de Vogel (*1942). Ed de Vogel is a renowned authority on Malesian orchids, especially those from New Guinea. His contributions to the flora of Sulawesi are perhaps less well known: with almost 2000 specimens of excellent quality collected there in 1973–74 and 1979 – among them the type specimen of this species – he was one of the most prolific plant collectors on the island during the 20th century.

Phenology. Flowering was recorded in August, fruiting in May.

Distribution and habitat. *Syzygium devogelii* is endemic to the province of Central Sulawesi, currently known to occur in lower montane forest at two localities in LLNP from 1350–1400 m elevation (Figure 4). In the Bariri NE inventory plot, it was fairly common, growing on mid-slope terraces with Rhodic Ferralsols (IUSS Working Group WRB 2014) derived from acid plutonic rocks. The forest there was dominated by Fagaceae, Myrtaceae, Burseraceae, Lauraceae, and Elaeocarpaceae (families with top five FIV) and contained six other species of *Syzygium*: *S. acuminatissimum*, *S. aff. baeuerlenii* (F.Muell.) Craven and Biffin (in Craven et al. 2006, 135), *S. lineatum*, *S. zeylanicum* (L.) de Candolle (1828, 260), and two undetermined species (Brambach et al. in press). See Culmsee and Pitopang (2009) for more information on the floristics of the Bariri forest.

Conservation status. *Syzygium devogelii* has a limited geographical distribution and seems to be restricted to lower montane forest within a narrow elevational belt. Known from only two localities, the EOO and AOO cannot be estimated reliably for the species. Because of the low collection density in Central Sulawesi, we believe that the species is more widespread and common than it currently appears. Deforestation has been recorded close to the type locality (using the Global Forest Change website, Hansen et al. 2013). Given the apparent narrow geographical and elevational distribution, ongoing deforestation and the recommendation to use a precautionary attitude

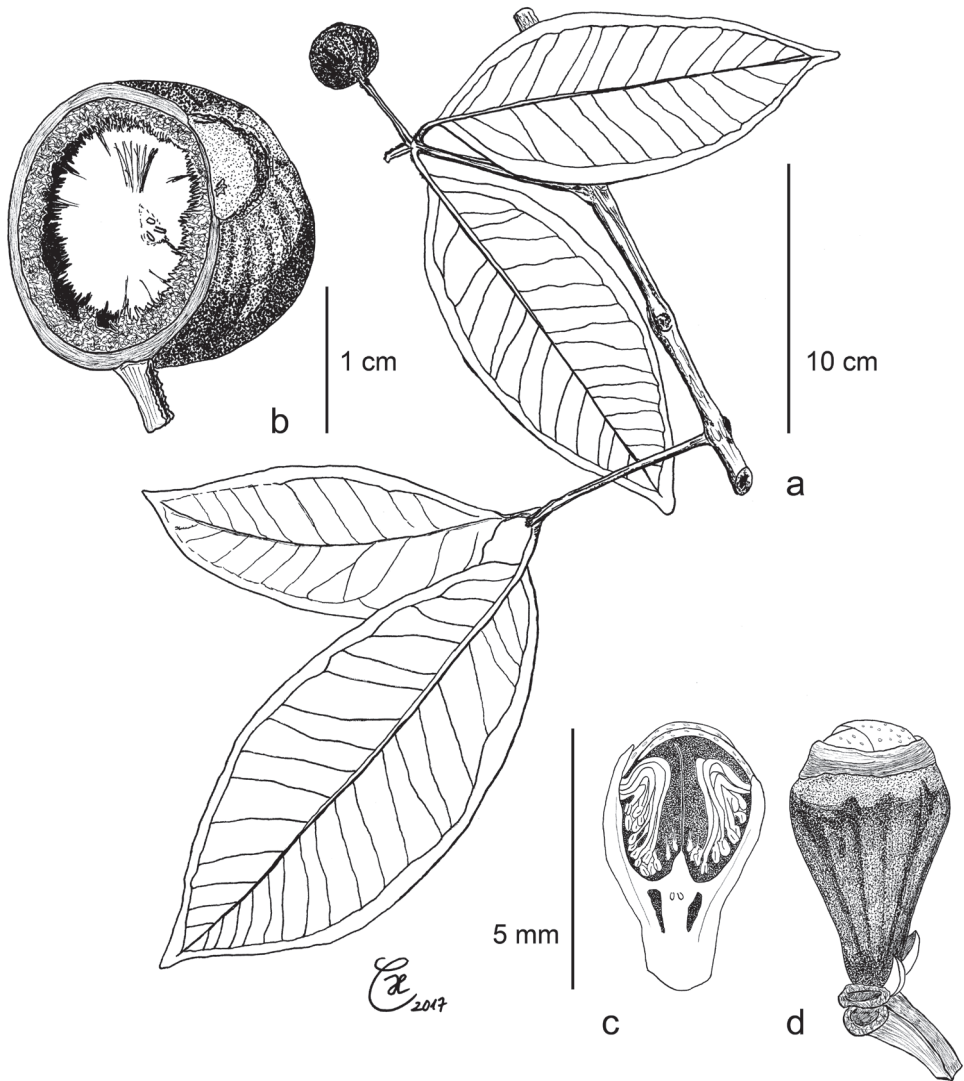


Figure 5. *Syzygium devogelii*: **a** leafy twig with fruit **b** longitudinal section of ripe fruit with inner, flat side of cotyledon and echinate outer surface **c** flower bud, longitudinal section **d** flower bud, exterior view. **a–b** holotype de Vogel 5293 **c–d** Culmsee 1564.

in conservation assessments (IUCN Standards and Petitions Subcommittee 2014) we propose a preliminary extinction risk assessment of “Endangered” (EN B1ab(i,ii,iii)).

Notes. Most species of *Syzygium* are reported to have cotyledons with rather smooth outer surfaces, unlike the peculiar echinate cotyledons of *S. devogelii*. We here interpret the tissue covering the outer surface of the cotyledons (Figure 5) and obscuring its protuberances as derived from the testa, as reported for the Australian species *Syzygium bungadinnia* (F.M.Bailey) Hyland (1983, 64), but closer examinations of fruit and seed structures are necessary to corroborate this interpretation.

Juvenile specimens of *Syzygium balgooyi* are similar to *S. devogelii* in their leaf shape, colour, and venation. In fact, both species were treated as one morphotype in Culmsee and Pitopang (2009, 2017). Besides the very different flowers, they can, however, be distinguished by the shape of the young branchlets: strongly flattened and with rounded ridges in *S. balgooyi* (Figure 1e) vs \pm flattened with 4 narrow wings in *S. devogelii* (Figure 5).

Additional specimens examined (Paratypes). INDONESIA. Central Sulawesi (Sulawesi Tengah), LLNP, Kab. Poso, Kec. Lore Tengah: 9 km NW of Bariri, 100 m east of climate tower, tree-inventory plot Bariri NE, 1°39.4'S, 120°10.5'E, 1400 m, 9 Sep 2006: *Culmsee H 1333* (sterile; BO [BO-1938455]!, CEB) & *1378* (sterile; CEB, K [K000993491]!); *ibid. loco*, 18 Aug 2011: *Brambach F, Mangopo H, Firdaus, Faber M, Tiranda R 0818* (sterile; BO [BO-1938442]!, CEB, GOET [GOET020015]!) & *0845* (sterile; BO [BO-1938443]!, CEB, L!).

9 km NW of Bariri, 80 m south of climate tower, tree-inventory plot Bariri S, 1°39.5'S, 120°10.4'E, 1400 m, Jul 2006: *Culmsee H 1252* (sterile; CEB, GOET [GOET020016]!) & *1564* (flower buds; CEB, L!).

4. *Syzygium eymae* Brambach, Byng & Culmsee, sp. nov.

urn:lsid:ipni.org:names:60474724-2

Figures 4, 6, 8

Diagnosis. *Syzygium eymae* is characterised by small (usually $2.3\text{--}4 \times 1.5\text{--}2.5$ cm), (sub-) sessile, leaves with thickly coriaceous, (broadly) elliptic or obovate blades, dense terminal inflorescences, and small, pyriform flowers with a calyptrate calyx that bears a minute apical opening and splits irregularly at anthesis. It differs from the morphologically similar *Syzygium paradoxum* (Merr.) Masamune (1942, 536) in angular young branchlets (vs terete), leaves without conspicuous gland dots (vs leaves conspicuously gland-dotted beneath), fewer pairs of secondary veins (5–7 vs 10–14), and smaller (5–6 \times 3 vs c. 12 \times 5 mm in mature buds), pyriform flowers without anthopodia (vs infundibuliform with anthopodia 5–7 mm long). Floral formula $B1\ Bt2\ (K4?^* C4?^*)\ A_{\infty}^* \hat{G}(2) \nmid Vx?$.

Type. INDONESIA. Central Sulawesi (Sulawesi Tengah), Kab. Tojo Una-Una, Border of Kec. Ulubongka and Kec. Ampana Tete, Mt Lumut, between summit and western secondary peak, c. 1°12.3'S, 121°47.6'E, \pm 2200 m ("Selebes, Res. Menado. O.afd. Poso. G. Lóemoet, Pilaartop en W. bijtop. (summit)"), 5 Sep 1938: *Eyma 3624* (flowers; holotype U [U.1439024]!; isotypes: BO [BO-1679767]!, L [L.2535689]!).

Description. **Trees**, height, **bark** and wood unknown. Young **branchlets** slender, 0.5–1 \times 1–2 mm, rectangular in cross section, ridges arising at the petioles and running downwards to next node, epidermis drying reddish black; remaining angular or becoming \pm terete, bark reddish brown and scaly; with 1–2 pairs of minute cataphylls near the base of the current flush.

Leaves opposite, (sub-)sessile. Petioles 0.5–2 \times 1–1.5 mm, absent or very short and stout, drying black. Blades (1.8–) 2.3–4 (–5.2) \times (1.2–) 1.5–2.5 (–3.1) cm, ratio

1.3–2, (broadly) elliptic or (broadly) obovate, base obtuse or rounded, apex rounded, acute, or shortly acuminate, margin revolute; thickly coriaceous (c. 0.3 mm thick), dull, drying dark reddish grey to reddish black above, (very) dusky red beneath; without black gland dots. Midrib impressed above, prominent, rounded, and darker than the lamina beneath. Secondary vein pairs (4–) 5–7, 3–10 mm apart, channelled and inconspicuous above, (slightly) prominent and more reddish than the lamina beneath; intersecondary veins sometimes present. Tertiary veins reticulate, channelled above, indistinct beneath. Inner intramarginal vein 1–2 mm from leaf margin, looping; outer intramarginal vein not present.

Inflorescences terminal, 2-nodate metabotryoids, ≤ 3 cm long, peduncles ≤ 1 cm long, axes angular. Bracts c. 1–1.5 mm long, deltate, keeled, caducous; bracteoles 2 per flower, c. 1 mm long, similar to bracts.

Flowers ≤ 10 per inflorescence, within the inflorescence in triads, anthopodium absent, mature buds $5\text{--}6 \times 3$ mm. Hypanthium $4\text{--}5 \times 4\text{--}5$ mm, pyriform, smooth, hypanthium rim 1.5 mm long. Calyx lobes calyptrate with small apical opening, slightly lighter-coloured than hypanthium when dry, splitting irregularly at anthesis, caducous. Petals calyptrate, adhering to the calyx. Stamens c. 50, filaments 6–7 mm long, white, anthers c. 0.4 mm long, ellipsoid. Ovary bilocular, ovules several per locule, ascending. Style 6–7 mm long, pointed.

Fruits and seeds unknown.

Etymology. The species is named after Pierre Joseph Eyma (1903–1945), one of the early botanists to explore the mountainous regions of Central Sulawesi (Eyma 1940, van Steenis-Kruseman and van Welzen 2014). Eyma collected many valuable specimens from high-elevation areas, including the type specimen of this species.

Phenology. The species was collected in flowering state in September 1938.

Distribution and habitat. *S. eymae* is endemic to the province of Central Sulawesi and currently only known from the type locality: Mt Lumut on Sulawesi's eastern peninsula (Figure 4). No information on habitat is given on the label of the type specimen. Mt Lumut is made up of ultramafic rocks (Geological Research and Development Centre 1993) and upper montane (cloud) forest would be the expected vegetation type there at 2200 m.

Conservation status. With only the type specimen known, we consider *S. eymae* “Data Deficient” (DD) at present, following the IUCN Red List Categories and Criteria (IUCN 2012).

Notes. The species of tribe *Syzygieae* Wilson (in Wilson et al. 2005, 15) bearing a calyptrate calyx have mostly been treated under the genus *Cleistocalyx* Blume (1850, 84, see Merrill and Perry 1937). The calyptrate calyx is a relatively rare character, currently known to occur in only about 30 of the > 1200 species of *Syzygieae* (Merrill and Perry 1937, Chantaranothai and Parnell 1993, Takeuchi 2002, Biffin et al. 2005, Craven and Biffin 2010). Its occurrence, however, is widely spread over the phylogenetic tree of the tribe; so *Cleistocalyx* is not monophyletic and has therefore been synonymised under an expanded *Syzygium* (Craven et al. 2006, Craven and Biffin 2010).

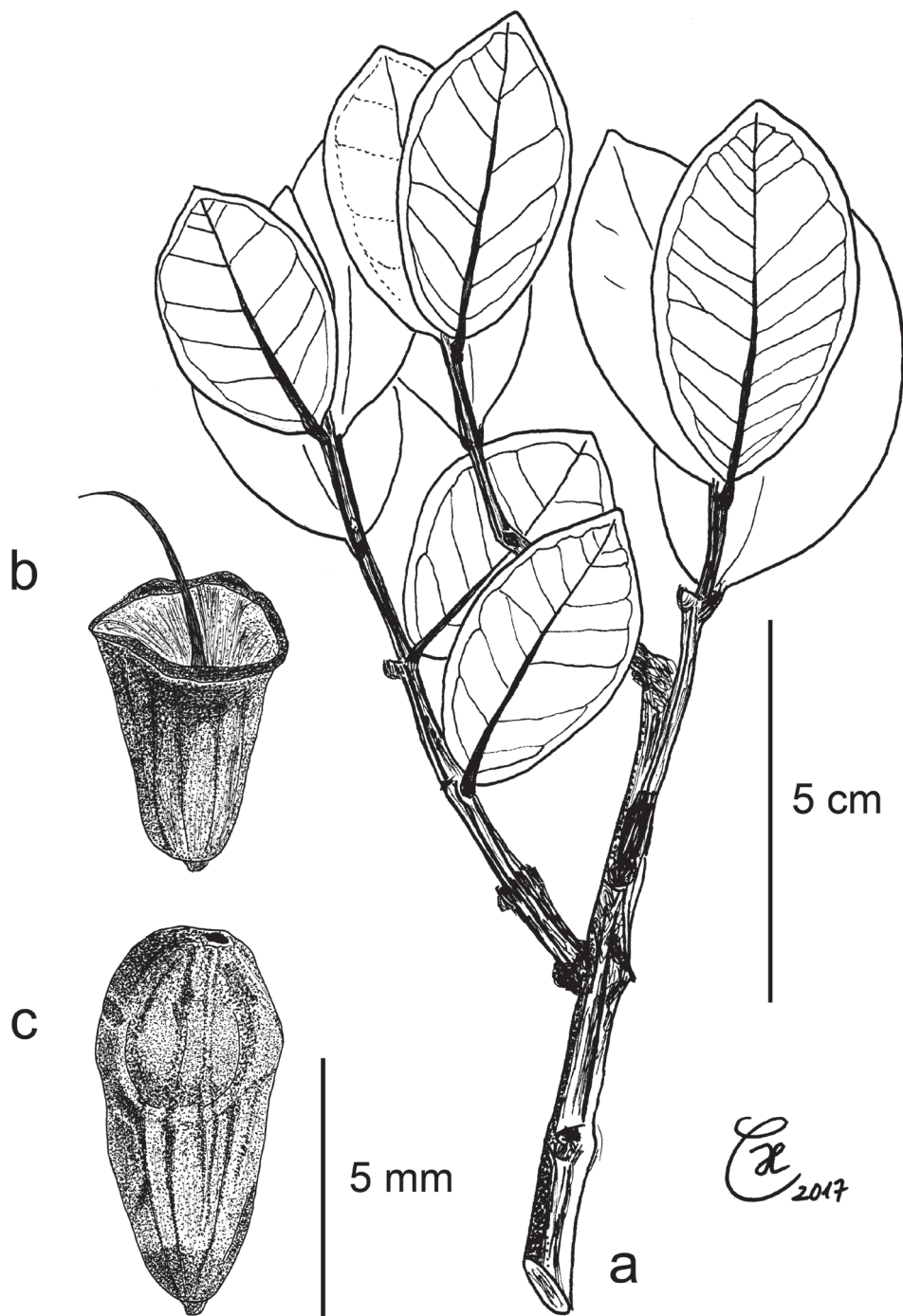


Figure 6. *Syzygium eymae*: **a** leafy twig **b** flower after shedding of calyx and stamens **c** closed pyriform flower, calyptrate calyx with minute apical opening. All drawings from isotype (L) *Eyma* 3624.

The flowers of *Cleistocalyx* are described as having “calyptrate calyces, the undivided, often more or less indurated upper parts of which fall as a lid”, the lid often remaining attached at one side of the flower at early anthesis (Merrill and Perry 1937). In *S. eymae*, the calyx clearly has the form of a calyptra, but at anthesis it splits irregularly into four or five parts, starting with a minute (< 0.5 mm diam.) apical opening (Figure 6). One or several of the irregular segments may remain attached to the hypanthium rim shortly after anthesis before eventually being shed. The mode of dehiscence of the calyx thus seems to represent an intermediate condition between *Cleistocalyx* and classical *Syzygium*, similar to the situation in *Syzygium apodophyllum* (F.Muell.) Hyland (1983, 49) from Queensland, Australia.

Most species of *Syzygium* with calyptrate calyces are clearly different from *S. eymae* in their much larger leaves with more pairs of secondary veins. The few small-leaved species can all be easily distinguished: *S. paradoxum* from Borneo differs by the characters given in the diagnosis. *S. pseudocalcicola* Craven & Biffin (in Craven et al. 2006, 139) from the Philippines and *S. canicortex* Hyland (1983, 66) from Queensland have many, closely parallel secondary veins and caudate leaf apices, *S. apodophyllum* has ovate leaves with a long-acuminate apex and clavate flowers.

Syzygium eymae is also superficially similar *S. paucivenium* (Merr.) Merrill (1951, 408) from Taiwan and the Philippines, but can easily be distinguished from that species by the leaves with channeled, inconspicuous secondary veins on the upper surface (vs. prominent and distinct), smaller inflorescences (<10 vs 20–30 flowers), smaller flowers (mature buds 5–6 vs. 9 mm long), and the presence of the calyptrate calyx (vs. truncate to shallowly lobed).

Several specimens collected on Mt Rorekautimbu in LLNP at 2400 m (e.g. *Brambach et al.* 0768) may belong here. They are morphologically similar to the type specimen, but have longer petioles. Since we currently lack flowering material of these specimens and because of the large distance between the respective collection localities, we prefer to await more specimens before incorporating these collections in *S. eymae*.

5. *Syzygium galanthum* Brambach, Byng & Culmsee, sp. nov.

urn:lsid:ipni.org:names:60474725-2

Figures 4, 7, 8

“Myrtaceae sp. 7” (Culmsee and Pitopang 2009)

Diagnosis. *Syzygium galanthum* is similar to *Syzygium hylochare* (Diels) Merrill and Perry (1942, 249) from New Guinea but differs from that species in larger leaves (usually 15–22 vs 8–14 cm long), more slender flowers with longer anthopodia (5–10 vs 3–5 mm) and milky white petals (vs pink or red). It is also similar to the widely cultivated *Syzygium malaccense* (L.) Merrill & Perry (1938b, 215) but has subangular (vs clearly angular) and more slender branchlets (2–3 vs 6–8 mm in diameter), smaller, chartaceous leaves (vs coriaceous), more slender inflorescences, more slender flowers with

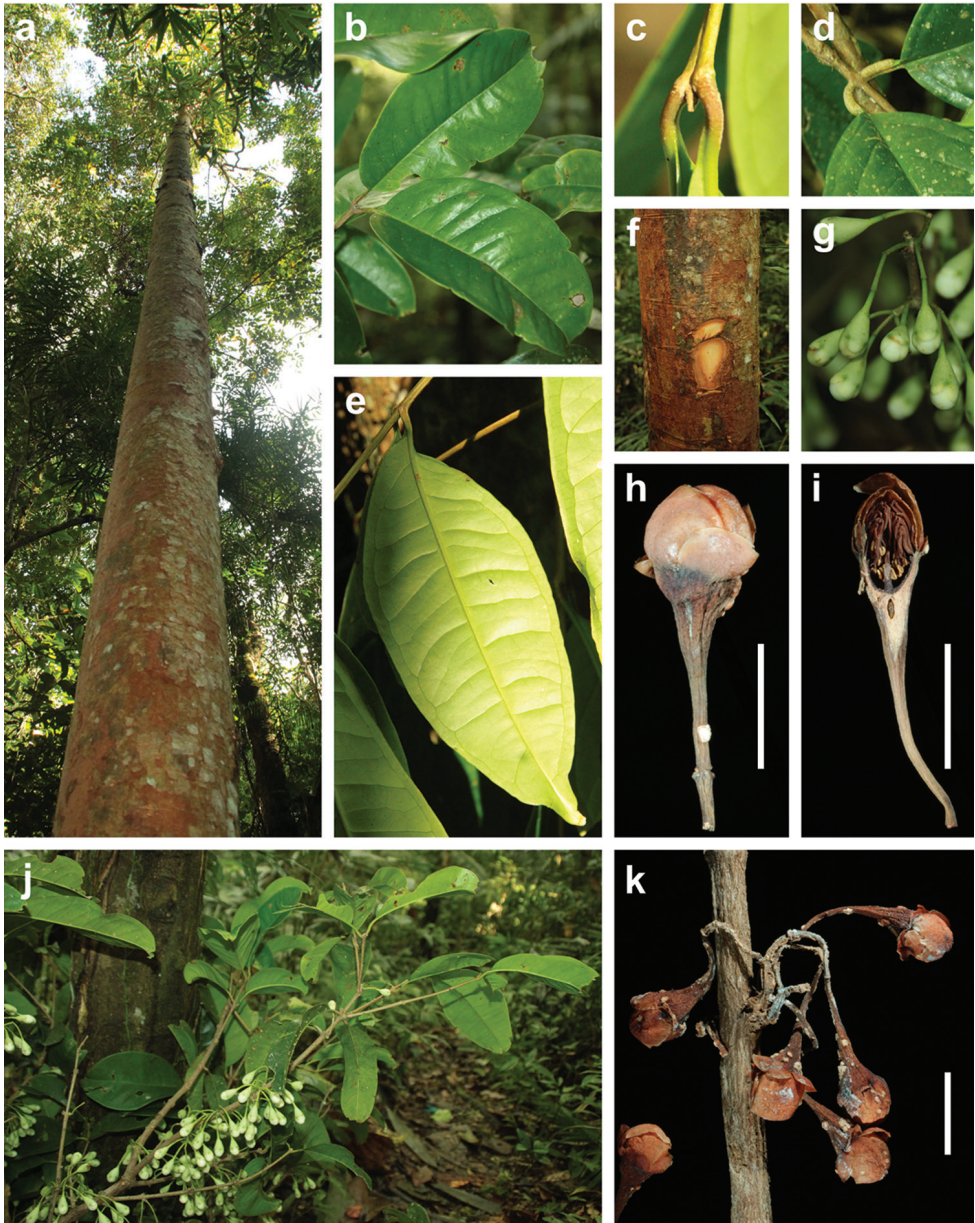


Figure 7. Morphological characters of *Syzygium galanthum*. **a** trunk, c. 15 m tall **b** upper side of leaves **c** branchlet tip with smooth younger petioles **d** older corky petioles **e** underside of leaf **f** bark slash **g** mature flower buds in fresh state **h** dried mature flower bud with apical part of inflorescence axis and white blister on the anthopodium **i** longitudinal section of mature flower bud in dried state **j** branch with mature flower buds below the leaves **k** detail of dried, fascicled inflorescences. **a–b** and **f–k** type collection Brambach et al. 1316 **c** and **e** Brambach et al. 1083 **d** Brambach et al. 1047. All scale bars: 1 cm.

longer anthopodia (5–10 mm vs 0–5 mm), hypanthia which dry reddish brown with many black glands (vs drying dark brown without conspicuous glands), and creamy-white petals (vs pink or red). Floral formula $B1 \ Bt2 \ K2:2 \ C4^* \ A_{\infty}^* \ \hat{G}(2) \ V_{\infty}$.

