PhytoKeys 63: 1–12 (2016)
doi: 10.3897/phytokeys.63.8033
http://phytokeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

A new species of *Dianthus* (Caryophyllaceae) from Antalya, South Anatolia, Turkey

İsmail Gökhan Deniz[1], Candan Aykurt[2], İlker Genç[3], Ahmet Aksoy[2]

1 *Department of Biology Education, Faculty of Education, Akdeniz University, Antalya, Turkey* **2** *Department of Biology, Faculty of Science, Akdeniz University, Antalya, Turkey* **3** *Istanbul University, Faculty of Pharmacy, Department of Pharmaceutical Botany, Istanbul, Turkey*

Corresponding author: *İsmail Gökhan Deniz* (gdeniz@akdeniz.edu.tr)

Academic editor: *Cl. Morden* | Received 4 February 2016 | Accepted 22 April 2016 | Published 26 April 2016

Citation: Deniz İG, Aykurt C, Genç İ, Aksoy A (2016) A new species of *Dianthus* (Caryophyllaceae) from Antalya, South Anatolia, Turkey. PhytoKeys 63: 1–12. doi: 10.3897/phytokeys.63.8033

Abstract

Dianthus multiflorus from Gazipaşa (Antalya), south Anatolia (Turkey), is described as a new annual species with verrucose calyx. The morphological differences from the species within the same group with *D. multiflorus*, which are *D. aydogdui, D. cyri* and *D. tripunctatus*, are discussed. The International Union for Conservation of Nature (IUCN) threat category and observations on the ecology of the populations are noted. The karyology and seed micromorphology of *D. multiflorus* and *D. tripunctatus* were examined by light microscopy and scanning electron microscopy.

Keywords

Dianthus, new species, taxonomy, Turkey

Introduction

Amongst all its neighbouring countries, Turkey is the richest in terms of plant taxa, being home to 9996 plant species (11707 taxa) (Güner et al. 2012). The floristic richness of the country is partially due to the high number of endemic and rare species present. The Mediterranean region is one of the important centers of endemism in Turkey, and Antalya is the richest province of Turkey in terms of plant diversity,

Copyright *İsmail Gökhan Deniz et al.* This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

hosting 773 of the country's endemic species. Amongst these endemic species, about 244 are best described as locally endemic, being found only in Antalya (Deniz and Aykurt 2014).

After *Silene* L., *Dianthus* L. is the second largest genus of Caryophyllaceae. This genus, containing approximately 300 species, is mainly distributed in the Mediterranean region of Europe and Asia (Reeve 1967; Bittrich 1993). The most comprehensive study on *Dianthus* species in the Flora of Turkey and East Aegean Islands was carried out by Reeve (1967) wherein 67 species were recorded. Since that date, new species and records have been added and the total number of *Dianthus* species recorded in Turkey has increased to 81 (Shishkin 1985, Davis et al. 1988, Gemici and Leblebici 1995, Güner 2000, Menemen and Hamzaoğlu 2000, Aytaç and Duman 2004, Özhatay and Kültür 2006, Vural 2008, Yılmaz et al. 2011, İlçim et al. 2013, Hamzaoğlu 2012, Hamzaoğlu and Koç 2015, Hamzaoğlu et al. 2014, 2015a, 2015b, 2015c). Among the annual *Dianthus* species recognized by Reeves (1967), there are only two species (*D. cyri* Fisch. & C.A.Mey. and *D. tripunctatus* Sm.) that have a verrucose calyx.

Dianthus aydogdui Menemen & Hamzaoğlu, which resembles *D. cyri* and *D. tripunctatus*, has been described from Salt Lake (Central Anatolia) province by Menemen and Hamzaoğlu (2000). The new species described here, *Dianthus multiflorus* Deniz & Aykurt, was collected from Gazipaşa province in Antalya. It is distributed on stony sliding slopes and serpentine soils in clearings of *Pinus brutia* forest. *Dianthus multiflorus* is included in the same group along with *D. aydogdui*, *D. cyri* and *D. tripunctatus*. *Dianthus multiflorus* shows distinct differences from these species by its habit, number of flowers on the stem, calyx and petal features.

Methods

Plant samples and morphological studies

Dianthus multiflorus specimens were collected from Gazipaşa province (Antalya) during field studies within the scope of the project "EXPO 2016 Endemic and Rare Flowers of Antalya". New species and its morphologically most similar species, *D. tripunctatus* were observed during field studies and their morphological characteristics were recorded both in the field and in the laboratory. Specimens collected were comprehensively evaluated by the use of the literature (Velenovsky 1891; Post 1932; Tutin 1964; Reeve 1967; Shishkin 1985; Strid 1986; Rechinger 1988) and the specimens present in GAZI, ISTE, and Akdeniz University herbariums. The overall morphology of the new species was examined with stereo-binocular microscope.

The seed micromorphology of *D. multiflorus* and *D. tripunctatus* was investigated using scanning electron microscopy (SEM) techniques. Seeds were attached to SEM stubs, coated with gold conjugate following the manufacturer specifications and examined with a Zeiss LEO-1430 scanning electron microscope.

Karyological studies

Chromosome number and karyological features of the *Dianthus multiflorus* and *D. tripunctatus* were determined from plant material collected from Antalya. All karyological observations were carried out on root tips. Root-tip meristems were provided from seeds by germinating them on wet filter paper in petri dishes at the temperature of 23°C. Firstly, root tips were pretreated for 24 h in a-monobromonaphthalene at 4 °C, fixed in 3:1 absolute alcohol-glacial acetic acid. Root tips were then hydrolyzed with 1 N HCL for 13 min. at 60 °C, stained in Feulgen solution, and squashed in acetoorcein. For karyotype analysis, the photographs were taken using OLYMPUS BX53 microscope with camera Kameram 12 CCD attachment. Chromosome counts in mitosis metaphase and karyotype analyses were obtained based on five root tips, five metaphase cells for each individual. Measurements of somatic chromosomes were made with the program KAMERAM, they were calculated with formula of the relative variation in chromosome length CV_{CL} (Paszko 2006), mean centromeric asymmetry (M_{CA}) according to Peruzzi and Eroğlu (2013) and chromosome total haploid length (THL) (Peruzzi *et al*. 2009). Chromosomes were classified to the nomenclature following Levan et al. (1964) and asymmetry types following Stebbins (1971).

Results

With the recognition of *Dianthus multiflorus* as a new species, there are now four annual species of *Dianthus*, (*D. multiflorus, D. tripunctatus, D. cyri* and *D. aydogdui)* that can be separated from other annual *Dianthus* species on the basis of their verrucose calyxes in Turkey. A detailed comparision of the morphological and ecological features of these species is shown in the Table 1.

***Dianthus multiflorus* Deniz & Aykurt, sp. nov.**
urn:lsid:ipni.org:names:77154520-1
Figs 1–4, Table 1–2

Diagnosis. *Dianthus multiflorus* is distinguished from related species by having flowers numerous [(30–)80–250(–300)], pedicels 0.5–30 mm, calyx 12–13 mm, petals white, and petal limb margins shallowly sinuate.

Type. TURKEY. Antalya: Gazipaşa, from Akoluk Village to Akkaya Hill of Taşeli Plateau, c. 3. km, stony sliding slopes and serpentine soils in clearings of *Pinus brutia* forest, 1075 m a.s.l., 05 July 2015, *İ.G. Deniz*, C. *Aykurt*, *6195* (holotype: Akdeniz University Herbarium 3823).

Annual, many-stemmed, divaricately branched herbs. Stem erect to ascending, fragile, slender, 20–80 cm, branching from the base, glabrous or minutely scabridulous especially toward base, usually purplish at base, many-flowered (30–)80–250(–300). Basal

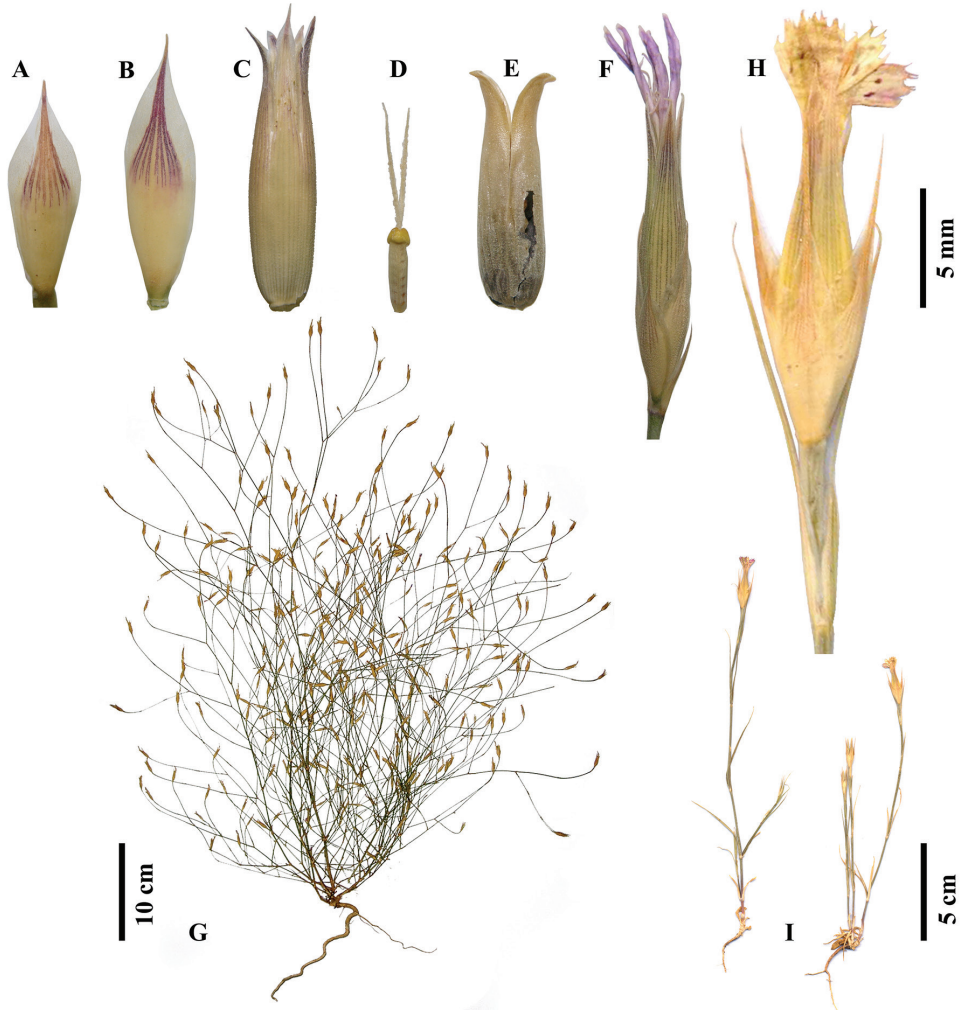

Figure 1. Habit and flower photographs of *Dianthus multiflorus* (**A–G** from holotype, *Deniz 6195*) and *D. tripunctatus* (**H–I** from ISTE 74221). (**A** Outer epicalyx segment **B** Inner epicalyx segment **C** Calyx **D** Pistil **E** Capsule **F, H** Flower **G, I** Habit).

leaves linear-lanceolate to lanceolate-spatulate, 25–35 × 2.5–4.5 mm, with scabridulous edges especially near base, obtuse at apex. Cauline leaves linear-narrowly triangular to linear-lanceolate, gradually smaller upwards, flattened, distinctly nervous, glabrous, with scabridulous margin and narrowly membranous toward base, acute to acuminate at apex, their sheaths shorter than the internodes; lower cauline leaves linear-lanceolate, 20–50 × 2–2.2 mm, longer or shorter than internodes, swollen and usually purplish at base; upper cauline leaves linear to linear-narrowly triangular, 4–20 × 0.5–1.5 mm, slightly swollen at base. Inflorescence dichotomously branched; flowers almost always solitary, occasionally two or three flowers borne on the same nod; branches usually minutely scabridulous;

Table 1. Comparison of diagnostic morphological characters of *Dianthus multiflorus* with its close relatives.

Characters	*D. multiflorus*	*D. tripunctatus*	*D. cyri*	*D. aydogdui*
Plant size (cm)	20–80	20–50	12–40	3–15
Flowering stem	Divaricately branched	Many branched	Many branched	Single stemmed
Epicalyx scales length	Almost equaling or shorter than calyx tube	Equaling calyx tube	Equaling or longer than calyx tube	Shorter than calyx tube
Epicalyx scales mucro length (mm)	3–3.5	3–8	7–12	1–3
Pedicels length (mm)	0.5–30	40–50	15–35	5–15
Number of flowers	Numerous (30–) 80–250 (–300)	4–15 (–40)	5–22	1–4
Calyx length (mm)	12–13	18–20	11–15	8–10
Calyx tube	Distinctly 35–40 nerved	Nervose-striate	Enervate	Nervose
Apex of calyx teeth	Acuminate	Acuminate	Aristate	Acute sometimes mucronate
Petal limb color	White with purple venation	Pink	Pink	Pink
Margin of petal limb	Emerginate with shallowly sinuate lobes	Dentate	Dentate	Dentate
Ecology	Sliding slopes and serpentine soils	Cliffs, road sides	Deep alluvial soils	Salty soils
Altitude	1000–1150 m	1–120 m	1200 m	950 m

pedicels 1–30 mm (sometimes very short, to 0.5 mm). Epicalyx scales 4, almost equaling or shorter than calyx tube, cartilaginous, straw-colored, markedly 8-nerved toward apex, glabrous, verrucose at middle and below surfaces, scabridulous at apex and on scarious margins; scarious margins terminating at or under apex; outer epicalyx segments obovate, 8–9 × 3–3.5 mm, with acuminate tip (ca. 3 mm), scarious margins up to 0.75 mm broad; inner epicalyx segments obovate, 11–12 × 4–4.5 mm, with acuminate tip (ca. 3.5 mm), scarious margins up to 0.8 mm broad. Calyx cylindric-lanceolate, verrucose, distinctly 35–40-veined, usually purplish at upper 2/3 part, 12–13 × 2.8–3 mm; teeth triangular, 4.5–5.5 mm long, 7–8–veined, with narrowly scarious and scabridulous margins. Petals white, 20 mm; limb narrowly obovate, 6–7 × 3 mm, emarginate with shallowly sinuate lobes, completely exerted from calyx, unspotted, barbulate, with 3 main purplish vein; claw 12–13 × ca. 1 mm. Anthers 3.6 mm long; filaments 7 mm long. Ovary 3.5 mm long; style 5 mm long. Capsule cylindrical, included in calyx, 10 × 3 mm. Seeds ovate to elliptic, 1.9–2.5 × 1.07–1.7 mm, black, minutely cuspidate at apex, granular, covered by irregularly polygonal or rectangular cells; anticlinal walls represented by shallow and wide grooves, with U-like undulations; the periclinal walls distinctly papillose. The cells of ventral surface 75–145 × 33.2–59.4 μm, more elongated and bigger than the cells of dorsal surface (31.4–86 × 25–45 μm).

Distribution, habitat and ecology. *Dianthus multiflorus* is known only from the type locality, between Akoluk Village to Taşeli Plateau, where it grows at altitude of 1000–1150 m on sliding slopes and serpentine soils in clearings of *Pinus brutia* Ten.

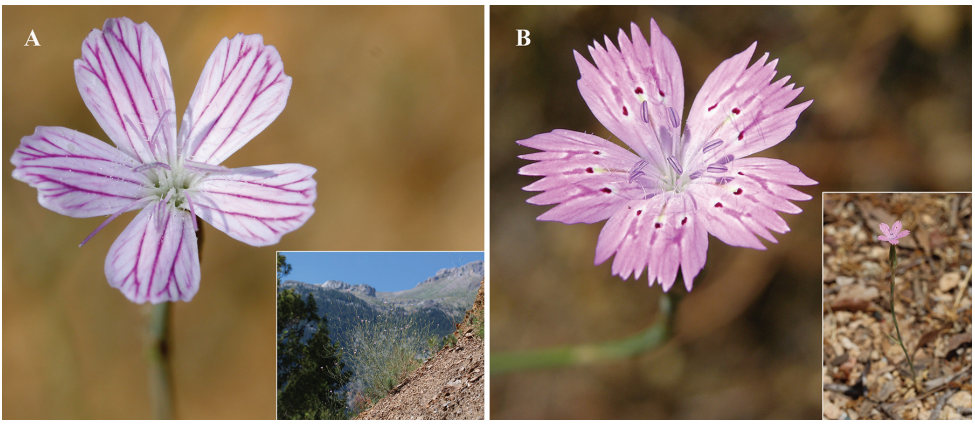

Figure 2. Field photographs of *Dianthus multiflorus* (**A**) and *D. tripunctatus* (**B**).

forest. Within this area, the new taxon is associated with plants such as: *Pinus brutia* var. *brutia*, *Quercus coccifera* L., *Helichrysum arenarium* Moench subsp. *aucheri* (Boiss.) P.H.Davis & Kupicha, *Carduus rechingerianus* Kazmi, *Centaurea urvillei* DC. subsp. *urvillei*, *Teucrium lamiifolium* d'Urv. subsp. *lamiifolium*, *Thymus cilicicus* Boiss. & Balansa. *Ballota saxatilis* Sieber ex C.Presl subsp. *saxatilis*.

Phenology. *Dianthus multiflorus* was observed flowering in June and July, and mature fruits are produced in July to middle of August.

Etymology. The species epithet is derived from its abundant flowers representing one of the main characters that distinguishes it from other similar species.

Proposed conservation status. *Dianthus multiflorus* is included in the Critically Endangered category according to IUCN criteria ver. 11 (IUCN 2014). The species was determined at only a single location and the extent of occurrence (EOO) value of the species was determined to be 7 km^2 taking into account location of occupancy and the area contained within the shortest continuous imaginary boundary. Additionally, the area of occupancy (AOO) value in this area was calculated as 4 km^2 [CR B1ab(i)+CR B2b(ii)].

Seed testa micro-morphology. A detailed comparison of seed micromorphology based on SEM analysis was made (Table 2). The seeds of *D. multiflorus* and *D. tripunctatus* are black, minutely cuspidate at apex, granular, and have anticlinal walls represented by shallow and wide grooves, with U-like undulations, while the periclinal walls are distinctly papillose. The seeds of *D. multiflorus are* covered by irregularly polygonal or rectangular cells, and the cells of ventral surface are more elongated and larger, conversely the seeds of *D. tripunctatus* are covered by irregularly rectangular cells and the cell size of ventral and dorsal surfaces are similar (Fig. 3).

Karyology. The chromosome number of *Dianthus multiflorus* and *D. tripunctatus* is $2n = 30$ (Fig. 4). The shortest chromosome length for *D. multiflorus* is 0.54 µm, the longest is 1.24 µm, and total haploid chromosome length (THL) is 12.21 µm. The karyotype formula of *D. multiflorus* consists of 28 median pairs and 2 submedian

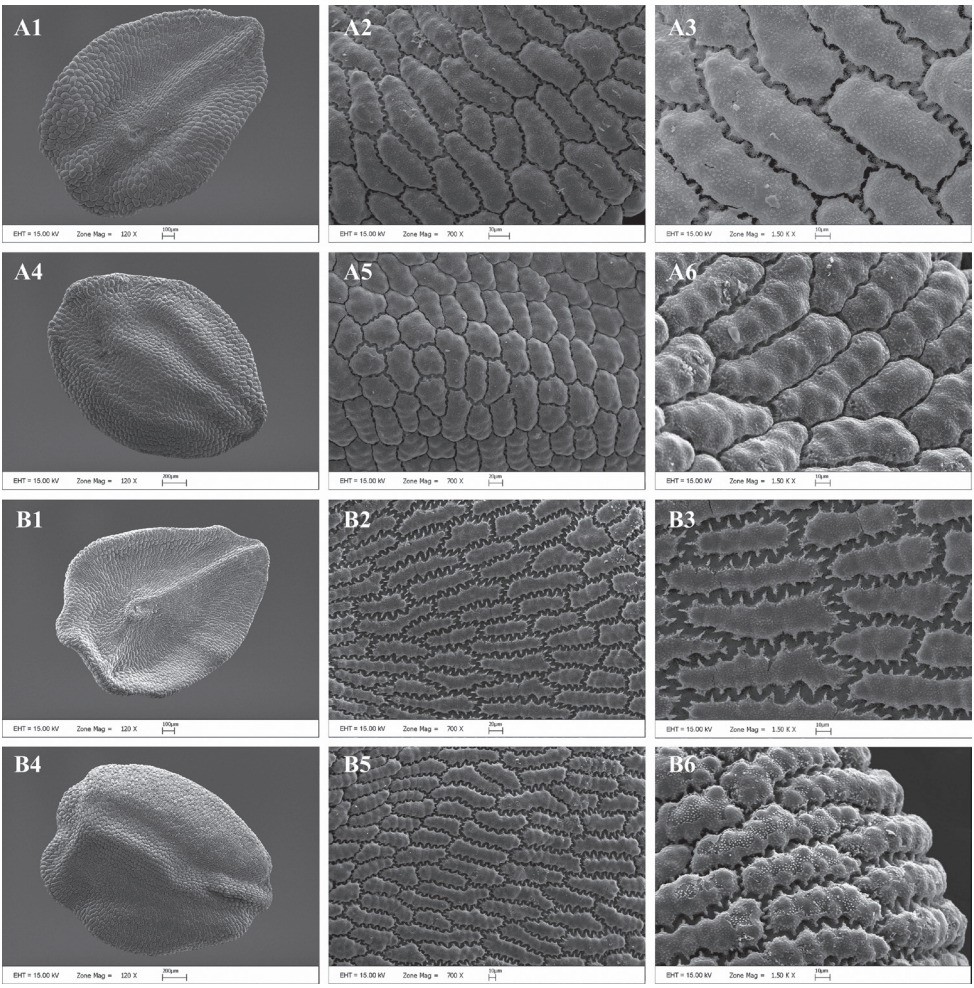

Figure 3. SEM photographs of the seed coat. **A** *Dianthus multiflorus* **B** *D. tripunctatus.* 1–3: Ventral surface. 4–6: Dorsal surface. (Scale bars 200 µm for A4 and B4; 100 µm for A1 and B1; 30 µm for A2; 20 µm for A5 and B2; 10 µm for A3, A6, B3, B5 and B6).

pairs. As for karyotype asymmetry, its karyotype was classified according to the symmetry classes of Stebbins (1971) as 3B. Intrachromosomal asymmetry (M_{CA}) is 6.26 and the interchromosomal asymmetry index (CV_{CL}) is 19.93. Our study showed that the shortest chromosome length for *D. tripunctatus* is 0.77 µm, the longest is 1.21 µm, and total haploid chromosome length (THL) is 14.09 µm. The karyotype formula of this species consists of 28 median pairs and 2 submedian pairs. As for karyotype asymmetry, the karyotype of this species is classified according to the symmetry classes of Stebbins (1971) as 3A. Intrachromosomal asymmetry (M_{CA}) is 6.42 and the interchromosomal asymmetry index (CV_{CL}) is 12.57. The karyogram is given in Figure 4 and ideogram was drawn based on the centromeric index (Fig. 4).

Table 2. Comparison of seed micromorphological and karyological characteristics of *Dianthus multiflorus* and *D. tripunctatus*.

	Characters	*D. multiflorus*	*D. tripunctatus*
Seed micromorphology	Seed size (mm)	1.9–(2.16)–2.5 × 1.07–(1.46)–1.07	1.9–(2.07)– 2.23 × 1.4–(1.62)–1.87
	Cell shape of seed coat	Polygonal or rectangular	Rectangular
	Cell size of ventral surface	75–145 × 33.2–59.4 µm	(60–)97.4–127.3 × 18.2–26
	Cell size of dorsal surface	31.4–86 × 25–45 µm	57–140 × 18.6–32.9
	Cell size of ventral surface according to dorsal surfaces	More elongated and bigger	Similar
Karyology	SC	0,54 µm	0.77 µm
	LC	1.24 µm	1.21 µm
	THL	12.21 µm	14.09 µm
	M_{CA}	6.26	6.42
	CV_{CL}	19.93	12.57
	Stebbins symetry	3B	3A

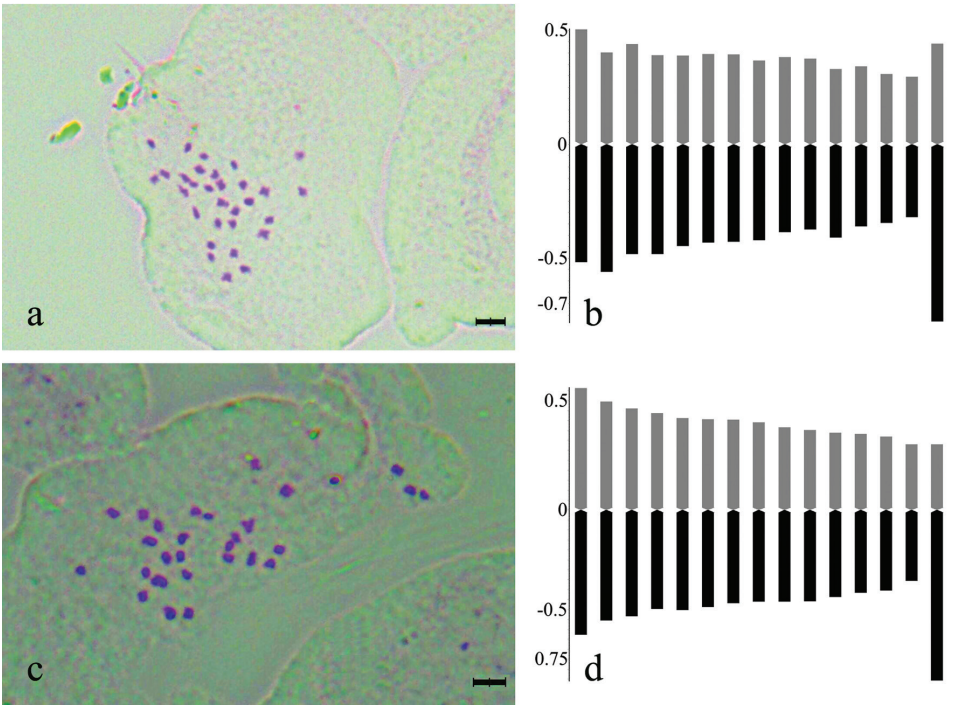

Figure 4. Somatic chromosomes and ideogram of *Dianthus multiflorus* (**a–b**) and *D. tripunctatus* (**c–d**). (Scale bars 2 µm).

According to Stebbin's (1971) classification, the karyotypes of *D. multiflorus* belong to type 3B, whereas the karyotypes *D. tripunctatus* belong to type 3A. The asymmetry indices also reveal some small differences between the two species. Nevertheless,

according to interchromosomal asymmetry index (CV_{CL}), *D. multiflorus* is more asymmetric than *D. tripunctatus*. The total haploid chromosome length (THL) in *D. multiflorus* is 12.21 μm and that of *D. tripunctatus* is 14.09 μm (Table 2).

Diagnostic key to the annual *Dianthus* species with verrucose calyx in Turkey

1 Stem unbranched, 3–15 cm; calyx 10 mm or shorter..... ***D. aydogdui***
– Stem many branched, 12–80 cm; calyx more than 10 mm **2**
2 Stem bearing (30–)80–250(–300) flowers; petal limb white with purple venation, shallowly sinuate at margins..... ***D. multiflorus***
– Stem bearing 4–15(–40) flowers; petal limb pink, dentate at margins..... **3**
3 Calyx tube nervose-striate; base of epicalyx segments adpressed to the calyx, their membranous margins conspicuous, 2 mm wide..... ***D. tripunctatus***
– Calyx tube enervate; base of epicalyx segments spreading, their membranous margins inconspicuous, not more than 0.5 mm wide..... ***D. cyri***

Discussion

Of the annual *Dianthus* species that occur in Turkey, there are only four species that have verrucose calyxes; *Dianthus aydogdui*, *D. cyri*, *D. multiflorus* and *D. tripunctatus*. *Dianthus aydogdui* was recently described from Salt Lake province (Menemen and Hamzaoglu 2000), and this species is distinct from *D. tripunctatus* and *D. Cyri* due to its short and single stems, and shorter epicalyx scales in relation to its calyx tube. *Dianthus multiflorus* is also closely related to *D. tripunctatus* and *D. cyri*. In particular, the habit and floral characteristics of *D. multiflorus* are quite different from other species. Its divaricately branched stems bear numerous flowers unlike those of *D. tripunctatus* and *D. cyri*. Contrary to the pink and dentate petal-limbs of *D. tripunctatus* and *D. cyri*, *D. multiflorus* has white petals with distinct dark purplish venation and emarginate with shallowly sinuate margins. *Dianthus multiflorus* shows more resemblance to *D. tripunctatus* than *D. cyri* by the length of its epicalyx scales and the features of calyxes. The calyx tubes of *D. multiflorus* and *D. tripunctatus* are nervose-striate whereas those of *D. cyri* are enervose. However, the calyx length of *D. multiflorus* is shorter than that of *D. tripunctatus*. Further, the epicalyx scales are shorter to almost equaling in the calyx tube in *D. multiflorus* whereas they are equaling in *D. tripunctatus* and shorter in *D. cyri*. *Dianthus multiflorus* and *D. tripunctatus* have acuminate calyx teeth compared to their being aristate in *C. cyri*.

Besides morphological characteristics, both seed micromorphological and karyological features of *D. multiflorus* and *D. tripunctatus* were also identified within the present study. According to the results of the seed micromorphological studies, the main difference between the seeds of *D. multiflorus* and *D. tripunctatus* is the shape and size of the coat cells. According to the results of the karyological studies, there are some

karyomorphological differences between the two species. According to Levin (2002), the correlation between THL and 1C values within and between species in related genera, THL is considered a good proxy for genome size. On this basis, Peruzzi and Altınordu (2014) proposed a standardized method, taking into account six quantitative parameters, in order to establish relationships among taxa. THL is one of these parameters and the total haploid chromosome length (THL) in *D. multiflorus* was comparatively lower than that of *D. tripunctatus*.

Conclusion

The most important reason for the high endemism values in the Antalya and Mediterranean regions of Turkey is the sudden climatic and topographic differences. The Taşeli Plateau, which is one of the endemism centers of the eastern part of the Antalya province, is at an altitude of approximately 2200 meters and is just 20 km from the Mediterranean Sea. The lower slopes of the region are characterized by a typical Mediterranean climate and vegetation types, but the climatic conditions are continental at higher altitudes. The distribution area of *Dianthus multiflorus* is located in these climatic and topographic transition regions, and discovery of the new species contributes to a better understanding the richness of the Turkish Flora. With this study, the total number of species belonging to the genus *Dianthus* has risen to 82, the study provides material and data to aid further research on *Dianthus*, an important member of the Caryophyllaceae.

Specimens Examined. ***Dianthus aydogdui*** **Menemen & Hamzaoğlu**–TURKEY. Aksaray: Salt lake province, The north way from Ulukışla to Salt Lake, 950 m, 24 June 1999, *E. Hamzaoğlu & M. Aydoğdu 2432* (isotype GAZI!); ***Dianthus cyri*** **Fisch. & C.A.Mey.**–TURKEY: 06 July 1970, *F. Sorger 70–43–1* (E!) http://data.rbge.org.uk/herb/E00475274; UNITED ARAB EMIRATES. Fujeirah Coast–Lulayyah: Open fields in shelttered coastal plantation, 26 February 1986, *R.A. Western 881* (E!) http://data.rbge.org.uk/herb/E00181825; ***Dianthus tripunctatus*** **Sm.**–TURKEY. Antalya: Karayolları beach, 40 m, 15.6.1983, *H. & G. Çakırer s.n.* (ISTE 50905!); Antalya: Ulaş Highway recreation park, 20 km from İncekum to Alanya, s.l., 19 June 1983, *H. & G. Çakırer s.n.* (ISTE 51106!); Antalya: Kemer, Çıralı, under *Pinus brutia*, 10 m, 5 May 2013, *R. Süleyman Göktürk 7621* (Akdeniz University Herbarium 1779!); İzmir: 30 May 1960, *N. Öktem 56* (ISTE 6218!); Muğla: Ortaca, between Dalyan and Tepe, 10–20 m, roadsides, 18 June 1991, *A. Güner 9501* (GAZI!).

Acknowledgements

We wish to thank the subject editor and reviewers for their constructive comments which helped us to improve the manuscript, Agency of EXPO 2016 Antalya for financial support, and the curators of the E, GAZI, ISTE and Akdeniz University Herbarium for specimens examined.

References

Aytaç Z, Duman H (2004) Six new taxa (Caryophyllaceae) from Turkey. Annales Botanici Fennici 41: 213–223.

Bittrich V (1993) Caryophyllaceae. In: Kubitzki K, Rohwer J, Bittrich V (Eds) The Families and Genera of Vascular Plants, Magnoliid, Hamamelid, and Caryophyllid Families, Vol. 2. Springer, Berlin, 206–236. doi: 10.1007/978–3-662–02899–5_21

Davis PH, Mill RR, Tan K (1988) *Dianthus* L. In: Davis PH, Mill RR, Tan K (Eds) Flora of Turkey and the East Aegean Islands (Suppl. 1), Vol. 10. Edinburgh University Press, Edinburgh, 71–72.

Deniz İG, Aykurt C (2014) Critically endangered (CR) plant taxa in Antalya Province. The Herb Journal (21) 2: 59–70.

Gemici Y, Leblebici E (1995) Seven new species for the Flora of Turkey. Candollea 50: 41–50.

Güner A (2000) *Dianthus* L. In: Güner A, Özhatay N, Ekim T, Başer KHC (Eds) Flora of Turkey and the East Aegean Islands (Suppl. 2), Vol. 11. Edinburgh University Press, Edinburgh, 48–49.

Güner A, Aslan S, Ekim T, Vural M, Babaç MT (Eds) (2012) Türkiye Bitkileri Listesi (Damarlı Bitkiler). Nezahat Gökyiğit Botanic Garden and Flora Researh Society Publishing, 1–1290.

Hamzaoğlu E (2012) *Dianthus*. In: Güner A, Aslan S, Ekim T, Vural M, Babaç MT (Eds) Türkiye Bitkileri Listesi (Damarlı Bitkiler), Nezahat Gökyiğit Botanik Bahçesi ve Flora Araştırmaları Derneği Yayını, İstanbul, 333–337.

Hamzaoğlu E, Koç M, Aksoy A (2014) A new pricking Carnation (*Caryophyllaceae*) grows on tuff from Turkey: *Dianthus aculeatus* sp. nov.. Biodicon 7(2): 159–162.

Hamzaoğlu E, Koç M (2015) *Dianthus burdurensis* (Caryophyllaceae), a new species from South-western Turkey. Phytotaxa 233(2): 196–200. doi: 10.11646/phytotaxa.233.2.8

Hamzaoğlu E, Koç M, Aksoy A (2015a) *Dianthus aticii*, a new species from Turkey (Caryophyllaceae). PhytoKeys 48: 21–28. doi: 10.3897/phytokeys.48.4446

Hamzaoğlu E, Koç M, Büyük İ, Aksoy A, Aydın SS (2015b) A new serpentine-adapted carnation (Caryophyllaceae) from Turkey: *Dianthus serpentinus* sp. nov. Nordic Journal of Botany 33(1): 57–63. doi: 10.1111/njb.00582

Hamzaoğlu E, Koç M, Büyük İ, Aksoy A, Soydam Aydın S (2015c) Presence of *Dianthus roseoluteus* Velen. (Caryophyllaceae) in Turkey and a new species: *Dianthus macroflorus* Hamzaoğlu, Systematic Botany 40(1): 208–213. doi: 10.1600/036364415X686512

IUCN Standards and Petitions Subcommittee (2014) Guidelines for Using the IUCN Red List Categories and Criteria. Version 11. ttp://www.iucnredlist.org/documents/RedListGuidelines.pdf [accessed 20 April 2016]

İlçim A, Behçet L, Mükemre M (2013) *Dianthus vanensis* (Caryophyllaceae), a new species from Turkey. Turkish Journal of Botany 37: 219–224.

Levan A, Fredga K, Sandberg AA (1964) Nomenclature for centromeric position on chromosomes. Hereditas 52: 201–220. doi: 10.1111/j.1601–5223.1964.tb01953.x

Levin DA (2002) The role of chromosomal change in plant evolution. Oxford University Press on Demand, New York, 240 pp.

Menemen Y, Hamzaoğlu E (2000) A new species of *Dianthus* (Caryophyllaceae) from Salt Lake, Central Anatolia, Turkey. Annales Botanici Fennici 37: 285–287.

Özhatay N, Kültür Ş (2006) Check-list of additional taxa to the supplement Flora of Turkey III. Turkish Journal of Botany 30: 281–316.

Paszko B (2006) A critical review and a new proposal of karyotype asymmetry indices. Plant Systematics and Evolution 258: 39–48. doi: 10.1007/s00606–005–0389–2

Peruzzi L, Altınordu F (2014) A proposal for a multivariate quantitative approach to infer karyological relationships among taxa. Comparative Cytogenetics 8: 337–349. doi: 10.3897/CompCytogen.v8i4.8564

Peruzzi L, Eroğlu HE (2013) Karyotype asymmetry: again, how to measure and what to measure? Comparative Cytogenetics 7: 1–9. doi: 10.3897/compcytogen.v7i1.4431

Peruzzi L, Leitch IJ, Caparelli KF (2009) Chromosome diversity and evolution in Liliaceae. Annals of Botany 103: 459–475. doi: 10.1093/aob/mcn230

Post GE (1932) Flora of Syria, Palestina and Sinai, Vol. 1. Beirut.

Rechinger KH (1988) *Dianthus* L. In: Rechinger KH (Ed.) Flora Iranica, Caryophyllaceae II, Vol. Akademische Druck-u Verlagsanstalt, Graz, 128–188.

Reeve H (1967) *Dianthus* L. In: Davis PH (Ed.) Flora of Turkey and the East Aegean Islands, Vol. 2. Edinburgh University Press, Edinburgh, 99–131.

Shishkin BK (1985) *Dianthus* L. In: Shishkin BK (Ed.) Flora of the U.S.S.R. V. 6, Bishen Singh Mahendra PalSingh & Koeltz Scientific Books, Dehra Dun, 611–654.

Stebbins GL (1971) Chromosomal evaluation in higher plants. Edward Arnold, 1–216.

Strid A (1986) *Dianthus* L. In: Strid A (Ed.) Mountain Flora of Greece, Vol. 1. Cambridge University Press. Cambridge, 176–200.

Tutin TG (1964) *Dianthus* L. In: Tutin TG, Heywood VH, Burges NA, Valentine DH, Walters SM, Webb DA (Eds) Flora Europaea Vol. 1, Cambridge University Press, Cambridge, 188–204.

Velenovsky J (1891) Flora Bulgarica. Prostat apud Fr. Rivnac., Pragae.

Vural C (2008) A new species of *Dianthus* (Caryophyllaceae) from mount Erciyes, Central Anatolia, Turkey. Botanical Journal of the Linnean Society 158: 55–61. doi: 10.1111/j.1095–8339.2008.00843.x

Yılmaz O, Kaynak G, Daşkın R, Meriçlioğlu A (2011) *Dianthus goekayi* (Caryophyllaceae), a new species from Turkey. Annales Botanici Fennici 48: 74–78. doi: 10.5735/085.048.0111

PhytoKeys 63: 13–18 (2016)
doi: 10.3897/phytokeys.63.8366
http://phytokeys.pensoft.net

SHORT COMMUNICATION

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

Typification of names of South American taxa related to *Woodsia montevidensis* (Woodsiaceae)

Marcelo D. Arana[1], Claudine M. Mynssen[2], Brigitte Zimmer[3], M. Monica Ponce[4]

1 *Orientación Botánica II, Departamento de Ciencias Naturales, Facultad de Ciencias Exactas, Físico-Químicas y Naturales, Universidad Nacional de Río Cuarto, Ruta 36 km 601, X5804ZAB Río Cuarto, Córdoba, Argentina* **2** *Instituto de Pesquisa Jardim Botânico do Rio de Janeiro, Pacheco Leão 915, 22460-030, Rio de Janeiro, RJ, Brazil* **3** *Botanical Garden & Botanical Museum Berlin-Dahlem, Königin-Luise Str. 6-8, D-14195 Berlin, Germany* **4** *Instituto de Botánica Darwinion (ANCEFN-CONICET), Labardén 200, Casilla de Correo 22, B1642HYD San Isidro, Buenos Aires, Argentina*

Corresponding author: *Marcelo D. Arana* (marana@exa.unrc.edu.ar)

Academic editor: *J. Prado* | Received 3 March 2016 | Accepted 12 April 2016 | Published 26 April 2016

Citation: Arana MD, Mynssen CM, Zimmer B, Ponce MM (2016) Typification of names of South American taxa related to *Woodsia montevidensis* (Woodsiaceae). PhytoKeys 63: 13–18. doi: 10.3897/phytokeys.63.8366

Abstract

A revision of the nomenclature of six South American taxa related to *Woodsia* is presented, as a part of a taxonomic revision of the genus in South America. Lectotypes are selected for *Cheilanthes crenata, Woodsia crenata* var. *pallidipes*, *Woodsia incisa, Woodsia montevidensis* var. *fuscipes* and the second step lectotypification for *Dicksonia montevidensis* and *Woodsia peruviana,* based on the analysis of their protologues and original herbarium material. All names are currently synonyms of *Woodsia montevidensis*. *Physematium incisum* (Gillies ex Hook. & Grev.) Kunze constitutes an illegitimate name and *Physematium cumingianum* is considered as nomen inquirendum.

Keywords

Cheilanthes, *Diacalpe*, *Physematium*, nomenclature, *Woodsia*, Woodsiaceae

Introduction

Woodsia (Polypodiidae: Woodsiaceae) is a genus comprising about 35-40 taxa of small and tufted ferns growing on or in the vicinity of cliffs and rocks (Brown 1964). They mainly occur in montane areas in the Northern Hemisphere, but few species are also present in South America and Southern Africa. The greatest species richness is found

Copyright *Marcelo D. Arana et al.* This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

in the Rocky Mountains of western North America (ca. 10 spp.) and the Himalayas in south Asia (ca. 19 spp.); absent from Australia, New Zealand, SE Asia, and the Pacific (Kramer 1990, Shao et al. 2015, Shmakov 2015). The Neotropical species belong to *Woodsia* subgenus *Physematium* (Kaulf.) Hook. emend. X.C. Zhang & R. Wei (Shao et al. 2015, Shmakov 2015). South American floristic works cite the genus *Woodsia* as being represented by a single, morphologically variable species, *Woodsia montevidensis* (Spreng.) Hieron., with a distribution ranging from Venezuela and Colombia to central Argentina and Southern Brazil (de la Sota 1977, Tryon and Stolze 1991).

In anticipation of the recent efforts to prepare floristic inventories for Neotropical and Andean regions of South America, especially the Flora of Argentina (http://www.floraargentina.edu.ar) and the Flora of Brazil (Mynssen 2016), the nomenclature of taxa related to the genus *Woodsia* from South America was re-examined, and we are here providing lectotypes for four names, and two second step lectotypifications with the aim of enhancing nomenclatural stability, following as closely as possible the authors' original intentions.

Material and methods

We have analysed the protologues and morphological features from specimens of the following herbaria: B, BA, BAB, BM, CONC, CORD, CTES, HB, JUA, K, L, LE, LIL, LP, LZ, MCNS, MERL, MO, MVFA, NY, OXF, P, PR, PRC, R, RB, RCVC, RIOC, S, SI, US and W (acronyms see Thiers 2016). Typification was done according to the current edition of the International Code of Nomenclature for algae, fungi and plants (ICN) (McNeill et al. 2012) and considering the proposal concerning inadvertent lectotypifications and neotypifications (Prado et al. 2015).

Typifications

In this paper we have arranged the South American taxa related to *Woodsia* in alphabetical order by the names under *Woodsia*, as all of them are current synonyms of *Woodsia montevidensis* (Spreng.) Hieron., following Brown (1964), de la Sota (1977), and Tryon and Stolze (1991).

1. ***Woodsia crenata*** (Kunze) Hieron. Bot. Jahrb. Syst. 34(4): 440. 1904. ≡ *Cheilanthes crenata* Kunze, Linnaea 9: 84. 1834. Type: Peru. "Peruv.(ia) Rupestribus ad Huanuco (6,200') Martio 1830 lectae" *E.F. Poeppig, s.n.* (Lectotype, designated here: W [W-0061329!]).

