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New species and new records of buellioid lichens from islands of the South Pacific Ocean

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Abstract

Buellia rarotongensis Elix from Rarotonga, *Gassicurtia albomarginata* Elix from Vanuatu and *Monerolechia papuensis* Elix from Papua New Guinea and are described as new to science. In addition, *Buellia cranwelliae* Zahlbr. and *B. maunakeansis* Zahlbr. are reported as new to Norfolk Island, *Buellia bahiana* Malme and *Gassicurtia subpulchella* (Vain.) Marbach as new to Rarotonga, *Buellia polyxanthonica* var. *isidiata* Elix & Kantvilas, *B. spuria* var. *amblyogona* (Müll.Arg.) Elix and *Cratiria chloraceus* Marbach as new to Papua New Guinea and *Orcularia elixii* Kalb & Giralt as new to Hawai'i. *Buellia maunakeansis* is also reported from Australia.

Introduction

The genus *Buellia* includes a large, heterogeneous assemblage of mostly crustose lichens with a chlorococcoid photobiont, lecideine to biatorine apothecia, and usually *Bacidia*-type asci with 1-septate, dark-pigmented ascospores. Research on buellioid lichens over the last decade or so has led to the segregation of several well-defined groups of species as separate genera, particularly for the corticolous species (Marbach 2000). Thus *Buellia* in the strict sense is now limited to species with *Callispora*-type ascospores, bacilliform or weakly clavate conidia and a hymenium usually inspersed with oil droplets (Bungartz et al. 2007); that is, the so-called *Hafellia* group (Moberg et al. 1999). However, there is a large residue of often-unrelated taxa that cannot be assigned to any segregate genera at this stage and remain classified in *Buellia* in the broad sense. Resolving the taxonomy of the Physciaceae/Caliciaceae clearly remains a challenge because sometimes the traditional characters offer insufficient resolution. For a sound phylogenetic re-assessment it will be necessary to use molecular tools and examine a broad, representative range of the diverse species in this group. For the Australian species, a preliminary key to genera as well as detailed descriptions of many of the segregate genera has been published (Elix 2011).

In the most recent checklist of *the lichens of the smaller Pacific Islands,* a total of 87 taxa of *Buellia s.lat.* were recorded (Elix and McCarthy 2008). Over a third of these reports were from the Hawaiian Islands following the extensive studies by Zahlbruckner and Magnusson, and summarized in Magnusson's catalogue (Magnusson 1956). Records of *Buellia s.lat.* from Papua New Guinea can be found in Aptroot (2009), where a total of 18 taxa were listed. Since that time some additional species have been recorded for the islands, but not surprisingly several taxa have also been relegated to synonymy. In this paper, I describe three new species of buellioid lichens, one from each of Papua New Guinea, Rarotonga and Vanuatu, as well as some new records for the islands.

Methods

Observations and measurements of photobiont cells, thallus and apothecium anatomy, asci and ascospores were made on hand-cut sections mounted in water and dilute KOH (K). Asci were also observed in Lugol's Iodine (I), with and without pre-treatment in K. Medullary sections were treated with 10% sulfuric acid (H_2SO_4) and apothecial sections with 50% nitric acid (N). Chemical constituents were identified by thin-layer chromatography (Elix 2014) and comparison with authentic samples.

New Species

1. ***Buellia rarotongensis*** Elix, sp. nov.

MycoBank No.: MB 814614

Similar to *Buellia subcoronata* (Müll.Arg.) Malme but differs in having pruinose apothecia and in growing on rocks.

Type: Cook Islands: Rarotonga: Te Ko'u track, 21°13'S, 159°46'E, alt. 60-100 m, on volcanic rocks among taro plots, *P.M. McCarthy s.n.*, 7 Jun 1998 (holo: CANB).

Thallus of scattered squamules; squamules orbicular to somewhat irregular, 0.2–3 mm wide, up to 0.15 mm thick, often bearing a single apothecium; upper surface white to grey-white, plane to irregularly undulate; prothallus black or not apparent; medulla white, lacking calcium oxalate (H_2SO_4–), I–; photobiont cells 8–15 µm diam. *Apothecia* 0.1–0.5 mm wide, lecideine, immersed, erumpent, initially with an accessory thalline margin that is soon excluded, becoming broadly adnate; disc black, with dense thallus-coloured pruina particularly when young, disc plane or becoming weakly convex; proper margin thick, prominent, persistent, often higher than disc, in section 35–50 µm thick, outer zone dark brown, K+ forming red-orange needle-like crystals, paler brown within. *Epihymenium* 12–15 µm thick, pale brown to brown or orange-brown, K–, N–, with crystals that dissolve in K. *Hypothecium* 150–250 µm thick, deep red-brown to brown-black, K+ forming red-orange needle-like crystals. *Hymenium* 65–90 µm thick, colourless, not inspersed; subhymenium colourless to brown, 40–50 µm thick, K+ dark olive-brown; paraphyses 1.5–2 µm wide, simple to sparsely branched, apices 3–4 µm wide, with pale brown caps; asci of the *Bacidia*-type, with 8 or fewer spores. *Ascospores* 1-septate, olive-brown then brown, ellipsoid, juvenile spores *Pachysporaria*-type, mature spores *Buellia*-type, (10–)12–18 µm long, 5–8 µm wide, rarely constricted; outer spore-wall smooth to finely ornamented. *Pycnidia* rare, immersed; conidia bacilliform, 7–10 µm long, 0.5–0.7 µm wide.

Chemistry. Thallus K+ yellow then red, P+ yellow-orange, C–, UV–; containing atranorin (minor), norstictic acid (major), connorstictic acid (minor).

This new species belongs to *Buellia sens. lat.* (see above). *Buellia rarotongensis* is a very distinctive species, readily recognised by the minute, scattered, white to grey-white squamules or areoles, many of which bear a single apothecium, the erumpent apothecia which ultimately become broadly adnate, the grey-white pruinose discs and the presence of atranorin and norstictic acid. Morphologically this new species resembles *B. subcoronata*, a terricolous species common in the subarid areas of continental Australia. However, *B. subcoronata* differs in having larger apothecia 0.8–1.0 mm wide, with markedly convex, epruinose discs, somewhat larger ascospores, 12–20 µm long, 5–10 µm wide, and shorter, broader conidia, 4–6(–7) µm long, 1–1.2 µm wide (Elix 2011). The thallus of *B. maunakeansis* (described below) comprises continuous to dispersed, convex areoles which may become flattened and sublobate (the latter may resemble squamules). Like *B. rarotongensis* it has pruinose discs and contains norstictic acid but differs in having broadly adnate to sessile apothecia, shorter bacilliform conidia (4–6 µm long) and in containing additional 4,5-dichlorolichexanthone rather than atranorin. In some respects, *B. rarotongensis* also resembles *B. ryanii* Bungartz, a saxicolous species from North America. Both may have subsquamulose thalli and initially immersed apothecia, but *B. ryanii* differs in having epruinose discs, shorter *Buellia*-type ascospores (9–13 µm long), shorter bacilliform to ellipsoid conidia (2–5 µm long) and by lacking lichen substances.

Etymology: The species is named after its distribution.

Distribution and habitat: At present *B. rarotongensis* is known from two localities in Rarotonga where it occurs on volcanic rocks in regrowth woodland. Associated species included *Parmotrema saccatilobum* (Taylor) Hale, *Parmotrema reticulatum* (Taylor) M.Choisy and *Xanthoparmelia subramigera* (Gyeln.) Hale.

Specimen examined: Cook Islands: Rarotonga, Raemaru Track, upper level, 21°14'S, 159°49'W, 200 m alt., on basalt rocks on fern dominated slopes with scattered *Albizzia*, *J.A. Elix 42874,* 8 Jun 1998 (CANB).

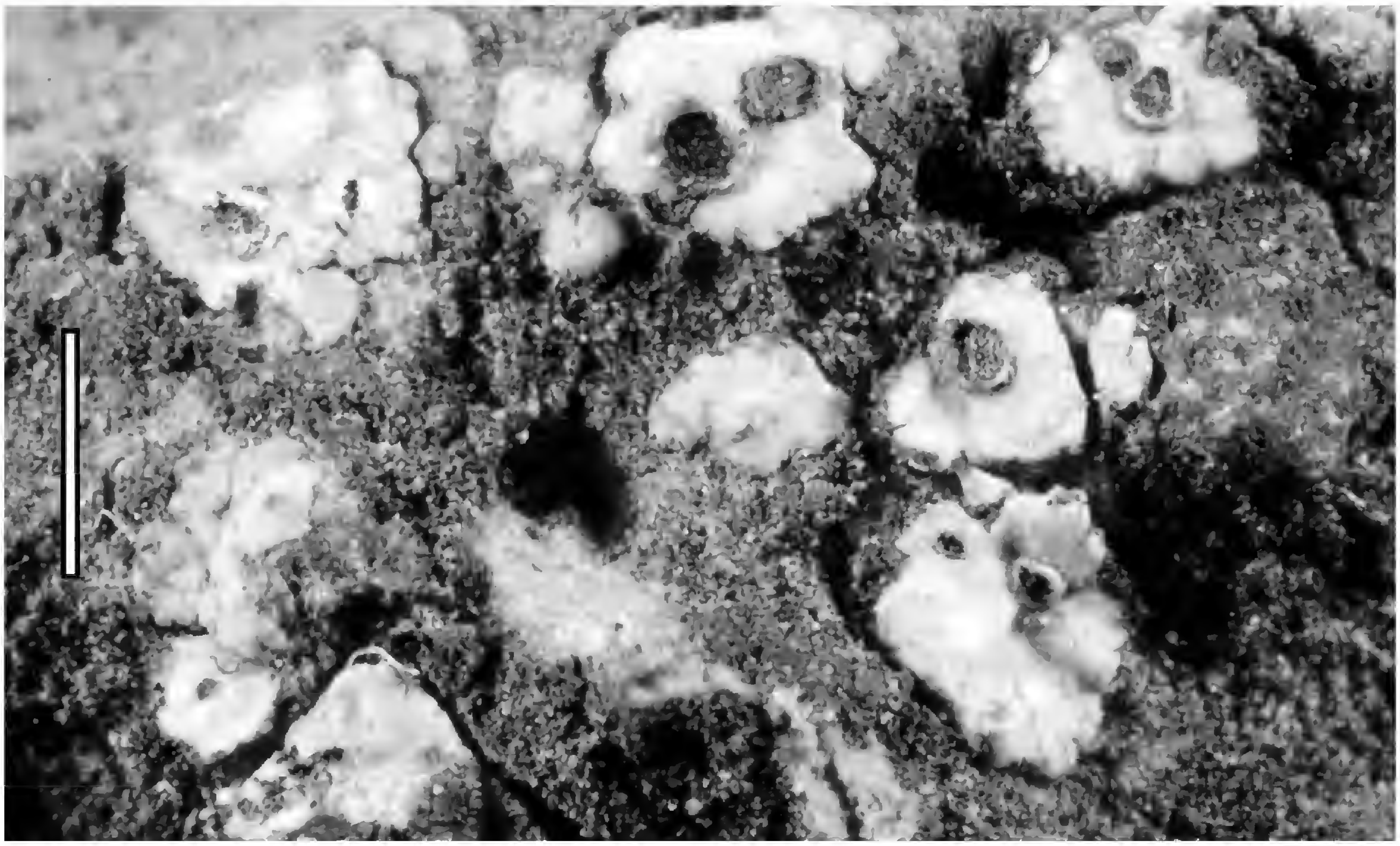

Fig. 1. *Buellia rarotongensis* (holotype). Scale bar = 1 mm.

2. *Gassicurtia albomarginata* Elix sp. nov.

MycoBank No.: MB 814615

Similar to *Gassicurtia subpulchella* (Vain.) Marbach but differs in having apothecia with a pale proper margin and epruinose discs and in containing 6-*O*-methylthiophanic acid.

Type: Vanuatu: Espiritu Santo: Logging Area near Lavatmas (N of Sara), 48 km NNW of Luganville, 15°07'S, 167°01'E, alt. 300 m, on upper branches of large felled *Endospermum medullosum* in poor lowland forest on flats, *Endospermum medullosum, Antiaris toxicarya, Pometia pinnata* dominated, *H. Streimann 62801 & P. Ala*, 22 Oct 1998 (holo: CANB; iso: B).

Thallus crustose, continuous, to 4 mm wide, rimose-areolate, areoles 0.5–0.1 mm wide; upper surface pale whitish grey to greenish white, smooth to finely granular or becoming sorediate; individual granules rounded, plane to weakly convex, 0.05–0.08 mm wide; prothallus black, in part surrounding the thallus; photobiont cells 8–13 µm wide; medulla white, I–. *Apothecia* 0.05–0.3 mm wide, lecideine, scattered, round, immersed to broadly adnate or rarely sessile; disc black, epruinose, weakly concave to plane; proper margin thick, persistent, glossy, raised above the disc, pale whitish grey to black, in section 40–50 µm thick, brown-black in the outer part, K– or K+ pale yellow solution, paler to colourless within. *Hypothecium* 120–170 µm thick, brown to dark brown or brown-black. *Epihymenium* 8–12 µm thick, pale olive-brown to dark brown, K–, N–. *Hymenium* 50–90 µm thick, colourless, not inspersed with oil droplets; paraphyses 1.5–1.7 µm wide, simple to sparsely branched, apices, 3–3.5 µm wide, with brown caps; *asci* of the *Bacidia*-type, 8-spored. *Ascospores* of the *Buellia*-type, 1-septate, olive-green to brown, narrow ellipsoid, (8–)10–13(–15) µm long, (3.5–)4–5(–6) µm wide, not curved, rarely constricted at the septum; outer spore-wall finely ornamented. *Pycnidia* not seen.

Chemistry: Thallus and medulla K–, C + orange, P–, UV+ orange; containing 6-*O*-methylthiophanic acid (major), thiophanic acid (major or minor), arthothelin (minor).

Species of *Gassicurtia* are characterized by crustose thalli, which may be areolate, verrucose, granular or coralloid, by having *Bacidia*-type asci, elongate fusiform conidia, 5–10 µm long, a non-inspersed hymenium, small *Buellia*-type ascospores that lack wall-thickenings at maturity (Marbach 2000, Elix 2011) and often contain red pigments. *Gassicurtia albomarginata* resembles *G. subpulchella*, a corticolous montane-tropical species known from Africa, Asia, North and South America (Marbach 2000) and Queensland (Elix 2011). Morphologically *G. subpulchella* differs in having pruinose discs with a black proper margin more or less level with the disc rather than a pale, elevated proper margin. In addition, *G. subpulchella* has somewhat larger apothecia 0.3–0.5 mm wide. Both species are characterized by the presence of thiophanic acid and arthothelin, but *G. subpulchella* contains minor amounts of 3-*O*-methylthiophanic acid rather than 6-*O*-methylthiophanic acid. *Gassicurtia pseudosubpulchella* Marbach is also morphologically similar but can readily be distinguished by its esorediate upper surface and the K+ purple proper exciple (Marbach 2000). *Gassicurtia albomarginata* could also be confused with *Amandinea efflorescens* var. *pseudohypopelidna* Marbach, a corticolous species from New Caledonia (Marbach 2000). Both taxa have a sorediate upper surface, similarly sized *Buellia*-type ascospores and contain xanthones. Like *G. subpulchella, A. efflorescens* var. *pseudohypopelidna* differs from *G. albomarginata* in having apothecia with a black proper margin more or less level with the disc rather than a pale, elevated proper margin. Further, although both species contain thiophanic acid and arthothelin, *A. efflorescens* var. *pseudohypopelidna* differs in containing major quantities of thuringione as well as minor amounts of 3-*O*-methylthiophanic acid.

Etymology: The specific epithet refers to the pale proper margin of the apothecia of this species.

Distribution and habitat: At present, this new species is known only from the type locality. Associated species included *Graphis ceylanica* Zahlbr., *G. subserpentina* Nyl., *Leiorreuma exaltatum* (Mont. & Bosch) Staiger, *Parmotrema neocaledonicum* (Nyl.) Elix, *P. saccatilobum* (Taylor) Hale, *P. tinctorum* (Despr. ex Nyl.) Hale and *Thecaria montagnei* (Bosch) Staiger.

Fig. 2. *Gassicurtia albomarginata* (holotype). Scale bar = 1 mm.

3. *Monerolechia papuensis* Elix, sp. nov.

MycoBank No.: MB 814616

Similar to *Monerolechia norstictica* Elix but differs in having larger squamules, longer ascospores and in containing additional 4,5-dichlorolichexanthone.

Type: Papua New Guinea: Central Province: Hombrom Bluff, 25 km NE of Port Moresby, 9°24'S, 147°20'E, alt. 650 m, on exposed conglomerate outcrop in *Eucalyptus* dominated savannah woodland, *H. Streimann 14994 & E.K. Naoni,* 10 Feb 1991 (holo: CANB; iso: B).

Thallus autonomous or initially parasitic on various *Pertusaria* or *Pyxine* species, areolate, subsquamulose or becoming distinctly squamulose, squamules discrete, somewhat irregular, margin lobate, brown, 0.5–1.5 mm wide, up to 0.1 mm thick; upper surface brown, plane to irregularly undulate; prothallus black, prominent, surrounding and between squamules or not apparent; medulla white, lacking calcium oxalate (H_2SO_4–), I–; photobiont cells 8–13 µm diam. *Apothecia* 0.3–0.7 mm wide, lecideine, initially immersed, but soon broadly adnate to sessile; disc black, epruinose, weakly concave to weakly convex; proper margin concolorous with disc, persistent or excluded in older, convex apothecia, in section 50–60 µm thick, outer zone brown-black, K+ forming red-orange needle-like crystals, paler brown within. *Epihymenium* 10–15 µm thick, dark brown, K–, N–. *Hypothecium* 185–210 µm thick, dark brown to brown-black, K+ forming red-orange needle-like crystals. *Hymenium* 45–60 µm thick, colourless, not inspersed; paraphyses 1.5–2 µm wide, simple to sparsely branched, with apices 3–4.5 µm wide and brown caps; asci approximating the *Lecanora*-type, with 8 or fewer spores. *Ascospores* 1-septate, olive-brown then brown, ellipsoid, juvenile spores *Pachysporaria*-type, mature spores *Physconia*- then *Buellia*-type, 12–17(–22) µm long, 5–7.5(–9) µm wide, not constricted; outer spore-wall smooth to finely ornamented. *Pycnidia* rare, immersed; conidia bacilliform, 3–4 µm long, 1 µm wide.

Chemistry. Thallus K+ yellow then red, P+ yellow-orange, C–, UV+ orange; containing 4,5-dichlorolichexanthone (minor), norstictic acid (major), connorstictic acid (minor).

Species of *Monerolechia* are characterized by thalli that are initially parasitic on various other lichens (particularly *Pertusaria* species) but become autonomous, in having asci approximating the *Lecanora*-type, short, bacilliform conidia 3–6 µm long, a non-inspersed hymenium, and small *Buellia*-type ascospores which lack wall-thickenings at maturity (Marbach 2000, Kalb 2004, Elix 2015). *Monerolechia papuensis* closely resembles *M. norstictica* as both species have autonomous squamulose or subsquamulose thalli of bullate areoles. *M. papuensis* is further characterized by the broadly adnate to sessile, lecideine apothecia, the epruinose discs, short bacilliform conidia and the presence of 4,5-dichlorolichexanthone, norstictic and connorstictic acids. *Monerolechia norstictica* differs from *M. papuensis* in having smaller squamules, 0.1–0.5 mm wide, shorter ascospores, 10–15 µm long, 5–7 µm wide, and in containing only norstictic and connorstictic acids (Elix 2015). In overall morphology this new species also resembles the cosmopolitan, *M. badia* (Fr.) Kalb. The initially parasitic thalli of both species become autonomous with a crustose thallus of bullate areoles with a chocolate-brown upper surface or become subsquamulose or squamulose. The two species have very similar apothecia, ascospores and conidia but can readily be differentiated chemically since *M. badia* lacks lichen substances. The substances present in *M. papuensis* are definitely not derived from any parasitized species and can readily be detected in sections of the apothecia or squamules by treatment with K (turning orange with formation of red crystals).

Etymology: The species is named after the type locality.

Distribution and habitat: At present *B. papuensis* is known from two localities in Papua New Guinea where it occurs on siliceous rocks. Associated species included *Parmotrema praesorediosum* (Nyl.) Hale, *Pertusaria xanthodactylina* A.W.Archer & Elix and *Pyxine sorediata* (Ach.) Mont.

Specimens examined: Papua New Guinea: Central Province: type locality, on exposed conglomerate outcrop in *Eucalyptus* dominated savannah woodland, *H. Streimann 14993 & E.K. Naoni,* 10 Feb 1981 (B, CANB, LAE); Morobe Province: Heads Hump, 5 km SE of Bulolo, 7°13'S, 146°41'E, alt. 800 m, on rock outcrop in *Imperata* dominated grasslands, *H. Streimann 33451,* 16 Apr 1983 (B, CANB).

Fig. 3. *Monerolechia papuensis* (holotype). Scale bar = 2 mm.

New Records

1. ***Buellia bahiana*** Malme, *Arkiv för Botanik* 21A: 17 (1927)

This pantropical species has been reported from Africa, Australia, North, Central and South America and the Pacific including Hawai'i, Tahiti and New Caledonia (Elix 2009). It is characterized by the white, grey-white or pale grey crustose thallus, the 8-spored asci, the K+ violet epihymenium, the densely inspersed hymenium, the relatively small ascospores, 13–20 µm long, 5.5–8.0 µm wide, with subapical and septal wall thickenings and a smooth outer surface, and by the presence of norstictic acid. A detailed description is given in Elix (2009).

Specimen examined: Cook Islands: Rarotonga, Avana, 21°14'41"S, 159°43'55"W, alt. 10 m, on rotted coconut stump in roadside garden, *J.T. Swarbrick L.162F-Cl,* 28 Jun 2009 (CANB).

2. ***Buellia cranwelliae*** Zahlbr., *Denkschriften der Akademie der Wissenschaften in Wien mathematisch-naturwissenschaftliche Klasse* 104: 375 (1941)

This species was previously known only from New Zealand (Galloway 2007). It is characterized by the white crustose thallus which may become sublobate or placodiform at the margins, a white medulla containing calcium oxalate (H_2SO_4+), 8-spored asci, a dark brown, N+ greenish-black excipulum, *Physconia-* then *Buellia-*type, 1-septate, olive-brown to brown, ellipsoid, ascopores (10–)11–16(–18) µm long, 5–8(–10) µm wide, which are rarely weakly constricted at the septum and have a smooth outer wall and the straight, bacilliform, conidia, 3–5 µm long. The thallus lacks lichen substances. An amended description of this species follows.

Thallus crustose, rimose to areolate, to 15 mm wide; individual areoles usually convex, 0.4–2 mm wide and to 1.5 mm thick, dispersed or becoming contiguous to form a more or less continuous thallus, ±becoming sublobate or placodiform at the margins; upper surface white to grey-white, smooth or slightly uneven; prothallus brown, marginal or not apparent; cortex *c.* 10 µm thick; medulla white, containing calcium oxalate (H_2SO_4+), I–; photobiont cells 8–12 µm diam. *Apothecia* 0.4–0.8 mm wide, lecideine, scattered or crowded, mainly broadly adnate, ±round but often distorted by mutual pressure when crowded; disc black, epruinose, ±plane to markedly convex; proper exciple thin, concolorous with the disc, entire but soon excluded, in section 30–50 µm thick, outer zone dark brown to brown-black, in part K+ deep yellow solution, N+ greenish-black, inner zone paler brown. *Hypothecium* 45–55 µm thick, brown, K–. *Epihymenium* 8–12 µm thick, dark red-brown, K–, N–. *Hymenium* 60–75 µm thick, colourless, not or finely inspersed; paraphyses 1.7–2.0 µm wide, simple to branched, with apices 3.5–5 µm wide and dark brown caps; asci *Bacidia*-type, with 8 or fewer spores. *Ascospores* at first of the *Physconia*-type, then of the *Buellia*-type, 1-septate, olive-brown to brown, ellipsoid, (10–)11–16(–18) µm long, 5–8(–10) µm wide, rarely weakly constricted at the septum; outer spore-wall smooth. *Pycnidia* immersed, ostioles black. Conidia bacilliform, straight, 3–5 µm long, 1–1.2 µm wide.

Chemistry. Thallus K–, P–, C–, KC–, UV–; no lichen substances detected.

Specimen examined: Norfolk Island: Rocky Point, Rocky Point Reserve, 29°03'S 167°55'E, alt. 40 m, on volcanic rocks along cliff tops, *J.A. Elix 18536 p.p. & H. Streimann*, 5 Dec 1984 (CANB).

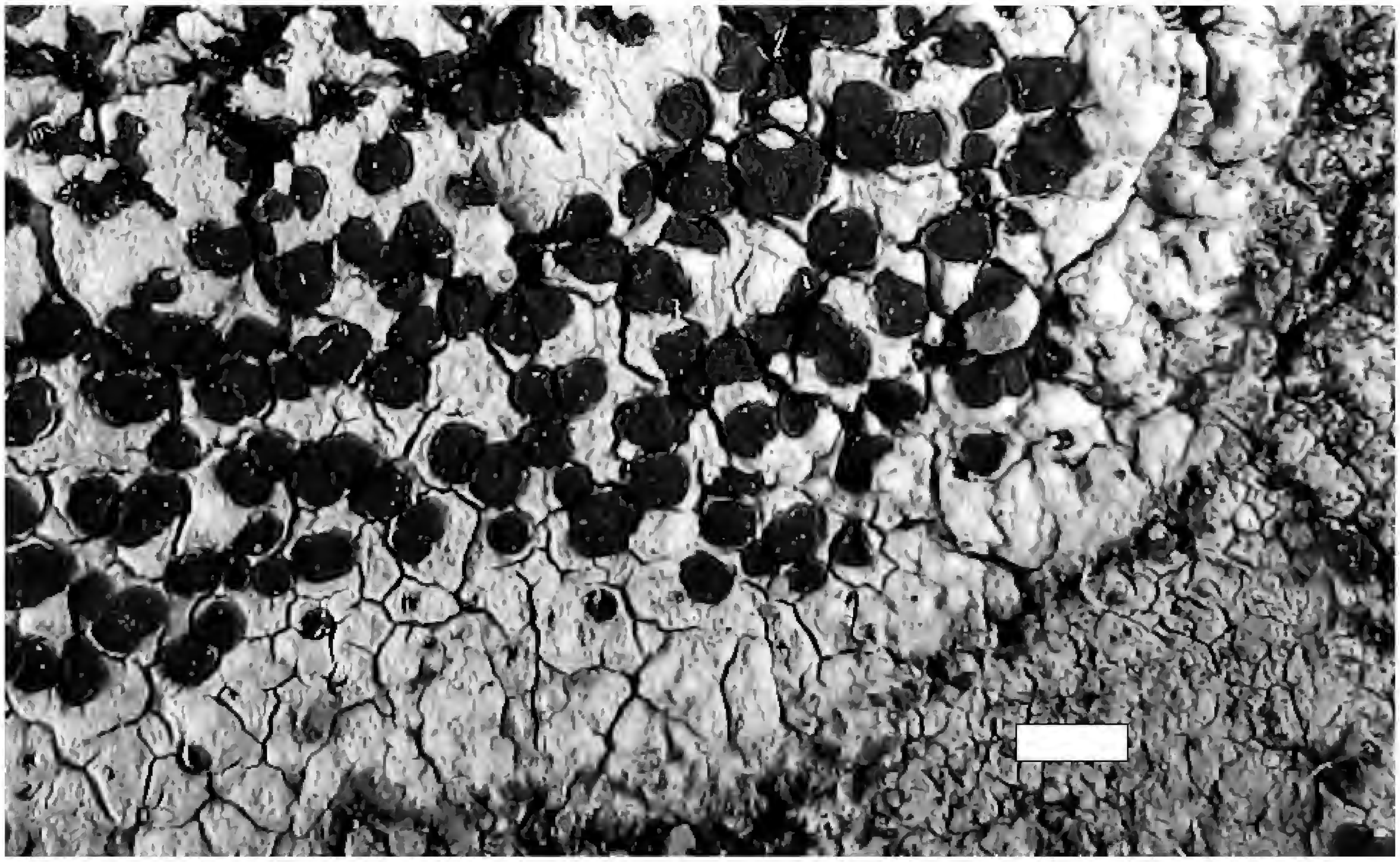

Fig. 4. *Buellia cranwelliae* (*H.Mayrhofer 12269* in GZU). Scale bar = 1 mm.

3. *Buellia maunakeansis* Zahlbr., *Annales Mycologici* 10: 383 (1912)

This species was previously known from Hawai'i (Magnusson 1955). The thallus of this species comprises contiguous to dispersed, convex areoles which become ±flattened, more or less continuous and sublobate and bear black, broadly adnate to sessile apothecia. The thallus contains 4,5-dichlorolichexanthone, norstictic and connorstictic acids. An amended description of this species follows.

Thallus crustose, areolate, continuous to dispersed, up to 35 mm wide; individual areoles 0.4–2.0 mm wide and high, markedly convex and dispersed, sometimes only weakly convex and becoming contiguous to form a more or less continuous thallus; upper surface white to pale grey, smooth and shiny, rimose or subgranular; prothallus not apparent; medulla white, containing calcium oxalate (H_2SO_4+), I–; photobiont cells 7–11 µm diam. *Apothecia* 0.4–1.0 mm wide, lecideine, scattered, mostly broadly adnate, rarely sessile; disc black, rusty brown pruinose when young, ±plane to markedly convex; proper exciple thin, concolorous with the disc, entire but soon excluded, in section 35–55 µm thick, outer zone opaque brown-black, K+ orange with formation of red crystals, N–, inner zone red-brown. *Hypothecium* 200–250 µm thick, intense red-brown to brown-black, K+ orange with formation of red crystals. *Epihymenium* 10–12 µm thick, dark red-brown, K–, N–. *Hymenium* 70–90 µm thick, colourless, not inspersed; subhymenium colourless to red-brown, 40–65 µm thick; paraphyses 1.7–2.0 µm wide, simple to branched, capitate, with apices dark brown, 3.5–5 µm wide; asci approximating the *Bacidia*-type, with 8 or fewer spores. *Ascospores* at first of the *Physconia*-type, then of the *Buellia*-type, 1-septate, olive-brown to brown, ellipsoid, 11–20 µm long, 6–10 µm wide, sometimes ± constricted at the septum; outer spore-wall smooth. *Pycnidia* immersed; conidia bacilliform, straight, 4–6 µm long, 1–1.2 µm wide.

Chemistry. Thallus K+ yellow then red, C–, P+ orange: containing 4,5-dichlorolichexanthone (minor), norstictic acid (major), connorstictic acid (minor).

Specimens examined: Australia: Queensland: Noosa Heads National Park, Devils Kitchen Track, 26°23'S, 153°06'E, alt. 15 m, on rocks on exposed headland, *J.A. Elix 10351,* 29 Jul 1982, (B, CANB), *J.A. Elix 10389,* 2 Sep 1982 (CANB).

Norfolk Island: Rocky Point, Rocky Point Reserve, 29°03'S, 167°55'E, alt. 40 m, on volcanic rocks along the cliff tops, *J.A. Elix 18532 pr.p., 18536A,* 5 Dec 1984 (CANB); Point Blackburne Reserve, 29°02'30"S, 167°59'30"E, alt. 2 m, on exposed boulder facing sea amongst dense shrubs, *H. Streimann 34201,* 4 Dec 1984 (CANB).

United States of America: Hawai'i: Oahu, Kailua Beach Reserve, 21°24'N, 157°44'W, alt. 2 m, on volcanic rocks along the foreshore, *J.A. Elix 13517,* 9 Jul 1983 (CANB).