Type. INDONESIA. Central Sulawesi (Sulawesi Tengah): LLNP, Kab. Poso, Kec. Lore Tengah, 3.5 km NE of Rompo, following road to Katu for 3 km, then following footpath N for 2 km, tree-inventory plot Tarara, 1°35.3'S 120°17.0'E, 1200 m, 29 Nov 2011: *Brambach F, Mangopo H, Firdaus, Faber M, Tiranda R 1316* (flowers; holotype L[L.3962132]!; isotypes BO [BO-1938381]!, CEB, GOET [GOET020017]!, K [K000993484]!).

Description. **Trees**, up to 25 m tall, diameter at breast height ≤ 30 cm, trunk straight, ≤ 15 m tall, with buttresses 0.4 m tall, sometimes with stilt roots. Outer **bark** bright- or rusty red, peeling off in thin sheets, inner bark pale or dark red, wood straw or cream-coloured. Young **branchlets** 1–2 \times 2–3 mm, subangular, flattened, epidermis olive, drying reddish brown, striate; becoming \pm terete, bark (reddish) brown, striate or fissured, later peeling off in small thin sheets.

Leaves (sub-)opposite. Petioles 6–18 \times 1–3 mm, channelled above, rounded beneath, turning corky, pale brown, drying (reddish) brown. Blades (10–) 12–23 (–26) \times (4–) 5.5–7.5 (–9) cm, ratio (1.7–) 2.5–3.2 (–3.5), (narrowly) elliptic or rarely oblanceolate, base acute, obtuse, or rounded, apex acuminate, acumen often recurved, margin flat or revolute; chartaceous, glossy green and often \pm bullate above, paler green beneath, drying dull and (greyish or olive) brown above, dull and (yellowish or greyish) brown beneath; pellucid dots scattered or numerous, usually visible on lower surface and sometimes also on upper surface. Midrib channelled above, prominent, rounded, drying pale or reddish brown, striate and with dark gland dots beneath. Secondary vein pairs (6–) 8–10 (–12), 7–25 mm apart, prominulous or not, concolorous with the lamina and usually inconspicuous above, prominent and concolorous with or more reddish than the lamina beneath; intersecondary veins present. Tertiary veins reticulate, lax, prominulous or not, concolorous with the lamina and usually inconspicuous above, prominent and concolorous with or more reddish than the lamina beneath. Inner intramarginal vein 3–8 mm from leaf margin, (strongly) looping; outer intramarginal vein 1–3 mm from leaf margin.

Inflorescences axillary on leafless portion of the twigs, often fascicled, lax, (sub-) sessile botryoids or monads, 3–5 cm long, peduncles absent or ≤ 1 cm long, axes angular, drying (reddish) brown with many black gland dots, turning corky at the base, often with conspicuous whitish blisters. Bracts c. 0.5 mm long, early caducous; bracteoles 2 per flower, similar to bracts.

Flowers 1–8 per inflorescence, within the inflorescence in monads, 4-merous, only known before anthesis, mature buds 15–25 \times 5–7 mm, anthopodium 5–10 (–14) mm long, slender. Hypanthium 7–11 \times 5–7 mm, infundibuliform, pale green, drying dark reddish brown, wrinkled, densely black gland-dotted and with conspicuous whitish blisters, hypanthium rim 3 mm long. Calyx lobes 2 \times 3–5 (outer) and 3–4 \times 5–7 (inner) mm, broadly rounded with thin hyaline margins, greenish white, drying red, sparsely gland-dotted. Petals c. 8 \times 6 mm, hood shaped before anthesis, milky white, drying yellowish red, faintly veined and densely pellucid-dotted. Stamens c. 100, filaments

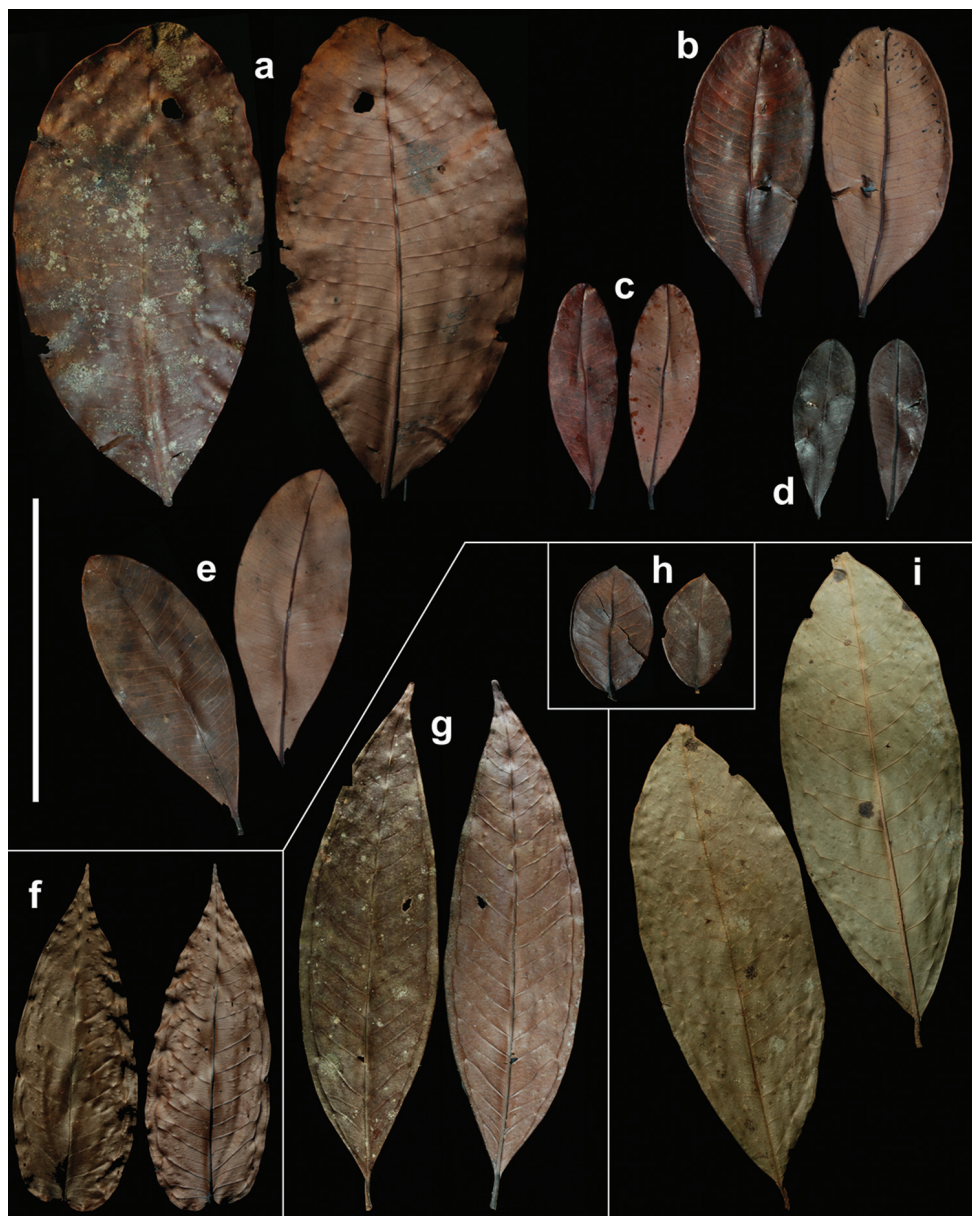


Figure 8. Leaves of all new species described. Variation of *Syzygium balgooyi* (a–e), *S. contiguum* (f), *S. devogelii* (g), *S. eymae* (h), and *S. galanthum* (i). **a** Brambach et al. 0283 **b** Brambach et al. 0681 **c** Brambach et al. 1333 **d** de Vogel 5413 [L.2517563] **e** Culmsee r2162 **f** Culmsee r463 **g** Brambach et al. 0818 **h** Eyma 3624 [L.2535689] **i** Brambach et al. 0533. Scale bar: 10 cm, valid for all leaves.

4–10 mm long before anthesis, yellowish green, anthers c. 1 mm long, ovoid or ellipsoid, yellow. Ovary bilocular, locules surrounded by spongy tissue, ovules many per locule, ascending. Style 10 mm long before anthesis, pointed, green.

Fruits and seeds unknown.

Etymology. The species name derives from the Greek γάλα (milk) and άνθος (flower) and refers to the petals' milky white colour (Figure 7g, j). The colour pattern of the flowers is furthermore similar to the one found in the amaryllidaceous genus *Galanthus* Linnaeus (1753, 288).

Phenology. The type specimen was collected with mature flower buds in late November, suggesting flowering in December.

Distribution and habitat. *Syzygium galanthum* is currently only recorded from LLNP in the province of Central Sulawesi (Figure 4). There it occurs scattered in undisturbed submontane forest at three localities from 700–1200 m over Sideralic Cambisols and mollic Umbrisols derived from varied parent material. The forests at these localities were dominated by species of Fagaceae, Lauraceae, Moraceae, and Sapotaceae, among others.

Conservation status. *Syzygium galanthum* has a limited geographical distribution (estimated EOO 140 km²) and seems to be restricted to submontane forest between 700 and 1200 m. We assume that the estimated AOO of 12 km² is unrealistically low, due to limited collection activities in Central Sulawesi. However, despite being inside the protected LLNP, recent deforestation activities have been detected near one of the collection sites (Pono inventory plot, detected using the Global Forest Change website, Hansen et al. 2013), possibly related to the establishment of cocoa plantations (Aiyen Tjoa, Tadulako University, personal communication June 2015). Given the ongoing deforestation activities in the species' narrow geographical range and the recommendation to use a precautionary attitude in conservation assessments (IUCN Standards and Petitions Subcommittee 2014) we propose a preliminary extinction risk assessment of "Endangered" (EN B1ab(i,ii,iii)).

Vernacular name. Tambeanitu (Bahasa Behoa, *Brambach et al.* 1316).

Notes. In the field, *S. galanthum* can be recognised by the leaves with corky petioles and rather few, ± arching secondary veins. Similar corky petioles occur in *S. peregrinum* (Blume) Merrill & Perry (1939, 154) from Borneo and the Southern Philippines. A peculiarity is the presence of white blisters on the inflorescence axes and flowers of dried material (Figure 7h, k). These blisters were not observed in fresh state and must have appeared during the drying process.

It appears that there is a group of morphologically similar species in Malesia, all characterised by pale-drying leaves with rather few secondary veins, inflorescences below the leaves, and medium-sized to large, showy, infundibuliform flowers with short or long anthopodia and either white or red/pink petals and stamens: e.g. *S. iliasii* Ashton (2011, 222) from Borneo, *S. galanthum* and several unnamed collections from Sulawesi, *S. hylochare*, *S. laqueatum* Merrill & Perry (1942, 257), and *S. phaeostictum* from New Guinea and possibly the Maluku Islands, and the widely cultivated *S. malaccense* with unknown geographical origin. As can be seen from material in L, the assignment of specimens to these species has not been consistent in the past and specific limits in the group need to be critically revised.

Additional specimens examined (Paratypes). INDONESIA. Central Sulawesi (Sulawesi Tengah), LLNP: Kab. Poso, Kec. Lore Tengah, 3.5 km NE of Rompo,

following road to Katu for 3 km, then following footpath N for 2 km, tree-inventory plot Tarara, 1°35.3'S 120°17.0'E, 1200 m, 22 Nov 2011: *Brambach F, Mangopo H, Firdaus, Faber M, Tiranda R 1047* (sterile; BO [BO-1938446]!, CEB, GOET [GOET020018]!) & *1083* (sterile; BO [BO-1938445]!, CEB, L!) & *1290* (sterile; BO [BO-1938444]!, CEB, K [K000993485]!).

Kab. Sigi, Kec. Kulawi, 2.4 km ENE of Toro, NE edge of Pono Valley, tree-inventory plot Pono, 1°29.7'S, 120°03.4'E, 1050 m, 16 Aug 2006: *Culmsee 537* (sterile; CEB, K [K000993492]!) & *890* (sterile; BO [BO-1938448]!, CEB); *ibid. loco*, Jul 2007: *Culmsee r497* (sterile; BO [BO-1938449]!, CEB, GOET [GOET020019]! , L!).

Kab. Sigi, Kec. Kulawi Selatan, 4 km ENE of Watukilo, 400 m N of Mboe River, tree-inventory plot Rantena, 1°36.2'S, 120°04.5'E, 700 m, 17–26 Jun 2011: *Brambach F, Mangopo H, Firdaus, Faber M, Tiranda R 0533* (sterile; BO [BO-1938447]!, CEB, L!).

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Two new species of *Sabulina* (Caryophyllaceae) from Washington State, U.S.A.

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Abstract

Sabulina basaltica and *Sabulina sororia* (Caryophyllaceae) are described as new species endemic to Washington State, U.S.A. *Sabulina basaltica* is restricted to high-elevation, basalt rocks in the northeastern Olympic Mountains, and *Sabulina sororia* to high-elevation, dunite rocks of the Twin Sisters Range in the North Cascade Mountains. Both were previously confused with *Sabulina rossii* (formerly called *Arenaria rossii* or *Minuartia rossii*). Their recognition as distinct species is supported by morphological and molecular characters and disjunct geographic distributions. Both are illustrated, mapped and compared to related species. We also present a molecular phylogeny of *Sabulina* based on nuclear ITS and plastid trnQ-rps16 DNA with increased sampling of North American taxa. The phylogeny resolves a single clade containing all glabrous, perennial, North American *Sabulina* taxa including *Sabulina rossii* and both of the new species.

Keywords

Caryophyllaceae, *Arenaria*, *Minuartia*, *Sabulina*, Washington, Olympic Mountains, Twin Sisters, endemic, new species

Introduction

While preparing a new Flora of the Pacific Northwest (Giblin et al., in press) the status of specimens from the North Cascade and Olympic Mountains in Washington State formerly called *Arenaria rossii* R. Br. ex Richardson var. *rossii* (Hitchcock et al. 1964, Hitchcock and Cronquist 1973) came into question. Ensuing study of the specimens demonstrated they do not fit any currently described species and are furthermore distinct from each other. On the basis of recent field work, morphological analyses, genetic sequencing, and disjunct distributions, they are here described as two new species in order to make names available for use in the new Flora.

Herbarium specimens of the two new species were first collected in 1911 from the Olympic Mountains and in 1939 from the Twin Sisters Range in the North Cascade Mountains, with the most recent collections prior to this study made in 1984 from the Olympic Mountains and in 1968 from the Twin Sisters Range. These specimens, 17 in total, are held by three local herbaria (OLYM, WTU and WWB; acronyms according to Thiers continuously updated); no duplicates were located through searches of digitized specimens at other herbaria.

These specimens have largely been overlooked in previous studies of *Arenaria* L. s. lat. To our knowledge, no floras or literature treat them under any names other than *A. rossii* var. *rossii* or *Minuartia rossii* (R. Br. ex Richardson) Graebn., with the exception of a vague reference to *M. stricta* (Sw.) Hiern. by Wolf et al. (1979). Maguire (1958) recognized three subspecies of *A. rossii* with a circumboreal distribution extending south to the U.S. Rocky Mountains but made no mention of plants from Washington. Wolf et al. (1979), following a revision of *Arenaria* by McNeill (1962), treated Maguire's three subspecies at the rank of species under the segregate genus *Minuartia* Loebl., as *M. austromontana* S.J. Wolf & Packer, *M. elegans* (Cham. & Schltdl.) Schischk., and *M. rossii*. In describing *M. austromontana*, Wolf et al. (1979) examined several of the herbarium specimens from WTU, concluding that "reports of this species from Washington are erroneous," and vaguely referred the specimens to *M. stricta* (Sw.) Hiern, a species not otherwise attributed to Washington by any sources. The most recent comprehensive treatment of *Minuartia* for North America (Rabeler et al. 2005) does not account for the Washington specimens and excludes Washington from the distributions of *M. austromontana*, *M. elegans*, *M. rossii*, and *M. stricta*.

Recent phylogenetic studies (Harbaugh et al. 2010, Greenberg and Donoghue 2011, Dillenberger and Kadereit 2014) clearly demonstrate that *Minuartia*, as defined by McNeill (1962) and applied by Rabeler et al. (2005), is highly polyphyletic. Dillenberger and Kadereit (2014) proposed a new generic classification for *Minuartia* s. lat. and resurrected the segregate genus *Sabulina* Rchb., newly circumscribed to include ca. 65 taxa widely distributed throughout the Northern Hemisphere. Of the 33 North American taxa formerly placed under *Minuartia* s.l. by Rabeler et al. (2005), 19 now belong to *Sabulina*, including *S. austromontana* (S.J. Wolf & Packer) Dillenb. & Kadereit, *S. dawsonensis* (Britton) Rydb., *S. elegans* (Cham. & Schltdl.) Dillenb. &

Kadereit, *S. macrantha* (Rydb.) Dillenb. & Kadereit, *S. michauxii* (Fenzl) Dillenb. & Kadereit, *S. rossii* (R. Br. ex Richardson) Dillenb. & Kadereit, and *S. stricta* (Sw.) Rchb. These taxa together are informally referred to here as the *S. rossii* species complex. Of these taxa, only one sample of *S. stricta* and one sample misidentified as *S. dawsonensis* (see Suppl. material 2) were included in the phylogeny by Dillenberger and Kadereit (2014); assignment of the remaining taxa was inferred by morphology. Morphological similarities likewise suggest the two new species from Washington belong to *Sabulina*. To confirm their placement and to clarify relationships between the new species and the above taxa, we present an expanded phylogeny of *Sabulina*.

Methods

A total of 127 herbarium specimens from ALA, KHD, MONTU, OLYM, UBC, V, and WTU for the above taxa were physically examined for morphological characters (see Suppl. material 1). Digital images of additional herbarium specimens accessible online (e.g., CPNWH 2017) from ALA, MONT, MONTU, WWB, and YU were examined for macromorphological characters. Identifications were verified for all specimens examined. Comparative measurements given below (e.g., Table 1) were obtained from herbarium specimens and published literature sources (e.g., Rabeler et al. 2005). Geographic distributions of related species were obtained from published literature sources and verifiable herbarium specimens. Field work focused on visiting known locations, with visits to the Olympic Mountains July 15–16 and July 24, 2016, and to the Twin Sisters Range August 6–7, 2016, to collect additional herbarium specimens, tissue samples for DNA extraction, and obtain information about distribution, habitat, and plant morphology. Living plants were photographed using a Nikon D800 digital SLR camera with 50 mm macro lens. Measurements for the two new species were obtained from living material and dried specimens, with herbarium specimens examined at 10×–40× magnification using a dissecting microscope with a calibrated, 0.1 mm scale (at 10×) ocular ruler.

For the molecular phylogeny, we used 14 samples of the *S. rossii* species complex including three samples in total of the two new species (see Suppl. material 2). Total genomic DNA was extracted using the FastDNA Kit (MP Biomedicals, Santa Ana, CA, U.S.A.) following the manufacturer's protocol, but adding 40 µl 1% polyvinylpyrrolidone during cell lysis. PCRs of nuclear internal transcribed spacer (ITS) and plastid spacer trnQ-rps16 were carried out with OneTaq 2x Master Mix (New England Biolabs, Ipswich, MA, U.S.A.) following the recommendations for reaction mix and PCR cycle program. For ITS, primers ITS4 and 5 (White et al. 1990) were used; for trnQ-rps16, trnQ^(UUG) and rps16x1 (Shaw et al. 2007). Annealing temperature for ITS was 52° C, for trnQ-rps16 56° C. PCR products were cleaned up with DNA Clean & Concentrator-5 Kit (Zymo Research, Irvine, CA, U.S.A.), following the manufacturer's protocol. Cycle sequencing was carried out with the same primers as the PCR.