Since Kunze's own herbarium in Leipzig is destroyed, we looked for further original material of *Cheilanthes crenata* from Huanuco, Peru collected by Poeppig at B, BM, K, L, LE, MO, NY, OXF, P, PCR, US and W. We were able to find original material at W that agrees well with Kunze`s original description, which we here select as lectotype, in order to avoid the misapplication of the name.

2. ***Woodsia crenata*** var. ***pallidipes*** Hieron., Bot. Jahrb. Syst. 34(4): 440. 1904. Type: Colombia. "Ad muros et rupes prope Puracé", 2680-2800 m, 1 Feb 1884, *F.C. Lehmann 3478*. Lectotype (designated here): B [B-200170834!]; isolectotypes: B [B-200170833!], K [K-000632733!], US [US-00066996!].

When Hieronymus (1904) described *Woodsia crenata* var. *pallidipes*, he cited four collections, three from Colombia and two from Bolivia. Bolivia: "sine loco, 1863", *Mandon 19* B [B-200171567!, on the right side of the sheet] and *Mandon 35* B [B-200171567!, on the left side of the sheet]. Colombia: "ad muros urbis Pasto", 2500 m, 11 Feb 1881, *F.C. Lehmann 656* B [B-20170836!], "ad muros et rupes prope Purace", 2680-2800 m., 1 Feb 1884, *F.C. Lehmann 3478* B [B-20170834!, B-2017083!], K [K-000632733!], US [US-00066996!], "ad muros et rupes prope Yermal, in provincia Antioquia", 1800-2400 m, Nov 1891, *F.C. Lehmann 7411* B [B-20170835!], K [K-000632732!]. We selected a specimen from the *F.C. Lehmann 3478* collection as lectotype because it corresponds with all characters used to describe the variety, furthermore the B specimen has a handwritten label by Hieronymus with the inscription "*Woodsia crenata* var. *pallidipes* Hieron." and there are duplicates in three herbaria.

3. ***Woodsia incisa*** Gillies ex Hook. & Grev., Icon. Filic. 2. t. 191. 1831 ≡ *Physematium incisum* (Gillies ex Hook. & Grev.) C. Presl, Tent.: 66. 1836. Type: Argentina. Mendoza: near San Luis, *J. Gillies s.n.* Lectotype (designated here): BM [BM-000937851!]; isolectotypes BM [BM-000937850!]; K [K-000229420!].

The type material at BM consists of four fronds with two different barcodes on the same sheet: BM [BM-000937850 and BM-000937851], both with separate labels with the same information. We selected the material affiliated with BM [BM-000937851] as lectotype because it is more complete.

The specimen *J. Gillies 8* housed at K [K-000229420!] is not part of the original material because it was collected at "Sierras de Tandil", located in Buenos Aires province, Argentina, far away from the type locality.

The combination *Physematium incisum* (Gillies ex Hook. & Grev.) Kunze (Kunze 1837) is an illegitimate name, posterior to Presl's combination.

4. ***Woodsia montevidensis*** (Spreng.) Hieron., Bot. Jahrb. Syst. 22: 363. 1896. ≡ *Dicksonia montevidensis* Spreng., Syst. Veg. 4(1): 122. 1827. Type: Uruguay. ("Brasilia") [Montevideo], Pan d'Açucar, *F. Sellow d 517.* Lectotype (first step designated by Tryon & Stolze [1991: 94]), second step (designated here): B [B-200094654!]; isolectotype B [B-200120343!].

The protologue only expresses "Monte Video. *Sello*". There are seven specimens of Sellow from Montevideo, five of them are kept in B, one in BM and another in K. Tryon and Stolze (1991: 94) typified *Woodsia montevidensis* with a specimen at B. From all specimens deposited in B, two of them are numbered *Sellow d 517* B [B-200094654! and B-200120343!] from Montevideo, as well quoted by Hieronymus when he made the combination under *Woodsia* (Hieronymus 1896). The specimen B [B-200094654!] is selected here as lectotype because it corresponds with all characters

used to describe the species, and probably it was the specimen seen by Sprengel because it bears the annotation of G. Hieronymus "Original von Sprengel". Also it shows on a second label n. 118. "(Sprengel)" on a third: "Pan d'Açucar", and on the fourth: "d.517". The specimen B [B-200120343!] is considered isolectotype.

The remaining specimens: B [B-200170837a], Montevideo, ex reliquiis Sellowianis, s.n., ded. Humboldt 1836, ex herb. Kunth, [the two fronds on the left], B [B-200170837b], Montevideo, Pan d' Açucar, ex reliquiis Sellowianis, s.n., ded. Humboldt 1836 [the two fronds on the right], B [B-200120342 and B-200120344] bear the only annotation "Brasilia" without specific locality (same label Herb. Reg. Berolinense, as K [K-000632729!], and BM [BM-000937849!], although probably being original material, are preferably excluded from lectotypification because the data of the label are not complete.

5. ***Woodsia montevidensis*** var. ***fuscipes*** Hieron., Hedwigia 46: 322. 1907. Type: Argentina. Salta. "Prov. de Salta, Los Potreros al pie del Nevado del Castillo, 24.03.1827", *P.G. Lorentz & G.H.E.W. Hieronymus 138*. Lectotype (designated here): B [B-200171577!]; isolectotypes: B [B-200171580!, B-200171581!], CORD!.

When Hieronymus described the variety *fuscipes*, he mentioned five collections in the protologue. Two collections from Bolivia: Illimani between Pongo and Apachate. alt.: 4350 m, 24 March 1873, collected by *A. Stübel 1239* (B [B-200171573!]) and La Paz, Murillo, Zongo ("prope Songo"), Nov 1890, collected by *M. Bang 878* (B [B-200171572!], MO [MO-1919967 digital image!]; P [P-01400358!]; PH [PH-00029464 digital image!]; UC not seen; US [US-00067000!]). From Argentina, three additional collections were considered by Hieronymus as belonging to this variety: *F. Schickendantz* 68 (B [B-200171578!, B-200171579!]), *F. Schickendantz* 360 (B [B-200171576!]), and *P.G. Lorentz & G.H.E.W. Hieronymus 138* (B [B-200171577!, B-200171580!, B-200171581!], CORD!). Specimens of all five collections are present at B. In order to avoid any ambiguity regarding the application of the name, the specimen *Lorentz & Hieronymus 138* (B [B-200171577!]) is selected as lectotype, while the three duplicates are regarded as isolectotypes in accordance to Art. 9.12 of the Code (McNeill et al. 2012). Also, the lectotype chosen shows the characters used to delimitate the variety and bears an annotation by Hieronymus "n. var," and handwritten locality data.

6. ***Woodsia peruviana*** Hook., Sp. Fil. 1: 61, pl. 21B. 1844. ≡ *Diacalpe peruviana* (Hook.) Trevis., Nuovo Giorn. Bot. Ital.7: 160. 1875. Type: Peru. "Huamantanga, shady places", 1834-1835, *A. Mathews 602*. Lectotype (first step designated by Tryon & Stolze (1991: 94), second step (designated here): K [K-000632731!]; isolectotypes B [B-20 0094655!, B-20 0171563!], BM [BM-000937848 digital image!], GH [GH-00022287 digital image!], and K [K-000632730 digital image!].

Tryon and Stolze (1991: 94) typified *Woodsia peruviana* with a specimen at K as holotype, but K holds two sheets of *Mathews 602* [K-000632730 and K-000632731],

the last one is here designated as lectotype because the material is more complete, has a handwritten annotation "Peru, Mathews" and "*Woodsia peruviana* Hook. Spec. Fil. Tab. XXI" on the sheet, and the label contains the locality data.

The specimen *A. Mathews s.n.* (US [US-00067001!]), according with Taylor's annotation in the label of the specimen, could probably be part of the type collection, but we prefer to exclude it of lectotypification because the locality is not clear (only "Peru" is written in the label) and it is not originally numbered by Mathews.

Unresolved name

Woodsia cumingiana (Kunze) Hook., Sp. Fil. [W. J. Hooker] 1: 61. 1844. ≡ *Physematium cumingianum* Kunze, Analecta Pteridogr.: 43. 1837. Type: "Habitat probabiliter in Chile, misit *H. Cuming*" (Herb. Kunze in LZ, destroyed).

The original material of this species, deposited in LZ, was destroyed. As Kunze (1837) observed in the protologue: "unicum vidi specimen observed", there is not referable isotype or even an illustration of the species. According to Stafleu and Cowan (1979), the original material of H. Cuming is kept at BM; however, no syntypes were found in this herbarium, nor in the Herbarium Hookerianum (K). Additionally, no material of this species from Chile was in B, BR, BM, E, GH, L, LE, OXF, P, W and Z, where duplicates of H. Cuming are deposited. Also, as consigned by Hooker (1844), most probably the type locality is mistaken, because he had the opportunity to revise the collections of Cuming immediately after his return and he was not able not find any specimen gathered by Cuming from either Chile or Peru. As the protologue expresses, the species is characterized by last segments oblong rounded, glandulosodentate decurrent, sori solitary upon the teeth, involucres glabrous, rachis and stipe subglabrous purple. With such description, the species is hardly to differenciate from many species of *Woodsia*, hence, the name is considered here as nomen inquirendum.

Acknowledgements

The authors are thankful to the collection managers and curators of the herbaria mentioned for granting access to their herbarium collections and sending images, in special to Anna Haigh (K), Armin Löckher (W), Germinal Rouhan (P), Gloria Barboza & Jimena Ponce (CORD), Hajo Esser (M), Lesley Scott (E) and Roxali Bijmoer (LE) for their valuable help with the location and sending images of the type material. We are grateful to Fernando Matos (NY), Jefferson Prado (SP) and Manuel Belgrano (SI) for his helpful comments about some necessary lectotypifications, and to JSTOR (http://plants.jstor.org/), CONICET (Argentina) and Herbarium Berolinense (Röpert 2000+ [continuously updated]) that provides the access to this website where images of the types discussed in this paper are.

References

Brown DFM (1964) A monographic study of the fern genus *Woodsia*. Beihefte Nova Hedwigia 16: 1–154.

de la Sota ER (1977) Pteridophyta. In: Cabrera AL (Ed.) Flora de la Provincia de Jujuy. Colección Científica del Instituto Nacional de Tecnología Agropecuaria, Buenos Aires, 13: 1–275.

Hieronymus GHEW (1896) Beitrage zur Kenntnis der Pteridophyten Flora der Argentina und einiger agrenzender Teile von Uruguay, Paraguay und Bolivien. Botanische Jahrbücher fur Systematik, Pflanzengeschichte und Pflanzengeographie 22: 359–420. http://www.biodiversitylibrary.org/page/206739#page/369/mode/1up

Hieronymus GHEW (1904) Plantae Lehmannianae in Guatemala, Columbia et Ecuador regionibusque finitimis collectae, additis quibusdam ab aliis collectoribus ex iisdem regionibus allatis determinatae et descriptae. Pteridophyta. Linnaea 34: 417–582. http://www.biodiversitylibrary.org/item/697

Kramer KU (1990) *Woodsia*. In: Kramer KU, Green PS (Eds) The Families and Genera of vascular plants- Volume I- Pteridophytes and Gymnosperms. Springer-Verlag, Berlin, 140.

Kunze G (1837) Analecta pteridographica: seu Descriptio et illustratio filicum aut novarum, aut minus cognitarum. Impensis Leopoldi Voss, Leipzig, 1–50.

McNeill J, Barrie FR, Buck WR, Demoulin V, Greuter W, Hawksworth DL, Herendeen PS, Knapp S, Marhold K, Prado J, Prud'homme van Reine WF, Smith GF, Wiersema JH, Turland NJ (Eds) (2012) International Code of Nomenclature for algae, fungi and plants (Melbourne Code) adopted by the Eighteenth International Botanical Congress Melbourne, Australia, July 2011. Regnum Vegetabile 154. Koeltz Scientific Books. http://www.iapt-taxon.org/nomen/main.php

Mynssen CM (2016) Woodsiaceae. In: Lista de Espécies da Flora do Brasil. Jardim Botânico do Rio de Janeiro. http://floradobrasil.jbrj.gov.br/jabot/floradobrasil/FB92305 [accessed 18 Jan. 2016]

Prado J, Sylvestre LS, Labiak PH, Windisch PG, Salino A, Barros ICL, Hirai RY, Almeida TE, Santiago ACP, Kieling-Rubio MA, Pereira AFN, Øllgaard B, Ramos CGV, Mickel JT, Dittrich VAO, Mynssen CM, Schwartsburd PB, Condack JP, Pereira JBS, Matos FB (2015) Diversity of ferns and lycophytes in Brazil. Rodriguésia, v. 66, n. 4. doi: 10.1590/2175-7860201566410

Prado J, Hirai RY, Moran RC (2015) (046–048) Proposals concerning inadvertent lectotypifications (and neotypifications). Taxon 64(3): 651. doi: 10.12705/643.29

Röpert D (Ed.) (2000+ [continuously updated]) Digital specimen images at the Herbarium Berolinense. http://ww2.bgbm.org/herbarium/default.cfm [accessed 2015-2016]

Shao Y, Wei R, Zhang X, Xiang Q (2015) Molecular Phylogeny of the Cliff Ferns (Woodsiaceae: Polypodiales) with a Proposed Infrageneric Classification. PLoS ONE 10(9): e0136318. doi: 10.1371/journal.pone.0136318

Shmakov AI (2015) The new system of family Woodsiaceae Новая система семейства Woodsiaceae. Turczaninowia 18(2): 11–16. doi: 10.14258/turczaninowia.18.2.2

Thiers B (2016) [continuously updated]: Index herbariorum: a global directory of public herbaria and associated staff. New York Botanical Garden's virtual herbarium. http://sweetgum.nybg.org/science/ih/ [accessed 1 Jan 2016]

Tryon RM, Stolze RG (1991) 17. Dryopteridaceae. Pteridophyta of Peru, part IV. Fieldiana, Botany 27: 1–176.

PhytoKeys 63: 19–29 (2016)
doi: 10.3897/phytokeys.63.7743
http://phytokeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

New functionally dioecious bush tomato from northwestern Australia, *Solanum ossicruentum*, may utilize "trample burr" dispersal

Christopher T. Martine[1], Jason T. Cantley[1], Emma S. Frawley[1], Alice R. Butler[1], Ingrid E. Jordon-Thaden[1,2]

1 *Department of Biology, Bucknell University, 1 Dent Drive, Lewisburg, PA, USA* **2** *University and Jepson Herbaria, University of California, Berkeley, CA, USA*

Corresponding author: *Christopher T. Martine* (chris.martine@bucknell.edu)

Academic editor: *Sandra Knapp* | Received 8 January 2016 | Accepted 5 April 2016 | Published 3 May 2016

Citation: Martine CT, Cantley JT, Frawley ES, Butler AR, Jordon-Thaden IE (2016) New functionally dioecious bush tomato from northwestern Australia, *Solanum ossicruentum*, may utilize "trample burr" dispersal. PhytoKeys 63: 19–29. doi: 10.3897/phytokeys.63.7743

Abstract

A new Australian species of functionally dioecious bush tomato of *Solanum* subgenus *Leptostemonum* is described. *Solanum ossicruentum* Martine & J.Cantley, **sp. nov.**, is thought to be allied with members of the problematic "Dioicum Complex" lineage, but differs in its short silvery indumentum, long calyx lobes, larger stature, and an unusual fruit morphology that may represent "trample burr" seed dispersal. The species occurs in a range extending from the eastern Kimberley in Western Australia to far northwestern Northern Territory and has been recognized for decades as a variant of *S. dioicum* W.Fitzg. Specimens of this species were previously referred to by D.E. Symon and others as *Solanum dioicum* 'Tanami.' Ex situ crossing studies and SEM images of inaperturate pollen grains produced in morphologically hermaphrodite flowers indicate that this taxon is functionally dioecious. The scientific name was chosen with the help of 150 seventh grade life science students from Pennsylvania, USA.

Keywords

Bush tomato, cryptic dioecy, inaperturate pollen, Keep River National Park, Kimberley, Mirima National Park, new species, Northern Territory, *Solanum*, *Solanum dioicum*, *Solanum* sp. Tanami, undergraduate research, Western Australia

Copyright *Christopher T. Martine et al.* This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Introduction

Dioecy in *Solanum* (Solanaceae) is one of the more fascinating phenomena in plant reproductive biology (Knapp et al. 1998). Species exhibiting this breeding system do so in a functional sense whereby male plants bear morphologically staminate flowers and female plants bear morphologically hermaphrodite flowers with anthers that (typically) produce inaperturate pollen. First described using crossing studies and SEM imaging for the Mesoamerican *S. appendiculatum* (Anderson 1979, Anderson and Levine 1982, Levine and Anderson 1986, Zavada and Anderson 1997), functional dioecy has now been identified in around 20 *Solanum* taxa (Barrett 2013, Martine et al. 2013). The highest incidence of functional (also referred to as "cryptic") dioecy in *Solanum* occurs in Australia, where Anderson and Symon (1989) unequivocally confirmed the condition in nine species (based on Symon 1981) via ex situ crossing experiments. Since that time, several new and putative dioecious *Solanum* species have been recognized in Australia, nearly all of them members of the "Dioicum Complex" (Symon 1981, Martine et al. 2006, 2009) in the Kimberley region of Western Australia (Brennan et al. 2006, Barrett 2013, M. Barrett pers. comm.).

Solanum ossicruentum Martine & J.Cantley, sp. nov. is one of the many recognizable variants currently included under the broad taxonomic umbrella (Symon 1981; Purdie et al. 1982) of *S. dioicum* W.Fitzg.. Identified by collectors (including D.E. Symon and P.K. Latz) since the 1970s as *Solanum dioicum* 'Tanami' or *Solanum* sp. 'Tanami', this taxon is not only morphologically distinct (Symon 1981, Wheeler et al. 1992), but largely occurs outside of the range of its allied species, extending into the northern edges of the Tanami Desert. Symon (1981) identified three widespread and recognizably different forms of the broadly circumscribed *S. dioicum*, identifying 'Tanami' as an inland form occupying the "eastern margin" of the species range and noted its distinctiveness in being "closely and densely silvery-pubescent, compact, and extremely prickly." Here we describe this form as a new species of *Solanum*.

Methods

Recent observations of the taxon by CTM in Mirima National Park (WA), the Carr Boyd Ranges (WA), and Keep River National Park (NT) are combined here with inferences from plants grown in cultivation from wild-collected seed and herbarium sheets held at the Northern Territory Herbarium, Palmerston (DNA). Seeds were germinated following a 24-hour soak in 1000-ppm gibberellic acid and sown in a controlled growth chamber environment as per Martine et al. (2016). To generate pollen images, fresh pollen mounts from male and female flowers were sputter coated with gold on a Denton Vacuum Desk IV Sputterer (Moorestown, NJ, USA) and examined under a scanning electron microscope (FEI Quanta 400, Hillsborough, OR, USA). Trichome densities were counted under a dissecting scope using 0.25 cm radius holes punched from fresh leaves of seven individual plants (5 leaves per plant and 2 samples per leaf).

Taxonomic treatment

Solanum ossicruentum **Martine & J.Cantley, sp. nov.**
urn:lsid:ipni.org:names:77154529-1
Figs 1, 2

Diagnosis. This species is distinguished from other dioecious solanums in northwestern Australia by its short silvery indumentum, long calyx lobes, larger and compact stature, and a bony hard mature fruit that remains enclosed in a heavily armed calyx.

Type. AUSTRALIA. Western Australia: Mirima (Hidden Valley) National Park, below upper lookout on Derdbe-Gerring Banan Lookout Trail, 15°45.827'S, 128°45.105'E, 18 May 2014 (staminate and "female" flowers; fruit), *Christopher T. Martine and Rachel F. Martine 4011* (holotype: DNA; isotypes: PERTH, BUPL, CONN)

Description. Clonal, upright woody shrub to 1–2 m tall and 1–2.5 m wide. Single woody stems ca. 2.5 cm diameter from woody rootstock, splitting at about 1/3 of total height to form a Y-shaped or inverted tripod-like growth form, ultimately branching 4–10 times. Overall plant aspect silvery to bluish-green to gray-green, the young growth tomentose-lanate, with older stems woody and gray. Internodes 4.5–8 cm. Stems with short, dense indumentum of stellate trichomes. Prickles straight, long, thin, somewhat sharp, 6–8 mm long, slightly widened at base, abundant and dense (7–15 per cm of internode) on all stems including older woody growth. Leaves 13–23 cm × 4–5 cm, alternate, lanceolate, unarmed; margins entire to undulate; base truncate to rounded, asymmetrical; petiole 10–19 mm long, with scattered prickles; blade soft silvery-blue/gray-green to sage green, concolorous, both sides densely silvery-tomentose (380–560 trichomes per 0.25 cm radius leaf disk); trichomes mostly short stalked, porrect-stellate with short central ray (midpoint). Inflorescences borne on new growth.

Male inflorescence a cyme about ca. 4–5 cm long with 2–12 flowers, unbranched, typically with only 2–3 flowers open at a time; peduncle ca. 2–2.5 cm long; rachis 2–2.5 cm long; pedicels ca. 2 mm, unarmed; calyx 5-lobed with or without a few prickles towards the base, the lobes 1.2–1.5 cm long with linear acumens; corolla 3.5–3.8 cm diameter, dark violet, rotate-stellate to rotate, glabrous adaxially and abaxially except for pubescence of minute simple hairs along folds; acumens 0.75–1.25 mm; stamens 5, ca. 9 mm long, equal; anthers ca. 5 mm long, oblong-lanceolate to somewhat tapered, connivent, yellow, poricidal; filaments ca. 4 mm, connate at base; ovary, style, and stigma vestigial, non-functional, and not exserted beyond the stamens.

Morphologically *hermaphrodite* flowers solitary, functionally *female*, with anthers producing inaperturate pollen (Fig. 2). Female flower on pedicel 0.25–1.0 cm long, armed with small prickles to 2 mm long; calyx densely armed along ribs of tube with long (9–10 mm), straight prickles and stellate trichomes; lobes 1.5–6 cm, narrowly linear, prickly; corolla ca. 3–7 cm diameter, rotate-stellate to stellate-campanulate/funnelform, vibrantly violet, glabrous adaxially and abaxially except for pubescence of minute simple hairs along folds; acumens ca. 1.5–2.0 mm; stamens of same propor-

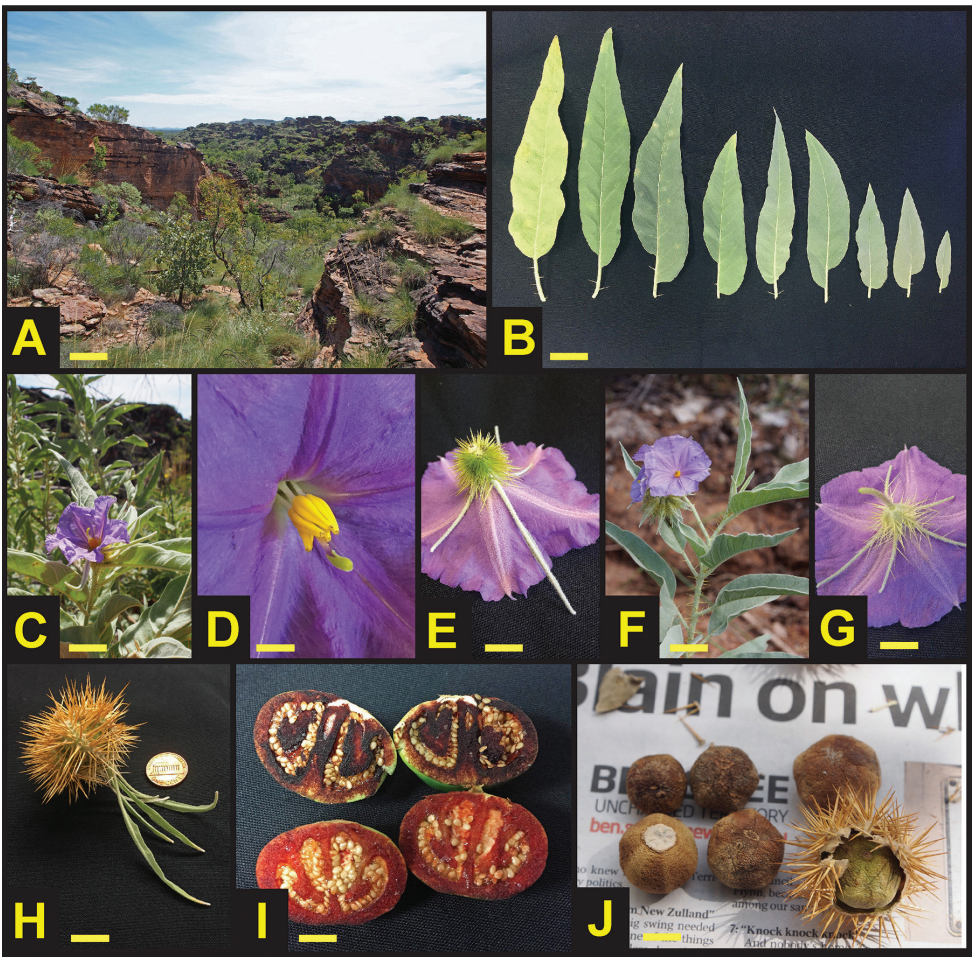

Figure 1. *Solanum ossicruentum* sp. nov. **A** Typical habitat, Mirima National Park, WA **B** Leaf morphology **C** Female individual, Mirima NP **D** Close-up of functionally female (morphologically hermaphrodite) flower **E** Abaxial side of functionally female flower showing elongated calyx lobes **F** Male individual, Mirima NP **G** Male flower, abaxial view **H** Developing fruit within calyx **I** Immature fruits showing blood-red staining at 2 minutes (lower) and 5 minutes (above) after cutting **J** Mature bony fruits removed from calyces and (lower right) as collected from ground beneath plant. Yellow scale bars as follows: 3 cm (**B, C, F**); 1 cm (**D**); 2 cm (**E, G, H, J**); 0.75 cm (**I**). Photos **A**, **C**, **F**, and **J** by C.T. Martine; all others by J.T. Cantley.

tions as in male flowers; ovary ca. 4 mm diameter at anthesis, with scattered short, green trichomes; style erect, ca. 14 mm long (including stigmatic surfaces); stigma green, ca. 4 mm long, with slight bifurcation along final 0.5–1.0 mm.

Fruit a berry 1.5–2.5 cm diameter, globose; immature fruit light green, fleshy, with slightly sticky flesh oxidizing from whitish-green to deep blood-red when cut; mature fruit drying to dark green, then chestnut brown, becoming leathery-reticulate in texture and bony hard, weakly six-angled, and loosely retained and partly-enclosed

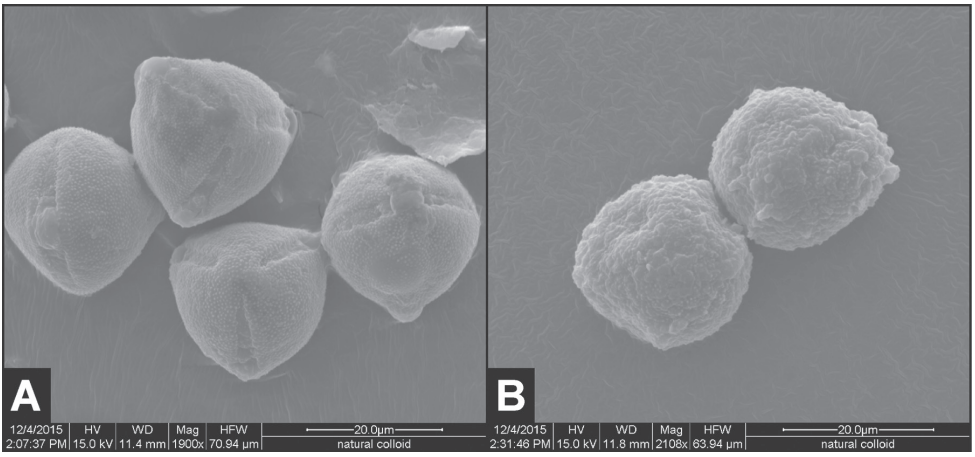

Figure 2. SEM images of *S. ossicruentum* sp. nov. pollen grains. **A** Functional pollen produced by male flowers, and **B** Inaperturate pollen produced by morphologically hermaphrodite, yet functionally female, flowers. Images by A. Butler.

(±75%-enclosed) in calyx, with a 6–8 mm diameter light-colored disk-shaped abscission scar. Fruiting calyx lobes 4.5–7.25 cm long and long-acuminate (acumens breaking off with age), densely armed with sharp prickles 7–8 mm long, tapering to long fine tip, 4–5 prickles per jagged line along ribs and spreading, short stellate-pubescent, more so on calyx ribs and around bases of prickles. Calyx slightly sticky-adherent to fruit when immature, readily separating from fruit as the berry matures, hardens, and shrinks from drying. Fruit and intact calyx ultimately detaching from plant as one light brown, sharply spiny, 3.5–4.5 cm diameter dispersal unit. Seeds ca. 1.5 mm diameter, tan to brown, conspicuously and minutely reticulate, up to 500–650 per fruit.

Distribution and ecology. *Solanum ossicruentum* is presently known from a wide range of localities in the sub-arid tropical zone of the Northern Territory and eastern Kimberley in Western Australia, including the northern edge of the Tanami Desert (Fig. 3), mostly within the Victoria Bonaparte Terrestrial Bioregion (Australian Government 2012). The species associates closely with red sandstone, quartzite sandstone, and conglomerates (as per Tyler 1996), where it is found on hills, ridges, outcrops, and plateaus, growing in gravel or from fissures in pavement and dissected rock. It has also been collected frequently in steep gorges and washes, as well as at the base of rock formations in sandy levees and alluvial deposits. Among the associated taxa noted on herbarium labels are species of *Triodia* (Poaceae), *Acacia* (Fabaceae), *Eucalyptus* (*Myrtaceae*), and *Grevillea* (Proteaceae). Although little is known about its relation with fire (one fruiting collection by Latz is from a recently burned habitat), the species is likely fire tolerant to some degree. Pollination biology of the species is unknown, but, like other Australian congeners, the flowers are likely buzz pollinated by bees in the genera *Xylocopa* and *Amegilla* (see Anderson and Symon 1988, Switzer et al. 2015). A small set (n=8) of ex situ hand pollinations conducted for this study showed that inaperturate pollen produced by functional females does not lead to fruit set when

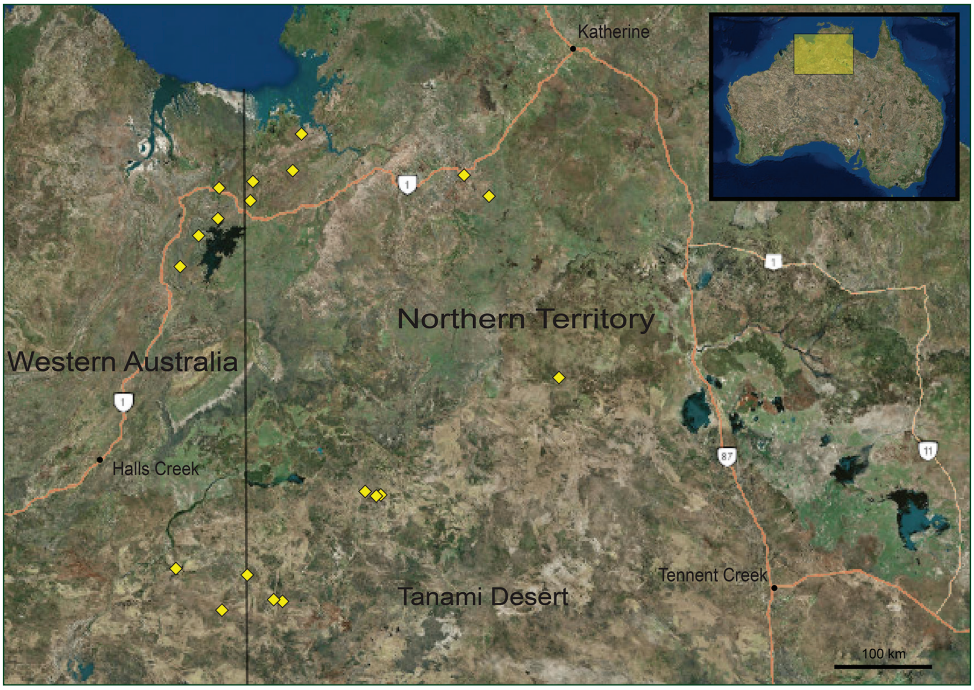

Figure 3. Map showing distribution of *S. ossicruentum* sp. nov. accessions held at the Northern Territory Herbarium, Palmerston (DNA) and examined for this description. Map base layer generated from ArcGIS.

used to pollinate other females – suggesting that, like other dioecious solanums, reproduction in this species is dependent on intersexual outcrossing via biotic pollination. SEM images of the pollen (Fig. 2) confirm that morphologically hermaphrodite flowers produce inaperturate grains incapable of germination.

Seed dispersal appears to follow the relatively uncommon "trample burr" pattern for *Solanum* described by Symon (1979), whereby lightweight fruits enclosed in spiny calyces are carried in the fur of mammals. The fruits of *S. ossicruentum* detach enclosed within a long-spiny calyx at maturity, the diaspores gathering in piles on the ground or getting caught in tufts of hummock-forming spinifex grass (*Triodia* spp.) growing below parent plants. In the course of this study, only seeds from mature, bony fruits – the condition they are in when dropped from the plant - proved to be germinable.

Uses. Doonday et al. (2013) describe the use of *Solanum dioicum* (sensu lato), or "salty bush tomato," by the Walmajarri people in the area of the Paruku Indigenous Protected Area, which encompasses part of the western range of *S. ossicruentum*. Although the authors suggest that the fruits (called "kara" in Walmajarri) are consumed by kangaroos, some Walmajarri people also "eat the outside part… but not the inside part" due to the "saltiness or unpleasantness of the fruit." While the unripened fruits of *S. ossicruentum* are fleshy and "salty" tasting (C. Martine, pers. obs.), the bony nature of mature fruits suggests that the usage described here does not relate to this taxon. Instead, it likely represents one of the other Kimberley forms of *S. dioicum* sensu lato.

Phenology. Most flowering specimens have been collected from February-July, with fruiting specimens collected in March-September. Seeds germinated for this study were from diaspores collected at the base of plants bearing flowers and immature fruits at Mirima National Park on 1 May 2014. These were assumed to have developed in the previous growth season.

Phylogeny. Previous phylogenetic work including accessions identified as this form (Martine et al. 2006, Martine et al. 2009) suggested that *S. ossicruentum* is a member of the "Dioicum Complex," a set of several dioecious species largely occupying the Kimberley region. Preliminary work using multiple intronic regions (Martine et al. in prep) infers that *S. ossicruentum* is either sister to the rest of that group or represents an independent dioecious lineage. It does not appear to form a clade with the other Australian dioecious species of the "Dioicum Complex" or with the dioecious *S. asymmetriphyllum* Specht and *S. sejunctum* Brennan, Martine & Symon from Kakadu National Park (Brennan et al. 2006, Martine et al. 2006; Särkinen et al. 2013).

Etymology. The name *Solanum ossicruentum* was chosen based on suggestions from middle school students in Lewisburg, Pennsylvania, USA. In the spring of 2015, CTM presented live plants of the taxon to an assembly of 150 seventh-grade life science students at Donald H. Eichhorn Middle School. The students, with the help of Mr. Bradley Catherman, were invited to examine the plants, ask questions, and then submit an essay proposing and justifying a potential Latin name for the putative new species. Numerous students were drawn to and suggested names based on the characteristics of the fruits, which stain blood red when cut open before maturity and then mature to a dry, bony condition. Thus *ossi-* is used for "bone" and *-cruentum* for "bloody."

Preliminary conservation status. Based on IUCN Red List Categories (IUCN 2011), *S. ossicruentum* is considered Data Deficient (DD). While the species appears to be relatively widespread over a range of approximately 90,000 km^2, its range is not comprehensively understood. A relatively small number of collections, coupled with the fact that populations often consist of multiple individuals, suggest that the species is common in some localities but uncommon on the regional and global scales. Further data are required before a certain conservation status can be determined. Like other dioecious species of clonal nature, "populations" of *S. ossicruentum* have the potential to represent large multi-stemmed genets connected by an underground network of stolons (e.g. Martine et al. 2013). Given that individual genets in dioecious taxa cannot self-fertilize, clonal individuals have particular potential to be reproductively isolated. Recent observations of a small unisexual population by CTM in the Carr Boyd Ranges (just north of Lake Argyle) found that numerous female flowers had bloomed and senesced, ostensibly for lack of nearby male individuals and/or effective pollinators, and preliminary results from a population genetics study (Cantley et al. in prep) show low levels of genetic diversity for the species in Mirima National Park – a surprising outcome given that dioecious taxa are obligate outcrossers.

Specimens examined. AUSTRALIA. Northern Territory: Jellebra Rockhole, 19°21'45"S, 129°00'35"E, 7 June 1996, *D.E. Albrecht 7756* (DNA, NT); Cockatoo Creek, Keep River area, 15°55'17"S, 129°03'31"E, 2 September 1974, *Gibbs & Fox 618*

(DNA, NE); Spirit Hills, 15°24'58"S, 129°28'39"E, 17 April 2007, *R.A. Kerrigan 1226* (DNA); 11 km east of NE Mt. Frederick, 19°37'S, 129°21'E,1 March 1981, *P.K. Latz 8597* (DNA, NT); Pargee Range, 19°36'S, 129°16'E, 2 April 1981, *P.K. Latz 8608* (DNA, ADW); 8 km SSW Victoria River Bridge, 15°40'47"S, 131°5'34"E, 16 April 1996, *P.K. Latz 14760* (DNA, NT, AREF); Cow Creek, Victoria River, Gregory National Park, 15°52'26.8"S, 131°19'58.6"E,2 May 2001, *C.P. Mangion & G. Boehme 1060* (DNA); Winnecke Hills, 18°37'11"S, 130°16'30"E, 1 May 2004, *C.P. Mangion & D.L. Lewis 1607* (DNA); Nigli Gap Walk, Keep River National Park, 15°45'30.4"S, 129°05'07.4"E, 26 May 2004, *C.T. Martine & W.R. Barker 772* (DNA, CONN); Gurrundalng Walk, Keep River National Park, 15°52'07.8"S, 129°03'11.1"E, 27 May 2004, *C.T. Martine & W.R. Barker 781* (DNA, CONN); 63 km S of Lajamanu, 18.39°S, 130.16°E, 10 Feb 1988, *T.M. Orr 57* (DNA); Mornington Station, 17°33'02"S, 132°01'15"E, 11 April 2004, *JA Risler & S. Legge 2673* (DNA); Bradshaw Military Training Area, 15°04'50"S, 129°33'28"E, 2 April 2007, *B.M. Stuckey & I.D. Cowie 64* (DNA, NSW); 165.8 km NE of Tanami, 18°33'S, 130°10'E, 18 May 1971, *D.E. Symon 6938* (DNA, NT, CANB, PERTH); **Western Australia:** North end of Ragged Range, 16°31'32"S, 128°23'21"E, 17 July 2001, *D.J. Edinger 2601* (DNA, PERTH); 1 mile N of Revolver Creek, Carr Boyd Ranges, 16°14'S, 128°34'E, 13 March 1978, *T.G. Hartley 14561* (DNA, CANB); Sturt Creek Station, 19°18'S, 128°19'E, 20 July 1973, *P.K. Latz* (DNA, NT, ADW, PERTH); Mirima National Park, 15°47'14.1"S, 128°45'37.0"E, 28 May 2004, *C.T. Martine & W.R. Barker* 787 (DNA, CONN); Carr Boyd Ranges, 16°05.207'S, 128°45.406'E, 3 May 2014, *C.T. Martine & R.F. Martine 4057* (DNA, BUPL).

Diagnostic couplet. A comprehensive key to the "Diocum Complex," including numerous newly recognized species, is forthcoming (Barrett and Barrett in prep). At present, the most complete diagnostic key for the species of the Kimberley region is the key in Barrett (2013), which lumps the primary variations of *S. diocium* sensu lato as a single taxon. The following couplet may be inserted where *S. dioicum* occurs at couplet 60.

60a Plants less than 1 m tall, many-branched; stems moderately prickly; leaf indumentum silvery or rusty, overall aspect silvery-green, yellowish-green, or reddish-green; stigma deeply bifurcating, lobes 2-5 mm; calyx lobes slightly exceeding corolla and enclosed fruits; fruits green and fleshy at maturity ....***Solanum dioicum*** **W.V. Fitzg.**

60a Plants 1–2 m tall, few-branched and conspicuously Y-shaped in form; stems exceptionally prickly; leaf indumentum silvery, overall aspect silvery-blue; stigma shallowly bifurcating, lobes 0.5-1 mm; calyx lobes far exceeding corolla and enclosed fruits; fruits bony and dry at maturity..... .....***Solanum ossicruentum*** **Martine & J. Cantley**

Discussion. *Solanum ossicruentum* has been noted for nearly 50 years as a widespread morphotype of *Solanum dioicum* known as 'Tanami' (Symon 1981, Purdie et al. 1982). The outstanding characters noted here, particularly its silvery tomentum, conspicuously long calyx lobes, upright and Y-shaped to inverted tripod-shaped stature,

and dioecious breeding system, make it easily recognizable in the field, and its putative trample-burr dispersal syndrome is unusual among allied species. Symon (1979) described the fruits of *S. dioicum* sensu lato as belonging to a large group of species with firm, yellowish berries – but he identified a set of six solanums in northern Australia as bearing "trample burr" fruits that are shed when ripe. Notably, Symon included *S. leopoldensis* Symon, another member of the "Dioicum Complex," in this group. The fruits of *S. leopoldensis*, like those of *S. ossicruentum*, mature to a bony condition and remain enclosed in a spiny calyx. The recently described *S. zoeae* R.L. Barrett is closely allied with *S. leopoldensis* and shares similar fruiting characteristics (Barrett 2013); and the forthcoming recognition of a number of new dioecious *Solanum* species in the Kimberley (Barrett and Barrett in prep) may provide evidence that "trample burr" morphology is more widespread than currently thought.

In overall aspect, the new species most closely resembles *S. beaugleholei* Symon and *S. phlomoides* A. Cunn. ex Benth. (both endemic to NW Australia) based on leaf morphology, tomentum, and coloration, but both of these species are less rigidly upright, have much larger (only partially enclosed) fleshy fruits, and exhibit an andromonoecious breeding system.

Recent surveys in remote regions of the Kimberley suggest that the total number of dioecious taxa in that region may be around 20 (Barrett 2013, M. Barrett pers. comm.), with three other named dioecious species endemic to the Northern Territory: *S. asymmetriphyllum*, *S. cowiei* Martine (Martine et al. 2014), and *S. sejunctum* (Brennan et al. 2006). The prevalence of functional dioecy among the solanums of Australia, relative to the few other incidences recorded elsewhere (Knapp 1998, Martine and Anderson 2007), continues to be of great interest and will be further informed by ongoing work in reproductive ecology (e.g., Martine and Anderson 2008; Jordon-Thaden et al. in prep), population genetics (Cantley et al. in prep.), and phylogenomics (Martine et al. in prep). It is hoped that these and other studies (e.g., Barrett and Barrett in prep) will help resolve the problematic taxonomy of *Solanum dioicum* sensu lato, a nomenclatural issue that currently impedes efforts to recognize and protect the true biodiversity of *Solanum* in northwestern Australia.

Acknowledgements

Rachel Martine, Isee Martine, Jackson Martine, and Erin Sullivan provided critical field support and specimen collection assistance in the field. Thanks to Ian Cowie and Deborah Bisa for assistance in the Northern Territory Herbarium. Tara Caton, Dan Hayes, and Wanda Boop provided greenhouse support at Bucknell. Helpful comments were provided by three anonymous reviewers during manuscript preparation; and communications assistance came from Jeff Canning, Heather Johns, and Andy Hirsch. Funding was provided through Bucknell via the David Burpee Endowment and the Wayne E. Manning Internship Fund (to ESF and ARB) and the Botanical Society of America Undergraduate Research Award (to ESF and ARB).