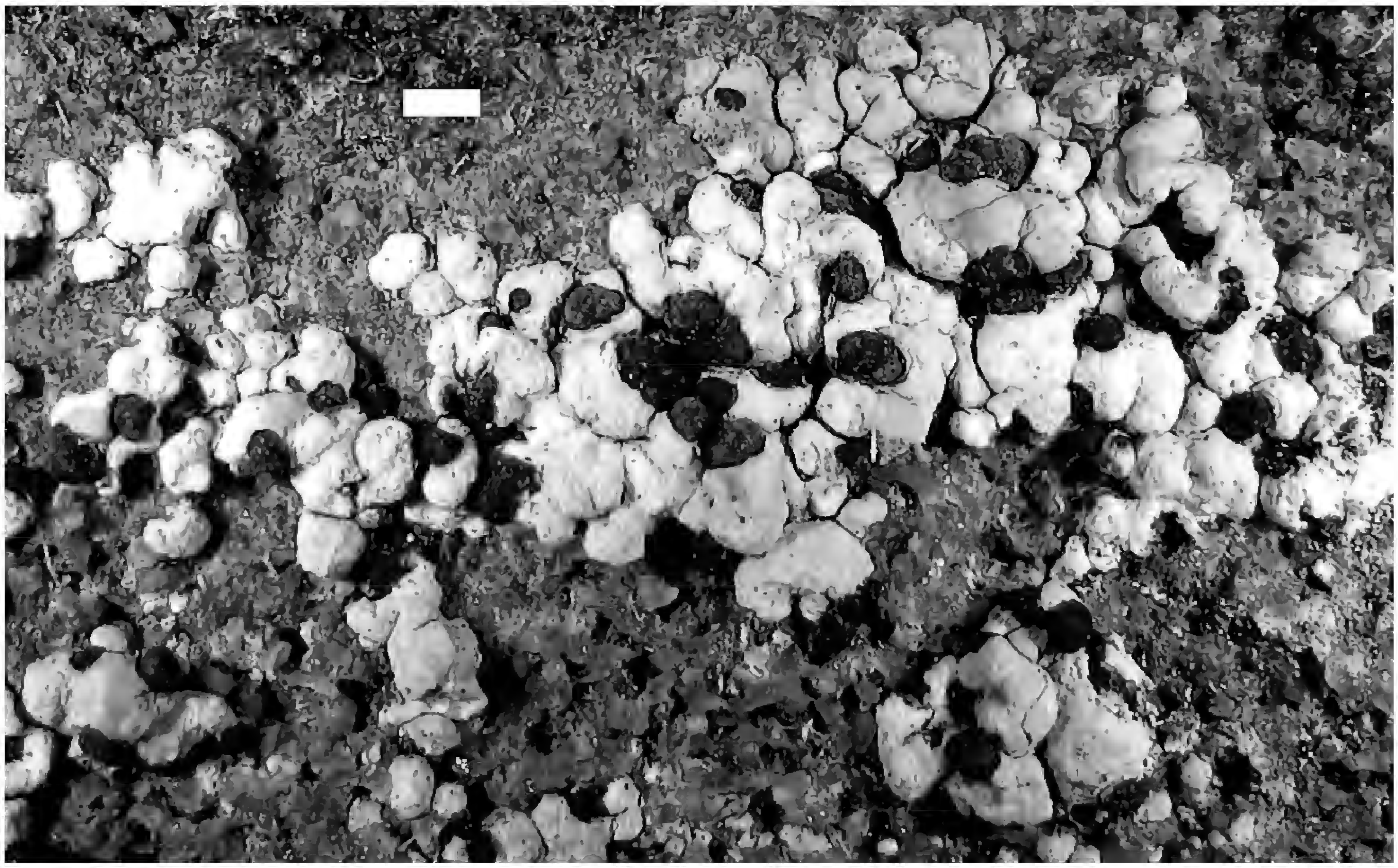

Fig. 5. *Buellia maunakeansis* (*Elix 10351* in CANB). Scale bar = 1 mm.

4. *Buellia polyxanthonica* var. *isidiata* Elix & Kantvilas, *Australasian Lichenology* 73: 31 (2013)

This taxon, previously known from tropical Australia (Elix & Kantvilas 2013), is characterized by the yellow to dull or deep yellow-green, crustose, rimose-areolate thallus with an isidiate upper surface, black, lecideine, broadly adnate to sessile apothecia, 0.1–0.4 mm wide, brown, 1-septate, *Physconia-* then *Buellia*-type ascospores, 12–20 μm long, 5–8 μm wide, and the presence of thiophanic and 3-*O*-methylthiophanic acids. A detailed description is given in Elix & Kantvilas (2013).

Specimen examined: Papua New Guinea: National Capital Province Province: Rea Rea Road, 17 km NW of Port Moresby, 9°23'S, 147°03'E, alt. 30 m, on small rock outcrop in *Eucalyptus* dominated savannah woodland, *H. Streimann 16372 & E.K. Naoni,* 15 Feb 1981 (CANB, LAE, H, UPNG).

5. *Buellia spuria* var. *amblyogona* (Müll.Arg.) Elix, *Australasian Lichenology* 65: 16 (2009)

This taxon is very common on rocks in mainland Australia and is also known from Lord Howe Island, Norfolk Island (McCarthy 2015) and New Zealand (Elix et al. 2015). It is characterized by the whitish to grey-white or grey, crustose thallus, usually with a prominent black prothallus, an amyloid medulla, the immersed then broadly adnate to sessile, rounded apothecia, a partly aeruginose, N+ red-violet to red-brown epihymenium, *Buellia*-type ascospores, 9–16 μm long, 4.5–7.5 μm wide, which rarely become constricted at the septum, bacilliform conidia 4–6 μm long, 1–1.5 μm wide, and the presence of atranorin and norstictic acid. It is distinguished from the superficially similar *B. homophylia* by the smaller spores and from *Buellia spuria* (Schaer.) Anzi var. *spuria* by containing norstictic acid rather than stictic acid as the major secondary metabolite. A detailed description is given in Elix (2011).

Specimens examined: Papua New Guinea: National Capital Province: near Buruni Village, 9°26'S, 147°08'E, alt. 100 m, on exposed rock outcrop in savannah woodland, *H. Streimann 14623A,14624A & A. Vinas,* 6 Feb 1981 (CANB). Morobe Province: Heads Hump, 5 km SE of Bulolo, 7°13'S, 146°41'E, alt. 800 m, on rock outcrop in *Imperata* dominated grasslands, *H. Streimann 33451A,* 16 Jun 1983 (CANB).

6. *Cratiria chloraceus* Marbach, *Bibliotheca Lichenologica* 74: 175 (2000)

This species was known previously from New Caledonia (Marbach 2000). It is characterized by the pale yellow to yellow-grey thallus, the yellow-pruinose apothecia, 1-septate, *Cratiria*-type ascospores, 14–20 × 6–8 μm, an excipulum that reacts K+ giving a intense red-violet solution, an inspersed hymenium and by the presence of arthothelin and thuringione. This taxon may contain arthothelin (major), thuringione (major or minor), 4,5-dichloronorlichexanthone (minor), ±6-*O*-methylarthothelin (minor). The closely related *Cratiria aggrediens* (Stirt.) Marbach is distinguished by its larger ascospores, 17–28 × 8–13 μm, and an excipulum that reacts with K giving an orange-red solution. A full description is given in Marbach (2000).

Specimen examined: Papua New Guinea: Morobe Province, Tauri River, Menyamya, 7°07'S, 145°59'W, alt. 1200 m, on planted *Casuarina* trunk at the settlement, in grasslands with some regrowth species, *H. Streimann 18943,* 29 Apr 1982 (CANB).

7. *Gassicurtia subpulchella* Malme, (Vain.) Marbach, *Bibliotheca Lichenologica* 74: 244 (2000)

Gassicurtia subpulchella is characterized by the yellow-grey, yellow or grey-white, warty or subgranular thallus, the grey, pruinose apothecia, the 8-spored asci, the olive to olive brown, to grey-olive, 1-septate ascospores 10–15 μm long, 4.0–5.5 μm wide and by the presence of thiophanic acid (major), arthothelin (trace), 3-*O*-methylthiophanic acid (trace), atranorin (trace) and an unknown red pigment. The proper exciple of the apothecia react K+ yellow. This species was known previously from Asia, Africa, North and South America (Marbach 2000), Queensland and Lord Howe Island (McCarthy 2015). Detailed descriptions are given in Marbach (2000) and Elix (2011).

Specimen examined: Cook Islands: Rarotonga, Raemaru Track, slope near summit cliff, 21°13'S, 159°48'W, alt. 270 m, on dead wood in open tropical woodland, *J.A. Elix 42874,* 8 Jun 1998 (CANB).

8. *Orcularia elixii* Kalb & Giralt, *Phytotaxa* 38: 56 (2011)

Orcularia elixii is characterized by the grey to brownish grey, thin, crustose thallus, the small, adnate to sessile lecideine apothecia, the 8-spored asci, the pale brown, 1-septate, *Orcularia*-type ascospores, 10–16 μm long, 5–8 μm wide, and by the absence of lichen substances. This species is close to *Orcularia insperata* (Nyl.) Kalb & Giralt but is distinguished by the smaller ascospores with larger lumina. It was previously known only from the type collection from eastern New South Wales (Kalb and Giralt 2011). A detailed description is given in Kalb & Giralt (2011).

Specimen examined: United States of America: Hawai'i: Oahu, Kailua Hills, 16 km NE of Honolulu, 21°23'N, 157°46'W, alt. 160 m, on *Acacia formosana* in *Leucina* scrub, *J.A.Elix 13603,* 11 Jul 1983 (B, CANB), growing together with *Buellia conspirans* (Nyl.) Vain.

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A tiny taxonomic thorn: *Brevianthus hypocanthidium* and *Aponardia huerlimannii* are one and the same

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Abstract

Brevianthus hypocanthidium and *Aponardia huerlimannii* are found to be synonymous and the new combination *Brevianthus huerlimannii* is made.

Introduction

In a recent paper a distinctive new species of *Brevianthus* was described from New Caledonia on the basis of material collected on Mont Kouakoue by the late Elizabeth Brown (Renner et al. 2015). The fact that a previously published name existed for this plant escaped our attention. The plant we described as *Brevianthus hypocanthidium* M.A.M.Renner & Engel was first recognised as a new species by Váňa and Grolle, who described it under the genus *Nardia* as *N. huerlimannii,* whose type is also from New Caledonia (Váňa 1970). Placement of *N. huerlimannii* within *Nardia* was tentative, neither author of *N. huerlimannii* was particularly happy with its generic placement, though no other genus was then available for what was undoubtedly a distinctive new species. *Nardia* is a member of the Gymnomitriaceae within suborder Jungermanniineae (Shaw et al 2015). *Brevianthus* belongs to the Brevianthaceae, an ally of Lophocoleaceae and Plagiochilaceae within suborder Lophocoleineae (Crandall-Stotler & Stotler 2000). Unfortunately, consideration of potential prior published names for Elizabeth Brown's plant was confined to suborder Lophocoleineae; a search within Gymnomitriaceae was considered unnecessary.

The type species of *Brevianthus* is from Tasmania, and was originally published as *Jackiella flava* Grolle (Grolle 1970). That similarities between the Tasmanian and New Caledonian plants, particularly their distinctive verrucose surface ornamentation, were overlooked is perplexing given that both species were authored or co-authored by Grolle and published in the same year (Grolle 1970, Váňa 1970). *Nardia huerlimannii* was placed in the new monotypic *Nardia* subgenus *Aponardia* R.M.Schust. by Schuster (2002), and though he too missed affinities with *Brevianthus*, he did state "I remain extremely skeptical that this can be retained in *Nardia*…" (Schuster 2002 p 360). *Nardia* subg. *Aponardia* was raised to generic rank, so removing *N. huerlimannii* from *Nardia*, by Váňa et al. (2012). Here we tranfer *Aponardia huerlimannii* to *Brevianthus* and provide the new combination. *Aponardia* (R.M.Schust.) Váňa and *Nardia* subgenus *Aponardia* R.M.Schust. follow their type species into synonymy of *Brevianthus* as a result of this transfer.

Nomenclature

Brevianthus J.J.Engel & R.M.Schust., Phytologia 47: 317. 1981.
Type: *Brevianthus flavus* (Grolle) J.J.Engel & R.M.Schust., Phytologia 47: 318. 1981.
= *Nardia* subg. Aponardia R.M.Schust., Nova Hedwigia Beiheft 119: 360. 2002, *syn. nov.*
≡ *Aponardia* (R.M.Schust.) Váňa, Phytotaxa 65: 46. 2012, *syn. nov.*
Type: *Nardia huerlimannii* Váňa & Grolle, Oesterr. Bot. Z. 118: 233. 1970.

Brevianthus huerlimannii (Váňa & Grolle) M.A.M.Renner & J.J.Engel, *comb. nov.*
≡ *Aponardia huerlimannii* (Váňa & Grolle) Váňa, Phytotaxa 65: 46. 2012.
Basionym: *Nardia huerlimannii* Váňa & Grolle, Oesterr. Bot. Z. 118: 233. 1970.
Type: New Caledonia, "… Pic Buse …, 500 m de la route vers la Montagne des Sources, 580 m," 30 Dec. 1950, *Hürlimann 2227* (holotype: Z; isotype: PRC).

= *Brevianthus hypocanthidium* M.A.M.Renner & J.J.Engel, PhytoKeys 50: 46. 2015, *syn. nov.*
Type: New Caledonia, Province Sud, Mont Kouakoue, slightly west of base camp at helicopter landing site, without date, *E.A. Brown 2006/17* (holotype: NOU; isotypes: NSW, F).

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Molecular phylogenetics reveals a new species of *Prostanthera* from tropical Queensland with links to more southerly taxa

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Abstract

Prostanthera eungella B.J.Conn & K.M.Proft (Lamiaceae) is described as a new species from the South Kennedy botanical region of northern Queensland. Concatenated nuclear (ETS) and chloroplast (*trn*H-*psb*A) sequence data for 38 species of *Prostanthera* were analysed using maximum-likelihood and Bayesian-inference methods. These combined data recovered *P. eungella* as part of a polytomy that included *P. galbraithiae*, *P. howelliae*, and a *P. tallowa* + *P. lasianthos* clade. A detailed description, photograph of the holotype specimen, and distribution map of *P. eungella* are provided.

Introduction

The Eungella plateau, c. 80 km west of Mackay (Eungella 21° 7' 52.3"S, 148° 29' 30.5"E), Queensland (Australia), is an isolated, Carboniferous massif comprising intrusions of the Urannah volcanic complex. Reaching elevations of 950–1259 m, it has an annual average precipitation of 2240 mm, rarely falling as snow on the higher peaks. Vegetation changes rapidly from complex lowland rainforest in the east of the plateau through to grassy eucalypt woodland in the west.

There is growing evidence that the Eungella plateau represents a significant area of biotic endemism (Kitching and Ashton 2013, Low 1993). Many plant species are restricted to the plateau and its surrounds, with some endemic plants associated with endemic fauna (Forster and Sankowsky 1995), whereas others reach their geographic limit in this region (Rossetto *et al.* 2007).

The taxonomic status and phylogenetic relationship of plants of *Prostanthera* (Lamiaceae: Westringieae) occurring in the Eungella district, South Kennedy botanical region (*sensu* Anonymous 1975) of Queensland, have remained unclear since first collected in 1992. These collections were gathered from open eucalypt forests and from the margin of rainforest. They have been tentatively identified as *Prostanthera lasianthos* Labill., presumably based on their toothed leaves which are superficially similar. However, their inclusion in that geographically widespread, morphologically variable species complex of *P. lasianthos* represents a disjunction of more than 700 km north of the most northerly populations of this species. Although collections from near Eungella were morphologically distinct from any other known species of *Prostanthera*, its affinities were unclear because morphological similarities do not always co-vary with genetic differences. For example, a recent molecular phylogeny of *Prostanthera* (Wilson *et al.* 2012) found that *P. tallowa* B.J.Conn is sister to *P. lasianthos*, even though it has certain morphological features that suggested a strong similarity to *P. linearis* R.Br. (Conn and Wilson 2012). Therefore, both chloroplast and nuclear DNA data were used to investigate the affinities of the plants of *Prostanthera* occurring in the Eungella region.

Materials and methods

Taxon sampling

Forty-eight taxa of *Prostanthera*, representing 44 published species, were sampled for genetic analysis (Table 1), with 26 of these sequences being new to this study. The selection of the two outgroup species (*Hemigenia purpurea* R.Br. and *Westringia longifolia* R.Br.) was based on the known sister relationship between these species and *Prostanthera* (Wilson *et al.* 2012). The genetic samples were either collected specifically for this study, dried in silica gel and stored at 4°C, or were taken from dried herbarium vouchers. The *Prostanthera* species included were based on Wilson *et al.* (2012), as well as other unpublished analyses by these authors, to represent the known phylogenetic and morphological diversity of the genus.

Acquisition of sequences

Sequences stored in GenBank (http://www.ncbi.nlm.nih.gov/genbank/), as provided by Wilson *et al.* (2012), were included to supplement the sequences extracted in this study (Table 1). Silica dried leaf material was used as a source for plant cellular DNA extraction using the DNeasy Plant Mini kit protocol (Qiagen, Hilden, Germany). A MyCycler thermal cycler (BioRad Laboratories Inc., Australia) was used for PCR amplification. A reaction mix for PCR consisted of 2.5 µL of 10X NH_4 buffer, 1.2 µL of 2.4mM $MgCl_2$, 0.5 µL of each 0.25mM dNTP, 0.5 µL of each primer, 0.25 µL of BIOTAQ™ (Bioline, www.bioline.com) and 18.05 µL of H_2O. Genomic DNA (1 µL) was added to complete a reaction volume of 26 µL. Non-coding chloroplast sequence was amplified from the *trn*H-*psb*A intergenic spacer using primers trnH (GUG) (Tate and Simpson 2003) and psbAF (Sang *et al.* 1997). The *trn*H-*psb*A intergenic spacer was chosen because its relatively high proportion of informative sites means that it is commonly used in phylogenetic analyses at the interspecific level (Shaw *et al.* 2005). The fast-evolving non-coding nuclear external transcribed spacer (ETS) was amplified using the 18S-E (Baldwin and Markos 1998) and ETS-PROS2 (Wilson *et al.* 2012) primers. The PCR protocol used similar methods to those used by Wilson *et al.* (2012); although annealing temperature was set to 53°C for amplification of the *trn*H-*psb*A intergenic spacer. Clean-up and sequencing reactions were performed by Macrogen (Seoul, Korea), using BigDye® Terminator v3.1 Cycle Sequencing Ready Reaction Kits and an Applied Biosystems 3730xl DNA Analyzer (ABI Biosystems, www.appliedbiosystems.com).

Double-stranded DNA consensus sequences were assembled using Sequencher® 4.5 (Gene Codes Corporation). A base in the ETS marker that was ambiguous due to overlapping base peaks was coded as polymorphic rather than uncertain. MUSCLE (Edgar 2004) on the CIPRES portal (Miller 2010) was used for sequence alignment after which BioEdit 5.0.9 (Hall 1999) was used for final editing. A concatenated alignment of the *trn*H-*psb*A intergenic spacer and ETS datasets was completed using Sequence Matrix (Vaidya *et al.* 2011).

Analyses

Maximum likelihood (ML) analyses were performed using RAxML-HPC2 version 8 (Stamatakis 2006, 2014) and Bayesian inference analyses were performed with MrBayes version 3.2.4 (Huelsenbeck and Ronquist 2001) on the CIPRES portal (Miller 2010). RAxML implements the GTR+Γ model in ML analyses. Maximum Likelihood analysis used a 1000-replicate bootstrap to estimate nodal support. For Bayesian analyses, substitution models for each partition were unlinked, and the number of substitution types was set to 6 and the rate variation across sites was set as gamma-distributed. Default program settings specified *a priori* probabilities for other parameters. For each analysis, two independent Metropolis coupled MCMC were run, each with one heated and three cold chains run, for 5 million generations and sampled every 1000th generation. Log likelihood scores were plotted using Tracer v1.6 (Rambaut *et al.* 2014) to estimate the burn-in duration (30000 generations). A majority-rule consensus constructed from the total 10000 trees from Bayesian analysis, as well as bootstrap values from ML analyses, were visualized using FigTree v1.4.0. (http://tree.bio.ed.ac.uk/). Posterior probability (PP) values of ≥ 95% (Larget and Simon 1999) and bootstrap (BS) values of ≥ 75% were considered as significant support.

Table 1. Chloroplast (*trn*H-*psb*A) and nuclear (ETS) markers amplified for species of *Prostanthera*, *Hemigenia purpurea* and *Westringia longifolia* (Westringeae: Lamiaceae). GenBank accessions are given for each marker. *H* = *Hemigenia*; *P* = *Prostanthera*; *W* = *Westringia*; * = new accessions for this study

Taxon	Collection details	*trn*H-*psb*A	ETS
H. purpurea	Wilson 122	–	JX047602
*P. albohirta**	Ford 6174	KU563336	KU532856
*P. althoferi**	Wilson 271	KU563337	KU532857
*P. althoferi**	Wilson 360	KU563338	KU532858
*P. ammophila**	Te 854	KU563339	KU532859
P. askania	Anon. AB873115	–	JX047626
*P. athertoniana**	Ford 1835	KU563340	KU532860
*P. baxteri**	Wilson 380	KU563341	KU532861
P. caerulea	Anon. AB790000	–	JX047647
*P. campbellii**	Perkins WA101	KU563342	KU532862
*P. canaliculata**	Hislop, Davis, Mills 178–7	KU563343	KU532863
*P. centralis**	Wilson 417	KU563344	KU532864
*P. clotteniana**	Ford 5982	KU563345	KU532865
P. cruciflora	Wilson 13	–	JX047631
P. densa	Wilson 173	KF145103	KF112049
P. denticulata	Wilson 241	–	JX047679
*P. eckersleyana**	Horn 2508	KU563346	KU532866
*P. eungella**	McDonald 5131	KU563347	KU532867
P. galbraithiae	Conn 5222	–	JX047667
P. granitica	Wilson 162	KU563349	JX047639
P. hindii	Washington 98/3	–	JX047645
P. hirtula	Wilson 170	–	JX047648
P. howelliae	Wilson 135	–	JX047644
*P. laricoides**	Edinger 6582	KU563351	KU532868
*P. lasianthos Grampians**	Conn 5311	KU563352	KU532869
*P. lasianthos Mt Field**	Henwood 864	KU563353	KU532871
P. lasianthos Mt Tomah	Wilson 44	KU563354	JX047663
*P. lasianthos Mt Wilson**	Proft 3	KU563355	KU532870
P. linearis	Wilson 137	–	JX047666
P. marifolia	Conn 4380	KF145108	JX047657
*P. mulliganensis**	Clarkson 5241	KU563356	KU532872
P. nivea	Wilson 61	KU563357	JX047651
*P. nudula**	Latz 24527	KU563358	KU532873
*P. patens**	Markey & Dillon 3715	KU563359	KU532874
P. phylicifolia	Wilson 107	–	JX047643
P. porcata	Wilson 106	–	JX047613
*P. prostantheroides**	Wilson 333	KU563360	KU532875
P. prunelloides	Wilson 113	–	JX047650
P. rhombea	Wilson 123	–	JX047637
P. ringens	Wilson 153	–	JX047605
*P. scutata**	Porter 320	KU563362	KU532876
P. scutellarioides	Wilson 110	–	JX047642
*P. serpyllifolia subsp. microphylla**	Byrne 3929	KU563363	KU532877
*P. serpyllifolia subsp. serpyllifolia**	Pigott *s.n.*	KU563364	KU532878
P. striatiflora	Johnstone *s.n.*	–	JX047676
P. tallowa	Wilson 234	KF692284	JX047664
*P. tallowa**	Wilson 236	KF563365	KU532879
*P. verticillaris**	Wilson 388	KU563366	KU532880
*P. violacea**	Wilson 401	KU563367	KU532881
*W. longifolia**	Wilson 458	KU563368	KU532882

Results

Data statistics

The total length of the *trn*H-*psb*A alignment was 482 characters. Several regions could not be aligned unambiguously, and were excluded from analysis. The final alignment consisted of 379 sites, of which 31 (8% of total alignment) of 74 variable sites were parsimony informative. The ETS alignment of 430 sites also contained regions that could not be aligned unambiguously. These regions were excluded from the final alignment that consisted of 358 sites, of which 164 were parsimony-informative sites (45.8% of total alignment) out of 241 variable sites. A test for compositional homogeneity using a Chi-square test revealed that the *trn*H-*psb*A alignment ($\chi^2 = 14.5$; $p = 1.0$; A = 35.4, C = 12.3, G = 17.0, T = 35.3) and the ETS alignment ($\chi^2 = 50.4$; $p = 1.0$; A = 25.2, C = 28.6, G = 27.6, T = 19) did not significantly deviate from compositional homogeneity.

Tree topology

The phylogeny obtained by the analysis of the combined *trn*H-*psb*A intergenic spacer and ETS (Fig. 1) agrees broadly with that recovered from the three-marker dataset of Wilson et al. (2012). Our results depict a well-supported clade (Bayesian posterior probabilities (PP) 1.0; Bootstrap (BS) 91%) congruent with clade 'C' of Wilson et al. (2012), and confirms a sister relationship between the narrow endemic *P. tallowa* and a broad geographic representation of *P. lasianthos s. str.* However, unlike the phylogeny of Wilson et al. (2012), which used different chloroplast markers and showed a strongly supported *P. lasianthos s. str.* clade, our results gave relatively weak support for a monophyletic *P. lasianthos s. str.* clade (PP = 0.88; BS = 69%). Our single accession of *Prostanthera* from the Eungella region of Queensland (as *P. eungella sp. nov.*) was placed outside *P. lasianthos s. str.* in a polytomy with *P. galbraithiae* B.J.Conn, *P. howellii* Blakely *s. str.*, and the *P. tallowa* + *P. lasianthos s. str.* clade. It had a weakly supported sister relationship (BS = 65%) with the *P. tallowa* + *P. lasianthos s. str.* clade.

Our analysis indicates clearly that our sample of *P. eungella* is not a component of the geographically widespread and morphologically variable *P. lasianthos* species complex. *Prostanthera galbraithiae* and *P. howelliae* have consistently formed a sequential sister relationship with a clade comprising *P. tallowa* and *P. lasianthos s. str.* (Wilson *et al.* 2012). Although all of these taxa, together with *P. eungella*, form a well-supported clade in this phylogeny (PP = 1.0; BS = 91%), the precise phylogenetic relationships within this clade remain to be resolved. Regardless of the true phylogenetic relationship amongst *P. galbraithiae*, *P. howelliae* and *P. eungella*, it is clear that the latter is not part of a clade comprising the nominant form of *P. lasianthos*, and nor is it morphologically similar to *P. galbraithiae* or *P. howelliae*.

Discussion

The fauna and flora of the Eungella rainforest and fringing open *Eucalyptus* forests consists of several unique elements as well as widespread species that are conspicuous by their absence (Winter and McDonald 1986). There are several faunal species that have their northern limits in this area, such as the Regent Bowerbird, the Golden-crowned snake, the Dwarf Crowned snake, the Tusked Frog, the Great Barred Frog, and several skinks. Examples of northern faunal species with their southern limits in the Eungella region include the Buff-breasted Paradise Kingfisher, the White-browed Robin, and the *Lampropholis basiliscus* skink (all taken from Winter and McDonald 1986). Species of trees have similar geographical patterns to those of the fauna. For example, *Syzygium resa* (B.Hyland) Craven & Biffin (Craven *et al.* 2006) and *S. wesa* B.Hyland (Hyland 1983) have their southern limits in the Eungella area (Craven *et al.* 2006). In contrast, *Eucalyptus andrewsii* Maiden and *E. campanulata* R.T.Baker & H.G.Sm. reach their northern limit in this region, and both form part of the floristic association from which *P. eungella* has been collected. Other northern species with limits in the Eungella area include: *Bleasdalea bleasdalei* (F.Muell.) A.C.Sm. & J.E.Haas (Weston 1995, as *Gevuina bleasdalei* F.Muell.), and *Cryoptocarya corrugata* C.T.White & W.D.Francis and *C. murrayi* F.Muell. (Hyland 2007). Southern species of Lauraceae that have their northern limits at Eungella include *Cryptocarya glaucescens* R.Br. (Hyland 2007) and *C. macdonaldii* B.Hyland (Hyland 1989).

Prostanthera eungella has phylogenetic affinities with more southern elements of the genus (Fig. 1), rather than with the more northern species *P. albohirta* C.T.White, *P. athertoniana* B.J.Conn & T.C.Wilson, *P. clotteniana* (F.M.Bailey) A.R.Bean and *P. mulliganensis* B.J.Conn & T.C.Wilson (none of which nest within clade 'C', Wilson *et al.* 2012, Fig. 1). When considering only the phylogenetic affinities amongst *P. galbraithiae, P. howelliae* and *P. eungella*, the Eungella accession could be considered as being part of a more broadly circumscribed *P. galbraithiae* or *P. howelliae*. Although these species, together with *P. eungella*, form a well-supported clade (PP = 1.0; BS = 91%), the sister relationships of *P. eungella* are unclear.

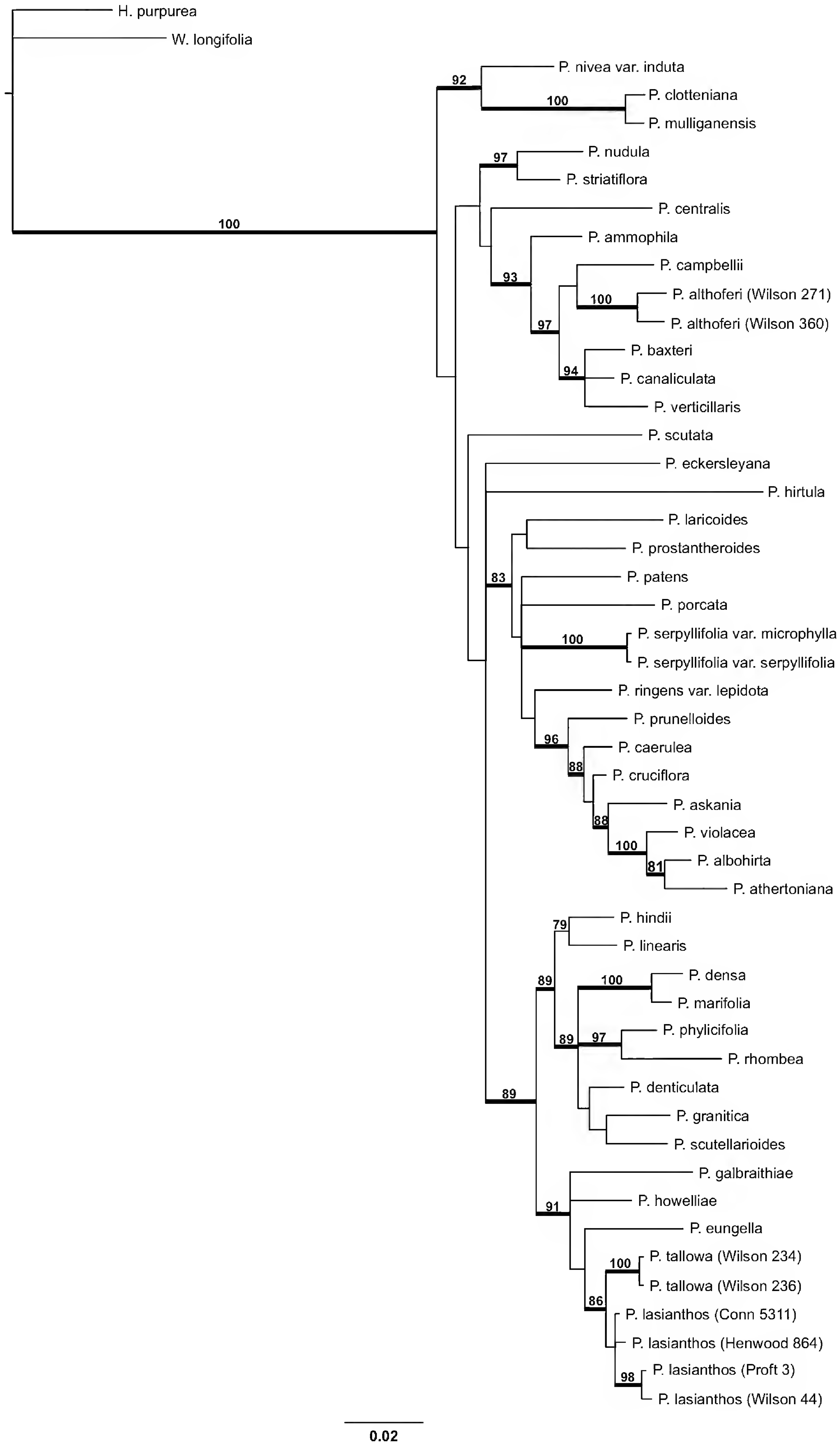

Fig. 1. 50% majority rule phylogram from Bayesian analysis of the concatenated *trn*H-*psb*A and ETS sequence data for *Prostanthera* including *Hemigenia purpurea* and *Westringia longifolia* as outgroup representatives. Bayesian analysis posterior probabilities of >0.95 from Mr Bayes are reported as thickened branches and Maximum likelihood bootstrap values ≥75% are reported above branches.