Table 1. Morphological comparisons of *Sabulina basaltica*, *S. sororia*, and other glabrous, perennial *Sabulina* species in North America.

Taxon	Growth form	Leaves	Inflorescence	Pedicels	Sepals (at anthesis)	Petals	Capsules	Seeds
<i>Sabulina austromontana</i>	cespitose or dense mats, 1–3 cm tall	3–10 mm, 1-veined	flowers solitary	3–15(–20) mm	2–3 mm, narrowly to broadly lanceolate, 3-veined, green	absent or rudimentary (rarely = sepals)	2–3 mm, ca = sepals	0.6–1 mm, brown, obscure-ely rugose
<i>Sabulina basaltica</i>	cespitose to tightly mat-forming, 0.5–3 cm tall	(0.6–)1–3.5(–4.5) mm, 3-veined	2–5(–8)-flowered cymes, with some flowers solitary	1–3.5(–6) mm	(1.6–)2.4–2.8(–3.3) mm, lanceolate to narrowly ovate-lanceolate, 3-veined, light green	(1–)1.2–1.8(–2) × as long as sepals	1.8–2.4 mm, < or = sepals	0.6–0.8 mm, dark reddish-brown to blackish, lightly rugose
<i>Sabulina dawsonensis</i>	loosely cespitose, 4–30 cm tall	4–15 mm, 1-veined to weakly 3-veined	(2–)7–15-flowered cymes	3–25 mm	2.5–4 mm, ovate to broadly lanceolate, 3-veined, green to purplish	0.5–0.8 × as long as sepals	3.5–4.5 mm, > sepals	0.5–0.6 mm, dark brown to blackish, lightly rugose
<i>Sabulina elegans</i>	loosely cespitose, 3–8 cm tall	3–10 mm, 1-veined	flowers solitary	10–40 mm	2–4 mm, ovate to lanceolate, 3-veined, purplish	0.6–1(–1.1) × as long as sepals (rarely absent)	2–4 mm, ca = sepals	0.6–1 mm, reddish-brown, lightly rugose
<i>Sabulina macrantha</i>	mat-forming to trailing, 2–15 cm tall	5–10 mm, 1-veined to weakly 3-veined	2–5(–8)-flowered cymes or some flowers solitary	2–15(–20) mm	3.5–5 mm, ovate to lanceolate, 3-veined, green to purplish	0.7–1.8 × as long as sepals	3–3.8 mm, < sepals	0.7–1.1 mm, blackish, distinctly rugose
<i>Sabulina michauxii</i>	loosely cespitose (occ. matted), 8–40 cm tall	8–30 mm, 1–3-veined	5–30-flowered	3–60 mm	3–6 mm, ovate to lanceolate, 3-veined, green	1.3–2 × as long as sepals, or < sepals in northern plants	3–4 mm, usually < sepals	0.8–0.9 mm, blackish, prominently rugose
<i>Sabulina rossii</i>	pulvinate to cespitose, 1–3 cm tall	1–4 mm, 1-veined	flowers solitary	1–20 mm	1.5–2.5 mm, oblong-ovate, 1-veined, purplish	1.2–2 × as long as sepals, or < sepals, or absent	1.5–2.5 mm, ca = sepals	0.6 mm, brown, obscurely rugose
<i>Sabulina sororia</i>	mat-forming to trailing, 0.5–4 cm tall	1.2–3.5(–5) mm, 1-veined	2–3-flowered cymes with some flowers solitary	(1–)2–8(–15) mm	(1.4–)1.7–2.5(–3) mm, ovate-lanceolate, 3-veined, green to purplish-tinged	1.3–2(–2.5) × as long as sepals	1.8–2.6 mm, > or rarely = sepals	0.7–0.8 mm, reddish-black, lightly rugose
<i>Sabulina stricta</i>	cespitose or mat-forming, 0.8–12 cm tall	2.5–14 mm, 1-veined to weakly 3-veined	2–3(–5)-flowered cymes or some (rarely all) flowers solitary	1–35 mm	(1.5–)2–3.5 mm, elliptic to ovate-lanceolate, 3-veined, green to purplish	0.6–1 × as long as sepals, or rudimentary to absent	2.5–3.2 mm, < or = sepals	0.4–0.6 mm, reddish-brown, obscurely rugose

Sequencing was carried out on an ABI 3730 capillary sequence machine at the Center for Genome Research and Biocomputing at Oregon State University. Sequencher v.4.10.1 (Gene Codes, Ann Arbor, Michigan, U.S.A.) was used for trace file editing, and sequences were submitted to GenBank (see Suppl. material 2).

Sequences were aligned using MUSCLE v.3.8.31 (Edgar 2004) implemented in seaview v.4.3.0 (Gouy et al. 2010). Maximum likelihood phylogenies were obtained using RAxML v.8.0.26 (Stamatakis et al. 2008) with the GTR+I[†] substitution model and the fast bootstrap algorithm with automatic halt based on the autoMRE criterion. Sequences of ITS and trnQ-rps16 were analysed separately, taxon sampling was complemented with published sequences from GenBank for *Sabulina michauxii* and *S. fontinalis*, and previously sequenced but unpublished sequences of *Sabulina* (see Suppl. material 2).

Results

Morphological comparisons indicate the plants from the Olympic Mountains (*Sabulina basaltica* in Table 1 and the key) differ from plants from the Twin Sisters Range (*S. sororia*) in leaf venation, sepal shape, sepal length, sepal length:width ratio, and capsule length relative to sepals, with minimal or no overlap between the two species in these characters (Table 1). The plants show additional, though more strongly overlapping differences in growth form, pedicel length, and stem, leaf, and sepal color. The Olympic Mountains plants and Twin Sisters plants together differ from all other glabrous, perennial *Sabulina* taxa in North America by the combination of partially cymose inflorescences, petals 1.2–2.5 times as long as the sepals, sepals 1.5–2.8(–3.3) mm, capsules 1.8–2.6 mm, and dark reddish-brown to blackish seeds 0.6–0.8 mm.

Geographically, the Olympic Mountain plants are separated from the Twin Sisters plants by a distance of ca. 130 air km across the Puget Sound trough (Fig. 6). The nearest known populations of other glabrous, perennial *Sabulina* species are in northeast Oregon (*S. austromontana*) at a distance of ca. 520 air km and in the Rocky Mountains of southern Canada (*S. austromontana* and *S. dawsonensis*) at a distance of ca. 640 air km.

The molecular phylogeny of the ITS data set (Fig. 1A) shows that the *S. rossii* species complex is monophyletic and highly supported (bootstrap support (BS) 100), and is sister to *S. fontinalis* (Short & R. Peter) Dillenb. & Kadereit (BS 100). Relationships among members of the *S. rossii* species complex were not fully resolved, but *S. basaltica* (BS 100), *S. dawsonensis* (BS 78), *S. stricta* (BS 71) and *S. macrantha* (BS 100) are supported to be monophyletic. *Sabulina austromontana* is closely related to *S. sororia* (BS 72). *Sabulina rossii* and *S. elegans* form a monophyletic group (BS 94) without support for the species within. *Sabulina basaltica* is part of a polytomy with *S. dawsonensis* and *S. stricta* and a clade comprising *S. rossii*, *S. elegans*, *S. austromontana* and *S. sororia*. The phylogeny of the plastid trnQ-rps16 marker (Fig. 1B) is less resolved, but the *S. rossii* species complex is also supported with a BS of 72. Only *S. dawsonensis* is supported as monophyletic (BS 83).

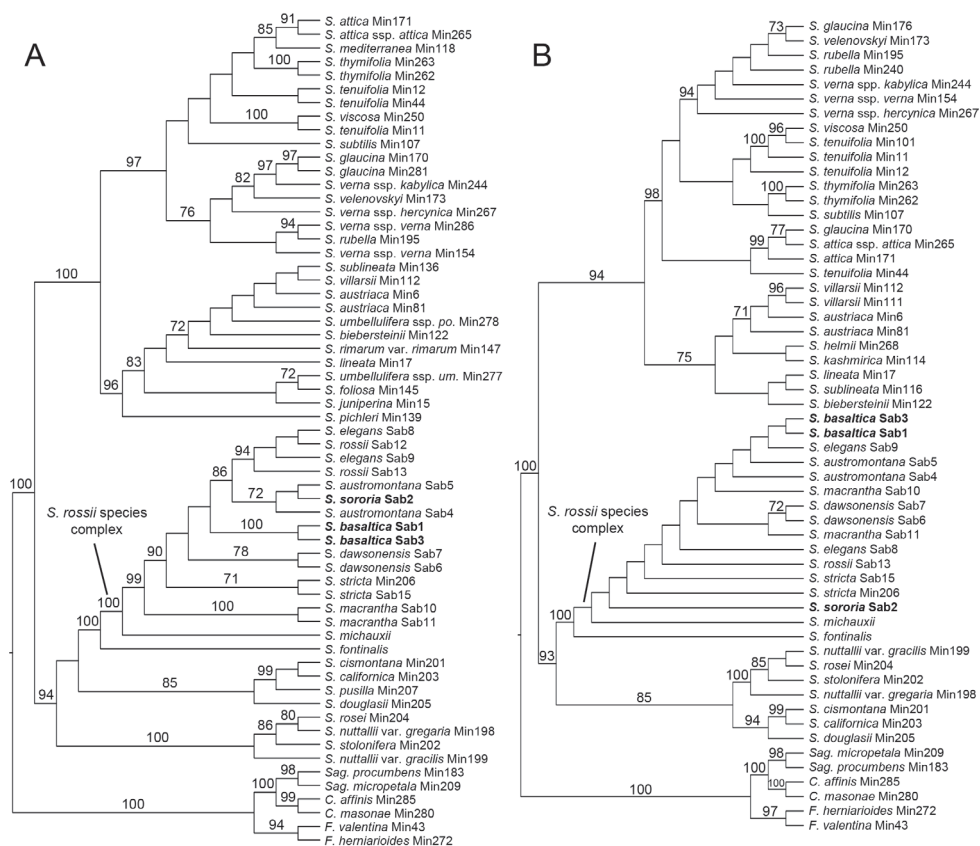


Figure 1. Maximum likelihood phylogenies of *Sabulina*. **A** Cladogram of the ITS dataset **B** Cladogram of the trnQ-rps16 dataset. Phylogenies obtained with RAxML, values above branches are bootstrap support values (only ≥ 70 shown) C., *Colobanthus*; F., *Facchinia*; S., *Sabulina*; Sag., *Sagina*.

Taxonomic treatment

Sabulina basaltica B.S.Legler, sp. nov.

urn:lsid:ipni.org:names:60474719-2

Figs 2A–E, 3

Type. U.S.A. Washington, Clallam Co.: Olympic National Park: along climbers trail at base of summit block on west side of Mt. Angeles, 1872 m, 47.995079°N, 123.468522°W, 15 Jul 2016, B.S. Legler 14177 (holotype: WTU!; isotype: OLYM!).

Diagnosis. Differs from all other glabrous, perennial *Sabulina* species in North America by the combination of 3-veined dried leaves, flowers partly in 2–5(–8)-flowered cymes, sepals mostly < 3 mm long, petals conspicuously longer than the sepals, capsules 1.8–2.4 mm long and mostly < or = sepals, and dark reddish-brown to reddish-black seeds 0.6–0.8 mm long.

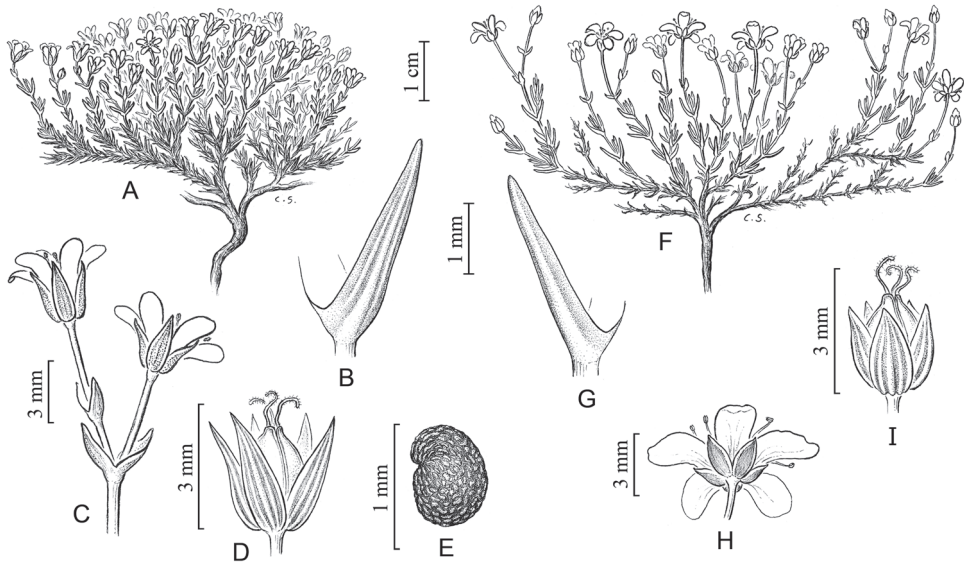


Figure 2. Line drawings of *Sabulina basaltica* and *Sabulina sororia*. **A–E.** *Sabulina basaltica*. **A** Habit **B** Dried leaf with 3 veins **C** Cymose, bracteate inflorescence with two flowers **D** Capsule with dried, 3-veined sepals (with sepals pushed outwards and withered petals removed to reveal capsule) **E** Seed **F–I** *Sabulina sororia* **F** Habit **G** Dried leaf with 1 vein **H** Flower **I** Capsule with dried, 3-veined sepals (withered petals removed).

Description. *Plants* perennial, forming dense (rarely loose) mats or cushions 2–8(–12) cm diameter, glabrous throughout. *Taproot* slender to slightly thickened, 1–3 mm diameter near summit. *Stems* numerous, radially spreading from the taproot, prolifically branching; older stems decumbent to ascending, 1–6 cm, brown to tan; new shoots arising from axillary fascicles on previous year's stems, ascending to erect, 0.5–3 cm, internodes of flowering shoots 0.1–1(–2) times as long as leaves, light green or maroon-tinged. *Leaves* usually strongly overlapping, occasionally well-spaced, connate proximally to form a tight, scarious sheath; blade (0.6–)1–3.5(–4.5) × 0.3–0.6 mm, ascending to nearly appressed, straight to slightly incurved or slightly recurved, light green to yellowish-green, not or only weakly shiny, subulate, rounded abaxially, nearly flat adaxially, veins not visible in fresh material, margins rounded, not scarious, smooth, apex obtuse to rounded, usually maroon; axillary fascicles of leaves usually present; previous year's leaves marcescent, long-persistent on older stems, with the midvein and two lateral veins becoming prominent, rigid. *Inflorescences* terminal, 2–5(–8)-flowered, open cymes usually mixed with solitary terminal flowers; bracts 1.1–2.6 mm, subulate to lanceolate, incurved, green with scarious margins, rounded abaxially, flat to concave adaxially, apex obtuse to bluntly acute. *Pedicels* 1–3.5(–6) mm, glabrous. *Flowers* perfect or functionally male or functionally female, many plants functionally monoecious to

nearly dioecious. *Hypanthium* obscure, disc-shaped. *Sepals* spreading-ascending at anthesis, light green, glabrous, lanceolate to narrowly ovate-lanceolate, (1.6–)2.4–2.8(–3.3) \times 0.7–0.9(–1.1) mm, (2.4–)3–3.2(–3.5) times as long as wide, scarious margins ca. 0.05–0.2 mm wide, base cupped, apex green to maroon, acute to shortly acuminate, outer surface flat to convex, weakly 3-veined at anthesis, becoming distinctly 3-veined in fruit or when dried. *Petals* white, spreading, narrowly to broadly oblong or narrowly obovate, 3.2–5.2 \times 1.1–2 mm, (1–)1.2–1.8(–2) times as long as sepals, base gradually tapered to a short, greenish-yellow claw, apex rounded to truncate, entire to weakly erose or slightly emarginate. *Nectaries* 5, at base of outer stamens, greenish-yellow, ca. 0.4 \times 0.4 mm, truncate, alternate with the petals. *Stamens* 10, in 2 series of 5, either all fertile or all abortive; filaments subulate, whitish-green; anthers orbiculate, pale yellow; fertile stamens with filaments 1.4–2.5 mm and anthers 0.4–0.5 mm; abortive stamens with filaments 0.2–0.5 mm and anthers 0.1–0.2 mm. *Ovary* superior; placentation shortly free-central; ovules usually 12 per ovary. *Styles* 3, distinct, erect to ascending; functionally male flowers with styles ca. 0.7 mm and stigmas scarcely developed; functionally female flowers with styles 1–1.7 mm and stigmas linear, glandular-puberulent adaxially. *Capsules* light green to greenish-tan (valve margins tan), on stipe ca. 0.1–0.2 mm, ovoid-conical, 1.8–2.4 \times 1–1.5 mm, slightly shorter than or equaling (rarely slightly longer than) and usually enclosed by the appressed sepals and withering-persistent petals, dehiscing in upper half by 3 valves, these becoming incurved on margins and slightly recurved at tip. *Seeds* 4–8 per capsule, 0.6–0.8 mm, dark reddish-brown to reddish-black, obliquely reniform with radicle prolonged into a curved bump, somewhat compressed, with rounded margins, surfaces sculpted with low, rounded, slightly elongate and sinuous bumps at $> 10\times$ magnification.

Additional specimens examined. **U.S.A. Washington, Clallam Co.** Third Peak, Mt. Angeles, 10 Aug 1911, *no collector* (OLYM); Mt. Angeles, 5500 ft, 2 Aug 1930, *J.W. Thompson 5481* (WTU); Mt. Angeles, 5500 ft, 10 Jul 1931, *G.N. Jones 3202* (WTU); Mt. Angeles, 6800 ft, 17 Jul 1931, *J.W. Thompson 7433* (WTU); Mt. Angeles, 5500 ft, 15 Jul 1933, *J.W. Thompson 9458* (WTU); Mt. Angeles, 15 Jul 1933, *H.E. Helmrich 259* (WTU); Mt. Angeles, 12 Jul 1936, *M.P. Harthill s.n.* (OLYM); Mt. Angeles, 31 Jul 1966, *L.C. Bliss s.n.* (WTU); Saddle between Mt. Baldy and Mt. Tyler, 5600 ft, 23 Jul 1976, *N. Buckingham 514* (OLYM); Blue Mountain, northeast ridge, T28N R5W S1, 5600 ft, 31 Jul 1984, *E.L. Tisch 2724* (OLYM); Blue Mountain, northeast ridge, T28N R5W S1, 5600 ft, 31 Jul 1984, *E.L. Tisch 2724 1/2* (OLYM); Along ridgeline ca. 100 meters southwest of summit of Mt. Angeles, 47.994735°N, 123.467501°W; 1896 m, 15 Jul 2016, *B.S. Legler 14178* (WTU); High point at east end of ridgeline along summit of Mt. Angeles, 47.995365°N, 123.463590°W; 1949 m, 15 Jul 2016, *B.S. Legler 14179* (WTU); Southeast rib of Steeple Rock along Hurricane Ridge, 47.961464°N, 123.452969°W; 1657 m, 16 Jul 2016, *B.S. Legler 14183* (WTU); South side of summit of Eagle Point, along Hurricane Ridge, 47.938951°N, 123.409042°W; 1893 m, 16 Jul 2016, *B.S. Legler 14184* (WTU, OLYM); **Jefferson Co.:** Iron Mountain, 6000 ft., 21 Jul 1934, *J.W. Thompson 11054* (WTU); Ridge north from Buckhorn Pass, T27N R4W S13, 6600 ft, 1 Aug 1981, *N. Buckingham*

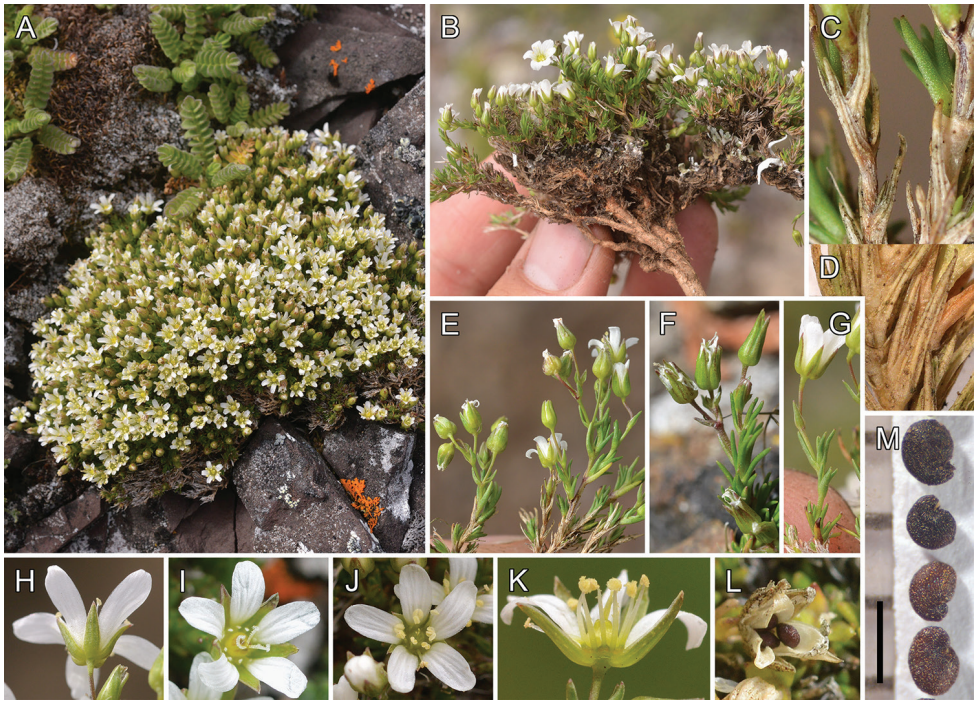


Figure 3. *Sabulina basaltica*. **A** Plant forming a tight mat (Legler 14178) **B** Excavated plant with taproot (Legler 14184) **C** Fresh leaves and persisting, 3-veined, dead leaves (Legler 14177) **D** Dead, persisting, 3-veined leaves (Legler 14178) **E–F** Cymose inflorescences (Legler 14177, Legler 14175) **G** Solitary terminal flower (Legler 14184) **H** Sepals and petals, showing shapes and lengths (Legler 14184) **I–J** Flowers with different combinations of stamen and style lengths (Legler 14177, Legler 14184) **K** Partially dissected flower showing hypanthium and nectaries (Legler 14183) **L** Dehiscent capsule with seeds (Legler 14183) **M** Seeds (Legler 14183). Black scale bar is 1 mm.