References

Anderson GJ (1979) Dioecious *Solanum* of hermaphrodite origin is an example of a broad convergence. Nature 282: 836–838. doi: 10.1038/282836a0

Anderson GJ, Levine DA (1982) Three taxa constitute the sexes of a single dioecious species of *Solanum*. Taxon 31: 667–672. doi: 10.2307/1219682

Anderson GJ, Symon DE (1988) Insect foragers on *Solanum* flowers in Australia. Annals of the Missouri Botanical Garden 75: 842–852. doi: 10.2307/2399372

Anderson GJ, Symon DE (1989) Functional dioecy and andromonoecy in *Solanum*. Evolution 43: 204–219. doi: 10.2307/2409175

Australian Government (2012) Interim Biogeographic Regionalization for Australia, Version 7. Department of Sustainability, Environment, Water, Populations and Communities, Canberra. https://www.environment.gov.au/system/files/pages/5b3d2d31-2355-4b60-820c-e370572b2520/files/bioregions-new.pdf

Barrett RL (2013) *Solanum zoeae* (Solanaceae), a new species of bush tomato from the North Kimberley, Western Australia. Nuytsia 23: 5–21. http://florabase.dpaw.wa.gov.au/science/nuytsia/655.pdf

Brennan K, Martine CT, Symon DE (2006) *Solanum sejunctum* (Solanaceae), a new functionally dioecious species from Kakadu National Park, Northern Territory, Australia. The Beagle, Records of the Museums and Art Galleries of the Northern Territory 22: 1–7. http://www.academia.edu/1542271/Solanum_sejunctum_Solanaceae_a_new_functionally_dioecious_species_from_Kakadu_National_Park_Northern_Territory_Australia

Chamala S, Garcia N, Godden GT, Krishnakumar V, Jordon-Thaden IE, De Smet R, Barbazuk WB, Soltis DE, Soltis PS (2015) MarkerMiner 1.0: A new application for phylogenetic marker development using angiosperm transcriptomes. Applications in Plant Science 3: apps.1400115. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4406834/

Doonday B, Samuels C, Clancy E, Milner J, Chungulla R, Whisputt M, Yoomarie S, Lulu V, Johns A, Brown S, Vernes T, Richards E, Wightman G (2013) Walmajarri Plants and Animals: Aboriginal Knowledge from the Paruku Indigenous Protected Area, Southern Kimberley. Northern Territory Botanical Bulletin No 42. Department of Land Resource Management, NTG, Broome.

Knapp S, Persson V, Blackmore S (1998) Pollen morphology and functional dioecy in *Solanum* (Solanaceae). Plant Systematics and Evolution 210: 113–139. doi: 10.1007/BF00984731

Levine DA, Anderson GJ (1986) Evolution of dioecy in American *Solanum*. In: D'Arcy WG (Ed.) Solanaceae: biology and systematics. Columbia University Press, New York, 264–273.

Martine CT, Frawley ES, Cantley JC, Jordon-Thaden IE (2016) *Solanum watneyi*, a new bush tomato species from the Northern Territory, Australia named for Mark Watney of the book and film "The Martian". PhytoKeys 61: 1–13. doi: 10.3897/phytokeys.61.6995

Martine CT, Vanderpool D, Anderson GJ, Les DH (2006) Phylogenetic relationship of andromonoecious and dioecious Australian species of *Solanum* subgenus *Leptostemonum* section *Melongena*: Inferences from ITS sequence data. Systematic Botany 31: 410–420. doi: 10.1600/036364406777585801

Martine CT, Anderson GJ (2007) Dioecy, pollination and seed dispersal in Australian spiny *Solanum*. Acta Horticulturae 745: 269–285. doi: 10.17660/ActaHortic.2007.745.12

Martine CT, Anderson GJ, Les DH (2009) Gender-bending aubergines: Molecular phylogenetics of cryptically dioecious *Solanum* in Australia. Australian Systematic Botany 22: 107–120. doi: 10.1071/SB07039

Martine CT, Symon DE, Capaldi Evans E (2013) A new cryptically dioecious species of bush tomato (*Solanum*) from the Northern Territory, Australia. PhytoKeys 30: 23–31. doi: 10.3897/phytokeys.30.6003

Purdie RW, Symon DE, Haegi L (1982) Flora of Australia. Solanaceae. Vol. 29. Australian Government Publishing Service, Canberra.

Ronquist F, Huelsenbeck JP (2003) MrBayes 3: Bayesian phylogenetic inference under mixed models. Bioinformatics 19: 1572–1574. doi: 10.1093/bioinformatics/btg180

Sarkinen T, Bohs L, Olmstead RG, Knapp S (2013) A phylogenetic framework for evolutionary study of the nightshades (Solanaceae): a dated 1000-tip tree. BMC Evolutionary Biology 13: 214. doi: 10.1186/1471-2148-13-214

Switzer CM, Hogendoorn K, Ravi S, Combes SA (2015) Shakers and head bangers: differences in sonication behavior between Australian *Amegilla murrayensis* (blue-banded bees) and North American *Bombus impatiens* (bumblebees). Arthropod-Plant Interactions. doi: 10.1007/s11829-015-9407-7

Symon DE (1979) Fruit diversity and dispersal in *Solanum* in Australia. Journal of the Adelaide Botanic Garden 1: 321–331.

Symon DE (1981) A revision of genus *Solanum* in Australia. Journal of the Adelaide Botanic Garden 4: 1–367.

Tyler I (1996) Geology and Landforms of the Kimberley. Department of Environmental Conservation, Kensington, WA.

Wheeler JR, Rye BL, Koch BL, Wilson AJG (1992) Flora of the Kimberley Region. Western Australia Herbarium, Department of Conservation and Land Management, Como, WA.

Zavada MS, Anderson GJ (1997) The wall and aperture development of pollen from dioecious *Solanum appendiculatum*: what is inaperturate pollen? Grana 36: 129–134. doi: 10.1080/00173139709362600

PhytoKeys 63: 31–40 (2016)
doi: 10.3897/phytokeys.63.7368
http://phytokeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

Miconia papillosperma (Melastomataceae, Miconieae): a new species from Amazonas, Brazil

Fabián A. Michelangeli[1], Renato Goldenberg[2]

1 *Institute of Systematic Botany, The New York Botanical Garden. Bronx, NY 10458-5126, USA* **2** *Universidade Federal do Paraná, Departamento de Botânica, Caixa Postal 19031, Curitiba, Paraná, 81531-970, Brazil*

Corresponding author: *Fabián A. Michelangeli* (fabian@nybg.org)

Academic editor: *R.P. Oliveira* | Received 1 December 2015 | Accepted 19 April 2016 | Published 13 May 2016

Citation: Michelangeli FA, Goldenberg R (2016) *Miconia papillosperma* (Melastomataceae, Miconieae): a new species from Amazonas, Brazil. PhytoKeys 63: 31–40. doi: 10.3897/phytokeys.63.7368

Abstract

Miconia papillosperma, a new species of Melastomataceae shrubs from Northern Brazil is described and illustrated. This new species is characterized by elliptic lanceolate leaves with the only pair of secondary veins running close to the margin. It is also unique in having seeds with a papillose testa, a character until now unknown in the Miconieae. The description of this new species from a relatively well collected area near a major road north of Manaus, Amazonas, Brazil, is further evidence of our lack of knowledge on plants in many Neotropical areas.

Keywords

Clidemia, seed morphology, taxonomy, *Tococa*

Introduction

As part of the NSF-funded project PBI-Miconieae (see http://sweetgum.nybg.org/melastomataceae), a large amount of unprocessed material and undetermined specimens have been seen by specialists in Melastomataceae in the last seven years, resulting on the determination of several thousand specimens at more than 20 different herbaria, the revision of several small and medium sized groups of this family (e. g. Judd and Ionta 2013; Judd et al. 2014; Gamba and Almeda 2014), and the description of almost

Copyright *F.A. Michelangeli, R. Goldenberg*. This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

100 new neotropical species of Melastomataceae. During the course of the project's herbarium work we found a group of specimens from Amazonas state in Brazil that merited further study. Upon close examination it became clear that these specimens belonged to a species of *Miconia* Ruiz & Pav. that had not been previously described.

Miconia, as traditionally defined by Cogniaux (1891), has almost 1100 species and is one of the largest genera of angiosperms, being also the largest exclusively Neotropical one (Goldenberg et al. 2013). In this traditional definition, *Miconia* is circumscribed as those members of the tribe Miconieae that have terminal inflorescences with flowers with rounded petals and that do not possess the diagnostic characters of other genera in the tribe that also have those characters (Goldenberg et al. 2013), such as *Calycogonium* DC., *Charianthus* D. Don, *Conostegia* D. Don, *Mecranium* Hook. f., *Pachyanthus* A. Rich., *Tetrazygia* Rich. ex DC., and *Tococa* Aubl. (see Skean 1993; Michelangeli 2000, 2005; Penneys and Judd 2005; Becquer Granados 2012; Judd et al. 2014; Kriebel et al. 2015).

With such a definition it is not surprising that molecular phylogenetic analyses have shown that *Miconia* is paraphyletic, with all other genera of the Miconieae nested within it (Michelangeli et al. 2004, 2008; Goldenberg et al. 2008). Due to this, some authors have advocated for an expanded *Miconia* that would encompass all the Miconieae (see Ionta et al. 2012). Since then, some species of Miconieae that would traditionally have been placed in other genera have been either recently described in *Miconia* (Ionta et al. 2012; Majure and Judd 2013; Michelangeli and Meier 2013; Gamba et al. 2014; Majure et al. 2014a, 2014b) or transferred to *Miconia* (Judd and Ionta 2013; Gamba and Almeda 2014; Judd et al. 2014).

The species described here has some superficial similarities with members of *Tococa* and *Clidemia* D. Don, and most collections that correspond to it have been determined as belonging to either one of those two genera. However, this new species does not fit the traditional definitions of either of these genera (sensu Cogniaux 1891), while it conforms to that of *Miconia*.

Materials and methods

Herbaria in Brazil and the US (INPA, MO, NY, SP, RB, UPCB, US; acronyms following Thiers 2015) with important collections of Amazonian Melastomataceae were consulted in order to find specimens that could be assigned to this new species and in the search of putative relatives. Online databases were then queried to locate additional duplicates (http://www.splink.org.br/; http://sweetgum.nybg.org/vh; http://www.tropicos.org). All specimens listed were seen by at least one of the authors.

Seeds for Scanning electron microscopy were removed from a mature fruit, boiled in water for 5 min and the remnants of the fruit removed with forceps under light microscopy. The seeds were then mounted on aluminum stubs and sputter-coated with gold-palladium for 3 min in a HUMMER 6.2 Sputter Coater (Aratech LTD) and imaged on a JEOL — JSM 5410LV SEM at the NYBG structural botany laboratories.

Georeferenced data when available were taken directly from the specimen labels. Otherwise, specimens were georeferenced using the locality description and following those on Google Earth. For details of each specimen consult the NYBG virtual herbarium (http://sweetgum.nybg.org/vh).

Taxonomy

***Miconia papillosperma* R. Goldenb. & Michelang., sp. nov.**
urn:lsid:ipni.org:names:77154669-1
Figs 1, 2

Diagnosis. A shrubby species of berry-fruited Melastomataceae characterized by elliptic-lanceolate leaves with the only pair of secondary veins running close to the margin, and with abundant simple, red trichomes. It differs from morphologically similar species of *Clidemia* by the inflorescences that are terminal, and of *Leandra* Raddi by the flowers with rounded petals. It differs from morphologically similar species of *Tococa* by the lack of ant domatia and the seeds with the testa cells puzzle or S-shaped. It differs from all other Amazonian *Miconia* by the seeds with a papillose testa.

Type. BRAZIL. Amazonas: Manaus–Caracaraí Road km 140, 1°48.09'S, 60°8.75'W, 27 Sep 1973, *C.C. Berg, F.A. Bisby, W.C. Steward, J.F. Ramos P18175* (holotype INPA; isotypes: K-000969284, MO-1726377, NY-01289602).

Description. Shrubs 0.4–2 m. Young branches, petioles, primary, secondary and tertiary veins on abaxial leaf surface, adaxial leaf surface, hypanthium and calyx (for the latter two, see below) moderately to densely covered with red trichomes 1.5–5 mm long, filiform, unbranched, erect but sometimes with a curved apex (mostly on the leaves), sometimes gland-tipped (mostly on inflorescences and hypanthia, but sometimes on the leaves and branches too); upper portions of young branches and inflorescences, more precisely above the insertion of leaves/bracts usually with dense tufts of trichomes smaller and slenderer than the ones elsewhere on the plant, these trichomes 0.4–0.8 mm long; throughout the plant there are also sparse, short, reddish glandular projections, up to 0.1 mm long, elongate. Leaves opposite, equal to subequal in each pair, lacking ant-domatia; petioles 6–15 mm long; blades 3.8–13 × 1.5-4 cm, elliptic-lanceolate to elliptic, base narrowly rounded or broadly acute, apex acute to shortly acuminate (up to 3.5 mm long), margins hyaline, denticulate to crenulate, ciliate; nerves 3, basal, the outer pair 2.5–5 mm from the margin, (the marginal veins sometimes confluent at the base, i.e., joining the secondary veins instead of the primary), the axils of the secondary sometimes related with a deepened abaxial surface, suggesting mite domatia (but lacking membranes), the tertiaries more or less evenly spaced every 2.5–5 mm, the quaternaries very faint, nerves moderate to strongly impressed on adaxial surface, strongly prominent on abaxial surface. Inflorescences apical or seldom with an additional pair of inflorescences at the axils of the second leaf pair, 1.5–2.5 cm long (up to 3.5 cm long when fruiting), peduncled dichasia or short panicles with up

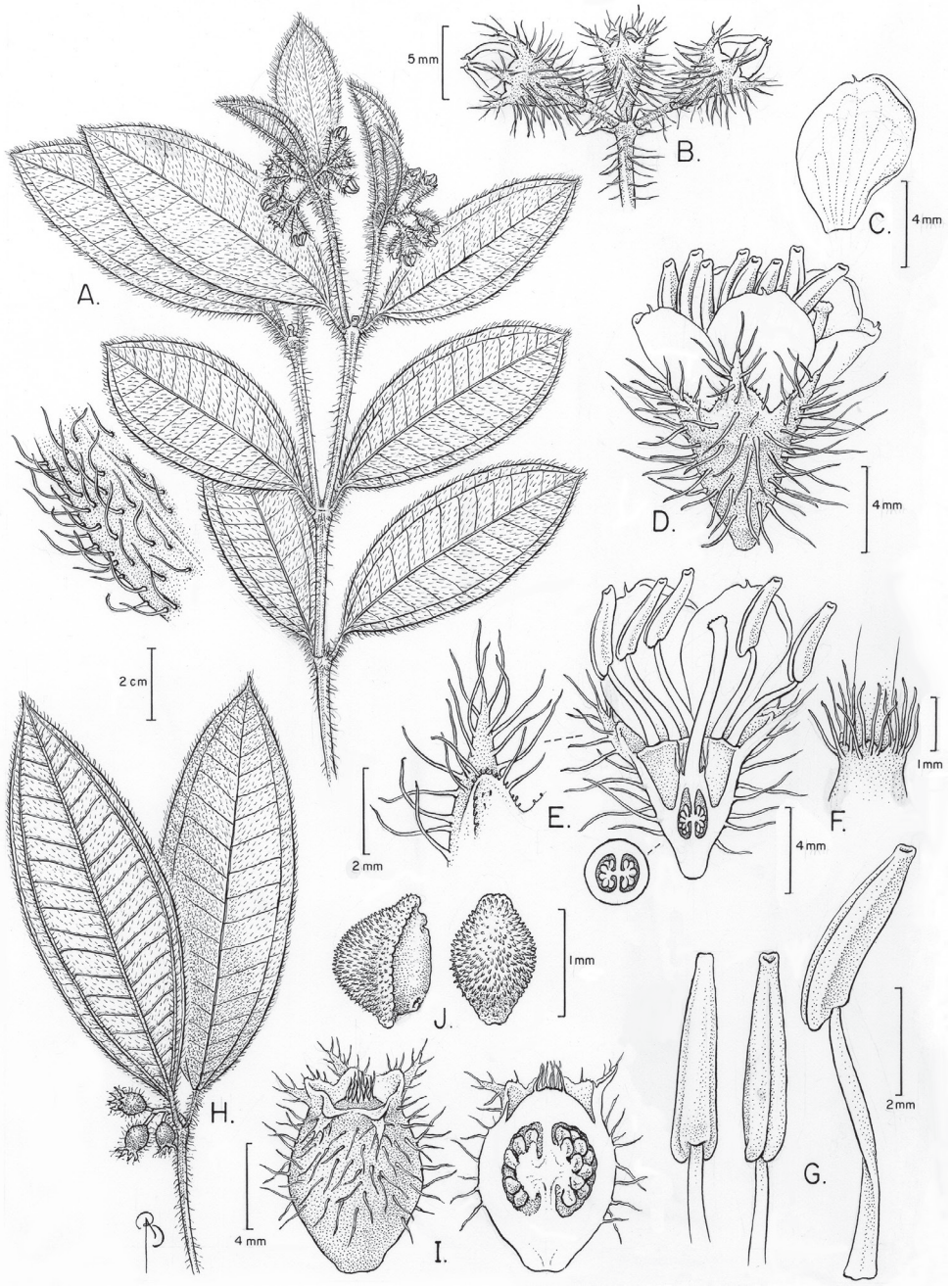

Figure 1. *Miconia papillosperma*. **A** Flowering branch **B** Detail of inflorescence **C** Petal, ventral view **D** Flower at anthesis **E** Longitudinal section of the flower showing hypanthia and ovary with details of an exterior calyx tooth and cross section of the ovary **F** Detail of the apex of the ovary **G** Stamens in dorsal, ventral and lateral view **H** Fruiting branch **I** Mature fruit in whole view and longitudinal section **J** Seeds in lateral and testa view. (**A–G** drawn from the NY isotype **H–J** from *Zaruchi 2564*, NY).

to 2 (–3) pairs of paraclades, these simple or with compound dichasia. Bracts and bracteoles early caducous, 0.8–1.3 mm long, subulate, the margins with minute glands as described above, ending on a terminal trichome, usually glandular, 1.2–1.8 mm long. Pedicel 0.6–0.9 mm long. Hypanthium 3.1–4 × 3.2–3.7 mm, campanulate, terete (not costate), outside moderately (the surface of the hypanthium is visible) covered with glandular trichomes 2–3 mm long, erect or slightly curved, and also sparsely covered with the glandular projections described above, inside glabrous, torus glabrous. Calyx persistent, with the same indumentum as the hypanthium; tube 1.4 mm long; sepals 1.9–2.1 mm long, broadly triangular, apex rounded or obtuse, margins ciliolate; outer teeth 0.9–1.6 mm long, shortly subulate, slightly to clearly longer than the sepals. Petals white or pink, 6.1–7.6 × 4.3–5.5 mm, obovate, apex rounded to emarginate, margins dentate, and glabrous, except for one or two trichomes 0.5–0.9 mm long, glandular, erect, near the apex. Stamens 10, isomorphic, white; filaments 4.8–5.1 mm long, glabrous; connective not prolonged below the thecae, dorsally arcuate, with a minute dorsal tooth 0.1–0.2 mm long, acute; thecae slightly (0.1–0.2 mm) projected below the filament insertion, 3.9–4.5 mm long, slightly ventrally curved at the apex, this emarginate, pore apical. Ovary 2–3–locular, 2.7–3 mm long, ca. 1/3 inferior, conical, smooth (not costate), glabrous but with a crown of trichomes 1.2–1.6 mm long, erect, glandular; style 5.9–6.5 mm long, curved at the apex, glabrous, stigma 0.5–0.6 mm diam., truncate. Fruits 8–9.3 × 6–7 mm, vinose, urceolate. Seeds 1.3–1.4 × 0.9–1 × 0.7–0.8 mm, raphe ellipsoid, convex, hemi-ovoid in lateral view; testa papillose, the anticlinal walls puzzle or S-shaped.

Distribution and ecology. All specimens were collected along a 25 km stretch along the road between Manaus and Caracaraí (BR-174, from km 115 to km 140, north of Manaus), or in the vicinity of the city of Presidente Figueiredo, just outside the "Reserva Biológica do Uatumã", about 75 km E (by air) of BR-174 . The plants grew on white-sand soil, associated to open vegetation locally recognized as "campina" (Fig. 3).

Phenology. Collected with flowers and fruits from March to October.

Etymology. The name reflects the unusual character of this species of having seeds with a papillose testa.

Conservation status. The extent of occurrence (EOO) that includes both sets of localities is 768 km^2 (Fig. 3). Even though some of the collections come from areas near the "Reserva Biológica do Uatumã" (a conservation unit kept by the Brazilian government), none have been made inside it. These are all areas near roads and with active low scale farming and logging. Following IUCN guidelines (IUCN 2012; IUCN Standards and Petitions Subcommittee 2014), we recommend that this species is categorized as endangered.

In the last five years at least six other Melastomataceae have been described from Amazonia (Goldenberg et al. 2011; Goldenberg and Meirelles 2011; Meirelles et al. 2015; Meirelles and Goldenberg 2014; Michelangeli 2014; Michelangeli and Goldenberg 2014). All but one of these species have very restricted distributions, underscoring that because our knowledge of plant diversity in Amazonia is still based mostly on a

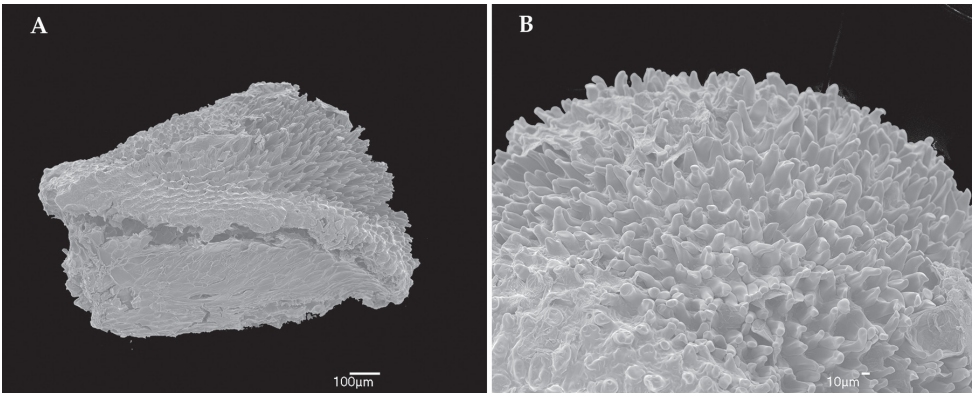

Figure 2. Scanning electron microphotograph of the seeds of *Miconia papillosperma*. **A** Whole seed **B** Detail of the papillose surface of the testa (from *Rocha 799*, NY).

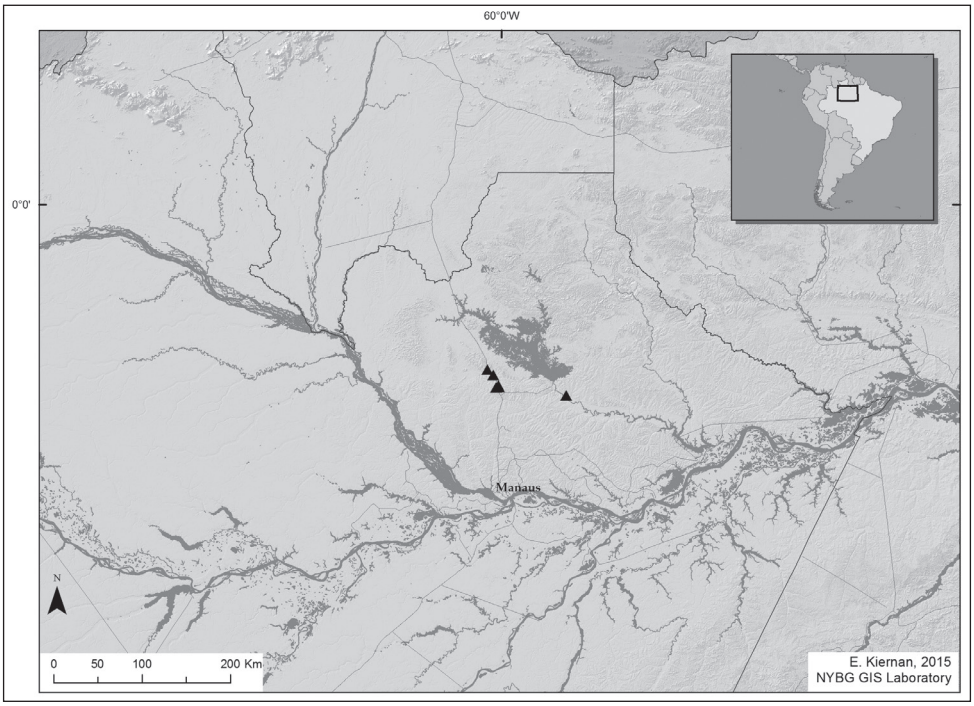

Figure 3. Geographic distribution of *Miconia papillosperma* (Amazonas, Brazil).

few well sampled localities, we still have a long way to go before we have a complete knowledge of the biodiversity of this region.

Additional specimens examined. Brazil. Amazonas: Estrada Manaus–Caracaraí km 130, 1°51.57'S, 60°05.16'W, 10 May 1973, *B.W. Nelson et al. P21084* (INPA, MO, NY); Estrada Manaus–Caracaraí km 130, 25 May 1974, *W.A. Rodrigues et al.*

9282 (INPA, UPCB); Estrada Manaus–Caracaraí km 130, 8 Aug 1974, *Artur (Loureiro) et al. s.n.* (INPA 43832); Estrada Manaus–Caracaraí km 115, 22 Sep 1977, *W.A. Rodrigues & M. Silva 9794* (INPA); Manaus–Caracaraí Road km 115, 1°58.86'S, 60°01.75'W, 14 Sep 1979, *J.L. Zarucchi et al. 2564* (INPA, NY, MO); Presidente Figueiredo, estrada Manaus–Caracaraí km 115, 9 Aug 1983, *C.A. Cid 4284* (INPA, K, NY, RB); Presidente Figueiredo, Campina das Pedras, ubicada en el Km 115 de la Rodovia BR-174 (Manaus–Caracaraí), en el lado oriental del Igarapé das Lajes, 29 Jun 985, *O. Huber 10665* (INPA, NY, SP); Presidente Figueiredo, Rebio Uatumã, Entorno, Estrada da Morena, ca. 40 km de Balbina, 21 Mar 2007, *J.G. Carvalho-Sobrinho 1439* (INPA, UPCB). Presidente Figueiredo, Rebio Uatumã, Entorno, Estrada assentamento, Ramal da Morena, 17 May 2007, *C.E. Zartman 7009* (INPA, UPCB); Presidente Figueiredo, Rebio Uatumã, Entorno, Estrada Balbina – Ramal da Morena, 2°4.88'S, 59°21.22'W, 26 Jul 2007, *J.E.L.S. Ribeiro 2863* (INPA, UPCB); Presidente Figueiredo, Cachoeira da Iracema, trilha da Cachoeira as margens do riacho, 1°59.33'S, 60°03.52'W, 10 Oct 2012, *M.J.R. Rocha et al. 799* (BHCB, NY).

Morphological comments. *Miconia papillosperma* is a very distinctive species that really does not closely resemble any other species of Miconieae known to us. Most of the specimens are in fruit and this is presumably why it remained undescribed until now. The elliptic-lanceolate to elliptic leaves with the only pair of secondaries very close to the margin resembles some species of *Macairea* DC., an unrelated group with capsular fruits in the Marcetia clade (see Michelangeli 2013), but the leaf surface and indument are different. The shrubby habit and abundant red trichomes on the leaves and young stems resemble some species of *Clidemia*, *Leandra*, and *Miconia*, but no other species in these genera has the leaves of *Miconia papillosperma*. *Tococa rotundifolia* (Triana) Wurdack and *Tococa hirta* O'Berg ex Triana also have similar reddish trichomes, but in both species at least one of the leaves of each pair has ant domatia and the venation pattern is quite different, with the secondaries running near halfway between the primary vein and the margin and not towards the margins of the lamina (Michelangeli 2005). The flowers of *T. rotundifolia*, with a winged hypanthium, can't be confused with those of *M. papillosperma*. However, the broad conical hypanthium with a calyx with subulate outer teeth, the anthers with a dorsal connective blunt tooth, and the ovary with a corona of glandular trichomes at the apex, does resemble other species of *Tococa*, most notably *T. ciliata* Triana and *T. hirta* (Michelangeli 2005). However, the seeds of all species of *Tococa* sensu stricto have the testa cells with straight walls (Michelangeli 2000; 2005), while the testa cells in *Miconia papillosperma* have clearly puzzle or S-shaped walls. In summary, we think that the best placement for this new species is within *Miconia* given its terminal inflorescence with flowers with rounded petals.

It should be noted that the seeds of *Miconia papillosperma* are unique within the tribe. To date the seeds of more than 500 species of the close to 2000 Miconieae have been imaged and studied and none of them have papillose testa (Groenendijk et al. 1996; Michelangeli 2000; Martin and Michelangeli 2008; Ocampo and Almeda 2013; Ocampo et al. 2014). Many species in different genera do have testas with convex or tuberculate cells, but these are not extended to form papillae. There is a clade within

Tococa that has trichomes on the seeds, but these are morphologically different from the papillae of *M. papillosperma*, and they are on the raphe and not on the testa. The ecological and taxonomic significance of these papillae should be investigated further.

Acknowledgements

Bobbi Angel masterfully prepared the illustration. This research was partially funded by the National Science Foundation through the PBI-Miconieae project (DEB-0818399). RG is a recipient of a CNPq productivity grant. We thank the curators of the following herbaria for access to their collections and/or sending photographs of selected specimens: INPA, K, MO, NY, RB, SP, UPCB and US. We are very grateful to Mayara Caddah and the Associate Editor for their numerous suggestions that greatly improved this manuscript. Elizabeth Kiernan prepared the distribution map and assisted in calculating the EOO.

References

Becquer ER, Michelangeli FA, Borsch T (2014) Comparative seed morphology of the Antillean genus *Calycogonium* (Melastomataceae: Miconieae) as a source of characters to untangle its complex taxonomy. Phytotaxa 166: 241–258. doi: 10.11646/phytotaxa.166.4.1

Becquer Granados ER (2012) Taxonomía de *Pachyanthus* (Melastomataceae: Miconieae). Brittonia 64: 179–207. doi: 10.1007/s12228-011-9212-2

Cogniaux CA (1891) Melastomaceae. G. Masson, Paris, 1256 pp.

Gamba D, Almeda F (2014) Systematics of the Octopleura Clade of *Miconia* (Melastomataceae: Miconieae) in Tropical America. Phytotaxa 179: 1–174. doi: 10.11646/phytotaxa.179.1.1

Gamba D, Almeda F, Alvear M (2014) *Miconia indicoviolacea* (Melastomataceae: Miconieae): a new Colombian species from the western flanks of the cordillera Occidental. Phytotaxa 177: 171–176. doi: 10.11646/phytotaxa.177.3.5

Goldenberg R, Almeda F, Caddah MK, Martins AB, Meirelles J, Michelangeli FA, Weiss M (2013) Nomenclator botanicus for the neotropical genus *Miconia* (Melastomataceae: Miconieae). Phytotaxa 106: 1–171. doi: 10.11646/phytotaxa.106.1.1

Goldenberg R, Caddah MK, Michelangeli FA (2011) A new species of *Miconia* (Melastomataceae) from Amazonas, Brazil. Brittonia 63: 245–249. doi: 10.1007/s12228-010-9157-x

Goldenberg R, Meirelles J (2011) A New Species of *Graffenrieda* (Merianieae, Melastomataceae) with a calyptrate calyx. Systematic Botany 36: 119–123. doi: 10.1600/036364411X553199

Goldenberg R, Penneys DS, Almeda F, Judd WS, Michelangeli FA (2008) Phylogeny of *Miconia* (Melastomataceae): patterns of stamen diversification in a megadiverse neotropical genus. International Journal of Plant Sciences 169: 963–979. doi: 10.1086/589697

Groenendijk JP, Bouman F, Cleef AM (1996) An exploratory study on seed morphology of *Miconia* Ruiz and Pavon (Melastomataceae), with taxonomic and ecological implications. Acta Botanica Neerlandica 45: 323–344. doi: 10.1111/j.1438-8677.1996.tb00520.x

Ionta G, Judd W, Skean JD, McMullen C (2012) Two new species of *Miconia* sect. *Sagraea* (Melastomataceae) from the Macaya Biosphere Reserve, Haiti, and twelve relevant new species combinations. Brittonia 64: 61–72. doi: 10.1007/s12228-011-9214-0

IUCN (2012) IUCN Red List Categories and Criteria: Version 3.1. Second edition. IUCN, Gland, Switzerland and Cambridge, UK, iv + 32 pp.

IUCN Standards and Petitions Subcommittee (2014) Guidelines for Using the IUCN Red List Categories and Criteria. Version 11. Prepared by the Standards and Petitions Subcommitee. http://www.iucnredlist.org/documents/RedListGuidelines.pdf.

Judd WS, Bécquer ER, Skean JD, Majure LC (2014) Taxonomic studies in the Miconieae (Melastomataceae). XII. Revision of *Miconia* sect. *Miconiastrum*, with emphasis on the *Miconia bicolor* complex. Journal of the Botanical Research Institute of Texas 8: 457–491.

Judd WS, Becquer ER, Majure LC (2014) Taxonomic studies in the Miconieae (Melastomataceae). XI. A revision of *Miconia* sect. *Calycopteris* on Hispaniola. Brittonia 66: 216–249. doi: 10.1007/s12228-014-9326-4

Judd WS, Ionta GM (2013) Taxonomic studies in the Miconieae (Melastomataceae). X. Revision of the species of the *Miconia crotonifolia* complex. Brittonia 65: 66–95. doi: 10.1007/s12228-012-9264-y

Kriebel R, Michelangeli FA, Kelly LM (2015) Discovery of unusual anatomical and continuous characters in the evolutionary history of *Conostegia* (Miconieae: Melastomataceae). Molecular Phylogenetics and Evolution 82: 289–313. doi: 10.1016/j.ympev.2014.09.021

Majure LC, Judd WS (2013) *Miconia paralimoides* (Miconieae: Melastomataceae), a new species from the Cordillera Central, Dominican Republic. Phytotaxa 131: 9–16. doi: 10.11646/phytotaxa.131.1.2

Majure LC, Judd WS (2013) *Miconia phrynosomaderma* (Melastomataceae: Miconieae), a new species from the Massif Du Nord, Haiti, and sixteen new names and combinations. Journal of the Botanical Research Institute of Texas 7: 265–274.

Majure LC, Becquer ER, Judd WS (2014a) *Miconia bullotricha* and *M. hirtistyla*, two new species of *Miconia* sect. *Lima* (Miconieae, Melastomataceae) from eastern Cuba. Phytokeys 33: 61–75. doi: 10.3897/phytokeys.33.6766

Majure LC, Judd WS, Ionta GM, Skean JD, Jr., Becquer ER, Neubig KM (2014b) *Miconia cineana* (Melastomataceae: Miconieae), a new species from the Massif de la Hotte, Haiti, based on morphological and molecular evidence. Systematic Botany 39: 906–914. doi: 10.1600/036364414X682247

Martin CV, Michelangeli FA (2009) Comparative seed morphology of *Leandra* (Miconieae, Melastomataceae). Brittonia 61: 175–188. doi: 10.1007/s12228-008-9060-x

Meirelles J, Caddah MK, Goldenberg R (2015) *Miconia macuxi* (Miconieae, Melastomataceae): a new species from the Amazonian white sand vegetation. Phytotaxa 220: 54–60. doi: 10.11646/phytotaxa.220.1.4

Meirelles J, Goldenberg R (2014) A new species of *Miconia* (Miconieae, Melastomataceae) from the Brazilian Amazon. Phytotaxa 173: 278–284. doi: 10.11646/phytotaxa.173.4.2

Michelangeli FA (2000) A cladistic analysis of the genus *Tococa* (Melastomataceae) based on morphological data. Systematic Botany 25: 211–234. doi: 10.2307/2666640

Michelangeli FA (2005) A Monograph of *Tococa* Aublet (Melastomataceae). Flora Neotropica Monographs 98: 1–114. http://www.jstor.org/stable/4393950

Michelangeli FA (2014) Taxonomic notes on myrmecophilous Melastomataceae: a new species, two new synonyms, and an old species reconsidered. Brittonia 66: 82–88. doi: 10.1007/s12228-013-9317-x

Michelangeli FA, Goldenberg R (2014) A new species of *Graffenrieda* (Melastomataceae) from the northern Amazon basin. Brittonia 66: 170–173. doi: 10.1007/s12228-013-9321-1

Michelangeli FA, Judd WS, Penneys DS, Skean JD, Bécquer-Granados ER, Goldenberg R, Martin CV (2008) Multiple events of dispersal and radiation of the tribe Miconieae (Melastomataceae) in the Caribbean. Botanical Review 74: 53–77. doi: 10.1007/s12229-008-9004-x

Michelangeli FA, Meier W (2013) A new anisophyllous species of *Miconia* (Melastomataceae: Miconieae) from the Coastal Cordillera in northern Venezuela. Phytotaxa 79: 37–44. doi: 10.11646/phytotaxa.79.1.3

Michelangeli FA, Guimaraes PJF, Penneys DS, Almeda F, Kriebel R (2013) Phylogenetic relationships and distribution of New World Melastomeae (Melastomataceae). Botanical Journal of The Linnean Society 171: 38–60. doi: 10.1111/j.1095-8339.2012.01295.x

Michelangeli FA, Penneys DS, Giza J, Soltis D, Hils MH, Skean JD Jr. (2004) A preliminary phylogeny of the tribe Miconieae (Melastomataceae) based on nrITS sequence data and its implications on inflorescence position. Taxon 53: 279–290.

Ocampo G, Almeda F (2013) Seed diversity in the Miconieae (Melastomataceae): morphological characterization and phenetic relationships. Phytotaxa 80: 1–129. doi: 10.11646/phytotaxa.80.1.1

Ocampo G, Michelangeli FA, Almeda F (2014) Seed Diversity in the Tribe Miconieae (Melastomataceae): Taxonomic, Systematic, and Evolutionary Implications. PLoS ONE 9(6): e100561. doi: 10.1371/journal.pone.0100561

Penneys DS, Judd WS (2005) A systematic revision and cladistic analysis of *Charianthus* (Melastomataceae) using morphological and molecular characters. Systematic Botany 30: 559–584. doi: 10.1600/0363644054782125

Skean JD Jr. (1993) Monograph of *Mecranium* (Melastomatacae-Miconiae). Systematic Botany Monographs 39: 1–116. http://www.jstor.org/stable/25027826

PhytoKeys 63: 41–45 (2016)
doi: 10.3897/phytokeys.63.8016
http://phytokeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

Spiradiclis pengshuiensis (Ophiorrhizeae, Rubioideae), a new species from Chongqing, China

Bo Pan[1], Hu-Sheng Ma[1], Rui-Jiang Wang[2]

1 *Guangxi Institute of Botany, Guangxi Zhuangzu Autonomous Region and Chinese Academy of Sciences, Guilin 541006, China* **2** *Key Laboratory of Plant Resources Conservation and Sustainable Utilization, Guangdong Provincial Key Laboratory of Applied Botany, South China Botanical Garden, Chinese Academy of Sciences, Guangzhou 510650, China*

Corresponding author: *Rui-Jiang Wang* (wangrj@scbg.ac.cn)

Academic editor: *Pavel Stoev* | Received 3 February 2016 | Accepted 14 May 2016 | Published 18 May 2016

Citation: Pan B, Ma H-S, Wang R-J (2016) *Spiradiclis pengshuiensis* (Ophiorrhizeae, Rubioideae), a new species from Chongqing, China. PhytoKeys 63: 41–45. doi: 10.3897/phytokeys.63.8016

Abstract

Spiradiclis pengshuiensis Bo Pan & R. J. Wang (Rubiaceae) is described as a new species from Chongqing in SW China. It is morphologically compared with *S. pauciflora* L. Wu & Q. R. Liu because of their similarities in habit, pubescent surface, small leaf laminas and subglobose capsules. Its conservation status is evaluated as "VU" according to the IUCN categories and criteria.

Keywords

China, New taxon, Rubiaceae, *Spiradiclis*

Introduction

The genus *Spiradiclis* Blume (Rubiaceae) mainly distributed in the tropical and subtropical limestone areas of Southern China and Northern Vietnam. Geographically, the localities of *Spiradiclis* species can extend northward to Mt. Emei (29°33'N) in Sichuan province of China and southward to Central Java (ca. 7°10'S) of Indonesia. The genus comprise about 50 species and ca. 91% species can be found in China, the center of species diversity (Chen and Taylor 2011, Deng et al. 2014, Wang et al. 2015, Wen et al. 2015, Wu et al. 2015, Wang 2016). *Spiradiclis* species are usually similar to *Ophiorrhiza* L. because of their similar inflorescence and flower characters,

Copyright *Bo Pan et al.* This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

but the former is characterized by globose or ovoid (vs. strongly laterally compressed in *Ophiorrhiza*) capsules.

During a botanical inventory in Pengshui County, the east of Chongqing Municipality, in 2013, the senior author found a striking *Spiradiclis* species growing on the dry cliffs. In order to get enough materials for morphological observation and comparison, we successively collected the vouchers during the flowering and fruiting seasons in recent years. This new species can be readily distinguished from other *Spiradiclis* species in habit and flowers and herein described and illustrated.

Material and methods

All materials were collected by ourselves and deposited at the herbarium of South China Botanical Garden, Chinese Academy of Sciences (IBSC). The morphological data were collected by a Digimatic Caliper (Mitutoyo, Japan).

Taxonomy

Spiradiclis pengshuiensis **B. Pan & R. J. Wang, sp. nov.**
urn:lsid:ipni.org:names:77154905-1
Figure 1

Diagnosis. *Spiradiclis pengshuiensis* is similar to *S. pauciflora* L. Wu & Q. R. Liu, from which it differs in having linear (vs. triangular) stipules, 4–6 (vs. 3–4) secondary veins each side of the leaf laminas, salverform (vs. funnelform) corolla with 9–15 mm (vs. 7–9 mm) long tubes (Table 1).

Type. CHINA. Chongqing Municipality: Pengshui County, Hanxia Town, Baixiang Village, 29°8'N, 108°6'E, 360 m alt., 29 Nov 2014, Rui-Jiang Wang 2931, long-styled flower (holotype IBSC; isotypes IBSC).

Description. Perennial herbs, 4–9 cm tall, densely pubescent on plant surfaces; stems erect or prostrate at base and then ascending, terete, rooting at nodes; inter nodes 2–15 mm long. Stipules linear, 0.9–1.2 mm long. Petiole (3.5–)7–12(–23.5) mm long. Leaf blades opposite, ovate, (4–)7–15(–25) × (2.5–)5–10(–15) mm; base cuneate or late cuneate, asymmetry, decurrent; apex obtuse to rounded, papery, green adaxially and pale green abaxially; secondary veins 4–6 on each side; margin revolute slightly. Inflorescence terminal, cymose, 1–7(–12)-flowered but only 1–3 blooming simultaneously; peduncles 1–2.1 cm long; bracts and bracteoles linear, 1–2 mm long. Flowers distylous; pedicels 0–2 mm long; hypanthium obconical, 1–2 mm long; calyx lobes 5, lanceolate, 0.8–1.5 × ca. 0.4 mm. Corolla salverform, white adaxially, pinkish to white abaxially, pubescent both sides; tube 9–15 × 1.5–2 mm; lobes (4–)5, oval, 5–7.5 × 2.5–3.5 mm. Stamens 5; anthers linear-oblong, 1.5–2 mm long, dorsi-fixed. Stigma bilobed, lobes ovoid; ovary 2-celled, ovules many, axile. Long-styled flowers:

Table 1. Morphological comparison of *Spiradiclis pengshuiensis* and *S. pauciflora*.