Prostanthera galbraithiae is restricted to heathy open forest and heathy woodland of the Gippsland Plains, Victoria (Conn 1998, 1999), and is characterised by having sessile, very narrowly ovate or oblong leaves that are more or less strongly revolute; corolla deep mauve to purple, with maroon dots at base of lobes and in mouth and throat, with an abaxial median lobe approximately the same width as the lateral lobes, and distinctly papillate anthers that lack an appendage. In contrast, *P. howelliae s. str.* (referred to as '*P. howelliae*-2' in Wilson et al. 2012) ranges from Gippsland (Victoria) to northern New South Wales in dry woodlands. It is characterised by narrowly ovate leaves with an entire, recurved margin, and short petioles (c. 0.1 mm long); anthers lacking an appendage, but each loculus has a basal tuft of coarse hairs; pink-mauve to purple-mauve corolla, with dark red, maroon or purple dots in throat, with an abaxial median lobe broader than the lateral lobes. Wilson et al. (2012) refer to a second accession of *P. howelliae* (as '*P. howelliae*-1') from the Goonoo State Forest (New South Wales) which has larger leaves than the nominant form. The phylogenetic affinities of this accession are with *P. descussata* and *P. granitica*. Since the taxonomic status of the Goonoo taxon has not been fully resolved, it was not included in the current study,

Prostanthera eungella is readily morphologically separable from *P. galbraithiae* and *P. howelliae* by its longer petioles (4 mm), toothed leaf margin, mostly white to pale mauve corolla, and anther appendages 2–2.3 mm long. On the basis of morphological differences and phylogenetic relationships we here describe as new, *P. eungella* to accommodate accessions of *Prostanthera* from the Eungella region of Queensland.

Taxonomy

Prostanthera eungella B.J.Conn & K.M.Proft, **sp. nov.**

Holotype: Australia: Queensland: South Kennedy: Swamp Ridge Road, c. 6.7 km NW of Eungella township, *W. McDonald 5131 & A.R. Bean, 24 May 1992* (NSW452207!); iso: AD, BRI-AQ543531!, CANB, K, MEL.

Erect shrub up to c. 1 m high. *Branches* subterete (slightly flattened laterally), with shallow lateral grooves within each axil to the next upper node, sparsely to moderately hairy [20–25 hairs/mm^2], particularly between lateral grooves and at nodes; hairs mostly antrorse, subappressed, ± straight, 0.05–0.2 mm long, white; moderately glandular [20–30 glands/mm^2]. *Leaves* dark green above, paler below, glabrous, except hairs restricted to midvein of adaxial surface (hairs retrorse or spreading, less frequently antrorse, subappressed, ±straight, up to 0.2 mm long), moderately glandular [20–50 glands/mm^2] (glands more distinctive on abaxial surface), aromatic (when crushed); *petiole* 4 mm long; *lamina* narrowly ovate, 39.5–44.5 mm long, 10.5–11.5 mm wide [length to width ratio 3.7–3.9, length of maximum width from base to total lamina length ratio 0.2–0.3]; base cuneate, slightly oblique; margin with up to 6 teeth (teeth mostly on distal half of margin, ± directed forward, 0.5 mm long, 0.5(–1) mm wide at base); apex attenuate; venation indistinct to faint, midrib slightly raised on abaxial surface. *Inflorescence* frondose, unbranched to 1-branched, hence conflorescence uni- or dibotryoidal; uniflorescence botryoidal; 6–20(–40)-flowered [per conflorescence]. *Pherophylls* not persistent, narrowly ovate, abruptly tapering at apex, c. 2 mm long. *Pedicel* 2–4 mm long, glandular, glabrous or often with scattered hairs. *Prophylls* persistent, inserted just below the calyx [a_1 axis to anthopodium ratio c. 4], opposite, linear, 1.5 mm long; base tapering; margin entire, usually partially fringed with hairs; apex attenuate; venation not visible. *Calyx* green; outer surface glabrous or with an occasional hair, densely glandular; inner surface glabrous except near margin of lobes densely hairy [at least 200 hairs/mm^2], sometimes ± restricted to near margin; hairs antrorse, appressed, white, c. 0.1 mm long; *tube* 2.5–3 mm long; *abaxial lobe* 2–2.5 mm long, apex rounded; *adaxial lobe* c. 2 mm long, apex rounded. *Corolla* 10–12 mm long, white in tube, mauve distally with dull orange tinge; outer surface glabrous basally, moderately to densely hairy distally [20–60 hairs/mm^2], hairs 0.3–0.6 mm long, spreading to antrorse, straight to slightly curled, moderately to densely glandular; inner surface glabrous basally, mouth and base of lobes (sometimes throughout) sparsely hairy [16–20 hairs/mm^2], hairs 0.2–0.4 mm long; *tube* 5.5 mm long; *abaxial median lobes* broadly spathulate, 6–8 mm long, c. 7 mm wide [length to width ratio 0.9–1.1], apex irregular and rounded, bilobed (sinus c. 1 mm long); *lateral lobes* oblong to slightly obovate, 4.5 mm long, 2.5 mm wide, apex slightly irregular, rounded to slightly retuse; *adaxial median lobe-pair* depressed ovate c. 4.5 mm long, c. 7.5 mm wide [length to width ratio c. 0.6], apex rounded, irregular, bilobed (sinus 1–1.5 mm long). *Stamens* with filaments 4–4.5 mm long, anthers c. 1 mm long, connective extended to form 1 basal appendage 2–2.3 mm long. Disc c. 0.4 mm long. *Pistil* 7–9 mm long, often glandular; *ovary* cylindrical obovoid, 0.4–0.6 mm long, diameter at base 0.2–0.4 mm, lobes 0.1–0.2 mm long; *style* 7.5–10.5 mm long; *stigma lobes* 0.4–0.7 mm long. *Fruiting calyx* slightly enlarged (abaxial lobe up to c. 3.5 mm long; adaxial lobe 2.5–3 mm long. *Mature mericarps* not seen. **Fig. 2**

Distribution: Known only from the Eungella region, west of Mackay, northern Queensland. **Fig. 3**

NATIONAL HERBARIUM OF N.S.W

Prostanthera eungella
B.J.Conn & K.M.Proft
HOLOTYPE
DETERMINAVIT Barry J. Conn 9 Sept. 2015

EX QUEENSLAND HERBARIUM (BRI)
Flora of Queensland South Kennedy
Prostanthera lasianthos Labill.
Coll. W.J.Mc.Donald 5131 24 MAY 1992
+A.R.Bean
21°05'S 148°20'E Alt. 1000 m.
Depth m.
Swamp Ridge Road, c. 6.7km NW of Eungella township.
Hillalong 8555-505677.
Open-forest of Eucalyptus campanulata, E. intermedia with lower tree layer of Allocasuarina littoralis.
A shrub to c. 1m high. Flowers mauve, throats white tinged with orange.
Locally common.

Det.
Dups. NSW MEL CANB K AD Labiatae
*May be cited as computerised collection number AQ 543531

Fig. 2. Photograph of holotype of *Prostanthera eungella* B.J.Conn & K.M.Proft (held at NSW).

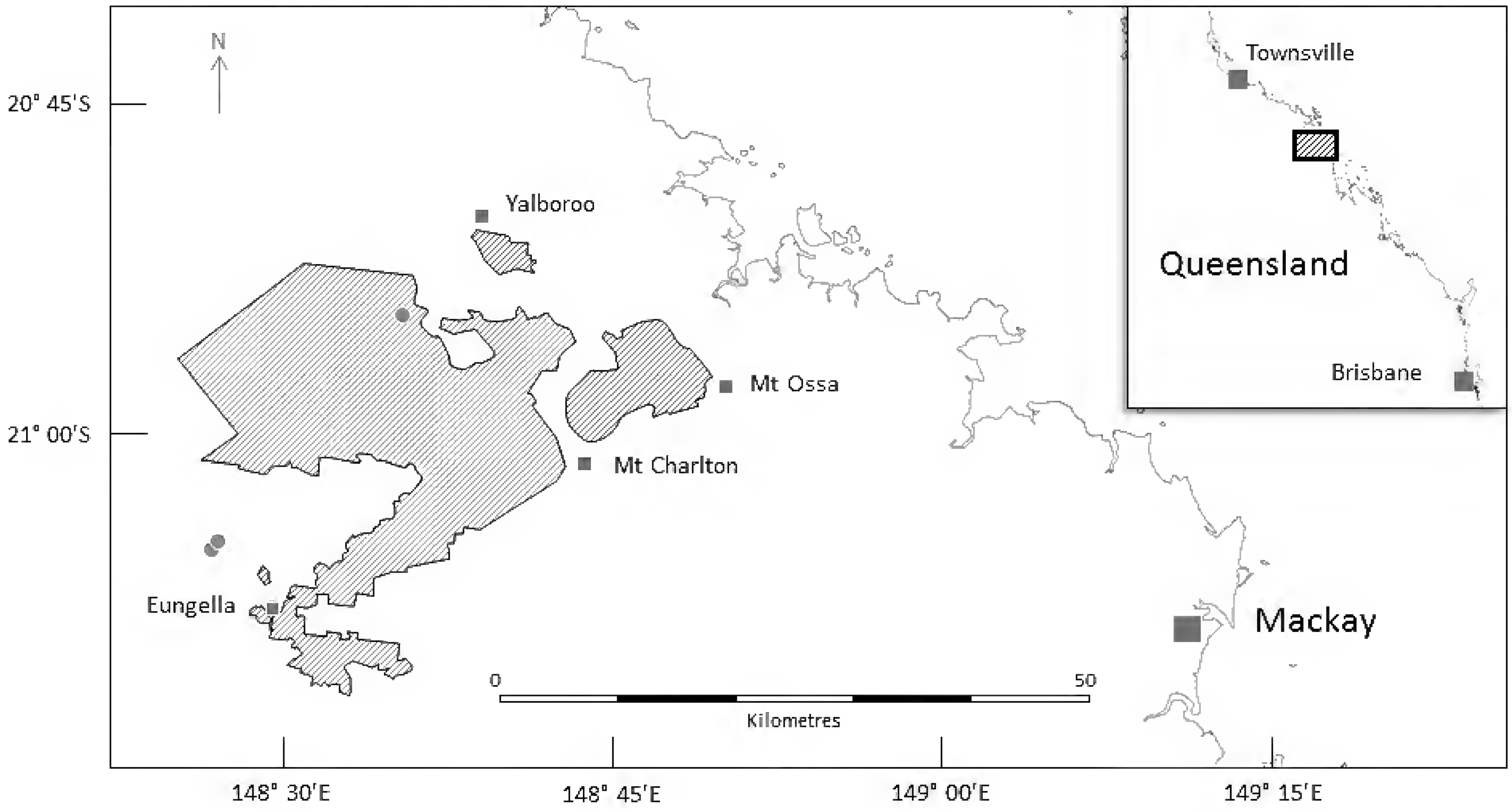

Fig. 3. Distribution map of *Prostanthera eungella*, west of Mackay, South Kennedy region, Queensland. The current known localities of *P. eungella* are marked by red dots. The Eungella National Park boundary is outlined and shaded with green hatching.

Habitat: Open-forest of *Eucalyptus campanulata* R.T.Baker & H.G.Sm., *Corymbia intermedia* (R.Baker) K.D.Hill & L.A.S.Johnson with lower tree layer of *Allocasuarina littoralis* (Salisb.) L.A.S.Johnson; altitude 1000 m (*McDonald 5131*); *Eucalyptus andrewsii* Maiden open forest on dark brown loam-clay on granite (*Pollock 222*); and edge of rainforest (*Foreman AE110*); grassy to layered open forest with *Glochidion ferdinandi*, *Kennedia rubicunda*, Poaceae, *Pteridium*, *Rubus*, on grey brown gravelly loam clay on metamorphosed granite (*Bruhl 3199*).

Flowering/fruiting: recorded as flowering in May and December, and fruiting in December.

Additional specimens: QUEENSLAND: South Kennedy: W Eungella Range, Schumanns Road, c. 1.1 km E of Swampy Ridge radar installation, *A.B. Pollock 222*, 25 Jun 1995 (BRI-AQ639028); Eungella National Park: Peak 996, Dicks Tableland, near Eungella, *P. Foreman AE110*, 26 Dec 1993 (BRI-AQ632038); NE of Eungella, beyond Schumanns Road, S of radar installation, *J.J. Bruhl 3199 & C.J. Prychid*, 12 Dec 2012 (NE99199).

Etymology: The specific epithet refers to the Eungella area of Queensland where this species is known to occur.

Conservation status: Data deficient: recorded as scarce (*Pollock 222*), assumed to be afforded some protection since recorded from the Eungella National Park.

Acknowledgments

We thank the curator and staff of the Queensland Herbarium (BRI) for allowing Barry Conn and Trevor Wilson the opportunity to examine their *Prostanthera* collections. Andrew Ford (CSIRO, Atherton, Queensland) generously provided silica gel dried material of the northern Queensland species of *Prostanthera* included in this study. Kirstin Proft was supported by the *Australian Biological Resources Study* (ABRS) grant CH210-16. Trevor Wilson was supported by the *Australian Biological Resources Study* (ABRS) grant RFL212-43 and the *Hansjörg Eichler Award* (Australasian Systematic Botany Society Inc.).

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Piper rukshagandhum (Piperaceae): a new species from southern Western Ghats, India

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Abstract

Piper rukshagandhum J.Mathew is described as a new species from the Achankovil forest, Kerala section of the southern Western Ghats, India. The diagnostic morphological characters, distribution, conservation status and colour images of the new species are presented. The significance of this newly discovered species in breeding programs of black pepper is also briefly discussed. A key to *Piper* from the southern Western Ghats is provided.

Introduction

Piper L. (Piperaceae) consists of approximately 1,300 species in the Neotropics with another 700 species distributed in the Old World tropics (Quijano-Abril et al. 2006). In India, *Piper* is represented by more than 100 species, most of which (65 species) are confined to the northeastern region. Evergreen forests of the southern Western Ghats also form a significant centre of diversity for *Piper*, with 18 taxa (17 species and two subspecies; see key for full list) reported from the Kerala region of the Western Ghats (Sasidharan 2013). Among these taxa, 10 are local endemics with one species categorized as critically endangered (IUCN 2012).

Floristic studies of the Achankovil forests in the Agasthyamala Biosphere Reserve, southern Western Ghats, conducted between 2009–2014, have uncovered several interesting specimens from the genus *Piper*. Study of literature and herbarium specimens revealed that some of these *Piper* specimens do not belong to any described species. This has resulted in the recognition of a novel species here described as *Piper rukshagandhum* J.Mathew.

Taxonomic treatment

Piper rukshagandhum J.Mathew, ***sp. nov.***

Diagnosis: *Piper rukshagandhum* differes from all *Piper* species except *P. velaudhanii* E.S.S.Kumar & S.P.Mathew by the colour of the spike and overall appearance. It differs from *P. velaudhanii* in having glabrous recurved receptacles (versus pubescent and straight), petioles to 3 cm long (versus to 1.5 cm long), unequal leaf base and long acuminated leaf tip (versus rounded leaf base and short acuminated leaf tip), smaller leaf size of 8-16 x 6-9 cm (versus 15-22 x 10-15 cm), pinkish young nodes (versus yellow to greenish coloured young nodes), blush red/pink coloured spike (versus greenish purple coloured), green fruit with pink apex (versus green fruit including apex) and its strong pungency (versus very weak pungency).

Type: India: Kerala: Kollam District, Kottavasal Valley, 77° 08' 11"E, 09° 13' 06"N, alt. 700 m, *J. Mathew 2811* (flowering: female), 28 Feb 2011 (holo: MH; iso: CMS).

A branched, evergreen dioecious, woody climber. Stem terete, glabrous, rooting at nodes; nodes swollen, young nodes pinkish in colour; internodes 1–7 cm long, slender, glabrous, green and slightly angular when young, brown and woody with lenticels at maturity. Leaves alternate; petioles 2–3 cm long; lamina 8–16 cm long, 6–9 cm wide, very broadly ovate, coriaceous and glabrous on both surfaces, apex long acuminate, base not equal, coriaceous, margin entire, venation pinnate with 2(3) prominent veins, all arising from the base or near it. Inflorescence a spike, leaf-opposed, solitary, pendulous. Male inflorescence 15 cm long, 100–120 flowered, blush red/pink in colour; peduncle 1.5–2.5 cm long, glabrous; receptacle sessile, globose, glabrous, parallel to the axis, recurved; bracts adnate to the axis, recurved, transformed into a fleshy cup with narrow slit-like mouth, glabrous. Male flower: stamens 2, short, 0.3–0.5 mm long; filaments thick, glabrous; anthers 2-celled, dehiscing through apical longitudinal slit. Female inflorescence 3–7 cm long, 16–22 flowered, blush red/pink in colour; peduncle 1.5–2.5 cm long, glabrous; receptacle sessile, globose, glabrous, parallel to the axis, recurved; bracts adnate to the axis, recurved, transformed into a fleshy cup with narrow slit like mouth, glabrous. Female flower: carpel 1; ovary globose, sessile; stigmas 4, white, sessile. Fruit a drupe, 6–8 mm long and wide, globose, sessile, green and apically purple -when young, red when ripe. Single seed. Figs 1-3.

Phenology: Flowering in November–December; fruit develop in December and mature in May.

Etymology: The specific epithet is derived from the Sanskrit *rukshagandha* which means pungency in reference to the very pungent fruit.

Conservation status: Field surveys have located about 20 individuals within the Kottavasal valley of the Achankovil forests covering an area of 2 km^2. This data was evaluated according to the IUCN categorization (IUCN 2012) and indicates that at least 'Critically Endangered' status would be appropriate for the species. Apart from habitat destruction caused by wild fires, no other specific threats where determined during the field studies.

Habitat: *Piper rukshagandhum* is a climber that grows on the edges of riverine valleys of the Agasthyamala Biosphere Reserve. Trees that provide support for *P. rukshagandhum* are *Elaeocarpus variabilis* Zmarzty and *Chionanthus mala-elengi* (Dennst.) P.S.Green subsp. *mala-elengi* which are both endemic to peninsular India. Common associates are *Oxyceros rugulosus* (Thwaites) Tirveng., *Eugenia mooniana* Wight and *Calamus gamblei* Becc., of which, *C. gamblei* is endemic to Western Ghats while the former two associates are Indo-Sri Lankan elements.

Additional specimen examined: INDIA: KERALA: Kollam District, Vellakkaltheri, 77° 14' 06"E, 09° 11' 24"N, alt. c. 1200 m, *J. Mathew 2793* (male) *& 2794* (female), 28 Nov 2011 (School of Environmental Sciences Herbarium, Kottayam, M.G. University, Kerala).

Relationships: Based on morphological characters *Piper rukshagandhum* is considered a member of section *Muldera* as proposed by Hooker (1886). Members of this section are dioecious and possess fleshy bracts. In the Flora of British India, Hooker placed five species within this section namely *P. galeatum* Cas., *P. maingayi* Hook.f., *P. pachyphyllum* Hook.f., *P. schizonephros* C.DC., and *P. trichostachyon* (Miq.) C.DC. Recently, Lekhak et al. (2012, 2014) included two additional species *P. relictum* Lekhak, Kambale & S.R.Yadav and *P. dravidii* Lekhak, Kambale & S.R.Yadav within the section, both restricted to high altitude lateritic plateaus of northern Western Ghats, India. *Piper trichostachyon* (Miq.) C.DC. was reported from peninsular India while *P. galeatum* Cas. is endemic to southern Western Ghats. However, the remaining species *P. maingayi, P. pachyphyllum* and *P. schizonephros* have not been recollected in India (Lekhak 2014).

Piper rukshagandhum is distinguished from other members of section *Muldera* by characteristic blush red/pink coloured spikes, fruit and internodes (Figs 1-3). Apart from these characters, this new species has a comparatively long petiole (c. 3 cm long) and an elongated male inflorescence (c. 15 cm long) (Fig. 3a, c). Ravindran (1990) noted that *P. nigrum* may have a hybrid origin suggesting *P. galeatum* and *P. trichostachyon* are putative parents. The fruits of these species have moderate pungency and flavor, while, *P. rukshagandhum* has large, strongly pungent fruit, and coupled with its ability to withstand dry wind and drought conditions will offer scope for improving the gene pool and may serve as suitable candidate for the future breeding program of *Piper* species.

Fig. 1. *Piper rukshagandhum*: **a,** flowering female spike, **b** flowering and fruiting female spike. Photos: J. Mathew (*Mathew 2793*).

Fig. 2. *Piper rukshagandhum* **a,** infructescence; **b,** mature fruit. Photos: J. Mathew (*Mathew 2811*).

Fig. 3. *Piper rukshagandhum* **a,** male spikes; **b,** leaf adaxial surface; **c,** leaf abaxial surface (note length of petiole); **d,** young leaf and pink nodes; **e,** woody stem. Photos: J. Mathew (*Mathew 2794*).

Key to *Piper* species from the Kerala region of southern Western Ghats

1 Spike upright cylindrical 2

1: Spike drooping, slender or erect 4

2 Leaves usually cordate or strongly oblique at base; spike non-conical towards tip .... *P. longum*

2: Leaves obtuse, oblique at base; spike conical towards tip 3

3 Vines up to 3 m long; spike to 6–9 cm in length; reddish tinge present the petiole and peduncle .... *P. colubrinum*

3: Vines up to 0.50 m long; spike to 4 cm in length; pale reddish tinge rarely present in petiole and peduncle .... *P. chaba*

4 Peduncle 6-8 cm long; leaves with 6 lateral nerves .... *P. barberi*

4: Peduncle to 4 cm long; leaves with 3, 5 or 7 lateral nerves 5

5 Bracts hooked at one side; fruits beaked .... *P. wightii*

5: Bracts not hooked; fruits not beaked 6

6 Spike purple or blush red in colour 7

6: Spike green or yellowish white in colour 8

7 Receptacle recurved; fruit mostly green but apex pink .... *P. rukshagandhum*

7: Receptacle straight; fruit green .... *P. velaudhanii*

8 Infructescence to 0.7 cm long .... *P. mullesua*

8: Infructescence 2.5–15 cm long 9

9 Plant bisexual .... *P. silentvalleyense*

9: Plants unisexual 10

10 Spikes with hairs 11

10: Spikes glabrous 12

11 Receptacles sessile, pubescent, parallel to the axis, compact shaped; plants not hairy .... *P. trichostachyon*

11: Receptacles stipitate, kidney-shaped, glabrous, right angle to the axis, distant and recurved; plants hairy .... *P. hymenophyllum*

12 Spikes more than 15 cm long .... *P. argyrophyllum*

12: Spikes less than 12 cm long 13

13 Leaves deeply cordate at base 14

13: Leaves round or acute at base 15

14 Lamina 6–12 x 3–6 cm, ovate, cordate at base, puberulous along the nerves beneath .... *P. hapnium*

14: Lamina 12–20 x 6–11 cm, ovate, rounded or shallowly cordate and slightly asymmetrical at the base, no pubescence along the nerves .... *P. betle*

15 Receptacle recurved, flowers distant .... *P. galeatum*

15: Receptacle straight, flowers compactly arranged 16

16 Lateral nerves of leaves 5 .... *P. schmidtii*

16: Lateral nerves of leaves 7 17

17 Flowering spike filiform, up to 20 cm long; fruits not pungent .... *P. trioicum*

17: Flowering spike compact, up to 12 cm long; fruits pungent 18

18 Mature fruit about 0.8 cm in diameter .... *P. nigrum* var. *hirtellosum*

18: Mature fruit about 0.4 cm in diameter .... *P. nigrum* var. *nigrum*

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A new species of *Micarea* (lichenized Ascomycota, Pilocarpaceae) from alpine Australia

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Abstract

Micarea argopsinosa sp. nov. (lichenized Ascomycota, Pilocarpaceae) is described from sheltered granite below the summit of Mt Ginini in the Australian Capital Territory. It has a thin, diffuse, greyish green thallus containing only argopsin, solitary or clustered, jet-black, convex apothecia with a K– and C– hymenium and a hyaline hypothecium, comparatively small 3-septate ascospores, and narrowly oblong to filiform, straight, curved or arcuate macroconidia with (1–)3-septa. A key is provided to distinguish the new species from broadly similar taxa known from Australia and elsewhere.

Introduction

The cosmopolitan but predominantly temperate lichen genus *Micarea* Fr. (Pilocarpaceae) includes approximately 100 species, occurring mainly on acidic bark, rock and soil. Thalli are crustose and effuse, granular or areolate, with or without soredia, and they contain diagnostic photobiont cells that are comparatively small and thin-walled (micareoid). The ascomata are usually adnate to sessile and immarginate, lack a thalline exciple, have a hyphal proper exciple, an amyloid hymenium, simple or branched paraphyses with scarcely swollen apices, a distinctive ascus apex structure (see below) and colourless, simple to transversely septate ascospores. Other informative characters include a small array of thalline chemical substances, as well as apothecial pigments and up to three types of conidia (Coppins 1983, 2009; Coppins and Kantvilas 1990; Czarnota 2007; Galloway 2007; Brand *et al.* 2014).

Twenty-one species of *Micarea* have been reported from Australia (Coppins and Kantvilas 1990; Coppins 2009; McCarthy 2015), and while the genus is known to be particularly diverse in Tasmania, the Tasmanian lichen flora includes many undescribed or unrecorded species (Kantvilas *et al.* 2008).

Among several discrete but informal species groups recognised by Coppins (1983) and expanded subsequently, the *M. lignaria-M. ternaria* group has solitary or clustered, jet-black, convex apothecia with a K– and C– hymenium and a usually hyaline hypothecium, as well as 3(–7)-septate ascospores. Thalli can contain alectorialic acid, gyrophoric acid, argopsin or they can lack lichen substances. In this contribution, a new and very distinctive species is described from alpine granite in the southern Australian Capital Territory (A.C.T.), and while it is compared with other known species of the *M. lignaria-M. ternaria* group, there are indications that the Australian lichen flora includes other similar, but as yet undescribed taxa.

Methods

Observations and measurements of photobiont cells, thallus and apothecium anatomy, asci, ascospores and conidia were made on hand-cut sections mounted in water and treated with 10% potassium hydroxide (K) and 50% nitric acid (N). Asci were also observed in Lugol's Iodine (I), with and without pre-treatment in K. Chemical constituents were identified by thin-layer chromatography (Elix 2014) and comparison with authentic samples.

New Species

Micarea argopsinosa P.M.McCarthy & Elix, **sp. nov.**

MycoBank No.: MB 815597

Characterised by a thin, diffuse, greyish green saxicolous thallus containing only argopsin, solitary or clustered, jet-black, convex apothecia with a K– and C– hymenium and a hyaline hypothecium, comparatively small 3-septate ascospores of 10–14.5 × 3–5 µm, and narrowly oblong to filiform, straight, curved or arcuate macroconidia that are (1–)3-septate and 10–19 × 1–1.5 µm.

Type: AUSTRALIA. Australian Capital Territory: Namadgi Natl Park, Mt Ginini, 35°31'47"S, 148°46'41"E, alt. 1665 m, on sheltered granite on scree slope, *P.M. McCarthy 4181*, 10 Dec 2013; holotype: CANB.

Thallus crustose, epilithic, diffuse, continuous or of scattered or contiguous areoles, pale greenish grey to medium or dark greyish green, c. 0.05–0.1(–0.14) mm thick, forming colonies 2–8 mm wide interspersed among the thalli of other, more robust crustose lichens. Areoles angular or irregular, occasionally somewhat rounded, plane to slightly but unevenly convex, 0.4–1.4 mm wide; surface dull, scurfy-granular to verruculose or minutely subpapillose, ecorticate, but with a discontinuous, 8–20 µm thick hyaline necral layer. *Algal layer* continuous or not, 40–80 µm deep; cells micareoid, yellowish green to bright green, globose to subangular (when tightly clustered), 5–7(–8) µm wide. *Medulla* poorly delimited, dominated by rock fragments and crystals; hyphae 2–3 µm wide, thin-walled, more loosely arranged below. *Prothallus* absent. *Apothecia* numerous, dull jet-black, adnate or basally constricted, solitary and rounded or shallowly lobate, paired or in rounded or elongate clusters or short rows of 3–8 (–10), the apothecial shape distorted by mutual pressure, at first slightly convex, becoming strongly convex to subglobose; proper margin initially 20–30 µm thick in surface view, entire and concolorous with the disc, soon becoming excluded; solitary apothecia (0.24–)0.38(–0.51) mm diam. [*n* = 60]; clustered apothecia (0.44–)0.79(–1.18) mm in maximum extent [*n* = 40], some clearly formed by merged and fused apothecia, others likely to be derived from lobed and later subdivided apothecia; disc smooth, epruinose; in section the proper exciple is non-carbonized, 25–40 µm thick, partially subtending the hypothecium, consisting of grey-black to violet-black, radiating, conglutinate, thick-walled hyphae 2.5–3.5(–4) µm diam., with thin lumina, the outermost cells of the excluded margin tightly packed, similar or more rounded, thick-walled and 2.5–3.5 µm diam. *Epihymenium* greenish black, 10–25 µm thick, K–, N+ red-violet (*cinereorufa* green). *Hypothecium* hyaline, 60–180 µm thick, not inspersed with granules or oil droplets, K–, I+ yellowish brown. *Hymenium* 45–60 µm thick, not inspersed, I+ dark blue, K–, C–; the upper parts violet-black to dark-aeruginose, continuous with the epihymenium; *paraphyses* tightly conglutinate, sparingly branched and anastomosed, long-celled, 1.5–2.5(–3) µm thick; apical cells not swollen. *Asci* narrowly clavate or cylindroclavate, 36–56 × 10–12 µm, 8-spored, in Lugol's iodine with an amyloid outer coat; tholus well-developed, predominantly amyloid, with a short conical ocular chamber subtending a non-amyloid apical cushion that broadens distally. *Ascospores* colourless, irregularly biseriate in the ascus, 3-septate at maturity, narrowly ellipsoid to oblong or short-fusiform, usually straight, occasionally a little bent, not constricted at the septa, (10–)12(–14.5) × (3–)4(–5) µm [*n* = 50], thin-walled, lacking a perispore; apices rounded to subacute. *Pycnidia* numerous, immersed in the areolae; apex plane to subconvex, dark greenish grey to black, 40–50(–70) µm diam., internally obpyriform, hyaline and 80–110 µm wide; conidiogenous layer not convoluted, 10–20 µm thick; macroconidia narrowly oblong to filiform, straight, curved or arcuate, (1–)3-septate, 10–19 × 1–1.5 µm; microconidia and mesoconidia not seen. **Fig. 1**

Chemistry: Thallus K–, C–, PD+ orange, UV–; argopsin (major) by TLC.

Relationships: The new species is characterised by a thin, diffuse, greyish green saxicolous thallus containing only argopsin, solitary or clustered, jet-black, convex apothecia with a K– and C– hymenium and a hyaline hypothecium, and comparatively small 3-septate ascospores of 10–14.5 × 3–5 µm. Its novelty is confirmed by comparison with the other species of the *Micarea lignaria-M. ternaria* group (see key below).

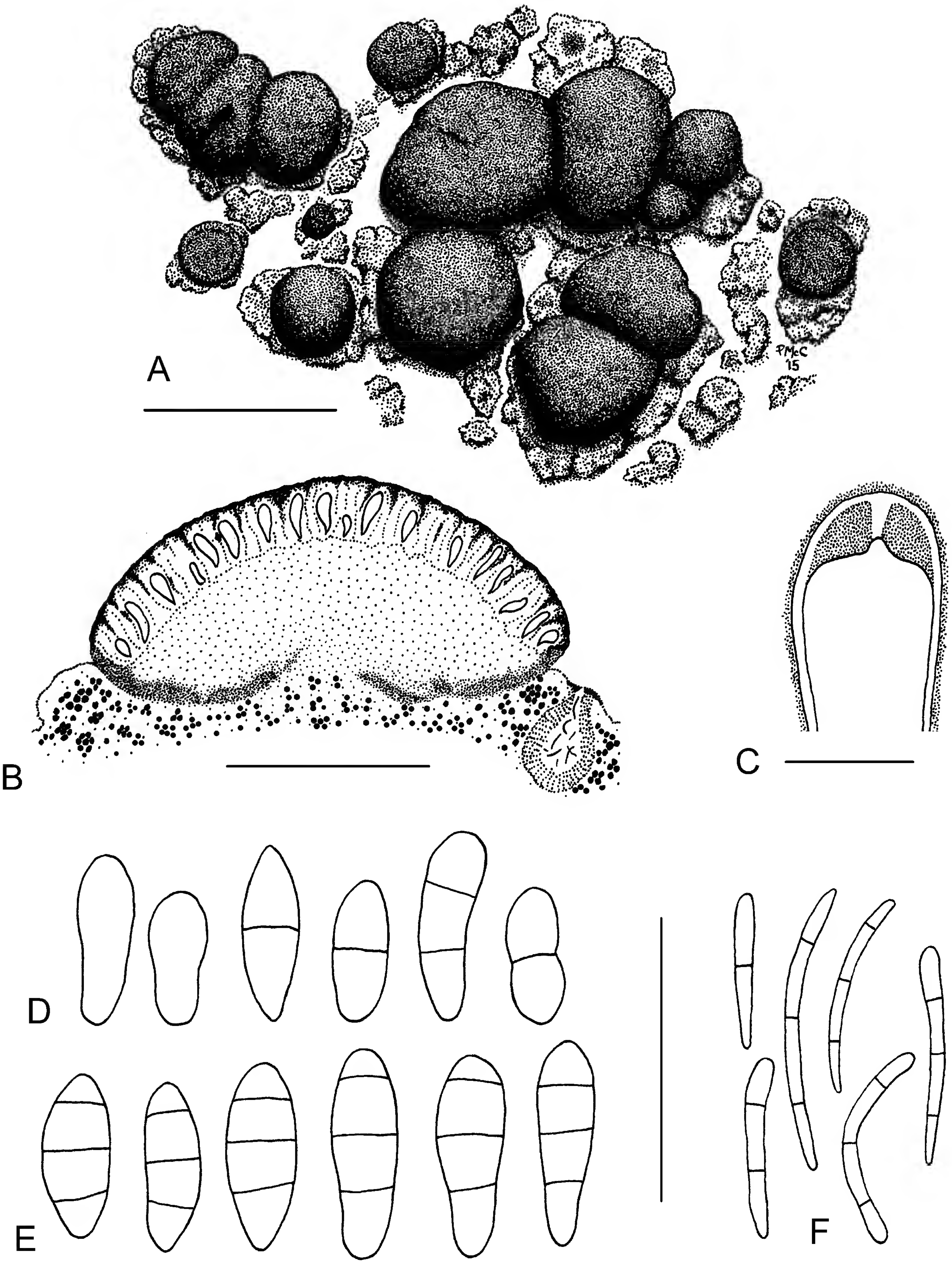

Fig. 1. *Micarea argopsinosa* (holotype). A, habit of thallus, apothecia and pycnidia; B, sectioned apothecium and adjacent pycnidium (semi-schematic); C, apex of a mature ascus; D, immature, 0–2-septate ascospores; E, mature, 3-septate ascospores; F, macroconidia. Scale bars: A = 0.5 mm; B = 0.2 mm; C = 10 µm; D–F = 20 µm.