2658 (OLYM); West face of Buckhorn Mountain just above ridgeline that connects Buckhorn Mountain to Peak 6988, 47.826286°N, 123.117615°W; 2026 m, 24 Jul 2016, B.S. Legler 14195 (WTU).

Etymology. The epithet *basaltica* refers to the basalt rock to which this species is apparently restricted.

Vernacular name. Suitable common names are Olympic sandwort or basalt sandwort.

Distribution and ecology. *Sabulina basaltica* is known only from subalpine and alpine peaks along the northeastern rim of the Olympic Mountains in Clallam and Jefferson counties, Washington, U.S.A. (Fig. 6C), at documented elevations of 1650–2100 meters. It is presently known from seven peaks: Mt. Angeles, Steeple Rock, Eagle Point, Blue Mountain, near Mt. Tyler, Buckhorn Mountain, and Iron Mountain. It is apparently confined to south or southwest facing rock faces composed of ocean floor basalts (mainly pillows and breccia) of the Crescent Formation (Tabor and Cady 1978, Babcock et al. 1992) on ca. 30–60° slopes (Fig. 5A). *Sabulina basaltica* occur as scattered individuals forming small tufts in exposed rock crevices with very sparse vascular

plant cover (Fig. 5B–C). The rock faces are exposed to solar radiation and wind. Snow accumulation is likely minimal due to wind ablation, and meltout likely occurs much earlier than on adjacent slopes. No plants were found on more protected east or north facing slopes, nor on more gentle slopes around the periphery of rock faces, whether vegetated or not.

Directly associated species include *Anemone multifida* Poir., *Antennaria* cf. *rosea* Greene, *Campanula piperi* Howell, *Carex nardina* Fr., *Dasiphora fruticosa* (L.) Rydb., *Erigeron compositus* Pursh, *Penstemon davidsonii* Greene var. *menziesii* (D.D. Keck) Cronquist, *Petrophytum hendersonii* (Canby) Rydb., *Phlox diffusa* Benth., *Polemonium pulcherrimum* Hook. subsp. *pulcherrimum*, *Potentilla villosa* Pall. ex Pursh, *Sabulina rubella* (Wahlenb.) Dillenb. & Kadereit, *Salix nivalis* Hook., *Saxifraga austromontana* Wiegand, *Saxifraga cespitosa* L., *Sedum lanceolatum* Torr., *Selaginella wallacei* Hieron., *Smelowskia americana* Rydb., *Trisetum spicatum* (L.) K. Richt., and *Viola flettii* Piper. Crustose lichens cover most of the rock surfaces. Adjacent conifer species at subalpine sites include *Callitropsis nootkatensis* (D. Don) D.P. Little, *Abies lasiocarpa* (Hook.) Nutt., *Juniperus communis* L. var. *kelleyi* R.P. Adams, and *Pinus albicaulis* Engelm.

Although oceanic basalts form an extensive belt around the northern, eastern, and southeastern sides of the Olympic Mountains (Tabor and Cady 1978), suitable climatic conditions for *S. basaltica* presumably occur only in the northeastern portion of the mountains within a rain shadow formed by one of the steepest precipitation gradients in North America (Phillips and Donaldson 1972). Average annual precipitation levels for Mt. Angeles and Buckhorn Mountain are estimated at ca. 200 cm (PRISM 2017). For comparison, Mt. Olympus, only 28 km to the southwest of Mt. Angeles, receives an estimated 600 cm of precipitation annually and Sequim, 30 km to the northeast, only 41 cm of annual precipitation (PRISM 2017). Furthermore, the growing season is relatively dry, with ca. 12% of total annual precipitation falling during May–September at Mt. Angeles (PRISM 2017). Based on climate and substrate, areas of suitable habitat for *S. basaltica* are predicted to occur in a discontinuous arc extending from the vicinity of Hurricane Ridge in the north to at least the vicinity of Mt. Constance to the southeast, and possibly farther south to The Brothers and adjacent peaks (Fig. 6C). Basalts of the Crescent Formation reappear on the southern tip of Vancouver Island, British Columbia, just to the north of the Olympic Mountains (Babcock et al. 1992), though at much lower elevations where previously covered by the Cordilleran ice sheet; we do not expect *S. basaltica* to occur there.

A pair of specimens from Blue Mountain, Clallam County (*E. L. Tisch* 2724 and *E. L. Tisch* 2724 1/2, OLYM) indicate on the label that plants were collected from “crevices in (limestone?) rock outcrop,” raising the possibility that *S. basaltica* is not confined to basalt. However, Blue Mountain contains outcrops of basalt rocks and a return visit to the site would be needed to determine the actual rock type from which the specimens were collected.

Phenology. Specimens of *Sabulina basaltica* with flowers were collected from mid July to mid August, and specimens with fruits from mid July to early August.

Conservation status. Population sizes on Mt. Angeles, Steeple Rock, and Eagle Point were estimated at ca. 1000, 100, and 300 plants, respectively, during visits in

2016. No estimate was attempted at Buckhorn Mountain due to difficulty of access, but about 30 plants were observed in the immediate vicinity of *Legler 14195*. Significant areas of potentially suitable habitat occur on other basalt peaks in the northeastern Olympic Mountains within a predicted area of extent of ca. 50 km²; however, the vascular plant flora for the majority of these peaks remains poorly documented or undocumented with herbarium specimens (CPNWH 2017), and the lack of information precludes range-wide estimates of the total number of populations and plants. Assignment of a formal conservation status may require additional field work to gauge rarity. All known populations and nearly all areas of potentially suitable habitat are protected within Olympic National Park and adjacent wilderness areas. The known populations are located on steep rock slopes away from trails and roads. Therefore, direct anthropogenic impacts are assumed to be minimal. Grazing pressure and disturbance from introduced mountain goats (*Oreamnos americanus* Blainville, 1816) pose an increasing impact to high elevation plant communities in the Olympic Mountains (Houston et al. 1994, Jenkins et al. 2012), and goats were observed in the vicinity of populations of *S. basaltica* on Mt. Angeles during the visit in 2016; however, no evidence of direct grazing or damage to *S. basaltica* was detected.

***Sabulina sororia* B.S.Legler, sp. nov.**

urn:lsid:ipni.org:names:60474720-2

Figs 2F–I, 4

Type. U.S.A. Washington, Whatcom Co.: Mt. Baker-Snoqualmie National Forest, on west side of ridge along Sisters Divide 0.45 air km southeast of outlet of Lake Wiseman, Twin Sisters Range, 1414 m, 48.707131°N, 121.934086°W, 6 Aug 2016, *B.S. Legler 14263* (holotype: WTU!; isotypes: MICH!, MO!, NY!, UBC!).

Diagnosis. Differs from all other glabrous, perennial *Sabulina* species in North America by the combination of 1-veined dried leaves, flowers partly in 2–3-flowered cymes, sepals mostly < 2.5 mm long, petals conspicuously longer than the sepals, capsules 1.8–2.6 mm long and mostly > sepals, and reddish-black seeds 0.6–0.8 mm long.

Description. *Plants* perennial, forming loose to dense mats 2–20 cm in diameter, glabrous throughout. *Taproot* slender to slightly thickened, 1–3 mm diameter near summit. *Stems* numerous, radially spreading from the taproot, prolifically branching; older stems decumbent to ascending, 1–10 cm, brown to tan; new shoots arising from axillary fascicles on previous year's stems, ascending to erect, 1–4 cm, internodes of flowering shoots 0.3–2(–3) times as long as leaves, deep green or purplish. *Leaves* slightly to strongly overlapping or well-spaced, connate proximally to form a tight, scarious sheath; blade 1.2–3.5(–5) × 0.4–0.7 mm, ascending to spreading-ascending, straight to slightly incurved or slightly recurved, green to deep green, often maroon-tinged, shiny, subulate, rounded abaxially, nearly flat adaxially, veins not visible in life, margins rounded, not scarious, smooth, apex obtuse to rounded, usually maroon; axillary fascicles of leaves usually present; previous year's leaves loosely marcescent on

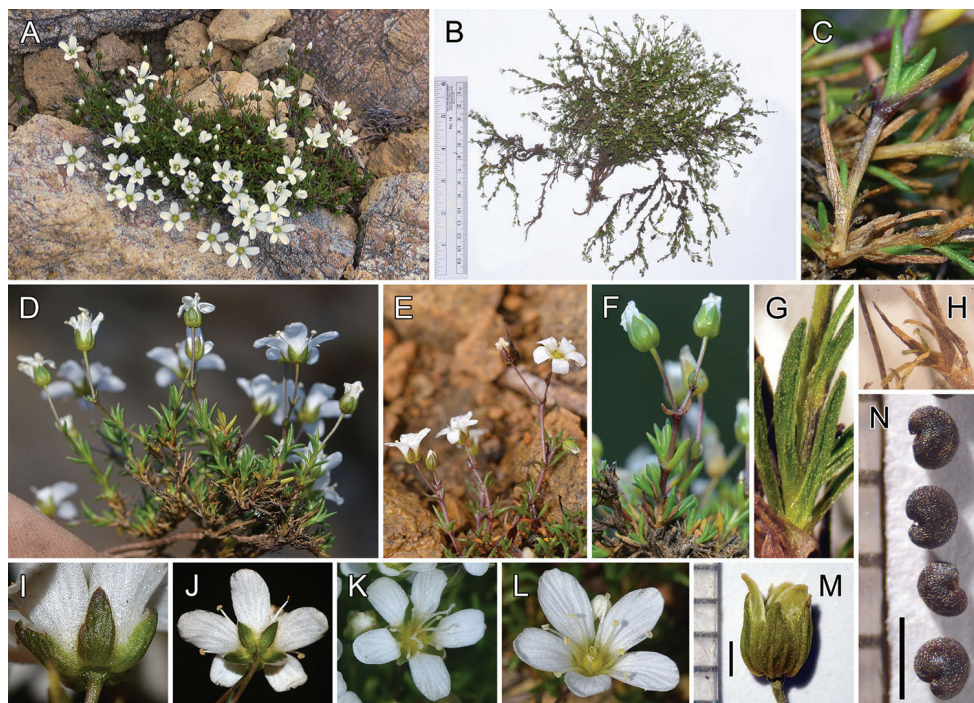


Figure 4. *Sabulina sororia*. **A** Plant forming a loose mat (Legler 14263) **B** Excavated plant with loosely sprawling stems (Legler 14268) **C** Fresh leaves and persisting, 1-veined, dead leaves (Legler 14263) **D** Excavated plant (Legler 14263) **E–F** Cymose inflorescences (Legler 14263) **G** Dried, 1-veined leaves (Legler 14263) **H** Dead leaves with only midvein persisting (Legler 14263) **I** Ovate-lanceolate, purple-tinged sepals (Legler 14263) **J** Sepals and petals, showing shapes and relative lengths (Legler 14263) **K–L** Flowers with different combinations of stamen and style lengths (Legler 14263) **M** Dried flower with dehiscent capsule longer than sepals (Legler 14263) **N** Seeds (Legler 14263). Black scale bars are 1 mm.

older stems, with only the midvein visible and persisting (no lateral veins). *Inflorescences* terminal, 2–3-flowered, open cymes, usually mixed with solitary terminal flowers; bracts 0.7–1.6 mm, lanceolate to ovate-lanceolate, incurved, green or maroon with scarious margins, rounded abaxially, flat to concave adaxially, apex obtuse to bluntly acute. *Pedicels* (1)–2–8(–15) mm, glabrous. *Flowers* perfect or functionally male or functionally female, most plants functionally monoecious to nearly dioecious. *Hypanthium* obscure, disc-shaped. *Sepals* spreading-ascending at anthesis, deep green, often lightly maroon-tinged, glabrous, broadly ovate to ovate-lanceolate, (1.4)–1.7–2.5(–3) × 0.6–1.1(–1.3) mm, 1.5–2.5(–3.5) times as long as wide, scarious margins ca. 0.05–0.15 mm wide, base cupped, apex green to maroon, acute, outer surface convex, smooth to very weakly 3-veined at anthesis, becoming 3-veined in fruit or when dried. *Petals* white, spreading, broadly oblong to obovate, 3.2–4(–5.2) × 1.2–2(–2.6) mm, 1.3–2(–2.5) times as long as sepals, base gradually tapered to a short, greenish-yellow claw, apex rounded to weakly truncate. *Nectararies* 5, at base of outer stamens, greenish-yellow, ca. 0.3–0.4 mm, truncate, alternate with the petals. *Stamens* 10, in 2 series of

5, either all fertile or all abortive; filaments subulate, whitish-green; anthers orbiculate, pale yellow; fertile stamens with filaments 1.5–2.8 mm and anthers (0.3–)0.4–0.5 mm; abortive stamens with filaments 0.2–0.6 mm and anthers 0.1–0.3 mm. *Ovary* superior; placentation shortly free-central; ovules usually 12 per ovary. *Styles* 3, distinct, erect to ascending; functionally male flowers with styles 0.6–0.9 mm and stigmas scarcely developed; functionally female flowers with styles 1.1–2.1 mm and stigmas linear, glandular-puberulent adaxially. *Capsules* light green to greenish-tan (valve margins tan), on stipe ca. 0.1–0.2 mm, ovoid-conical, 1.8–2.6 × 1.1–1.8 mm slightly longer than (rarely slightly shorter than) and mostly enclosed by the appressed sepals and withering-persistent petals, dehiscent in upper half by 3 valves, these becoming incurved on margins and slightly recurved at tip. *Seeds* apparently 8 per capsule, 0.7–0.8 mm, reddish-black, obliquely reniform with radicle prolonged into a curved bump, somewhat compressed, surfaces sculpted with low bumps at > 10× magnification.

Additional specimens examined. U.S.A. Washington, Whatcom Co.: Twin Sisters Range, 11 Aug 1939, W.C. Muenscher 10281 (WTU); Twin Sisters Range, 12 Aug 1939, W.C. Muenscher 10306 (WTU); Head of Orsina Creek, at west base of Twin Sisters Mountain, 4900 ft, T37N R6E S11, 12 Jul 1961, A.R. Kruckeberg 5225 (WTU); Northwest slope of Twin Sisters, ca. 6200 ft, 28 Jul 1968, R.J. Taylor 2158 (WWB); Crest of ridge along Sisters Divide 0.7 air km southeast of outlet of Lake Wiseman, Twin Sisters Range, 48.704998°N, 121.931408°W; 1508 m, 7 Aug 2016, B.S. Legler 14268 (ID, US, WTU).

Etymology. The epithet *sororia* is from the Latin word *sororis*, sister, in reference to the Twin Sisters Range.

Vernacular name. Twin Sisters sandwort.

Distribution and ecology. *Sabulina sororia* is known only from the Twin Sisters Range on the western flank of the Cascade Mountains in Whatcom County, Washington, U.S.A. (Fig. 6D). The Twin Sisters Range consists of a large body of relatively unaltered dunite rock approximately 16 km long by 6.5 km wide (Tabor et al. 2003) oriented in a northwest to southeast direction, with a maximum elevation of 2135 meters and sustained ridgeline elevations above 1500 meters. The dunite rock likely formed in the earth's mantle and was subsequently uplifted along a series of nearly vertical thrust faults (Ragan 1963); it is a dense, crystalline, ultramafic rock composed mostly of olivine with lesser amounts of chromite and pyroxenite, rich in magnesium, iron, chromium and nickel (Ragan 1963, Onyeagocha 1978). The rock weathers to a distinctive light reddish-brown color with a coarse-grained surface. Ultramafic rocks display a pronounced effect on the overlying vegetation (Kruckeberg 2002, and references therein), and the Twin Sisters dunite is no exception with its depressed treeline and sparse vegetation cover above treeline.

Sabulina sororia is apparently restricted to rocky or gravelly, sparsely vegetated, sub-alpine and alpine slopes. Documented elevations range from 1490 to 1890 meters. Habitat information from older herbarium specimens is sparse, indicating only a “west-facing alpine ridgeline” (Grable 5023), “moist, gravelly, serpentine soil on an alpine slope” (Taylor 2158), “along streambank” (Muenscher 10281), and “olivine in massive



Figure 5. Representative habitats. **A–C** *Sabulina basaltica* habitat **A** Basalt slope near the type locality (Legler 14177) **B–C** Plants in crevices of basalt rock faces (Legler 14177, Legler 14183) **D–F** *Sabulina sororia* habitat **D** Reddish-colored dunite slope at the type locality (Legler 14263) **E–F** Plants among dunite rock and gravel (Legler 14263, Legler 14268).

fell-fields and talus, with krummholz lodgepole pine and subalpine fir in snow-melt basin” (Kruckeberg 5225). At the two sites visited by B. Legler in August 2016, *S. sororia* was observed growing most frequently in mesic, coarse, gravelly and rocky soil derived from dunite on erosional surfaces with slopes ranging from flat to ca. 30° (Fig. 5D–F). A few plants were found in exposed crevices of stable dunite rock outcrops along a narrow ridgeline with slopes of ca. 45–60°. The species apparently avoids areas with late-lying snow. *Sabulina sororia* occurs as scattered individuals, forming a minor component of the sparse, low vegetation cover. Total vegetation cover of all plant species at these two sites is estimated at 5–20%. Average precipitation for the higher elevations of the Twin Sisters Range is estimated at ca. 180–190 cm per year, with about 30% of the total precipitation falling during May–September (PRISM 2017).

Directly associated species consist of scattered tufts or mats of *Carex spectabilis* Dewey, *Cassiope mertensiana* (Bong.) G. Don, *Cerastium arvense* L. subsp. *strictum* Gaudin, *Cryptogramma acrostichoides* R. Br., *Danthonia intermedia* Vasey, *Erigeron aureus* Greene, *Polystichum lemmonii* Underw., *Sabulina rubella* (Wahlenb.) Dillenb. & Kadereit, *Saxifraga cespitosa* L., *Sibbaldia procumbens* L., *Silene acaulis* (L.) Jacq., and *Smelowskia ovalis* Rydb. Trees and taller shrubs are absent from these sites, though

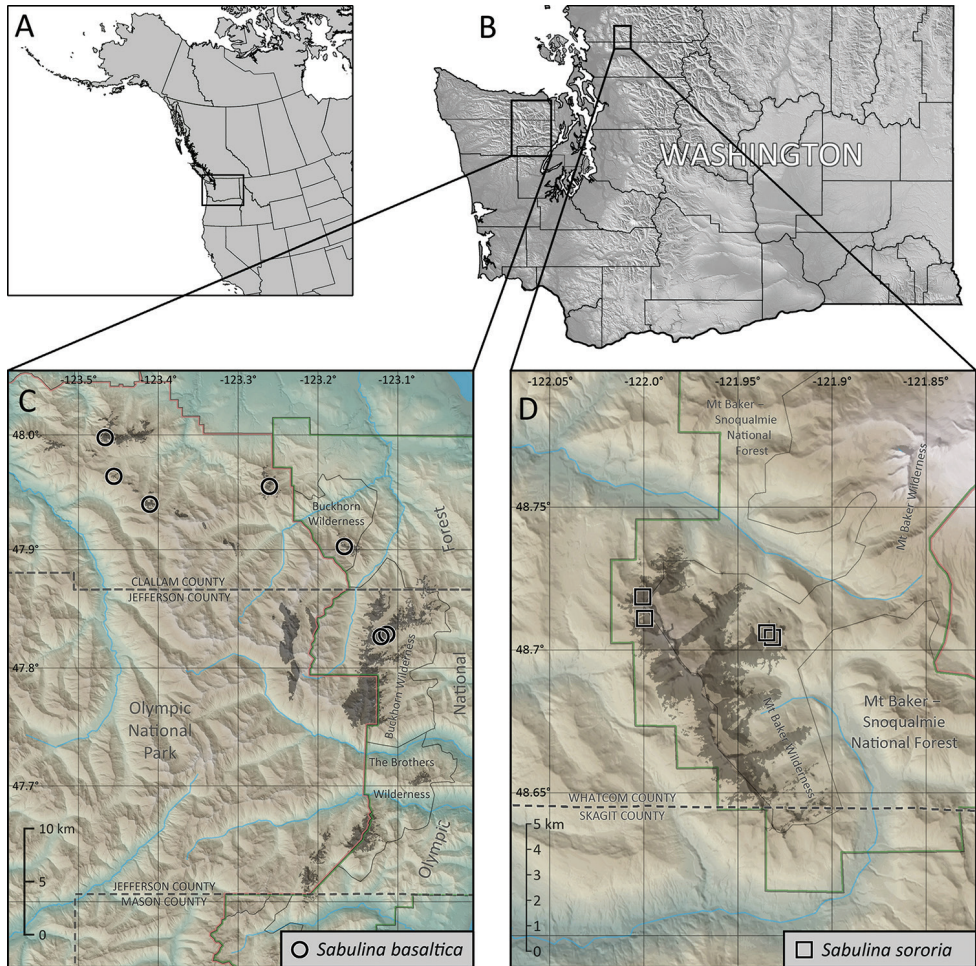


Figure 6. Distribution of *Sabulina basaltica* and *S. sororia*. **A–B** Reference maps of western North America and Washington State, indicating locations of inset maps **C** Known locations for *Sabulina basaltica* (open black circles) within the northeastern Olympic Mountains; gray shading indicates the predicted extent of potential habitat based on exposures of oceanic basalt rocks at subalpine to alpine elevations **D** Known locations for *Sabulina sororia* (open black squares) within the Twin Sisters Range; gray shading indicates the predicted extent of potential habitat based on exposures of dunite rock away from large snowfields at subalpine to alpine elevations.

adjacent ridgelines and slopes hold patches of *Abies lasiocarpa* (Hook.) Nutt., *Callitropis nootkatensis* (D. Don) D.P. Little, *Pinus contorta* Douglas ex Loudon var. *latifolia* Engelm., *Tsuga mertensiana* (Bong.) Carrière, *Juniperus communis* L. var. *kelleyi* R.P. Adams, and *Phyllodoce empetriformis* (Sm.) D. Don. Crustose lichens are sparse, and bryophytes nearly absent.