Characters	*S. pengshuiensis*	*S. pauciflora*
Habit	Erect or prostrate at base	Creeping or with upper parts ascending
Indument	Pubescent whole plant surfaces	Pubescent whole plant surfaces
Stem	Terete	Terete
Stipules	Linear, 0.9–1.2 mm long	Triangular, less than 1 mm
Petioles length (mm)	3.5–23.5	3–10
Leaf blades	Ovate; base cuneate or late cuneate, asymmetry, decurrent; apex obtuse to rounded	Ovate to elliptic-ovate; base obtuse to broadly cuneate; apex obtuse to acute
Leaf texture	Papery	Papery
Leaf size (mm)	(4–) 7–15(–25) × (2.5–) 5–10 (–15)	5–20 × 5–15
Leaf color	Green adaxially and pale green abaxially	Olive-green adaxially, pale or sometime purplish red abaxially
Secondary veins on each side	4–6	3–4
Inflorescence	Terminal, 1–7(–12)-flowered	Terminal, 3–7(–9)-flowered
Peduncle length (cm)	1–2.1	1–3
Pedicel length (mm)	0–2	0.3–3
Calyx lobes	Lanceolate, 0.8–1.5 mm long	Ovate-triangular, 1.2–1.6 mm long
Corolla	Salverform; corolla tube 9–15 cm long; lobes oval, 5–7.5 mm long	Funnelform; corolla tube 7–9 mm long; lobes ovate-triangular, 2.5–3 mm long
Pin flowers	Corolla pubescent adaxially, without ring hairs; styles 9–12 mm long	Ring hairs present in adaxial side of corolla; styles 7.5–8.5 mm long
Style length in thrum flowers (mm)	ca. 5	2.7–3
Capsules	Subglobose, 3–5 mm in diam.	Subglobose, ca. 2 mm in diam.
Phenology	Flowering in November to next January, fruiting in December to February	Flowering in March to June, fruiting in May to August

stamens included; filaments adnate to the lower corolla tube, ca. 1.5 mm long; styles 9–12 mm long; stigma ca. 0.5 mm long, red to brown, extended to corolla throat, not exserted. Short-styled flowers: stamens extended to corolla throat, not exserted; filaments adnate to upper corolla tube, ca. 0.5 mm long; styles ca. 5 mm long; stigmas ca. 1.5 mm long, included. Capsules subglobose, 3–5 mm in diam., with persistent calyx lobes, dehiscent septicidally and loculicidally; valves 4, ovate, 3–5 mm long. Seeds 15–20 per capsule, ca. 0.5 mm long, brown, irregular pyramid to cuboid, foveolate on surface.

Phenology. Flowers from November to next January; fruits from December to next February.

Distribution and habitat. *Spiradiclis pengshuiensis* is known only from the type locality. Its habitat is on the cliffs nearby the A-Yi-He river but with very poor conditions.

Conservation status. Only three small populations and less than 500 individuals of *Spiradiclis pengshuiensis* within 5 km^2 were found in the A-Yi-He Scenic Area. The tourist activity is the primary factor in the decline of populations. In addition, the

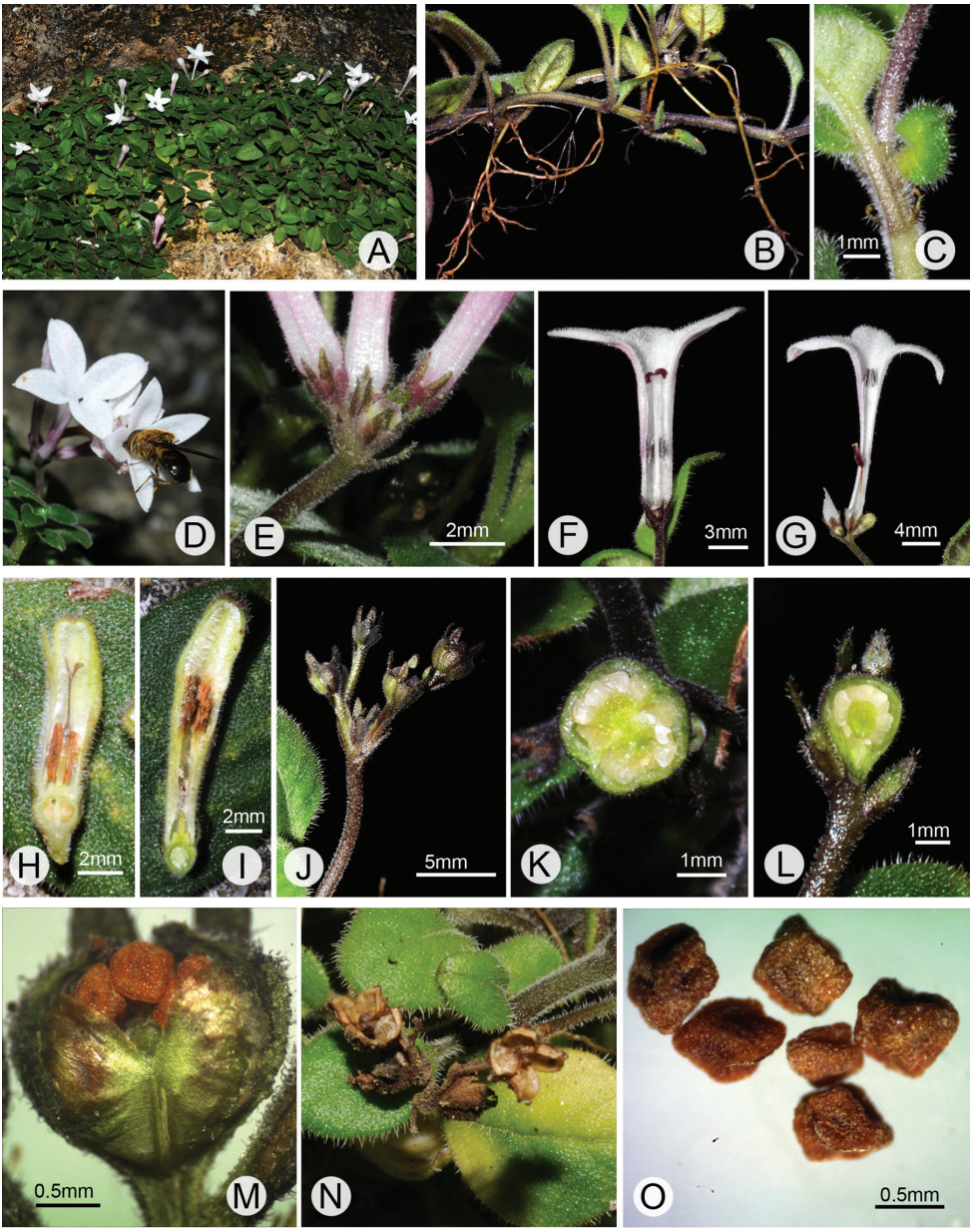

Figure 1. *Spiradiclis pengshuiensis* sp. nov. **A** habitat **B** habit **C** linear stipules **D** visiting insects **E** bracts and hypanthium **F–I** longitudinal section of long- (**F, H**) and short-styled flowers (**G, I**), respectively, showing the induments, relative positions and morphology of the stigmas and anthers and the developing capsules in distylous flowers **J** infructescence **K–L** transverse and longitudinal section of young capsules, respectively **M** mature capsule **N** dehiscent capsules **O** seeds. Photos by Ruijiang Wang.

plants always grow on the cliffs with little soil and insufficient water, which limited the development and dispersal of the species. Therefore we assign a preliminary IUCN threat status of Vulnerable [VU, B2ab(ii, iii, iv)] to *S. pengshuiensis* (IUCN 2001).

Specimens examined. CHINA. Chongqing Municipality: Pengshui County, Hanxia Town, Baixiang Village, 29°8'N, 108°6'E, 350 m alt., 29 Nov 2014, short-styled flowers, Rui-Jiang Wang 2932, 2937 (IBSC); same locality, 12 Jan 2016, fruiting, Rui-Jiang Wang 3095, 3099 (IBSC).

Acknowledgements

This work was supported by National Natural Science Foundation of China (31070177) and Natural Science Foundation of Guangxi (2013GXNSFBA019078).

References

Chen T, Taylor CM (2011) *Spiradiclis* Blume. In: Wu ZY, Raven PH (Eds) Flora of China, vol. 19. Science Press, Beijing & Missouri Botanical Garden Press, St. Louis, 330–339.

Deng SJ, Wen HZ, Huang XX, Wang RJ (2014) *Spiradiclis coriaceifolia* and *S. tonglingensis* spp. nov. (Rubiaceae, Ophiorrhizeae) from Guangxi, China. Nordic Journal of Botany 32: 594–601. doi: 10.1111/njb.00461

IUCN (2001) IUCN Red List Categories and Criteria (Version 3.1). IUCN Species Survival Commission, Gland, Switzerland and Cambridge. http://www.iucnredlist.org/info/categories_criteria2001

Wang RJ, Wen HZ, Deng SJ, Zhou LX (2015) *Spiradiclis danxiashanensis* (Rubiaceae), a new species from South China. Phytotaxa 206(1): 30–36. doi: 10.11646/phytotaxa.206.1.5

Wang RJ (2016) *Spiradiclis yangchunensis* (Rubiaceae), a new species from Guangdong, China. Plant Science Journal 34(1): 13–17. doi: 10.11913/PSJ.2095–0837.2016.10013

Wen HZ, Wang RJ, Deng SJ (2015) *Spiradiclis longanensis*, a new species of Rubiaceae from China. PhytoKeys 55: 113–117. doi: 10.3897/phytokeys.55.4975

Wu L, Wang JL, Liu QR (2015) *Spiradiclis pauciflora* (Rubiaceae), a new species from limestone areas in Guangxi, China. Annales Botanici Fennici 52(3–4): 257–261. doi: 10.5735/085.052.0318

PhytoKeys 63: 47–62 (2016)
doi: 10.3897/phytokeys.63.7952
http://phytokeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

Molecular and morphological evidence for *Penstemon luculentus* (Plantaginaceae): a replacement name for *Penstemon fremontii* var. *glabrescens*

Robert L. Johnson[1], Mikel R. Stevens[2], Leigh. A. Johnson[1], Matthew D. Robbins[3], Chris D. Anderson[2], Nathan J. Ricks[2], Kevin M. Farley[2]

1 *Department of Biology, Brigham Young University, 3115A Monte L. Bean Museum, Provo, Utah 84602 USA* **2** *Department of Plant and Wildlife Sciences, Brigham Young University, 5131 Life Sciences Building, Provo, Utah 84602 USA* **3** *United States Department of Agriculture, Agricultural Research Service, Forage and Range Research Laboratory, 690 N. 1100 E., Logan, Utah 84322 USA*

Corresponding author: *Robert L. Johnson* (robert_johnson@byu.edu)

Academic editor: *Sandra Knapp* | Received 27 January 2016 | Accepted 2 May 2016 | Published 20 May 2016

Citation: Johnson RL, Stevens MR, Johnson LA, Robbins MD, Anderson CD, Ricks NJ, Farley KM (2016) Molecular and morphological evidence for *Penstemon luculentus* (Plantaginaceae): a replacement name for P*enstemon fremontii* var. *glabrescens*. PhytoKeys 63: 47–62. doi: 10.3897/phytokeys.63.7952

Abstract

Penstemon luculentus R.L.Johnson & M.R.Stevens, **nom. nov.** replaces *Penstemon fremontii* var. *glabrescens* Dorn & Lichvar. The varietal name *glabrescens* was not elevated because it was already occupied by *Penstemon glabrescens* Pennell, a different species. This new arrangement is supported by molecular and morphological evidence. An analysis of genetic diversity in populations of both varieties of *P. fremontii* Torr. & A. Gray (*glabrescens* and *fremontii*) from the Piceance Basin, Colorado, using SSR (simple sequences repeats) or microsatellites markers, revealed significant genetic differentiation between the two. *Penstemon fremontii* var. *glabrescens* was also genetically different from *P. gibbensii* Dorn and *P. scariosus* var. *garrettii* (Pennell) N.H. Holmgren. The combination of hirtellous stems, glabrous leaves, non-glandular inflorescence, and long anther hairs distinguish *P. luculentus* from other morphologically similar species.

Keywords

Colorado, Rio Blanco, Piceance, White River Shale, *Penstemon*

Copyright *Robert L. Johnson et al.* This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Introduction

While investigating *Penstemon scariosus* Pennell (1920) and its varieties, the authors encountered two herbarium specimens from Rio Blanco County, Colorado (BRY81341, BRY81345) that had hirtellous stems, a trait not found in *P. scariosus*. Further investigation led us to determine that the specimens had been misidentified and that they correctly belonged to *Penstemon fremontii* var. *glabrescens* Dorn and Lichvar (1990) under existing taxonomic circumscription. Similarly, we encountered several herbarium specimens labeled as *P. gibbensii* Dorn (1982) from Rio Blanco County, Colorado (BRY112313, BRY112314, BRY112315, BRY112316) that also belonged to *P. fremontii* var. *glabrescens*. All but one of these specimens was collected prior to the publication of *P. fremontii* var. *glabrescens* and they had not been annotated since to reflect this newer taxonomy. The original determinations of these specimens reflect the observed similarity of *P. fremontii* var. *glabrescens* to *P. scariosus* and *P. gibbensii*, rather than with *P. fremontii* Torr. & A. Gray in Gray (1862) *sensu stricto*.

Though var. *glabrescens* was recognized at the varietal level within *P. fremontii*, uncertainty as to its placement within this taxon has been expressed. In the most recent treatment of the Colorado Flora: Western Slope, Weber and Wittmann (2012) state, "In our opinion, this variety is not closely related to *P. fremontii* and it might be better placed, as a species, closer to the peripheral *P. scariosus* and *P. gibbensii*." The similarity of var. *glabrescens* to *P. gibbensii* and *P. scariosus* was also mentioned in its original publication and morphological comparisons made with these taxa (Dorn and Lichvar 1990), although there was no indication with which of the four varieties of *P. scariosus* those comparisons were made.

Penstemon gibbensii can be easily distinguished from *P. fremontii* var. *glabrescens* by the abundant glandular pubescence present on the inflorescence axis (including sepals and corolla) and distal portions of the stem as compared to the later. The glandular hairs often extend from the distal stem region to mid-stem or below, though becoming less dense proximally. *Penstemon scariosus* only occasionally has glandular hairs (in some varieties) with hairs sparse and never extending onto the proximal portion of the stem. Variety *glabrescens* is most easily distinguished from *P. fremontii sensu stricto* by its glabrous leaves and longer-haired anthers versus *P. fremontii* that has hirtellous leaves and shorter anther hairs. Variety *glabrescens* is most easily distinguished from *P. scariosus* by its hirtellous stem, *P. scariosus* having glabrous stems.

In this paper, we re-evaluate some morphological characteristics between *P. fremontii* and *P. fremontii* var. *glabrescens*. We also make comparisons against *P. scariosus* var. *garrettii* (Pennell 1920) N.H. Holmgren in Cronquist et al. (1984) because it represents a variety of *P. scariosus* that is geographically proximate and of similar floral characteristics. We also compare the genetic structure within and between *P. fremontii* varieties *fremontii* and *glabrescens*, *P. gibbensii*, and *P. scariosus* var. *garrettii* from the same region using simple sequence repeat (SSR; i.e., microsatellite markers). These markers are useful in inferring genetic exchange among biological populations (Balloux and Lugon-Moulin 2002). It is our opinion that *P. fremontii* var. *glabrescens* is a distinct taxon and should be elevated as a unique species.

Taxonomic treatment

Penstemon luculentus **R.L.Johnson & M.R.Stevens, nom. nov.**
urn:lsid:ipni.org:names:77154920-1

Penstemon luculentus R.L.Johnson & M.R.Stevens, nom. nov. ≡ *Penstemon fremontii* Torr. & A. Gray var. *glabrescens* Dorn & Lichvar, Madroño 37(3): 195–199, f. 1, 2 [map]. 1990. (non *Penstemon glabrescens* Pennell in Contributions from the United States National Herbarium 20: 375–376. 1920). Type: USA. Colorado: Garfield Co, Douglas Pass, 8000 ft., 7 July 1987, *R. Dorn 4656* (holotype RMS!).

Note. Elevating *P. fremontii* var. *glabrescens* to a species using the epithet *glabrescens* was not possible because *Penstemon glabrescens* is already occupied (Pennell 1920).

Etymology. *P. luculentus* is derived from the Latin "*luculentus*," meaning brilliant or bright. The name was chosen to reflect the brilliant blue flower color, which is particularly striking in the field contrasting against the whitish or tan shale background typically associated with the species (Fig. 1A, B).

Remarks. *Penstemon luculentus* (≡ *P. fremontii* var. *glabrescens*) grows almost exclusively on steep slopes composed of Green River shale or sometimes intermixed with sandstone fragments from overlying strata. It is locally common on road cuts. It occurs primarily within the Piceance drainage with populations occurring abundantly on exposed shale along Piceance Creek and the adjacent tributaries, including the Yellow Creek drainage in Rio Blanco Co., CO. (Fig. 2). It also occurs on shale slopes of the Roan Creek drainage in Garfield Co., CO. The Colorado Natural Heritage Program (CNHP) gives this taxon a global rank of G3G4T2 and a state rank of S2 due to threats from gas and oil drilling throughout its habitat in the Piceance Basin (CNHP 2015). The ranking of G3G4 indicates a status between vulnerable and apparently secure. The rank of S2 specifies a state status of "imperiled – at high risk of extinction due to very restricted range, very few populations (often 20 or fewer), recent and widespread declines, or other factors" (Rondeau et al. 2011). Currently oil and gas drilling have not had a noticeable impact on its populations, but that could change if oil extraction begins to include the mining of oil shale.

Methods

A minimum of one herbarium voucher and four tissue samples were collected at each accession site (Table 1). These samples were collected either during July 2013 or June 2014. DNA extractions were from lyophilized or silica gel dried leaf tissue collected, *in situ* (Table 1), using the method detailed by Todd and Vodkin (1996). We used the same PCR parameters and ten of the fluorescently labeled primers (Table 2.) reported by Anderson et al. (2016) to run each DNA sample. Furthermore, we followed their protocol using Geneious 8.0.5 (Kearse et al. 2012) to score the output generated from

Figure 1. A *Penstemon luculentus* in its commonly found native whitish or tan shale habitat **B** An individual *P. luculentus* plant growing in its typical shale habitat.

the ABI 3730xl (Applied Biosystems, Carlsbad, CA, USA) at Brigham Young University's DNA Sequencing Center (Provo, UT, USA) for the population genetic structure study (Fig. 3A, B).

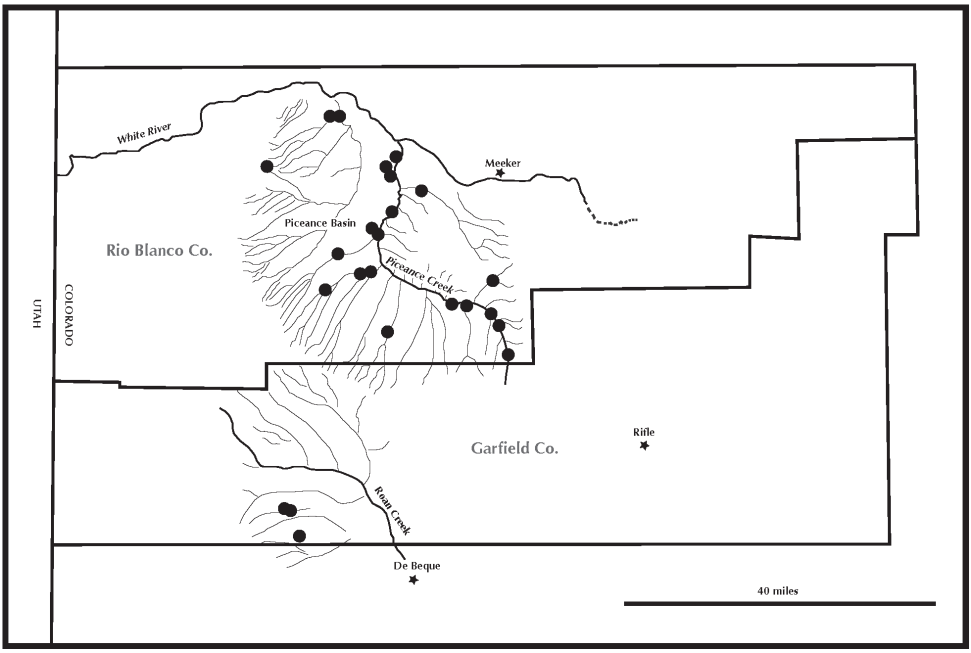

Figure 2. Map showing known distribution of *P. luculentus* in Rio Blanco and Garfield counties Colorado.

To understand the population genetic structure of the accessions we sampled (Table 1), we used STRUCTURE 2.3 (Falush et al. 2003; Pritchard et al. 2000). The optimal number of genetically distinct clusters or groups (*K*) was determined by testing *K* values from 2 to 8 (1 was not tested as multiple clusters were expected) and plotting the second order difference (ΔK) between each *K* value (Fig. 3A) according to Evano et al. (2005). Analyses consisted of 10 iterations using a burnin period of 50,000 reps with 1,000,000 MCMC reps following burnin, admixture assumed, and sampling locations used as priors. Genetic diversity was partitioned using an analysis of molecular variance (AMOVA) implemented in GenAlEx 6.501 (Peakall and Smouse 2012) to compute pairwise F_{ST} and R_{ST} values between taxa (Table 3). The AMOVA was implemented using 999 permutations to calculate P-values for each F_{ST} or R_{ST} value. Both pair-wise matrices were then used in GenAlEx to conduct principal coordinate analyses (PCoA) to visualize the differences between taxa (Fig. 4).

We made morphological comparisons, using field-collected plants and herbarium specimens obtained from the Stanley L. Welsh Herbarium (BRY) and Rocky Mountain Herbarium (RMS). We took multiple measurements from 38 herbarium sheets of *P. fremontii* var. *glabrescens* (≡ *P. luculentus*) including the holotype and four paratypes, and 20 sheets each of *P. fremontii sensu stricto* and *P. scariosus* var. *garrettii*. Sheet selection was based on the specimen completeness (i.e. only entire plant(s), not partial plants) and the specimen's pressed condition. Accurate floral measurements required corollas to have dried completely pressed without shrinkage. Sheets of *P. fremontii* and

Table 1. Identification number (ID#) and geographic origin of the 32 accessions of *Penstemon* included in this study. Vouchers for each accession were deposited in the Stanley L. Welsh Herbarium (BRY), Brigham Young University Provo, Utah, USA.

ID#	Taxon	N	Accession location	Latitude	Longitude	Voucher no.
1	*P. scariosus* var. *garrettii*	8	North of Little Mountain Peak, Sweetwater Co., WY	41°10'58.4"N	109°16'51.7"W	BRY121014
2	*P. scariosus* var. *garrettii*	8	Goslin Mountain, Daggett Co., UT	40°56'44.5"N	109°15'35.1"W	BRY121028
3	*P. scariosus* var. *garrettii*	8	North of Lone Tree, Uinta Co., WY	41°05'10.1"N	110°11'19.3"W	BRY121027
4	*P. scariosus* var. *garrettii*	8	Oilfield Reservoir area, Moffat Co., CO	40°39'14.9"N	109°00'24.7"W	BRY119254
5	*P. scariosus* var. *garrettii*	8	Price Canyon, Utah Co., UT	39°49'43.2"N	110°57'28.0"W	BRY117079
6	*P. scariosus* var. *garrettii*	8	South of Manila, Daggett, Co., UT	40°52'56.1"N	109°41 '33.5"W	BRY117080
7	*P. scariosus* var. *garrettii*	8	East of Fruitland, Duchesne Co., UT	40°12'15.7"N	110°47'57.1"W	BRY133591
8	*P. scariosus* var. *garrettii*	8	Midway, Wasatch Co., UT	40°32'03.2"N	111°28'57.7"W	BRY117064
9	*P. scariosus* var. *garrettii*	8	Northeast of Birdseye, Utah, Co., UT	39°55'38.0"N	111°32'37.0"W	BRY124358
10	*P. scariosus* var. *garrettii*	8	Argyle Canyon, Duchesne Co., UT	39°53'44.3"N	110°38'18.7"W	BRY121021
11	*P. scariosus* var. *garrettii*	8	Northwest of Whiterocks, Duchesne Co., UT	40°35'45.1"N	110°06'06.1"W	BRY113493
12	*P. scariosus* var. *garrettii*	8	Pine Mountain, Sweetwater Co., WY	41°03'42.5"N	108°57'45.0"W	BRY121020
13	*P. scariosus* var. *garrettii*	4	along HWY 191 North of Vernal, Uintah Co., UT	40°39'41.4"N	109°28'50.1"W	BRY121013
14	*P. scariosus* var. *garrettii*	4	along HWY 191 North of Vernal, Uintah Co., UT	40°42'41.5"N	109°29'38.0"W	BRY121026
15	*P. scariosus* var. *garrettii*	8	Sowers Canyon, Duchesne Co., UT	39°55'21.5"N	110°35'13.7"W	BRY119259
16	*P. scariosus* var. *garrettii*	8	Yellowstone Creek Drainage, Duchesne Co., UT	40°33'00.5"N	110°19'16.4"W	BRY119253
17	*P. scariosus* var. *garrettii*	8	Head of Warner Draw, Uintah Co., UT	40°44'52.9"N	109°13'41.6"W	BRY119256
18	*P. scariosus* var. *garrettii*	8	Red Cloud Loop, Uintah Co., UT	40°37'28.7"N	109°45'38.8"W	BRY119261
19	*P. scariosus* var. *garrettii*	8	Cat Peak, Utah Co., UT	39°53'56.8"N	110°57'34.0"W	BRY109209
20	*P. scariosus* var. *garrettii*	8	Willow Creek Guard Station area, Wasatch Co., UT	40°02'36.2"N	111°08'59.2"W	BRY119260
21	*P. luculentus*	8	Piceance Canyon, Rio Blanco Co., CO	39°45'42.4"N	108°00'46.4"W	BRY126454
22	*P. luculentus*	8	Piceance Canyon, Rio Blanco Co., CO	39°48'03.2"N	108°07'28.9"W	BRY130985
23	*P. luculentus*	8	Piceance Canyon, Rio Blanco Co., CO	39°51'31.5"N	108°18'47.5"W	BRY130983
24	*P. luculentus*	8	Piceance Canyon, Rio Blanco Co., CO	39°49'36.4"N	108°25'06.8"W	BRY130982
25	*P. luculentus*	8	Piceance Canyon, Rio Blanco Co., CO	39°53'40.1"N	108°23'29.7"W	BRY130981
26	*P. luculentus*	8	Piceance Canyon, Rio Blanco Co., CO	39°55'40.1"N	108°17'36.4"W	BRY130980

ID#	Taxon	N	Accession location	Latitude	Longitude	Voucher no.
27	*P. luculentus*	8	Piceance Canyon, Rio Blanco Co., CO	40°00'26.2"N	108°11'33.8"W	BRY130979
28	*P. luculentus*	8	Piceance Canyon, Rio Blanco Co., CO	40°03'51.4"N	108°15'06.7"W	BRY126453
29	*P. fremontii*	8	Near Meeker, Rio Blanco Co., CO	39°58'59.1"N	107°58'02.6"W	BRY121022
30	*P. fremontii*	8	Piceance Canyon, Rio Blanco Co., CO	39°48'19.7"N	108°05'16.1"W	BRY104606
31	*P. fremontii*	8	Piceance Canyon, Rio Blanco Co., CO	39°53'27.8"N	108°10'47.9"W	BRY104599
32	*P. gibbensii*	8	Browns Park, Daggett Co., UT	40°50'49.1"N	109°02'59.3"W	BRY28472

Note: N = number of tissue samples for each accession.

Table 2. The ten SSR markers used in this study with associated variability of each marker relative to each taxon and across taxa.

	Taxon												Allele totals	
	P. fremontii (N=24)			*P. luculentus* (N=64)			*P. gibbensii* (N=8)			*P. scariosus* var. *garrettii* (N=152)				
Locus	A	A_U	Size range (bp)	A	A_U	Size range (bp)	A	A_U	Size range (bp)	A	A_U	Size range (bp)	A_C	A_T
Pen04	17	1	216-252	24	18	215-254	3	0	218-248	20	2	212-252	17	38
Pen23	11	0	158-184	14	0	154-190	6	0	160-174	23	8	150-195	15	23
PS014	7	1	211-236	12	2	214-239	2	1	219-221	16	4	209-242	12	20
PS016	13	0	150-170	20	1	149-173	6	1	161-168	30	11	136-189	21	34
PS048	1†	0	225	2	0	213-225	3	0	225-233	10	6	213-245	4	10
PS077	5	0	118-139	6	1	123-145	3	1	134-150	9	2	118-145	7	11
PS079	14	7	160-201	14	3	139-201	3	1	135-148	14	3	133-175	13	27
PS080	7	1	212-228	19	4	213-238	3	0	218-223	23	10	196-242	15	30
PS082	14	2	164-219	19	3	192-217	3	0	205-212	21	5	168-224	19	29
PS084	5	0	118-138	12	8	117-143	2	0	118-128	7	1	118-148	6	15

Note: N = number of samples for each taxon, A = number of alleles observed in a given taxon, A_U = number of alleles unique to a given taxon, A_C = number of alleles shared between two or more taxa, A_T = total number of alleles identified in this study for a given marker.

†Locus was monomorphic.

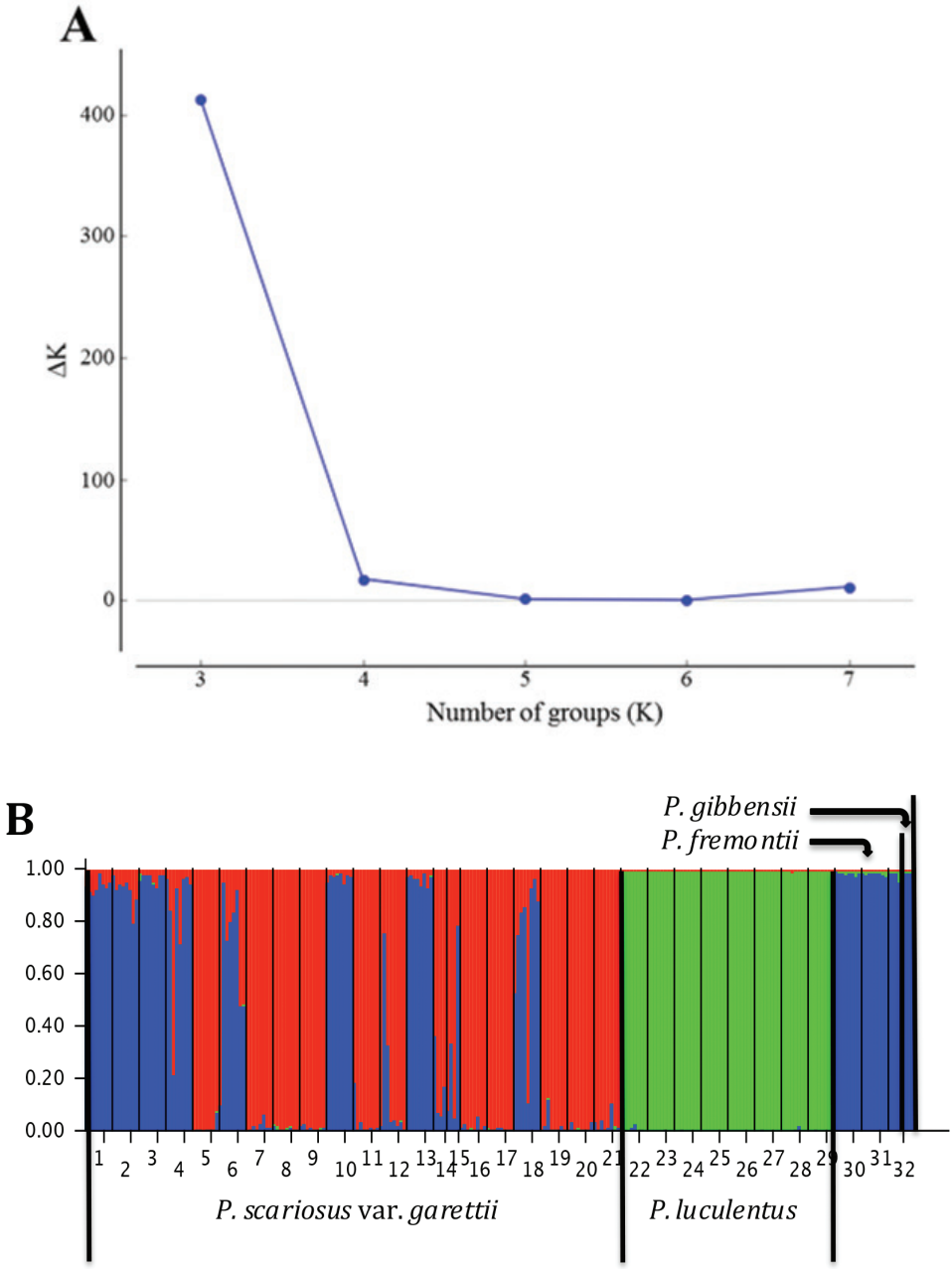

Figure 3. A Plot of the second order difference (ΔK) of K values (2–8) tested in STRUCTURE analysis identifying $K = 3$ as the optimal number of populations based on the accessions of *Penstemon luculentus*, *P. fremontii*, *P. scariosus* var. *garrettii*, and *P. gibbensii* tested. As the K values tested were from 2 to 8, the first difference in K values (ΔK) starts at $K = 3$ **B** Bar plot of inferred ancestry coefficients from STRUCTURE analysis results for with $K = 3$ using 248 samples from 32 accessions. Each number on the x axis represents the accessions ID# in Table 1.

Table 3. R_{ST} and F_{ST} values (bottom diagonals) with accompanying P-values (top diagonals) for the pairwise comparisons of *Penstemon luculentus*, *P. fremontii*, *P. scariosus* var. *garrettii*, and *P. gibbensii*.

Pairwise population R_{ST} values				
	Taxon			
Taxon	***P. scariosus* var. *garrettii***	***P. luculentus***	***P. fremontii***	***P. gibbensii***
P. scariosus* var. *garrettii	0.000	0.001	0.001	0.154
P. luculentus	0.060	0.000	0.001	0.031
P. fremontii	0.215	0.127	0.000	0.026
P. gibbensii	0.013	0.076	0.132	0.000
Pairwise population F_{ST} values				
P. scariosus* var. *garrettii	0.000	0.001	0.001	0.001
P. luculentus	0.148	0.000	0.001	0.001
P. fremontii	0.124	0.117	0.000	0.001
P. gibbensii	0.170	0.279	0.262	0.000

P. scariosus var. *garrettii* were selected from the same or adjacent counties to Rio Blanco Co. in Utah and Colorado. Small measurements were taken from digital images with an Olympus SZX-16 dissecting microscope and processed using CellSens Standard 1.8 imaging platform (Olympus Corporation). Because of size similarities between measured plant characteristics, data were plotted as box percentile plots (Fig. 5) with the boxes delimiting the 75th and 25th percentiles and whiskers delimiting the 10th and 90th percentile. Outliers were shown as circles outside the whiskers. We did not have enough material to include *P. gibbensii*.

Results and discussion

We first analyzed the SSR data, between, and within specimens of *P. luculentus*, *P. fremontii*, *P. scariosus* var. *garrettii*, and *P. gibbensii* (Table 1) using STRUCTURE. The results revealed that the best *K* value for these taxa was $K = 3$ and at that *K* value, *P. luculentus* distinctly differed in population genetic composition from any of the other morphologically similar species (Fig. 3A, B). All eight sites (64 specimens) of *P. luculentus* sampled across the plant's range were similar in genetic composition. Varying levels of admixture were detected among sites of *P. scariosus* var. *garrettii*. Some sites genetically resemble *P. gibbensii* and *P. fremontii* with inferred ancestry coefficients of all specimens of 0.9 or greater for the *P. gibbensii* and *P. fremontii* group (blue in Fig. 3B). However, some sites were genetically distinct from all other species with inferred ancestry coefficients of all specimens of 0.9 or greater for their own *P. scariosus* var. *garrettii* group (red in Fig. 3B). Still other sites contained specimens that varied in their relatedness to either of these two groups. *Penstemon fremontii* showed greater genetic similarity to *P. gibbensii* and *P. scariosus* var. *garrettii* than with *P. luculentus*. This genetic similarity may be due to several factors, such as a possible common ancestor

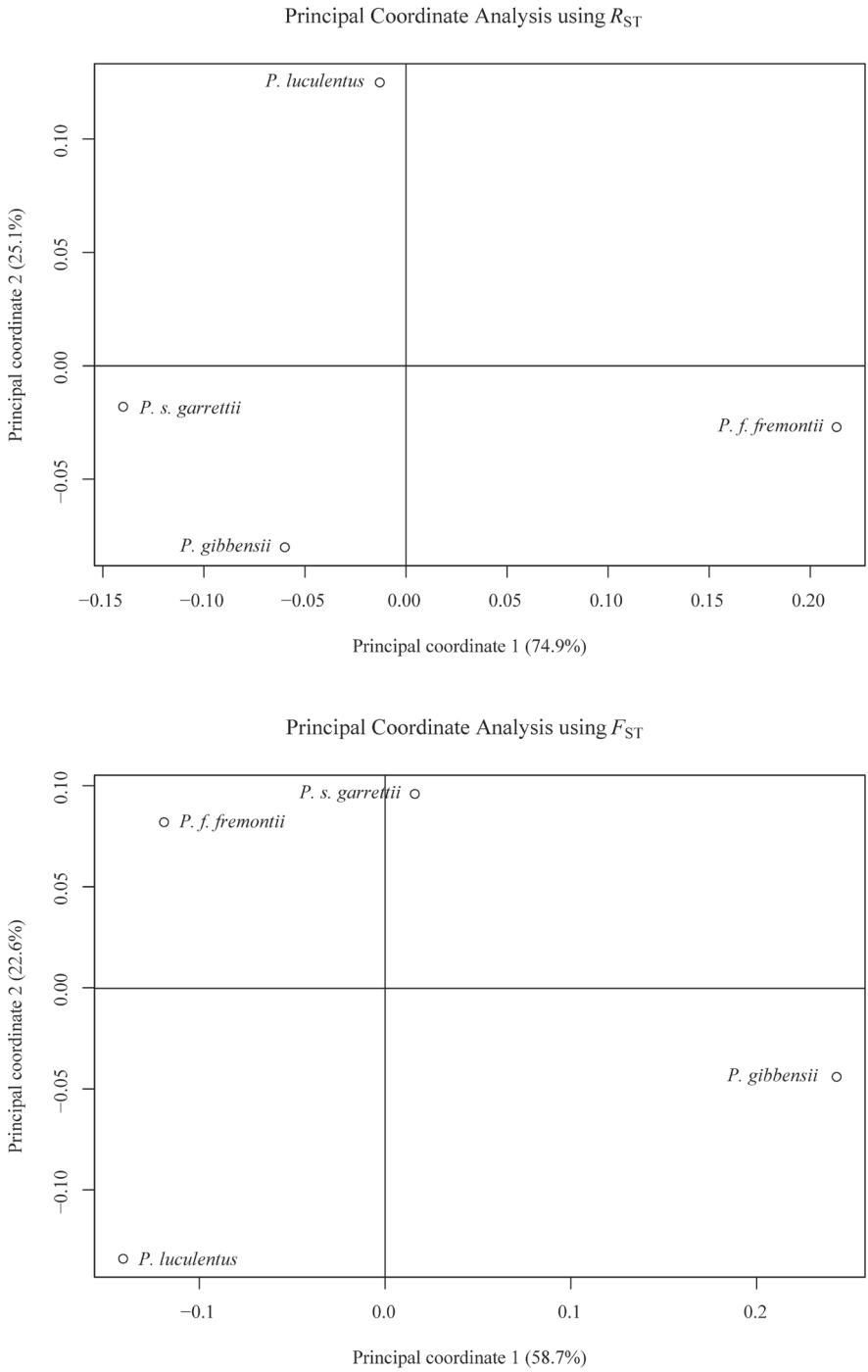

Figure 4. Plots of eigenvectors of the first two coordinates of principal coordinate analysis based on pairwise R_{ST} (top graph) or F_{ST} (bottom graph) values computed from genotypes of ten SSR markers on all taxa. Numbers in parentheses on each axis indicate the percent variation explained by each coordinate.

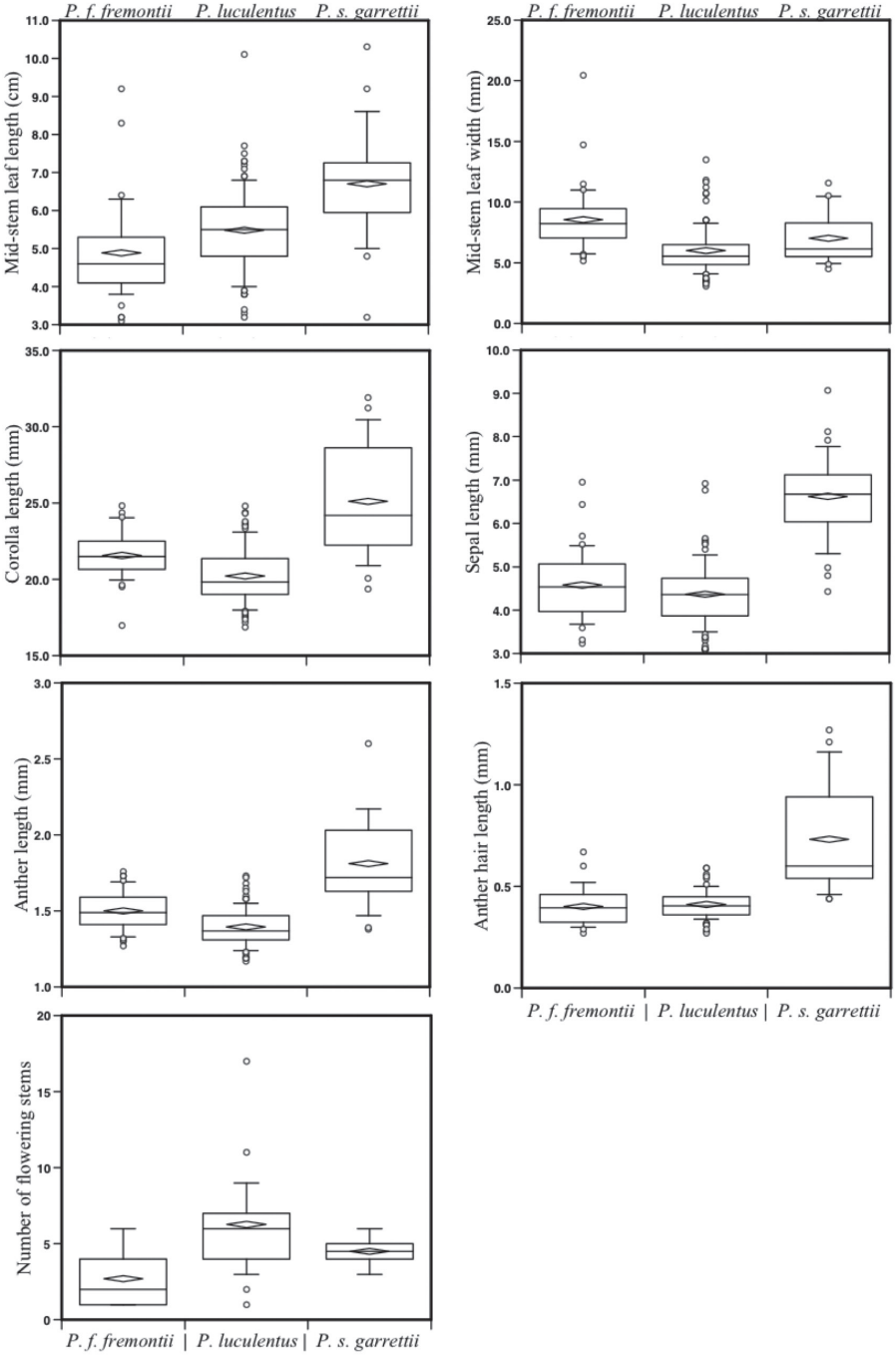

Figure 5. Box percentile plots showing variations among plant characteristics between *P. fremontii*, *P. luculentus*, and *P. scariosus* var. *garrettii*. Boxes delimit the 75th and 25th percentiles. The whiskers delimit the 10th and 90th percentile with outliers shown as circles outside the whiskers. The horizontal bar shows the 50th percentile and the horizontal triangle is the mean.

or historical recombination between species. The elucidation of the factors involved in creating these genetic relationships is beyond the scope of this work and requires further research.