Our incomplete understanding of the *Micarea lignaria-M. ternaria* group in Australia can be appreciated by a brief assessment of several other un-named taxa. Thus, specimens broadly similar to *M. argopsinosa* are known from Tasmania [The Nut, 40°46'S, 145°18'E, on moist, sheltered soil, *G. Kantvilas 284/99* (HO 445388); South Sister, 41°32'S, 148°10'E, on exposed dolerite boulders, *G. Kantvilas 361/07* (HO 456291)], and while they are close to the new species in their thalline and apothecial morphology, and in possessing small 3-septate ascospores, both specimens lack lichen substances.

Two saxicolous collections from South Gippsland, Victoria [Strezelecki State Forest, 38°28'S, 146°31'E, *J.A. Elix 29897, 29898* (CANB)] share similar morphology and anatomy with *M. argopsinosa*, but their chemistry is anomalous, viz. gyrophoric acid (major) in the thallus, but not in the apothecia, with or without argopsin (minor). Finally, a diminutive specimen on twigs of *Eucalyptus pauciflora* in the southern A.C.T. [Namadgi National Park, Mt Scabby summit, 35°45'08"S, 148°56'35"E, *P.M. McCarthy 4200* (CANB)] is reminiscent of *M. lignaria* var. *lignaria* (see below), but its spores are persistently 3-septate and significantly smaller (20–28 × 2.5–3.5 µm), and the thallus lacks lichen substances.

Etymology: The epithet *argopsinosa* refers the occurrence of the β-orcinol depsidone argopsin in the thallus of the new species.

Distribution and habitat: *Micarea argopsinosa* is known only from the sheltered surface of a granite outcrop, approximately 100 metres below the summit of Mount Ginini in the southern A.C.T. Associated saxicolous lichens included *Amandinea punctata* (Hoffm.) Coppins & Scheid., *Buellia ocellata* (Flot.) Körb., *Circinaria caesiocinerea* (Nyl. ex Malbr.) A.Nordin, S.Savic & Tibell, *Fuscidea australis* Kantvilas, *Lecanora polytropa* (Ehrh.) Rabenh., *L. rupicola* (L.) Zahlbr., *Lecidea diducens* Nyl., *Pertusaria erubescens* (Taylor) Nyl., *Ramboldia petraeoides* (Nyl. ex C.Bab. & Mitt.) Kantvilas & Elix, *Rhizocarpon badioatrum* (Flörke) Th.Fr., *R. distinctum* Th. Fr., *R. geographicum* (L.) DC., *R. intersitum* Arnold, *R. lecanorinum* Anders, *R. polycarpum* (Hepp) Th.Fr., *R. reductum* Th.Fr., *Xanthoparmelia mougeotina* (Nyl.) D.J.Galloway, *X. stygiodes* (Nyl. ex Cromb.) O.Blanco, A.Crespo, Elix, D.Hawksw. & Lumbsch and *X. xanthomelaena* (Müll.Arg.) Hale.

Key to the species of the *Micarea lignaria-ternaria* group

Based on Coppins (1983, 2009), Coppins and Kantvilas (1990) and Fryday (2004).

1 Thallus with a cream-coloured to yellowish tinge, containing xanthones 2

1: Thallus without a cream-coloured or yellowish tinge, not containing xanthones 3

2 Ascospores 19–26 × 3.5–4 µm, (1–)3-septate, often curved [Tasmania, New Zealand, southern S America] .... **M. isabellina**

2: Ascospores 16–38 × 4–7 µm, 3–7-septate, straight or slightly curved [Europe] .... **M. lignaria** var. **endoleuca**

3 Ascospores 10–14.5 µm long, 3-septate .... **M. argopsinosa**

3: Ascospores 14–38 µm long, 3-septate or 3–7-septate 4

4 Ascospores 3–7-septate, 16–38 × 4–7 µm; thallus containing argopsin [Europe, Macaronesia, N and S America, Réunion, Siberia, Taiwan, New Guinea] .... **M. lignaria** var. **lignaria**

4: Ascospores 3-septate, mostly 14–22 µm long; thallus not containing argopsin 5

5 Thallus containing alectorialic acid [Tasmania, New Zealand, southern S America] .... **M. magellanica**

5: Thallus without lichen substances [British Isles, Arctic Europe, Alaska] .... **M. ternaria**

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Meteoriopsis undulata Horik. & Nog. (Bryophyta: Meteoriaceae) new to the Australian flora

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Abstract

Meteoriopsis undulata Horik. & Nog. (Bryophyta: Meteoriaceae), previously known only from Japan, Taiwan and China, is reported as new to Australia from two collections in the Wet Tropics of north-eastern Queensland. A revision of the current Australian moss key is suggested to accommodate this species.

Introduction

The genus *Meteoriopsis* was revised by Manuel (1977) to include only three species from Asia: *M. reclinata* (Müll.Hal.) M.Fleisch. ex Broth., *M. squarrosa* (Hook.) M.Fleisch. ex Broth. and *M. undulata* Horik. & Nog. *Meteoriopsis reclinata* was the only species reported from Australia. *Meteoriopsis undulata* was known at that time only from Japan, but subsequent collections from Taiwan and from Guanxi province in China broadened its distribution (Noguchi 1986, Wu and Lin 1986). A further species, *M. novoguinensis* Nog. from Papua New Guinea, was described by Noguchi (1986).

In May 2015 we collected an epiphytic moss from two locations in the Wet Tropics of north-eastern Queensland: one from a rotting vine (collection no. WT-616) and the other from a tree trunk (WT-637). We identified these in the field as *Isocladiella wattsii* (Broth.) B.C.Tan, H.P.Ramsay & W.B.Schofield because of the presence of long flagelliform branchlets, which was considered a defining character for that species among Australian mosses (Ramsay 2012). We subsequently sent part of WT-637 to Helen Ramsay (Royal Botanic Garden, Sydney). However, after she and Alison Downing (Macquarie University) examined the specimen they pointed out that it belonged in *Meteoriopsis* (Meteoriaceae) and suggested that it might be *Meteoriopsis undulata*.

Morphological assessment

We consequently compared WT-616 and WT-637 with published descriptions of *Meteoriopsis* species and two similar species of Meteoriaceae, *Pseudotrachypus ancistrodes* (Renault & Cardot) V.Nath & Bansal and *Meteorium filiforme* Nog. We also examined authoritatively identified specimens of *Meteoriopsis novoguinensis* (CBG-8307764 and CBG-8307764), *M. undulata* (CBG-8207146), *M. squarrosa* (*Koponen 30732* ex H in MELU) and *P. ancistrodes* (CBG-9504251 and CBG-84051153, as *Pseudobarbella ancistrodes*) available in Australian herbaria, and our own collections of *M. reclinata*.

Our material does not fit within *M. reclinata* nor *M. squarrosa* because its leaf margins are undulate, flagelliform branchlets are present, and the leaves are widely spreading rather than ± squarrose and become gradually smaller towards the apex of branches. *M. novoguinensis* and *P. ancistrodes* were also discounted because of obvious differences in gross morphology: *M. novoguinensis* is a much larger plant than WT-616 and WT-637 and has a more bristly appearance, and the papillae are less distinct, as noted by Noguchi (1986) in comparing it with *M. undulata*. Both *P. ancistrodes* and *M. filiforme* have a trailing habit. In addition, *P. ancistrodes* has much larger stem leaves (to 2.5 mm long), the laminal cells are only rarely bipapillose, and there are no flagelliform branchlets. *Meteorium filiforme* also has much larger stem leaves (to 3 mm long), the laminal cells are entirely unipapillose, the leaf margins are entire rather than denticulate, and the leaves of the secondary filiform branches are broadly ovate, rounded with a shortly acuminate apex.

We concluded that WT-616 and WT-637 did belong in *Meteoriopsis* and best matched *Meteoriopsis undulata*, although flagelliform branchlets were not mentioned by Noguchi (1936) or Manuel (1977). Table 1 shows stem, branch and branchlet leaf measurements of WT-616 and WT-637 against those of CBG-8207146 and published measurements. The gross morphology of WT-637 is very close to that of CBG-8207146, which was collected in Japan by Zen Iwatsuki and Hiroshi Kiguchi and identified by Iwatsuki, with the identification later confirmed by Akira Noguchi. It formed no. 1578 of the Musci Japonii Exsiccati series 32 (1981), edited by Iwatsuki and Noguchi. The following description is based on our Australian material (Figs 1, 2). The locations of our collections are shown in Fig. 3.

Table 1: Morphological measurements of WT-616, WT-637 and CBG 8207146 and published measurements of *Meteoriopsis undulata*.

Character	**WT-616 & WT-637**	**(CBG-8207146)**	**Noguchi (1936)**	**Manuel (1977)**	**Wu and Lin (1986)**	**Wu and Pei (2011)**
Stem length (cm)	8–13	N/A	15	7.5	not mentioned	not mentioned
Stem leaf length (mm)	(1.39–) 1.84–1.91	1.73–2.9	1.8	1.08–2.01	(1.45–) 1.7–2.35 (–2.55)	1.8**
Stem leaf width (mm)	(0.47–) 0.53–0.63	(0.58–) 0.79–0.9	0.6	0.38–1.0	(0.5–) 0.65–0.9 (–1.05)	0.6**
Branch length (mm)	5–7	5–8	5–10	5–10	5–12	5–12
Branch leaf length (mm)	1.6–1.8	(1.27–) 1.72–1.91	1.6	0.9–1.89	0.6–1.25	not mentioned
Branch leaf width (mm)	0.69–0.86	0.51–0.71	0.73	0.39–0.9	0.15–0.25	not mentioned
Branchlet length (mm)	2–14	7–9	not mentioned	not mentioned	c. 10	not mentioned
Branchlet leaf length (mm)	0.4–0.53	0.65–0.82	not mentioned	not mentioned	0.6–1.1*	not mentioned
Branchlet leaf width (mm)	0.09–0.13	0.17–0.2	not mentioned	not mentioned	0.15–0.2*	not mentioned
Lamina cell l × w – stem leaf (μm)	54–64 × 4.5–6.4	41–46 × 5.4–5.9	not mentioned	25.0–32.5 (–45.0) × 3.75–5.0	(25–) 30–60 (–70) × 2.5–5	20–60 × 5–6**
Lamina cell l × w – branch leaf (μm)	41–64 × 6	42–51 × 4.5–6.5	not mentioned	22.5–40.0 × 3.75–7.5	not mentioned	not mentioned
Lamina cell l × w – branchlet leaf (μm)	40–45 × 5–7	37–48 × 2.6–3.9	not mentioned	not mentioned	not mentioned	not mentioned

* Not included in text; estimate from illustration of *M. undulata* in Wu & Lin (1986)

** Not specified whether stem or branch

Meteoriopsis undulata **Horik. & Nog. in Nog., *J. Sci. Hiroshima Univ.* sect. B., div. 2, 3: 16**

TYPE: Holotype (*Noguchi 9400*, Hiroshima University Herbarium) destroyed in World War 2 (*fide* Noguchi, cited in Manuel 1977). Paratypes not extant (*fide* Manuel 1977). Neotype (*fide* Manuel 1977) Japan, Kyushu, Miyazaki-Pref. Nakago-mura, Yasuhisa, *Noguchi 9399*, 5 April 1927, herb. Kamamoto University (not seen); isoneotype MO-3961584 (digital image seen).

Plants yellowish green, in open to compact wefts, with a leafy creeping primary stem to 13 cm long, c. 170 μm diam., occasionally forked or with lateral branches; the primary stem giving rise to branches in a pinnate arrangement, although the arrangement is often obscured because the branches are turned to one side and grow away from the substrate. Branches densely leafy, 2–3 mm apart along stem, to 8 mm long but mostly < 6 mm, c. 115 µm diam., commonly with 1–8 elongate flagelliform branchlets up to 14 mm long projecting laterally from the branches, the branchlets fragile and deciduous; branchlets in various stages of development, from dormant buds to fully formed branchlets; branchlet junction subtended by a ring of scaly leaves. Secondary branches rare. Rhizoids brown, in fascicles at intervals along stem. Stem leaves ovate-lanceolate from a broader base, insertion narrow, occasionally somewhat auriculate, tapering to a long narrow point, concave, rather undulate and plicate when dry, less so when wet, (1.39) 1.82–1.91 × 0.47–0.63 mm; margin denticulate, almost smooth in upper leaf; costa narrow, failing in mid-leaf; laminal cells in mid-leaf elongate-fusiform, 54–64 × 4.5–6.4 µm, longer towards apex, forming a herringbone pattern under low power transmitted light because of the elongate ends of cells, 1–3-papillose on both adaxial and abaxial surfaces, papillae prominent, cells at extreme apex smooth. Branch leaves widely spreading, insertion U-shaped, clasping, ovate-lanceolate, tapering to a fine point, 1.6–1.8 × 0.69–0.86 mm near the branch base but often gradually becoming smaller distally so that the branch appears attenuate; margin denticulate, somewhat undulate when wet, leaf contorted and plicate when dry; costa narrow, ending above mid-leaf; laminal cells above leaf base elongate-fusiform, thin-walled, forming a herringbone pattern as in stem leaves, 1–2(–3)-papillose on both adaxial and abaxial surfaces, cells papillose to apex; median cells 41–64 × 4.4–6.4 µm; cells in leaf base rectangular, smooth. Flagelliform branchlet leaves appressed to branchlet stem when dry, spreading when wet, lanceolate with a long, narrow tip, 0.4–0.53 × 0.09–0.13 mm; insertion straight to curved, margin denticulate; costa very narrow, failing below midleaf, laminal cells fusiform, mostly unipapillose on both adaxial and abaxial surfaces (sometimes 2-papillose, rarely 3-papillose), 40–45 × 5–7 µm, those at the base rectangular, somewhat granular, smooth; apical cells linear, smooth.

Dioicous. Perichaetia not seen. Perigonia not seen.

Our observations and measurements of WT-637 agree broadly with those of *M. undulata* (CBG-8207146) and with descriptions published by Noguchi (1936, 1976), Manuel (1977), and Wu and Pei (2011). Differences in leaf or laminal cell sizes may be accounted for by environmental variation. Similarly, differences in colour — 'yellowish-green' (Noguchi 1936) and 'dark green' (Noguchi 1976) — probably reflect differences in light intensity in the habitat. The description that best matched WT-637 was that for Taiwanese specimens of *M. undulata* by Wu and Lin (1986), who illustrated the leaves of the flagelliform branchlets.

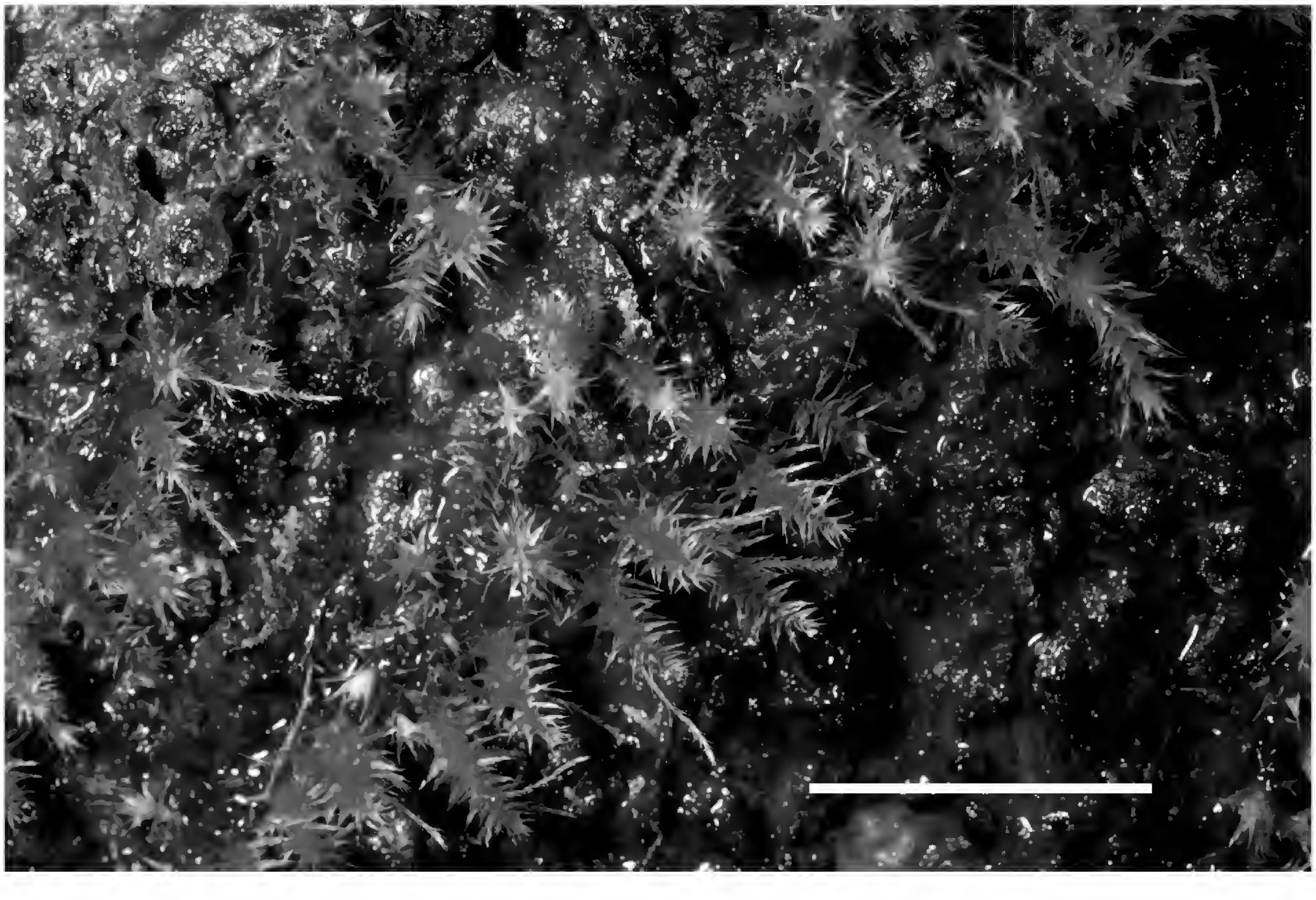

Fig. 1. *Meteoriopsis undulata* (WT-637) photographed *in situ* on the trunk of a tree, K-tree Track, Wooroonooran National Park, 29 May 2015. Scale bar: 10 mm.

Specimens of *Meteoriopsis undulata* examined: AUSTRALIA: QUEENSLAND: Cook: Wet Tropics: Tully Gorge National Park, H Road, on rotting vine, *Meagher & Cairns WT-616*, 27 May 2015 (BRI); Wooroonooran National Park, K-tree Track, epiphytic on tree trunk, *Meagher & Cairns WT-637*, 29 May 2015 (BRI). JAPAN: Shikoku: Tokushima-ken, Naka-gun, Aioi-cho, Hono, 130 m alt., on tree trunks, *Iwatsuki & Kiguchi, s.n.*, 28 August 1978 (CBG-8207146).

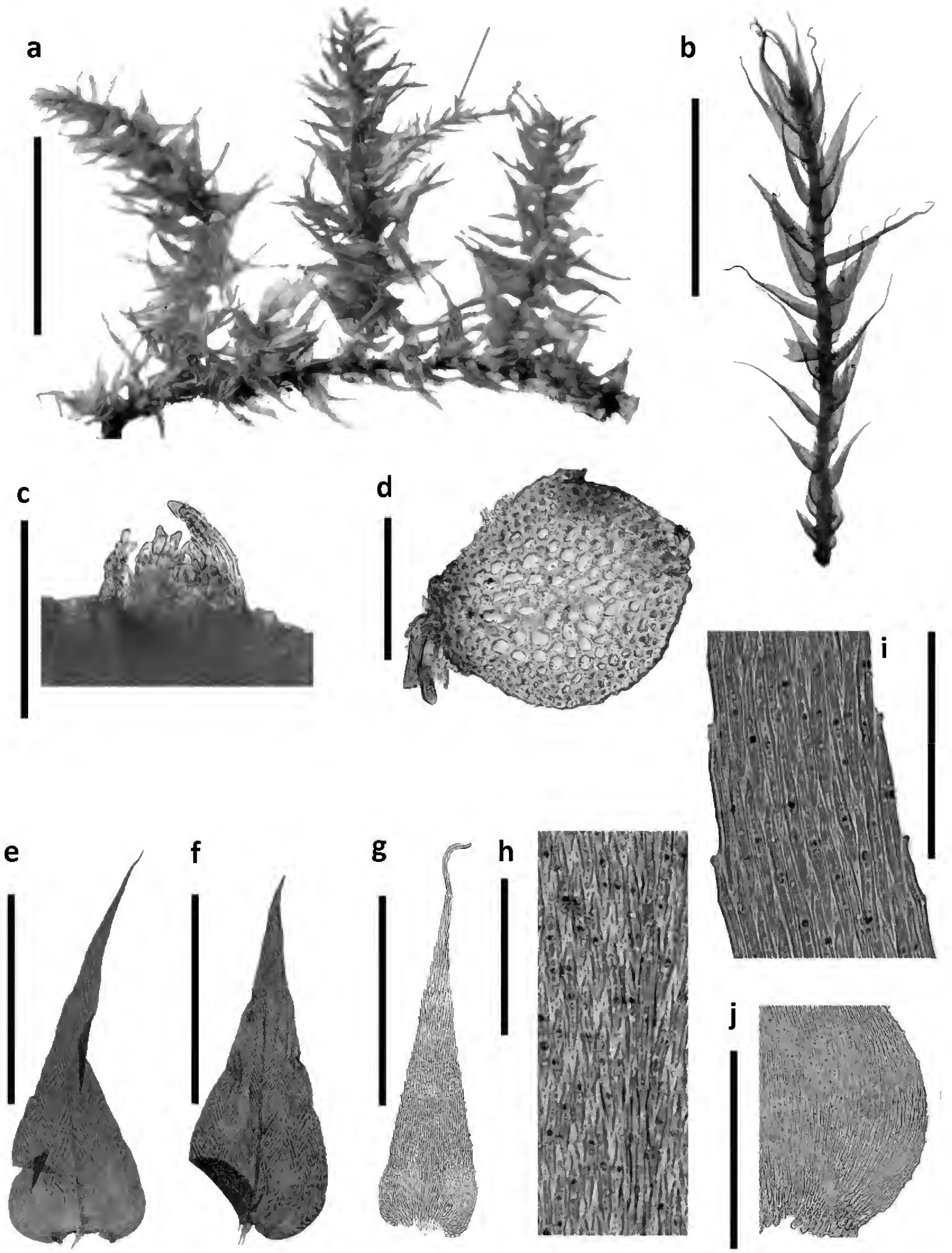

Fig. 2. *Meteoriopsis undulata*. **a,** part of plant with flagelliform branchlet (arrowed) arising from the middle branch; **b,** short flagelliform branchlet; **c,** scale leaves surrounding a branchlet junction; **d,** stem cross-section; **e,** typical stem leaf; **f,** typical branch leaf; **g,** typical flagelliform branchlet leaf; **h,** cells in centre of stem leaf, with end of costa visible on right; **i,** cells in the upper part of stem leaf; **j,** basal area of stem leaf showing denticulate margin and indistinct alar cells. Scale bars: a = 10 mm, b,e,f = 1 mm, c,d = 100 µm, e,f = 1 mm, g,j = 0.5 mm, h,i = 50 µm. All images from WT-637.

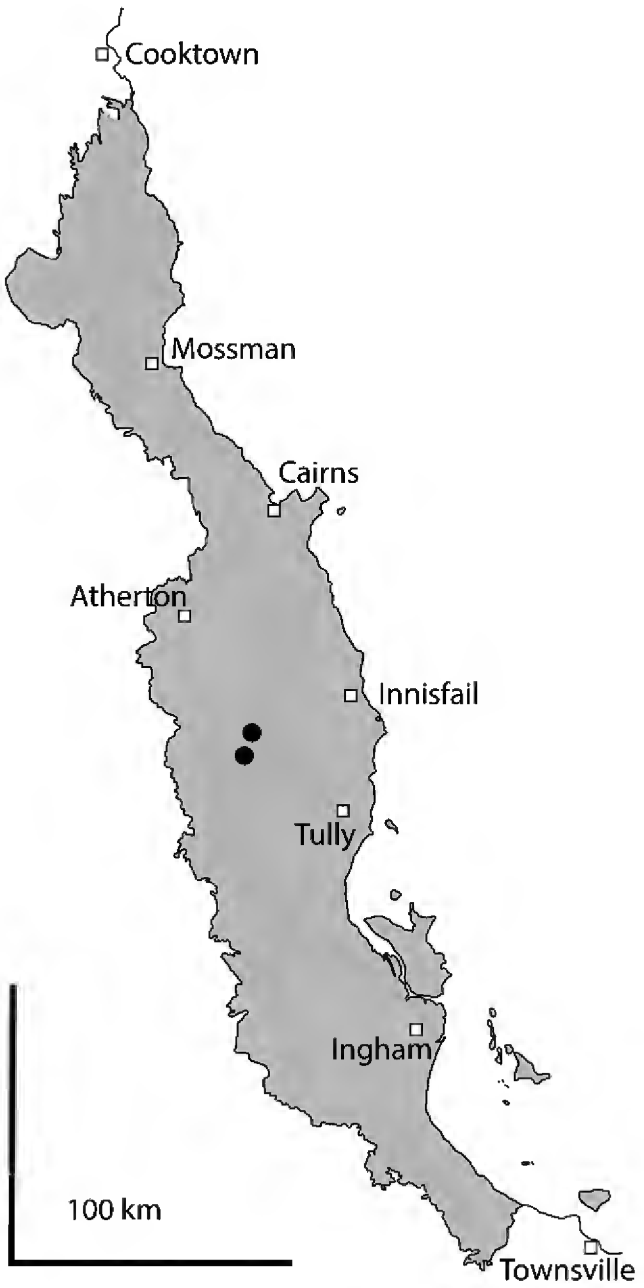

Fig. 3. The Australian Wet Tropics bioregion, showing the locations of collections of *Meteoriopsis undulata* (black circles). The Australian Wet Tropics World Heritage area is shown in grey.

Discussion

Papillosity: The laminal cells of WT-637 usually have one or two papillae on each side of the cell, and sometimes three on each side (Fig. 2h, i). This is consistent with Wu and Lin (1986) who reported '1–2 papillae, rarely 3 papillae per cell'. In his original description (1936) Noguchi recorded laminal cells as 'plerumque unipapillosae' – 'mostly unipapillose', suggesting some variation within the leaves he examined; however, Noguchi's later description stated only 'unipapillose' (Noguchi 1986). There is some variation in the description of papillosity in other species of *Meteoriopsis*. For example, Noguchi (1976) described laminal cells in *M. reclinata* as possessing one, rarely two papillae, whereas Streimann (1991, 2012) described the same species as having 1 (–3) papillae per cell – one high central papilla, rarely 2–3, or papillae indistinct. This disparity is not unusual; mosses commonly show morphological plasticity under varying environmental conditions (Buryova and Shaw 2005, Pereira et al. 2013). Variation is also common in other characters in *Meteoriopsis*; for example, Noguchi (1976) attributed variations in the length of the chain of linear cells at the leaf apex to an 'ecological feature'. However, he did not ascribe variations in papillosity to environmental effects, stating 'papillae may be a distinguishing character among taxa'.

Flagelliform branchlets: When Noguchi (1936) first described *Meteoriopsis undulata* he did not mention flagelliform branchlets, but later he described the species as having 'branches...often bearing long lateral flagella' (Noguchi 1986). Wu and Lin (1986) also mentioned 'lateral slender branchlets', suggesting they may be a kind of propagula, and illustrated leaves from these branchlets; nevertheless, the most recent description in the Moss Flora of China (Wu and Pei 2011) makes no mention of branchlets. Lateral flagelliform branchlets are a significant feature of WT-616 and WT-637 and can be seen clearly in the habitat photograph (Fig. 1). When we examined these specimens in a dried state several months after collection, many of the flagelliform branchlets had broken off and were loose within the packets, which suggests that they may act as deciduous vegetative propagules. The isoneotype of *Meteoriopsis undulata* (MO-3961584) has at least two flagelliform branchlets, one of which is separated from its branch. We also found several branchlets in the herbarium specimen of *M. undulata* (CBG-8207146), all separated from their branches and most somewhat longer than those in WT-637 but shorter than those in WT-616. It may be that the production of flagelliform branchlets is a seasonal phenomenon; deciduous branchlets might grow during the wet season before being dislodged by natural disturbance as they dry out later in the year.

Imura and Iwatsuki (1990) classified vegetative diaspores on a range of Japanese mosses and provided definitions to standardise terminology. They described one type of diaspore they termed 'flagella', defined by 'a slender, flagelliform, branch-like structure with small, suppressed leaves, often observed in axils of upper leaves of some mosses'. Because the basal connection of a flagellum consists of many cells, Imura and Iwatsuki (1990) considered flagella to be specialised branches. The basal connections in our material were difficult to observe when the flagella were in situ; however, the connections were clearly ringed by minute leaves (Fig. 2), which supports the idea that flagella are specialised branches.

Floribundaria walkeri (Renauld & Cardot) Broth., a moderately common species of Meteoriaceae in the Wet Tropics, can have flagellate branches, but the flagella are extensions of branches rather than specialised branches, and the plants have a soft, silky appearance.

Scaly leaves or pseudoparaphyllia?: WT-616 and WT-637 have numerous branches bearing flagelliform branchlets in various stages of development in leaf axils. Other branches have small buds towards the ends of some of the branches (Fig. 2c), and others lack buds or bear developing flagelliform branchlets. In mosses, branches that develop in the axils of stem leaves are often protected by axillary hairs and proximity to the leaf, whereas lateral branch buds are often covered by modified leaves for their protection (Akiyama 1990). Dormant branch buds may be protected by pseudoparaphyllia, which are derived from stem epidermal cells, or by scaly leaves, which are derived from cells of the branch primordia (Akiyama and Ishimura 1993). Because branching in WT-616 and WT-637 is mostly pinnate, we think that the buds must be dormant flagelliform branchlet buds.

Akiyama and Nishimura (1993) recognised that pseudoparaphyllia are taxonomically useful but acknowledged that there has been difficulty distinguishing them from scaly or rudimentary leaves. In his search for pseudoparaphyllia in a variety of North American mosses, Ireland (1971) found no pseudoparaphyllia in three genera in the Meteoriaceae: *Barbella*, *Meteoriopsis*, and *Papillaria*. Allen (1987) surveyed branch primordia in Pterobryaceae and compared them with Meteoriaceae. He found that Pterobryaceae commonly have pseudoparaphyllia, whereas they are absent in Meteoriaceae. He cautioned that 'a fine line exists between foliose pseudoparaphyllia and rudimentary branch leaves' and 'distinguishing between [them] can be a formidable task'.

Bruce Allen, at the herbarium of the Missouri Botanical Garden (MO), advised us that the herbarium has a duplicate specimen (MO-2854950) of the material of *M. undulata* we borrowed from Canberra, as well as an isoneotype of *M. undulata*. After viewing our photos of WT-637 and comparing them with the specimen in MO, he concluded that *M. undulata* has scale (rudimentary) leaves around branch primordia, and not foliose pseudoparaphyllia (pers. comm. B. Allen, December 2015).