The southern terminus of the Twin Sisters Range extends slightly into adjacent Skagit County, and 6 km farther to the southeast of this are two smaller dunite bodies

exposed at slightly lower elevation (Tabor et al. 2003). An examination of aerial imagery suggests marginally suitable habitat for *Sabulina sororia* may occur in these areas, though no surveys have been conducted to determine its presence. It seems unlikely that *S. sororia* will be found elsewhere in the Cascades Mountains or over non-dunite rocks; however, small, subalpine exposures of ultramaphic rocks in Skagit and Snohomish counties may warrant investigation.

Phenology. Specimens indicate the flowering period for *Sabulina sororia* extends from mid July to mid August, and fruiting period from early to mid August. The full ranges of flowering and fruiting periods likely vary based on timing of snowmelt and site exposure.

Conservation status. Although apparently restricted to the Twin Sisters Range, *Sabulina sororia* may occur in suitable microsites throughout the upper elevations of the range within an extent of occurrence estimated at ca. 16 km². The total number of plants cannot be estimated due to inadequate sampling across the range, possibly preventing assignment of a formal conservation status at this time. The Twin Sisters Range lies almost fully within the Mt. Baker-Snoqualmie National Forest, and the entire northeastern slope of the range lies within the Mt. Baker Wilderness. No roads or trails penetrate the range, resource extraction is absent from the higher elevations, and very few people visit each year due to difficulty of access. Direct anthropogenic impacts are therefore assumed to be very minimal.

Discussion

Sabulina basaltica and *S. sororia* can be reliably distinguished from each other morphologically (Table 1, and see key), with the differences comparable to those used to distinguish among other members of the *S. rossii* species complex (e.g., leaf length and venation, sepal length and shape, petal length relative to sepals, capsule length, and seed size and color), suggesting they are appropriately recognized at the same taxonomic rank of species. Their recognition as two distinct species is further supported by the absence of plants with intermediate morphology that could not be unambiguously assigned, their disjunct geographic distributions relative to each other (Fig. 6) and all other glabrous, perennial *Sabulina* species, and their unique ecological niches. Attempts to re-circumscribe any of the previously published *Sabulina* taxa to accommodate *S. basaltica* or *S. sororia* would be impractical.

The results of the molecular phylogenetic analyses (Fig. 1) also support the existence of two independent taxa in Washington. *Sabulina sororia* is part of a group of four closely species (*S. rossii*, *S. elegans*, *S. austromontana* and *S. sororia*), while *S. basaltica* is outside of this group (Fig. 1A). In the ITS phylogeny (Fig. 1A), all species are either supported as monophyletic, or the samples are in a polytomy with samples of one or more other species of the *S. rossii* species complex. The two samples of *S. basaltica* are not closely related to other sequenced samples of the complex, but are supported as sister to each other. Given the general pattern, the lack of affinity of *S. basaltica* to

other samples of the *S. rossii* species complex supports the status of *S. basaltica* as an independent species.

ITS sequence data point to an unexpectedly close relationship between *S. sororia* and *S. austromontana* (Fig. 1A) even though they are readily distinguished morphologically (Table 1). The close relationship may indicate that growth form, inflorescence architecture and petal length are labile within the *S. rossii* species complex. An analogous situation is found within the European genus *Facchinia* Rchb., recently split out of *Minuartia* s. lat. by Dillenberger and Kadereit (2014). In that study, *F. cherlerioides* (Sieber) Dillenb. & Kadereit and *F. grignensis* (Rchb.) Dillenb. & Kadereit were unexpectedly resolved as sister species by ITS sequence data, yet they differ substantially from each other in morphology (Dillenberger and Kadereit 2015).

Sabulina basaltica and *S. sororia* resemble, and might be confused with, *S. macrantha* and forms of *S. stricta* found in the southern Rocky Mountains and California, based on shared characters of cymose inflorescences and a similar low growth form with relatively short pedicels. Both of the new species differ from *S. macrantha* by their shorter leaves, shorter sepals, shorter capsules, and smaller seeds with less rugose surfaces, and from *S. stricta* in their markedly longer petals, shorter capsules, and larger, dark reddish-brown to blackish seeds. *Sabulina basaltica* further differs from *S. macrantha* and *S. stricta* in its strongly 3-veined leaves.

Hitchcock et al. (1964) treated both *Sabulina basaltica* and *S. sororia* as *Arenaria rossii* var. *rossii* (= *S. rossii*). This questionable application of name may reflect Hitchcock's preference for conservative, or broad, species concepts (Hitchcock et al. 1955). *Sabulina rossii* is distinguished from both of the new species and all other glabrous, perennial *Sabulina* species in North America by the presence of vegetative propagules formed from tight, readily dislodged axillary or terminal leaf fascicles (in other species the fascicles remain firmly attached). The main stem leaves of *S. rossii* are also typically spreading (vs. ascending) and strongly fleshy with a fleshy sheath, usually giving them the appearance of being connate-perfoliate. The sepals of *S. rossii* are 1-veined, while both *S. basaltica* and *S. sororia* have 3-veined sepals, and flowers in *S. rossii* are strictly solitary (vs. partially cymose). *Sabulina rossii* is restricted to the high arctic, mostly in areas near the Arctic Ocean and adjacent connected waterbodies.

Sabulina rubella (Wahlenb.) Dillenb. & Kadereit, a normally stipitate-glandular species which also occurs in the Cascade and Olympic mountains, very rarely produces glabrous individuals (Rabeler et al. 2005) with a low, tufted growth form and short pedicels (B. Legler, pers. obs.). These plants may be separated from *S. basaltica* and *S. sororia* by their larger capsules (4–4.5 mm), smaller (0.4–0.5 mm), reddish-brown seeds, broadly ovate to elliptic petals abruptly narrowed to the clawed base, and acute to subulate leaf tips. The authors know of no such glabrous plants of *S. rubella* from Washington State.

The close relationship between *Sabulina fontinalis* and the *S. rossii* species complex (Fig. 1) has been noted in other studies (Greenberg and Donoghue 2011, Dillenberger and Kadereit 2014). Here we exclude *S. fontinalis* from the *S. rossii* species complex due to its divergent morphology (e.g., plants annual; stems square in cross-section; leaves to

4 mm wide; flowers mostly 4-merous) which has led previous authors to place *S. fontinalis* variously under *Sagina* L., *Spergula* L., or *Stellaria* L. (e.g., Rabeler et al. 2005).

Several of the characters commonly used to distinguish among glabrous, perennial *Sabulina* taxa in North America warrant further clarification. Leaf veins are usually not visible in fresh material, but upon drying or decaying show a single prominent mid-vein and, in some species, a faint to prominent pair of lateral veins. The inflorescence may consist solely of solitary, terminal flowers not subtended by bracts, or partly to fully of 2–many-flowered, bracteate cymes. However, in several species, including *S. basaltica* and *S. sororia*, one must sometimes use care to look for the 2–several-flowered cymes mixed among the often more numerous solitary flowers. The bracts of cymose inflorescences can usually be distinguished from vegetative leaves by their shorter, proportionately broader shape and thin, scarious margins. Petal length must be used with caution on dried specimens and it should be noted that published descriptions (Maguire 1958, Wolf et al. 1979, Rabeler et al. 2005) appear to under-represent the range of petal lengths for *S. elegans*, *S. michauxii*, and *S. rossii* (Table 1).

The following key includes all glabrous, perennial species of *Sabulina* in North America. Leaf veins should be observed on dried or dead, persisting leaves. Leaf length is for main stem leaves, not axillary fascicles. Sepal veins are often weakly visible on living plants, but become clearly defined on dried specimens. Sepal length is taken at anthesis, as sepals often elongate slightly in fruit. Petal length is for fresh material, and petals may shrink relative to the sepals upon drying; this can be mitigated by carefully arranging and pressing individual flowers between tissue paper.

- 1 Plants reproducing vegetatively by means of tight, readily dislodged, axillary or terminal fascicles of leaves; primary stem leaves mostly widely spreading, strongly fleshy and \pm connate-perfoliate, often purple-tinged, 1-veined, 1–4 mm; flowers often absent; sepals 1.5–2.5 mm, oblong-ovate, weakly 1-veined, purplish; petals 1.2–2 times as long as sepals, or sometimes < sepals or absent; high arctic of eastern Siberia to North America, Greenland, and Spitzbergen... *Sabulina rossii*
- Plants not reproducing by means of readily dislodged vegetative propagules; leaves mostly ascending to appressed, with a scarious to herbaceous sheath, 1- or 3-veined; flowers nearly always produced; sepals and petals various....2
- 2 Petals mostly 1.2–2(–2.5) times as long as the sepals; flowers partly in 2–8(–30)-flowered, terminal cymes (often also some flowers solitary and terminal).....3
- Petals 0.5–1(–1.1) times as long as the sepals, or rudimentary to absent; flowers partly in 2–5(–8)-flowered, terminal cymes, or flowers all solitary and terminal.....6
- 3 Sepals 3–6 mm; main stem leaves 5–30 mm; shoots of current year's growth 2–40 cm; seeds 0.8–1.1 mm, blackish.....4
- Sepals 1.4–2.8(–3.3) mm; main stem leaves 0.6–4(–4.5) mm; shoots of current year's growth 0.5–4 cm; seeds 0.6–0.8 mm, dark reddish-brown to reddish-black.....5

- 4 Inflorescences 5–30-flowered; longer pedicels gen > 15 mm; stems erect to ascending, 8–40 cm; leaves 8–30 mm, tips blunt to pungent; petals 1.3–2 times as long as sepals (or < sepals in northern plants); Great Plains to north-east U.S.A. and southeast Canada ***Sabulina michauxii***
- Inflorescences 1–5(–8)-flowered; longer pedicels 3–15(–20) mm; stems procumbent to ascending, 2–15 cm; leaves 5–10 mm, tips rounded; petals 0.7–1.8 × as long as sepals; Rocky Mountains from Wyoming to New Mexico, west to Nevada ***Sabulina macrantha***
- 5 Leaves 3-veined; sepals (1.6–)2.4–2.8(–3.3) mm, lanceolate to narrowly ovate-lanceolate, (2.4–)3–3.2(–3.5) times as long as wide; mature capsules mostly slightly < sepals; pedicels 1–3.5(–6) mm; plants usually forming dense, tight mats or cushions; crevices of exposed basalt summits; Olympic Mountains, Washington ***Sabulina basaltica***
- Leaves 1-veined; sepals (1.4–)1.7–2.5(–3) mm, ovate to ovate-lanceolate, mostly 1.5–2.5 times as long as wide; mature capsules mostly > sepals; pedicels (1–)2–8(–15) mm; plants mat-forming or trailing; bare dunite rock and gravel; Twin Sisters Range, Washington ***Sabulina sororia***
- 6 Flowers all solitary and terminal at stem tips, not subtended by bracts (uppermost stem leaves not distinct from those below); leaves 1-veined 7
- Flowers partly in 2–15-flowered, bracteate, terminal cymes (often also some flowers solitary and terminal, very rarely all flowers solitary and terminal); bracts generally with thin, scarious margins, often smaller and broader than the stem leaves; leaves 1-veined or weakly 3-veined 8
- 7 Sepals light green, linear-lanceolate to narrowly lanceolate; petals absent or rudimentary (rarely nearly equaling sepals); pedicels 3–15(–20) mm; plants tightly cespitose; Rocky Mountains of southern Canada and northern U.S.A. ***Sabulina austromontana***
- Sepals purplish, lanceolate to ovate-lanceolate; petals usually present (occasionally absent), 0.6–1(–1.1) times as long as sepals; pedicels 10–40 mm; plants loosely tufted to cespitose; eastern Siberia, Alaska, and northwest Canada to Rocky Mountains of central Canada ***Sabulina elegans***
- 8 Seeds 0.7–1.1 mm, blackish, prominently rugose at 10 × magnification; sepals 3–6 mm at anthesis; southeast Canada and eastern U.S.A., or U.S.A. Rocky Mountains **see couplet 4**
- Seeds 0.4–0.6 mm, reddish-brown to blackish, obscurely rugose at 10 × magnification; sepals (1.5–)2–4 mm at anthesis 9
- 9 Inflorescences (2–)7–15-flowered; capsules 3.5–4.5 mm, equaling or longer than sepals; seeds dark brown to blackish; sepals ovate to lanceolate; stems ascending to erect, 4–30 cm; Alaska and much of Canada, south to north-central U.S.A. ***Sabulina dawsonensis***
- Inflorescences 1–3(–5)-flowered; capsules 2.5–3.2 mm, equaling or shorter than sepals; seeds reddish-brown to brown; sepals elliptic-ovate to ovate-lanceolate; stems decumbent to erect, 0.8–12 cm; circumboreal in arctic regions, and disjunct in Colorado and California ***Sabulina stricta***

Sabulina basaltica joins seven other vascular plant taxa endemic to higher elevations of the northeastern and eastern portions of the Olympic Mountains: *Astragalus australis* (L.) Lam. var. *cottonii* (M.E. Jones) S.L. Welsh, *Campanula piperi*, *Erigeron flettii* G.N. Jones, *Petrophytum hendersonii*, *Senecio neowebsteri* S.F. Blake, *Synthyris lanuginosa* (Piper) Pennell & J.W. Thomp., and *Viola flettii*. These are all concentrated on relatively dry, subalpine to alpine rock faces, scree slopes and tundra-like meadows and co-occur with several plant taxa widely disjunct from the Rocky Mountains, such as *Astragalus microcystis* A. Gray, *Carex obtusata* Lilj., and *Oxytropis borealis* DC. var. *viscida* (Nutt.) S.L. Welsh. In general, the vascular plant flora of the Olympic Mountains shows relatively high levels of endemism and floristic similarities to both the Rocky Mountains and coastal and boreal regions of British Columbia and Alaska (Houston et al. 1994, Buckingham et al. 1995). The mountains are disconnected from other high-elevation ranges by encircling lowlands and saltwater.

To explain these patterns it is widely proposed that the northeastern Olympic Mountains acted as a refugium during Pleistocene glacial advances (Buckingham et al. 1995, Houston et al. 1994, Peterson et al. 1997, Gavin et al. 2013). The Cordilleran ice sheet reached a maximum depth of ca. 1000 meters in the lowlands along the northern and eastern sides of the mountains ca. 17,000 yr B.P. (Porter and Swanson 1998), leaving ridgelines well above the ice, while alpine glaciers were concurrently limited by relatively arid regional conditions (Thackray 2001) and had furthermore began retreating from their maximum extent ca. 20,000 yr B.P. (Booth 1987, Thackray 2001). The asynchronous timing of alpine and continental ice undoubtedly led to persistently ice-free areas at high elevations. These areas lie in the rainshadow cast by the bulk of the mountains to the west and remained relatively arid throughout the last glacial maximum and up through the present day (Gavin et al. 2013), potentially providing long-term habitat stability for taxa adapted to dry alpine conditions. As noted by Gavin et al. (2013) and Houston et al. (1994), it is probably no coincidence that the endemic plant taxa in the northeastern Olympics are mostly restricted to the very ridgelines that remained ice-free and relatively dry. *Sabulina basaltica*, likewise adapted to these habitats, may have persisted here through multiple glacial cycles. The lack of a clear close relationship between *S. basaltica* and any other single member of the *S. rossii* species complex (Fig 1A) provides further evidence of long-term isolation, suggesting *S. basaltica* is a paleoendemic.

In contrast, the Twin Sisters Range, where *Sabulina sororia* is endemic, exhibits relatively low species diversity and was previously thought to house no endemic vascular plant taxa (Kruckeberg 2002). This contrasts with relatively high levels of endemism observed in other large exposures of ultramaphic rocks in western North America, including the Wenatchee Mountains in central Washington and the Klamath-Siskiyou region of southwest Oregon and northeast California (Kruckeberg 2002). However, these latter areas lie south of the Cordilleran ice sheet limits and only experienced alpine glaciation at most. The Twin Sisters Range, by comparison, was enveloped on all sides by an ice sheet estimated at its maximum to be ca. 1500–1800 meters deep in the adjacent lowlands to the west (Porter and Swanson 1998) and reaching elevations of

over 2000 meters in the adjacent North Cascade Mountains to the east (Kovanen and Easterbrook 2001), with few peaks apparently remaining above the ice. Observations of non-dunite glacial erratics at just over 1500 m elev. on the Twin Sisters Range (Ragan 1962, Kruckeberg 1991) corroborate these estimates. However, the highest peaks in the range, including North Twin (2012 m) and South Twin (2135 m), reportedly remained above the ice sheet (Ragan 1962), creating a potential refugium. We suspect that *S. sororia*, able to grow on exposed, rocky ridgelines and slopes, may have found suitable habitat within this small refugium to persist in-situ through the last glacial maximum. Alternatively, *S. sororia* may be a neoendemic that colonized and differentiated following the most recent retreat of the ice sheet, as suggested by its close relationship to *S. austromontana* (Fig 1A). Phylogeographic methods may provide means of testing these scenarios.

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Supplementary material 1

Voucher information for herbarium specimens examined

Authors: Ben S. Legler, Markus S. Dillenberger

Data type: occurrence

Explanation note: General information and provenance for herbarium vouchers of *Sabulina* taxa examined for morphological characters and geographic distribution. Included are taxon names, general collection locations, collector names and numbers, herbarium acronyms and accession numbers.

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Link: <https://doi.org/10.3897/phytokeys.81.13106.suppl1>

Supplementary material 2

Sample information and GenBank accessions of sequenced specimens

Authors: Ben S. Legler, Markus S. Dillenberger

Data type: occurrence

Explanation note: Voucher specimens of Caryophyllaceae taxa sequenced for phylogenetic analysis. Included are taxon names, sample extraction numbers, general collection location, collector names and numbers, herbarium acronyms and accession numbers, and GenBank numbers for ITS and trnQ-rps16 sequences.

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Morphometric analysis and bioclimatic distribution of *Glebionis coronaria* s.l. (Asteraceae) in the Mediterranean area

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Abstract

We present a revision of *Glebionis coronaria* in the Mediterranean area based on: a) micro-morphology of the disc floret cypselas observed with a high-resolution confocal microscopy; b) measurements of the disc cypselas with a stereoscopic microscope – duly scaled; c) its distribution in several bioclimatic belts; d) field observations; e) comparisons of herbarium samples. Because of this study, we propose the elevation of *Glebionis coronaria* var. *discolor* to the rank of species, as *Glebionis discolor* **comb. & stat. nov.**, based on morphological and ecological characteristics such as the disposition of the intercostal glands, the size of the disc cypselas wings and its distribution according to the bioclimatic belts. *Glebionis coronaria*, with totally yellow ray florets and intercostal glands aligned, is exclusive to the thermo-Mediterranean bioclimatic belt, while *Glebionis discolor*, with white ray florets on a yellow base and intercostal glands arranged randomly, is found in the thermo- and meso-Mediterranean belt.

Illustrations of micromorphological characteristics of the cypselas, an identification key, a taxonomic synopsis including information on nomenclatural types, synonyms, descriptions of the taxa, and, as supplementary information, a list of the specimens examined and bioclimatic classification of samples localities are also presented.

Keywords

Bioclimatic Distribution, Biogeography, *Glebionis*, Identification Key, Micromorphology, Nomenclature

Introduction

The genus *Glebionis* Cass. ex Spach is present in the Mediterranean area with two species: *Glebionis coronaria* (L.) Cass. ex Spach (= *Chrysanthemum coronarium* L.) and *G. segetum* (L.) Fourr. (= *Chrysanthemum segetum* L.).

For the first species, d'Urville (1822) described the variety with yellow ray florets as *Chrysanthemum coronarium* var. *concolor* d'Urv., and the other with white ray florets with a yellow base as *C. coronarium* var. *discolor* d'Urv. The only character used by d'Urville to distinguish the two varieties was the colour of the ray florets.

Cassini (1826) gave the first description of the genus *Glebionis* based on the species *Chrysanthemum roxburghii* Desf., and published the new combination *Glebionis coronaria* based on *Chrysanthemum coronarium*, which was described later by Spach (1841). Subsequently, Pau described a new species under the name of *Chrysanthemum merinoanum* for the island of Ibiza with the following diagnosis: “Intermedio entre el *coronarium* y el *segetum*, pero más afine del primero, del cual difiere por las hojas simplemente pinado-cortadas; los aquenios son muy parecidos, pero carecen de alas tan pronunciadas, y sólo llevan una. lígulas blanquecinas, en la base amarillas, apenas festonadas en la terminación;....” (Pau 1899). Recently, Rosselló and Sáez (2001) designated a lectotype of *C. merinoanum* Pau (MA 128240) from a specimen collected by Pau on the island of Ibiza, emphasizing that the type material is indistinguishable from other Balearic and Spanish accessions of *C. coronarium* L.

Many authors recognize these two different entities (Fiori 1923, Rechinger 1936, Valdés et al. 1987, Vogt and Aparicio 1999, Bacchetta 2006, Sell 2006, Abd El-Twab et al. 2008, Chilton and Turland 2008, Cano et al. 2012, 2013). Turland (2004) proposes to maintain the name *Chrysanthemum coronarium* L. as the conserved name to designate the type of *Chrysanthemum coronarium* L. [Typus: Greece, Kriti (Crete): Nomos Irakliou, Eparhia Kenourgion, 500 m E of Gangales, E side of road to Vali (35°03'39"N, 25°00'57"E), 250 m, large field with *Hordeum* crop, 13 Apr 2003, Kyr-iakopoulos & Turland sub Turland 1166 (UPA; isotypi: B, BM, MO), typ. cons. Humphries (in Jarvis et al., *Regnum Veg.* 127: 33. 1993)] previously proposed a lectotype of *Chrysanthemum coronarium* after the lectotypification of Dillon (Herb. Clifford: 416, *Chrysanthemum* no. 1, fol. 1 – BM). However, this specimen cannot be used for the lectotypification as it clearly presents ray florets with a darker base.

Turland (l.c.) also confirmed the differentiation of the two varieties and proposed a new combination under the name of *Glebionis coronaria* var. *discolor* (d'Urv.) Turland (Basionym: *Chrysanthemum coronarium* var. *discolor* d'Urv. in *Mém. Soc. Linn. Paris* 1: 368. 1822). Turland (l.c.) notes that the two entities appear to be widespread in the Mediterranean region and show no obvious correlation with geographic distribution.