To gain an improved understanding of the relationships between *P. luculentus*, *P. fremontii*, *P. scariosus* var. *garrettii*, and *P. gibbensii*, we analyzed the SSR allele results using AMOVA (analysis of molecular variance). The analysis revealed that, based on F_{ST}, molecular variance was partitioned as 15% among taxa, 26% among individuals across taxa, and 59% within individuals of the same taxa, with an overall F_{ST} of 0.149 (P-value = 0.001). For the AMOVA analysis based on R_{ST}, molecular variance was partitioned as 11% among taxa, 78% among individuals, and 11% within individuals, with an R_{ST} value of 0.106 (P-value = 0.002). All pair-wise F_{ST} and R_{ST} values were statistically significant except for the R_{ST} value of *P. gibbensii* and *P. scariosus* var. *garrettii* (Table 3). Analysis with both F_{ST} and R_{ST} indicated that *P. luculentus* has a unique genetic composition as compared to the other taxa which is illustrated in the graphs of the first two coordinates of the PCoA analyses (Fig. 4). These results support the validity of *P. luculentus* being recognized as a unique species distinct from *P. fremontii sensu stricto*. The F_{ST} analysis suggests that *P. scariosus* var. *garrettii* and *P. fremontii* are more closely related than either are to *P. gibbensii*, while the R_{ST} analysis suggests that *P. scariosus* var. *garrettii* and *P. gibbensii* are more similar. This discrepancy suggests that microsatellite mutations, which are modeled in the stepwise mutation model of R_{ST} (reviewed by Balloux and Lugon-Moulin 2002), contribute to genetic differentiation among the taxa examined. The determination of the mutation rates of each SSR locus is beyond the scope of this study, but should be considered in future analyses with these loci.

Morphological comparisons revealed overlap in the size of many plant characters between *P. luculentus*, *P. fremontii*, and *P. scariosus* var. *garrettii*. Even though there was overlap in the range of measured characteristics, the means do reveal segregating features (Fig. 5). Overall, *P. luculentus* had more flower stems, a smaller caulescent leaf width, a smaller corolla, and a smaller anther cell length but was found to be intermediate in caulescent leaf length. While *P. luculentus* was similar to *P. fremontii* in sepal and anther hair length, these characters were much shorter than those found in *P. scariosus* var. *garrettii*.

Conclusion

While *P. luculentus* has similar morphologically characteristics to *P. fremontii*, and *P. scariosus* var. *garrettii*, there are distinctions that can reliably segregate these taxa. Distinguishing characteristics are more apparent when comparing these taxa *in situ*. The combination of hirtellous stems, glabrous leaves, non-glandular inflorescence, and long anther hairs can be used to segregate *P. luculentus* from other related taxa. Differences in other morphological characters are subtler, largely observed as differences in the means of their measurements, and are not reliably diagnostic.

Molecular evidence suggests that *P. luculentus* is distinct from *P. fremontii sensu stricto*. It is also distinct from *P. scariosus* var. *garrettii* and *P. gibbensii*. While *P. luculentus* is not sympatric with *P. scariosus* var. *garrettii*, it is well within the geographic range of *P. fremontii*. We observed *P. luculentus* and *P. fremontii*, growing naturally, within 100 m of each other with no apparent hybridization between them. Although we did not observe the two taxa growing interlaced, it is possible that they could co-occur in some areas of the Piceance Basin. Despite both *P. luculentus* and *P. fremontii* commonly occurring in the Piceance Basin, there was no morphological evidence that these taxa are exchanging alleles even though they are blooming simultaneously. The results of our study of both the SSR and morphometric data indicate that *P. luculentus* should be elevated to species status.

Taxonomic key

P. luculentus can be segregated from *P. fremontii*, *P. scariosus*, and *P. gibbensii* using the following key. We don't attempt to segregate the different varieties of *P. scariosus* in this key but recognize where they would segregate from *P. luculentus*. The taxonomic status of the varieties of *P. scariosus* is currently being investigated.

1 Stems hirtellous, eglandular **2**
– Stems glabrous or with hairs glandular and only occurring distally or on inflorescence axis..... **3**
2 At least some leaf blade surfaces hirtellous, basal leaves spatulate to broadly oblanceolate, usually present at anthesis..... ***Penstemon fremontii***
– Leaf blades glabrous or with scabrous hairs restricted to leaf margins, basal leaves linear to lanceolate when present, usually absent at anthesis..... ..... ***Penstemon luculentus***
3 Distal portion of stem and inflorescence axis with glandular hairs..... **4**
– Distal portion of stems and inflorescence axis glabrous .... ***Penstemon scariosus* var. *scariosus*, *Penstemon scariosus* var. *garrettii***
4 Sepals < 5mm, glandular hairs abundant..... ***Penstemon gibbensii***
– Sepals 5–6+ mm, glandular hairs sparse .... ***Penstemon scariosus* var. *albifluvis*, *Penstemon scariosus* var. *cyanomontanus*, occasionally *Penstemon scariosus* var. *garrettii***

Acknowledgements

This study was initiated as a collateral discovery while determining the extent of where *Penstemon scariosus* is geographically found. We would like to gratefully acknowledge the funding supported by a BLM grant L14AC00346 "Molecular Characterization of White River Beardtongue, *Penstemon scariosus* var. *albifluvis*" to MRS, RLJ and LAJ

and the Department of Plant and Wildlife Sciences, Brigham Young University. We are also grateful for plant specimen loans of *P. fremontii*, and *P. fremontii* var. *glabrescens* from the Rocky Mountain Herbarium (RMS), University of Wyoming.

References

Anderson CD, Ricks NJ, Farley KM, Maughan PJ, Stevens MR (2016) Identification and characterization of microsatellite markers in *Penstemon scariosus* (Plantaginaceae). Applications in Plant Sciences 4(3): 1500105. doi: 10.3732/apps.1500105

Balloux F, Lugon-Moulin N (2002) The estimation of population differentiation with microsatellite markers. Molecular Ecology 11(2): 155–165. doi: 10.1046/j.0962-1083.2001.01436.x

CNHP (2015) Colorado Natural Heritage Program. Colorado Rare Plant Guide: *Penstemon fremontii* var. *glabrescens*. http://www.cnhp.colostate.edu/download/projects/rareplants/guide.asp?id=24426 [accessed 18.12.2015]

Cronquist A, Holmgren AH, Holmgren NH, Reveal JL, Holmgren PK (1984) Intermountain Flora: Vascular Plants of the Intermountain West, U.S.A. Vol. 4. New York Botanical Garden Press, New York, 1–573.

Dorn RD (1982) A new species of *Penstemon* (Scrophulariaceae) from Wyoming. Brittonia 34(3): 334–335. doi: 10.2307/2806704

Dorn RD, Lichvar RW (1990) A new variety of *Penstemon fremontii* (Scrophulariaceae) from Colorado. Madrono: A West American Journal of Botany 37(3): 195–199

Evanno G, Regnaut S, Goudet J (2005) Detecting the number of clusters of individuals using the software STRUCTURE: a simulation study. Molecular Ecology 14: 2611–2620. doi: 10.1111/j.1365-294X.2005.02553.x

Falush D, Stephens M, Pritchard JK (2003) Inference of population structure using multilocus genotype data: Linked loci and correlated allele frequencies. Genetics 164(4): 1567–1587.

Gray A (1862) Character of some new or obscure species of plants, of monopetalous orders, in the collection of the United States South Pacific Exploring Expedition under Captain Charles Wilkes, U. S. N. with various notes and remarks. Proceedings of the American Academy of Arts and Sciences 6: 37–80.

Kearse M, Moir R, Wilson A, Stones-Havas S, Cheung M, Sturrock S, Buxton S, Cooper A, Markowitz S, Duran C, Thierer T, Ashton B, Meintjes P, Drummond A (2012) Geneious Basic: An integrated and extendable desktop software platform for the organization and analysis of sequence data. Bioinformatics 28(12): 1647–1649. doi: 10.1093/bioinformatics/bts199

Peakall R, Smouse PE (2012) GenAlEx 6.5: Genetic analysis in Excel. Population genetic software for teaching and research-an update. Bioinformatics 28(19): 2537–2539. doi: 10.1093/bioinformatics/bts460

Pennell FW (1920) Scrophulariaceae of the central Rocky Mountain states. Contributions from the United States National Herbarium 20: 313–381.

Pritchard JK, Stephens M, Donnelly P (2000) Inference of population structure using multilocus genotype data. Genetics 155(2): 945–959.

Rondeau RK, Handwerk J, Simers L, Granau, Pague C (2011) The state of Colorado's biodiversity. Prepared by The Nature Conservancy by the Colorado Natural Heritage Program, Colorado State Univeristy, Fort Collins, Colorado.

Todd JJ, Vodkin LO (1996) Duplications that suppress and deletions that restore expression from a chalcone synthase multigene family. Plant Cell 8(4): 687–699. doi: 10.1105/tpc.8.4.687

Weber WA, Wittmann RC (2012) Colorado Flora: Western Slope, A Field Guide to the Vascular Plants, 4th edition. University Press of Colorado, Boulder, Colorado, 1–532. doi: 10.5876/9781607321439.01

PhytoKeys 63: 63–76 (2016)
doi: 10.3897/phytokeys.63.6262
http://phytokeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

A new species in the tree genus *Polyceratocarpus* (Annonaceae) from the Udzungwa Mountains of Tanzania

Andrew R. Marshall[1,2], Thomas L.P. Couvreur[4,5,6], Abigail L. Summers[1,2,3], Nicolas J. Deere[1,7], W.R. Quentin Luke[8], Henry J. Ndangalasi[9], Sue Sparrow[3], David M. Johnson[10]

1 *CIRCLE, Environment Department, University of York, York, UK* **2** *Flamingo Land Ltd., Kirby Misperton, North Yorkshire, UK* **3** *Biology Department, University of York, York, UK* **4** *Institut de Recherche pour le Développement, UMR-DIADE, BP 64501, F-34394 Montpellier cedex 5, France* **5** *Université de Yaoundé I, Ecole Normale Supérieure, Département des Sciences Biologiques, Laboratoire de Botanique systématique et d'Ecologie, B.P. 047, Yaoundé, Cameroon* **6** *Netherlands Centre for Biodiversity Naturalis (section NHN), Biosystematics Group, Wageningen University, the Netherlands* **7** *Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, Canterbury, UK* **8** *East African Herbarium, National Museums of Kenya, Nairobi, Kenya* **9** *Department of Botany, University of Dar es Salaam, Dar es Salaam, Tanzania* **10** *Department of Botany & Microbiology, Ohio Wesleyan University, Delaware, Ohio 43015 USA*

Corresponding author: *Andrew R. Marshall* (andy.marshall@york.ac.uk)

Academic editor: *M.A. Jaramillo* | Received 30 October 2014 | Accepted 14 May 2015 | Published 1 June 2016

Citation: Marshall AR, Couvreur TLP, Summers AL, Deere NJ, Luke WRQ, Ndangalasi HJ, Sparrow S, Johnson DM (2016) A new species in the tree genus *Polyceratocarpus* (Annonaceae) from the Udzungwa Mountains of Tanzania. PhytoKeys 63: 63–76. doi: 10.3897/phytokeys.63.6262

Abstract

Polyceratocarpus askhambryan-iringae, an endemic tree species of Annonaceae from the Udzungwa Mountains of Tanzania, is described and illustrated. The new species is identified as a member of the genus *Polyceratocarpus* by the combination of staminate and bisexual flowers, axillary inflorescences, subequal outer and inner petals, and multi-seeded monocarps with pitted seeds. From *P. scheffleri*, with which it has previously been confused, it differs in the longer pedicels, smaller and thinner petals, shorter bracts, and by generally smaller, less curved monocarps that have a clear stipe and usually have fewer seeds. Because *P. askhambryan-iringae* has a restricted extent of occurrence, area of occupancy, and ongoing degradation of its forest habitat, we recommend classification of it as Endangered (EN) on the IUCN Red List.

Keywords

East Africa, Eastern Arc, endemism, Ndundulu, *Polyceratocarpus*

Copyright *Andrew R. Marshall et al.* This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Introduction

The Eastern Arc Mountains of Kenya and Tanzania are well known for their high levels of biodiversity and endemism across many plant and animal groups (Lovett and Wasser 1993, Myers et al. 2000, Newmark 2002, Burgess et al. 2007, Dawson and Gereau 2010). The 13 mountain blocs making up the chain are somewhat isolated from one another, and each block exhibits its own unique suite of species. Many of the forests occupying these mountains are under threat from expanding agriculture and human population increase: an estimated 2.79 Mha of forest was lost between 1908 and 2000 (Willcock et al. 2016), with just 10% of the Eastern Arc Mountains still forested (Platts et al. 2011). These development pressures have added urgency to the inventory of the unique biota of this region.

Within the Eastern Arc chain, the 19,375 km^2 Udzungwa Mountains form the largest mountain bloc (Platts et al. 2011) and comprise the largest area of forest in the Eastern Arc Mountains, totaling around 1,600 km^2 (Marshall et al. 2010). The Udzungwa Mountains have enormous biodiversity value, with the highest plant species richness, the highest endemic vertebrate species richness, and the second highest endemic plant species richness of all mountain blocs in the region (Platts et al. 2010; Rovero et al. 2014). The distinctive character of Udzungwa biodiversity has been recently highlighted by high-profile mammal species discoveries including the kipunji monkey (*Rungwecebus kipunji*; Davenport et al. 2006) and Udzungwa elephant shrew (*Rhynchocyon udzungwensis*; Rovero et al. 2008).

Species of the flowering plant family Annonaceae are prominent among the understory trees and woody climbers of the Eastern Arc Mountains. In these mountains, there are 50 known Annonaceae species, 16 of which are endemic, including 12 out of 127 reported endemic tree species (R.E. Gereau, unpubl. data).

The genus *Polyceratocarpus* Engl. & Diels (Annonaceae subfamily Malmeoideae, tribe Piptostigmateae, Chatrou et al. 2012) is distinguishable from other African genera of the family by the combination of a tree habit, percurrent tertiary veins of the leaves, axillary (sometimes cauliflorous) inflorescences, occurrence of both staminate and bisexual flowers, petals of the outer and inner whorls roughly equal in size and shape, numerous monocarps with multiple seeds arranged in a single row, and pitted seeds with spiniform ruminations (Couvreur et al. 2009, Couvreur et al. 2012). Engler and Diels (1900) published the genus based on *P. scheffleri* Engler & Diels, collected in the Usambara Mountains. Since that time seven additional species have been added to the genus, all from western and central Africa.

Over the last 30 years a number of *Polyceratocarpus* specimens have been collected from the Udzungwa Mountains to the south and west of the range of *P. scheffleri*. It has become clear that these specimens differ consistently from *P. scheffleri* and other congeners by a combination of vegetative, floral, and fruit characters, and they are described here as a new species.

Taxonomic treatment

Polyceratocarpus askhambryan-iringae **A.R. Marshall & D.M. Johnson, sp. nov.**
urn:lsid:ipni.org:names:77155232-1
Figs 1–3

Diagnosis. This species may be distinguished from other species of *Polyceratocarpus* by the combination of glabrous non-glaucous leaves with finely reticulate to weakly scalariform tertiary venation, pedicels 15–22 mm long, broadly ovoid buds, chartaceous petals 10–17 mm long, 5 to 18 carpels/monocarps, and relatively large torulose monocarps.

Type. *Marshall 2117* (holotype K; isotypes DSM, MO, NHT), Tanzania, Iringa Region: Ndundulu Forest, Kilombero Nature Reserve, Udzungwa Mountains, 07°48'S, 36°31'E (WGS84), 1490 m, 30 May 2011.

Description. Monopodial *tree* to 20 m tall, 4.0–25.4 cm diam.; bark smooth, sparsely lenticellate, often with weak horizontal striations and pits on large trees, grey-brown; branches spirally arranged on trunk, branching from half to two fifths of the height of the main stem, perpendicular but sinuous and drooping slightly; twigs longitudinally rugulose, inconsistently marked with small but prominent lenticels, glabrous, brown. *Leaves*: petiole 4–9 mm long, 1.6–3.3 mm thick, roughened, black, glabrous; lamina narrowly to broadly elliptic-oblong to oblanceolate, or rarely obovate, (5.0-)9.0–25.7 by (3.7-)4.9–8.6(-11.6) cm, chartaceous to coriaceous, greenish gray in sicco, glabrous on both surfaces, base rounded and minutely subcordate, apex acuminate with the acumen 12–20 mm long or occasionally obtuse, midvein plane to slightly impressed above, raised below, secondary veins 9 to 17 per side, diverging at 45–60° from midrib, eucamptodromous to weakly brochidodromous, slightly raised to slightly impressed above, raised below, tertiary veins finely reticulate to somewhat scalariform, indistinct to slightly raised above, raised and conspicuous below. *Inflorescences* 1- or 2-flowered, axillary or occasionally ramiflorous, forming tubercles on leafless growth; pedicels 15–29 mm long 1–3 mm diam., finely appressed-puberulent, bearing a bract 0.8–1 mm long 1/4–2/5 of the distance above pedicel base. Flowers bisexual or staminate, buds broadly ovoid; sepals 3, valvate, crescent-shaped, 2–3.5 mm long, partially connate at the base so that as corolla expands the calyx becomes discoid to triangular with diameter of 7–8 mm, appressed-puberulent abaxially; petals in two whorls of 3, pale yellow in vivo; outer petals occasionally tinged pink on abaxial surface in vivo, valvate, spreading horizontally and recurving at anthesis, narrowly elliptic to elliptic or oblong-elliptic, 10–16 mm long by (5-)8–11 mm wide, coriaceous, apex obtuse, sparsely pubescent adaxially, ferruginous appressed-puberulent but becoming glabrate and verrucose abaxially; inner petals sometimes with a pale brownish-yellow median stripe abaxially, valvate, erect at anthesis with the apices recurved, narrowly elliptic-lanceolate, elliptic, or elliptic-oblanceolate, 11–17 mm long × 5–7 mm wide, coriaceous, external surface marked by a broad flattened ridge that narrows from base to apex, glabrous adaxially, appressed-puberulent with

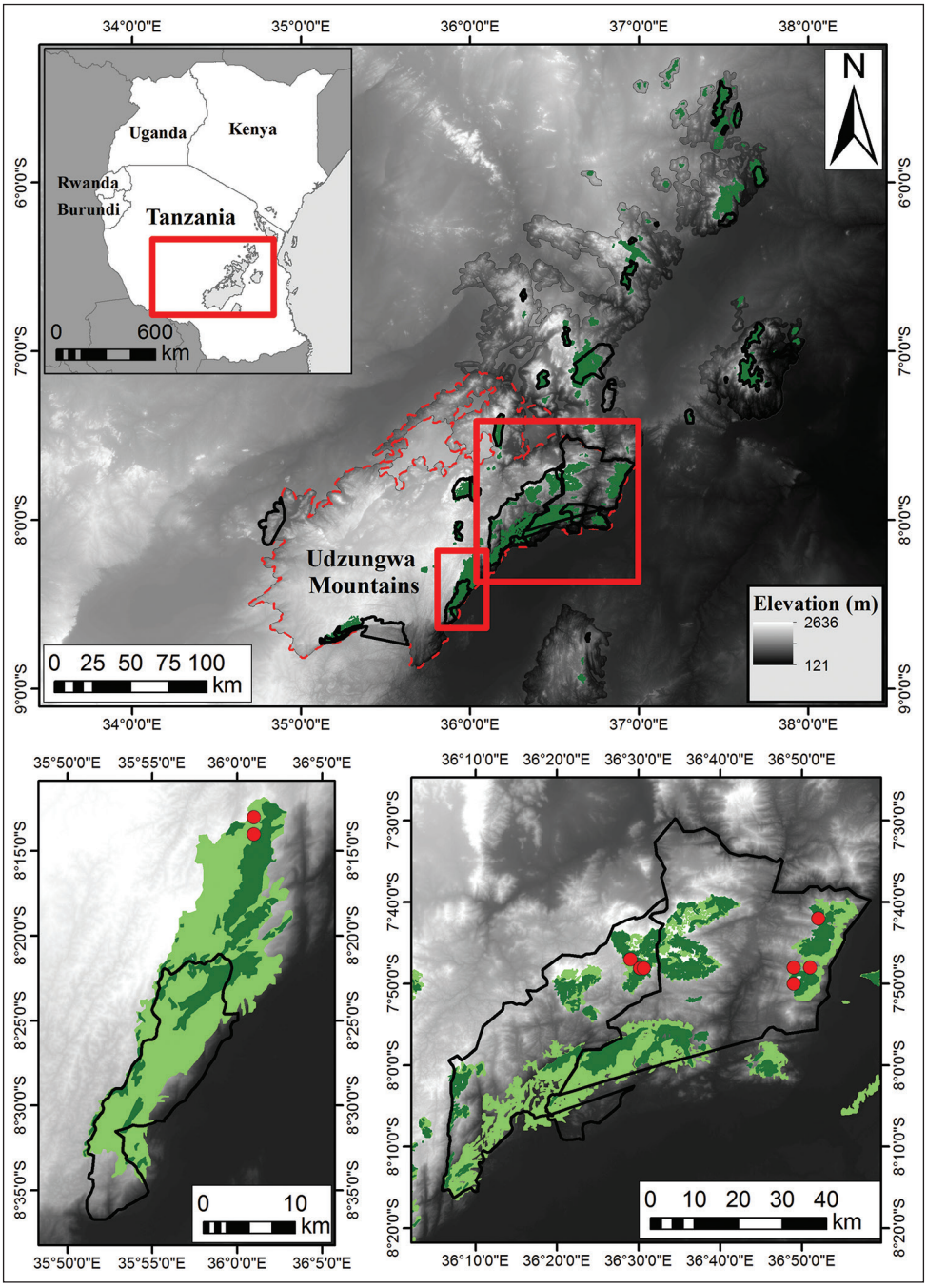

Figure 1. Known distribution of *Polyceratocarpus askhambryan-iringae* in the Eastern Arc Mountains (EAM). EAM boundary and forest cover (green) derived from Platts et al. (2011). Black boundaries within EAM boundary show protected areas. Pale green areas in the lower maps show degraded forest with canopy <10%.

trichomes densest along ridge and at apex abaxially, verrucose on both surfaces, apex acute; stamens ca. 200, 2.0–2.8 mm long, clavate, apex of connective obliquely truncate, pale brown with orange apex, glabrous?; carpels 5 to 18, oblong, 2.9–4.0(-6.0) mm long by 0.9–1.1(-2.3) mm wide, densely pale brown/ferruginous-puberulous; stigma bilobed, capitate, 1 mm in diam., glabrous, ovules ca. 10, uniseriate; torus subglobose to broadly pyriform to oblate, 4.4–4.9 mm long by 2.6–5.4 mm diam., 3–8 mm diam. at base. Pedicel of fruit 20–44 mm long by 3–7 mm diam., weakly longitudinally rugulose, glabrate; torus of fruit ellipsoid to broadly pyriform, 7–15 mm diam. × 8–12 mm long, grey-brown. *Monocarps* up to 18 per fruit, green (rarely with orange or vinaceous tinge) in vivo, dark brown when dried, weakly (to strongly) recurved-falciform, (1.9) 6.0–8.6 cm by 0.7–2.2 cm, torulose, minutely verrucose, glabrate or with a few scattered hairs, base sub-sessile or short-stipitate, stipe 1–11 mm long, 2–6 mm thick, apex rounded or sometimes short-beaked. *Seeds* 1–15 per monocarp, 15 mm long by 13 mm wide by 10 mm thick, arranged in a single [or two irregular?] rows, flattened-ellipsoid, pitted, with spiniform ruminations (fig. 3) and raphe/antiraphe sunken in a circumferential groove.

Distribution. *Polyceratocarpus askhambryan-iringae* is endemic to the Udzungwa Mountains of Tanzania. It is known from Mwanihana Forest in the Udzungwa Mountains National Park, Ndundulu Forest in the Kilombero Nature Reserve, and the Uzungwa Scarp Forest Reserve (Fig. 1).

Habitat and ecology. Inhabits montane forest on brown sandy loam soils (pH range 4–5 measured in Ndundulu Forest). Mean annual rainfall of collection localities approximately 1500–2000 mm/yr (Marshall, Ndangalasi, unpubl. data). Thirty-eight mature individuals were found mostly on slopes or ridge-tops at elevations 1090–1540m. Mature flowers were collected in May, November, and December, fruits in February and May-October.

Associated taxa recorded with *Polyceratocarpus askhambryan-iringae* include the following: **(1) Ndundulu Forest:** *Allanblackia ulugurensis* Engl., *Alsodeiopsis schumannii* Engl.; *Anisotes pubinervius* (T.Anderson) Heine, *Anthocleista grandiflora* Gilg, *Beilschmiedia kweo* (Mildbr.) Robyns & Wilczek, *Bertiera pauloi* Verdc., *Cassipourea gummiflua* Tul.; *Cassipourea malosana* Alston; *Chlorophytum brachystachyum* Baker, *Cleistanthus polystachyus* Hook.f. ex Planch., *Clerodendrum cephalanthum* Oliv., *Coffea* sp., *Cola greenwayi* Brenan, *Cola stelechantha* Brenan; *Craterispermum longipedunculatum* Verdc.; *Diospyros abyssinica* (Hiern) F.White, *Drypetes gerrardii* Hutch.; *Englerina* sp. nov.; *Garcinia buchananii* Baker; *Garcinia volkensii* Engl.; *Grewia mildbraedii* Burret; *Justicia rodgersii* Vollesen; *Lasiodiscus usambarensis* Engl.; *Maytenus undata* (Thunb.) Blakelock; *Monodora globiflora* Couvreur; *Monanthotaxis schweinfurthii* Engl. & Diels; *Myrianthus holstii* Engl., *Ocotea usambarensis* Engl.; *Ochna holstii* Engl.; *Parinari excelsa* Sabine, *Peddiea fischeri* Engl., *Pavetta nitidissima* Bridson, *Plectranthus leptophyllus* (Baker) A.J.Paton, *Rinorea angustifolia* Baill. subsp. *ardisiiflora* (Oliv.) Grey-Wilson; *Rinorea* sp.; *Rytigynia lichenoxenos* (K.Schum.) Robyns subsp. *glabrituba* Verdc.; *Sclerochiton obtusisepalus* C.B.Clarke; *Solanecio epidendricus*

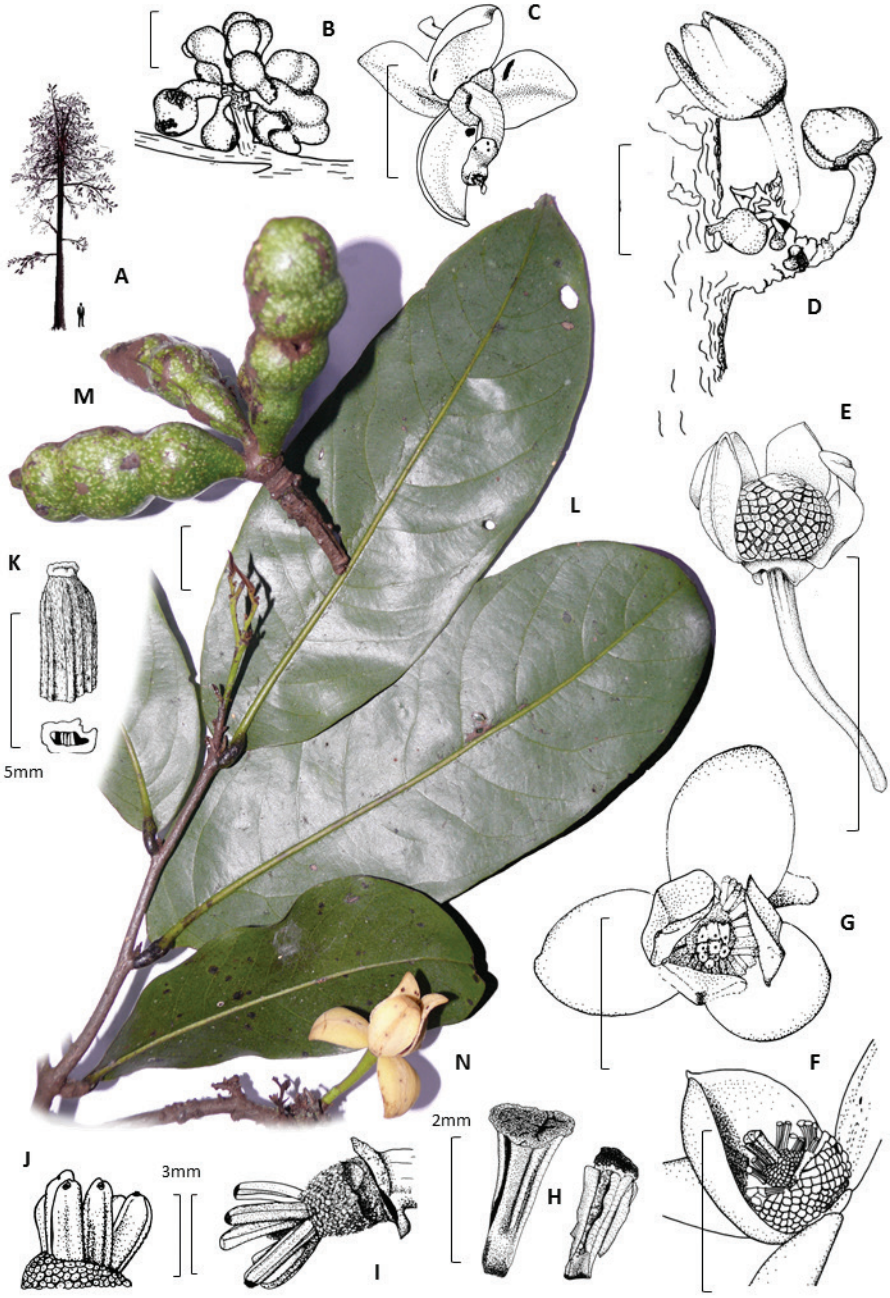

Figure 2. *Polyceratocarpus askhambryan-iringae* drawings of **A** tree architecture **B** fresh fruits **C** fresh flower below **D** fresh ramiflorous flower buds **E–F** dry and fresh bisexual flower (one petal removed) **G** fresh bisexual flower above **H** dried stamens **I–J** fresh and dry carpels lacking stigmas **K** dried carpel with stigma, plus photographs of **L** fresh leaves **M** fruit and **N** flower. Drawings by Sue Sparrow, **A** by Andrew Marshall, **E** and **K** by Andrew Brown, from the following specimens: Marshall 2070 (**B**); Marshall 2117 (**C-E** and **G-L**) and Luke 11279 (**F**). Scale bars: 20 mm unless stated.

(Mattf.) C.Jeffrey; *Strombosia scheffleri* Engl.; *Strychnos mellodora* S.Moore; *Strychnos mitis* S.Moore; *Strychnos* sp. nov; *Syzygium guineense* DC.; *Tabernaemontana stapfiana* Britten; *Tarenna pavettoides* (Harv.) Sim; *Thalictrum rhynchocarpum* Quart.-Dill. & A.Rich.; *Uvariopsis lovettiana* Couvreur & Q.Luke; *Vepris stolzii* I.Verd.; *Vernonia calvoana* Engl. subsp. *leucocalyx* (O.Hoffm.) C.Jeffrey; *Vernonia luhomeroensis* Q.Luke & Beentje; *Vernonia* sp. nr. *pteropoda* Oliv. & Hiern; *Warneckea* sp. nov.; *Xymalos monospora* Baill.; *Zanthoxylum paracanthum* (Mildbr.) Kokwaro; *Zehneria* sp. nr. *oligosperma* C.Jeffrey. **(2) Uzungwa Scarp Forest Reserve:** *Cassipourea gummiflua* Tul; *Cleistanthus polystachyus* Hook.f. ex Planch.; *Craterispermum longipedunculatum* Verdc.; *Diospyros uzungwaensis* Frim.-Møll. & H.J.Ndangalasi; *Drypetes gerrardii* Hutch.; *Lasiodiscus usambarensis* Engl.; *Psychotria megalopus* Verdc.; *Tabernaemontana stapfiana* Britten; *Tarenna uzungwaensis* Bridson. **(3) Mwanihana:** *Acalypha psilostachya* Hochst. ex A.Rich. var. *psilostachya*; *Anisotes pubinervius* (T.Anderson) Heine; *Caloncoba welwitschii* Gilg; *Chrysophyllum gorungosanum* Engl.; *Coffea mufindiensis* Hutch. ex Bridson subsp. *mufindiensis*; *Dorstenia* sp. aff *tenuiradiata* Mildbr.; *Isoglossa lactea* Lindau ex Engl. subsp. *lactea*; *Isolona linearis* Couvreur; *Newtonia buchananii* (Baker) G.C.C.Gilbert & Boutique; *Ochna holstii* Engl.; *Parinari excelsa* Sabine; *Phyllopentas ulugurica* (Verdc.) Kårehed & B. Bremer; *Kedrostis* sp.; *Polystachya* sp aff. *canaliculata* Summerh.; *Raphidiocystis chrysocoma* (Schumach.) C.Jeffrey; *Selaginella kraussiana* (Kunze) A.Braun; *Stellaria mannii* Hook.f.; *Tricalysia aciculiflora* Robbr.; *Uvariopsis lovettiana* Couvreur & Q.Luke; *Vepris nobilis* (Delile) Mziray; *Zanthoxylum paracanthum* (Mildbr.) Kokwaro.

Additional specimens examined. TANZANIA. Iringa Region, Kilolo District: east Udzungwa National Park, forest south of Mwanihana hill c. 2 km S of last camping site of Mwanihana trail, 1400 m, 07°48'S, 36°49'E, Couvreur 101 (DSM, OWU, WAG); Mwanihana Forest above Sanje village, 1220 m, no grid reference, Lovett 222 (K); Udzungwa Mountains National Park, 1200 m, 07°48'S, 36°49'E, Luke 7738 (EA, K); Udzungwa Mountains National Park, 1440 m, 07°42'S, 36°52'E, Luke 11279 (EA, NHT, MO, K); Ndundulu FR, Camp 589-Camp 590, 07°47'S, 36°29'E, 1440 m, Luke et al. 10366 (MO); Kilombero Nature Reserve, Ndundulu Forest, 1540 m, 07°48'S, 36°31'E (WGS84), Marshall 2036, 2070, (NHT, MO, K); Uzungwa Scarp Forest Reserve, Uluti, 1534 m, 08°14'S, 36°01'E, Ndangalasi HJN 392 (DSM, OWU); Uzungwa Scarp Forest Reserve, Ilutila, 1709 m, 08°13'S, 36°01'E, Ndangalasi 393 (DSM, OWU); Udzungwa, Kilombero FR, W of Ruaha River, 1700 m, Rogers & Hall 2300 (K); Mwanihana Forest above Sanje village, 1400 m, 07°50'S, 36°49'E, Thomas 3656 (MO); Mwanihana Forest above Sanje village, 1400 m, 07°50'S, 36°49'E, Thomas 3698 (MO, WAG). Morogoro Region, Kilombero District: Sonjo-Mwanihana trail, 1090 m, 07°48'S, 36°51'E, Luke 5051 (EA, K).

An additional specimen from Iringa Region (Nyambanitu Forest, Ede 65, K), may also represent this species but bears only an old fruit pedicel lacking monocarps. Further potential *Polyceratocarpus* collections from Iringa Region (Lulanda Forest Reserve: Gereau 2651, 2664, 2665, MO; Lovett 2256, MO, WAG; Luke & Luke 12779, EA & K), were identified as neither *P. askhambryan-iringae* nor *P. scheffleri*, while another

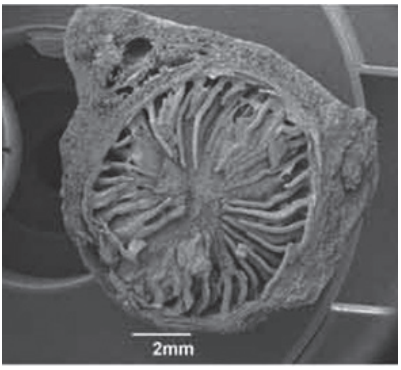

Figure 3. SEM photograph of *Polyceratocarpus askhambryan-iringae* dried seed cross-section, showing spiniform ruminations.

from Morogoro Region was not considered to be from this genus at all (Kimboza Forest Reserve: Parry 1816, TFD; cited Verdcourt 1971).

Additional field notes. *Slash* dry, slightly stringy, pale yellow (to pale peach), occasionally streaked yellow-brown, dark brown at outer edge formed by the colour of the inner bark, potpourri aroma. *Leaf* lamina dark green above, mid-green with greyish tinge below, turning greenish-grey when dried, new flush pinkish; petiole initially pale green in vivo, becoming roughened grey-brown with age; midrib yellow-green above and below in vivo. *Flower* buds broadly ovoid, green or pale brown-yellow with occasional pink tinge at apex in vivo; sepals yellowish-green in vivo.

Etymology. This new species of *Polyceratocarpus* was named by Askham Bryan College and Iringa International School as part of a rainforest education program.

Conservation status. Our IUCN Red List assessment for *P. askhambryan-iringae* was based on "area of occupancy" (AOO), "extent of occurrence" (EOO; IUCN 2012) and the level of threat. The 38 observed mature *P. askhambryan-iringae* stems were found at four collection localities, with only 112 km between the most distant individuals. The four collection localities represented three different levels of governmental protection, including Forest Reserve (Uzungwa Scarp), Nature Reserve (Kilombero, KNR; and also Uzungwa Scarp proposed status) and National Park (Udzungwa Mountains; UMNP), with only UMNP having the maximum level of protection under Tanzanian law (IUCN category II; Dudley 2008). At the time of survey, the greatest threat to *P. askhambryan-iringae* was widespread timber-felling observed in Uzungwa Scarp Forest Reserve. Conversely, threats to *P. askhambryan-iringae* in KNR and UMNP were much lower, both comprising only very occasional removal of pole-sized trees by villagers, and potential damage from an increasing elephant population (Marshall et al. 2012). KNR was further threatened by a lack of formal ranger patrols and rapid population expansion in the nearest villages. Given that the sources of threat were closely associated with the three protected areas, for the purpose of Red List assessment we considered three rather than four threat-defined "locations" (IUCN 2012). In calculating AOO, we used 10 km^2 grid cells so that the projected area was

not extrapolated far beyond the expected habitat tolerance of the species. We estimated an AOO of 300 km^2 and an EOO of 1,410 km^2, with EOO, AOO, habitat quality and the number of mature individuals, all presumed declining as a result of timber-felling in USFR. Given this continuing decline, plus an EOO of less than 5,000 km^2, an AOO of less than 500 km^2, and a population at no more than five locations, the species qualified firmly as endangered on the IUCN Red List (IUCN 2012), EN B1ab(i, ii,iii,v)+2ab(i,ii,iii,v). Within the Udzungwa Mountains, closed-canopy forest was not extensive at elevations suitable for *P. askhambryan-iringae*, and hence we expect that future expeditions will not expand the AOO or EOO of *P. askhambryan-iringae* above the IUCN endangered threshold. However, the Rubeho and Mahenge mountain blocs adjacent to Udzungwa were more poorly known, and may contain suitable habitat in which this species might also be found.

Discussion

A) Systematics

Polyceratocarpus askhambryan-iringae is similar to *P. scheffleri* and has previously been confused with it. As far as is known, however, *P. scheffleri* is confined to the Usambara Mountains and *P. askhambryan-iringae* to the Udzungwa Mountains; previous reports of *P. scheffleri* from the Udzungwa Mountains (e. g. Lovett et al. 1988, Couvreur et al. 2006, Eastern Arc Mountains & Coastal Forests CEPF Plant Assessment Project 2009) have been based on misidentifications of *P. askhambryan-iringae*. To facilitate separation of the two East African species, their differences are contrasted in the following key:

1 Lamina rounded and minutely subcordate at base, with tertiary veins reticulate to weakly scalariform; pedicel 15–29 mm long, bearing a bract 0.8–1 mm long; sepals connate only at base, distinct, crescent-shaped; petals 10–17 mm long; monocarps up to 18 per fruit, (1.9–) 6–8.6 cm long, weakly recurved-falciform, short-stipitate (1–11 × 2–6 mm); seeds per monocarp up to 15 ....***Polyceratocarpus askhambryan-iringae***

– Lamina cuneate to broadly cuneate at base, with tertiary veins distinctly scalariform; pedicel 10–16 mm long, bearing a bract 7–9 mm long; sepals connate into a disc with indistinguishable sepal lobes; petals 18–32 mm long; monocarps 5 to 33, 6–20 cm long, strongly curved, sessile; seeds per monocarp up to ca. 25 .....***Polyceratocarpus scheffleri***

The genus *Polyceratocarpus* outside East Africa has a Guineo-Congolean distribution, with the other seven species scattered from Côte d'Ivoire to northern Angola and the Democratic Republic of the Congo. *Polyceratocarpus askhambryan-iringae* and *P. scheffleri* both differ from most of the more western species in having larger numbers of

carpels and large strongly torulose monocarps. The only other species with such a high number of carpels (18 to 20) is *Polyceratocarpus laurifolius* Paiva from northern Angola, but that species differs from *P. askhambryan-iringae* in having densely pubescent twigs, a distinctly cuneate base to the leaf, a larger bract on the pedicel, and larger sepals. *Polyceratocarpus laurifolius* also differs from *P. askhambryan-iringae* in having larger petals of the staminate flowers than of the bisexual ones (Paiva 1966); in *P. askhambryan-iringae* no petal dimorphism between staminate and bisexual flowers was seen.

Polyceratocarpus askhambryan-iringae (as "*Polyceratocarpus* sp.") was one of four *Polyceratocarpus* species included in the phylogenetic analysis of Couvreur et al. (2009) focused on the phylogeny of several closely related African genera of Annonaceae. In this analysis *P. askhambryan-iringae* appeared as sister to the other three species of *Polyceratocarpus* sampled (*P. microtrichus* (Engl. & Diels) Ghesq. & Pellegr., *P. parviflorus* (Baker f.) Ghesq., and *P. pellegrinii* Le Thomas) forming a monophyletic group with strong bootstrap and posterior probability support. The other five species remain to be sampled. The genus itself, however, was nested within the western and central African genus *Piptostigma* Oliv., to which it is morphologically dissimilar, so additional sampling is needed.

B) Regional endemism and biodiversity

East Africa is an area of both high endemism and high diversity for Annonaceae, with 28 genera and 85 species known from Tanzania alone (Couvreur et al. 2006). In particular, the Eastern Arc Mountains form an area of high species endemism for East African Annonaceae. Furthermore, many Annonaceae genera represented in these mountains have main areas of diversity in the Guineo-Congolean region and are represented in the Eastern Arc Mountains by endemic taxa. In addition to *Polyceratocarpus*, the genera *Annickia* Setten & Maas, *Greenwayodendron* Verdc., *Isolona* Engl., *Monodora* Dunal, *Uvariodendron* (Engl. & Diels) R.E. FR., and *Uvariopsis* Engl. all follow this pattern (Verdcourt 1971, 1986, Couvreur et al. 2006, Couvreur 2009, Couvreur and Luke 2010).

Polyceratocarpus askhambryan-iringae also adds to the growing list of species unique to the Udzungwa bloc, including various recently discovered plants (e.g. Luke and Beentje 2003; Knox et al. 2004). There are now 71 known endemic plant species from the Udzungwa Mountains (comprising 15 trees, including *P. askhambryan-iringae*); among the Eastern Arc Mountains this is second only to the Uluguru Mountains (86 endemic species [14 trees]; R.E. Gereau, unpubl. data). *P. askhambryan-iringae* is the second large tree (≥20m) and the third endemic Annonaceae species to be described from the Udzungwa Mountains over the last 20 years, following the respective discoveries of *Omphalocarpum strombocarpum* Y.B.Harv. & Lovett (Harvey and Lovett 1998), *Toussaintia patriciae* Q.Luke & Deroin (Deroin and Luke 2005) and *Monodora globiflora* Couvreur (Couvreur et al. 2006). Given further new species descriptions in preparation and the larger size of the Udzungwa Mountains, it is likely to be the most important Eastern Arc Mountain bloc for tree species endemism. More plant species

are known from the Udzungwa Mountains than other Eastern Arc Mountain blocs, and while this is partly due to increased survey effort over other blocs, recent projections by distribution models estimate that the number of endemic/threatened plant taxa will not be superseded following increased exploration of other blocs (Platts et al. 2010).