The production of vegetative propagules in dioicous mosses may compensate for the absence of one gender in a population (Glime and Bisang 2014a,b). In this respect it is noteworthy that perichaetia are lacking in WT-616, WT-637 and CBG-8207146, although there are a few perichaetia in MO-2854950 (pers. comm. B. Allen, January 2016).

Perichaetia and perigonia: Manuel (1977) noted that in *Meteoriopsis* the perichaetia are terminal on short branches arising from the primary stem, and are inconspicuous; perigonia are sessile in the axils of leaves on pendent stems, and are conspicuous. Both perichaetia and perigonia have long paraphyses. He also noted that he had not seen perichaetia or perigonia on any specimen of *M. undulata* (all from Japan), and that in *M. reclinata* and *M. squarrosa* perichaetia were rare.

Noguchi (1976), who examined specimens of *M. undulata* from Taiwan, found perichaetia but not sporophytes. Wu and Lin (1986) also found perichaetia, and gave the only description of the perichaetial leaves: lanceolate to linear, broader at the base, apex slightly curved, about 1.5–2.4 × 0.2–0.4 mm. However, they did not describe archegonia or paraphyses. WT-616 and WT-637 do not bear perichaetia or perigonia. Reproduction in *M. undulata*, but not necessarily *Meteoriopsis* in general, therefore appears to be primarily if not wholly asexual by fragmentation.

Disjunct distribution: The Wet Tropics of northern Queensland is an outlier in the known distribution of numerous Asian bryophytes such as *Meteoriopsis undulata* (Fig. 4). Two other examples are *Entodontopsis pygmaea* (Paris & Broth.) W.R.Buck & Ireland (otherwise known from Vietnam, Thailand, China, India and Nepal) and *Bazzania bilobata* N.Kitag. (otherwise known from Thailand and China). However, these might not represent genuinely disjunct distributions, because bryophytes are poorly known in many parts of the South East Asian archipelago. For example, there are very few collections from Indonesia's Irian Jaya, which covers the entire western half of New Guinea. Potential natural vectors for the long-distance dispersal of bryophyte diaspores in the Asian–Australasian tropics include cyclones, migrating birds and fruit bats.

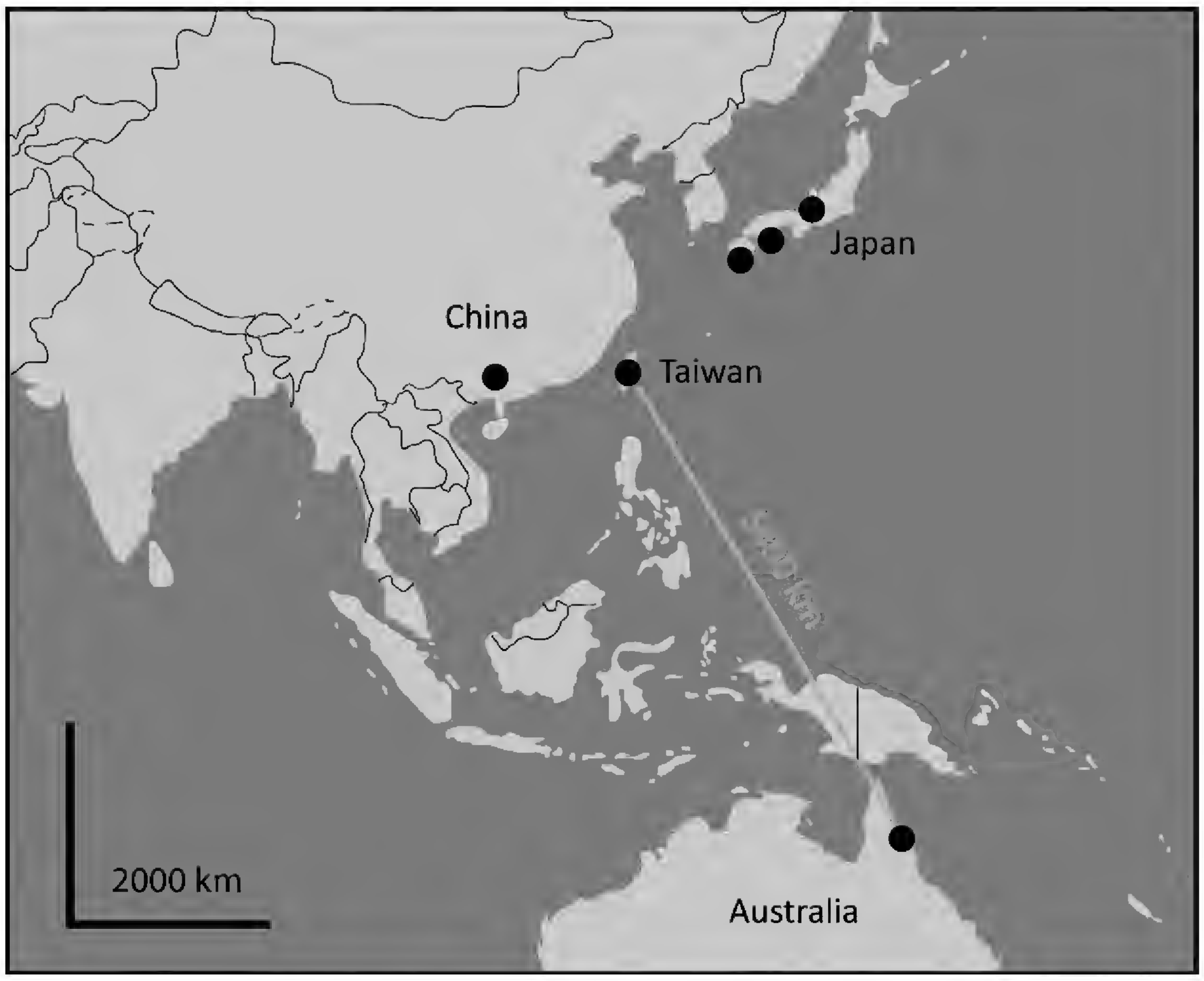

Fig. 4. The known global distribution of *Meteoriopsis undulata*, showing the disjunction of the Wet Tropics sites.

Position in the Australian moss key: Two versions of the Australian moss key have been published. The earlier version (Buck et al. 2002) was superseded by a revised version (Buck and Vitt 2006), which is available online and should be the version used to identify Australian mosses to genus. The following notes refer only to Buck and Vitt (2006).

Meteoriopsis as currently accepted in the Australian flora (i.e. *Meteoriopsis reclinata*) keys out at couplet 218, but to arrive there one must accept that the cells are unipapillose. Since in *M. undulata* they are very commonly 2–3-papillose as well as unipapillose, allowance needs to be made for *Meteoriopsis* to key out further along in the key. In addition, *Floribundaria walkeri* might not be keyed correctly because its cells typically have the papillae in two rows, rather than one as suggested by 'Laminal cells seriately papillose' in couplet 229 of the existing key. We therefore suggest the following replacement for the existing couplet 229:

229 Plants with caducous flagelliform branchlets arising ± at right angles from branches, the junctions surrounded by minute leaf-like scales... ***Meteoriopsis***

229: Plants lacking flagelliform branchlets as above (although branches may be terminally flagellate)........... .... 229A

229A Laminal cells seriately papillose in 1 or 2 rows... ***Floribundaria***

229A: Laminal cells with papillae scattered over the lumina.. 230

Conclusion

WT-616 and WT-637 are more or less identical to *Meteoriopsis undulata* Horik. & Nog. as identified by Iwatsuki for CBG-8207146 and described by Wu and Lin (1986), and we therefore identify them as that species. As Manuel (1977) and Wu and Pei (2011) did not mention flagella in their descriptions, flagella may have been absent when their specimens were collected or lost during repackaging of dried material. Alternatively, the production of flagella may be initiated by an environmental trigger that had not occurred for plants they examined.

A study of *Meteoriopsis* from the South East Asian archipelago (particularly Borneo, Sumatra, Celebes and Papua New Guinea), including numerous specimens unidentified to species level in Australian herbaria, would help to refine the delimitation of species and determine whether the Wet Tropics is a genuinely large disjunction in the distribution of *M. undulata*.

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Phylogenetic position of *Meteoromyrtus* (Myrtaceae)

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Abstract

We investigated the phylogenetic affinities of the rare and threatened Indian species *Meteoromyrtus wynadensis* (Bedd.) Gamble. Sequences from the ITS and ETS regions of nrDNA and the *trn*K/*mat*K and *psb*A–*trn*H regions of the plastid genome were compiled in a 45 taxon dataset augmented by sequences from Genbank. Phylogenetic analysis using maximum parsimony and Bayesian approaches showed that *Meteoromyrtus* is deeply embedded in *Eugenia* and sister to *E. reinwardtiana* in a clade with other Old World taxa. The evidence clearly indicates that the genus should be considered a synonym of *Eugenia* and that the species should henceforth be known by its original name *E. wynadensis* Bedd.

Introduction

Meteoromyrtus Gamble is a monotypic genus from India. The sole species, *M. wynadensis* (Bedd.) Gamble, was originally described as a *Eugenia* by Richard Beddome (1864). Beddome's publications in Indian botany have recently been enumerated by Turner (2012) who also clarified the dates of publication of his major works, *Flora Sylvatica for Southern India* and *Icones plantarum Indiae orientalis*. In the *Forester's Manual of Botany*, included in the former publication, Beddome (1872) stated that his species was intermediate between *Eugenia* L. and *Pimenta* Lindl. "having the pendulous ovules of the former and the habit and inflorescence of the latter." Beddome retained his species in *Eugenia* with a question mark but Gamble (1918) transferred it to a new genus on the basis of the distinctive pendulous ovules. Note that Gamble changed the spelling of Beddome's epithet to '*wynaadensis*' but that change is not justified (see Byng et al. 2015).

Meteoromyrtus wynadensis is confined to the southern part of the Western Ghats, near the conjunction of the states of Karnataka, Kerala and Tamil Nadu. The species was last assessed by the IUCN in 1998 for the Red List and is categorised as Critically Endangered B1+2c (version 2.3) (WCMC 1998, Irwin & Narasimhan 2011). According to the IUCN assessment, "the only remaining population apparently occurs at Theerthundamala in Cannanore District" (Tamil Nadu), and "the habitat for only remaining population is steadily declining. The populations in Wynnad [sic] and Nilgiri Hills in Tamil Nadu are thought to have been destroyed." However, there appears to have been no more recent assessment of the records of the species from Kerala (Pandurangan et al. 1984) or Karnataka (Rao and Yoganarasimhan 1986).

Recent phylogenetic analyses, using both plastid and nuclear ribosomal DNA sequences, have established the major clades in Myrtaceae (Sytsma et al. 2004; Wilson et al. 2005; Biffin et al. 2007; Thornhill et al. 2015) and a new classification, based on a *mat*K/*trn*K sequence analysis, has been published (Wilson et al. 2005). Other workers have published more in-depth analyses of some of these clades. Amongst these, there have been several investigations of the tribe Myrteae, which includes both *Eugenia* and *Pimenta*, as well as *Myrtus* L. and other genera, like *Psidium* L. The tribe Myrteae is diverse and geographically widespread. It is defined by possession of opposite leaves, stems bearing simple (occasionally 2-armed) hairs, and fleshy fruits, often containing a number of seeds (Wilson et al. 2005; Wilson 2011). The most comprehensive phylogeny of this tribe was published by Lucas et al. (2007) who sampled approximately 60% of its genera. These authors combined data from ITS, ETS, *psb*A–*trn*H and part of *mat*K in an analysis that recovered seven clades, with only a few taxa that were not strongly associated with any particular clade. The tribe itself was very strongly supported with the genus *Myrtus* sister to all other taxa. Other studies have focussed on individual clades or genera within the tribe: the *Eugenia* group (Van der Merwe et al. 2005, Cruz et al. 2013, Mazine et al. 2014), the *Myrcia* group (Lucas et al. 2011, Staggemeier et al. 2015), *Myrceugenia* O.Berg. (Murillo et al. 2012, 2013), and *Rhodomyrtus* (DC.) Rchb. and its allies (Snow et al. 2011). As a result of these studies, changes have been proposed that affect the circumscription of several genera. For example, *Eugenia* is now considered to include both *Hexachlamys* O.Berg. (Cruz et al. 2013, Mazine et al. 2014) and *Monimiastrum* J.Guého & A.J.Scott (Van der Merwe et al. 2005, Snow 2008).

The phylogenetic study of *Eugenia* by Van der Merwe et al. (2005) focused primarily on taxa from southern Africa and Mauritius and confirmed the monophyly of the African species groups designated X and Y (Van Wyk et al. 1980, 1982, Van Wyk and Botha 1984) supported by morphological and anatomical characters. The phylogeny of Van der Merwe et al. (2005) also gave support to the hypothesis, suggested by Van Wyk and co-workers, that group X was more closely related to New World species and that group Y was more closely related to Old World species, including those from Mauritius. It should also be noted that both of these groups fall into the poorly supported clade 9 of Mazine et al. (2014).

The aim of the present study is to determine the phylogenetic position of *Meteoromyrtus*, querying its status as a distinct genus and testing the conjecture that its affinities lie with either *Eugenia* or *Pimenta*.

Materials and Methods

Sampling: We compiled a 45-taxon dataset, 43 taxa sampled from Myrteae, which largely represented previously published data. Five accessions were new in the dataset and additional sequence data for at least one locus was added for nine further taxa. Ingroup sampling included *Meteoromyrtus*, representatives of *Eugenia* from six of the eight previously identified subclades (Mazine et al. 2014), as well as the sister genus *Myrcianthes* O.Berg. Outgroups were chosen on the basis of the previous molecular study of the tribe by Lucas et al. (2007). That study identified the *Myrteola* O.Berg. and *Pimenta* clades as closely related to *Eugenia* and forming a well-supported clade, which was recently dubbed the MEP clade by Vasconcelos et al. (2015). Therefore, we used samples from the *Pimenta* and *Myrteola* groups of genera and added *Myrtus communis* L. and *Calycolpus moritzianus* (O.Berg) Burret as further outgroups within Myrteae. We rooted the trees on *Lindsayomyrtus* B.Hyland & Steenis and *Tristaniopsis* Brongn. & Gris representing tribes outside Myrteae. Details of all taxa studied and associated GenBank numbers are listed in Table 1.

Table 1. Voucher and accession numbers for taxa included in this study. Herbarium abbreviation codes follow Index Herbariorum (RBGS = Royal Botanic Gardens, Sydney for cultivated plants). Bold text indicates some or all data for a taxon are new to this study.

Taxon	Voucher	Source	ITS	ETS	*psb*A	*mat*K
***Calycolpus moritzianus* (O.Berg) Burret**	COL; C. Parra-O 480	Colombia: Santander, El Mortiño	KU945986	KU945977	KU945999	KU945991
***Campomanesia guazumifolia* (Cambess.) O.Berg**	UNSW; P.G. Wilson s.n.	cult. RBGS (Wild source unknown)	AM234076	KU945978	AM489821	AY521532.2
Eugenia albanensis Sond.	PRU; A.E. van Wyk 12723	South Africa	AY487286	AY454129	—	—
Eugenia arenosa Mattos	K; Mazine 1021	Brazil	KJ187605	KJ187658	KJ469654	—
Eugenia axillaris (Sw.) Willd.	K; Hamilton 553	Turks and Caicos	KJ187607	KJ187660	KJ469656	—
Eugenia ternatifolia Cambess. (Eugenia beaurepairiana)	K; Mazine 1008	Brazil	KJ187609	KJ187662	KJ469658	
Eugenia brasiliensis Lam.	K; Lucas 126	Brazil	KJ187613	KJ187666	KJ469662	—

Taxon	Voucher	Source	ITS	ETS	*psb*A	*mat*K
Eugenia brongniartiana Guillaumin	NOU; Pillon 176	New Caledonia	KJ187615	KJ187668	KJ469664	—
***Eugenia buxifolia* Lam.**	NSW; K.Wilson 10740	France: Reunion Is. (cult. Conservatoire Botanique National de Mascarin, Les Colimaçons)	KU945987	KU945979	KU946000	KU945992
Eugenia capensis (Eckl. & Zeyh.) Harv.	PRU; A.E. van Wyk 12694	South Africa	AY487292	AY454134	—	—
Eugenia cerasiflora Miq.	PRU; A.J. Urban s.n.	Brazil	AY487296	AY454137	—	—
Eugenia crassipetala J.Guého & A.J.Scott	PRU; D. Florens s.n.	Mauritius	AY487288	AY454131	—	—
Eugenia erythrophylla Strey	PRU; M.M. van der Merwe 259	cult. South Africa	AY463139	AY454145	—	—
Eugenia florida DC.	K; Lucas 106	French Guiana	AM234090	AM489912	AM489830	—
Eugenia foetida Pers.	ASU; A. Salywon 1208	USA, Florida	AY487298	AY454139	—	—
***Eugenia gregii* (Sw.) Poir.**	NSW; P.G.Wilson 1534	cult. RBGS (Wild source unknown)	AY487285	AY454128	KU946001	KU945993
Eugenia involucrata DC.	PRU; A.J. Urban s.n.	Brazil	AY487294	AY454135	—	—
Eugenia kanakana N.Snow. (*Monimiastrum globosum*)	PRU; D. Florens s.n.	Mauritius	AY487297	AY454138	—	—
Eugenia langsdorffii O.Berg	K; Da Silva & Farias 4528	Brazil	AM234092	AM489914	—	—
Eugenia latifolia Aubl.	K; M. Prevost 4707	French Guiana	AM234091	AM489913	AM489831	—
Eugenia lucida Lam.	PRU; D. Florens s.n.	cult. Mauritius	AY487289	AY454132	—	—
***Eugenia mespiloides* Lam.**	NSW; K.Wilson 10741	France: Reunion Is. (cult. Conservatoire Botanique National de Mascarin, Les Colimaçons)	KU945988	KU945980	KU946002	KU945994
***Eugenia myrcianthes* Nied. (*Hexachlamys edulis*)**	LPAG; L. Katinas 201	South America (Wild source unknown)	—	KU945982	—	AY525131.2
	K; Mazine 1091	Brazil	KJ187652	—	KJ469702	—
Eugenia natalitia Sond.	PRU; A.J. Urban s.n.	cult. South Africa	AY463135	AY454141	—	—
	Maurin 1796	South Africa	—	—	—	JF270773
Eugenia orbiculata Lam.	PRU; D. Florens s.n.	Mauritius	AY487290	AY454133	KJ469679	—
Eugenia picardiae Krug & Urb.	PRU; A.J. Urban s.n.	Brazil	AY487295	AY454136	—	—
Eugenia punicifolia (Kunth) DC.	K; M. Prevost 4724	French Guiana	AM234087	AM489909	AM489827	—
***Eugenia reinwardtiana* (Blume) DC.**	NSW; P.G. Wilson s.n.	cult. RBGS (Wild source unknown)	KU945989	KU945981	KU946003	KU945995
Eugenia simii Dümmer	PRU; A.E. van Wyk 12704	South Africa	AY463134	AY454140	—	—
Eugenia stictosepala DC.	K; Zappi 406	Brazil	AM234086	AM489908	—	—
Eugenia sulcata Spring ex Mart.	K; Lucas 68	Brazil	AM234089	AM489911	AM489829	AM489987
Eugenia tinifolia Lam.	PRU; D. Florens s.n.	Mauritius	AY487287	AY454130	—	—

Taxon	Voucher	Source	ITS	ETS	*psb*A	*mat*K
Eugenia tropophylla H.Perrier	PRU; T.K. Lowrey 2134	Madagascar	AY487303	AY454150	—	—
Eugenia uniflora **L.**	ASU; D. Damrel 2304 (ITS, ETS), FLAS; J.R. Abbott 23855 (psbA)	USA:, Florida	AY487284	AY454127	GU135338.2	—
	NSW; P.G. Wilson 1335	cult. RBGS (Wild source unknown)	—	—	—	AF368207.3
Eugenia verdoorniae A.E.van Wyk	PRU; A.E. van Wyk 12697	cult. South Africa	AY463137	AY454143	—	—
Eugenia woodii Dummer	PRU; A.E. van Wyk 12695	cult. South Africa	AY463138	AY454144	—	—
Eugenia zeyheri (Harv.) Harv.	PRU; A.E. van Wyk 12696	cult. South Africa	AY463136	AY454142	—	—
Lindsayomyrtus racemoides **(Greves) Craven**	NSW; K.D. Hill 2039	cult. RBGS (Wild source: Australia: Queensland, Daintree NP, Noah Creek)	HM160111/ HM160112	KU945983	—	AF184706.3
Lophomyrtus bullata **Burret**	OTA; Belsham M31	cult. New Zealand	AM234145	AM489923	AM489841	—
	Shane Wright s.n.	New Zealand (Wild source unknown)	—	—	—	KU945996
Meteoromyrtus wynadensis **(Bedd.) Gamble**	UGoa; Rajkumar 310	India: Kerala, Wayanad Forest	KU945990	KU945984	KU946004	KU945997
Myrcianthes cisplatensis (Cambess.) O.Berg	ASU; Landrum 11233	Uruguay	JN660914	—	JQ033349	JN661013
Myrcianthes pseudomato (D.Legrand) McVaugh	K; Beck 9667	Bolivia	AM234100	AM489951	AM489868	—
Myrcianthes pungens (O.Berg) D.Legrand	ESA; Forster 1013	Brazil	KJ187656	KJ187709	KJ469706	—
Myrtus communis **L.**	K; Lucas 211	cult. RBG Kew	AM234149	AM489955	AM489872	—
	WIS; Sytsma 7205	cult.	—	—	—	AY525136.2
Neomyrtus pedunculata **(Hook.f.) Allan**	OTA; Belsham M42	cult. New Zealand	AM234144	AM489956	AM490637	—
	CHR; D. Glenny 8174	New Zealand: Westland, Kelly's Creek	—	—	—	KU945998
Pimenta racemosa (Mill.) J.W.Moore	K; B. Holst 8866	cult.	AM234082	AM489959	AM489875	AY521545
Tristaniopsis laurina **(Sm.) Peter G.Wilson & J.T.Waterh.**	UNSW22390	cult. RBGS (Wild source: Australia: unknown)	EF041514	KU945985	—	AF184710.3

***Molecular data*:** New extractions of total genomic DNA were made from silica-dried, herbarium or fresh plant material. Tissue was disrupted dry with tungsten beads using the Qiagen Tissue Lyser and extractions used the DNeasy Plant DNA Mini kit (Qiagen, Hilden, Germany) following the manufacturer's protocol.

Sequences were compiled for 6 regions: 2 nuclear regions, the nuclear encoded internal transcribed spacer (ITS) and external transcribed spacer (ETS) of the ribosomal RNA gene; and 4 plastid regions were amplified for a subset of available taxa, a portion of the chloroplast *trn*K intron inclusive of the *mat*K gene and its 5' and 3' spacers and the *psb*A–*trn*H intergenic spacer. Data for all loci was supplemented with published sequences from GenBank. Primers used for PCR amplification and sequencing as follows: ETS, *myrt*F (Lucas et al. 2007) and ETS–18S (Wright et al. 2001); ITS, s3 (Kass and Wink 1997) and 26se (Sun et al. 1994), 5' *mat*K spacer, 909 (Lam et al. 2002) and 2518 (Gadek et al. 1996); *mat*K, 2516 and 2519 (Gadek et al. 1996); 3' *mat*K spacer, *mat*K5 and *trn*K2R (Steele and Vilgalys 1994); *psb*A–*trn*H, *psb*A (Sang et al. 2007) and *trn*H2 (Tate and Simpson 2003). In addition to the above, internal primers 756R (O'Brien et al. 2000) and 2521 (Gadek et al. 1996) were also used to sequence *mat*K

All PCR reactions were carried out in 25 µL volumes containing 200 µM of each primer, 200 µM of each dNTP, 0.004% BSA, 2–2.5 mmol $MgCl_2$ and 1U Immolase™ DNA polymerase (Bioline, Luckenwalde, Germany) with a hot start PCR cycle. After an initial 10 min hot start at 95°C PCR reactions were subjected to 40 cycles as follows: denaturation for 30 s at 94°C; annealing for 30 s at 50–53°C; and extension for 1 min at 72°C, with a final extension for 4 min at 72°C. The annealing temperature for ETS, ITS and *psb*A–*trn*H was 53°C, and *mat*K 50°C. Double-stranded PCR templates were purified with SureClean (Bioline (Aust) Pty. Ltd, Australia) and direct sequencing was processed at the DNA Analysis Facility of The Ramaciotti Centre for Gene Function Analysis (University of New South Wales, Sydney, Australia).

Table 2. Sequence statistics for all loci in the combined dataset. Aligned sequence lengths, variable characters, number of scored potentially parsimony informative indels and nucleotide substitution models applied to each partition for Bayesian analyses are presented.

Locus	ITS	ETS	5' *mat*K spacer	*mat*K	3' *mat*K spacer	*psb*A
Taxa with data (of 45 total taxa)	45	44	9	18	12	24
Aligned length (bp)	847	541	801	1528	277	640
Parsimony informative characters (bp)	151	154	15	48	6	43
Parsimony uninformative characters (bp)	95	104	43	162	28	92
Indels	10	28	3	1	2	4
AIC model	GTR+I+G	GTR+G	GTR	GTR+G	HKY	GTR+I+G
Inverted sequence (bp)	-	-	-	-	8	21

Sequence alignment: Sequence chromatograms were edited in ABI software Sequence Navigator 1.0.1 and consensus sequences generated which were then aligned manually in PAUP* version 4.0b10 (Swofford 2002). In aligning sequences, gaps were positioned to maximize conformity to known indel types such as simple and inverted duplications of adjacent sequences (Golenberg et al., 1993; Levinson and Gutman 1987). Overlapping indels of different length, and insertions of the same length but bearing different relationships to surrounding sequence, were treated as having independent origins, while indels of the same length and position and showing minor differences in nucleotide sequence were scored as the same state (Simmons and Ochoterena 2000). Potentially informative indels were scored as additional presence/absence characters and appended to the sequence matrix. Gaps were treated as missing data in the phylogenetic analyses. Coding sequences of the *mat*K gene were translated in MacClade (version 4.08a; Maddison and Maddison 2000) to check for internal stop codons.

Heuristic searches were conducted in PAUP* using tree bisection reconnection branch-swapping on best trees to recover the most-parsimonious (MP) trees. 1000 replicates of random taxon addition searching were conducted in which multistate characters were treated as polymorphisms, in order to detect multiple islands of trees. Relative support for the clades identified by parsimony analysis was estimated using the jackknife rather than bootstrap resampling in PAUP*, following the recommendations of Simmons and Freudenstein (2011). For jackknife analyses, 10000 replicates of faststep searching were conducted in which each replicate used random-taxon addition, no branch swapping, and the percentage of characters deleted was set at 33%. Jackknife (JK) values 50–74% were interpreted as weak support for clades; 75–89% moderate support; 90–99% strong support and 100% jackknife was considered robust. Sequence statistics for each locus are presented in Table 2.

The MP phylogenies generated were compared to those obtained using the Markov Chain Monte Carlo (MCMC) method implemented in MrBayes 3.2.2 (Ronquist et al. 2012). The most appropriate nucleotide substitution models to apply in likelihood-based analyses were determined using the Akaike's information criterion in MrModeltest 2.3 (Nylander 2004), with data partitioned into the 6 regions indicated above and excluding the appended scored indels, with each partition assigned a unique substitution model (Table 2). Bayesian analyses also included indels from all regions combined as an extra partition, with the indels binary encoded, and applying a default two-state Markov model with gamma distribution of rates and coding set to variable (as there were no invariant sites). Statefreqpr was set to fixed (empirical) for this partition to reflect only having two states.

Bayesian posterior probabilities (PP) were estimated using three independent runs of four million generations using four chains with tree sampling every 1000 generations. All parameters were set to be unlinked and with rates variable between partitions, with all other priors for the analysis set flat (i.e. as Dirichlet priors). Runs were assessed as sufficient when displaying convergence of effective sampling size (ESS) for all statistics in Tracer 1.6 (Rambaut et al. 2014), the standard deviation of split frequencies was clearly <0.01 and the potential scale reduction factor (PSRF) for all parameters was 1.000. Trees generated prior to the four Markov chains reaching stationarity (the burn-in ~25%) were discarded. The remaining trees were used to construct a 50% majority rule consensus tree, with nodes assigned posterior probabilities (PP) of 0.95–1.00 considered as supported.

Results

The nuclear dataset was almost complete: all taxa had ITS sequence, all but one had ETS sequence (Table 1). There was substantial missing data for all plastid loci however: only nine taxa had *mat*K 5' spacer sequences, 18 had at least partial *mat*K gene sequences and 12 taxa had sequence for the 3' *mat*K spacer, 24 taxa had *psb*A–*trn*H sequence, but analyses excluding those loci were not inconsistent in structure and showed only minimally different support for clades, with all loci included in the final analyses.

Aligned sequence lengths, variable characters, number of scored informative indels and models applied to each partition for Bayesian analyses are presented in Table 2. Sequences for most of the *mat*K gene and its 5' spacer could not be generated for *Meteoromyrtus,* reflecting the degraded nature of the sourced herbarium material.

Inclusion of indels in both Bayesian and parsimony analyses resulted in moderate improvements in branch supports, and for the Bayesian analysis produced the only fully resolved tree, though many branches lacked support. Therefore indels were included in all the analyses presented here. Regions containing inversions in the 3' *mat*K spacer (8bp) and the *psb*A–*trn*H intergenic spacer (21bp), were scored as a single presence/absence event with the indel partition and the actual bases excluded from analyses.

As separate analyses of nuclear and chloroplast loci indicated no conflict in phylogenetic signal all analyses presented are for the combined dataset. Heuristic searching of the combined dataset inclusive of scored indels yielded 12 equally most parsimonious (MP) trees of 1787 steps in a single island. For the most part the MP strict consensus tree was well resolved although supports between clades were generally weak (figure not shown). Jackknife support >50% are indicated on the Bayesian majority-rule consensus tree (Fig. 1).

Calycolpus and *Myrtus* are strongly supported as sister taxa in these analyses (PP = 1.00, JK = 99%) and form the earliest diverging lineage within Myrteae, although this position is poorly supported (PP = 0.87, JK = 57%). As with earlier studies these data retrieve a strongly supported clade including *Eugenia*, *Hexachlamys* and *Monimiastrum* and which also includes *Meteoromyrtus* (PP = 1.00, JK = 97%).

Although the MEP clade received strong Bayesian support in the study by Lucas et al. (2007) and the two unpublished phylogenies shown in Vasconcelos et al. (2015), it is poorly supported by our data (PP = 0.87, JK = 57%). While the *Myrteola* and *Pimenta* groups are strongly supported (PP = 1.00, JK = ≥95%), the *Eugenia* group itself (*Eugenia* + *Myrcianthes*) has weak jackknife support even though the posterior probability is strong (PP = 1.00, JK = 70%).