From the karyological point of view the two varieties of *G. coronaria* are both diploid, with $2n = 18$ (Pavone et al. 1981 Strother and Watson 1997, Vogt and Aparicio 1999, Inceer and Hayirlioglu-Ayaz 2007, Paciolla et al. 2010, Lograda et al. 2013). Abd El-Twab et al. (2008) confirm this account and point out that the chromosome complement of *G. coronaria* consists of 18 median-centromeric chromosomes, while *G. coronaria* var. *discolor* consists of 16 median- and 2 sub-median-centromeric chromosomes.

The aims of this paper were: (a) to highlight and compare some important micro-morphological characters of the two entities of *Glebionis coronaria*; (b) to relate their taxonomic differences with their bioclimatic characteristics; (c) to indicate new informative characters for identification of these two taxa; (d) to prepare a key, make a more complete description and provide notes on ecology and distribution of these two entities.

Methods

Sampling areas

To clarify the morphological and ecological characters of the two varieties, we carried out several samplings in different areas of the Mediterranean basin: Sicily, southern Italian Peninsula (Calabria), and Iberian Peninsula (southern Spain and Portugal) (Fig. 1).

The sampling was on bioclimatic criteria and according to the climate classification of Rivas-Martínez and Rivas-Saenz (1996-2009). A statistical analysis was performed with T-Student to establish a possible relationship between the two entities and bioclimatic belts.

Plant material

A micro- and macro-morphological study was made of sampled plants from pure non mixed populations. All the specimens collected in the field are conserved in the herbaria of Jaén (JAEN) and Reggio Calabria (REGGIO). We have also consulted the following herbaria which have specimens proceeding from eastern Mediterranean regions, the source location of the species originally described by Linnaeus: REGGIO, JAEN, FI, MS, CAT, SEV, VAL, COFC, MA. All 194 examined specimens are listed alphabetically by country in Appendix 1.

Seeds of *G. coronaria* var. *coronaria* obtained from pure populations in southern Portugal and Sicily and seeds of *G. coronaria* var. *discolor* obtained from pure populations in Jaén (Spain) were cultivated for three years. Both specimens were cultivated in the thermo-Mediterranean town of Andújar (Spain) and in the meso-Mediterranean town of Jaén, where they were grown separately and together to determine their vigour and the permanence of the characters.

High-resolution confocal microscopy was used to study the micro-morphology of the disc floret cypselas. A total of 880 cypselas (322 of the entity with yellow ray florets and



Figure 1. Sampling areas.

558 of the entity of white ray florets) were measured by taking images with a stereoscopic microscope –duly scaled– of both entities from different populations of plants cultivated in Portugal, Spain and Italy. The measurements were based on several observations ranging from 296 for the variety with yellow ray florets, to 425 for the variety with white ray florets; a statistical treatment was then applied using the XLSTAT programme.

Using these samples, measurements were taken of the length and width of the disc cypselas (excluding ventral and dorsal wings) and the width of the ventral wings (Table 1). We added a measure of the glands dispersion in each cavity formed between the ribs of the disc cypselas. To measure the degree of glands dispersion, a linearity coefficient (Lc) is proposed. A two-pixel wide straight line was drawn on the image between the two most separated glands in length within the group. The glands in contact with the straight line (A) were counted, and these glands were related to all the glands occupying the cavity (T). For cypselas whose morphology was not straight, but whose glands were aligned, two or more lines were used to count the aligned glands, applying a correction factor depending on the number of lines used (C). The formula and its correction are as follows:

$$Lc = (A-1)/T - (C-1)/A,$$

where (C-1)/A is the correction factor. If only one line is used, it is = 0.

Lc	Linearity coefficient
A	Aligned glands
T	Number of glands in the valley
C	Number of straight lines used

Table 1. Disc cypsela measurements of *Glebionis coronaria* and *G. discolor* comb. & stat. nov.

Characters	Parameters	Species	
		<i>G. coronaria</i>	<i>G. discolor</i>
Wing Width	No. observations	298	425
	Mean (mm)	0.741	0.557
	Int. for the mean of 95% (mm)	(0.719; 0.762)	(0.543;0.572)
	Student's test p value	< 0.01	
	Z test p value	< 0.01	
Disc Cypsela Width Without Wing	No. observations	315	425
	Mean (mm)	1.960	1.932
	Int. for the mean of 95% (mm)	(1.905; 2.015)	(1.856; 2.007)
	Student's test p value	0.552	
	Z test p value	0.552	
Disc Cypsela Length	No. observations	313	424
	Mean (mm)	2.740	2.830
	Int. for the mean of 95% (mm)	(2.678; 2.803)	(2.792; 2.868)
	Student's test p value	0.016	
	Z test p value	0.016	
Linearity Coefficient (Lc)	No. observations	193	356
	Mean	0.683	0.473
	Int. for the mean of 95%	(0.661; 0.706)	(0.455; 0.490)
	Student's test p value	< 0.01	
	Z test p value	< 0.01	
Ratio Cypsela-Wing Width	No. observations	296	425
	Mean	2.771	3.740
	Int. for the mean of 95%	(2.676; 2.866)	(3.556; 3.923)
	Student's test p value	< 0.01	
	Z test p value	< 0.01	

Results

To verify the observations made in the field, both varieties (from pure populations in different regions) were cultivated from seeds in the two bioclimatic belts for three years. In the thermo-Mediterranean belt, the seeds of both entities sprouted and produced plants that maintained their characters unchanged from year to year. In the meso-Mediterranean belt both seed entities sprouted initially; however only the white floret variety completed its life cycle and maintained its characters.

According to Heywood (1976), sessile non-mucilaginous glands are present between the ribs of cypselas in both varieties. However, after careful observation (Tab. 1), we noticed that in the variety with yellow ray florets these glands were neatly arranged between the ribs (Fig. 2a), while they were disordered in the variety with white ray florets (Fig. 2b).

Other characters that differentiate the two entities are the width and shape of the abaxial wing of the disc floret cypselas. In the yellow floret variety, this wing is wider

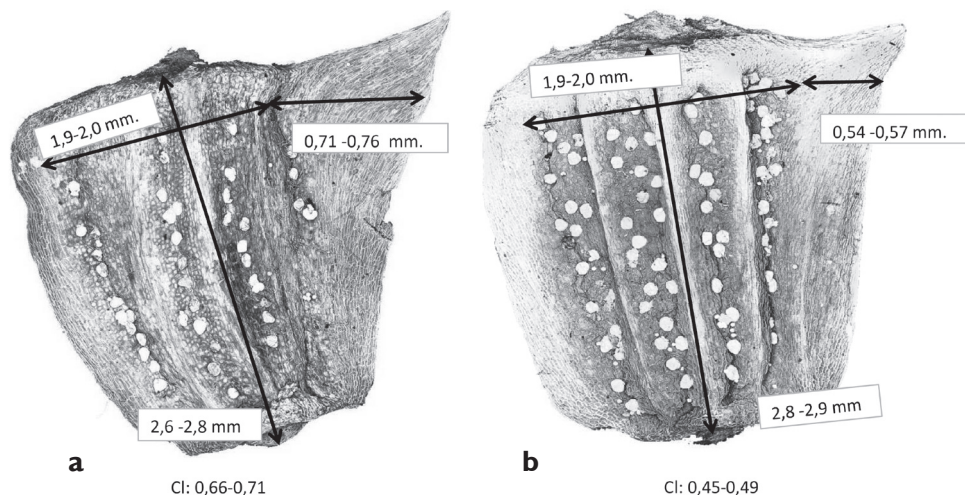


Figure 2. Disc cypselas of *Glebionis coronaria* (a) and *G. discolor* (b) photographed with high-resolution confocal microscopy.

and the distal tip is facing upward, while in the white floret variety it is narrower and not facing upward (Table 1, Fig. 2a–b).

Both the arrangement of the glands in the intercostal spaces and the wing width are good characters—among others—for differentiating the two entities, as can be seen from the statistical study (Figs 3, 4). The linearity coefficient was used to measure objectively the arrangement of the glands in the intercostal spaces.

In the boxplot (Fig. 3), the Linearity coefficient of the glands present in the intercostal valleys of the inner cypselas can be observed. In both species, they do not overlap, so it is an important differentiator character: it is therefore that both taxa present morphological differences in the arrangement of the glands.

As for the boxplot analysis of the wing width measurements of the cypselas (Fig. 4), it is observed as this character is also different in both taxa, by not overlapping measures significantly and having a bounded variance.

However, the ratio cypselas-wing width (Fig. 5), the measures of width (Fig. 6) and length (Fig. 7) of the disc cypselas, are not adequate parameters to differentiate both taxa, since the overlap of the measurements is evident. Although the cypselas length is statistically different between both taxa, as can be seen in Table 1.

An average confidence interval of 95% was used in the statistical treatment. A parametric distribution analysis was applied and gave a P-value with a significance of less than 0.05 in the Student's T test and the Z test. The margin of error is < 1.62 % in the case of the length of the disc cypselas, and < 0.01% for the arrangement of glands (linearity) and the ratio cypselas-wing width of the disc cypselas (Table 1).

In the analysis of the width of the disc cypselas for the two species, the P value is > 0.05, The character of width and length of disc cypselas therefore does not have much strength in differentiating the species (Figs 6, 7).

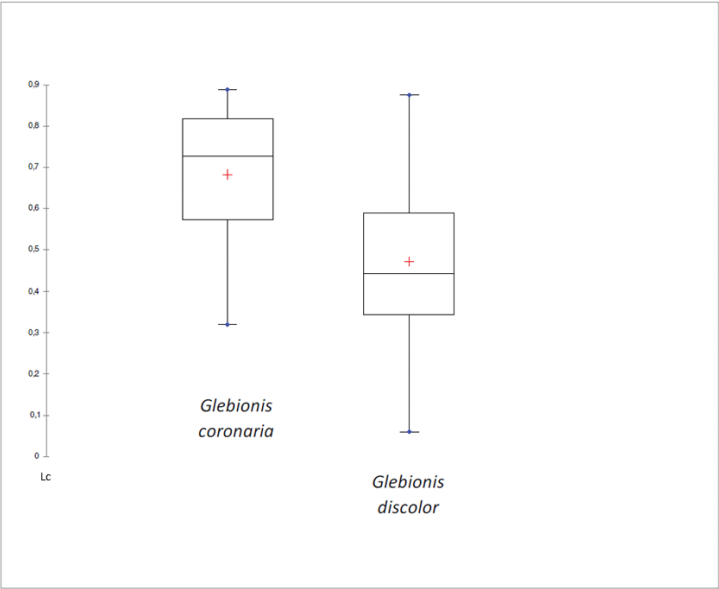


Figure 3. Box plot of alignment of glands distributed along the cypsels of *Glebionis coronaria* and *G. discolor* (Lc = Linearity coefficient).

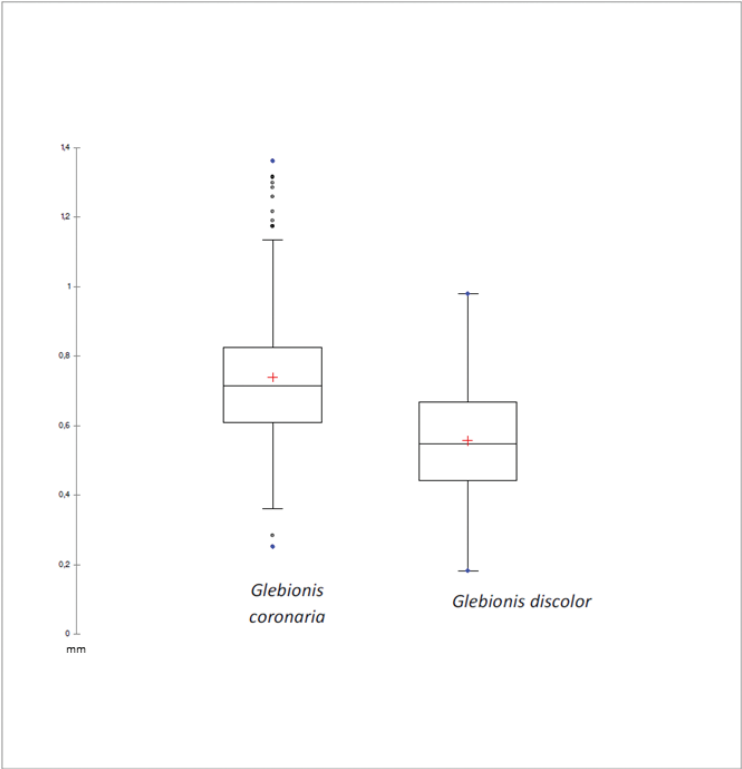


Figure 4. Statistical analysis by box plot of cypsels wing width of *Glebionis coronaria* and *G. discolor*.

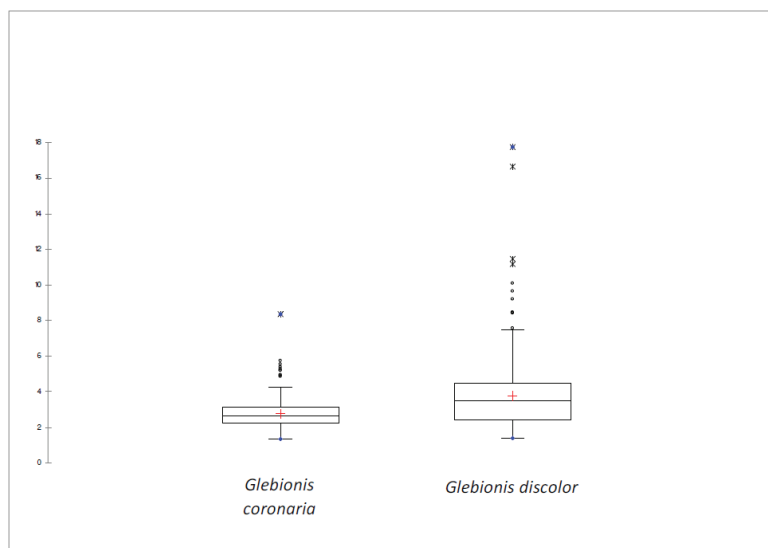


Figure 5. Statistical analysis by box plot of ratio cypselae-wing width of *Glebionis coronaria* and *G. discolor*.

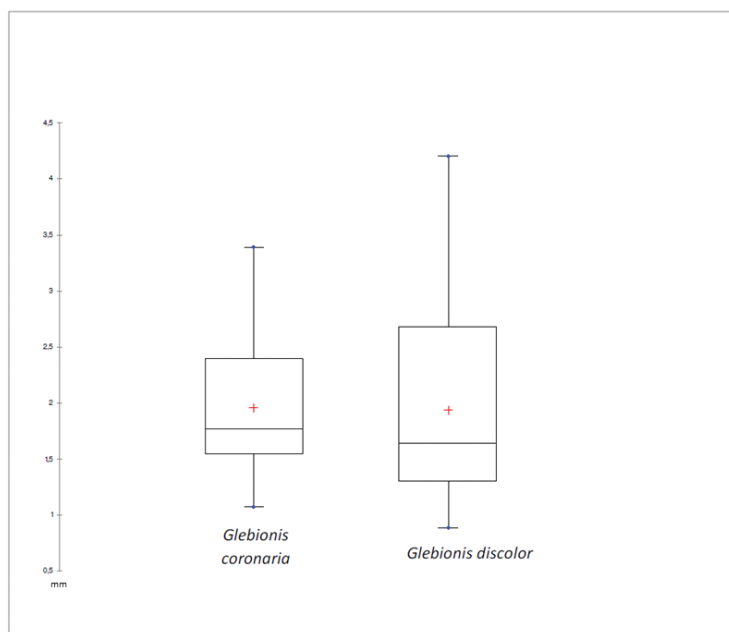


Figure 6. Statistical analysis by box plot of disc cypselae width of *Glebionis coronaria* and *G. discolor*.

According to the Worldwide Bioclimatic Classification System proposed by Rivas-Martínez and Rivas-Saenz (1996-2009), the localities in which the two *Glebionis coronaria* entities were sampled, fall in two bioclimatic belts: thermo-Mediterranean and meso-Mediterranean [Fig. 8 and Appendix 2].

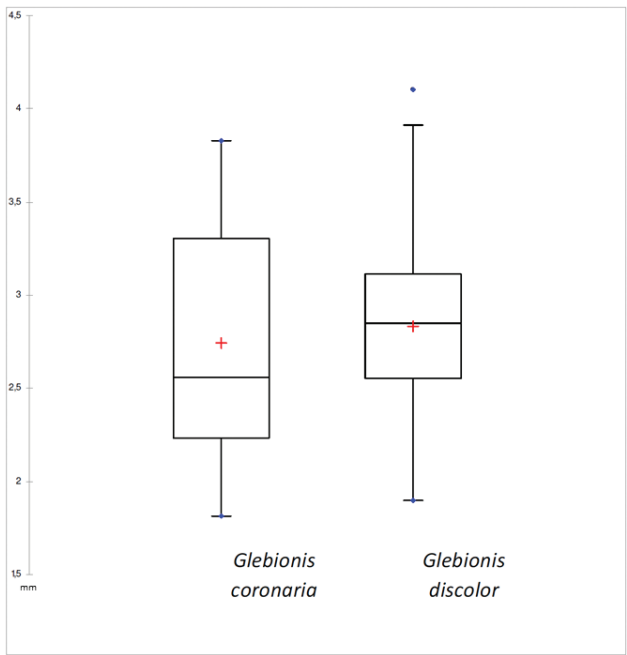


Figure 7. Statistical analysis by box plot of disc cypselas length of *Glebionis coronaria* and *G. discolor*.

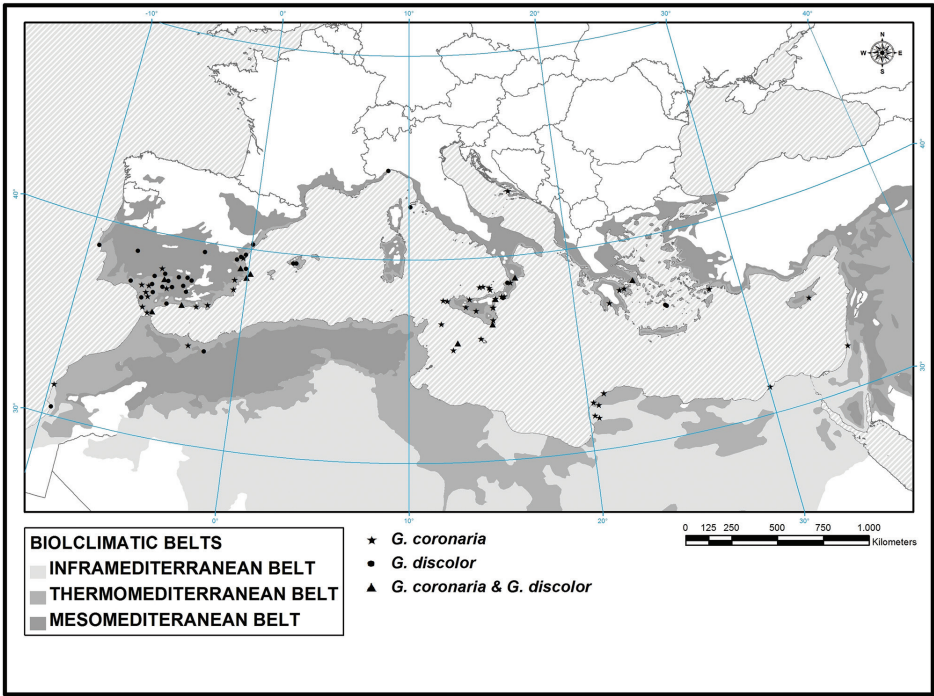


Figure 8. Thermoclimatic distribution of *Glebionis coronaria* (thermo-Mediterranean) and *G. discolor* (thermo and meso-Mediterranean) selected samples studied.

Table 2. Distribution of *Glebionis coronaria* and *G. discolor* comb. & stat. nov. selected samples studied, related to the different bioclimatic belts.

Bioclimatic belts	N. localities	<i>G. coronaria</i>		<i>G. discolor</i>		Total n. of samples
		N. of samples	%	N. of samples	%	
Upper Infra-Mediterranean	11	10	91%	2	18%	12
Lower thermo-Mediterranean	32	27	84%	11	34%	38
Upper thermo-Mediterranean	50	25	50%	28	56%	53
Lower meso-Mediterranean	25	8	32%	19	76%	27
Upper meso-Mediterranean	4	1	25%	3	75%	4
Lower meso-Temperate	1	0	0%	1	100%	1
Total	123	71		64		135

The thermo-Mediterranean belt is differentiated into the lower (with 400 <Itc <450) and upper thermo-Mediterranean belt (350 <Itc <400). We have collected both *G. coronaria* entities in pure and/or mixed populations in these belts.

Specifically, *G. coronaria* var. *coronaria* was sampled in 84% of the 32 stations in the thermo-Mediterranean belt, while *G. coronaria* var. *discolor* was sampled in 34% (Table 2).

The two entities are more or less equally distributed in 50 stations in the upper thermo-Mediterranean belt: *G. coronaria* var. *coronaria* was sampled in 50% and *G. coronaria* var. *discolor* was sampled in 56% (Table 2).

G. coronaria var. *coronaria* was sampled in 32% of the 25 stations in the lower meso-Mediterranean bioclimatic belt (285 <Itc <350), while *G. coronaria* var. *discolor* was sampled in 76% (Table 2).

Only *G. coronaria* var. *discolor* was sampled in the single station in the lower meso-temperate belt (Table 2).

On this basis, the application of the X² test (=0,00247) highlighted the high significance of the preferential distribution of *G. coronaria* var. *coronaria* samples in the warmer belts (infra- and lower thermomediterranean), while *G. coronaria* var. *discolor* was observed to have a significantly greater presence in cooler belts (meso- and upper thermomediterranean) than *G. coronaria* var. *coronaria*.

Discussion

D’Urville (1822) describes two varieties of *Chrysanthemum coronarium* –*discolor* and *concolor*– taking into consideration only the external female ray floret colour.