The four *P. askhambryan-iringae* localities are coextensive with other recent discoveries of rare and endemic Eastern Arc animals, e.g. the Critically Endangered endemic Sanje mangabey (*Cercocebus sanjei*; Mwanihana and Uzungwa Scarp), the Critically Endangered kipunji monkey (*Rungwecebus kipunji*; Ndundulu; also found on Rungwe Mountain), the endemic Udzungwa forest partridge (*Xenoperdix udzungwensis*; Ndundulu), the endemic rufous-winged sunbird (*Nectarinia rufipennis*; Mwanihana, Ndundulu and Uzungwa Scarp), the endemic Udzungwa elephant shrew (*Rhynchocyon udzungwensis*; Ndundulu and Mwanihana), further emphasizing the exceptional local biodiversity value. The exceptional biodiversity of these areas led to the incorporation of Mwanihana forest into the Udzungwa Mountains National Park in 1991, and later incorporation of Ndundulu forest into the Kilombero Nature Reserve in 2007 (Marshall et al. 2007).

The discovery of *P. askhambryan-iringae* further highlights the need for improved conservation of Uzungwa Scarp Forest Reserve, one of the most important forests in the region for primates and birds (Dinesen et al. 2001), where herpetofauna endemism has been estimated at eight times that of the Eastern Arc as a whole (Menegon, unpublished data). Uzungwa Scarp FR is home to the Kihansi spray toad (*Nectophrynoides asperginis*), which was extinct in the wild, but was successfully reintroduced in October 2012 following zoo conservation breeding (Channing et al. 2009; Gereau et al. 2014). We hope that our discovery of yet another new endemic will add weight to ongoing proposals for gazettement of Uzungwa Scarp Forest Reserve as a Nature Reserve, the highest designation of protected area possible under the Tanzania Forestry Service.

Acknowledgements

Thanks to COSTECH and TAWIRI for permits. The collection expedition to Ndundulu Forest was primarily funded by Flamingo Land Ltd., through the Udzungwa Forest Project. Preliminary surveys of Ndundulu were funded by HMJ Design and Mazuri Foods Ltd., through the British and Irish Association of Zoos and Aquaria Mammal Working Group, and by the Wildlife Conservation Society. Collections from the Uzungwa Scarp Forest Reserve were funded by Danish International Development Agency (DANIDA) through the ENRECA Project at the Department of Botany, University of Dar es Salaam. Thanks to National Museums of Kenya staff especially John Kimeu, for herbarium support. Roy Gereau (Missouri Botanical Garden) is thanked for comments on the manuscript. Nancy Murray (Ohio Wesleyan University) for helpful comments on the manuscript. Phil Roberts (University of York) is thanked for administrating the production of illustrations, and Andrew Brown for producing two of the sketches. We also thank the many field assistants who helped with collections, and with expedition

logistics, especially Richard Mgata from Udekwa village, who climbed tall trees in pursuit of vital material for this description. TLPC thanks the Netherlands Organization for Scientific Research (NWO), Hugo de Vries Fonds and Air France-KLM for financial help in Tanzania in 2006. Frank Mbago is thanked for assistance while in the field with TLPC. We also thank the United Bank of Carbon for funding to develop a schools' rainforest education program around this species, which led to the chosen species name. And last but not least we thank all the participating schools, colleges, youth groups and people who helped the success of this program, particularly Katie Boswell, Amber Hall, Joshua Sammy, Sharon Sheppard and the First Sherburn Rainbows and Brownies.

References

Burgess ND, Butynski TM, Cordeiro NJ, Doggart NH, Fjeldså J, Howell KM, Kilahama FB, Loader SP, Lovett JC, Mbilinyi B, Menegon M, Moyer DC, Nashanda E, Perkin A, Rovero F, Stanley WT, Stuart SN (2007) The biological importance of the Eastern Arc Mountains of Tanzania and Kenya. Biological Conservation 134: 209–231.

Channing A, Howell K, Loader S, Menegon M, Poynton J (2009) *Nectophrynoides asperginis*. The IUCN Red List of Threatened Species. Version 2014.2. http://www.iucnredlist.org [Downloaded on 10 October 2014]

Chatrou LW, Pirie MD, Erkens RHJ, Couvreur TLP, Neubig KM, Abbott JR, Mols JB, Maas JW, Saunders RMK, Chase MW (2012) A new subfamilial and tribal classification of the pantropical flowering plant family Annonaceae informed by molecular phylogenetics. Botanical Journal of the Linnean Society 169(1): 5–40. doi: 10.1111/j.1095-8339.2012.01235.x

Couvreur TLP, Gereau RE, Wieringa JJ, Richardson JE (2006) Description of four new species of *Monodora* and *Isolona* (Annonaceae) from Tanzania and an overview of Tanzanian Annonaceae diversity. Adansonia sér 3 28(2): 242–266.

Couvreur TLP (2009) Monograph of the syncarpous African genera *Isolona* and *Monodora* (Annonaceae). Systematic Botany Monographs 87: 1–150.

Couvreur TLP, van der Ham RWJM, Mbele YM, Mbago FM, Johnson DM (2009) Molecular and morphological characterization of a new monotypic genus of Annonaceae, *Mwasumbia*, from Tanzania. Systematic Botany 34(2): 266–276. doi: 10.1600/036364409788606398

Couvreur TLP, Luke WRQ (2010) A new species of Uvariopsis (Annonaceae), endemic to the Eastern Arc Mountains of Tanzania. Blumea 55(1): 68–72.

Couvreur TLP, Mass PJM, Meinke S, Johnson DM, KeßLer PJA (2012) Keys to the genera of Annonaceae. Botanical Journal of the Linnean Society 169(1): 74–83. doi: 10.1111/j.1095-8339.2012.01230.x

Davenport TRB, Stanley WT, Sargis EJ, De Luca DW, Mpunga NE, Machaga SJ, Olson LE (2006) A new genus of African monkey, *Rungwecebus*: morphology, ecology, and molecular phylogenetics. Science 312: 1378–1381. doi: 10.1126/science.1125631

Dawson SE, Gereau RE (2010) New species of *Aidia* and *Polysphaeria* (Rubiaceae) from East Africa. Novon 20(3): 256–264. doi: 10.3417/2009110

Deroin T, Luke WRQ (2005) A new *Toussaintia* (Annonaceae) from Tanzania. Journal of East African Natural History 94: 165–174. doi: 10.2982/0012-8317(2005)94[165:ANTAFT]2.0.CO;2

Dinesen L, Lehmberg T, Rahner MC, Fjeldså J (2001) Conservation priorities for the forests of the Udzungwa Mountains, Tanzania, based on primates, duikers and birds. Biological Conservation 99: 223–236. doi: 10.1016/S0006-3207(00)00218-4

Dudley N (2008) Guidelines for Applying Protected Area Management Categories. IUCN, Gland. doi: 10.2305/IUCN.CH.2008.PAPS.2.en

Eastern Arc Mountains & Coastal Forests CEPF Plant Assessment Project (2009) *Polyceratocarpus scheffleri*. The IUCN Red List of Threatened Species. http://www.iucnredlist.org

Engler A, Diels L (1900) Übersicht über die bekannten Gattungen der Anonaceen und Beschreibung einiger neuen Gattungen dieser Familie aus dem tropischen Afrika. Notizblatt des Königlichen botanischen Gartens und Museums zu Berlin 23: 45–59. doi: 10.2307/3993968

Harvey YB, Lovett JC (1998) A new species of *Omphalocarpum* (Sapotaceae) from eastern Tanzania. Kew Bulletin 54(1): 197–202. doi: 10.2307/4111038

Gereau RE, Kariuki M, Ndang'ang'a PK, Werema C, Muoria P (2014) Biodiversity Status and Trends in the Eastern Arc Mountains and Coastal Forests of Kenya and Tanzania Region, 2008–2013. BirdLife International – Africa Partnership Secretariat, Nairobi, 80 pp. doi: 10.5962/bhl.title.96053

IUCN (2012) IUCN Red List Categories and Criteria: Version 3.1 (Second edition). IUCN, Gland, Switzerland and Cambridge.

Knox EB, Luke WRQ, Thulin M (2004) A new giant *Lobelia* from the Eastern Arc Mountains, Tanzania. Kew Bulletin 59: 189–194. doi: 10.2307/4115849

Lovett JC, Bridson DM, Thomas DW (1988) A preliminary list of the Moist Forest Angiosperm Flora of Mwanihana Forest. Annals of the Missouri Botanical Garden 75(3): 874–885. doi: 10.2307/2399376

Lovett JC, Wasser SK (1993) Biogeography and ecology of the rain forests of Eastern Africa. Cambridge University Press, Cambridge. doi: 10.1017/CBO9780511895692

Luke WRQ, Beentje HJ (2003) A New *Vernonia* (Compositae: Vernonieae) from the Udzungwa Mountains, Tanzania. Kew Bulletin 58: 977–980. doi: 10.2307/4111212

Marshall AR, Aloyce Z, Mariki S, Jones T, Burgess N, Kilihama F, Massao J, Nashanda E, Sawe C, Rovero F, Watkin J (2007) Tanzania's second Nature Reserve: improving the conservation status of the Udzungwa Mountains? Oryx 41(4): 429–430.

Marshall AR, Jørgensbye HIO, Rovero F, Platts PJ, White PCL, Lovett JC (2010) The species-area relationship and confounding variables in a threatened monkey community. American Journal of Primatology 72: 325–336.

Marshall AR, Willcock S, Platts PJ, Lovett JC, Balmford A, Burgess ND, Latham JE, Munishi PKT, Salter R, Shirima DD, Lewis SL (2012) Measuring and modelling above-ground carbon and tree allometry along a tropical elevation gradient. Biological Conservation 154: 20–33. doi: 10.1016/j.biocon.2012.03.017

Myers NRA, Mittermeier CG, de Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403(6772): 853–858. doi: 10.1038/35002501

Newmark WD (2002) Conserving biodiversity in East African forests: a study of the Eastern Arc Mountains. Springer, 1–205. doi: 10.1007/978-3-662-04872-6

Paiva JAR (1966) Revisão das Annonaceae de Angola. Memórias da Sociedade Broteriana 19: 5–128.

Platts PJ, Ahrends A, Gereau RE, McClean CJ, Lovett JC, Marshall AR, Pellikka PKE, Mulligan M, Fanning E, Marchant R (2010) Can distribution models help refine inventory-based estimates of conservation priority? A case study in the Eastern Arc forests of Tanzania and Kenya. Diversity & Distributions 16: 628–642. doi: 10.1111/j.1472-4642.2010.00668.x

Platts PJ, Burgess ND, Gereau RE, Lovett JC, Marshall AR, McClean CJ, Pellikka PKE, Swetnam RD, Marchant R (2011) Delimiting tropical mountain ecoregions for conservation. Environmental Conservation 38(3): 312–324. doi: 10.1017/S0376892911000191

Rovero F, Rathburn GB, Perkin A, Jones T, Ribble DO, Leonard C, Mwakisoma RR, Doggart N (2008) A new species of giant sengi or elephant-shrew (genus *Rhynchocyon*) highlights the exceptional biodiversity of the Udzungwa Mountains of Tanzania. Journal of Zoology 274: 126–133. doi: 10.1111/j.1469-7998.2007.00363.x

Rovero F, Menegon M, Fjeldså, Collett L, Doggart N, Leonard C, Norton G, Owen N, Perkin A, Spitale D, Ahrends A, Burgess ND (2014) Targeted vertebrate surveys enhance the faunal importance and improve explanatory models within the Eastern Arc Mountains of Kenya and Tanzania. Diversity and Distributions. doi: 10.1111/ddi.12246

Verdcourt B (1971) Annonaceae. In: Milne-Redhead E, Polhill RM (Eds) Flora of Tropical East Africa. Whitefriars Press, 1–132.

Verdcourt B (1986) New taxa of East African Annonaceae. Kew Bulletin 41(2): 287–297. doi: 10.2307/4102932

Willcock S, Phillips OL, Platts PJ, Swetnam RD, Balmford A, Burgess ND, Ahrends A, Bayliss J, Doggart N, Doody K, Fanning E, Green JMH, Hall J, Howell KM, Lovett JC, Marchant R, Marshall AR, Mbilinyi B, Munishi PKT, Owen N, Topp-Jørgensen JE, Lewis SL (2016) Land cover change and carbon emissions over 100 years in an African biodiversity hotspot. Global Change Biology. doi: 10.1111/gcb.13218 [in press]

PhytoKeys 63: 77–97 (2016)
doi: 10.3897/phytokeys.63.8181
http://phytokeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

New combinations in *Odontostemma* (Caryophyllaceae)

Richard K. Rabeler[1], Warren L. Wagner[2]

1 *University of Michigan Herbarium – EEB, 3600 Varsity Drive, Ann Arbor, MI 48108-2228, USA*
2 *Department of Botany, MRC-166, National Museum of Natural History, Smithsonian Institution, P.O. Box 37012, Washington, DC 20013-7012, USA*

Corresponding author: *Richard K. Rabeler* (rabeler@umich.edu)

Academic editor: *A. Calvente* | Received 19 February 2016 | Accepted 29 April 2016 | Published 2 June 2016

Citation: Rabeler RK, Wagner WL (2016) New combinations in *Odontostemma* (Caryophyllaceae). PhytoKeys 63: 77–97. doi: 10.3897/phytokeys.63.8181

Abstract

Sixty-three new combinations in *Odontostemma* (Alsineae, Caryophyllaceae) are made to accommodate placement of all currently recognized taxa of *Arenaria* subg. *Odontostemma* within the genus *Odontostemma*.

Keywords

Odontostemma, *Arenaria*, Caryophyllaceae, nomenclature

Introduction

In their study of relationships in *Arenaria* L. and major lineages within the Alsinoideae using nuclear and plastid DNA, Harbaugh et al. (2010) found that three members of *A.* subg. *Odontostemma* (Benth. ex G. Don) F.N. Williams clustered in a clade with *Pseudostellaria* Pax and *Lepyrodiclis* Fenzl, distinct from most of *Arenaria* s.s., instead clustering more closely with *Stellaria* L. and *Cerastium* L. This alignment was also seen in the broad study of family relationships by Greenberg and Donoghue (2011).

Sadeghian et al. (2015) completed the most recent and more comprehensive analyses of *Arenaria* in the broad sense. They confirmed the results of Harbaugh et al. (2010)

Copyright *R. K. Rabeler & W. L. Wagner.* This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

and Greenberg and Donoghue (2011), showing that *Arenaria* s.s. and *Eremogone* Fenzl are in different clades and are each monophyletic and that *Arenaria* subg. *Odontostemma* is in a third clade separate from those including *Arenaria* s.s. and *Eremogone*; *Odontostemma* is also monophyletic. In addition, *Arenaria* subg. *Solitaria* McNeill is sister to *Odontostemma* and subg. *Dolophragma* (Fenzl) McNeill appears distantly related to any *Arenaria* species; both of these subgenera should also be excluded from *Arenaria* and treated as distinct genera.

With only seven names currently available in *Odontostemma* (six provided by Sadeghian et al. (2015) for species they sampled), nearly all members of *Arenaria* subg. *Odontostemma* require new combinations in *Odontostemma*. With active flora projects in India (Flora of India Checklist, in prep.) and China (Flora of China, e.g. Wu et al. 2001) bringing more information to light about these areas, we feel that it is time to supply the 63 combinations necessary for recognizing remaining taxa as members of the genus *Odontostemma*.

Methods

The information about type specimens of the basionyms of the new combinations that we have included is based on examining protologues and searching major indices (Tropicos - http://www.tropicos.org/; JSTOR Global Plants - https://plants.jstor.org; Chinese Virtual Herbarium (CVH), http://www.cvh.org.cn), as well as websites of several individual herbaria (B [http://ww2.bgbm.org/herbarium/default.cfm], E [http://elmer.rbge.org.uk/bgbase/vherb/bgbasevherb.php], K [http://apps.kew.org/herbcat/navigator.do?_ga=1.234000091.472586779.1455676163], P [https://science.mnhn.fr/institution/mnhn/collection/p/item/search] , US [http://collections.nmnh.si.edu/search/botany/?ti=3], and WU [http://herbarium.univie.ac.at/database/search.php]) for extant specimens. We also examined images of specimens at A which had not been included in JSTOR and at KUN for twenty-one taxa where information in the CVH appeared to be incomplete. Herbarium abbreviations follow *Index Herbariorum* (Thiers 2016, continuously updated, http://sweetgum.nybg.org/science/ih/). We have examined a digital image from one (or more) of these sources for any specimen for which we cite a barcode in the type citations. In cases where specimen deposition is not clearly stated in a protologue, we have added "?" after the abbreviation where, based on information about the location of the herbarium where the author worked and/or deposited their herbaria (see Index of Botanists - http://kiki.huh.harvard.edu/databases/botanist_index.html), we expect, but cannot confirm, a type specimen should have been deposited.

In the cases where syntypes are cited, we have refrained from designating lectotypes. It is not a requirement for the names to be validly and effectively published and we consider those decisions should be made during the course of a taxon-level revision where a serious study of all specimens would lead to the best selections.

Discussion

Odontostemma Benth. ex G. Don was originally described by Bentham to segregate *O. glandulosum* Benth. ex G. Don from *Arenaria* (Don 1831). Most subsequent authors have included *Odontostemma* in *Arenaria*, most recently as a subgenus (McNeill 1962, Wu et al. 2001). *Arenaria* subg. *Odontostemma* includes about 65 species (Wu et al. 2001), all native to eastern Asia with 57 species endemic to China (Wu et al. 2001). Wu et al. (2001) noted that species have sometimes been grouped into five sections (two of which have not been validly published); Sadeghian et al. (2015) suggested it is premature to suggest subdividing the genus pending additional taxon sampling.

Odontostemma taxa can be recognized by a combination of characters. Most members have two, or seldom three (or more in one species), styles, sepals that curve outward distally and are saccate proximally with truncate or acute apices, and seeds with an inflated testa that lacks reticulate striations. If one were to apply the generic segregations reported in Sadeghian et al. (2015) to the Wu et al. (2001) treatment of *Arenaria* in China, the 102 species would be distributed among five genera, with *Arenaria* comprising just six species. A key to these genera, based in part on McNeill (1962) and Wu et al. (2001), follows:

Key to *Arenaria* and segregate genera

1 Styles 2 (seldom 3; 4(5) in *O. weissianum*), capsule valves 4 (seldom 6; 8(10) in *O. weissianum*); plants diffuse **2**

– Styles 3, capsule valves 6 (rarely styles 2 and capsule valves 4, then plants densely pulvinate [some *Arenaria* subg. *Dicranilla* (Fenzl) F.N. Williams]); plants diffuse, caespitose, or pulvinate **3**

2 Sepals often curved outward distally, often saccate proximally, obscurely veined, apex truncate or acute; seeds usually inflated, roughened, surface obscurely marked; east Asia ..... ***Odontostemma***

– Sepals straight, not saccate proximally, veins prominent, apex acute-acuminate or obtuse; seeds not inflated, surface often roughened and tuberculate; France [*Arenaria provincialis* Chater & G. Halliday] ..... ***Arenaria*** (in part)

3 Plants densely caespitose or pulvinate **4**

– Plants diffuse, sometimes weakly caespitose **6**

4 Sepals thickened proximally, veins 1-3, prominent ..... ***Eremogone*** (in part)

– Sepals not thickened proximally, veins indistinct **5**

5 Plants densely caespitose but not pulvinate; cauline leaves sometimes overlapping, but not decussate; flowers solitary, rarely in pairs; sepal apex and margins hardened ..... ***Solitaria***

– Plants densely pulvinate (rarely densely caespitose); cauline leaves decussate in 4 rows; flowers solitary or in three-flowered cymes; sepal apex and margins scarious, but not hardened ..... ***Dolophragma***

6 Leaves filiform to subulate, often grass-like, or short and needle-like with margins often white-scarious; sepals thickened proximally, veins often prominent ..... ***Eremogone*** (in part)

– Leaves linear to ovate to orbicular, neither grass-like nor needle-like, margins not scarious; sepals not or barely thickened proximally, veins obscure or prominent..... ***Arenaria*** (in part)

The name Odontostemma is a compound word formed from *odont*, Greek, tooth, and *stemma*, Greek, wreath or garland. Although Odontostemma appears to be feminine, the gender must be treated as neuter. According to Article 62.2 (see esp. 62.2(c)) of the International Code of Nomenclature (McNeill et al. 2012), a compound genus name takes the gender of the last element; *-stemma* is neuter.

This detail was apparently overlooked when five of the new combinations were made in Sadeghian et al. (2015). Article 32.2 of the International Code (McNeill et al. 2012) allows these names to be corrected "without change of the author citation or date". These names should now be cited as follows: *Odontostemma barbatum* (Franch.) Sadeghian & Zarre, *Odontostemma ionandrum* (Diels) Sadeghian & Zarre, *Odontostemma pogonanthum* (W.W. Sm.) Sadeghian & Zarre, *Odontostemma roseiflorum* (Sprague) Sadeghian & Zarre, and *Odontostemma trichophorum* (Franch.) Sadeghian & Zarre.

Taxonomic treatment

Odontostemma **Benth. ex G. Don**

Odontostemma Benth. ex G. Don, Gen. Hist. 1: 449. 1831
Arenaria subg. *Odontostemma* (Benth. ex G. Don) F.N. Williams, Bull. Herb. Boissier 3: 603. 1895.
Gooringia F.N. Williams, Bull. Herb. Boissier 5: 530. 1897.

Type. *Odontostemma glandulosum* Benth. ex G. Don, Gen. Hist. 1: 449. 1831

Description. Herbs annual, biennial, or perennial, diffuse, not pulvinate. Leaf blades linear to ovate, rarely subulate. Inflorescences cymose, terminal or sometimes axillary, the flowers often borne on long pedicels. Sepals often curved outward distally, often saccate, veins inconspicuous, margin membranous, apex truncate or acute. Petals usually longer than sepals (sometimes shorter, when cleistogamous flowers present), apex emarginate or shallowly bifid or toothed. Styles 2, seldom 3 [4(5) in *O. weissianum*]. Seeds often inflated, roughened, without reticulate striations.

About 65 species: Asia; 59 species (57 endemic) in China.

New combinations

Odontostemma amdoense **(L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155278-1

Arenaria amdoensis L.H. Zhou in C.Y. Wu, Fl. Xizang. 1: 688. 1983.

Type. China: Xizang: river beaches, Ando Xian, 4830 m, Qinghai-Xizang Freezing-soil Complex Exped. 551 (holotype, NWBI, not seen).

Odontostemma auricomum **(Y.W. Tsui ex L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155279-1

Arenaria auricoma Y.W. Tsui ex L.H. Zhou, Acta Biol. Plateau Sin. 6: 31. 1987.

Type. China: Yunnan: mountain sands, Zhongdian, 4200–4750 m, 1 September 1962, Zhongdian Exped. 1831 (holotype KUN, KUN0510342; isotype, KUN, KUN1205404).

Odontostemma barbatum **(Franch.) Sadeghian & Zarre var. hirsutissimum (W.W. Sm.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155332-1

Arenaria barbata var. *hirsutissima* W.W. Sm., Notes Roy. Bot. Gard. Edinburgh 11: 195. 1920.

Type. China: Yunnan: dry open stony mountain meadows, eastern flank, Lijiang Range, 3350–3650 m, 27°40'N, August 1910, G. Forrest 6299 (holotype, E, E00313712; isotype, K, K000723902).

Odontostemma bomiense **(L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155280-1

Arenaria bomiensis L.H. Zhou in C.Y. Wu, Fl. Xizang. 1: 685. 1983.

Type. China: Xizang: mountain grasslands, Bomi, ca. 3700 m, P.C. Tsoong 6347 (holotype, PE, not seen).

Odontostemma chamdoense **(C.Y. Wu ex L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155281-1

Arenaria chamdoensis C.Y. Wu ex L.H. Zhou in S.W. Liu, Fl. Qinghai. 1: 506. 1997.

Type. China: Xizang: on gravel, Chamdo (Sheezha), 4600 m, 24 August 1976, C.Y. Wu 5033 (holotype, KUN, KUN1205408; isotype, KUN, KUN1207757).

Odontostemma delavayi **(Franch.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155282-1

Arenaria delavayi Franch., Bull. Soc. Bot. France 33: 432. 1886.

Type. China: Yunnan: in rock clefts near summit of Mt. Tsang-chan, above Tali, 4000 m, P.J.M. Delavay 1039 (holotype P, P01902938; isotypes: P [2 sheets], P01902939, P01902940).

Odontostemma dimorphitrichum **(C.Y. Wu ex L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155283-1

Arenaria dimorphitricha C.Y. Wu ex L.H. Zhou, Acta Biol. Plateau Sin. 6: 28. 1987.

Type. China: Sichuan: margin of woods, grassy slope, Mu-li, Gi-bo-shan, 2800 m, 7 August 1937, F.I.B. Yunnan Exp., T.T. Yü 7644 (holotype, KUN, KUN1205413; isotype, A, A00235507).

Odontostemma dsharaense **(Pax & K. Hoffm.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155284-1

Arenaria dsharaensis Pax & K. Hoffm. in Pax, Repert. Spec. Nov. Regni Veg. Beih. 12: 366. 1922.

Type. China: East Tibet: along creeks near snow patches, Ta tsien lu, west chain of Dshara parallel, east Chung ku, 4700 m, H.W. Limpricht 1818 (holotype, WRSL?; isotype WU, WU0046569).

Odontostemma euodontum **(W.W. Sm.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155285-1

Arenaria euodonta W.W. Sm., Notes Roy. Bot Gard. Edinburgh 11: 195. 1920.

Syntypes. China: Yunnan: open situations on and amongst boulders, Kari Pass, Mekong-Yangtze Divide, 3960 m, 27°40'N, July 1914, G. Forrest 12891 (syntype, E, E00313702; isosyntypes, KUN, KUN0510655 [labeled "holotype"]), PE, PE00551428); China: SE Tibet: open stony pasture and screes, on Doker-La, Mekong-Salween Divide, 28°20'N, August 1917, G. Forrest 14640 (syntype, E, E00316014; isosyntype, K, K000723895).

Odontostemma filipes **(C.Y. Wu ex L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155286-1

Arenaria filipes C.Y. Wu ex L.H. Zhou, Acta Biol. Plateau Sin. 6: 34. 1987.

Type. China: Sichuan: wooded margins, Mu-li, Gi-bo-shan, 2800 m, 7 August 1937, F.I.B. Yunnan Exp., T.T. Yü 7637 (holotype, KUN, KUN1205418; isotypes, A, A00235539, KUN, KUN1205415, PE [2 sheets], PE00551451, PE00551452).

Odontostemma fimbriatum **(Mattf.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155333-1

Arenaria fimbriata Mattf., Notizbl. Bot. Gart. Berlin-Dahlem 11: 335. 1932; *Cerastium fimbriatum* E. Pritz., Bot. Jahrb. Syst. 29: 320. 1900, not Ledeb. (1815), nom. illeg.

Syntypes. China: Sichuan?: highest regions, Tai pa Shan, August, Giraldi 1187 (B, presumably destroyed), Giraldi 1188 (B, presumably destroyed).

Odontostemma giraldii **(Diels) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155287-1

Lepyrodiclis giraldii Diels, Bot. Jahrb. Syst. 36 (Beibl. 82): 38. 1905; *Arenaria giraldii* (Diels) Mattf., Notizbl. Bot. Gart. Berlin-Dahlem 11: 336. 1932.

Type. China: Shaanxi?: Im Ki shan, 65 km SE of Sce kin Tsuen, Giraldi 2599 (B, presumably destroyed).

Odontostemma inconspicuum **(Hand.-Mazz.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155288-1

Arenaria inconspicua Hand.-Mazz., Symb. Sin. 7: 197. 1929.

Syntypes. China: Yunnan: bare, muddy, mica and granite areas, Mekong-Salwin-Kette, back Pongatong, 28°9'N, 4300-4375 m, 4 August 1916, H. Handel-Mazzetti 9677 (syntype, WU, WU0043550; isosyntype, K, K000723884); Doker-La, border of Tibet, 4600 m, 17 September 1915, H. Handel-Mazzetti 8146 (syntype, WU, WU0043551).

Odontostemma inornatum **(W.W. Sm.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155289-1

Arenaria inornata W.W. Sm., Notes Roy. Bot. Gard. Edinburgh 11: 196. 1920.

Type. China: Yunnan: on boulders and ledges of cliffs, Mekong-Salween Divide, 3650 m, 28°12'N, July 1917, G. Forrest 14444 (holotype, E, E00313710; isotype K, K000723894).

Odontostemma ionandrum **(Diels) Sadeghian & Zarre var.** ***melanotrichum*** **(H.F. Comber) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names: 77155335-1

Arenaria ionandra var. *melanotricha* H. F. Comber, Notes Roy. Bot. Gard. Edinburgh 18: 229. 1934.

Type. China: Yunnan: moist chalky pasture, eastern flank of Lijiang Range, 27°35'N, 3350 m, September 1910, G. Forrest 6509, (holotype, E, E00313708; isotypes, ISBC0147277, KUN0511451).

Odontostemma karakorense **(Em. Schmid) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155336-1

Arenaria karakorensis Em. Schmid, Repert. Spec. Nov. Regni Veg. 31: 42. 1932.

Syntypes. China: Xizang: Kiam, 5100 m, 11 August 1927, W. Bosshard s.n. (W, presumed destroyed) ; China: Aksai-Chin, ca. 5000 m, 5 September 1927, W. Bosshard s.n. (W, presumed destroyed).

Odontostemma leucasterium **(Mattf.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155290-1

Arenaria leucasteria Mattf., Notizbl. Bot. Gart. Berlin-Dahlem 11: 334. 1932.

Type. China: Szechuan: in scree, Mt. Konka, Risonquemba, Konkaling, 5080 m, June-August 1928, J.F. Rock 16847 (holotype, B, presumed destroyed; isotypes, E, E00313707, GH, GH00053922, N [not seen], US, US00103300).

Odontostemma littledalei **(Hemsl.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155291-1

Arenaria littledalei Hemsl., Bull. Misc. Inform. Kew 1896: 209. 1896. *Gooringia littledalei* (Hemsley) F.N. Williams, Bull. Herb. Boissier 5: 530. 1897.

Type. China: Tibet, Goring Valley, 30˚12'N, 90˚25'W, 5000 m; St. George R. Littledale s.n. (holotype, K, K000723881).

Odontostemma longicaule **(C.Y. Wu ex L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155292-1

Arenaria longicaulis C.Y. Wu ex L.H. Zhou, Acta Biol. Plateau Sin. 6: 38. 1987.

Type. China: Yunnan: 1938, Nat. Pek. Univ. Exped. s.n. (holotype, PE, not seen).

Odontostemma longipes **(C.Y. Wu ex L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155293-1

Arenaria longipes C.Y. Wu ex L.H. Zhou, Acta Biol. Plateau Sin. 6: 39. 1987.

Type. China: Sichuan: cliffs, Muli, Shao-siang-liang-tze, ca. 3500 m, 16 August 1937, F.I.B. Yunnan Exp., T.T. Yü 7743 (holotype, KUN, KUN1205431; isotypes, A, A00235717, KUN, KUN0510918, PE [2 sheets], PE00024087, PE00551827).

Odontostemma longipetiolatum **(C.Y. Wu ex L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155294-1

Arenaria longipetiolata C.Y. Wu ex L.H. Zhou, Acta Biol. Plateau Sin. 6: 29. 1987.

Type. China: Sichuan: forests, Mu-li, Between Gei-bao-shan and Mu-li-si, 2580 m [2800 m on holotype, transcription error?], 7 August 1937, F.I.B. Yunnan Exp., T.T. Yü 7655 (holotype, KUN, KUN1205433; isotypes, IBSC, IBSC0147267, KUN, KUN1205434, PE [2 sheets], PE00551828, PE 00551829).

Odontostemma longisetum **(C.Y. Wu) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155295-1

Arenaria longiseta C.Y. Wu in C.Y. Wu et al., Fl. Yunnan. 6: 835. 1995.

Type. China: Yunnan: Deqen, 3800-3900 m, 13 August 1940, K.M. Feng 6599 (holotype, KUN, KUN1205436; isotypes, KUN [2 sheets], KUN1205435, KUN1207758).

Odontostemma longistylum **(Franch.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155337-1

Arenaria longistyla Franch., Bull. Soc. Bot. France 33: 433. 1886.

Type. China: Yunnan: on Mt. Li-kiang, 4000 m, 13 August 1886, P.J.M. Delavay 2103 (holotype, P, P04966773).

Odontostemma longistylum **var.** ***pleurogynoides*** **(Diels) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155339-1

Arenaria longistyla var. *pleurogynoides* Diels, Notes Roy. Bot. Gard. Edinburgh 5: 182. 1912.

Type. China: Yunnan: on limestone drift at base of cliffs, eastern flank of Lijiang Range, 27°20'N, 3650 m, September 1906, G. Forrest 2902 (holotype, E, E00313706; isotype, P, P04966776).

***Odontostemma mairei* (H. Lév.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155296-1

Cerastium mairei H. Lév., Repert. Spec. Nov. Regni Veg. 13: 341. 1914, not *Arenaria mairei* Emb. (1933); *Arenaria iochanensis* C.Y. Wu in C. L. Tang, Fl. Reipubl. Popularis Sin. 26: 241. 1996.

Type. China: Yunnan: on rocks, du lo-Chan summit, 3400 m, August 1913, E. E. Maire s.n. (holotype, E, E00313695).

***Odontostemma melanandrum* (Maxim.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155297-1

Cerastium melanandrum Maxim., Bull. Acad. Imp. Sci. Saint-Pétersbourg, Sér. 3, 26: 429. 1880; *Arenaria melanandra* (Maxim.) Mattf. ex Hand.-Mazz., Symb. Sin. 7: 202. 1929.

Type. China: Kansu, 1873, Przewalski s.n. (LE?).

***Odontostemma melandryiforme* (F.N. Williams) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155298-1

Arenaria melandryiformis F.N. Williams, J. Linn. Soc., Bot. 38. 399. 1909.

Syntypes. China: Xizang, Beong-chin, W of Chumbi, 1882, King's collector 1127 (K, K000742175); China: Xizang, Syam-poo, Chumbi district, 1884, King's collector 123 (K, K000742176).

***Odontostemma melandryoides* (Edgew.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155299-1

Arenaria melandryoides Edgew. in Hook.f., Fl. Brit. India 1: 241. 1874.

Type. India: Sikkim, alt. 4260-5480 m, J. D. Hooker 13 (holotype, K?, not seen; isotype, GH, GH00037640).

Odontostemma membranisepalum **(C.Y. Wu) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155300-1

Arenaria membranisepala C.Y. Wu in C.Y. Wu et al., Fl. Yunnan. 6: 155, Addenda 835. 1995.

Type. China: Yunnan: Lijiang?, C.Y. Wu & D.Y. Leu 21238 (holotype, KUN, KUN1205438).

Odontostemma minimum **(C.Y. Wu ex L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155301-1

Arenaria minima C.Y. Wu ex L.H. Zhou, Acta Biol. Plateau Sin. 6: 35. 1987.

Type. China: Sichuan: mountain rock slope, Muli, Wachin, Jin-chang, 4000 m, 27 October 1937, F.I.B. Yunnan Exp., T.T. Yü 14649 (holotype: KUN, KUN0510991).

Odontostemma monanthum **(F. N. Williams) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155302-1

Arenaria monantha F.N. Williams, J. Linn. Soc., Bot. 38: 401. 1909.

Type. China: Xizang: hills above Lhassa, August 1904, H.J. Walton 1138 (holotype, K, K000723880; isotype, BM, BM000946346).

Odontostemma moniliferum **(Mattf.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155303-1

Arenaria monilifera Mattf., Notizbl. Bot. Gart. Berlin-Dahlem 11: 334. 1932.

Type. China: Xizang: Tongolo, 17 June 1894, J.A. Soulié 2507b (holotype, B, presumed destroyed).

Odontostemma napuligerum **(Franch.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155304-1

Arenaria napuligera Franch., Bull. Soc. Bot. France 33: 429. 1886.

Syntypes. China: Yunnan, in rock clefts, Mt. Koua-la-po, near Hokim, 26 April 1884, P. J. M. Delavay 87 (syntypes, P [3 sheets], P01902952, P01902953, P01902954; isosyntypes, K, K000723890, KUN, KUN0511009); along rocky road to Yen-tze-hay, near Lankong, 2500 m, P. J. M. Delavay 1665 (syntypes, P [3 sheets], P01902955, P01902956, P01902957; isosyntype, K, K000723891).

***Odontostemma napuligerum* var. *monocephalum* (W.W. Sm.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155341-1

Arenaria napuligera var. *monocephala* W.W. Sm., Notes Roy. Bot. Gard. Edinburgh 11: 196. 1920.

Type. China: Xizang: at Ka-gwr-pw temple, near the Yunnan frontier, in alpine turf on precipices, 4725 m, July 1913, F.K. Ward 814 (holotype, E, E00313701).

***Odontostemma nigricans* (Hand.-Mazz.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155305-1

Arenaria nigricans Hand.-Mazz., Symb. Sin. 7: 196. 1929.

Type. China: Yunnan: between saddles of Mt. Lamatso, between Yungning and Dschungdien (Zhongdian?), dry limestone cliffs, 3200 m, 12 August 1915, H. Handel-Mazzetti 7609 (holotype, WU, WU0043552; isotype, E, E00313704).

Odontostemma nigricans var. zhenkangense (C.Y. Wu ex L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.
urn:lsid:ipni.org:names:77155342-1

Arenaria zhenkangensis C.Y. Wu ex L.H. Zhou, Acta Biol. Plateau Sin. 6: 36. 1987; *Arenaria nigricans* var. *zhenkangensis* (C.Y. Wu ex L.H. Zhou) C.Y. Wu in C. L. Tang, Fl. Reipubl. Popularis Sin. 26: 209. 1996.

Type. China: Yunnan: on rocky slope, Zhengkang, Snow Range, Hsiaoshiishan, 2850 m [2500 m on holotype (transcription error?), 2 August 1938, F.I.B. Yunnan Exp., T.T. Yü 17133 (holotype, KUN, KUN1205466; isotypes, KUN, KUN1205463, PE, PE00024079).

Odontostemma nivalomontanum **(C.Y. Wu ex L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155306-1

Arenaria nivalomontana C.Y. Wu ex L.H. Zhou, Acta Biol. Plateau Sin. 6: 29. 1987.

Type. China: Yunnan: on rocky slope, Zhangkang, Xueshang, 2900 m, 31 July 1938, F.I.B. Yunnan Exp., T.T. Yü 17125 (holotype, KUN, KUN0511016); isotypes, PE [2 sheets], PE00551915, PE00551916).

Odontostemma omeiense **(C.Y. Wu ex L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155307-1

Arenaria omeiensis C.Y. Wu ex L.H. Zhou, Acta Biol. Plateau Sin. 6: 30. 1987.

Type. China: Sichuan: under thickets, Omei-hsien, Mt. Omei, ca. 3100 m, 5 August 1938, W.P. Fang 12979 (holotype, KUN, KUN0511017; isotype, A00235605]).

Odontostemma paramelanandrum **(H. Hara) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155308-1

Arenaria paramelanandra H. Hara, J. Jap. Bot. 52: 193. 1977.

Type. Nepal: Chakure Lekh, S of Jumla, 14000 ft, 21 July 1952, O. Polunin, W.R. Sykes, & L.H.J. Williams 4827 (holotype, BM, BM000521527).

Odontostemma pharense **(McNeill & Majumdar) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155309-1

Arenaria pharensis McNeill & Majumdar, Bot. J. Linn. Soc. 80: 373. 1980.

Type. China: Xizang: Phari plain, 4360 m, 14 October 1928, J. C. Dawa 398 (holotype, CAL, photo of holotype, DAO; isotype K, K000742178, photo of isotype, DAO).

Odontostemma polyspermum **(C.Y. Wu ex L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155310-1

Arenaria polysperma C.Y. Wu ex L.H. Zhou, Acta Biol. Plateau Sin. 6: 33. 1987.

Type. China: Yunnan: side of mountain stream, Upper Kiukiang Valley, (Clulung) Chialahmuto, 3700 m, 7 August 1938, F.I.B. Yunnan Exp., T.T. Yü 19742, (holotype, KUN, KUN1205439; isotypes, A, A00235512, PE [3 sheets], PE00551959, PE00551960, PE00551961).

Odontostemma pseudostellaria **(C.Y. Wu, L.H. Zhou & W.L. Wagner) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155311-1

Arenaria pseudostellaria C.Y. Wu, L.H. Zhou & W.L. Wagner, Fl. China 6: 59. 2001. *Arenaria linearifolia* Franch., Pl. Delavay. 97. 1889, not Poiret (1804), nor Desvaux (1816); *Moehringia linearifolia* (Franch.) F.N. Williams, J. Linn. Soc., Bot. 34: 437. 1899; *Moehringella linearifolia* (Franch.) H. Neumayer, Verh. Zool.-Bot. Ges. Wien 73: 14. 1923.

Type. China: Yunnan: in woods, Fang-yang-tchang, above Mo-so-yn, 3000 m, 17 June 1887, P.J.M. Delavay 2899 (holotype, P, P04987073).

Odontostemma quadridentatum **(Maxim.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155312-1

Lepyrodiclis quadridentata Maxim., Fl. Tangut. 84. 1889; *Arenaria quadridentata* (Maxim.) F.N. Williams, J. Linn. Soc., Bot. 33: 432. 1898.

Type. China: Qinghai: Danube-ngvarsi valley, 16 May 1885, G.N. Potanin s.n. (LE, not seen).

Odontostemma reductum **(Hand.-Mazz.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155313-1

Arenaria reducta Hand.-Mazz., Kaiserl. Akad. Wiss. Wien, Math.-Naturwiss. Kl., Anz. 57: 47. 1920.

Type. China: Yunnan: alpine meadows on the W side of Mt. Piepun, SE of Dschungdien, 4400-4650 m, 11 August 1914, H. Handel-Mazzetti, 4725 (holotype, WU, WU0043553).

Odontostemma rockii **(Diels) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155314-1

Arenaria rockii Diels, Notizbl. Bot. Gart. Berlin-Dahlem 9: 1027. 1926.

Type. China: Yunnan: in limestone gravel, eastern slopes of Mount Dyinaloko, northern peak of the Likiang Snow Range, 4725 m, August 1923, J.F. Rock 10398 (holotype, B, presumably destroyed; isotype, US, US00103309).

Odontostemma saginoides **(Maxim.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155343-1

Arenaria saginoides Maxim., Fl. Tangut. 89. 1889.

Type. China: northeastern Tibet, on rocks, 3960 m, 9 July 1884, C.J. Maximowicz? (LE?, not seen).

Odontostemma salweenense **(W.W. Sm.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155315-1

Arenaria salweenensis W.W. Sm., Notes Roy. Bot. Gard. Edinburgh 12: 194. 1920.

Type. China: Yunnan: on stony pasture and humus-covered boulders in side valleys, Maikha-Salween Divide, 26°25'N, 3050 m, August 1919, G. Forrest 18474 (holotype, E [mounted on 2 sheets], E00117725 & E00117578; isotypes, K, K000723893, KUN, KUN0511179, WSY [2 sheets], WSY0062587, WSY0095442).

Odontostemma schneiderianum **(Hand.-Mazz.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155316-1

Arenaria schneideriana Hand.-Mazz., Kaiserl. Akad. Wiss. Wien, Math.-Naturwiss. Kl., Anz. 57: 46. 1920.

Type. China: Yunnan: in gravelly limestone, W side of Mt. Piepun, SE of Dschungdien (Zhongdian?), 4400-4700 m, 11 August 1914, H. Handel-Mazzetti, 4724 (holotype, WU, WU0043554; isotypes, E, E00313696, KUN, KUN0511180).

***Odontostemma setiferum* (C.Y. Wu ex L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155317-1

Arenaria setifera C.Y. Wu ex L.H. Zhou, Acta Biol. Plateau Sin. 6: 37. 1987.

Type. China: Yunnan: Bijiang, open slope, Chih-tse-lo, 4000 m, 4 September 1933, H.T. Tsai 54133 (holotype, KUN, KUN0511301; isotype, A, A00235713).

***Odontostemma spathulifolium* (C.Y. Wu ex L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155318-1

Arenaria spathulifolia C.Y. Wu ex L.H. Zhou, Acta Biol. Plateau Sin. 6: 35. 1987.

Type. China: Yunnan: open hillside, N flank of Haba Snow Range, 3500-4200 m, 20 August 1939, K.M. Feng 2082 (holotype, KUN, KUN0511307; isotypes, A, A00235684, KUN, KUN1205447).