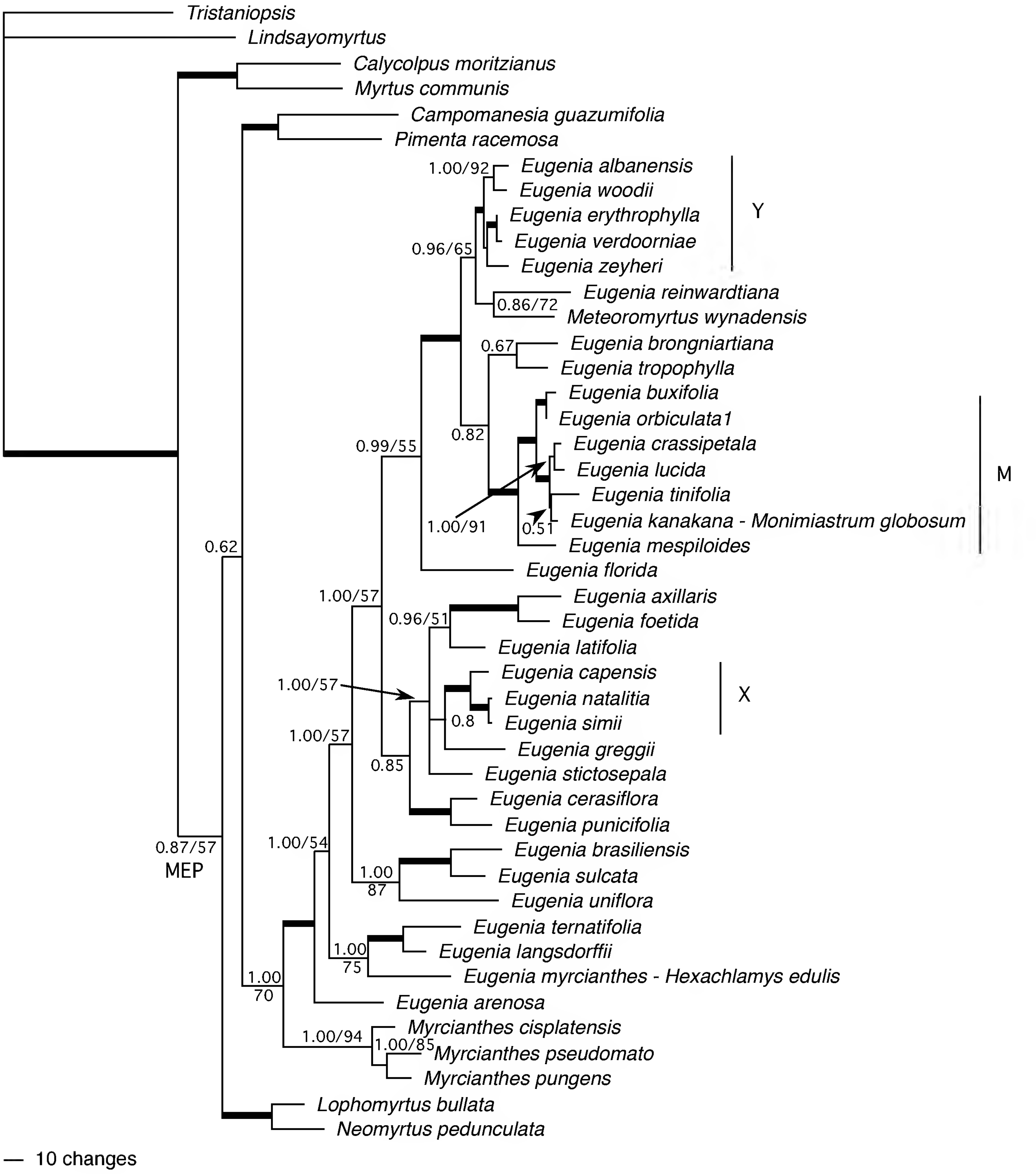

Fig. 1. Bayesian 50% majority rule consensus tree. Thick lines received support PP = >0.95 and JK = ≥95%. Other values shown on tree indicate clade support from Bayesian posterior probabilities (PP, left) and jackknife values from maximum parsimony analysis of >50% (JK, right).

Discussion

Morphological characters: The molecular phylogenetic results confirm that *Meteoromyrtus* was correctly placed by Beddome (1864) in *Eugenia* and that there is no support for a relationship with *Pimenta*. The suggested relationship with *Pimenta* was based on the pendulous ovules, which is a feature of most species in that genus. Placentation in *Eugenia* is variable and the arrangement of ovules has generally been described as follows: "ovules 2–numerous per locule, usually on a pad-like placenta arising from the medial septum" (Landrum and Kawasaki 1997). Placentation and ovule number and position are rarely recorded in Floras and other publications that describe species of *Eugenia*. When descriptions of these features in non-South American taxa can be found, they always conform to the general description given above. This includes *E. reinwardtiana* (Blume) DC., which appears as sister to *Meteoromyrtus* in our analysis. So the distinctly pendulous ovules, which inspired the generic name, are quite unusual in the genus but must be interpreted as a likely autapomorphy.

One feature of *Meteoromyrtus* that does not seem to have been noted previously is the nature of the hairs. In the protologue, the young growth and inflorescences are described as being 'densely fulvo-tomentose' but the hairs themselves are not described. Examination of leaves revealed that the hairs are unequally 2-armed with one short and one very long arm. Landrum and Kawasaki (1997) record 2-armed, or dibrachiate, hairs in Brazilian Myrtaceae as "common in *Myrceugenia*, *Calyptranthes*, *Marlierea*, and some species of *Myrcia* and *Eugenia*." Schmid (1972, p. 427) records and illustrates the range of variation of trichomes in *Eugenia*, including some that are asymmetrically dibrachiate. Snow (2011) also illustrates asymmetrically dibrachiate hairs and notes that they are a distinguishing feature of the Malagasy species *Eugenia ardyceae* N. Snow. Asymmetrically dibrachiate hairs have also been recorded for *Blepharocalyx cruckshanksii* (Hook. & Arn.) Nied. by Landrum (1986) and *Ugni candollei* O.Berg. by Landrum (1988) but *Eugenia* is the only genus of Myrteae occurring in the Old World where this type of hair has been recorded.

Phylogenetic position: *Calycolpus* is clearly closely allied to *Myrtus*. Landrum (2010) suggested that if this relationship, mooted by unpublished data, was shown to be well supported, it would "indicate that *Calycolpus* is an independent lineage, separate from most other American genera of Myrtaceae." The isolated position of the sister species, *Myrtus communis*, in the broader Lucas et al. (2007) analysis, is further evidence that this could be the case.

The *Eugenia* clade is strongly supported as monophyletic (PP = 1.00, JK = 97%) and, although sampling is limited, most of the species groupings agree with those identified by Mazine et al. (2014). The only variation is that *E. florida* DC., which was a member of clade 8 in that study, is here included amongst taxa of their clade 9. However, this is probably not significant since their clade 9 was a grouping of convenience and much of the backbone of their analysis lacked Bayesian or bootstrap support.

Meteoromyrtus is found to be sister to *E. reinwardtiana* in all analyses, with weak jackknife support (JK = 72%) but no Bayesian support (PP = 0.86). This species pair occurs in a well-supported clade (PP = 1.00, JK = 100%) consisting of some African species (group Y), Mascarene species (including those formerly assigned to the genus *Monimiastrum*), a Madagascan species, *E. tropophylla* H.Perrier and *E. brongniartiana* Guillaumin, the lone New Caledonian species that appears to be closer to the Mascarene species than it is to the geographically closer Australasian species, *E. reinwardtiana*. The lack of strong support for the relationship between *E. reinwardtiana* and *Meteoromyrtus* is not surprising given that, apart from taxa from the African and Indian Ocean areas, few species from the Asia-Pacific area have been sequenced.

In India, the south-western Ghats are an area of high endemism; apart from *Meteoromyrtus* seven of the recorded species of *Eugenia* are endemic, three of which are listed as rare and threatened by Ahmedullah and Nayar (1986). If future studies could access material from Indian species like *E. argentea* Bedd., *E. rottleriana* Wight & Arn., and *E. roxburghii* DC., as well as other taxa from Malesia and the Pacific, this would allow a better understanding of patterns of diversity and dispersal. Such an understanding will be of great importance since it is clear that all Old World taxa have their origins in the New World but a wider analysis has the potential to clarify the history of the independent origins of the two African groups of species, X and Y.

All *Eugenia* species found in the Mascarenes are endemic to single islands (Baider and Florens 2013): 17 Mauritius, 3 Réunion, 1 Rodrigues. We newly sampled two Réunion species and their placement lies within the robust exclusively Mascarene clade (PP = 1.00, JK = 100%; clade M, Van der Merwe et al. 2005), not as sister taxa but both as early-diverging lineages (Fig. 1). This may suggest several dispersal scenarios with either multiple dispersals to Réunion and Mauritius of ancestral species, or an initial dispersal to Réunion from outside with all the Mauritian taxa arising after subsequent dispersals from Réunion. *Eugenia mespiloides* Lam. which is IUCN listed as vulnerable (UICN et al. 2013) occurs as the earliest lineage amongst the mostly Mauritian taxa included here, while *E. buxifolia* Lam. is sister to *E. orbiculata* Lam. (PP = 1.00, JK = 98%). Inclusion of more taxa from this island group within an expanded dataset may clarify the position of *E. mespiloides*.

It is interesting to note that all non-American species of *Eugenia* sampled in the present study are found in the large group 9 of Mazine et al. (2014), hinting that every dispersal event outside South America within *Eugenia* was from this group. We agree with the assertion by Mazine et al. (2014) that, to confirm this, a more extensive sampling of *Eugenia* species from Africa and Asia is required.

Conclusion

Our results show that *Meteoromyrtus* is a *Eugenia* despite the unique morphological characters that led to its recognition as a separate genus, a finding foreshadowed by Byng et al. (2015). Based on this result we propose that the correct name should now be *Eugenia wynadensis* Bedd.

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Notes on the rediscovery of mosses *Anomodon perlingulatus* (Anomodontaceae) and *Curvicladium kurzii* (Neckeraceae) in Yunnan, China

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Abstract

Anomodon perlingulatus Broth. ex P.C. Wu & Y. Jia and *Curvicladium kurzii* (Kindberg) Enroth are reported as rheophytic mosses for the first time in China. They were so rarely collected that their habitat preferences remained unknown. The newly obtained specimens have expanded our understanding on their morphological variability and ecological preferences. After re-examining the type specimen held in H, the large size of median cells in *A. perlingulatus* is confirmed to be a measurement error made in the original description. An updated description is provided. Both *A. perlingulatus* and *C. kurzii* can be categorized as facultative rheophytes because of the limited number of specimens collected so far. We anticipate that with a better understanding of potential habitats of both species, that more occurrences in the neighboring provinces are likely to be discovered.

Rediscovery of *Anomodon perlingulatus* Broth. ex P.C. Wu & Y. Jia

Anomodon perlingulatus was first recognized by Brotherus (1907) from a single specimen collected by the Italian missionary Giuseppe Giraldi in 1899. However, the name was a *nomen nudum*. A diagnostic description was prepared and published in 2000 by P.C. Wu and Y. Jia based on the type material in H (Wu and Jia 2000).

During the examination of a series of *Anomodon* species collected in Yunnan Province, China, the first author found a specimen collected from the Gao-Li-Gong Mountain region that appeared to be morphologically consistent with the description of *A. perlingulatus*, except for the size of the median cells. The identification of the Yunnan collection as *A. perlingulatus* was soon confirmed after a re-measurement of the lamina cells of the type specimen (*H-BR 0159005*) by the third author. According to our examination, the cell size in the middle of the lamina is 7–10 µm × 10–13 µm, rather than "60–70 µm × 75–90 µm" as recorded in the species description by Wu and Jia (2000). We believe this was probably a result of a transcription error. Unfortunately, subsequent publications have either copied (Wu and Jia 2002; Wu *et al.* 2002) or slightly modified (Xiong 2014) this error from the original species description. According to the scale bar from Xiong (2014), the size of cells in the middle portion of the lamina is calculated as 7.8–9.4 µm × 8.4–11.7 µm based on the illustration, which is very close to the cell size of both the type specimen and our Yunnan collections. A detailed description based on our newly collected material is here provided.

Anomodon perlingulatus Broth. ex P.-C. Wu & Y. Jia *Acta Phytotaxonomica Sinica* 38: 260. f. 2. 2000. [Anomodontaceae]

Published Illustrations: Wu and Jia (2002: 188, Plate 76, Figs 1–10); Wu *et al.* (2002: 137, Plate 446, Figs 1–10); Xiong (2014: 278, Plate 317, Figs 10–16)

Plants light green to yellowish green, not glossy. Medium sized, stems creeping, 1.5–3.0 cm long, primary branch 3.0–5.5 cm long, secondary branches 0.8–3.5 cm long, irregularly branched proximally and pinnately branched towards the distal end of primary branch. Leaves moderately appressed on branches when dry, erect-spreading when moist. Central strand present, formed by a group of small cells without increase in cell wall thickness (Fig. 1G). Leaves relatively fragile, abruptly narrowed from the broadly ovate base, forming a lingulate-shaped distal portion with rounded apex, unistratose in cross-section. Leaves from primary and secondary branches similar, differ slightly in size. Stem leaves mostly broken without apices. Primary branch leaves: 2.2–2.6 mm long, 0.8–0.9 mm wide at base, and 0.18–0.22 mm wide at apex; secondary branch leaves, 2.0–2.3 mm long, 0.6–0.7 mm wide at base, 0.22–0.24 mm wide at apex; and for young secondary branch leaves, 1.3–1.5 mm long, 0.4–0.5 mm wide at base, 0.16–0.22 mm wide at apex. Costa strong, 66–75 µm thick at base, occupying up to 95% of the leaf length, and ending about 12–16 cells below apex. In primary branch leaf, cells above costa irregular quadrate, 7–8 µm × 9–10 µm, thin-walled, 3–6 tiny papillae per cell; cells in middle short rectangular to polygon shaped, 7–9 µm × 10–13 µm, thin-walled, multipapillose; cells in central basal irregularly long-rectangular, lighter in color, thick-walled, minutely porose, 8–12 µm × 28–48 µm, 1–2 papillae per cell, sometimes these elongated pale-colored cells present only on one side of leaf; costa cells strongly porose, 50–80 µm long. Cells from secondary branch leaves similar in size and shape. Sporophytes unknown. **Fig. 1.**

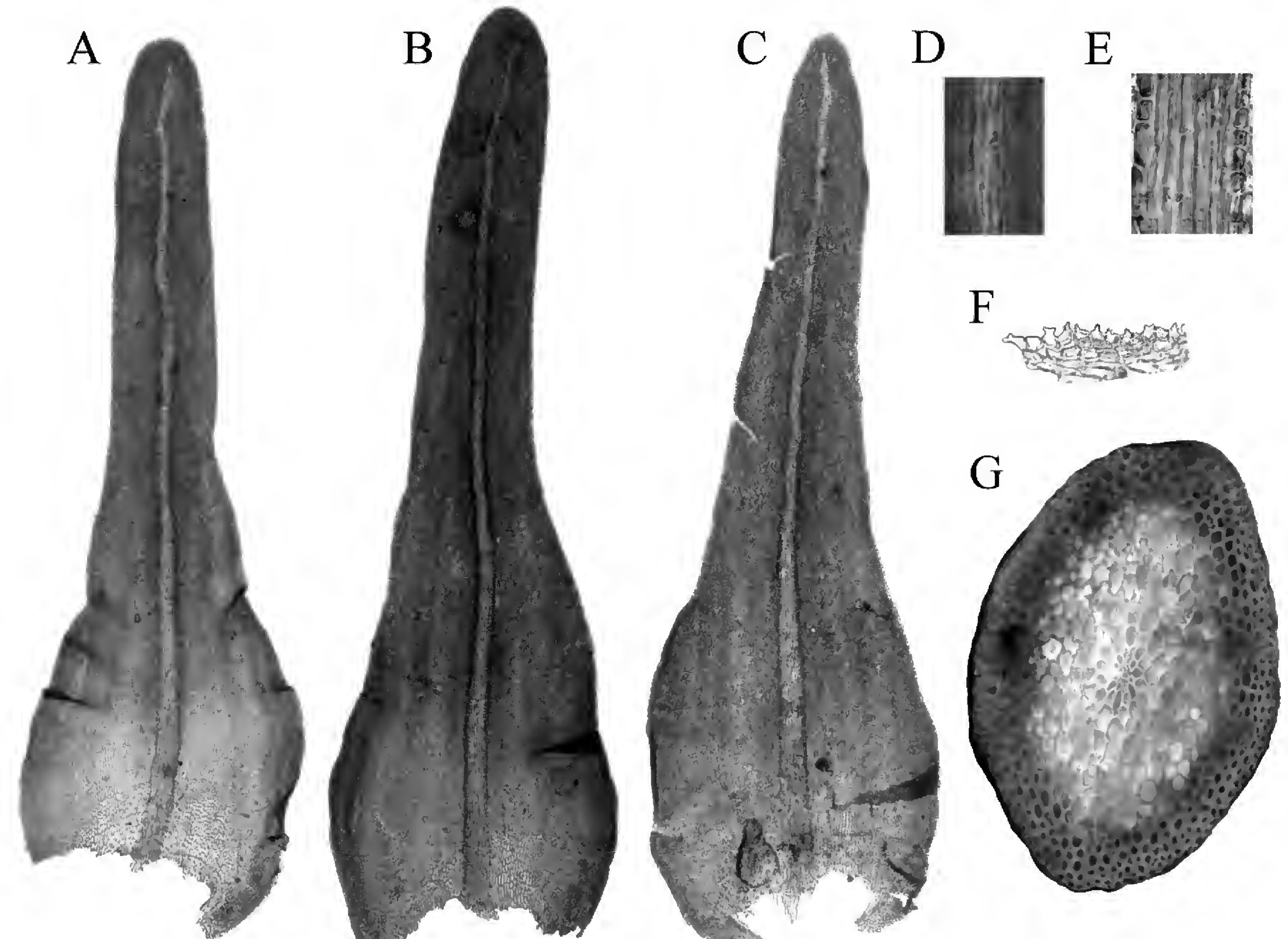


Fig. 1. *Anomodon perlingulatus* **A**, leaf from primary branch; **B–C**, leaves from secondary branch; **D**, costa cells in the middle of leaf; **E**, costa cells in the bottom of leaf; **F**, marginal cells at decurrent leaf; **G**, cross section of stem. Scale bar = 50 µm. All images from *Y.L. Yao 15-1033* (CAS).

Recognition: *Anomodon perlingulatus* is smaller than *A. minor* (Hedw.) Lindb. and *A. viticulosus* (Hedw.) Hook. & Taylor by leaf size, and the elongated and slim leaf apex is easily seen with the help of a hand-lens. Besides the unique leaf shape, the costa cells of *A. perlingulatus* are mostly smooth (Fig. 1D–E) with only inconspicuous prorations while several rounded papillae are more commonly seen in both *A. minor* and *A. viticulosus.*

Distribution and Ecology: The specimens of *Anomodon perlingulatus* were obtained from rocks along rivers where they are seasonally submerged. This is the first report of this species being found in a rheophytic environment, even though a more wide-spread species, *A. viticulosus* in western Yunnan always occupies similar habitats. From our field experience, *A. perlingulatus* often occupies the same niche with other more commonly collected members of the genus, such as *A. viticulosus* and *A. minor*, a rather common phenomenon where several *Anomodon* species tend to grow in mixed populations (Granzow-de la Cerda 1997).

Mao and Zhang (2011) reported *Anomodon perlingulatus* from the Langcangjiang (Headwater of Mekong River) Valley in northwest Yunnan Province. However, after examining the duplicates at CAS the specimens are actually *A. viticulosus.* Xiong (2014) cited several specimens collected in neighboring Guizhou Province, however, there is no habitat information. Unfortunately, those specimens have not been available to us to confirm their identity, even though we feel quite confident of its occurrence based on the illustration.

Many obligate rheophytes such as *Handeliobryum sikkimense* (Paris) Ochyra (Ochyra and Shevock 2012), *Sciaromiopsis sinensis* Broth., *Schistidium riparium* H.H. Blom, Shevock, D.G. Long & Ochyra (Blom *et al.* 2011), and several species of *Neckeropsis* (Enroth 1999) have a thickened leaf border, as an adaptation to fast flowing water (Vitt and Glime 1984). However, *A. perlingulatus* lacks this structure, just like several other rheophytic bryophytes found in the same habitats such as *Cyptodontopsis leveillei* (Thér.) P. C. Rao & Enroth (Ma *et al.* 2014)*, Hydrocryphaea wardii* Dixon (Shevock *et al.* 2006), and *Yunnanobryon rhyacophilum* Shevock, Ochyra, S. He & D.G. Long (Shevock *et al.* 2011).

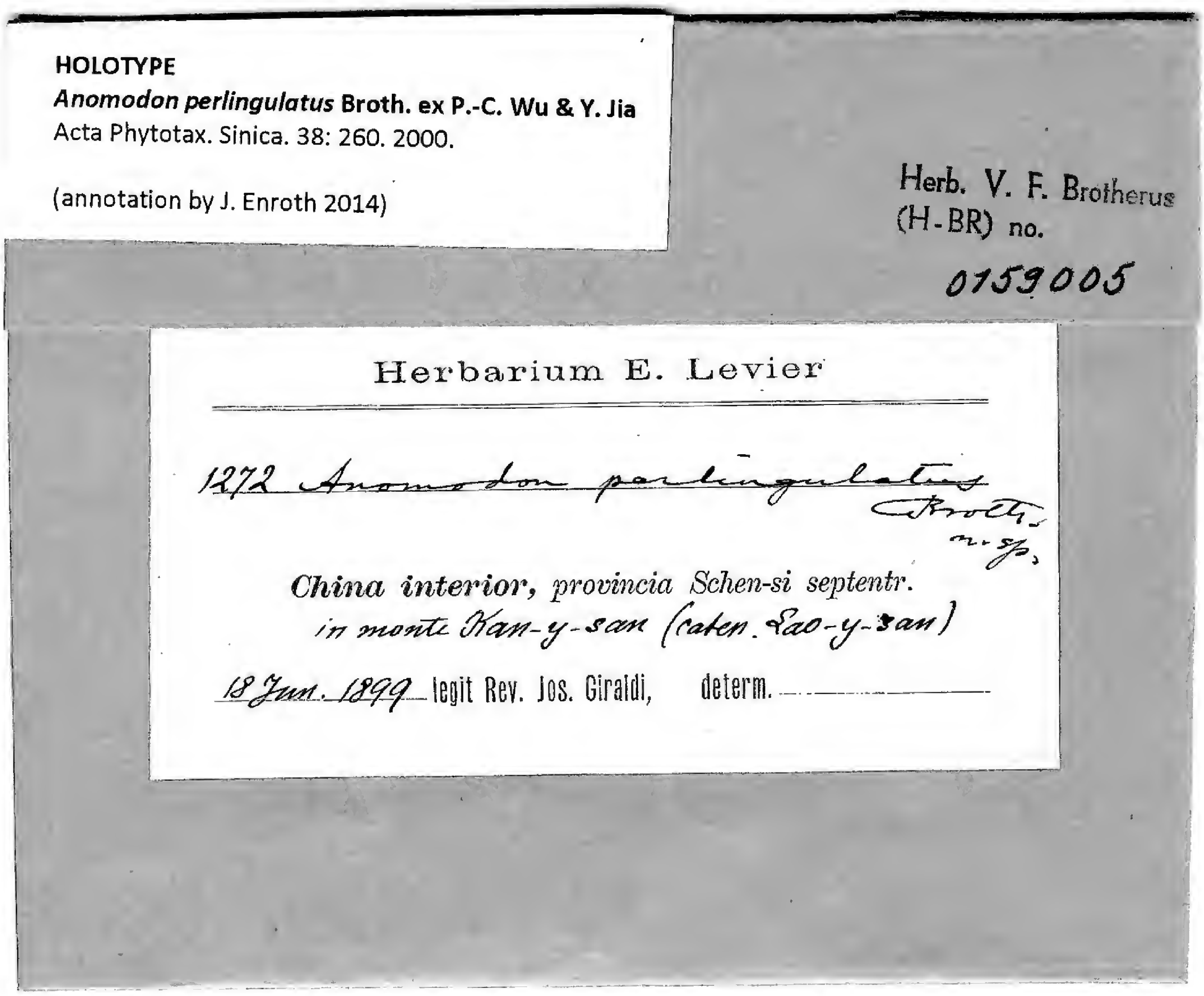
Many leaves from the proximal part of the primary branch were broken, leaving strong costae behind. These badly eroded leaves were likely a result of silt abrasion in swift-running water. This suggests *A. perlingulatus* may not be specifically adapted to this aquatic environment, or else this species may have evolved certain mechanisms to combat frequent physical disturbances. Since *Anomodon* species rarely produce capsules in China, the fragments scoured away from mature leaves by water could function as asexual propagules, a phenomenon also observed in the rheophilous species *Neckeropsis moutieri* (Broth. & Paris) M. Fleisch. (He and Zhang 2007). The sporophyte of *A. perlingulatus* remains unknown, and the species is highly likely to be diocious, so the fragile leaf border may serve as an efficient means of vegetative dispersal.

Due to the under-collection of this species, its specific ecological requirements in rheophytic habitats are difficult to elaborate. Also, because there is no experimental evidence to verify the function of broken margins of old leaves in vegetative dispersal, it is prudent to categorize *A. perlingulatus* as a facultative rheophyte. Nonetheless, rocky and woody substrates along riparian sites that experience irregular submersion are still the most likely habitats for *A. perlingulatus.*

Specimens examined: Honghe, Ge-Jiu City, Man-Hao Zhen, Lv-Shui-He tropical rain forest scenic spot, alt. 470 m, on granite rock at river bank, seasonally submerged, *Y. L. Yao 15-1033*, 3 Oct 2015 (CAS, KUN); Nujiang. Fu-Gong Co., Pi-He Xiang, alt. 1080 m, on shady wall of large marble boulder by river, *D. G. Long 35187*, 23 Aug 2005 (CAS, E, KUN); Zi-Li-Jia Xiang, east side of Nujiang, alt. 1130 m, on rock of river bank seasonally submerged, *W. Z. Ma 13-5192*, 22 Sep 2013 (CAS, H, KUN).

Notes: In Brotherus (1907), the species epithet was printed as "*perlinguatus*", but Brotherus wrote "*perlingulatus*" on the specimen label (Fig. 2), which consists of the Latin prefix "*per-*" and "*lingulatus*", indicating the plants are characterized by "tongue-shaped" leaves throughout. The Latin "*linguatus*" means "eloquent, gifted in speech", which apparently makes much less sense especially when the leaves are indeed tongue-shaped.

It is interesting that both the correct and misspelled species epithet appear in literature. Initially, Brotherus had it right on the type specimen label but later it appeared with a typographical error in the protologue (Brotherus 1907), and over a century later, Wu and Jia (2000) corrected the error but again missing the second "l" in Moss Flora of China Volume 6 (Wu *et al.* 2002). We brought this issue to the attention of the herbarium in Missouri Botanical Garden (MO) and *Anomodon perlingulatus* has since been amended on TROPICOS (http://www.tropicos.org/). The label of the type material states "China interior, provincia Schen-si septentr., in monte Kan-y-san (caten. Lao-y-san), 18 Jun. 1899, legit Rev. Jos. Giraldi". It is important to note that the number *1272* on the label is not Giraldi's collection number but a herbarium number, because the label is titled as "Herbarium E. Levier".



HOLOTYPE
Anomodon perlingulatus **Broth. ex P.-C. Wu & Y. Jia**
Acta Phytotax. Sinica. 38: 260. 2000.

(annotation by J. Enroth 2014)

Herb. V. F. Brotherus
(H-BR) no.
0159005

Herbarium E. Levier

1272 Anomodon perlingulatus
Broth.
n. sp.

China interior, provincia Schen-si septentr.
in monte Kan-y-san (caten. Lao-y-san)

18 Jun. 1899 legit Rev. Jos. Giraldi, determ.

Fig. 2. Label of the holotype specimen of *Anomodon perlingulatus.*

Redicovery of *Curvicladium kurziii* (Kindberg) Enroth

Curvicladium is a Himalayan monospecific genus, established by Enroth (1993) based on species previously placed in the genera *Thamnobryum* (also as *Thamnium*, which is a later homonym) and *Pinnatella*. The generic features of *Curvicladium* were discussed in great detail by Enroth (1993) and the most striking features, especially relative to *Pinnatella*, include: often arcuate stems and branches, coarse teeth formed by multiple cells in the leaf apex, a long (8–11 mm) and twisted seta, and post-fertilization growth of perichaetial leaves. Olsson *et al.* (2010) showed that *Curvicladium* belongs in an essentially Asian and morphologically heterogenous *Pinnatella*-clade in the Neckeraceae, but its detailed relationships remain unresolved.

Previously known in China from a single specimen collected in Yunnan over 50 years ago, *Curvicladium kurzii* is now reported from several National Nature Reserves in the province, and with one occurrence documented in a stream channel. The historical voucher specimen was collected by "D. of F.Y.U." (Enroth 1993), which we deciphered as an abbreviation for "Department of Forestry, Yunnan University". Additional material of this species might be found among undetermined specimens in the herbarium at Yunnan University (YUKU). The collecting site of this specimen was cited differently as "Chen-Kang County" in Enroth (1993) and "Zeng-Kong Co." in Wu (2011), however, there is no county spelling like either of the above in Yunnan today. We assume those spellings were originated from Postal Romanization, where "Zhen-Kang" County in Lin-Cang City, southwest Yunnan, turned out to be the best match.

As we were about to "announce" the finding of this rare species from Yong-De-Da-Xue-Shan National Nature Reserve in Yong-De County, the first author realized there was an interesting background regarding the name of this county. There was no county named Yong-De before it separated from a part of the previous Zhen-Kang County in 1964, and all recorded plant specimens labeled with "Chen-Kang" before that year were actually collected in what is now Yong-De County (Liu 2006). This statement is further confirmed by "Snow mountain, 2300 m, on bark, 18. IV. 1964" from the specimen label (Enroth 1993), namely referring to the Da-Xue-Shan (which means giant snow mountain) in Yong-De County. Thus our *C. kurzii* collections were not a second location but just a rediscovery of the historical record.

Two more populations of this largely Himalayan genus were found in different counties in Yunnan during later bryological expeditions, and a search of herbarium collections at CAS and KUN also yielded additional locations (see specimens examined).

Curvicladium kurzii (Kindberg) Enroth *Annales Botanici Fennici* 30: 110. 1993.

[Neckeraceae]

Published Illustrations: Wu (2011: 370, Plate 387, Figs. 1–9); Gangulee (1976: 1442 as *Pinnatella kurzii*).

Specimens examined: Honghe, Jin-Ping Co., Zhe-Mi Xiang, Liang-Zi Village, Xi-Long Mountain, Fen-Shui-Ling National Nature Reserve, on trunk of huge tree in old-growth broad-leaved forest, alt. 2240 m, *W.Z. Ma 15-7037*, 30 Sep 2015 (CAS, KUN); Baoshan, Teng-Chong Co., near Lin-Jia-Pu Forestry station, on trunk in broad-leaved evergreen forest, alt. 2439 m, *W. Z. Ma 14-5518*, 19 Mar 2014 (KUN); same general vicinity, *W. Z. Ma 14-5535* (KUN); along trial to Nan-Zhai-Gong-Fang Pass, Gao-Li-Gong-Shan National Nature Reserve, on metamorphic rock in stream water splashing zone, alt. 2513 m, *W. Z. Ma et Shevock 14-5766*, 12 Jul 2014 (CAS, H, KUN); Dehong, Ying-Jiang Co., Meng-Long Xiang, Sa-Shui River, on granite rock by stream, alt. 1940 m, *W. Z. Ma 15-6298*, 4 May 2015 (CAS, KUN); Lincang, Yong-De Co., Yong-De National Nature Reserve near wildlife monitoring cabin, alt. 2274 m, *W. Z. Ma et Shevock 14-5576*, 29 Jul 2014 (CAS, KUN); same general vicinity, on base of hardwood trunk in filtered light, *Shevock et W. Z. Ma 45244*, 30 Jul 2014 (CAS, KUN, H, MO); same general vicinity, on hardwood trunk in filtered light, *Shevock et W. Z. Ma 45250*, 30 Jul 2014 (CAS, H, KUN). **Fig. 3.**

Recognition: *Curvicladium kurzii* shares many morphological similarities with *Pinnatella*, such as the general branching pattern and the overall leaf shape, as well as the rectangular intra-marginal cells near the alar region. However, *C. kurzii* is easily distinguished from the latter by having arcuate branches that sometimes grow up to 10 cm long, as well as capsules borne on a long seta compared with exserted capsules in *Pinnatella*.

Fig. 3. Plants of *Curvicladium kurzii* with capsules. Scale bar = 1 cm. Image from *W.Z. Ma 15-6298* (CAS).

Distribution and ecology: The elongated stem would allow *C. kurzii* some flexibility in a water-flowing environment. Similar to the long seta of *Handeliobryum sikkimense* (Ochyra and Shevock 2012), the long seta of *C. kurzii* could be viewed as a special adaptation in the periodically submerged habitat. In addition, the post-fertilization growth of perichaetial leaves observed by Enroth (1993), may be a special protective mechanism that reduces the mechanical impact from running water to the maturing capsules. Even though only one specimen so far was collected in rheophytic habitats, the above-mentioned morphological traits indicate that *C. kurzii* can also be a facultative rheophyte.

Although rarely collected, *Curvicladium kurzii* is not suggested to be viewed as a dispersal-limited species which deserves any further conservation attention based on the current distribution data. Apart from the previously cited location in Yong-De County, geographically speaking, our newly collected populations of *C. kurzii* were scattered in four different southern counties in Yunnan. The distance between Ying-Jiang (24°51'17" N, 97°53'43" E) and Jin-Ping (22°39'49" N, 102°47'56" E), the two most distant sites, is roughly over 550 km, covering 2/3 the width of the province. This shows *C. kurzii* has the capability to colonize a wide range of its potential habitats in Yunnan. Actually, *C. kurzii* is quite widespread in southwest Asia as it had been reported from India, Nepal and Thailand (Enroth 1993). We believe this species is largely under-collected rather than very rare.

Because all our recent collections were obtained from National Nature Reserves, the presence of this species is somehow associated with forests preserved in good condition. Unlike most other members of Neckeraceae, *C. kurzii* appears to be fairly intolerant to fluctuation in light and water supply, and field data suggests it is often associated with a forest environment with deep shade and high atmospheric humidity. This probably implies that *C. kurzii* is very sensitive to anthropogenic disturbances that unpredictably change the light regime. In searching for more populations of *C. kurzii*, future bryological expeditions should pay special attention to montane forests between elevation 1900 m and 2600 m at shaded, humid and even perhaps rheophytic sites in Sichuan, Taiwan, Yunnan and Xizang. There may be an interesting distribution pattern of *C. kurzii* associated with primary forests should more new occurrences be discovered.