Specimens with totally yellow ray florets are now treated as *Glebionis coronaria* (L.) Cass. ex Spach. Also, Turland (2004) considers these two entities as distinct taxa treated at the rank of variety, and proposes a new combination in *Glebionis coronaria* for var. *discolor* (*Glebionis coronaria* var. *discolor* (d’Urv.) Turland, comb. nov. – Basionym: *Chrysanthemum coronarium* var. *discolor* d’Urv. in Mém. Soc. Linn. Paris 1: 368. 1822). This author also maintains that the two varieties may appear in independent

or mixed populations, with no difference in distribution. We cannot agree with this author, as our sampling carried out in Sicily, southern Italy, Spain and Portugal, and our observations of specimens from Great Britain (Gibraltar), France, Croatia, Greece, Turkey, Cyprus, Malta, Israel, Egypt, Morocco and Libya reveal that the *G. coronaria* var. *coronaria* is distributed exclusively throughout the whole of the thermo-Mediterranean belt with thermo-climatic values of $It/Itc = 350-450$; while *G. coronaria* var. *discolor* is found throughout the thermo- and meso-Mediterranean belt with values of $It/Itc = 220-350$ (Tab. 2), but it is more represented in percentage terms in stations in the meso-Mediterranean belt.

An entity at the specific level of *Chrysanthemum* with bicolour ray florets was previously described by Pau (1899) as *C. merinoanum*. In our opinion, this species is different from *Chrysanthemum coronarium* var. *discolor* d'Urville. According to the analysis of the herbarium sample (MA 128240) and from the description given by Pau (1899): "Intermedio entre el *coronarium* y *segetum*.... lígulas blanquecinas...; aquenios calvos, los externos trigonos con una sola ala...", *C. merinoanum* Pau is a probable hybrid of *C. coronarium* var. *discolor* and *C. segetum*. In fact, *C. coronarium* var. *discolor* lacks the characters of *C. segetum* and has external cypselas with two wings and two dorsal ribs. *C. merinoanum*, however, has only one wing on the cypselas and leaves that are clearly like those of *C. segetum*.

Moreover, our studies on the morphology of disc cypselas using high-resolution confocal microscopy, morphometric analysis and statistical techniques have revealed sufficient differences to justify raising the variety to a higher rank. Since two subspecies cannot coexist in the same geographic area and even less in the same habitat (criterion of allopatry), we consider them to be two distinct species.

For all these reasons, we propose a lectotypification and a change in rank for *Chrysanthemum coronarium* var. *discolor* d'Urville. The two species are listed below, with their differential characteristics highlighted.

Conclusions

The two entities traditionally included in *Glebionis coronaria* (L.) Cass. ex Spach based on external female ray floret colour have differences in their morphological and ecological features that enable them to be attributed to two different species.

In the study of the material collected in the Mediterranean area, we can confirm that the two varieties given by d'Urville (1822) present major differences in their micro- and macro-morphological characters and their distribution. Moreover, the aforementioned characters of the cypselas are very important for the determination of herbarium specimens, as the colours of the ray florets do not persist when the plants are dried.

Since *Glebionis coronaria* is conserved in the form of plants with yellow ray florets, corresponding to *Chrysanthemum coronarium* var. *concolor* d'Urv. and necessarily to *G. coronaria* var. *coronaria*, we establish a change of rank for the var. *discolor* d'Urv. Both

entities present clear differences in the colour of their ray florets, the shape and size of their disc cypselas and in the disposition of their glands. For this reason, based strictly on the ICN (McNeill et al. 2012), we maintain the species *Glebionis coronaria* and propose *G. discolor* comb. & stat. nov.

Taxonomic treatment

Identification key

- 1 Glabrous plant. Female ray florets with completely yellow limb. Disc cypselas 2.6–2.8 mm long, with a pronounced wing (average width 0.71–0.76 mm) and intercostal glands aligned. Species distributed mainly throughout the thermo-Mediterranean bioclimatic belt ***G. coronaria***
- Plants frequently puberulous. Female ray florets white with a yellow base. Disc cypselas 2.8–2.9 mm long with poorly pronounced wings (average width 0.54–0.57 mm) and intercostal glands arranged randomly. Species distributed throughout the thermo-Mediterranean and meso-Mediterranean bioclimatic belt ***G. discolor***

Taxonomic synopsis

***Glebionis coronaria* (L.) Cass. ex Spach, Hist. Nat. Vég. 10: 181. 1841**

≡ *Chrysanthemum coronarium* L., Sp. Pl.: 890. 1753, *nom. cons.* ≡ *Pyrethrum indicum* Roxb. ex Sims 1813 ≡ *Chrysanthemum coronarium* var. *concolor* d'Urv. in Mém. Soc. Linn. Paris 1: 368. 1822 ≡ *Chrysanthemum roxburghii* Desf. 1829 ≡ *Pinardia coronaria* (L.) Less., Syn. Gen. Compos.: 255. 1832 ≡ *Xanthophthalmum coronarium* (L.) P. D. Sell in Sell and Murrell, Fl. Great Britain & Ireland 4: 556, 2006. Typus [by Turland (2004)]: Greece, Kriti (Crete): Nomos Irakliou, Eparhia Kenourgiou, 500 m E of Gangales, E side of road to Vali (35°03'39"N, 25°00'57"E), 250 m, large field with *Hordeum* crop, 13 Apr 2003, Kyriakopoulos & Turland sub Turland 1166 (UPA; isotypi: B, BM, MO).

Note. *Glabrous plant.* Stems branched, tall 20–80 cm. Leaves semi-amplexicaul, oblong or obovate, 2-pinnatisect with oblong or lanceolate segments. Involucre 10–20 mm long; outer bracts ovate, with brownish marginal bands with a whitish scarious margin; inner bracts without marginal bands but with wider scarious margins. Female ray florets with completely yellow limb. Disc cypselas 2.6–2.8 mm long, with a pronounced wing (average width 0.71–0.76 mm) and intercostal glands aligned (Table 1, Fig. 2a). $2n = 18$.

Habitat. Cultivated grounds, along the ways and waste places.

Bioclimatic distribution. Species distributed mainly throughout the thermo-Mediterranean bioclimatic belt.

***Glebionis discolor* (d'Urv.) Cano, Musarella, Cano-Ortiz, Piñar Fuentes, Spampinato & Pinto Gomes comb. & stat. nov.**

urn:lsid:ipni.org:names:77163641-1

Basionym: *Chrysanthemum coronarium* var. *discolor* d'Urv. in Mém. Soc. Linn. Paris 1: 368. 1822). \equiv *Chrysanthemum coronarium* subsp. *discolor* (d'Urv.) Rech. f. in Beih. Bot. Centralbl. 54B: 634. 1936 \equiv *Glebionis coronaria* var. *discolor* (d'Urv.) Turland in Taxon 53: 1073. 2004. Lectotype designated here: Greece, Melos, 05/1819, D'Urville (K 000929476).

Note. Like *G. coronaria* but plants frequently puberulous. Female ray florets white with a yellow base. Disc cypselas 2.8–2.9 mm long, with poorly pronounced wings (average width 0.54–0.57 mm) and intercostal glands arranged randomly (Table 1, Fig. 2b). $2n = 18$.

Habitat. Cultivated grounds, along the ways and waste places.

Bioclimatic distribution. Species distributed throughout the thermo-Mediterranean and meso-Mediterranean bioclimatic belt.

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Appendix I

Selected specimens examined of *Glebionis coronaria*, *G. discolor* comb. & stat. nov. and *Chrysanthemum merinoanum*.

Glebionis coronaria:

- ALGERIA. Hab. in ditione urbis Alger, loco dicto Kouba, 1879, *M. Gandoger* n° 499 (FI); recolté aux env. de Bone, Herbages, 21 april 1972 *A. Chabert* (FI); Oran, 1892, *Debaux* (FI).
- CROATIA. Dalmazia – Lesina, marzo 1882, *Marchesetti* (FI); Dalmazia – Pelagosa, marzo 1882, *Marchesetti* (FI).
- CYPRUS. In campis prope Larnaka vetus, Iul. 1880, *Sintenis et Rigo* 807 (FI); Ayia-Anna (Larnaca), Altim. 150 m, bords de culture sur substrat de calcaires et marnes du Paléogène, 15-04-1991, *Alziar et al.* (FI); entre Xylophagou et Ayia Thekla (Larnaca), altim. 5m, champ (blé) abandonné, et pseudosteppe à *Sarcopoterium*, 12-IV-1991, *Alziar et al.* (FI).
- EGYPT. Ramle presso Alessandria, marzo 1898, *Marchesetti* (FI); ...del porto di Alessandria che segue il litorale della regione di Ramle ed Abuhir, maggio 1867, *Figari* (FI); barbus field, sandy soil, Burg El Arabi, W. Medit Coast. 30.3.1957,... (FI).
- FRANCE. Pyrenées, in cultis, marzo 1848, *Franqueville* (FI).
- GREAT BRITAIN. **Gibraltar**: Catalan Bay, arenas mezcladas con rocas calizas, 16 may 1985, *J. Bensusan, S. Talavera, B. Valdés* 124741 (SEV).
- GREECE. Kriti (Crete), Nomos Irakliou, Eparhia Kenourgion, 500 m E of Gargales, E side of road to Vali (35°03'39"N, 25°00'57"E), 250 m, large field with Hordeum crop, 13 Apr 2003, Kyriakopoulos & Turland sub Turland 1166 (MO 5792988); In ruderalis, ad vias Graeciae, Athenis 8 april 1852, *Heldreich* (FI). Rodi-Egeo, San Giovanni, 1934, ... (FI).

- ISRAEL. Ramath-Gan, near Tel-Aviv, field borders, 12.IV.1928, *N. Feinbrun*, *L. Schachnowitz et D. Soltchansky* (FI).
- ITALY. **Calabria:** Torrente Fiumarella, Pellaro (Reggio Calabria), 11m, 38°01'14,89"N, 15°38'42.95"E, 19 May 2012, *C.M. Musarella*, 4179/1-2-3-4 (REGGIO); Torrente Fiumarella, Pellaro (Reggio Calabria), 11m, 38°01'14,89"N, 15°38'42.95"E, 19 May 2012, *C.M. Musarella*, 130106-130107-130108 (JAEN); S. Nicola da Crissa, Serre (Vibo Valentia), 10 June 2005, *Spampinato G.* 2331 (REGGIO); SP 3 km 48, 741 m slm, sopra Bagaladi (Reggio Calabria), 23 May 2013, *Cano, Musarella, Mendoza, Piñar-Fuentes* 4181; Catanzaro, nei campi lungo le siepi e i sentieri sotto Bellavista (fondo Tubolo, proprietà Arbitrio), maggio-giugno 1895, *L. Micheletti* (FI); dintorni di Catanzaro, 4/6/1883, *A. Fiori* (FI); Catanzaro, lungo le siepi e i sentieri sotto Bellavista, maggio 1895, *L. Micheletti* (FI). **Sicily:** Monte Kalfa (Messina), 24 February 2001, *A. D'Arrigo* 000896 (MS); M. Grasso (Siracusa), 08 April 1989, *Bartolo G., Pulvirenti S.* 3002 (CAT); Fiume Ferro (Catania), 01 June 1985, *Spampinato G.* 3003 (CAT); Piana di Catania, 01 August 1957, 3004 (CAT); Lipari (Isole Eolie, Messina), 27 April 1982, *Brullo S.* 3008 (CAT); Lampedusa (Isole Pelagie, Agrigento), 18 March 1985, *Brullo S., Minissale P., Spampinato G.* 3009 (CAT); M. Mela (Agrigento), 25 April 1969, *Brullo S.* 3010 (CAT); Isole Eolie, Messina, 31 May 1980, *Brullo S.* 3011 (CAT); Alicudi (Lipari, Cava di Pomice (Isole Eolie, Messina), 13 May 1972, *Brullo S.* 3012 (CAT); da Piano Conte alla Terme di San Calogero (Isole Eolie, Messina), 28 May 1969, *Furnari F.* 3013 (CAT); Filicudi (Isole Eolie, Messina), 30 April 1980, *Brullo S.* 3014 (CAT); Termini Imerese, Fiume Imera (Palermo), 27 April 1983, *Brullo S.* 3015 (CAT); Pantano Longarini, Pozzallo (Ragusa), 25 April 1969, *Brullo S.* 3017 (CAT); Favignana (Isole Egadi, Trapani), 14 April 1973, *Brullo S.* 3018 (CAT); Noto (Siracusa), 16 May 1980, *Brullo S.* 3019 (CAT); Linosa, ad oras et in culti (ligulae concolores), 24 aprili 1873, *S. Sommier* (FI); Insula Linosa (olim Aethusa) prope portum, 1 Martii 1906 legi, *Stephen Sommier* (FI); Insula Lampedusa (olim Lopadusa) prope portum vulgata, 08 martii 1906 legi, *Stephen Sommier* (FI); Insula Pantelleria (olim Cossyra), Alle Balate, In insula vulgata, 16 Martii 1906 legi, *Stephen Sommier* (FI); Caltanissetta, IV 1893, *A. Fiori* 03 (FI); Insula Linosa (olim Aethusa) prope paguis, 1 Martii 1906 legi, *Stephen Sommier* (FI); Marettimo, gita dal faro a Capo Troja, 27/04/1935, , (FI). **Sardinia:** Quartu Sant'Elena, San Forzorio sponda E dello Stagno di Simbirizzi, 19 Maggio 1065, *G. Martinoli, T. Onnis* (FI).
- LIBYA. **Cyrenaica:** Tolmeta, 17 March 1975, *Brullo S., Furnari F.* 3022 (CAT); Spiaggia Sini Bu Giarrar, 20 March 1974, *Brullo S., Furnari F.* 3023 (CAT); Scavi di Tolmeta, 11 May 1974, *Brullo S., Furnari F.* 3024 (CAT); Driana, 31 March 1974, *Brullo S., Furnari F.* 3025 (CAT); Tolmeta, scavi, 28 March 1974, *Brullo S., Furnari F.* 3026 (CAT); Tolmeta, 9 March 1975, *Brullo S., Furnari F.* 3028 (CAT); Zona alta di Wadi el – Bab, 05 March 1982, *Furnari F., Signorello P.* 3029 (CAT); Driana, 28 March 1981, *Brullo S., Furnari F.* 3031 (CAT); Tolmeta, 11 March 1974, *Brullo S., Furnari F.* 3032 (CAT); Tolmeta Scavi, 24 March 1974,

- Brullo S., Furnari F. 3033* (CAT); Sebelet Bu Giarrar, 20 March 1974, *Brullo S., Furnari F. 3034* (CAT); El Abiar, 01 April 1974, *Brullo S., Furnari F. 3035* (CAT); Got el Gein, 06 May 1974, *Brullo S., Furnari F. 3036* (CAT); Tocra, 01 April 1974, *Brullo S., Furnari F. 3042* (CAT); Piana di Soluq – ana, 10 March 1982, *Furnari F., Signorello P. 3045* (CAT); Rabiati al Magur (Msus), 02 April 1981, *Brullo S., Furnari F. 3046* (CAT); Sebelet el Cuz, 03 April 1974, *Brullo S., Furnari F. 3041* (CAT); Carrhuba, 01 April 1975, *Brullo S., Furnari F. 3044* (CAT).
- MALTA. **Comino:** Insula Comino, 24 aprilis 1907 legi, *Stephen Sommier n° 390* (FI); Melitae in campis et agris, agosto 1848, *G.C. Grech-Delicata* (FI); Insula Gaulos, 4/8/1874, *J.F. Duthie* (FI);
 - MOROCCO. Nador, Plain de Gereb, 36 Km from Selouane, road to Mechrâ-Homadi, Marls and limestones, slopes and dried river bed, 31 May 1993, 400m., 34°50'N 2°52'W, *M. A. Mateos et B. Valdés 150086* (SEV); entre Mogador et Maroc, Ibrahim, 1883, *Cosson* (FI).
 - PORTUGAL. In insula Azorre, marzo 1838, *Guthnick* (FI); communicated from the Island of Terceira, Azores, by T.C. Hunt, Esq., British Consul., 8-1846, *A. Chabert* (FI); Albufeira-Gralheira, por entre as rochas calcárias, 23/4/1968, *I. Nogueira* (FI).
 - SPAIN. **Andalucía:** Almuñecar, en cunetas y bordes de camino y carreteras, a la salida de la población (Granada), 5m, 30SVF47, 28 May 1982, *Marín Calderón y Hurtado 851975* (JAEN); Almuñeca Punta de la Mona (Granada), 10 m, 6 June 1974, *C. Fernandez Lopez 74-1621* (JAEN); alrededores de Alcalá de Guadaira (Sevilla), 6 March 1975, *R. de Clavijo 64849* (SEV); Alrededores Puente Genil, Entre Puente Genil, Jauja, Río Anzur (Cordoba), 18 April 1980, *Díaz et Muñoz 63449* (SEV); Tarifa, E. side of causeway (Cadiz), 27 March 1969, *V. H. Heywood, D. M. Moore et al. 13695* (SEV); Las Cabezas, Autopista Sevilla-Cádiz (Sevilla), 30 April 1979, *E. F. Galiano, A. Ramos et E. Elvira 63744* (SEV); Conquero (Huesca), 12 May 1979, *P. Romero et al. 52401* (SEV); entre Arcos y Bornos. Carretera a la presa del pantano de Bornos. Bajura, tierras de aluvión (Cadiz), 50-100 m, TF75, 9 May 1980, *A. Martínez 63743* (SEV); Vejer (Cadiz), 4 May 1969, *E. F. Galiano, Gibbs, S. Silvestre et B. Valdés 63597* (SEV); entre Pilas y Aznalcázar (Sevilla), 9 April 1966, *64004* (SEV); El Gandul (Sevilla), 24 March 1969, *E. F. Galiano, et B. Valdés 63595* (SEV); Almería, el Ejido, márgenes carretera, 17 March 1984, *G. Mateo & R. Lázaro VAL50139* (VAL); Almería, 5 Km ESE of Campohermoso, 1.5 Km, N of Fernán Pérez, 180m, 36°55'N 2°5'W, 30S 582200 4086900 (VAL); Almodóvar del Río, desembocadura del río Guadiato (Córdoba), 2 June 1981, *F. Infante, J. A. Varela 32699* (COFC); Valle del Guadiato, puente de la Cabrilla (Córdoba), 24 April 2010, *C. Granados 51013* (COFC); Xabia Almodóvar del Río, desembocadura del río Guadiato (Córdoba), 24 April 2010, *C. Granados 32702* (COFC); Puente Genil, Cortijo de "Tíscar", Laguna salada, margen derecho del río Genil (Córdoba), 24 April 1981, *F. Infante, E. Hernández 35467 1/2* (COFC). **Comunidad Valenciana:** Altea – Marina Baixa (Alicante), desembocadura Riu Algar, 5m, 30SYH577720 May 2008, *Aguilella, Torres*,

Lluzar, Sanchez & Moreno VAL193969 (VAL); Xátiva (Costera), Riu Canyoles (Valencia), 30SYJ1627, 3 March 2010, *C. Torres, E. Lluzar VAL202586* (VAL); Xátiva (Costera), Riu Canyoles (Valencia), 30SYJ1622, 15 April 2010, *C. Torres Gómez, E. Lluzar VAL202534* (VAL); Paiporta (Horta), L'Horta (Valencia), herbazales nitrófilos em campos abandonados, 20m. 30SYJ226652, 28.IV.2011, *S. Fos VAL205853* (VAL); Novelda (Alicante) 14.IV.1933, *C. Pau & E. Moroder VAL161408* (VAL); S-facing limestone bank at edge of field, 17 April 1994, *S. L. Jury n°14685 VAL 143065* (VAL); Marines, Viejo (Valencia), monte, 450m, YK10, 18 April 1999, *L. Moratalla VAL108096* (VAL); Catarroja, Puerto (Valencia), Borde de un camino, 28 February 1998, *Daniel Ballesteros Bargues 105636* (VAL); Dehesa de campamor (Alicante), XG99, 8 February 1987, *G. Mateo et col. VAL70611* (VAL); Paterna (Valencia), herbazal nitrófilo en cuneta de carretera, 50m. 30SYJ2375, 9 April 1992, *J. Cuchillo VAL85417* (VAL).

- TURKEY. Caria, 1843, *Pinard* (FI)

***Glebionis discolor*:**

- ALGERIA. Hab. in ditione urbis Alger, loco dicto Kouba, 1879, *M. Gandoger n° 489* (FI); environs d'Oran, dans les cultures, 28 mars 1913, *A.F.* (FI); Penez, 1891, *Debaux* (FI).
- GREAT BRITAIN. **Gibraltar:** Catalan Bay, arenas mezcladas con rocas calizas, 16 May 1985, *J. Bensusan, S. Talavera, B. Valdés 124741*(SEV).
- GREECE. Greece, Melor, 05/1819, D'Urville (K 000929476); Isole dell'Egeo – Lero, maggio 1938, *T. Colonnello Pietro Bertoglio* (FI); Isola di Rodi: fra Villanova e Fanez, 4 maggio 1922, *N. Mazzocchi-Alemanni* (FI); Dodecanneso: Chefalo, 1-VIII-1924, *A. Desio* (FI); Isola di Rodi: Cattavia, 26 aprile 1922, *N. Mazzocchi-Alemanni* (FI); Isola di Rodi: dintorni di Rodi, 15-30 aprile 1922, *N. Mazzocchi-Alemanni* (FI); Rodi – Dintorni, 17.V.1912 e 9.2.914, ... (FI); Isola di Rodi: Lindos, 25 aprile 1922, *N. Mazzocchi-Alemanni* (FI); Isola di Rodi (Egeo), Rodi, 5 agosto 1923, *A. Fiori* (FI).
- ITALY. **Calabria:** Torrente Fiumarella, Pellaro (Reggio Calabria), 10m, 38°01'15.72"N, 15°38'42.00"E, 19 May 2012, *C.M. Musarella 130101-130102* (JAEN); Torrente Fiumarella, Pellaro (Reggio Calabria), 10m, 38°01'15.72"N, 15°38'42.00"E, 19 May 2012, *C.M. Musarella 4178/1-2-3* (REGGIO); Pentedattilo (Reggio Calabria), 24 April 2000, *C.M. Musarella 000240* (MS); Catanzaro, sotto Bellavista, giugno 1895, *L. Micheletti* (FI); Catanzaro, sotto Bellavista, nei ruderi e lungo le siepi, maggio 1895, *L. Micheletti* (FI). **Sicilia:** Monte Kalfa (Messina), 24 February 2001, *A. D'Arrigo 000897* (MS); Pantano Bruno, Pozzallo (Ragusa), 25 April 1969, *Brullo S. 3021* (CAT); Insula Linosa (olim Aethusa) prope paguis, 1 Martii 1906 legi, *Stephen Sommer* (FI); Insula Linosa (olim Aethusa) prope paguis, 2 Martii 1906 legi, *Stephen Sommer* (FI); In aris Linosa, IV/1905, *L. Micheletti* (FI); In cultis Lampedusa..., IV 1905, *G. Zodda* (FI). **Liguria:** Varazze, 24 V 1929, Gavioli 15606 (FI); **Toscana:** Insula Pianosa (olim Planasia vel Planaria), al Marchese – prima l'abitato18-19/5/1909 legi, Stéphen Sommer (FI).