***Odontostemma szechuense* (F.N. Williams) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155344-1

Arenaria szechuensis F.N. Williams, J. Linn. Soc., Bot. 34: 437. 1899.

Type. China: Sichuan: Tachien-lu, 1893, J.A. Soulié 814 (holotype, K, K000723892).

***Odontostemma thangoense* (W.W. Sm.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155319-1

Arenaria thangoensis W.W. Sm., Rec. Bot. Surv. India 4: 180. 1911.

Type. India: Thango, 13000-14000 ft.; W.W. Smith 2572 (E?, not seen).

***Odontostemma trichophyllum* (C.Y. Wu ex L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155320-1

Arenaria trichophylla C.Y. Wu ex L.H. Zhou, Acta Biol. Plateau Sin. 6: 27. 1987.

Type. China: Yunnan: grassy slope, Mu-li, Hwa-to, 3900 m, 28 July 1937, F.I.B. Yunnan Exp., T.T. Yü 7428 (holotype, KUN, KUN1205449; isotype, KUN, KUN0511370).

Odontostemma tumengelaense **(L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155321-1

Arenaria tumengelaensis L.H. Zhou, Acta Phytotax. Sin. 18: 357. 1980.

Type. China: Xizang: riverside grasslands, Tumengela Colliery, 5000 m, 30 July 1963, J.X. Yang 1993 (holotype, WUK, WUK0215558; isotypes, KUN [2 sheets], KUN1205455, KUN1205458).

Odontostemma weissianum **(Hand.-Mazz.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155322-1

Arenaria weissiana Hand.-Mazz., Kaiserl. Akad. Wiss. Wien, Math.-Naturwiss. Kl., Anz. 57: 47. 1920.

Syntypes. China: Yunnan: in gravelly limestone, W side of Mt. Piepun, SE of Ds-chungdien (Zhongdian?), 4300–4650 m, 11 August 1914, H. Handel-Mazzetti 4682 (syntype, WU, WU0043555); China: Yunnan: Mt. Yulung-schan, near Lidjiang ("Likiang"), no date given, H. Handel-Mazzetti 3657 (syntype, WU, WU0043557), same location, H. Handel-Mazzetti 3698 (syntype, WU, WU0043556; isosyntype, E, E00313715).

Odontostemma weissianum **var.** ***bifidum*** **(C.Y. Wu & H. Chuang) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155326-1

Arenaria weissiana var. *bifida* C.Y. Wu & H. Chuang in C.Y. Wu et al, Fl. Yunnan. 6: 836. 1995.

Type. China: Yunnan: mountain slope, Huann-fu-ping, A-tun-tze, August 1935, C.W. Wang 68878 (holotype, KUN, KUN1205457; isotypes, A, A00235698, PE [2 sheets], PE00574388, PE00574392).

Odontostemma weissianum **var.** ***puberulum*** **(C.Y. Wu ex L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155327-1

Arenaria weissiana var. *puberula* C.Y. Wu ex L.H. Zhou, Acta Biol. Plateau Sin. 6: 34. 1987.

Type. China: Sichuan: cliffs, Mu-li, Hwa-to, 3900 m, 28 July 1937, F.I.B. Yunnan Exp., T.T. Yü 7432, (holotype, KUN, KUN1205460; isotypes, KUN, KUN1205459, PE [2 sheets], PE00025036, PE00574410).

Odontostemma xerophilum **(W.W. Sm.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155323-1

Arenaria xerophila W.W. Sm., Notes Roy. Bot. Gard. Edinburgh 11: 198. 1920.

Syntypes. China: Yunnan: limy pasture and ledges of limestone cliffs, mountains in N.E. of Yangzi bend, 3050 m, 27°45'N, September 1913, G. Forrest 10998 (syntype, E, E00313694; isosyntypes, K, K000723889, KUN, KUN0511441, PE, PE00574412); China: Yunnan: open dry pasture, Atuntze valley, 28°28'N, August 1914, G. Forrest 13210 (E, not seen; isosyntypes, ISBC, not seen, PE, PE00574414).

Odontostemma xerophilum **var.** ***xiangchengense*** **(L.H. Zhou) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155345-1

Arenaria xiangchengensis L.H. Zhou, Acta Biol. Plateau Sin. 6: 36. 1987; *Arenaria xerophila* var. *xiangchengensis* (L.H. Zhou) C.Y. Wu in W. T. Wang et al., Vasc. Pl. Hengduan Mount. 1: 404. 1993.

Type. China: Sichuan: margin of pine forest, Xiangcheng, Tungzung, 3000 m, 20 September 1937, F.I.B. Yunnan Exp., T.T. Yü 13403 (holotype, KUN, KUN0511449; isotypes, A, A00235702, PE, PE00574411).

Odontostemma yulongshanense **(L.H. Zhou ex C.Y. Wu) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155346-1

Arenaria yulongshanensis L.H. Zhou ex C.Y. Wu in W. T. Wang et al., Vasc. Pl. Hengduan Mount. 1: 410. 1993; *Arenaria trichophora* Franch. var. *angustifolia* Franch., Pl. Delavay. 95. 1889, not *A. angustifolia* McNeill (1961).

Type. China: Yunnan: limestone rocks on snowy ridges, Likiang, 4000 m, 14 Aug 1886, P.J.M. Delavay 2480 (holotype, P, P01902968; isotypes K, K000723899, P [3 sheets], P01902969, P01902970, P01902971).

Odontostemma yunnanense **(Franch.) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155324-1

Arenaria yunnanensis Franch., Bull. Soc. Bot. France 33: 431. 1886.

Type. China: Yunnan: in shady rock clefts, near summit of Mt. Pengay-tze, above Houang-kia-pin, 4 Sep 1882, P.J.M. Delavay 8 (holotype, P, P01902976; isotypes, BM, BM00946351, E, E00313693, K, K000723900, KUN, KUN0511455, P [5 sheets], P01902977, P01902978, P01902980, P01902981, P01902982).

Odontostemma yunnanense **var.** ***caespitosum*** **(C.Y. Wu) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155328-1

Arenaria yunnanensis var. *caespitosa* C.Y. Wu in C.Y. Wu et al., Fl. Yunnan. 6: 835. 1995.

Type. China: Yunnan: Deqen, 10 July 1940, K.M. Feng 5278 (holotype, KUN, KUN1205462; isotypes, KUN [2 sheets], KUN1205461, KUN1205464, PE, PE00574440).

Odontostemma zhongdianense **(C.Y. Wu) Rabeler & W.L. Wagner, comb. nov.**
urn:lsid:ipni.org:names:77155325-1

Arenaria zhongdianensis C.Y. Wu in C.Y. Wu et al., Fl. Yunnan. 6: 152, Addenda 835. 1995.

Type. China: Yunnan: Zhongdian, 3300 m, 14 August 1962, Zhongdian Exp. 832 (holotype, KUN, KUN1205465; isotypes, KUN [2 sheets], KUN1205467, KUN1205468).

Excluded taxa

Arenaria longistyla var. *eugonophylla*

Although appearing in Wu et al. (2001) and attributed to Fernald as published in Rhodora 21: 5. 1919, this name does not appear on that page and we have not been able to locate a place of publication.

Arenaria microstella C.Y. Wu in C. L. Tang, Fl. Reipubl. Popularis Sin. 26: 213. 1996.

This taxon is likely related to *O. bomiense* (Wu et al. 2001). It was described in Chinese, thus was invalidly published, and was mentioned, but not validly published, by Wu et al. (2001).

Acknowledgements

Danielle Hanrahan (GH) for providing images of 9 type specimens; Zhuo Zhou (KUN) for providing images of 34 type specimens, and comments on status of some of them; Roy Gereau (MO) and Kanchi Gandhi (GH) for nomenclatural advice.

References

Don G (1831) A General History of the Dichlamydeous Plants (Vol. 1). J.G. and F. Rivington, London. doi: 10.5962/bhl.title.21964

Greenberg AK, Donoghue MJ (2011) Molecular systematics and character evolution in Caryophyllaceae. Taxon 60: 1637–1652.

Harbaugh DT, Nepokroeff M, Rabeler RK, McNeill J, Zimmer EA, Wagner WL (2010) A new lineage-based tribal classification of the family Caryophyllaceae. International Journal of Plant Science 171: 185–198. doi: 10.1086/648993

McNeill J (1962) Taxonomic studies in the Alsinoideae: I. Generic and infra-generic groups. Notes from the Royal Botanic Garden, Edinburgh 24: 79–155.

McNeill J, Barrie FR, Buck WR, Demoulin V, Greuter W, Hawksworth DL, Herendeen PS, Knapp S, Marhold K, Prado J, Prud'homme van Reine WF, Smith GF, Wiersema JH, Turland NJ (2012) International Code of Nomenclature for algae, fungi, and plants (Melbourne Code) adopted by the Eighteenth International Botanical Congress Melbourne, Australia, July 2011. Koeltz Scientific Books, Königstein, Germany. [Regnum Veg. 154]

Röpert D (2016) Digital specimen images at the Herbarium Berolinense. http://ww2.bgbm.org/herbarium/default.cfm [accessed 15 Feb 2016]

Sadeghian S, Zarre S, Rabeler RK, Heubl G (2015) Molecular phylogeny of *Arenaria* (Caryophyllaceae: tribe Arenarieae) and its allies inferred from nuclear DNA ITS and plastid DNA rps16 sequences. Botanical Journal of the Linnaean Society 178: 648–669. doi: 10.1111/boj.12293

Thiers B (2016) Index Herbariorum: A global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium. http://sweetgum.nybg.org/ih/ [continuously updated]

Wu CY, Zhou L, Wagner WL (2001) *Arenaria*. In: Wu CY, Raven PH, Hong DY (Eds) Flora of China, volume 6. Science Press, Beijing & Missouri Botanical Garden Press, St. Louis, 40–66.

PhytoKeys 63: 99–106 (2016)
doi: 10.3897/phytokeys.63.8895
http://phytokeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

A new species of *Clinanthus* from northern Peru (Asparagales, Amaryllidaceae, Amarylloideae, Clinantheae)

Segundo Leiva[1], Alan W. Meerow[2]

1 *Universidad Privada Antenor Orrego, Av. América Sur 3145 Casilla postal 1075, Trujillo, Perú* **2** *USDA-ARS-SHRS, National Germplasm Repository, 13601 Old Cutler Road, Miami, Florida 33158, USA*

Corresponding author: *Alan W. Meerow* (alan.meerow@ars.usda.gov)

Academic editor: *L. Peruzzi* | Received 18 April 2016 | Accepted 16 May 2016 | Published 2 June 2016

Citation: Leiva S, Meerow AW (2016) A new species of *Clinanthus* from northern Peru (Asparagales, Amaryllidaceae, Amarylloideae, Clinantheae). PhytoKeys 63: 99–106. doi: 10.3897/phytokeys.63.8895

Abstract

Clinanthus milagroanthus S. Leiva & Meerow, **sp. nov.** is described from the Department of La Libertad in Peru. The new species is most closely related to *C. mirabilis* (Ravenna) Meerow, with further affinities to *C. viridiflorus* (R. & P.) Meerow. It can be distinguished from *C. mirabilis* by its wider leaves, the much more brightly colored and wide spreading limb, and the much lighter colored perigone tube (yellowish green vs. dark green in *C. mirabilis*). A conspicuous bulge just proximal to the midpoint of the tube is a unique character of the new species.

Resumen

Clinanthus milagroanthus S. Leiva & Meerow, **sp. nov.** se describe desde el Departamento de La Libertad, Perú. La nueva especie es más estrechamente relacionados con *C. mirabilis* (Ravenna) Meerow, con adicionales afinidades con *C. viridiflorus* (R. & P.) Meerow. Se puede distinguir de *C. mirabilis* por sus hojas más anchas, el limbo mucho más amplio de colores brillantes, y el color de tubo perigonio mucho más claro (color amarillento vs. verde verde oscuro en *C. mirabilis*). Una protuberancia visible casi proximal al punto medio del tubo es un carácter único de la nueva especie.

Keywords

Geophyte, Andes, Clinantheae, new species, taxonomy

Copyright *Segundo Leiva, Alan W. Meerow.* This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Introduction

Peru is the center of diversity for the genus *Clinanthus* Herb., which was segregated from *Stenomesson* Herb. by Meerow et al. (2000), who demonstrated that the latter was polyphyletic. There are between 15 and 20 species in the genus, which has never been monographed. The species are primarily known from locations above 2000 m (León et al. 2013; unpubl. herbarium data), but a cluster of species has colonized the Peru Current-cooled *lomas* of the coast (León et al. 2013; unpubl. herbarium data). One species, *C. humilis* (Herb.) Meerow, which retains the ovary inside the bulb until shortly before seed ripening (Herbert 1839; Baker 1871), reaches elevations above 4000 m (León et al. 2013; unpubl. herbarium data). Many are local endemics known only from the type localities (León et al. 2013). Exploration in the Department of La Libertad has uncovered a species new to science, and it is herein described.

Materials and methods

No specimens matching the new species have been observed in herbarium collections in Peru, nor encountered by the second author in collections examined over the past 30 years at GB, K, MO, and NY. The description is based upon live material from the type collection. Colors are referenced to the Royal Horticultural Society (RHS) Color Charts (RHS 1995).

Taxonomy

***Clinanthus milagroanthus* S. Leiva & Meerow, sp. nov.**
urn:lsid:ipni.org:names:77155329-1
Figs 1–2

Diagnosis. *Clinanthus milagroanthus* is most closely related to *C. mirabilis* (Ravenna) Meerow (Fig. 3A) by the white color and morphology of the staminal cup, in which the free portions of the filaments are slightly incurved and inserted at the sinus between the cup lobes. Both of these species have affinity with *C. viridiflorus* (R. & P.) Meerow (Fig. 3B–C). All three species have grayish-green glaucous leaves, particularly large apicula at the apex of the outer tepals, and large anthers relative to other species of the genus. These species form a distinct clade in the genus based on ribosomal DNA sequences with close relationship to the genus *Paramongaia* Velarde (Fig. 3D; Meerow et al. 2000; Ravenna 1988; unpubl. data). All three species have glaucous, gray-green leaves. The perigone of *C. viridiflorus* is entirely green (Fig. 3B–C); that of *C. mirabilis* is deep green except for the orange-red limb (Fig. 3A). Our new species has the widest leaves in the complex and bears the showiest flowers, most notably by the sharp constrast between the white staminal cup and the bright red tepals. It can be distinguished

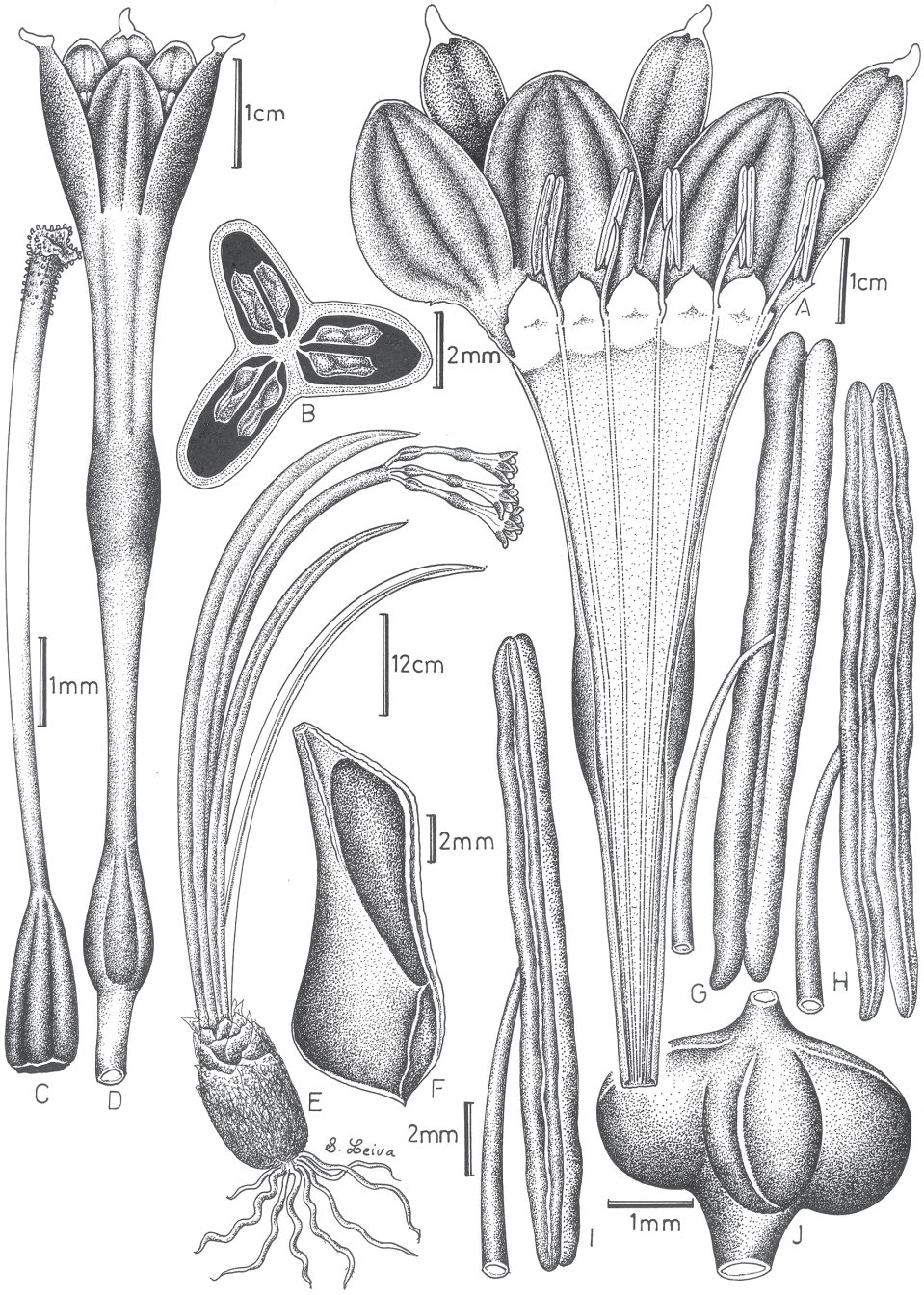

Figure 1. *Clinanthus milagroanthus* S. Leiva & Meerow. **A** Perigone dissected showing androecium **B** Cross-section of the capsule **C** Gynoecium **D** Flower at anthesis **E** Habit **F** Seed **G** Anther in dorsal view **H** Anther in ventral view **I** Anther in side view **J** Capsule. Drawing by S. Leiva & M. Leiva from S. & M. Leiva Leiva 5795 (HAO).

from *C. mirabilis*, to which it bears closest resemblance, by the much more brightly colored and wide spreading limb, and the much lighter colored perigone tube (yellowish green vs. dark green in *C. mirabilis*). The conspicuous bulge just proximal to the midpoint of the tube is a unique character of the new species.

Type. PERÚ. Dpto. La Libertad, Prov. Otuzco, Distrito Salpo, above Murañe (on the Salpo-Pagash road), 8°1'16.5"S, 78°33'16.2"W, 2827 m elevation, 22 Mar 2015, S. Leiva & M. Leiva 5795 (HOLOTYPE: HAO; ISOTYPE: F)

Description. Geophytic herb from tunicate bulbs, 60–80 cm tall, with numerous creamy-white roots (brown where stained by the humic substrate), 25–35 cm long. Bulbs long conical or tapered, 9–10 cm long and 6.5–7 cm in diameter, with a papery brown to black tunic, white below. Leaves distichous, sessile, lorate, erect or slightly reflexed towards the abaxial surface, succulent, dark green on adaxial surface, light green on abaxial, glabrous, acute at apex, slightly cuneate at the base, slightly revolute at the margins, caniculate along the midrib adaxially, midrib prominent abaxially, (57-) 65–68 cm long by 5.5–5.7 cm wide. Inflorescences with 5 flowers arranged in pseudoumbels, scape ancipitous, elliptical in cross section, dull yellowish-green, succulent, solid, 35–36 cm long by 1.4–1.5 cm diameter; spathe bracts membranous, two, creamy or slightly yellowish, glabrous, eventually marcescent, surrounding the base of the flowers; pedicels slightly wider proximally, yellowish-green, succulent, glabrous, 2-edged, slightly curved towards the abaxial surface, 1–1.3 cm long by 0.4–0.5 cm in diameter. Flowers actinomorphic, bisexual, trimerous; perigone infundibular, succulent, 7–7.2 cm long, the tepals fused into a tube for 2/3 to 4/5 of the perigone length; tube RHS Green 143C green proximally, darkening in the inflated portion, then becoming Yellow-Green 145B to almost white at the throat, cylindrical for the proximal 1.2–1.5 cm and 2.5–3 mm diam., gradually dilated to 5 mm for the next 1–1.3 cm, then abruptly inflated to ca. 7 mm diam for ca. 1.3 cm, constricting distally to ca. 5 mm diam, the final 2 cm portion of the tube with 6 longitudinal channels; limb of six tepals in two series, spreading to 3.4–4.0 cm at anthesis at ca. 45°angle from the throat; outer tepals narrowly oblong, intensely red (RHS Red Group 40A to 40B) on both surfaces, with a conspicuous white, papillate apiculum at apex, glabrous on both surfaces, succulent, distinctly ribbed, 2.5–2.6 cm long by 1–1.2 cm wide; inner tepals broadly elliptic, same color and surface attributes as outer, obtuse at apex with a minute white apiculum, 2.2–2.3 cm long by 1.4–1.5 cm wide. Stamens six, connate proximally into a short, externally white 6-lobed staminal corona, stained yellowish-green internally towards the base, 5–6 mm long and 1.3–1.4 cm diam, the lobes deltoid with a mucronate apex, each 5–6 mm long and 5–6 mm wide; free portion of stamens filiform, inserted at the sinus between each lobe of the corona, incurved, white, 8–9 mm long; anthers narrowly oblong, sagittate at the base, introrse, 17–18 mm long and 2–2.1 mm wide, pollen bright yellow. Style exserted, filiform, creamy white, with translucent papillae distally, 80–83 mm long; stigma 3-lobed, white to slightly yellow, 1.5–1.6 mm wide. Ovary inferior, turbinate, 3-locular, 15–18 mm long, 6–7 mm wide; ovules numerous, superposed in two vertical rows in each locule. Capsule tricoccous, green

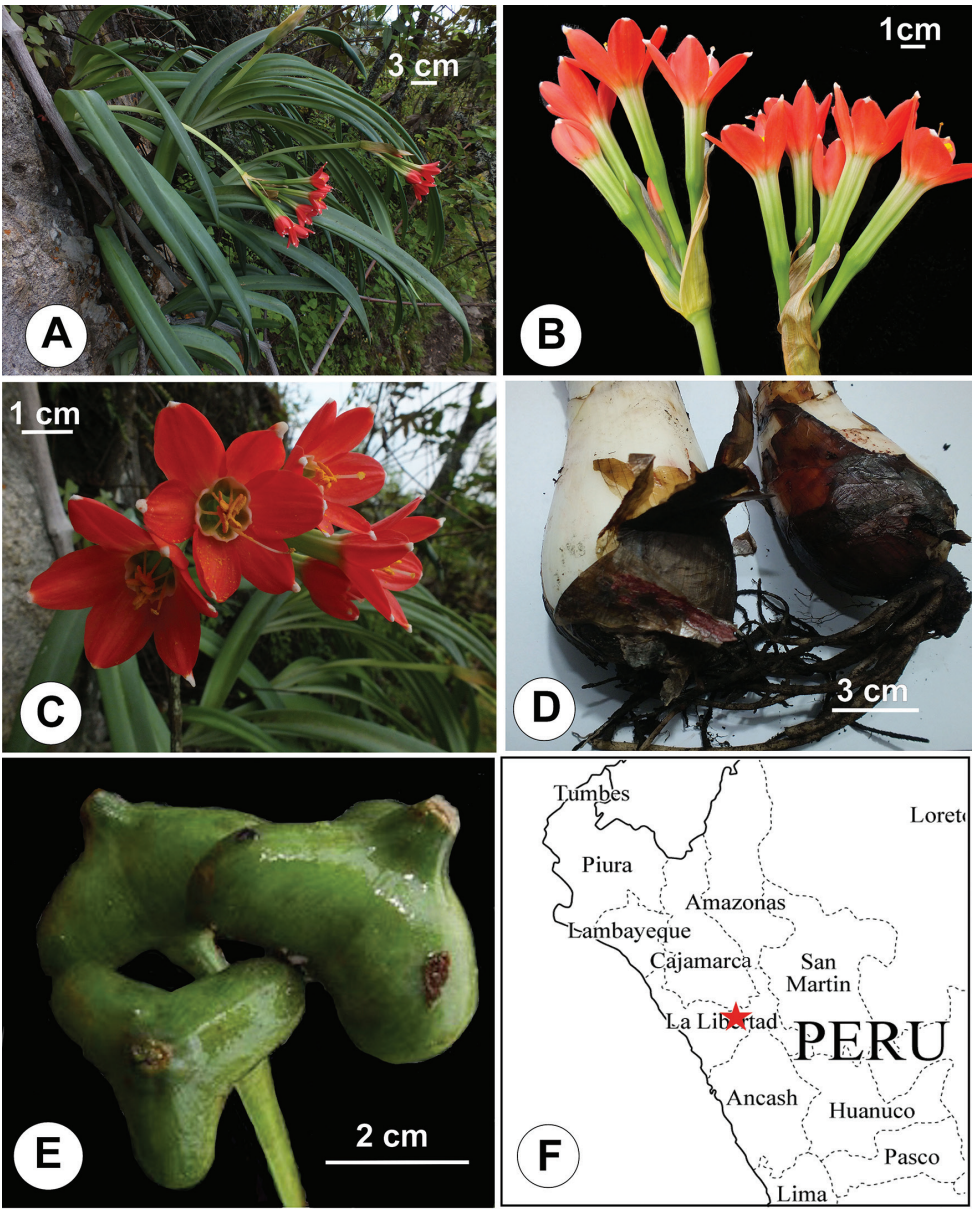

Figure 2. *Clinanthus milagroanthus* S. Leiva & Meerow. **A** Habit **B** Inflorescence showing spathe bracts **C** Flowers **D** Bulbs **E** Capsules **F** Known distribution of *C. milagroanthus* in Peru (red star). All photos of S. Leiva & M. Leiva 5795, HAO.

when young, becoming glaucous with age, 2.4–2.6 cm high 3.5–4 cm wide, loculicidally dehiscent; seeds 100–105, flattened, slightly polyhedral, narrowly winged on the edges, covered with a lustrous, brittle, black phytomelanous testa, 17 to 18 mm long, 7 to 7.3 mm wide.

Distribution and ecology. *Clinanthus milagroanthus* is only known from the local area of the type collection where it is moderately abundant. Despite having searched the surrounding area, it has so far been limited to the area of Muräne along the Salpo-Pagash road in the Department of La Libertad, Prov. Otuzco, District Salpo, ca. 8°01'16.4"S and 78°33'16.2"W, at 2824 m elevation, as a member of the grass and shrub vegetation on the edges of the road, preferring moist, black organic soil among rocks. Some associated species include *Escallonia micrantha* Mattf. (Escalloniaceae), *Bidens triplinervia* Kunth (Asteraceae), *Austrocyndropuntia subulata* subsp. *exaltata* (A. Berger) D. R. Hunt (Cactaceae), *Vicia andicola* Kunth (Fabaceae), *Puya casmichensis* L. B. Sm. (Bromeliaceae), *Begonia geraniifolia* Hook. (Begoniaceae), *Passiflora peduncularis* Cav. (Passifloraceae), and unidentifed *Smallanthu*s Mack., *Verbesina* L. (Asteraceae), *Solanum* L. (Solanaceae), *Lupinus* L. (Fabaceae). *Clinanthus milagroanthus* flowers with the first rains in November or December, continuing through fruit maturation until March or April.

Current conservation status. Using the criteria of the IUCN (IUCN 2012) *Clinanthus milagroanthus* is considered critically endangered (CR). The extent of its range is less than 100 km^2 around the type locality (Criterion B1), is known from a single population (Criterion B1a) with less than 100 mature individuals in the population, and is projected to decline further (Criterion B1b). It may have been impacted by construction of the road between Salpo to Pagash or Platanar. However, there has not been an assessment of whether it experienced a decline in its range from this event. The species requires a thorough study of ecology, population structure and distribution to clarify its status.

Vernacular name. "cebolla de peña."

Etymology. The specific epithet honors Ms. Milagros Leiva Salinas, a student of Human Medicine, who has been studying the phytochemistry of Peruvian genera of Amaryllidaceae.

Additional material examined. PERÚ. Dpto. La Libertad, Prov. Otuzco, Dist. Salpo, arriba del Murañe (ruta Salpo-Pagash), 8°01'16.4"S and 78°33'16.2"W, 2824 m, 1 Apr 2013, *S. Leiva & M. Leiva 5443* (HAO)

Notes. We have used the original orthography for the names cited below. The genus *Callithauma* Herbert was established by Herbert (1837) to accommodate *C. viridiflorum* (R. & P.) Herbert. He later (Herbert 1841) described a second sp., *C. angustifolium*, which he distinguished by its narrower leaves, smaller flowers, exserted style and 3-lobed stigma. Bentham and Hooker (1883) subsumed the genus under *Stenomesson*. Baker (1878) described *Callithauma viridiflorum* var. *elwesii*, which Macbride (1931) raised to the rank of species in *Stenomesson.* Baker (1888) appeared to reduce Herbert's (1841) *C. angustifolium* to a variety of *S. viridiflorum*. Ravenna (1971) described *S. mirabile* and assigned it to subgenus *Callithauma* (but didn't formally validate the new subgenus). He later (Ravenna 1988) restablished the genus *Callithauma*, with only *C. viridiflorum*, noting its relationship to *Paramongaia*, and erected a new genus, *Anax* Ravenna, with *Anax elwesii* (Baker) Ravenna as the type species, and including *A. mirabilis* (Ravenna) Ravenna. Ravenna's (1988) diagnostic

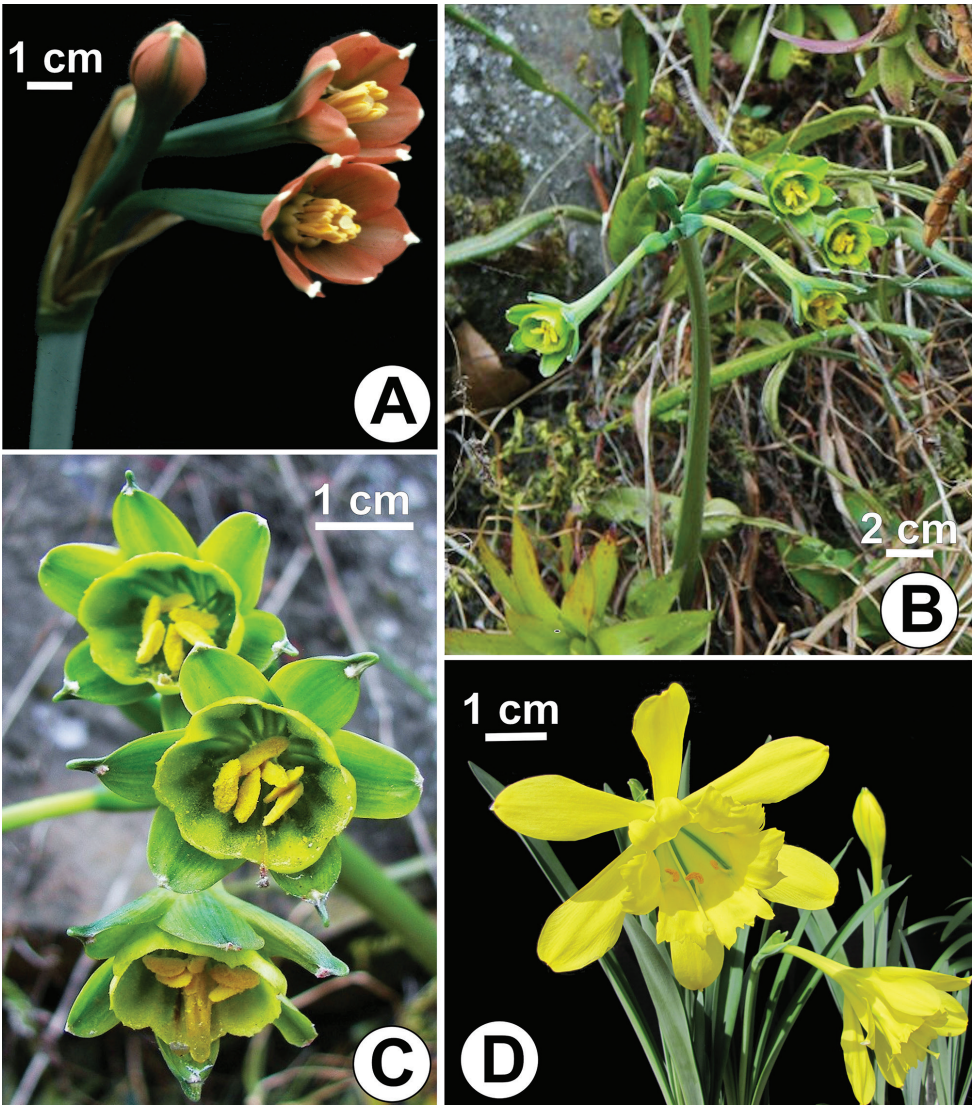

Figure 3. Species related to *Clinanthus milagroanthus*. **A** *C. mirabilis* (S. Leiva et al. 2000, HAO) **B–C** *Clinanthus viridiflorus* (Weigend et al. 5701, NY) **D** *Paramongaia weberbaueri* (Meerow 2303, FTG).

characters for distinguishing these two genera were somewhat ambiguous. Meerow et al. (2000) showed clear molecular evidence that the genus *Stenomesson* was polyphyletic, and established the new tribe Clinantheae for the genera *Clinanthus*, *Pamianthe* Sealy and *Paramongaia*. *Paramongaia weberbaueri* Velarde and *Clinanthus mirabilis* were resolved as sister species, in a clade in turn sister to three other species of *Clinanthus*. We are in the process and obtaining a larger number of DNA sequences of the tribe Clinantheae to better evaluate the generic limits within the tribe.

Acknowledgements

We thank Michael Dillon and Nora H. Oleas for their careful review of this paper.

References

Baker JG (1871) *Stenomesson humilis*. Saunders Refugium Botanicum 5(1): sub t. 308.

Baker JG (1878) *Callithauma viridiflorum* var. *elwesii* Baker. Gardeners Chronicle n.s.: 77.

Baker JG (1888) Handbook of the Amaryllideae, including the Alstroemerieae and Agaveae. George Bell & Sons, London, 216 pp. doi: 10.5962/bhl.title.15516

Bentham G, Hooker JD (1883) Genera Plantarum 3: 733. A. Black, London.

Herbert W (1837) Amaryllidaceae. James Ridgeway & Sons, London.

Herbert W (1839) *Clitanthes humilis*. Edwards's Botanical Register 25(Misc.): 87.

Herbert W (1841) *Callithauma viridiflorum*. Curtis' Botanical Magazine 67: tab. 3866.

IUCN Species Survival Commission (2012) IUCN Red List Categories and Criteria Version 3.1, 2nd Ed. International Union for the Conservation of Nature, Gland, Switzerland.

León B, Sagástegui A, Sánchez I, Zapata M, Meerow A (2013) Amaryllidaceae endémicas del Perú. Revista Peruana de Biología 13: 690–697. doi: 10.15381/rpb.v13i2.1938

Macbride F (1931) Spermatophytes mostly Peruvian III. Publications of the Field Museum of Natural History, Botanical Series 11: 3–35.

Meerow AW, Guy CL, Li Q-B, Yang S-L (2000) Phylogeny of the American Amaryllidaceae based on nrDNA ITS sequences. Systematic Botany 25: 708–726. doi: 10.2307/2666729

Ravenna PF (1971) *Stenomesson mirabile* Rav. sp. nov. Plant Life 27: 77–79.

Ravenna PF (1988) *Anax* and *Callithauma*, two genera of Amaryllidaceae-Eustephieae from Peru. Phytologia 64: 215–218. doi: 10.5962/bhl.part.16903

Royal Horticultural Society (1995) RHS Colour Chart. Royal Horticultural Society, London.

PhytoKeys 63: 107–125 (2016)
doi: 10.3897/phytokeys.63.8198
http://phytokeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

A revision of *Poa* subsection *Aphanelytrum* (Poaceae, Pooideae, Poaeae, Poinae); and a new species, *Poa auriculata*

Paul M. Peterson[1], Robert J. Soreng[1]

1 *Department of Botany MRC-166, National Museum of Natural History, Smithsonian Institution, Washington, DC 20013-7012 USA*

Corresponding author: *Paul M. Peterson* (peterson@si.edu)

Academic editor: *C. Morden* | Received 20 February 2016 | Accepted 25 May 2016 | Published 6 June 2016

Citation: Peterson PM, Soreng RJ (2016) A revision of *Poa* subsection *Aphanelytrum* (Poaceae, Pooideae, Poaeae, Poinae); and a new species, *Poa auriculata*. PhytoKeys 63: 107–125. doi: 10.3897/phytokeys.63.8198

Abstract

In this study the peculiar Andean grass genus *Aphanelytrum*, with two species, is reduced to *Poa* subsect. *Aphanelytrum* **comb. & stat. nov.** A third species, *Festuca reclinata*, is assigned to the subsection, which shows states transitional between a more typical *Poa* and *Aphanelytrum*. *Poa* subgen. *Poa* supersect. *Homalopoa* sect. *Dioicopoa* subsect. *Aphanelytrum* **comb. & stat. nov.** is characterized in having stooling perennials with decumbent to spreading culm bases that continuously branch and often root at low to mid-culm nodes, glabrous spikelets with long rachillas 1.2–4.2 mm long, short glumes less than ½ the length of the florets, and lemmas with bifid apexes that are mucronate to short-awned. We provide for the three species taxonomic discussions, morphological and anatomical descriptions, keys, illustrations, and a list of specimens. Also, we provide two new names, *Poa hitchcockiana* **nom. nov.** and *Poa sanchez-vegae* **nom. nov.**, and one new combination, *Poa reclinata* **comb. nov.** A new species, *Poa auriculata* **sp. nov.** from Peru, not thought to be a member of *P.* subsect. *Aphanelytrum*, is presented. It is the first in the genus with prominent auricles. In addition, we place *Poa apiculata* in *Poa* subgen. *Poa* supersect. *Homalopoa* sect. *Dioicopoa* subsect. *Tovarochloa* **comb. & stat. nov.**

Resumen

En este estudio el género peculiar de gramíneas andinas *Aphanelytrum*, representado por dos especias, ha sido reducido a *Poa* subsecc. *Aphanelytrum* **comb. & stat. nov.** Una tercera especie es incluida en la subsección, *Festuca reclinata*, esta presenta características transicionales entre las especies más típicas de *Poa* y *Aphanelytrum*. *Poa* subgen. *Poa* supersecc. *Homalopoa* secc. *Dioicopoa* subsecc. *Aphanelytrum* **comb. & stat. nov.** se caracteriza por incluir plantas perennes, stoloniferas, con los culmos decumbentes o extensos, continuamente ramificados, a menudo enraizados en los nudos basales hasta los intermedios, las espi-

Copyright *Paul M. Peterson, Robert J. Soreng*. This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

guillas son glabras con rachillas largas de 1.2–4.2 mm de longitud, las glumas más cortas son de la ½ de longitud de los flósculos y las lemas con los ápices bífidos son mucronadas hasta breve-aristadas. Nosotros proveemos para las tres especias discusiones taxonómicas, descripciones morfológicas y anatómicas, claves, ilustraciones y la lista de las muestras usadas. Tambien, proveemos dos nombres nuevos - *Poa hitchcockiana* **nom. nov.** y *Poa sanchez-vegae* **nom. nov.**, y una combinación -*Poa reclinata* **comb. nov.** Una nueva especie - *Poa auriculata* **sp. nov.** de Perú es presentada. Esta es la especie primera del género con prominentes aurículas. En adición, transferimos *Poa apiculata* a *Poa* subgen. *Poa* supersecc. *Homalopoa* secc. *Dioicopoa* subsecc. *Tovarochloa* **comb. & stat. nov.**

Keywords

Anatomy, *Aphanelytrum*, descriptions, *Dioicopoa*, *Homalopoa*, illustrations, key, morphology, taxonomy, *Tovarochloa*

Introduction

The genus *Aphanelytrum* (Hack.) Hack., first named without a description by Sodiro (1889) with a single species, "*A. decumbens* Hack." (ex Sodiro, nom. nud.) is based on a single collection he made from Ecuador (Chase 1916). Hackel (1897) formally described it as a subgenus of *Brachyelytrum* P. Beauv.; *B*. subgen. *Aphanelytrum* Hack., including a single new species *Brachyelytrum procumbens* Hack. Hackel (1902) subsequently recognized *Aphanelytrum* as a genus with the single species *A. procumbens* (Hack.) Hack. This species is found at mid- to high elevations (2000–4050 m) in humid to montane forests in the Andes of Bolivia, Colombia, Ecuador, and Peru (Hitchcock 1927; Clayton and Renvoize 1986; Jørgensen and Ulloa Ulloa 1994; Renvoize 1998; La Torre 2002; Soreng et al. 2003; Lægaard 2005; Sánchez Vega et al. 2007). *Aphanelytrum peruvianum* Sánchez Vega, P.M. Peterson, Soreng & Lægaard, a second species, was described recently (Sánchez Vega et al. 2007) from Cajamarca, Peru.

Aphanelytrum procumbens is a peculiar grass for having spikelets with minute and unveined glumes and two or three florets that are widely-spaced because of the long flexuous rachillas that are ½ to ¾ as long as the florets, the lemmas are keeled and 5-veined (Chase 1916; Hitchcock 1927; Nicora and Rúgolo de Agrasar 1987; Watson and Dallwitz 1992; Lægaard 2005). *Aphanelytrum peruvianum* differs from *A. procumbens* in having 1–3(–4)-veined glumes (1–2 mm long), narrow leaf blades (0.2–1.2 mm wide), shorter culms (14–24 cm long), shorter internodes (3–13 mm long), shorter 3- or 5-veined lemmas (2.2–3.5 mm long), and shorter anthers (2–2.9 mm long) [Sánchez Vega et al. 2007].

The placement and evolutionary relationships of *Aphanelytrum* have been controversial since its inception. It was originally placed in the subfamily "Festuceae" [Festucoideae], applied in the broad sense of Bentham (1881), Hackel (1887), and Hitchcock (1935). Hackel mistook the upper individual florets for single-flowered spikelets and placed *Aphanelytrum in Brachyelytrum* [*B. procumbens*] within tribe Agrostideae, subtribe Stipinae. Chase (1916) reinterpreted the spikelet morphology, and placed the genus between the subtribes Melicinae and Centothecinae, which at that time were considered adjacent subtribes of the subfamily Festucoideae, tribe Festuceae. After major realign-

ments of the classification of the Poaceae (e.g. Clayton and Renvoize 1986), the genus was placed in a much more narrowly defined subfamily Pooideae (syn. Festucoideae), tribe Poeae (syn. Festuceae) near *Poa* L. (Clayton and Renvoize 1986). *Aphanelytrum* and *Poa* have very similar leaf anatomical characteristics, as well as multi-flowered, membranous spikelets with 5-veined, keeled lemmas, glabrous ovaries, and caryopses with an oval hilum (Clayton and Renvoize 1986; Clayton et al. 2006). In the most recent Poaceae classification (e.g. Soreng et al. 2015) *Aphanelytrum* is placed as a synonym of *Poa* in the subtribe Poinae, as suggested in studies by Gillespie et al. (2008), Soreng et al. (2007, 2015), Soreng and Peterson (2012), and Refulio Rodriguez et al. (2012).

Based on ITS sequences, Gillespie et al. (2008) found the monotypic *Tovarochloa* (*T. peruviana* T.D. Macfarl. & P. But) to be a weakly supported sister of *Aphanelytrum procumbens* and *A. peruvianum*. In a plastid *trn-TLF* derived tree, Refulio Rodriguez et al. (2012) verified this result showing a strongly supported *Aphanelytrum procumbens* sister to *Tovarochloa,* and published a section in *Poa* for *Tovarochloa* (nom. inval.; later validated as *P.* sect. *Tovarochloa* (T.D. Macfarl. & P. But) Molinari, see Molinari-Novoa 2015), but they left the genus *Aphanelytrum* unplaced within *Poa*. *Tovarochloa peruviana* is a small, delicate and diminutive annual species with 1-flowered spikelets that was previously linked to *Dissanthelium* Trin. (Clayton and Renvoize 1986; Macfarlane and But 1982; Tovar 1993), now both are included within *Poa* Gillespie et al. 2008; Refulio Rodriguez et al. 2012; Soreng et al. 2015). Giussani et al. (in press) estimated the time of divergence of *Tovarochloa* and *Aphanelytrum* at between 1.24 and 5.05 mya.