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Two new moss records in the family Grimmiaceae from Turkey, Southwest Asia

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Abstract

Grimmia incurva Schwägr. and *Schistidium umbrosum* (J.E.Zetterst.) H.H. Blom (Grimmiaceae) are reported for the first time from Turkey, Southwest Asia. Turkish plants are described and illustrated from material collected from Göllüdağ Volcano in the Central Anatolia (Niğde) which has a semi-arid, continental climate with a severe frost period in winter.

Introduction

The genus *Grimmia* is one of the largest groups in the acrocarpous moss family Grimmiaceae. Species of *Grimmia* are often difficult to identify (Ignatova and Muñoz 2004), and likewise the genus *Schistidium* has a reputation for being taxonomically difficult. The genus *Schistidium* currently comprises around 120 species (McIntosh 2007), while *Grimmia* contains about 95 species (Hastings and Greven 2007).

Grimmia species grow on rocks at low to high altitudes on all continents, and most of them are drought resistant. Therefore, they can withstand extremely harsh cold and dry climates (Ignatova and Muñoz 2004). According to Ros et al. (2013) 29 species of *Grimmia* have been reported for Turkey. Here we report *Grimmia incurva* Schwägr. new for Turkey, taking to 30 the number of *Grimmia* species reported for this country.

Members of the genus *Schistidium* generally grow on nutrient-rich rocks in arctic to temperate regions (Batan et al. 2013). Nineteen species of *Schistidium* have been reported for Turkey (Kürschner and Erdağ 2005, Townsend 2005, Tonguç Yayıntaş 2008, 2014, Kürschner and Frey 2011, Batan et al. 2013). *Schistidium umbrosum* (J.E.Zetterst.) H.H. Blom increases this total by one. Description and illustration of the species further contributes to the moss flora of Turkey.

Material and Methods

This study is based on specimens collected from Göllüdağ Volcano in the Central Anatolia (Niğde) in May 2015 (Fig. 1) and now held in the Herbarium of Niğde University. The specimens were identified using relevant literature (Blom 1996, Cortini-Pedrotti 2001, Greven, 1995, 2003, Hastings and Greven 2007, Ignatova and Muñoz 2004, Nyholm 1998, McIntosh 2007, Smith 2004).

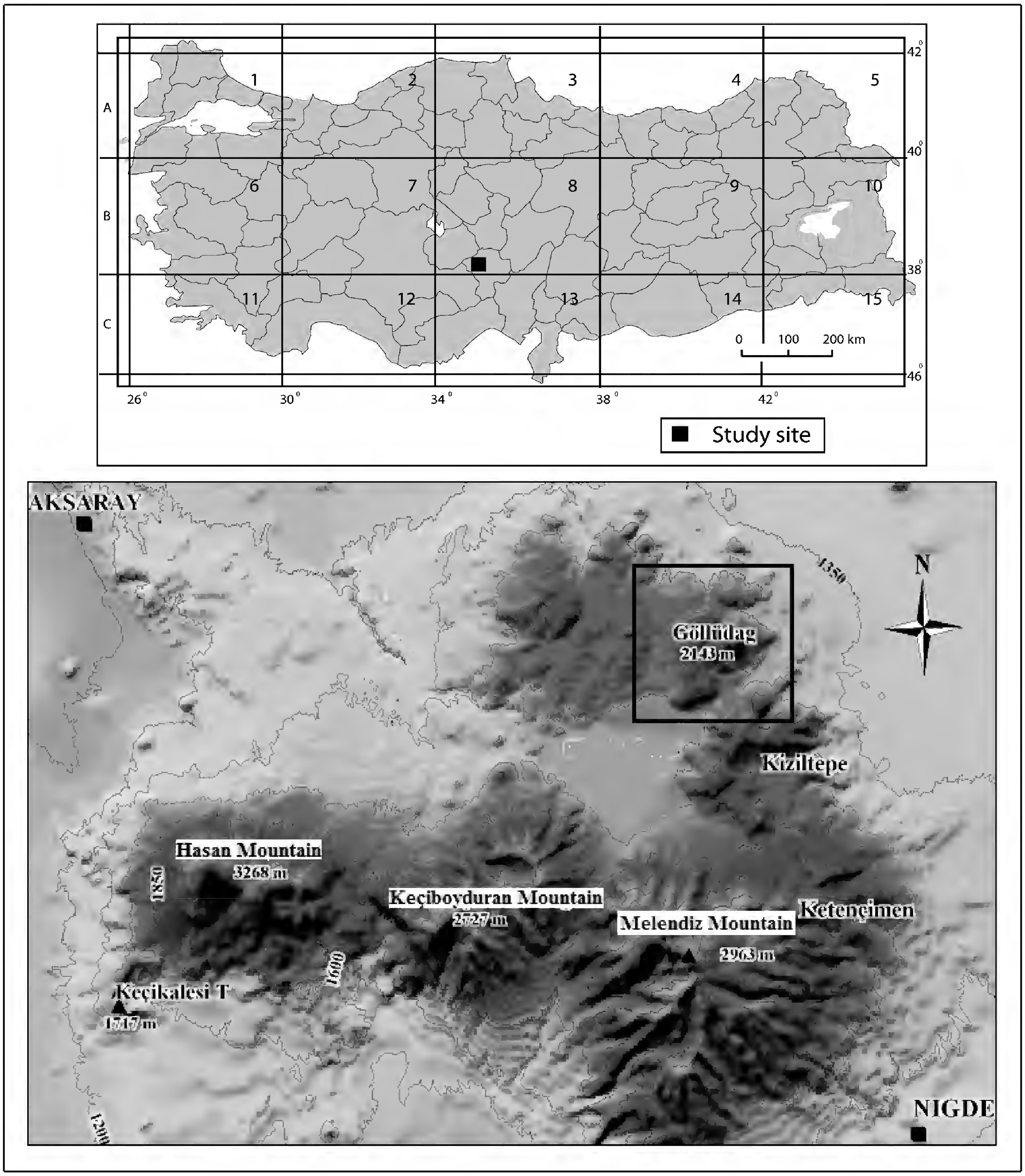

Figure 1. Göllüdağ Volcano region (modified from Bayer Altın 2010)

Taxonomy

Grimmia incurva **Schwägr.** Species Muscorum Frondosorum, Schwägrichen, Christian Friedrich Supplementum Primum 1: 90. 1811.

Synonyms: *G. contorta* (Wahlenb.) Arnott, *G. curvifolia* Lindb., *G. hagenii* Kaurin, *G. torngakiana* Bras. & Hed., *G. uncinata* Kaulf.

Description of the Turkish specimens: Plants form dark green to blackish rounded cushions. *Stems* erect 1–2.5 cm long, occasionally 1–2 branched. *Leaves* oblong, linear to lanceolate, 2–3 mm long and 0.5 mm wide, incurved and moderately contorted and crisped when dry, spreading when moist, tapering to acuminate, with short hyaline apex, sharply keeled distally, margins plane in distal part of leaf, recurved below on one side; *lamina* mostly bistratose, unistratose near costa and in basal part of leaf; *costa* differentiated, semi-circular in cross-section; upper leaf cells subquadrate, 8–12 µm; *mid-leaf cells* rectangular, moderately sinuose and incrassate; *basal marginal cells* elongate with thin walls and the basal juxtacostal cells are elongate rectangular with thick and porose longitudinal walls. Observed specimens were sterile, no perichaetia, antheridia, or sporophytes. **Fig. 2 (1–9)**.

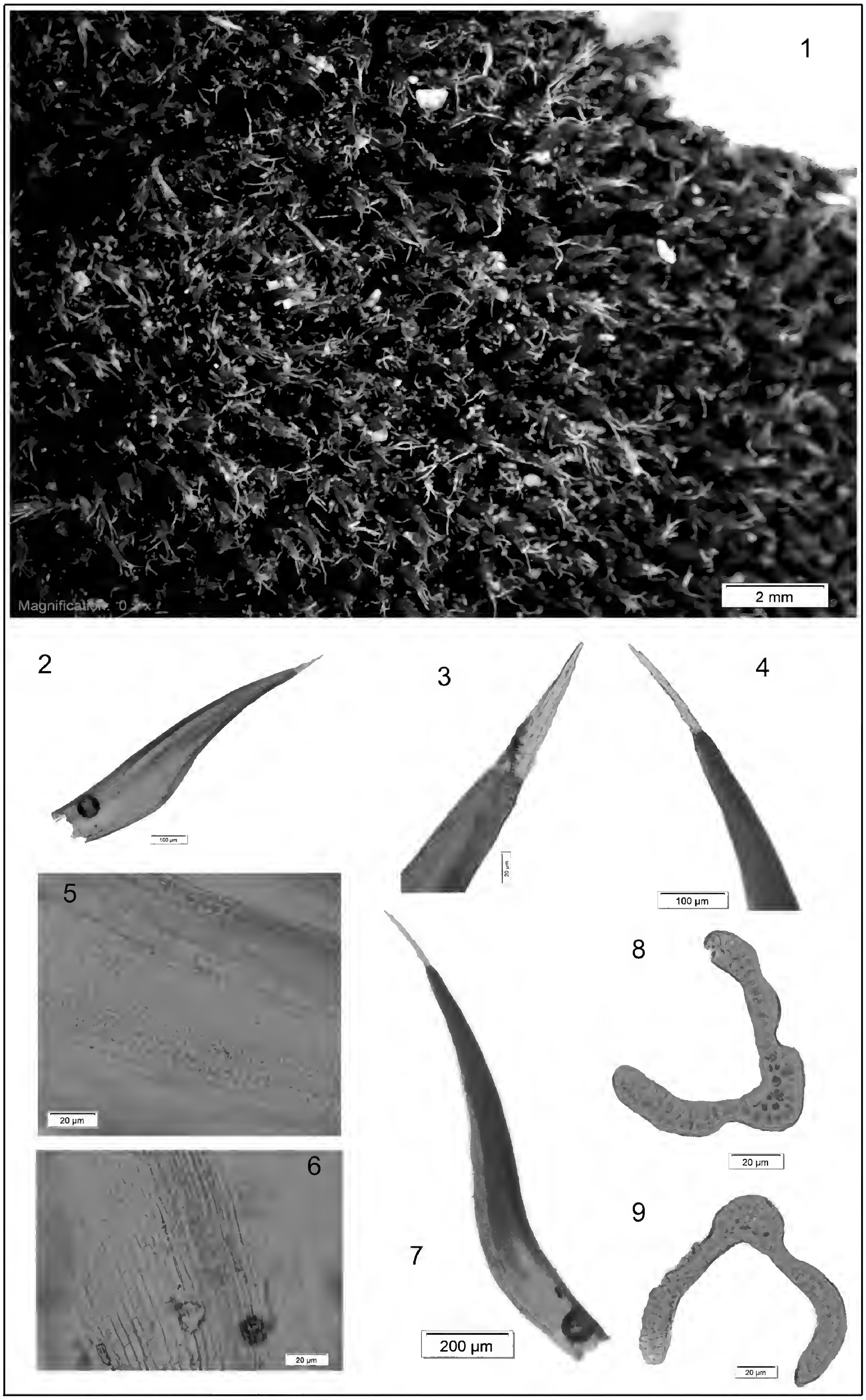

Figure 2. ***Grimmia incurva*** **(Ezer 1780);** 1, habit; 2 and 7, leaf; 3 and 4, leaf apex with hyaline hair-point; 5, upper laminal cells; 6, basal cells; 8 and 9, leaf cross-sections. Scale bars shown.

Specimen examined: Turkey: Central Anatolia: Niğde: Göllüdağ Volcano, Aşağıseki place, on basaltic rock, alt. c. 1729 m, (38° 16' 49.60" N, 34° 33' 01.20" E), *Karakaş 64* and *Ezer 1780*, 19 May 2015 (Herbarium of Niğde University).

According to the literature (Greven 1995, 2003, Ignatova and Muñoz 2004, Hastings and Greven 2007, Smith 2004), this species is dioicious; *capsules* very rare, emergent to exserted obloid, yellowish; *setae* arcuate when moist, 2–3 mm long; *operculum* rostellate with short beak; *peristome teeth* orange and strongly perforated; *spores* 10–12 µm; *calyptra* mitrate.

Grimmia donniana Smith, *G. elongata* G. Kaulfuss and *G. fuscolutea* Hook., are similar species to *G. incurva*. Linear-lanceolate, contorted to almost crisped leaves with a short hair-point are characteristic of *G. incurva* while *G. fuscolutea* has slightly flexuose leaves with a long hair-point. *Grimmia elongata* has a unistratose lamina, whereas lamina of *G. incurva* is mostly bistratose, unistratose near costa and in basal part of leaf. Also, *Grimmia donniana* has thin-walled basal marginal cells and usually numerous exserted capsules. *Grimmia incurva* may superficially resemble *Andreaea* members and *Dicranoweisia crispula* in the field, but *G. incurva* differs from them by the presence of short hair-points. Comparison of the main different and similar characters between Turkish specimens and some other collections are listed in Table 1.

Table 1. Comparison of Turkish *Grimmia incurva* specimens and other collections.

	Turkish plants	Russian plants (Ignatova and Muñoz 2004)	European plants (Greven 1995)	North American plants (Hastings and Greven 2007)
Plants	dark green to blackish, 1–2.5 cm long	dark green or blackish-green, (1–)2–3 cm long	dark green or blackish-green, 1–3 cm long	green to blackish, 1–2 cm
Leaves shape	oblong, linear to lanceolate	linear-laceolate	linear	oblong to linear-lanceolate
Leaf length	2–3 x 0.5 mm	(1–)2.5–3(–4) x (0.3–) 0.4-0.6 mm	2–5 mm	2.5–4.5 x 0.3–0.5 mm
Hyaline hair-point	short	short to absent	short	short, occasionally long
Lamina	mostly bistratose, unistratose near costa	mostly bistratose in distal 1/3, unistratose near costa	partly bistratose above	distal laminal cells 1-stratose, margins and apex 2-stratose
Costa	semi-circular in cross-section	strongly prominent dorsally, semi-circular in cross-section, with 2 ventral epidermal cells	projecting on dorsal side	projecting on abaxial side
Upper and mid-leaf cells	subquadrate, moderately sinuose and incrassate, 8–12 µm	subquadrate, slightly sinuose walls, 9-14 µm	shortly rectangular, sinuosely incrassate, 9–15 µm	rectangular, slightly sinuose, thick-walled
Basal marginal cells	elongate with thin walls	slightly shorter	rectangular, hyaline	short to long rectangular, thin-walled
Basal juxtacostal cells	elongate rectangular with thick and porose longitudinal walls	elongate rectangular with thick and porose longitudinal walls and transverse walls	nodular thickenings	long rectangular, thick-walled
Sporophyte	unknown	rare	regularly present	occasionally present

Ecology and distribution: *Grimmia incurva* usually grows on acidic rock at moderate to high elevations. It is one of the characteristic species of the alliance Andreaeion rupestris (Greven 1995, Dierssen 2001). In Turkey *Grimmia incurva* was collected on basaltic rock surface from Göllüdağ Volcano (Niğde). It was found together with the moss species *Bryum dunense* A. J. E. Sm & H. Whitehouse and *Grimmia orbicularis* Bruch ex Wilson. *Grimmia incurva* is distributed in Europe (Austria, Azores, Bulgaria, France, Germany, Italy, Macedonia, Scotland, Slovakia, Spain, Sweden, Switzerland), Asia (Central China, Japan, Mongolia, Russia (Altai Mts., Caucasia, Chukotka, Kamchatka, Khabarovsk Territory, Kola Peninsula, Magadan Province, Middle and South Urals, Yakutia), America (Mexico, North America), and Greenland (Greven 1995, 2003, Ros et al. 2013, Ignatova and Muñoz 2004, Hastings and Greven 2007).

***Schistidium umbrosum* (J.E.Zetterst.) H.H. Blom.** Blom, Hans Haavardsholm, Bryophytorum Bibliotheca 49: 125. 1996.

Basionym: *Grimmia apocarpa* fo. *umbrosa* J.E.Zetterst.

Description of the Turkish specimens: Plants form small, dense cushion or tufts, greyish green or olivaceous-green in upper parts, brown to black in lower parts. *Stems* slender, up to 2.5 cm, intricately branched, central strand distinct. *Leaves* sharply keeled in upper part, slightly curved or straight, acute, 1.7 mm long, 0.6 mm wide, hair point very shortly decurrent, 0.3 mm, rather coarse, shortly decurrent, sharply spinulose-denticulate; margins smooth, recurved towards apex, bistratose in upper part; *lamina* smooth, unistratose, less frequently bistratose in upper part; *laminal cells* irregular in shape, thick-walled, sinuose, upper leaf cells 8 µm wide, oval to shortly oblong; *basal leaf cells* incrassate, rectangular, 25–30 µm; *costa* widened above and central parts, widened just below apex, excurrent or percurrent, smooth or with few low papillae near apex; *sporophytes* common, and immersed; *seta* thick, 0.25 mm long; *capsule* orange-brown, cupulate, 0.7 x 0.8 mm; *exothecial cells* thin-walled, isodiametric and transversely elongated; *peristome teeth* orange-brown to brownish red, recurved, from broad base and abruptly contracted to a fine point, 280–310 µm long, strongly perforated, coarsely papillose; *spores* 12–14 µm, finely granulose. **Fig. 3 (1–13)**.

Specimens examined: Central Anatolia. Niğde: Göllüdağ Volcano, Sarıkaya place, on basaltic rock, alt. c. 1936 m, (38° 15' 52.60" N 34° 33' 57.50" E), *Karakaş 90* and *Ezer 1789*, 6 September 2015 (Herbarium of Niğde University).

Schistidium umbrosum is closely related to *S. pulchrum* which was reported for Turkey from the Erciyes Mountain by Kara et al. (2014). *Schistidium pulchrum* has an oblong-cylindrical urn, whereas *Schistidium umbrosum* has a cupulate, obovoid, or subsphaerical urn. Also, the dull reddish-brown strongly perforated and coarsely papillose peristome teeth of *S. umbrosum* distinguish this species from *S. pulchrum*. Comparison of the main different and similar characters between Turkish specimens and some other collections of *S. umbrosum* are listed in Table 2.

Table 2. Comparison of Turkish *Schistidium umbrosum* specimens and other collections.

	Turkish plants	Norwegian and Swedish plants (Blom 1996)	Nordic plants (Nyholm 1998)
Plants	small, up to 2.5 cm	small, 0.8–3.5 cm	small, 0.8–3.5 cm
Leaves	1.7 x 0.6 mm, sharply keeled in upper part	(1.0–)1.2–1.9(–2.1) x (0.3)0.4–0.75 mm, sharply keeled in upper part	(1.0–)1.2–1.9(–2.1) x (0.3)0.4–0.75 mm, sharply keeled in upper part
Hair point	very shortly decurrent, 0.3 mm	not or very shortly decurrent, 0–0.4(–0.7) mm	not or very shortly decurrent, 0–0.4(–0.7) mm
Margins	smooth, bistratose in upper part	smooth or rarely denticulate in apical part, in upper and central parts bistratose	smooth, rarely denticulate below apex, in upper and central parts bistratose
Lamina	smooth, unistratose, less frequently bistratose in upper part	smooth, in upper and central parts unistratose with few to several bistratose spots	smooth, unistratose or patly bistratose in upper part
Laminal cells	irregular in shape, thick-walled, sinuose	gradually becoming shorter towards apex, irregular in shape, thick-walled, ± sinuose	irregular in shape (transversely ovate to shortly oblong), incrassate, ± sinuose
Upper leaf cells	8 µm wide, oval to shortly oblong	(6)7–9 µm, transversely oval to shortly oblong	(6)7–9 µm wide
Basal leaf cells	rectangular, 25–30 µm long	shortly oblong, up to 20–41 µm	up to 20–40 µm
Costa	widened just below apex, excurrent or percurrent	often widened just below apex, excurrent or rarely percurrent	often widened just below apex
Sporophytes	common, and immersed	commonly present, mostly deeply immersed	unreported
Urn	orange-brown, cupulate, 0.7 x 0.8 mm	straw yellow to light orange-brown, cupulate or broadly ovoid, 0.55–0.75–1.0 x 0.5–0.8 mm	straw yellow to light orange-brown, cupulate or broadly ovoid, 0.55–1.0 x 0.5–0.8 mm
Exothecial cells	thin-walled, isodiametric and transversely elongated	In patches of short transversely rectangular, square and shortly rectangular, thin-walled	predominantly isodiametric and transversely elongated
Peristome teeth	orange-brown to brownish red, recurved, strongly perforated, 280–310 µm	dull, dark orange-brown to brownish red, ± straight and twisted once around the axis, strongly perforated to fenestrate in upper half, (260)280–390 (–420) µm	dark orange-brown to brownish red, strongly perforated in upper half, (260)280–390(–420) µm
Spores	12–14 µm, finely granulose	(8)10–13(–15) µm, finely granulose	10–13(–15) µm, finely granulose

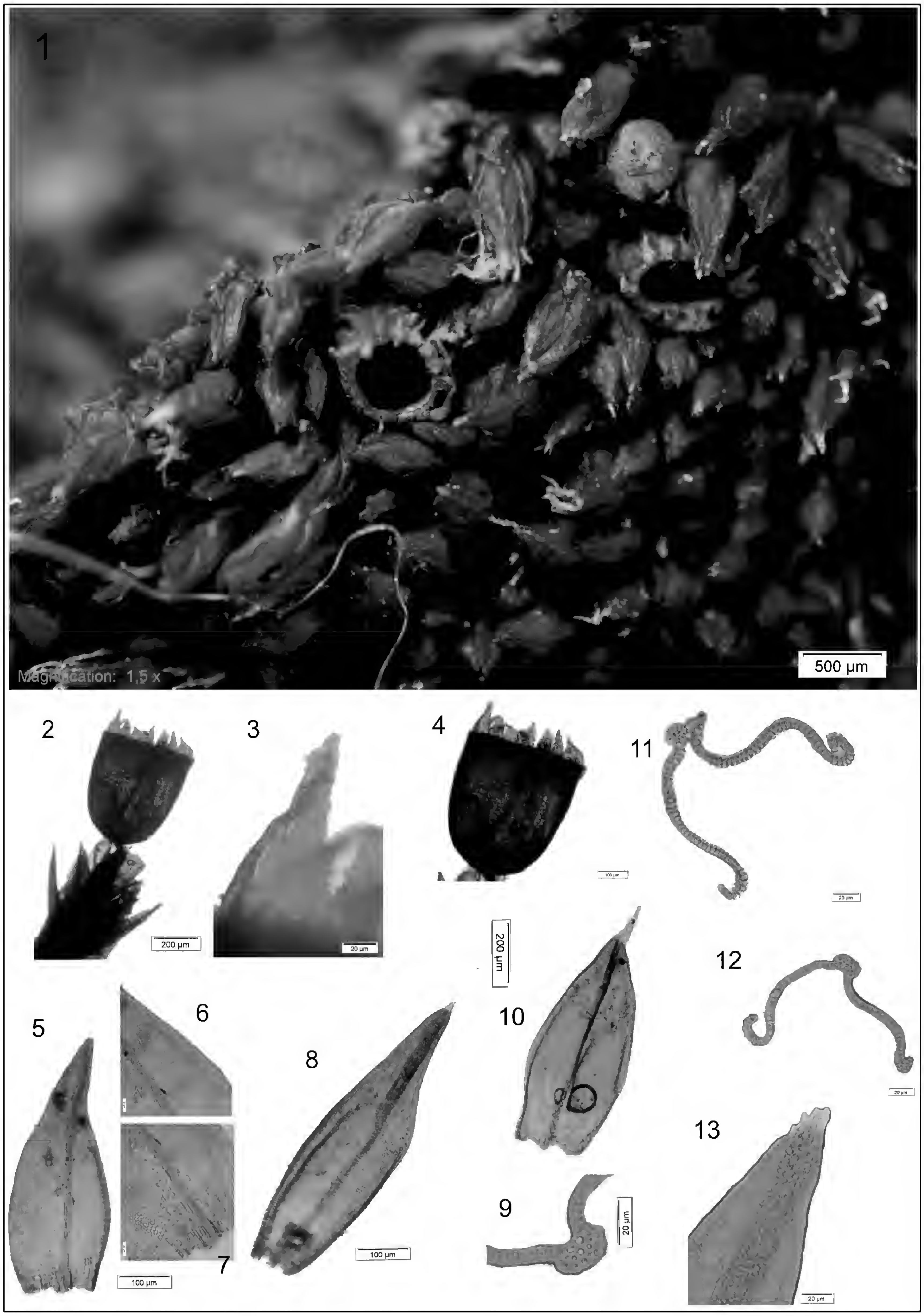

Figure 3. ***Schistidium umbrosum*** **(Ezer 1780)*;*** 1, habit; 2, sporophyte; 3, peristome teeth; 4, urn; 5 and 8, leaves; 6, median leaf cells; 7, basal leaf cells; 9, cross-section of costa; 10, perichaetial leaf; 11 and 12, leaf cross-section; 13, leaf apex. Scale bars shown.

Ecology and distribution: *Schistidium umbrosum* is subneutrophytic [pH 5.7–7.0 (–7,5)], mesophytic, sciophytic. The species prefers vertical or overhanging cliffs of base-rich rocks like hard schists and calcareous sandstone in the subalpine and alpine regions. It is one of the characteristic species of the alliance Grimmion tergestinae (Nyholm 1998, Dierssen 2001). In Turkey *Schistidium umbrosum* was collected on basaltic rock surface from Göllüdağ Volcano (Niğde). It was found together with the moss species *Grimmia alpestris* (Web. & Mohr) Schleich. and *Pseudoleskea incurvata* (Hedw.) Loeske. *Schistidium umbrosum* is distributed in the Alps, Austria, Bosnia-Herzegovina, Canada, Central Norway, Georgia, Greenland, Montenegro, Northern Sweden, NW Finland, North America, Slovakia, Svalbard, and Switzerland (Blom 1996, Nyholm 1998, Ros et al. 2013).

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Triunia names and lectotypifications: reply to Guymer and Forster

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Abstract

The recent recognition of *Triunia kittredgei* Olde (Olde 2015) has been challenged by G.P. Guymer and P. Forster (2015) who have suggested that the name should be rejected and that the application of previous names should continue to apply in the genus *Triunia* L.A.S.Johnson & B.G.Briggs. They have argued that two varietal lectotypifications in *Helicia youngiana* C.Moore & F.Muell. by H. Sleumer (1955), varieties later recognised as species in the genus *Triunia,* should be overturned in favour of two later lectotypifications by D. Foreman (Foreman 1986). Their arguments are here separately examined and refuted.

Introduction

C.T. White (1933) recognised specimens of *Helicia youngiana* from Queensland as comprising two varieties, var. *robusta* and var. *montana,* but did not cite holotypes. He listed all specimens in the protologue of var. *robusta* in varying degrees of prominence. In 1955, H.D. Sleumer lectotypified both varieties, citing *Kajewski 1219* (NSW - *haud vidi*) as the 'lecto-*typus*' of var. *robusta* and *C.T. White* [*s.n.*] (NSW - *haud vidi*) as the '*typus*' of var. *montana*. In 1975, *Helicia youngiana* and its varieties were transferred to *Triunia,* a new genus erected by L.A.S. Johnson and B.G. Briggs (1975). In 1986, both varieties were recognised as distinct species, *Triunia robusta* (C.T.White) Foreman and *Triunia montana* (C.T.White) Foreman. In the same paper, Foreman lectotypified the two varietal names with different specimens to those of Sleumer, making no remark at the time about Sleumer's prior lectotypifications. In 1987, Foreman recognised a fourth species *Triunia erythrocarpa* from elements previously included in *T. robusta*, but included *Kajewski 1219* (BRI) in the citation of specimens.

Olde (2015) rejected Foreman's lectotypes as superfluous and therefore ineffective but noted also that neither of Sleumer's lectotypes were at NSW, their designated repository. Replacement lectotypes were explicitly designated from among the remaining isolectotypes; *Kajewski 1219* (BRI) for *H. youngiana* var. *robusta* and *C. T. White s.n.* (BRI) for *H. youngiana* var. *montana.* By including an isolectotype of *T. robusta* in the citation of specimens of his *T. erythrocarpa,* Foreman unwittingly invalidated his own name. Olde (2015) published the new name *Triunia kittredgei* for the species to which Foreman (mis)applied the name *T. robusta* and treated Foreman's *T. erythrocarpa* as a synonym of *T. robusta.*

Guymer and Forster (2015) challenged recognition of the name *Triunia kittredgei* Olde and the revised application of the name *Triunia robusta* (C.T.White) Foreman. They argued that the newly discovered prior lectotypes of *Helicia youngiana* var. *robusta* and *Helicia youngiana* var. *montana* designated by Sleumer

(1955), and the nomenclatural consequences flowing from them, should be rejected in favour of the later lectotypifications of Foreman (1986); that the nomenclatural status quo should be maintained. Guymer and Forster (2015) present a table (Table 1) in which the characters described in the protologue of *Helicia youngiana* var. *robusta* are compared with White's cited specimens and claimed that the character list shows that Sleumer's lectotypification of *Helicia youngiana* var. *robusta* (*Kajewski 1219)* is in serious conflict with the protologue. They argued that Article 9.19(b) of the code should apply. Additionally, they have rejected Sleumer's lectotype of *Helicia youngiana* var. *montana,* for which they had neither put forward a substantive argument nor argued against the validation outlined by Olde (2015).

Discussion

Triunia robusta (C.T.White) Foreman (1986).

Basionym: *Helicia youngiana* var. *robusta* C.T.White (1933).

Protologue: Guymer and Forster (2015, p. 457) have provided White's diagnosis of *Helicia youngiana* var. *robusta*. The remainder of the protologue states:

'This is the form the fruits of which are described by Bailey, l.c.'. According to him they measure in the fresh state 1 ¾ in. (4.5 cm.) long and 1 ½ in. (3.8 cm.) diam.

Distribution: This variety is confined to the subtropical rain-forests of Queensland. East Malanda lies within the tropics but its alt. 700 m., gives the forests a subtropical rather than tropical character.

Locality records: Maroochy (most southerly record), *F.M. Bailey, J. Low*. Yandina Eumundi, *F.M. Bailey, J.F. Bailey, J.H. Simmonds, J.B. Staer*. East Malanda, Atherton Tableland, alt. 700 m., common in rain-forest, *S.F. Kajewski, no. 1219* (flower buds), Sept. 22 (small to medium-sized tree; bark dark grey with numerous small white corky pustules, when cut light pink).'

Lectotype (Sleumer 1955): East Malanda, Atherton Tableland, alt. 700 m., common in rain-forest, *S.F. Kajewski, no. 1219* (flower buds), Sept. 22 1929 (NSW - 'lecto-*typus*, haud vidi'). *Typus* not found. Isolectotypes: A589471; B (*n.v.*); BRI-AQ317458; K001096591; MEL2277218A; NY2361410; NY2361411; S [S-G7589] ex NY. The duplicates at BRI and MEL were not cited by Sleumer, and it is possible that one of these was intended for distribution to NSW.

Replacement lectotype (Olde 2015): BRI-AQ317458.

Superfluous lectotype (Foreman 1986): Eumundi, xi. 1892, *J.H. Simmonds s.n.* (BRI-AQ317462); superfluous isolectotype: A589475.

Residual syntypes (additional to Foreman's lectotype above): Maroochie [Yandina], *F. M. Bailey s.n.*, Nov 1879 (MEL93791A); Maroochie [Yandina], *F.M. Bailey s.n.*, vii. 1888, (BRI022471 =BRI-AQ317456; MEL2277223A); Eumundi, *F.M. Bailey s.n.*, Nov 1892, (MEL2277217A); Eumundi, *J.F. Bailey & J.H. Simmonds s.n.*, xi. 1894 (BRI164313 =BRI-AQ317466; MEL2277221A) (the collectors cited by Foreman (1986) as *F.M. Bailey & J.H. Simmonds*); Eumundi, *J.F. Bailey s.n.*, May 1892 (BRI-AQ104858); Eumundi, *J.F. Bailey s.n.*, 1900 (A589477; BRI164317 = BRI-AQ317470; MEL2277219A; MEL2277220A; NSW169006!); Maroochie [Yandina], *J. Low s.n.* (BRI164316 = BRI-AQ317464; MEL2277222A); Eumundi, *J.H. Simmonds s.n.,* May 1892 (BRI-AQ105362); Eumundi, *J.B. Staer s.n*, xi. 1892 (BRI164312 (*n.v.*); Eumundi, *J.B. Staer s.n.*, Oct. 1911 (NSW169005!). This list is expanded from that provided by Olde (2015).