- LIBYA. **Cyrenaica:** Soluch a sud di Bengasi, 10 mar. 1933, *R. Pampanini* 8582 (FI); Sirual Zauiet el-Hamama, 29 mar. 1933 *R. Pampanini* 8583 (FI); Cirene, 18 aprile 1933, *R. Pampanini* 8584 (FI); ez-Zuetina a nord-est di Agedabia, 11 aprile 1934, *R. Pampanini e R. Pichi-Sermolli* 8586 (FI); Chaulan, 20 aprile 1934, *R. Pampanini e R. Pichi-Sermolli* 8587 (FI).
- MOROCCO. Agadir, prope oppidulum Taфраute, Tizi Mlil, in rupestribus siliceis, 9362, 1600m, 29°45'N, 8°52'W, 26 May 1985, *C. Blanché, J. Fernández Casas, J. Molero, J. M. Montserrat & A. Romo* 123837 (SEV); Oujda, 6 Km from Oujda in the road to Taza, Calcareous soils, 550m, 34°41'N 1°59'W, 29.V.1993, *M. Etlafiski, M. A. Mateos & B. Valdés* 150060 (SEV); in lapidosis arenaris prope Goulimine, 400-500m, 13 aprilis 1935, *E. Wilczek* (FI).
- PORTUGAL. S. Pedro do Estoril proximo da ribera do Caparide (Lisboa), 21 May 1978, *L. A. Grandvaux Barbosa* 121257 (SEV).
- SPAIN. **Andalucía:** El Zumbel (Jaén), 600m, UVG-37, 10 April 1974, 74-1999 (JAEN); Linares, ciudad camino (Jaén), 430m, 30SVH4415J, 12 March 1992, *García Rosa* 921968 (JAEN); Jabalquinto (Jaén), alrededores margo-calizas, 480m, 30SVH3608, 02 May 1994, *B. Lendinez (Etnobotánica)* 940730 (JAEN); Lopera (Jaén), alrededores, 300m, 30SUH0093, 15 May 1995, *Concepción Alcalá Sanz* 950606 (JAEN); Baeza, puente Mazuecos, El Guadalquivir Aluvi (Jaén), 300m, 30SVG6098, 22 May 1994, *M.A. Espinosa et B. Chica* 944365 (JAEN); cerca de Cerro Molina (Jaén), margas y calizas, 440m, 30SVG3582, 11 May 1991, *A. Gonzalez* 910615 (JAEN); Jaén, Puente Jontolla (Jaén), margas calizas, 440m, 30SVG3480, 28 March 1991, *A. Gonzalez* 910271 (JAEN); Carretera Las Infantas (Jaén), margas calizas, 360m, 30SVG3291, 10 July 1998, *D. Casado Ponce* 980649 (JAEN); Los Yesares (Jaén), margas y yesos, 480m, 30SVG3583, 19 May 1991, *A. Gonzalez* 910643 (JAEN); Mengibar, orilla del Guadalquivir (Jaén), 240m, 30SVH3004, 08 May 1982, *E. García Hernandez* 82943 (JAEN); Jaén, C. Tallán – 400m, VG-38, 13 May 1981, *C. Fernandez Lopez, M. Portela, L. Morillas* 812177 (JAEN); Úbeda, El Donadio, Cerro de los Valencia (Jaén), 400m, 30SVG6898, 17 May 1996, *M.A. Espinosa, C. Fernandez, A. Camacho* 960368 (JAEN); Arjona hacia Porcuna, arroyo margas calizas (Jaén), 380m, 30SVG0297, 26 March 1997, *D. Casado* 970606 (JAEN); Porcuna San Pantaleón (Jaén), margas calizas, 380m, 30SUG8893, 25 January 2002, *D. Casado Ponce* 620138 (JAEN); Marmolejo, Los Miñones (Jaén), terrenos silíceos, 300m, 30SUH9115, 20 April 1984, *E. Cano* 844080 (JAEN); Andújar, proximidades del casco Mirasierra (Jaén), 212m, 18 April 2012, *E. Cano* 130113 (JAEN); Andújar, proximidades del casco Mirasierra (Jaén), 212m, 18 April 2012, *E. Cano* 4180 (REGGIO); Mengibar, Orilla del Río Guadalquivir (Jaén), 240m, 30S VH 3004, 8 May 1982, *E. García Hernández* VAL151608 (VAL); entre Morón y Montellano (Sevilla), 15 April 1977, *E. Ruiz de Clavijo* 29165 (SEV); entre Morón y Montellano (Sevilla), 29 April 1977, *E. Ruiz de Clavijo* 29026 (SEV); entre Écija y Herrera (Sevilla), cunetas, 5 April 1977, *B. Cabezudo, S. Talavera et al.* 63598 (SEV); Carretera Lora – Constantina (Sevilla); 12 April 1981, *P. Escalza, M. López et R. Luque*

64151(SEV); Morón de la Frontera (Sevilla), zona arvense, 26 February 1978, *M. R. Guerrero Cabezas et I. Fernández* 63451 (SEV); entre novelda Motril y Almuñécar (Granada), 21 May 1971, *E. F. Galiano, E. Paunero, S. Silvestre et B. Valdés* 8399 (SEV); *Chrysanthemum coronarium* L – Corral et Fernández, 31.VII.1980, 64005 (SEV); Camino del canal de riego que desemboca en la carretera de Córdoba a Sevilla, S. Talavera; Pinar y Arroyo Guadalbaida (Córdoba), 23 May 1980, *Fernández* 63745 (SEV); Jerez, Salida hacia Sanlúcar (Cadiz), 9 March 1978, *J. Pastor, S. Talavera et B. Valdés* 63596 (SEV); entre el Viso del Alcor y Carmona (Sevilla), 13 April 1975, *E. Ruiz de Clavijo* 66249 (SEV); entre Écija y Herrera, Santa María de la Gracia: Río Genil (Sevilla), 25 June 1986, *C. López et C. Romero* 157848 (SEV); Almuñécar (Granada), em cunetas y bordes de caminos y carreteras, a la salida de la población, 5m. 30SVF47, 28 May 1982, *Marín Calderón y Hurtado* VAL70610 (VAL); Arroyo salado, carretera Montilla-Montalbán (Córdoba), VG-56, 1 April 1985, *F. García* 18820; carretera Santaella-Montalbán (Córdoba), limite oeste de la Teris, 22 May 1985, *F. García* 18856; arroyo Guadalora, Estación de Hornachuleos (Córdoba), carretera de Hornachuelos Km1, 18 April 1980, *P. Fernández, I. Porras* 17163; Río Anzur, Cortijo los Davales (Córdoba), VG-53, 18 April 1985, *F. García* 18900; Río Lucena (Córdoba), entre Moriles y los “Pedros”, VG-54, 15 April 1985, *F. García* 18901; cruce del Bembezar con arroyo Guadalora, Carretera de Hornachuelos (Córdoba), 8 April 1979, *L. Corral, P. Fernández* 17160; carretera Córdoba-Sevilla, Km 40 (Córdoba), 27 January 1980, *P. Fernández, I. Porras* 17736; camino vecinal Hornachuelos-Villaviciosa de Córdoba (Córdoba), cruce con carretera al pantano Bembezar, 1 May 1980, *L. Corral, P. Fernández* 17739; arroyo de Guadalbaida, Cerro Gordo, Tramo de las Posadas (Córdoba), 23.V.1980, *P. Fernández, I. Porras* 17742; Hornachuelos, Fuente del Caño de Hierro (Córdoba), 18 March 1981, *P. Fernández, I. Porras* 17734; valle del Guadiato, puente de la Cabrilla (Córdoba), 4 March 2008, *C. Lucena* 51013; Facultad de Ciencias, Avda San Alberto Magno (Córdoba), 20 March 1990, *E. Ruiz de Clavijo* 55070; Almodóvar del Río, desembocadura del río Guadiato (Córdoba), 5 April 1981, *J. A. Varela* 32701 1/2; Almodóvar del Río, desembocadura del río Guadiato (Córdoba), 5 April 1981, *J. A. Varela* 32701 2/2; Alahurín de la Torre (Málaga), finca Ana María La Baja, M. Royo, 24 March 2011, *C. Granados, M. Royo, J. L. Uberta* 59911; **Aragona:** Pilas, Cortijo Hato-Ratón, dehesa, arenas (Huesca), 8 May 1995, *E. Moreno, M. E. Ocaña, M. Parra* 136034 (SEV); Gibrleón, cercanías (Huesca), 17.V.1979, *S. Silvestre et S. Talavera* 63742 (SEV); **Balearic Islands:** Mallorca, Algaida, alrededores del pueblo em direccion a Monturi, em borde de camino, 39°34'N 2°54'E, 31SDD9079, 2 June 1996, *C. Aedo, N. López, R. Morales, C. Navarro, Ll. Sáez & M. Velayos*..... (VAL); Illes Balears, Mallorca, Campos, caminos, 4 May 1952, *P. Ferrer* VAL158014 (VAL); **Castilla-La Mancha:** Mota del Cuervo, Monte Gila (Cuenca), Ladera de um pequeño montículo, 710m, 30SWJ1374, 21 May 2000, *V. Hernaz* VAL140930 (VAL); **Comunidad Valenciana:** Altea, Playa de L’Albir (Alicante) en *Resedo-Chrysanthemum coronarii* O. Bolós & R. Molinier, 7 April 1984, *G. Stübing & J. B. Peris*

110918 (SEV); La Nucia, La Marina Baixa (Alicante), pr. poble, 30SYH5078, 19 March 2008, *C. Torres, E. Lluzar VAL189752* (VAL); Xátiva, Costera, Riu Canyoles (Valencia), 15 April 2010, 30SYJ1622C, *Torres Gómez, E. Lluzar.....*(VAL); Riba-roja, Camp de Túria (Valencia), Entrepins herbazal sobre vertidos, 90m, 30SYJ1380, 5 April 2001, *A. Peña VAL205419* (VAL); Castelló de la Plana, La Plana Alta Platija del Grau (Castellón), 2m, 31TBE43, 2 June 1989, *J. Tirado & C. Villaescusa VAL20109* (VAL); Oropesa, La Plana Alta, Camp de Batalla (Castellón), 100m, 31TBE5, 24 May 1993, *A. Aguilera & J. Tirado VAL28220* (VAL); Xabia, Marina Alta (Alicante), vora camins, 1 May 1992, *L. García VAL27571* (VAL); Bunyol, La Foia de Bunyol, Carcalín (Valencia), herbazales subnitrófilos, 400m, 30 SXJ 86, 24 April 1997, *J. Riera VAL40721* (VAL); Yávota, collado de Montratón (Valencia), herbazal de camino, 400m, XJ8660, 13 April 1996, *C. Macián VAL99065* (VAL); El Pla, Carcaixent (Valencia), YJ22, 23 April 1986, *S. Pierra VAL54641*; campo de cereal por la Valleta d'Agres, El Condat (Alicante), 550m, YH19, 6 June 1988, *J. A. Nebot VAL66835* (VAL); Sagunto (Valencia), playa Almardá, arenal costero, 0m, YJ3997, 1 May 1991, *A. García VAL75769* (VAL); **Extremadura:** Badajoz, Pâturages nitrophiloes (*Anacyclo radiati-Hordeum leporini*), 21 May 1973, *S. Rivas Goday et S. Rivas-Martínezbaez*

Chrysanthemum merinoanum:

- SPAIN. **Balearic Islands:** Ibiza (Balears) in campis, IV 1899, *Pau 128240* (MA).

Appendix 2

Bioclimatic classification of samples localities and realted distribution of *Glebionis coronaria* and *G. discolor* comb. & stat. nov.

Locality	<i>Glebionis coronaria</i>	<i>Glebionis discolor</i>	Climate	Ombrotype
Abuhir	x		Lower Mesomediterranean	Upper Arid
Agadir		x	Upper Inframediterranean	Lower Semiarid
Alahurín de la Torre		x	Lower Thermomediterranean	Lower Dry
Alcalá de Guadaira	x		Upper Thermomediterranean	Lower Dry
Alicudi	x		Lower Thermomediterranean	Lower Dry
Almería 5 km Campohermoso	x		Lower Thermomediterranean	Lower Semiarid
Almería el Ejido	x		Lower Thermomediterranean	Lower Semiarid
Almodóvar del río	x	x	Upper Thermomediterranean	Upper Dry
Almuñécar	x	x	Lower Thermomediterranean	Lower Dry
Alrededores Puente Genil	x		Upper Thermomediterranean	Upper Dry
Altea	x	x	Lower Thermomediterranean	Lower Dry
Arjona hacia Porcuna		x	Lower Mesomediterranean	Lower Dry
Arroyo de Guadalbaida posadas		x	Upper Thermomediterranean	Upper Dry
Arroyo salado		x	Lower Mesomediterranean	Upper Dry
Atenas	x		Upper Thermomediterranean	Upper Semiarid

Locality	<i>Glebionis coronaria</i>	<i>Glebionis discolor</i>	Climate	Ombrotype
Atenas (acropolis)	x	x	Upper Thermomediterranean	Upper Semiarid
Badajoz		x	Lower Mesomediterranean	Lower Dry
Baeza Puente Mazuecos		x	Lower Mesomediterranean	Upper Dry
Bagaladi	x		Lower Mesomediterranean	Lower Subhumid
Bu giarrar	x		Upper Inframediterranean	Lower Semiarid
Caltanissetta	x		Lower Mesomediterranean	Lower Dry
Caria	x		Upper Thermomediterranean	Lower Subhumid
Carretea Santaella-Montalbán		x	Upper Thermomediterranean	Upper Dry
Carretera Córdoba-Sevilla		x	Upper Thermomediterranean	Upper Dry
Carretera las infantas		x	Upper Thermomediterranean	Lower Dry
Carretera Lora ù constantina		x	Upper Thermomediterranean	Upper Dry
Castelló de la plana		x	Upper Thermomediterranean	Lower Dry
Catalan bay	x	x	Lower Thermomediterranean	Lower Subhumid
Catanzaro	x	x	Lower Mesomediterranean	Lower Subhumid
Catanzaro	x	x	Lower Mesomediterranean	Lower Subhumid
Catarroja	x		Lower Thermomediterranean	Lower Dry
Cerca de Cerro Molina (Úbeda)		x	Lower Mesomediterranean	Lower Dry
Cossyra	x		Lower Thermomediterranean	Lower Dry
Cruce del Bembezar con arroyo Guadaluora		x	Upper Thermomediterranean	Upper Dry
Dehesa de Campamor	x		Upper Thermomediterranean	Lower Semiarid
Driana	x		Upper Inframediterranean	Lower Semiarid
El Abiar	x		Upper Thermomediterranean	Upper Arid
El Gandul (Se)	x		Upper Thermomediterranean	Lower Dry
El Pla Carcaixent		x	Upper Thermomediterranean	Lower Dry
El Zumbel		x	Upper Mesomediterranean	Upper Dry
Entre Arcos y Bornos.	x		Upper Thermomediterranean	Upper Dry
Entre Écija y Herrera		x	Upper Thermomediterranean	Lower Dry
Entre el Viso del Alcor y Carmona		x	Upper Thermomediterranean	Upper Dry
Entre Morón y Montellano		x	Upper Thermomediterranean	Upper Dry
Entre Motril y Almuñecar		x	Lower Thermomediterranean	Lower Semiarid
Entre Pilas y Aznalcázar	x		Upper Thermomediterranean	Lower Dry
Epidaura	x		Upper Mesomediterranean	Lower Subhumid
Estación de Hornachuleos		x	Upper Thermomediterranean	Upper Dry
Favignana	x		Lower Thermomediterranean	Lower Dry
Filicudi	x		Lower Thermomediterranean	Lower Dry
Fiume Ferro (Ct),	x		Upper Thermomediterranean	Lower Dry
Gibraleón cercanías		x	Upper Thermomediterranean	Lower Dry
Gozo	x		Lower Thermomediterranean	Lower Dry
Hornachuleos		x	Upper Thermomediterranean	Upper Dry
Illes Balears Mallorca		x	Lower Thermomediterranean	Upper Semiarid
Insula Comino	x		Lower Thermomediterranean	Lower Dry
Insula Linosa (Aethusa)	x	x	Lower Thermomediterranean	Lower Semiarid
Insula Pianosa		x	Upper Thermomediterranean	Lower Dry
Isole Eolie (Me)	x		Upper Thermomediterranean	Upper Dry

Locality	<i>Glebionis coronaria</i>	<i>Glebionis discolor</i>	Climate	Ombrotype
Jabalquinto (Jaén)		x	Lower Mesomediterranean	Lower Dry
Jerez		x	Upper Thermomediterranean	Upper Dry
Kalampta	x		Upper Thermomediterranean	Lower Subhumid
Kalfa (Me)	x		Lower Mesomediterranean	Lower Subhumid
La Nucia la marina baixa		x	Upper Thermomediterranean	Lower Dry
Lampedusa	x		Upper Inframediterranean	Lower Semiarid
Larnaka	x		Lower Thermomediterranean	Lower Semiarid
Las Cabezas	x		Upper Thermomediterranean	Lower Dry
Lesina	x		Lower Mesomediterranean	Upper Dry
Linares Ciudad Camino		x	Lower Mesomediterranean	Lower Dry
Linosa	x	x	Lower Thermomediterranean	Lower Semiarid
Lipari	x		Lower Thermomediterranean	Upper Dry
Lopadusa	x	x	Upper Inframediterranean	Lower Semiarid
Los Yesares		x	Upper Thermomediterranean	Lower Semiarid
M. Grasso (Sr),	x		Upper Thermomediterranean	Lower Dry
M. Mela (Ag)	x		Upper Thermomediterranean	Lower Dry
Mallorca Algaida		x	Lower Mesomediterranean	Upper Dry
Marettimo	x		Lower Thermomediterranean	Upper Semiarid
Marmolejo		x	Upper Thermomediterranean	Lower Dry
Mogador (actual Esauria)	x		Lower Thermomediterranean	Upper Semiarid
Monte Kalfa (Me)		x	Lower Mesomediterranean	Lower Subhumid
Morón de la Frontera		x	Upper Thermomediterranean	Upper Dry
Mota del Cuervo		x	Upper Mesomediterranean	Lower Dry
Nador	x		Lower Thermomediterranean	Lower Semiarid
Nafplio	x		Upper Thermomediterranean	Lower Dry
Noto (Sr)	x		Upper Thermomediterranean	Lower Dry
Novelda	x		Upper Thermomediterranean	Upper Semiarid
Oia (Santorini)		x	Lower Mesomediterranean	Lower Dry
Oropesa la plana alta		x	Upper Thermomediterranean	Lower Dry
Oujda		x	Upper Thermomediterranean	Upper Semiarid
Pantano Bruno, Pozzallo (Rg)		x	Lower Thermomediterranean	Lower Dry
Pantano Longarini	x		Lower Thermomediterranean	Lower Dry
Paterna	x		Upper Thermomediterranean	Lower Dry
Pellaro		x	Lower Thermomediterranean	Lower Subhumid
Pellaro	x		Lower Thermomediterranean	Lower Subhumid
Pentidattilo		x	Lower Mesomediterranean	Lower Subhumid
Petra – Olimpa	x		Upper Thermomediterranean	Upper Semiarid
Piana di Catania	x		Upper Thermomediterranean	Lower Dry
Piana di Soluq ù ana	x		Lower Thermomediterranean	Lower Semiarid
Porcuna San Pantaleón		x	Lower Mesomediterranean	Lower Dry
Ramath-Gan	x		Upper Inframediterranean	Lower Dry
Riba-Roja camp de túria		x	Upper Thermomediterranean	Lower Dry
Río Anzur		x	Lower Mesomediterranean	Upper Dry
Río Lucena		x	Upper Mesomediterranean	Upper Dry
S. Pedro do Estoril		x	Upper Thermomediterranean	Lower Subhumid

Locality	<i>Glebionis coronaria</i>	<i>Glebionis discolor</i>	Climate	Ombrotype
S.Nicola da Crissa, Serre (VV), Sagunto (V)	x	x	Upper Thermomediterranean	Lower Subhumid
Sebchet Bu Giarrar	x		Upper Inframediterranean	Lower Semiarid
Tarifa	x		Lower Thermomediterranean	Lower Subhumid
Terme di San Calogero	x		Lower Thermomediterranean	Upper Dry
Termini Imerese	x		Lower Thermomediterranean	Lower Dry
Thyra (Santorini)		x	Lower Mesomediterranean	Lower Dry
Tocra	x		Upper Inframediterranean	Lower Semiarid
Tolmeta	x		Upper Inframediterranean	Lower Semiarid
Tolmeta	x		Upper Inframediterranean	Lower Semiarid
Úbeda		x	Lower Mesomediterranean	Lower Dry
Valle del Guadiato	x		Lower Mesomediterranean	Upper Dry
Varazze		x	Lower Mesotemperate	Lower Subhumid
Vejer	x		Lower Thermomediterranean	Upper Dry
Villaviciosa de Córdoba		x	Lower Mesomediterranean	Upper Dry
Wadi El ú bab	x		Upper Inframediterranean	Upper Semiarid
Xabia	x	x	Lower Thermomediterranean	Lower Dry
Xátiva	x	x	Upper Thermomediterranean	Upper Dry
Yávota		x	Lower Mesomediterranean	Lower Dry
TOTAL	71	64		