Festuca reclinata Swallen, known only from the Páramo del Almorzadero in the Cordillera Oriental of Colombia, has been linked to *Aphanelytrum* based on exhibiting similar morphologies (Stančík and Peterson 2007; Sánchez Vega et al. 2007). The growth habit, panicles, and spikelet characteristics of *F. reclinata* are strikingly similar to those found in *A. peruvianum* and *A. procumbens* (Sánchez Vega et al. 2007). All three species have weak, decumbent culms with intravaginal branching, narrow few-spikeleted panicles, spikelets with long flexuous rachillas, and small glumes. In comparison with *F. reclinata, A. peruvianum* has smaller lemmas (2.2–3.5 mm vs. 7–8.5 mm in *F. reclinata*), smaller anthers (2–2.9 mm vs. 3.5–3.8 mm), and shorter spikelets (5–7 mm vs. 10–13 mm) [Sánchez Vega et al. 2007]. The strongly keeled lemmas in *F. reclinata* do not agree with its placement in *Festuca* (Sánchez Vega et al. 2007). Also like *Aphanelytrum* and *Poa*, *F. reclinata* has fused sheath margins, terete rachillas (vs. dorsoventrally compressed in *Festuca*), and lacks the thickened annulate callus typical of *Festuca*. *Aphanelytrum procumbens* has a caryopsis with short elliptical hilum, less than 1/5 the grain in length (typical of *Poa* vs. linear and proportionally longer in *Festuca*), but caryopses have not been observed in *A. peruvianum* or *F. reclinata*.

The main goal of this study is to present a systematic revision *Poa* subsect. *Aphanelytrum* comb. & stat. nov. that includes three species. We make a new combination for *F. reclinata*, and provide new names for *Aphanelytrum procumbens* and *A. peruvianum*. In addition, we include a key to the species, complete descriptions, illustrations, distribution, specimens examined, and comments for these three species. Furthermore, we place *Poa apiculata* in *Poa* subsect. *Tovarochloa* comb. & stat. nov.

While reviewing Peruvian specimens of *Poa*, Robert J. Soreng (RJS) found a peculiar collection by John J. Wurdack (*Wurdack 1145*) from Departamento Amazonas, Provincia Chachapoyas located on the summit of Puma-urcu that is similar to *Poa scabrivaginata* Tovar and *Festuca reclinata* but differed from the forgoing, and all other *Poa* species, in having auriculate collars. We describe this as a new species of *Poa,* but do not include it as a member of *P.* subsect. *Aphanelytrum*.

Materials and methods

Herbarium specimens from the following 13 herbaria were examined: AAU, BC, COL, CPUN, K, LPB, MA, MO, QCNE, US, USM, USZ, and W (Thiers 2013).

For leaf anatomy, 5 mm long leaf blades were taken from dried herbarium specimens, rehydrated in boiling water, and fixed in FAA for 24 hours. They were transferred to 70% ethanol, followed by a water rinse and treated for three hours in 50% hydrofluoric acid (Martens & Uhl 1980). After being neutralized and washed in water the specimens were dehydrated in 2,2-dimethoxypropane (Postek and Tucker 1976) and embedded in Polyfin (Polysciences, Inc.) paraffin wax. Transverse serial sections were made at 4 μm, stained with buffered Toluidine Blue O (Sakai 1973) and mounted in Lipshaw's synthetic mounting resin. Photomicrographic images were captured using a Zeiss Standard 16WL compound microscope equipped with a Retiga 1300i digital camera using ImagePro (MediaCybernetics).

Taxonomic treatment

***Poa* subsect. *Aphanelytrum* (Hack.) Soreng & P.M. Peterson, comb. & stat. nov.**
urn:lsid:ipni.org:names:77155363-1
within *Poa* subg. *Poa* supersect. *Homalopoa* (Dumort.) Soreng & L.J. Gillespie sect. *Dioicopoa* E. Desv., see Gillespie et al. 2007

Basionym. *Brachyelytrum* subg. *Aphanelytrum* Hack., Die Nat. Pflanzenfam., Nachträge zu Teil II, Abteilung 2. 42. 1897.

Aphanelytrum (Hack.) Hack., Oesterr. Bot. Z. 52: 12. 1902. *Aphanelytrum procumbens* (Hack.) Hack., Oesterr. Bot. Z. 52: 13, text f. 1902.

Aphanelytrum Hack. ex Sodiro, Anales Univ. Centr. Ecuador 3(25): 480. 1889, nom. nud.

Type species. Based on *Brachyelytrum procumbens* Hack. ≡ *Aphanelytrum procumbens* (Hack.) Hack. ≡ *Poa hitchcockiana.*

Diagnosis. *Poa* subsect. *Aphanelytrum* differs from most species of *Poa* in having stooling perennials with decumbent to spreading culm bases that continuously branch and often root at low to mid-culm nodes, glabrous spikelets with long rachillas

1.2–4.2 mm long, short glumes less than ½ the length of the florets, and lemmas with bifid apices that are mucronate to short-awned.

Description. Stooling perennials with intravaginal innovations. Culms 14–80 (–100) cm tall, decumbent to spreading near base, culm bases that continuously branch and often root at low to mid-culm nodes. Leaf blades 3–14 cm long, 0.2–5 (–5.5) mm wide, flat to loosely involute; ligules 1–3 mm long, membranous. Panicles few-flowered with 5–22 spikelets. Spikelets 5–18 mm long, 2–4-flowered, membranous, glabrous, disarticulating above the glumes and between the florets; rachilla 1.2–4.2 mm long, terete in cross section, often prolonged above upper floret; callus glabrous; glumes 0.1–3.5 mm long, less than ½ the length of the florets, 0–3 (–4)-veined; lemmas 2.2–9.6 mm long, 3- or 5-veined, lanceolate or ovate, apex bifid, mucronate to short-awned, if awned up to 2 mm long; paleas 2–7 mm long, apex bifid; lodicules 2, glabrous; stamens 3, anthers 2–4.7 mm long; ovaries glabrous. Caryopses compressed laterally or unknown.

Three species of northern to central Andes of South America.

Key to the species of *Poa* subsection *Aphanelytrum*

1 Glumes veinless, 0.1–0.5 (–0.7) mm long, minute or absent ..... ***Poa hitchcockiana***

– Glumes veined, 1–3.6 mm long, lower glumes 1 or 3-veined, upper glumes 3 or 4-veined **2**

2 Spikelets 10–13 cm long, 4-flowered; lemmas 6.6–8 mm long; leaf blades 3–5 mm wide; paleas 4.6–5.2 mm long; culm internodes 14–80 mm long... ..... ***Poa reclinata***

– Spikelets 5–7 mm long, 3-flowered; lemmas 2.2–3.5 mm long; leaf blades 0.2–1.2 mm wide; paleas 2–3.2 mm long; culm internodes 3–18 mm long.. ..... ***Poa sanchez-vegae***

Poa hitchcockiana **Soreng & P.M. Peterson, nom. nov.**

urn:lsid:ipni.org:names:77155364-1
Figs 1, 2D, 4C

Brachyelytrum procumbens Hack., Die Nat. Pflanzenfam., Nachträge zu Teil II, Abteilung 2. 42. 1897. *Aphanelytrum procumbens* (Hack.) Hack., Oesterr. Bot. Z. 52: 13, text f. 1902.

Aphanelytrum decumbens Hack. ex Sodiro, Anales Univ. Centr. Ecuador 3(25): 480. 1889, nom. nud.

Type. ECUADOR. Crescit in silvis opacis regionis subandinis, 2000 m, Jul 1887, *L. Sodiro, s.n.* (holotype: W-19813 seen digitally!; isotype: US-865406 fragm. ex W!).

Figure 1. *Poa hitchcockiana*: **A** Habit **B** Panicle **C** Sheath, ligule, and blade **D** Spikelet **E** Lower floret with glumes at base **F** Glumes at base of lower floret **G** Lemma **H** Palea, ventral view **I** Stamens with ovary **J** Lodicules at base of ovary **K** Pistil, lodicules at base **L** Caryopsis **M** cross section of caryopsis. **A–D, J–K** (*Peterson 16571 & Refulio Rodriguez*) **E, F, L, M** (*Apollinaire 717 & Arthur*, US-913275).

Description. Straggling and stooling perennials with intravaginal innovations. Culms 30–80 (–100) cm tall, decumbent to erect, delicate, glabrous; nodes 3–8 (–14); internodes 2–14 cm long. Leaf sheaths ½ to 4/5 as long as the internodes, membranous to hyaline, often shiny, upper sheaths open ½ the length, keeled; ligules 1–2 mm long, membranous to hyaline, apex erose, often lacerate; blades 6–14 cm long (flag leaf usually 4–6 cm long), 1.5–4.2 (–5.5) mm wide, flat, thin, lax, linear. Panicles 5–18 (–22) cm long, 2–5 cm wide, few-flowered with 10–22 spikelets, oblong; branches flexuous, effuse and spreading, the lower branches capillary with 2–5 spikelets immediately branching below, the upper branches usually with 2 spikelets. Spikelets 8–18 mm long, 2- or 3-flowered (often appearing 1-flowered with disarticulation of upper florets), laterally compressed, greenish; disarticulation between the florets; all florets usually perfect; rachilla joints 1.5–4.2 mm long, often prolonged above upper floret; glumes 0.1–0.5 (–0.7) mm long, without veins, minute or absent, apex acute or irregularly lobed or toothed; lemmas 5–9.6 mm long, 5-veined, lanceolate, apex acuminate, mucronate or short-awned, the awn up to 2 mm long; paleas 4–7 mm long, 2-keeled, apex bifid; lodicules 0.8–1.1 mm long, lanceolate, membranous, glabrous; stamens 3; anthers 2.8–4.7 mm long, yellowish; ovaries glabrous with two styles and two stigmas. Caryopses 3.25–4.2 mm long, compressed laterally, glabrous, hilum short.

Leaf anatomy. The transverse section leaf anatomy of *Poa hitchcockiana* is C_3, XyMS+ with non-radiate, spongy chlorenchyma, without adaxial palisade cells. There is a single primary vascular bundle associated with the midrib and a sclerenchyma girder 2 or 3-cells thick on the abaxial surface (Fig. 2D). Lateral primary vascular bundles are widely spaced and also have a few abaxial sclerenchyma cells.

Phenology. Flowering year round [?], although no collections made in February, May, and September.

Distribution. *Poa hitchcockiana* is found along the paramo or moist jalca vegetation between 2000–4025 m of the Cordillera de los Andes in Colombia, Ecuador, Bolivia, and Peru.

Conservation status. Since the species is widespread it is of least concern (IUCN 2010). However, the typical size of populations is undocumented and it has been noted by the authors that the grass is sought after by grazers since it is often found growing among the protection of perennial shrubs.

Etymology. Since the epithets *procumbens* and *decumbens* are blocked in *Poa* by the earlier *P. procumbens* Curtis and *P. decumbens* (L.) Scop., we provide a new name commemorating the "father of American agrostology," Albert Spear Hitchcock (1865–1935).

Comments. The only wide ranging species of *Poa* subsect. *Aphanelytrum*, *P. hitchcockiana* also has the most unusual spikelet morphology with extremely long rachillas (1.5–4.2 mm long) and very short [0.1–0.5 (–0.7) mm long] to obscure or often absent, unveined glumes. *Poa* rachillas rarely exceed 1.5 mm, but some have spikelets with rachillas up to 2 mm long (e.g. *P.* sect. *Secundae* V.L. Marsh ex Soreng) *P. curtifolia* Scribn., *P. hartzii* Gand., *P. stenantha* Trin.; (*P.* sect. *Cenisiae*

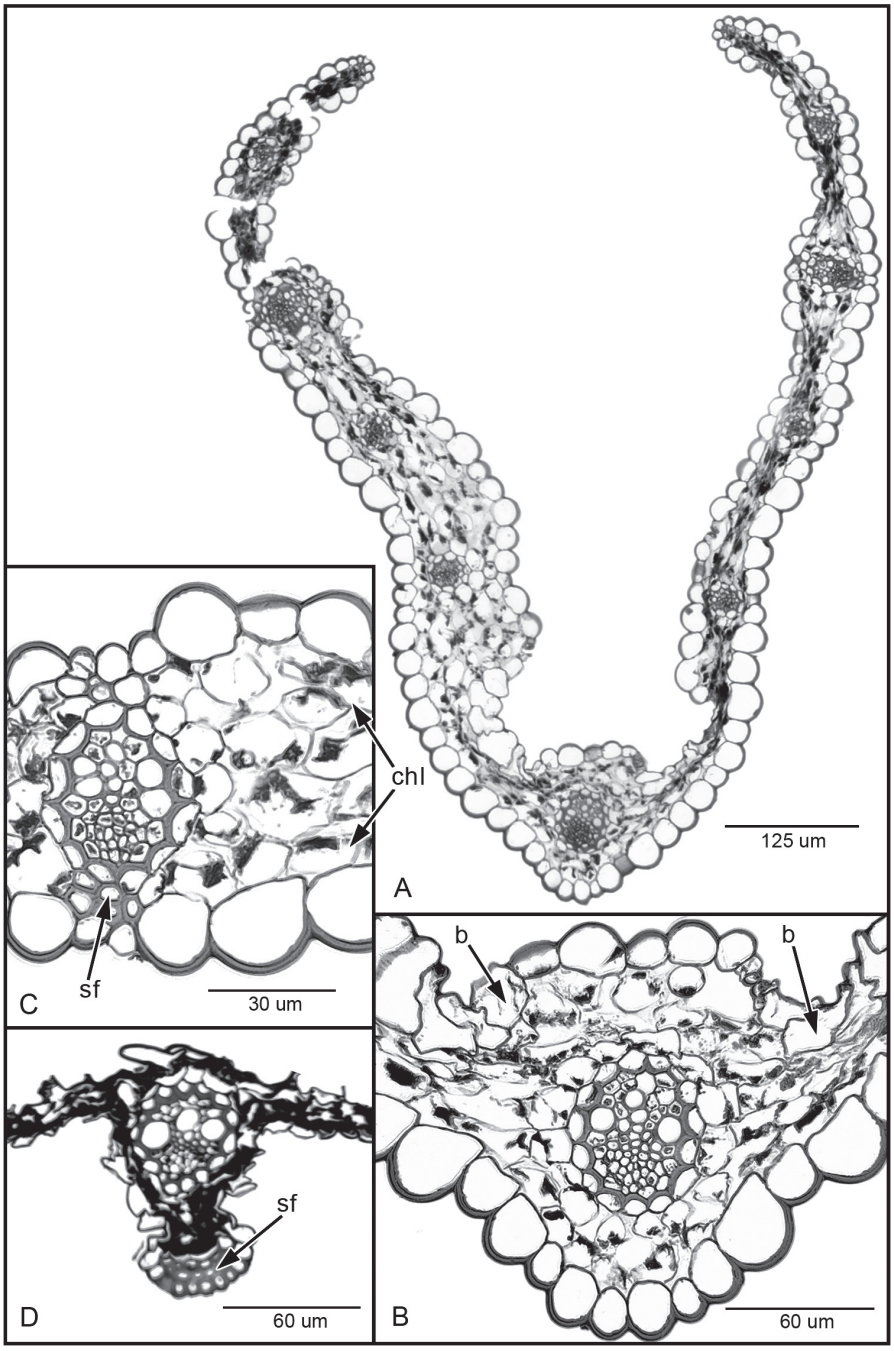

Figure 2. Leaf blade transverse sections of *Poa sanchez-vegae* (**A**–**C**) and *Poa hitchcockiana* (**D**). *Poa sanchez-vegae*: **A** Entire leaf blade **B** Midvein showing a single primary vascular bundle with bulliform cells (b indicated by arrows) **C** Lateral primary vascular bundle with a few associated abaxial sclerenchyma fibers (sf) and spongy chlorenchyma (chl). *Poa hitchcockiana*: **D** Midvein showing a single primary vascular bundle with abaxial sclerenchyma fibers (sf) and collapsed chlorenchyma.

Asch. & Graebn.) *P. davisii* Bor; (*P.* supersect. *Homalopoa*) *P. bajaensis* Soreng, and a few other species in the *Homalopoa* (H) clade (see Soreng et al. 2010). Four species of the related genus *Nicoraepoa* Soreng & L.J. Gillespie have rachillas up to 3 mm long (Soreng & Gillespie 2007). However, there are no known species of *Poa* with unveined glumes.

Specimens examined. BOLIVIA. El Beni: Bella Vista, 26 Dec 1923, *A.S. Hitchcock 22756* (US). **La Paz**: Murillo, 2450 m, 7 Apr 1981, *S.A. Renvoize 4269, T.A. Cope & S.G. Beck* (MO); 16°08'S, 68°07'W, 2900 m, 18 Mar 1987, *J.C. Solomon 16417* (MO, US); 16°10'S, 68°07'W, 3000 m, 1 Mar 1980, *J.C. Solomon 5240* (MO); 3100m, 16 Mar 1982, *T. Feuerer 10719B* (MO); 7 Apr 1989, *Feuerer 5855C* (MO). Santa Rosa, 3030 m, 4 Aug 1979, *S.G. Beck 1085* (US). Nor Yungus, 3300 m, *O. Buchtien 4268* (US); 3250 m, 3 Apr 1981, *S.A. Renvoize 4188 & T.A. Cope* (K, LPB); Franz Tamayo, 14°43'47"S, 69°04'17"W, 3998 m, 18 Jun 2005, *A.F. Fuentes 8338, R. Hurtado, I. Jiménez, E. Cuevas & R. Cuevas* (LPB, MO, USZ); Inquisivi, 16°48'00"S, 67°16'00"W, 3400–3500 m, 9 Mar 1991, *M. Lewis 38263* (MO). **COLOMBIA. Boyacá**: Nevado de Cocuy, 3750 m, 10 Sep 1938, *J. Cuatrecasas 1360* (US); 4025 m, 7 Oct 1972, *A.M. Cleef & P.A. Florschultz 5960* (US). **Cauca**: 3700 m, 5 Apr 1985, *J.R.I. Wood 4784* (MO). **Cundinamarca**: Bogota, 10 Aug 1859, *A. Lindig 1009* (MO, US); Paramo de Chipaque, 3300 m, *R. Jaramillo M. 5340* (COL). **Meta**: Paramo de Sumapaz, 3700 m, *A.M. Cleef 7686* (COL). **Tolima**: 16 Dec 1984, *J.R.I. Wood 4650* (MO). Camino del Verjon, 3100 m, Jul 1911, *Apollinaire 717 & Arthur* (US-727001), *Apollinaire 717 & Arthur* (US-913275). J. *Celestino Mutis 5533* (MA, US). **ECUADOR. Cañar**: Interandina, 3000 m, 2 Jul 1950, *M. Acosta Solís 16962* (US). **Carchi**: 00°49'00"N, 77°57'00"W, 3800 m, 10 Mar 1992, *S. Lægaard 101662* (AAU); 00°40'00"N, 77°52'00"W, 3400 m, 1 Nov 1993, *W.A. Palacios 11739* (MO, QCNE). **Imbabura**: 00°20'00"N, 78°00'00"W, 3600–3650 m, 7–8 Feb 1992, *S. Lægaard 101171* (AAU). **Loja**: Cajanuma, 04°05'S, 79°12'W, 2700–3100 m, 5 Mar 1987, *I. Grignon 84297* (AAU, MO, US). **Napo**: 00°56'00"S, 78°23'00"W, 3600 m, 16–18 Nov 1984, *S. Lægaard 53356* (AAU, QCA, US). **Pichincha**: Paso de Huanpango, 3280 m, Jul 1928, *G. Firmín 439* (US); Pedregal, 3400 m, 7 Jul 1944, M. Acosta Solís 8333 (US); Montes Pichinchas, 3700 m, 21 Jan 1856, *W. Jameson s.n.* (US), *Jameson 168* (US); Pasochoa near Quito, 1890, *L. Sodiro s.n.* (US); La Campiña, 3000 m, *T. Holmgren 649* (US). **Tungurahua**: Cordillera de Llanganates, 3000 m, 16 Nov 1939, E. Asplund 9737 (US). **PERU. Cusco**: Paucartambo, 2800 m, 17 Mar 2002, *P.M. Peterson 16571 & N.F. Refulio Rodriguez* (US, USM); Calca, 3430 m, 17 Mar 2002, *P.M. Peterson 16581 & N.F. Refulio Rodriguez* (US, USM); Pillco, 17 Apr 1967, *C. Vargas C. 19264* (US); Quispicanche, 13°35'32.8"S, 70°58'39.9"W, 3097 m, 20 Mar 2007, *P.M. Peterson 20582, R.J. Soreng & K. Romaschenko* (US, USM); **Moquegua**: El Abra, 2000 m, Mar 1967, *C. Vargas C. 19104* (US). **San Martín**: Huicungo, 7°58'S, 77°20'W, 2900–3150 m, 27 Jun 1999, *A. Cano s.n.* (SI, USM); *B. León 3797* (USM).

***Poa reclinata* (Swallen) Soreng & P.M. Peterson, comb. nov.**
urn:lsid:ipni.org:names:77155361-1
Fig. 3

Festuca reclinata Swallen, Contr. U.S. Natl. Herb. 26(6):254. 1949.

Type. COLOMBIA. Departamento Santander, Cordillera Oriental, Paramo de Almorzadero, 3500–3700 m, 20 Jun 1940, *J. Cuatrecasas & H. Garcia Barriga 9970* (holotype: US-1798714!; isotypes: BC-635144 seen digitally!; COL-34839 seen digitally!).

Description. Stooling perennials forming small tussocks with intravaginal innovations. Culms 30–40 cm tall, decumbent to erect, often weak, spreading to prostrate, culm bases continuously branch and often root at low to mid-culm nodes, glabrous; nodes 2 or 3 in distal half; internodes 1.4–8.0 cm long. Leaf sheaths about 2/3 as long as the internodes, membranous, greenish-white, scabrous, upper sheaths open 1/2 the length, collars flared; ligules 1–2.5 mm long, membranous, apex acute, ephemeral; blades 5–15 cm × 0.3–0.5 mm, flat, thin, lax, green, abaxially scabrous. Panicles 9–10 × 2–3 cm, few-flowered with 5–8 spikelets, flexuous, ovate, branched; branches glabrous. Spikelets 10–13 mm long, 4-flowered, glabrous; obovate; rachilla 1.2–2.4 mm long, minutely scabrous; glumes 1.3–3.6 mm long, membranous, lanceolate, green, glabrous, upper margins hairy; lower glumes 1.3–2 mm long, 1-nerved, apex acute; upper glumes 3–3.5 mm long, less than ½ as long as the florets, 3-veined, apex acuminate; lemmas 6.6–8 mm long, 5-veined, lanceolate, membranous, green, scabrous, apex bifid, two-dentate, awned between the teeth, the awn 1–2 mm long; paleas 4.6–5.2 mm long, membranous, keels scabrous, apex bifid; lodicules 0.6–0.8 mm long, lanceolate; anthers 2.7–3.3 mm long; ovaries glabrous. Caryopses not seen.

Leaf anatomy. The leaf anatomy of *Poa reclinata* is C_3, XyMS+ and the transverse sections have many widely spaced vascular bundles with small ribs; sclerenchyma is under both abaxial and adaxial epidermis, discontinuous, small, extending to the vascular bundles forming girders; bulliform cells are absent; epidermis is sparsely hairy. An anatomical description of *P. reclinata* is also found in Watson & Dallwitz (1992) and Stančík & Peterson (2007, figs 13g, 77c–f).

Phenology. Flowering in July.

Distribution. *Poa reclinata* is known only from the type locality, the paramo of the Colombian Cordillera Oriental, Dept. Santander (Stančík and Peterson 2007).

Conservation status. The species is rare and its conservation status is data deficient (IUCN 2010).

Etymology. The specific epithet is probably in reference to the decumbent, spreading or prostrate culms, a frequent characteristic of the species in this subsection of *Poa*.

Comments. Stančík and Peterson (2007) mentioned that the spikelets and panicles of *Festuca* [*Poa*] *reclinata* were similar to *Aphanelytrum procumbens* [*Poa hitchcockiana*], but the glumes in the former are veined. They provisionally placed *F. reclinata* in *F.* subg. *Subulatae* (Tzvelev) E.B. Alexeev sect. *Glabricarpae* E.B. Alexeev, as suggested by Aleexev (1986), along with *Festuca caldasii* (Kunth) Kunth and *F. woodii* Stančík.

Figure 3. *Poa reclinata*: **A** Habit **B** Sheath, ligule, and blade **C** Spikelet **D** Lower floret **E** Upper glumes **F** Lower glume **G** Lemma **H** Palea and rachilla, lateral view **I** Stamens with palea **J** Lodicules and with pistil. (*Cuatrecasas 9970 & Garcua Barriga*, US-1798714).

The latter two species of *Festuca* have open sheaths, flattened and hairy (hispid?) rachillas, and lemmas with rounded keels and annulate calluses, whereas *Poa reclinata* has fused sheaths ½ their length, terete rachillas that are minutely scabrous, and lemmas with compressed keels and smooth transitions from callus to lemma. We hope to confirm the placement of *P. reclinata* in *P.* subsect. *Aphanelytrum* in future DNA studies.

Poa sanchez-vegae **Soreng & P.M. Peterson, nom. nov.**
urn:lsid:ipni.org:names:77155370-1
Fig. 2A–C, 4A, B, D–L

Aphanelytrum peruvianum Sánchez Vega, P.M. Peterson, Soreng & Lægaard, J. Bot. Res. Inst. Texas 1(2): 842. 2007.

Type. PERU. Departamento Cajamarca, Provincia Cajamarca, Distrito Cajamarca, Cerro Akumullca, al SO de Cajamarca, sobre la cima de la ladera occidental del Valle de Cajamarca (7°14'15"S Lat, 78°29'24"W Long), 3300 m, 20 Mar 2003, *I. Sánchez-Vega 11781, M. Sánchez-Montoya, R. Cueva R. & J. Montoya* (holotype: CPUN!; isotypes: AAU!, F!, HAO!, HUT!, LOJA!, MICH!, MO!, SI!, US-3472470!, US-3686568!, USM!).

Description. Caespitose perennials. Culms 14–24 cm tall, with many culms near base, primary and secondary culms appressed, somewhat decumbent near base with intravaginal branching, culm bases continuously branch and often root at low to mid-culm nodes; internodes 3–18 mm long, numerous. Leaf sheaths longer than the internodes, membranous to hyaline, open to near base to open completely to base, slightly keeled; ligules 2–3 mm long, membranous to hyaline, decurrent, apex erose often lacerate; blades 3–7 cm long (flag leaf ca 1.6 mm long), 0.2–1.2 mm wide, flat to loosely involute, thin, linear, apex naviculate. Panicles 1.7–2.5 cm long, few-flowered with 5–10 spikelets; branches flexuous, the lower branches with two spikelets, the upper branches with single spikelet. Spikelets 5–7 mm long, usually 3-flowered, purplish, glabrous, disarticulating above the glumes and between the florets; lower and middle florets usually staminate; upper florets usually pistillate; rachilla joints 1.2–2 mm long, prolonged above the upper floret; glumes 1–2 mm long, subequal, apex acute, often mucronate; lower glume linear, 1-veined; upper glume oblanceolate, 3(4-)-veined, often toothed or irregularly lobed minutely bifid; lemmas 2.2–3.5 mm long, 3- or 5-veined, ovate, apex mucronate with two acute lobes on each side of the mucro, the mucro 0.1–0.3 mm long; paleas 2–3.2 mm long, 2-keeled, apex bifid; lodicules 0.7–0.8 mm long, lanceolate, membranous, glabrous; stamens 3; anthers 2–2.9 mm long, yellowish to purplish; ovaries glabrous with two styles and two stigmas. Caryopses glabrous.

Leaf anatomy. The transverse section leaf anatomy of *Poa sanchez-vegae* is C_3, XyMS+ with non-radiate, spongy chlorenchyma, without adaxial palisade cells (Fig. 2A–C). There are bulliform cells on the adaxial surface on either side of the midveins

Figure 4. *Poa sanchez-vegae* (**A, B, D–L**) and *Poa hitchcockiana* (**C**). *Poa sanchez-vegae*: **A** Habit **B** Sheath, ligule, and blade **D** Panicle **E** Spikelet **F** Glumes, showing lower 1-veined and upper 4-veined **G** Glumes, showing lower 1-veined and upper 3-veined **H** Lemma **I** Paleas **J** Palea, anthers, and rachilla **K** Lodicules and pistil **L** Pistil. (*Sánchez Vega 11781, Sánchez Montoya, Cueva R. & Montoya*, US-3472470, US-3686568). *Poa hitchcockiana*: **C** Sheath, ligule, and blade (*Peterson 16571 & Refulio Rodriguez*).

primary vascular bundle without additional sclerenchyma (Fig. 2B). However, there are a few abaxial sclerenchyma cells associated with the lateral primary vascular bundles (Fig. 2C).

Phenology. Flowering in March.

Distribution. *Poa sánchez-vegae* is known only from the type locality near the western highlands of the Cajamarca Valley and is found on rocky sites associated with jalca vegetation (humid alpine grass ecosystems) at 3300 m (Sánchez-Vega et al. 2007).

Conservation status. *Poa sanchez-vegae* is rare and the conservation status is data deficient (IUCN 2010). However, the authors unsuccessfully searched for additional material of this species at the type locality on 26 Mar 2008, accompanied by two of the original collectors, Isidoro Sánchez-Vega and Juan Montoya. The site had been turned into a pine plantation.

Etymology. Since the existing specific epithet was occupied in *Poa* we provide a new name commemorating Isidoro Sánchez Vega, a renowned Peruvian Botanist.

Comments. Based on morphological characters, Isidoro Sánchez-Vega in consultation with Simon Lægaard, first identified the type collection of *P. sanchesz-vegae* as an unknown species of *Aphanelytrum*. In Sánchez Vega et al. (2007), we described this taxon as a new *Aphanelytrum,* and mention that *Festuca reclinata* superficially resembled the genus. In addition, *P. sanchez-vegae* aligned near or on an unusually long branch within *Poa* in preliminary cpDNA and ITS sequence analyses (Gillespie et al. 2007). Gillespie et al. (2008) included three accessions of *Poa hitchockiana* (≡ *Aphanelytrum procumbens*) that formed a clade sister to *P. sanchez-vegae* (≡ *A. peruvianum*) which together was sister to two accessions of *P. apiculata* (≡ *Tovarochloa peruviana*). These results clearly support our classification of *P. sanchez-vegae* and *P. hitchcockiana* as members of *P.* subsect. *Aphanelytrum*.

Other novelties

***Poa* subsect. *Tovarochloa* (Macfarl. & P. But) Soreng & P.M. Peterson, comb. & stat. nov.**

urn:lsid:ipni.org:names:77155398-1

within *Poa* subg. *Poa* supersect. *Homalopoa* (Dumort.) Soreng & L.J. Gillespie sect. *Dioicopoa* E. Desv., see Gillespie et al. 2007

Basionym. *Tovarochloa* T.D. Macfarl. & P. But, Brittonia 34(4): 478. 1982.

Type species. Based on *Tovarochloa peruviana* T.D. Macfarl. & P. But ≡ *Poa apiculata* Refulio.

Comments. For consistency in rank, since *Poa apiculata* Refulio (≡ *Tovarochloa peruviana*) apparently is sister to the three species in *Poa* subsect. *Aphanelytrum,* we erect *Poa* subsect. *Tovarochloa*.

Poa auriculata **Soreng & P.M. Peterson, sp. nov.**
urn:lsid:ipni.org:names:77155360-1
Fig. 5

Type. PERÚ. Departamento Amazonas, Provincia Chachapoyas, summit of Pumaurcu southeast of Chachapoyas, occasional on dry cliff face, 3100–3200 m, 3 Jul 1962, *J.J. Wurdack 1145* (holotype: US-2382274!).

Diagnosis. *Poa auriculata* differs from *Poa scabrivaginata* Tovar in having 4–6-flowered spikelets, a glabrous callus, glumes 2–3 mm long, and lemmas 2.5–3.8 mm long.

Description. Caespitose, annuals or short-lived perennials. Culms 40–72 cm tall, erect, scabrous, shiny, often weak; nodes 3–5. Leaf sheaths 2/3 to 4/5 as long the internodes, membranous, greenish to stramineous, scabrous, upper sheaths open for 1/3 the length, keeled, summit with prominent triangular auricles; ligules 3.3–5 mm long, membranous to hyaline, apex erose, often split down the center; blades 6–15 cm long (flag leaf 3–6 cm long), 3–6 mm wide, flat, thin, lax, linear, scabrous. Panicles 5–11 cm long, 2.5–5 cm wide, ovate, open; branches flexuous, effuse and spreading with numerous spikelets, scabrous, the lower branches capillary. Spikelets 5–7 mm long, 4–6-flowered, glabrous, ovate, greenish-yellow tinged with purple; rachilla 0.4–1.0 mm long; glumes 2–3 mm long, membranous, subequal; lower glumes 2–2.5 mm long, 1-veined, linear lanceolate, apex acuminate; upper glumes 2.4–3 mm long, 3-veined, the veins not conspicuous, lanceolate, apex acute; lemmas 2.5–3.8 mm long, 5-veined, lanceolate, membranous; apex acute, unawned; paleas 2.3–3.7 mm long, membranous, 2-keeled, the keels scabrous, apex minutely bifid; lodicules 0.4–0.5 mm long, ovate, membranous, glabrous; stamens 3; anthers 1.9–2.1 mm long, yellowish; ovaries glabrous with two styles and two stigmas. Caryopses not seen.

Phenology. Flowering in June and July.

Distribution. *Poa auriculata* is known only from the type locality in Cordillera de los Andes of Peru near Chachapoyas between 3100–3200 m growing on a dry cliff face.

Conservation status. The species is rare, but its conservation status is data deficient (IUCN 2010).

Etymology. The specific epithet refers to the triangular auricles that are found on the summit of the sheaths, a feature that is unique among species of *Poa*.

Comments. Initially RJS considered *Poa auriculata* to be related to species in *P.* subsect. *Aphanelytrum*. We do not place the new species in *P.* subsect. *Aphanelytrum* because the spikelets have short rachillas and are 4–6-flowered, the habit is annual to short-lived perennials with erect culms, and the lemmas are unawned without mucros. However, aside from the auricles, *P. auriculata* is morphologically consistent with the 300 or so species that reside within *P.* subg. *Poa* supersect. *Homalopoa*. We hope to include a sample of this species in upcoming molecular analyses.

Poa scabrivaginata differs from *P. auriculata* in having 2-flowered spikelets (4–6 in *P. auriculata*), a few cobwebby hairs on the callus (verses glabrous), glumes 3.6–4.3 mm long (verses 2–3 mm), and lemmas 4.2–4.5 mm long (verses 2.5–3.8 mm) [Tovar 1965]. *Poa aequatoriensis* Hack., another species possible to confuse with *P. auriculata*,

Figure 5. *Poa auriculata*: **A** Habit **B** Sheath, auricles, ligule, and blade **C** Spikelet **D** Glumes **E** Lower glume **F** Floret **G** Lemma **H** Palea, lateral view **I** Stamens with palea **J** Pistil enclosed in palea **K** Lodicules, pistil, and rachilla. (*Wurdack 1145*, US-2382274)

differs in having 2- or 3-, rarely 4-flowered spikelets, a few cobwebby hairs on the callus, and lemmas 3.6–4 mm long (Tovar 1965). *Poa aequatoriensis* is more wide ranging and has been reported in Colombia, Ecuador, and Peru whereas *P. scabrivaginata* is known from the type (Depto. de Huánuco, Tambo de Vaca, *J.F. Macbride 4354* at US) and one other possible collection (Depto. de Cajamarca, Celendin, I. Sánchez Vega 2668 at MO) [Sylvester et al. in press].

Acknowledgements

We thank the Smithsonian Institution's Restricted Endowment Fund, the Scholarly Studies Program, Research Opportunities, Atherton Seidell Foundation, Biodiversity Surveys and Inventories Program, Small Grants; the National Geographic Society for Research and Exploration (Grant No. 8087-06); Alice R. Tangerini for preparing the illustrations and anatomical plate; Stan Yankowski for preparing the anatomical sections; two anonymous reviewers and Clifford Morden for suggesting improvements to the manuscript.

References

Alexeev EB (1986) *Festuca* L. (Poaceae) in Venezuela, Colombia and Ecuador. Novosti Sistematiki Vysshchikh Rastenii 23: 5–23.

Bentham G (1881) Notes on Gramineae. Journal of the Linnean Society, Botany 19: 14–134. doi: 10.5962/bhl.title.54360

Chase A (1916) The structure of spikelets of *Aphanelytrum*. Botanical Gazette 61: 340–343. doi: 10.1086/331779

Clayton WD, Renvoize SA (1986) Genera graminum – grasses of the world. Kew Bulletin, Additional Series 13: 1–389.

Clayton WD, Vorontsova MS, Harman KT, Williamson H (2006 onwards) GrassBase – The online World grass flora. The Board of Trustees, Royal Botanic Gardens. http://www.kew.org/data/grasses-db.html [accessed 29 January 2016]

Gillespie LJ, Archambault A, Soreng RJ (2007) Phylogeny of *Poa* (Poaceae) based on *trnT-trnF* sequence data: major clades and basal relationships. Aliso 23: 420–434. doi: 10.5642/aliso.20072301.33

Gillespie LJ, Soreng RJ, Bull RD, Jacobs SWL, Refulio Rodriguez NF (2008) Phylogenetic relationships in subtribe Poinae (Poaceae, Poeae) based on nuclear ITS and plastid *trnT-trnL-trnF* sequences. Botany 86: 938–967. doi: 10.1139/B08-076

Giussani LM, Gillespie LJ, Scataglini MA, Negritto MA, Anton AM, Soreng RJ (in press) Breeding system diversification and evolution in American *Poa* supersect. *Homalopoa* (Poaceae: Poeae: Poinae). Annals of Botany.

Hackel E (1897) Gramineae (Hackel). In: Engler A, Prantl K (Eds) Die Naturlichen Pflanzenfamilian Nachträge zu Teil II, Abteilung 2: 39–47.

Hackel E (1902) Neue Graeser. Oesterreichische Botanische Zeitschrift 52: 107–110. doi: 10.1007/BF01680763

Hitchcock AS (1927) The grasses of Ecuador, Perú, and Bolivia. Contributions from the United States National Herbarium 24: 291–556.

Hitchcock AS (1935) Manual of Grasses of the United States. US Department of Agriculture Miscellaneous Publication 200: 1–1040.

IUCN (2010) IUCN Red List of Threatened Species. Version 2010.3.

Jørgensen P, Ulloa Ulloa C (1994) Seed plants of the high Andes of Ecuador—A checklist. AAU Reports 34: 1–443.

Lægaard S (2005) Poaceae (Gramineae). In: Sklenář P, Luteyn JL, Ulloa Ulloa C, Jørgensen PM, Dillon MO (Eds) Flora genérica de los páramos. Memoirs of the New York Botanic Garden 92: 358–391.

La Torre MI (2002) Primer registro de *Aphanelytrum* (Poaceae: Pooideae) para el Perú. Arnaldea 8: 53–56.

Macfarlane TD, But PP (1982) *Tovarochloa* (Poaceae: Pooideae), a new genus from the high Andes of Perú. Brittonia 34: 478–481. doi: 10.2307/2806505

Martins J, Uhl N (1980) Methods for the study of leaf anatomy in palms. Stain Technology 55: 241–246. doi: 10.3109/10520298009067247

Molinari-Novoa EA (2015) Some nomenclatural changes regarding Peruvian endemics. Polish Botanical Journal 60: 67–69. doi: 10.1515/pbj-2015-0015

Nicora E, Rúgolo de Agrasar ZE (1987) Los géneros de Gramíneas de América Austral: Argentina, Chile, Uruguay y áreas limítrofes de Bolivia, Paraguay y Brasil. Editorial Hemisferio Sur S. A., Buenos Aires, 611 pp.

Postek MT, Tucker SC (1976) A new chemical dehydration method for light microscopy preparations of plant material. Canadian Journal of Botany 54: 872–249. doi: 10.1139/b76-090

Refulio Rodriguez NF, Columbus JT, Gillespie LJ, Peterson PM, Soreng RJ (2012) Molecular phylogeny of *Dissanthelium* (Poaceae: Pooideae) and its taxonomic implications. Systematic Botany 37: 122–133. doi: 10.1600/036364412X616701

Renvoize SA (1998) Gramineas de Bolivia. The Royal Botanic Gardens, Kew, 644 pp.

Sakai WS (1973) Simple method for differential staining of paraffin embedded plant material using Toluidine Blue O. Stain Technology 48: 247–249. doi: 10.3109/10520297309116632

Sánchez Vega I, Peterson PM, Soreng RJ, Lægaard S (2007) *Aphanelytrum peruvianum* (Poaceae: Poinae): a new species from Perú. Journal of the Botanical Research Institute of Texas: 1: 841–845.

Sodiro PL (1889) Gramineas ecuatorianas de la provincia de Quito. Anales de la Universidad Central del Ecuador 3: 474–484.

Soreng RJ, Bull RD, Gillespie LJ (2010) Phylogeny and reticulation in *Poa* based on plastid *trnTLF* and nrITS sequences with attention to diploids. In: Seberg O, Petersen G, Barfod AS, Davis JI (Eds) Diversity, Phylogeny, and Evolution in the Monocotyledons. Aarhus University Press, Aarhus, 619–644.

Soreng RJ, Davis JI, Voionmaa MA (2007) A phylogenetic analysis of Poaceae tribe Poeae sensu lato based on morphological characters and sequence data from three plastid-encoded

genes: evidence for reticulation, and a new classification for the tribe. Kew Bulletin 62: 425–454. doi: 10.3417/0026-6493(2007)94[821:NPPANS]2.0.CO;2

Soreng RJ, Gillespie LJ (2007) *Nicoraepoa* (Poaceae, Poeae), a new South American genus based on *Poa* subgenus *Andinae*, and emendation of *Poa* section *Parodiochloa* of the sub-Antarctic islands. Annals of the Missouri Botanical Garden 94: 821–849.

Soreng RJ, Peterson PM (2012) Revision of *Poa* L. (Poaceae, Pooideae, Poeae, Poinae) in Mexico: new records, re-evaluation of *P. ruprechtii*, and two new species, *P. palmeri* and *P. wendtii*. PhytoKeys 15: 1–104. doi: 10.3897/phytokeys.15.3084

Soreng RJ, Peterson PM, Davidse G, Judziewicz EJ, Zuloaga FO, Filgueiras TS, Morrone O (2003) Catalogue of New World grasses (Poaceae): IV. subfamily Pooideae. Contributions from the United States National Herbarium 48: 1–730.

Soreng RJ, Peterson PM, Romaschenko K, Davidse G, Zuloaga FO, Judziewicz EJ, Filgueiras TS, Davis JI, Morrone O (2015) A worldwide phylogenetic classification of the Poaceae (Gramineae). Journal of Systematics and Evolution 53: 117–137. doi: 10.1111/jse.12150

Stančík D, Peterson PM (2007) A revision of *Festuca* (Poaceae: Loliinae) in South American Paramos. Contributions from the United States National Herbarium 56: 1–184.

Sylvester SP, Soreng RJ, Peterson PM, Sylvester MDPV (in press) An updated checklist and key to the open-panicled species of *Poa* L. (Poaceae) in Peru including three new species, *Poa ramoniana*, *Poa tayacajaensis*, and *Poa urubambensis*. PhytoKeys.

Thiers B (2013) Index Herbariorum: A global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium http://sweetgumnybgorg/ih/.

Tovar Ó (1965) Revisión de las especies Peruanas del género *Poa*. Memorias del Museo de Historia Natural "Javier Prado" 15: 1–65.

Tovar Ó (1993) Las Gramíneas (Poaceae) del Perú. Ruizia; Monografías del Jardín Botánico 13: 1–480.

Watson L, Dallwitz M (1992) The Grass Genera of the World. C.A.B. International, Wallingford, 1038 pp.