Notes: The main thrust of White's paper, in which varieties were erected in *Helicia youngiana,* was concerned with the specimens collected by Australian-born plantsman Mr. Sethric 'Frank' Kajewski (1904–1997), who was employed by the Arnold Arboretum of Harvard University for five years to collect plant specimens in the South Pacific Islands and who returned and collected in North Queensland from May to December 1929. This can be gleaned from its title "Ligneous plants collected for the Arnold Arboretum in North Queensland by S.F. Kajewski in 1929." However, the work extends beyond these specimens, especially in his treatment of *Helicia youngiana*.

The underlying problem is that White (1933) included specimens of what are now considered two taxa in his concept and description of *Helicia youngiana* var. *robusta*. Olde (2015) argued that the name *Triunia robusta* (C.T.White) Foreman had been incorrectly applied to one of these two taxa because Foreman not only overlooked Sleumer's lectotypification but lectotypified it superfluously with a different specimen, that application of the name *T. robusta* to Sleumer's lectotype left the other taxon unnamed, and that the name *Triunia kittredgei* Olde therein described effectively remedied that situation. The name *Triunia robusta* correctly applied requires that *Triunia erythrocarpa* Foreman be synonymised under it.

Guymer and Forster (2015) have asserted that Sleumer's lectotypification of *Helicia youngiana* var. *robusta* C.T.White is in serious conflict with the protologue and should be superseded by Foreman's lectotypification, which is in better agreement with it. Their argument is here examined.

There can be little doubt that all the specimens cited in the protologue of *Helicia youngiana* var. *robusta* C.T.White were used to compile its description. Among the cited specimens is *Kajewski 1219,* the extensive details of which are fully spelt out in the protologue, in comparison with the remaining synonyms which are cited by their general location and collector only. The prominence and detail associated with this citation and the title of White's paper itself presumably influenced Sleumer in selecting *Kajewski 1219* as the lectotype. At the time of Sleumer's lectotypification, there was no suggestion that two taxa might be recognised in the variety.

Guymer and Forster (2015) argued that features mentioned in White's diagnosis apply better to *Simmonds s.n.* than to *Kajewski 1219*. However, the evidence offered for the supersedence of Sleumer's lectotypification in their Table 1 is considered here to be flawed and inadequate. White's diagnosis of *Helicia youngiana* var. *robusta* makes much use of the range-extending words 'up to' which Guymer and Forster ignore in their comparisons. The majority of characters are covered by White's use of these critical words and Sleumer's lectotype falls within those given ranges. In regard to leaf length cited in White's diagnosis, it is unclear whether this includes the petiole or not.

Three characters not covered by range-extending words are White's description of the adaxial surface of the leaf as 'smooth and very shining', the bud size and shape, and the fruits.

Guymer and Forster have suggested that White's use of the words 'very shining above' is in conflict with the leaf surface of the Kajewski specimen, which they describe as only 'slightly shining'. This is a subjective interpretation, not reflected in the images published in Olde (2015), and in any case a minor variance. Others might equally describe the surfaces of both as 'shiny'. However, White also described the adaxial surface of the leaves as smooth, a character not mentioned by Guymer and Forster, but which, when surfaces are compared, goes some way to support their argument of conflict between the Kajewski specimen and the protologue. The scattered asperities and dimpled adaxial surface of the leaf of *T. robusta* was seen in Olde's 'Revised Key to species of *Triunia*' as one of a number of critical characters that distinguish *T. kittredgei* from *T. robusta* (correctly applied). It could be argued perhaps, that the uneven leaf surface on the Kajewski specimens were thought by previous authors, including White, to be unworthy of comment. Certainly, no other author has made mention of it. However, this conflict alone does not justify rejection of Sleumer's lectotype, especially when cast against one of White's main intentions; the classification and naming of Kajewski specimens. It is only one of several critical characters outlined by Olde in the key. On this point, Olde's key should be amended at key lead 1* (Olde 2015, p.189) and the word 'smooth' deleted. There is no alternate choice in the dichotomous couplet at 1, and the word is factually incorrect positioned prior to the following couplet.

All the specimens of *Kajewski 1219* are in young bud and not covered by the protologue, which states the buds are 'cylindrical, 1.5 cm long'. It is possible that White intended the description for specimens with mature buds or perhaps unintentionally omitted the qualifying words 'up to' but, in any event, buds are not a diagnostic character in the genus, since all adult flowers are of similar size and the young inflorescences similar in shape. Bud length is merely an ontogenetic state and in their table of comparison Guymer and Forster do not mention that the bud length (and shape) on the Kajewski specimen also applies to other specimens at a similar stage of development.

Fruits, cited in the protologue, are not present at all in either the Kajewski or the Simmonds collections and are not relevant to a comparison and discussion of these two specimens. A logical consequence of the argument put forward by Guymer and Forster requires that both Sleumer and Foreman should have chosen a lectotype with fruit.

Therefore, the evidence presented by Guymer and Forster in support of the argument that Sleumer's lectotype is in serious conflict with White's protologue, is here considered to be weak and inadequate because it ignores critical words in the protologue. In addition, it does not demonstrate conflict on any diagnostic character except the one pointed out here, and does not address White's intention to describe Kajewski's specimens, including *Kajewski 1219*. For the above reasons, there can be no reasonable objection to Sleumer's selection of *Kajewski 1219* as the lectotype, with independent reviews by experienced nomenclaturists affirming this assessment. However, this does not deny the argument that one particular specimen would make a better lectotype than another, but it has no relevance when the selected lectotype is not in serious conflict with the protologue. At the time of its selection by Sleumer, there was no suggestion that the specimen might represent a different species. Nor has the suitability of Sleumer's lectotype been questioned by anyone in the past sixty years. Moreover, the matter was not raised by Foreman (1986, 1987, 1995), who had unfortunately overlooked it.

It must be noted that there are any number of accepted lectotypes for which a better specimen could have been chosen, or do not fully match the protologue on every point. By way of example, the lectotype of *Grevillea leptobotrys* Meisner (1848, pp. 256–7) which has an extensive Latin protologue (NY284642, *fide* D.J. McGillivray & R.O. Makinson (1993, p. 425)), is a fragmentary specimen in a packet, barely sufficient for the name to be correctly applied, even though many suitable specimens more conformant with the protologue were available.

Acceptance of Guymer and Forster's argument could trigger and justify a whole raft of better re-lectotypifications that, notionally, may completely overwhelm the nomenclature. It is indisputable that many cases could be cited where lectotypes do not exactly match described taxa in every minute detail. No two plants are ever exactly identical. All that the Code requires is that the lectotype is a close approximation to the concept of the taxon adopted by the describing author, and could not alternatively be assigned to some other recognised taxon. In the Code, interpretation of the word 'serious' is subjective and there is an inference that disagreements arising from it should be resolved by consensus formed after individual and institutional examination of the arguments, rather than by a formally designated resolution mechanism or arbitrator. One solution might be the formal referral of similar disputes to the Nomenclature Committee for Vascular Plants by including such tasks in its remit. In this case, the Code itself would need some minor alteration and clarification.

Guymer and Forster (2015) also incorrectly assert (p. 458) that Foreman (1986) 'did not accept' Sleumer's earlier lectotypification. This statement must have been inferred since Foreman himself made no such statement. Its basis is perhaps the Kajewski specimen at K (K001096591) which bears an annotation by Sleumer and a label by Foreman. Sleumer has annotated the specimen with the words 'Lecto-Isotype!' 'Revised for the Flora Malesiana, dated and signed by H. Sleumer 11/54'. Foreman's label states '*Triunia erythrocarpa* Foreman Not part of the lectotype of *Helicia youngiana* var *robusta*. Signed and dated by D. Foreman 17/12/1996'. However, Foreman did not follow any formal procedure to overturn Sleumer's published lectotypification, and did not mention in any of his taxonomic treatments that Sleumer had previously lectotypified it. Furthermore, had he known, Foreman surely would not have included the Kajewski specimen in the protologue of his circumscription of *Triunia erythrocarpa* Foreman, thus rendering that name illegitimate. The evidence on the Kew specimen shows only that Foreman saw Sleumer's annotation ten years after his own superfluous lectotypification and retrospectively sought to reaffirm it.

Since Article 9.19 of the Code requires that 'the author who first designates (Art. 7.9 and 7.10) a lectotype … in conformity with Art. 9.11–13 must be followed', it is again asserted here that the name *Triunia robusta* applies to the species known currently as *T. erythrocarpa*, and that *T. erythrocarpa* must be synonymised under it. The name *Triunia kittredgei* Olde is correctly applied to the species in south-eastern Queensland formerly known as *T. robusta* after the name was vacated.

Triunia montana (C.T.White) Foreman (1986).

Basionym: *Helicia youngiana* var. *montana* C.T.White (1933).

Protologue: 'Leaves entire, elliptic or elliptic-lanceolate, up to 11 cm. long and 5 cm. wide, apex acuminate often lengthily so, coriaceous, smooth and glossy on both surfaces. Racemes up to 6 cm long, pedicels up to 5 mm long, rhachis and pedicels densely hirsute as in the typical form. Buds not seen. Individual bracts (described from a few persistent ones in old inflorescences) 1 cm long, 5 mm broad. Fruit not seen.

Distribution: Only known from the higher parts of the Bellenden Ker Range, northeastern Queensland.

Locality Records: Bellenden Ker, Palm Camp, *F.M. Bailey* (Meston's Bellenden Ker Exped. 1889). Bellenden Ker (near the summit), *C.T. White*, Jan. 1923.'

Lectotype (Sleumer 1955): [Queensland] Bellenden-Ker, near the summit: *[C.T.]White* [Jan. 1923] (NSW – '*typus,* haud vidi'). *Typus* not found at NSW.

Replacement lectotype (Olde 2015): Queensland: Cook: Bellenden-Ker, near the summit, *C.T. White s.n.*, Jan 1923 (BRI-AQ317460 – photo seen); isolectotypes MEL2277215A (*n.v.*); MEL2277216A (*n.v.*).

Superfluous lectotype (Foreman 1986): [Queensland] Bellenden Ker, Palm Camp, *F.M. Bailey s.n.* (Meston's Bellenden Ker Exped. 1889) BRI164626.

Residual syntypes: Bellenden Ker, Palm Camp, *F.M. Bailey s.n.* (Meston's Bellenden Ker Exped. 1889), BRI-AQ317454 (photo seen); MEL2277213 (*n.v.*).

Sleumer (1955) lectotypified the name using the White specimen given in the protologue by citing it as '*typus,* haud vidi' and its repository as NSW. Foreman (1986) superfluously lectotypified with the Bailey specimen. Since Sleumer's lectotype cannot be found at NSW, Olde (2015) designated another sheet of the White specimen in BRI (BRI-AQ317460) as replacement lectotype.

Sleumer selected one of White's two syntypes unseen ('haud vidi') and gave an assumed but incorrect herbarium location for it. Whereas Olde has argued that Sleumer's lectotypification is effective and that one of the three isolectotypes for this syntype can serve as the lectotype, Guymer and Forster have inferred that Sleumer's lectotypification is not effective by stating (p. 459) that Olde (2015) assumed that Sleumer (1955) lectotypified *H. youngiana* var. *montana* C.T.White. They implied, that Sleumer, by referring to a 'non-existent specimen at NSW' that he had not seen, failed to effectively lectotypify the name. They recommended acceptance of Foreman's later alternative lectotypification in which the alternative syntype is cited, by stating that it should be accepted as the 'first'. The argument is academic because the name *Triunia montana* is not in dispute. However, there was no attempt by them to address the argument presented by Olde (2015, p. 191) that 'The International Code of Nomenclature for algae, fungi, and plants (Melbourne Code) (McNeill et al. 2012), does not require a lectotype to be seen by its designator. However, if the lectotype is effectively lost, under Article 9.11, a lectotype as a substitute for it may be designated.'

It is perhaps surprising that a lectotype, designated unseen and its repository incorrectly assigned, does not invalidate the lectotypification. However, there is no requirement in the Code for the typifying author to have seen the lectotype being designated; an explanation that was clearly made by Olde (2015) and confirmed by Mr N. Turland (pers. communication) who was consulted on the validity of Sleumer's lectotypification. The debate serves to illustrate a relatively obscure feature of the code concerning valid lectotypification. Sleumer's lectotypification of *Helicia youngiana* var. *montana* C.T.White, later recognised as *Triunia montana* (C.T.White) Foreman, is entirely effective and due credit must be given to him for it. Although the Foreman lectotype admittedly has better qualifications for selection, as pointed out by Guymer and Forster (*l.c.*), the Sleumer lectotype is not in serious conflict with the protologue and must stand.

Summary

Guymer and Forster have essentially argued that Sleumer's lectotypifications of two varietal names under *Helicia youngiana* are invalid and should be overturned in favour of those later designated by Foreman. However, they have not demonstrated that Sleumer's lectotypes are in serious conflict with C.T. White's protologues and their argument must be rejected. If they wish to change this situation then a case for conservation of the name *Triunia robusta* over *T. kittredgei* must be made. This is an entirely separate argument and one that is perhaps not really supportable in so small a genus with little cognate literature and low usage impact. While acknowledging the difficulties associated with name changes in [Australian] taxonomy, the unfortunate change put forward by Olde (2015) is no different from many others in the literature and should be accepted. The correct name for *Triunia* populations previously referable to *Triunia robusta* is *Triunia kittredgei*. The name *Triunia robusta* correctly applied requires that *Triunia erythrocarpa* Foreman be synonymised under it.

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Three's a crowd: a revision of the monotypic family Goebeliellaceae (Porellales: Jungermanniopsida).

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Abstract

Three species of *Goebeliella* are here recognized on morphological evidence. The three species can be distinguished by a range of qualitative and quantitative characters, including width of the hyaline leaf-border, leaf lobe cell wall thickening and wall internal structure, horn shape and anatomy, and female bract shape and conformation.

The type specimen of *G. cornigera* was collected in New Zealand, and agrees in all respects with other individuals from that country. *Goebeliella cornigera* is endemic to New Zealand. The other two species are endemic to New Caledonia, and both are present in the syntype material of *G. bicornuta*, which is reinstated and lectotypified. No other names have been published within *Goebeliella*, leaving the second species from New Caledonia without a name. The name *Goebeliella glauca* is proposed for this new species.

Introduction

The Porellales is a speciose lineage of leafy liverworts comprising some 2500 species in seven families (Jubulaceae, Porellaceae, Radulaceae, Lepidolaenaceae, Lejeuneaceae, Frullaniaceae, Goebeliellaceae). These families share several distinctive morphological features, including incubously inserted fundamentally tri-lobed leaves (bi-lobed in Porellaceae and Radulaceae), rhizoids in fascicles, and a complete absence of branch production from the ventral merophyte. Species in most families bear a conspicuous perianth, and many lack associated stem-derived protective structures, though *Lepidogyna* is exceptional in its massive coelocaule topped by a perianth remnant (Schuster 1984).

The most striking feature is the possession of lobules, or 'water-sacs' on the leaves of the gametophyte in almost all species within the order. Lobule structure varies between lineages, and lobule form is a critically important source of morphological characters informing species circumscription (Renner et al. 2010, 2013; von Konrat et al. 2011).

Of the seven families, four have diversity in the hundreds of species, the Lejeuneaceae in particular probably comprises in excess of 1000 species, and the other three families have diversity lower by orders of magnitude. The Jubulaceae has four species in two genera (Patch et al. 2010; Larraín et al. 2015), the Lepidolaenaceae around 20 species in three genera, and the Goebeliellaceae a single species, *Goebeliella cornigera* (Mitt.) Steph.

Goebeliella cornigera was first described as *Frullania cornigera* Mitt. in the bryophyte treatment of Hooker's Flora of New Zealand (Mitten 1855). The specific epithet was chosen for the paired, horn like structures present at the base of each leaf. *Frullania cornigera* was transferred to a new genus established for it by Stephani (1911) to reflect the uniqueness of Mitten's plant. Stephani (1911) also recognized a second species from New Caledonia. Both species treated by Stephani possess air-cells in the leaves and underleaves, hyaline leaf and underleaf border and heavy corrugated thickenings on the cell walls, in addition to these paired horns. These features make *Goebeliella* readily recognizable in both field and herbarium, and to some extent its uniqueness also obscures its relationships. *Goebeliella* was placed into its own family by Verdoorn (1932), who allied it to both Pleuroziaceae and Radulaceae. Affinities with Porellaceae and Radulaceae were posited by Evans (1939), while Schuster (1965) presented evidence for a relationship with the Frullaniaceae. Molecular phylogenetic studies have resolved *Goebeliella* sister to the Lepidolaenaceae (Davis 2004; He-Nygren et al. 2004; Heinrichs et al. 2005; Forrest et al. 2006).

In this paper morphological evidence supporting the recognition of three species of *Goebeliella* is presented. Two species are endemic to New Caledonia, and one endemic to New Zealand.

Materials and Methods

Specimens held in the herbaria F, G, NSW, and collections from New Caledonia made by M. von Konrat, B. Shaw and J. Larraín were examined for this study.

Structures were examined under Zeiss D125 dissecting microscope, and Zeiss DM2500 compound microscope following rehydration and slide-mounting in water. Dissections were performed by hand. Images were captured with Zeiss DFC295 and DFC420 digital cameras and the LAS application suite by Leica (Leica Microsystems, North Ryde, Sydney). SEM specimens were rehydrated for 24 hours in a humidity chamber, plunge-frozen in liquid nitrogen in a vacuum chamber and evacuated to Tor 10^{-2}, or as close to this as the evacuator could achieve. The specimens were then mounted on stubs, sputter coated with gold only, and examined.

Results

Three morphological groups are present within *Goebeliella cornigera*, each circumscribable by a suite of qualitative macro- and micro-morphological characters. These characters are illustrated and described in the figures accompanying the species treatments in the Taxonomic Treatment below, where hypotheses of relationship explaining the correlated distribution of character states among individuals are formally proposed. Two of these morphological groups occur only in New Caledonia, the third – which corresponds with the syntypes of *G. cornigera* – occurs only in New Zealand.

Discussion

The outstanding feature of *Goebeliella* is its possession of paired horn-like 'lobules' on each leaf. No other extant lineage consistently has more than one lobe modified into a 'lobule'. The only other examples of paired lobules are found in the Cretaceous fossil genus *Kaolakia*, which bears paired lobules on each leaf (Heinrichs et al. 2011), and in *Frullania* the first branch leaf may bear paired lobules (von Konrat & Braggins 2001).

The term 'lobule' is often loosely applied to two different structures. In 'lobules' of the Frullaniaceae, Jubulaceae and Lepidolaenaceae a space is enclosed by invagination of a leaf lobe, typically the second or third (or both), inward from the dorsal surface, so that the dorsal leaf surface is enclosed, and the ventral surface is on the outside of the lobule.

A transformation series from plane lobules to helms can be inferred from leaf-lobe variation in some *Frullania* species, particularly *Frullania explanata*, and in the underleaves of *Lepidolaena* species, whose underleaf lobes are often partially or completely modified into helms. In these genera the leaf margin forms the helm mouth, which is typically orientated toward the shoot base. That these lobules are not homologous with lobules of the Porellaceae and Radulaceae is well established (Schuster 1984). In the Porellaceae and Radulaceae, the lobules are formed by folding of the postical leaf-lobe under the antical. The inner lobule surface is therefore formed by the ventral side of both the dorsal and ventral leaf-lobes, and the dorsal surface is on the outside of the lobule, and actually sits against the substrate. In Radulaceae this surface gives rise to rhizoids. To reflect this non-homology the lobules enclosing the dorsal surface of a single lobe have been referred to as 'helms', while those that enclose the ventral leaf surface between two lobes have been referred to as 'lobules' (Schuster 1966), and this terminology is followed here.

The modified leaf-lobes of *Goebeliella* have been referred to as 'horns' and horn-like lobules, for instance in Schuster (1965). These horns in *Goebeliella* differ from the helms of the Frullaniaceae and Lepidolaenaeceae in several respects, including having their opening at the apex rather than the base, having a bulbous base, and being stalked. Which leaf surface do they enclose and how? The mouth of the horn in *Goebeliella* is surrounded by elongate thin-walled cells similar to those forming the margin on the dorsal leaf-lobe. The form of these cells is consistent with homology to lobe marginal cells, yet they appear to be limited to the horn apex. Normal leaf-lobes have a differentiated margin around their entire free portion, in leaves divided to near the base the margin extends all the way around the lobe. In *Frullania* helms the mouth corresponds with the entire free margin of the lobe, and can be traced from the end of the stem insertion line on one side, to the junction with the stylus on the other.

In contrast, the horns of *Goebeliella* are divided to one or two cells above the stem, yet marginal cells are present only at the very apex, how might this be possible? Some clues are provided by the leaves preceding female bract production. The middle and ventral lobes of female bracts and the preceding leaves have plane laminae. Other leaves separating those with plane lobes from those with fully formed horns bear lobes modified to varying degrees into horn-like structures (Fig. 1). The degree of modification is negatively correlated with proximity to the gynoecium. In some sense the sequence of leaves preceding gynoecia form a developmental transformation series between plane lobes and lobes taking the form of helms. This might not inform how horns evolved, but it may inform how parts of the horn relate to normal lobes.

Fig. 1. Transitional lobule from a female bract in *G. bicornuta* (*Shaw 17204*).

Normal lobes are cucullate, with a continuous margin of differentiated cells. Transitional lobes have a sac in the upper half of the lobe, with a circular opening bordered by differentiated marginal cells. The lower half of the lobe is plane, and the base on either side is bordered by differentiated cells. Unlike plane lobes, transitional lobes have a discontinuous border of differentiated cells, broken at the transition between plane and saccate halves. The lobe lamina in some transitional leaves is spiraled through almost 360°, with the dorsal leaf surface on the inside of the spiral.

One possible way to homologize horns with plane lobes is through sac formation in the upper part of lobe by fusion of margins of a twisted or spiraled lobe. This could explain the opening at the top being bordered by marginal cells, and the absence of other marginal cells on the sides of the resulting cylinder of tissue, perhaps by incorporation into the cylinder walls. What happens to marginal cells at the junction between plane and saccate portions of transitional lobes is unclear. Under this model of horn formation the anatomical dorsal surface of the lobe would be enclosed within the 'helm'. The lobe base may remain plane to varying degrees, as in transitional lobes on female bracts, in fully formed horns the plane portion is reduced to the stalk. If this model is robust there are three non-homologous modifications to leaf-lobes that involve formation of lobules in the broad sense. Three different terms would best reflect this hypothesized non-homology, so I advocate using the term 'horn' when referring to leaf lobes that have been putatively spiraled and fused to enclose a space, in addition to the terms helm and lobule.

However, these are not the only structures that enclose spaces within the Porellales. In *Neotrichocolea* individual subsidiary lobes invaginate. More broadly across the Jungermanniales in the relatively unrelated genera *Delavayella* and *Tetracymbaliella* the lobe and underleaf margins may elaborate and invaginate to form a 'sac', and in *Plagiochila* the leaf base may inroll to the same end.

Just as helms and lobules are a source of critically important species circumscribing characters in other families of Porellales, including Frullaniaceae and Radulaceae, so they are in *Goebeliella*. Diagnostic differences between species are found in the horns, including cell shape, stalk length, and the presence of papilliform cells at the helm apex.

Stylus-like structure: at the base of the stalk on the ventral horn, between stalk and stem, there is a stylus-like structure. Is this the remnant of a highly reduced leaf-lobe, as it is in Frullaniaceae? In leaves with transitional morphology or plane lobules, there is no evidence of a stylus. This is consistent with the hypothesis that the stylus-like structure in *Goebeliella* is a by-product of horn formation on the ventral leaf-lobe. Further evidence for this hypothesis comes from ventral lobes of transitional morphology found on leaves immediately preceding the female bracts. At the base of these lobes a projecting ear of lamina is present, whose margin is separated from the rest of the lobe by a shallow notch. The depth of this notch increases with helm expression. So, the stylus-like appendage at the base of the ventral horn is not fully homologous with the stylus of Frullaniaceae species in that it is derived from only part of a lobe, rather than being equivalent to a lobe in its entirety. For this structure I propose the term pseudo-stylus.

Species concept: Schuster (1965) in his treatment of *Goebeliella* examined specimens from New Caledonia and New Zealand. Though he commented on differences between them, notably the opacity of medial cell walls in some of the New Caledonian specimens, he did nothing further with these observations, probably because his primary task in that treatment was to establish the relationships of what was still, then, an unusual and isolated element whose phylogenetic placement had not been firmly resolved.

The three morphological groups identified within *Goebeliella* are circumscribed by macro- and micro-morpholoical characters from all facets of their form. Though some characters, such as the presence of papilliform cells above the mouth of the horn are subtle, they are consistently correlated with other different character states such as, in this specific instance, the border of the dorsal leaf-lobe being one cell tier deep and formed by quadrate cells whose radial walls bear heavy thickening. Other characters, such as colour and the correlated manifestation of cell wall structure, are obvious at lower levels of magnification. The morphological groups are geographically structured, one is found in New Zealand, the other two in New Caledonia. The best explanation for the correlated distribution of character states among individuals is the existence of three tokogenetic groups within which character states have diverged and become fixed (Fitzhugh 2005). The stability of morphological character states separating the three morphological groups, their number, and their distribution in all aspects of plant form suggest that the three species hypotheses proposed below will fulfill many other species criteria, including those posited by phylogenetic and biological species concepts. The morphologically based species hypotheses outlined below can be tested against data relevant to these additional criteria.

Figures 2-73 illustrating the three species of *Goebeliella* recognized in this treatment are placed at the end of the paper. Plates are not devoted to single species, rather they are designed to show various structures from the three species side-by-side to facilitate comparison and reference. On each plate the figures are arranged into three columns, each column corresponds to one species, from left to right *G. cornigera*, *G. bicornuta* Steph., and *G. glauca* M.A.M.Renner.

Taxonomic Treatment

Goebeliellaceae Verdoorn *Manual of Bryology* 425. 1932.

= Goebelielloideae (Verdoorn) Hamlin *Records of the Dominion Museum* 7: 348. 1972.

Goebeliella Steph. *Hedwigia* 51: 61. 1911.

Type: *Goebeliella cornigera* (Mitt.) Steph. *Hedwigia* 51: 62. 1911.

Basionym: *Frullania cornigera* Mitt. in Hooker, *Flora Novae Zelandiae* 2: 163. 1855.

Morphological circumscription of the family Goebeliellaceae and its constituent genus was treated by Schuster (1965). The family as circumscribed by Schuster (1965) and authors before him (Verdoorn 1932) has been corroborated by molecular phylogenetic studies (e.g. Heinrichs et al. 2005), and remains current. To the characters currently accepted as distinctive of the family Goebeliellaceae could be added the horn-like form of the middle and ventral leaf-lobes. As hypothesized in the discussion above, the form of these leaf-lobes is not homologous with the helms and lobules of other families in the Porellales, and is indeed unique within Jungermanniopsida.

Key to species of *Goebeliella*

1. Plants with grey-red bloom when dry. Underleaf width half or less that of dry shoots, horns visible almost in entirety in ventral view. Leaf-lobe medial cells with more or less evenly-thickened cell walls. Cell walls with rugose 'ornamentation'. Pseudo-stylus reduced to a two- or three-celled spur capped by a slime papilla. Female bracts cucullate when hydrated, dorsal margin of innermost bract lobe almost perpendicular to shoot axis, bract medial and ventral lobe apices rounded .... ***Goebeliella glauca* M.A.M.Renner**

1: Plants green, brown or red when dry. Underleaf width nearly equal to dry shoot width, horns mostly obscured by under-leaves in ventral view. Leaf-lobe medial cells with sinuous cells walls. Leaf-lobe cell walls with granular ornamentation. Pseudo-stylus with distinct lamina. Female bracts concave or flat, not cucullate when hydrated, dorsal margin of innermost bract inclined at about 45° to shoot axis, bract medial and ventral lobe apices rounded or obtuse **2**

2. Leaf-lobe margin with one tier of hyaline cells, whose radial walls bear heavy thickening. Horns with two bulging cells at mouth projecting at right angles to one another. Postical horn with long stalk. Underleaves plane, occasionally weakly concave in ventral view. Shoot systems regularly and closely pinnate. Female bracts spreading from perianth surface, bract medial and ventral lobe apices obtuse .... ***Goebeliella bicornuta* Steph.**

2: Leaf lobe margins with two or three tiers of hyaline cells, the outer most differentiated into thin-walled long rectangular cells. Horns without papillae above the opening. Postical horn with short stalk. Underleaves concave in ventral view. Shoot systems regularly and openly pinnate. Female bracts appressed to perianth surface, bract medial and ventral lobe apices rounded .... ***Goebeliella cornigera* (Mitt.) Steph.**

Goebeliella cornigera (Mitt.) Steph., *Hedwigia* 51: 62. 1911.

Frullania cornigera Mitt. in Hooker, *Flora Novae Zelandiae* 2: 163. 1855.

Type: New Zealand, Northern and Middle Islands: Bay of Islands, amongst *Sendtnera attenuata*, *Dr J.D. Hooker* (lectotype here designated: BM000969465!); New Zealand, Port Cooper, *Lyall*. (paralectotype: BM000969464!)

Shoot systems green to orange-red to red or red-black, openly pinnately branched with widely spaced secondary shoots, dried primary shoots 795–1135 µm wide, dried secondary shoots 675–845 µm wide; branching of *Frullania*-type, first branch leaf with a pair of horns. **Stems** cordate in transverse section around 200 µm diameter on primary shoots, with medial furrow on dorsal surface, cortical cells in 1 tier, smaller than medulla cells, walls bearing heavy, warm-brown pigmented thickenings constricting the lumen to a narrow cylinder, medulla cells with bulging, confluent yellow to orange-brown pigmented thickenings more or less continuous over cell walls. **Leaf-lobes** on primary shoots elliptic, 1100–1180 µm long by 900–960 µm wide, postical margin straight other margins curved, densely imbricate, concave, margin entire, differentiated marginal cells continuous around the margin except in antical and postical base, insertion J-shaped. Leaf-lobe cells divided into three zones. Marginal cells in two or three tiers of hyaline cells devoid of contents, outermost tier long short to long rectangular, 7.5–18.3 µm long 5.4–12.1 µm wide, long axis oriented perpendicular to lobe margin, walls hyaline and unthickened; inner tier cells with elliptic to rounded-oblong lumena due to heavy thickening of cell walls, walls hyaline but with heavy concave to triangular trigones and cell angles and continuously thickened medial cell walls, often differentially thickened at middle, long axis orientated perpendicular to lobe margin; lobe median cells occupying antical half of lobe between marginal cells above and basal cells below, dimorphic, with air-cells scattered among normal chlorophyllous cells, air-cells clear, devoid of content, rounded-oblong to elliptic, 12.1–16.4 µm long, 8.1–9.7 µm wide, walls evenly and continuously rounded, without rounded projection into the lumen; normal cells 12.4–24.3 µm long, 6.4–10.4 µm wide, walls heavily thickened and sinuous due to pronounced rounded medial thickenings, typically one thickening present on each side of the medial wall, either alternating or opposing the thickening on the other side, long axis of cell orientation variable, but often parallel with radial lines from leaf base to margin; lobe basal cells long rectangular, 24.3–44.2 µm long, lumen 4.9–9.9 µm wide between heavily thickened cell walls bearing 3–6 confluent nodular thickenings on longitudinal walls, secondary thickenings orange pigmented, transverse walls unthickened. Cell walls of leaf-lobe medial portion appearing granular, basal and marginal cells without apparent texture. **Horns** falcate, antical margin evenly curved or slightly more curved toward apex, 417–520 µm long, postical margin straight at base, curved through 90° in upper half, 237–315 µm long, base 101–127 µm wide, both stalks short, antical horn stalk longer, to 20–27 µm, cells of mouth thin-walled and hyaline, long rectangular, papilliform cells above mouth absent, cells of horn body long rectangular, cell surfaces lacking pitted sculpting along cell walls. Pseudo-stylus at base of antical horn leaf-like, small, 4–6 cell tiers tall and wide. **Underleaves** transversely broad-elliptic, contiguous, concave particularly in upper half in ventral view when wet, fan-shaped when dry due to recurving of lateral and basal margins, 393–523 µm long, 595–804 µm wide on dry primary shoots, 303–433 µm long, 426–616 µm wide on dry secondary shoots, insertion shallowly curved, base on either side of insertion with small auricle, marginal cells in three or four tiers, outermost cells 10.1–22.5 µm long, 5.7–11.6 µm wide, quadrate to long rectangular, thin-walled, hyaline, long axis oriented perpendicular to margin, inner cells quadrate to rectangular, with weakly thickened, sinuous, hyaline walls; median cells narrow oblong 14.3–19.2 µm long, 6.7–9.8 µm wide, walls heavily thickened and sinuous due to pronounced rounded medial thickenings, orientation of long axis variable, air cells present, scattered throughout medial portion, basal cells long, cell lumen constructed by heavy confluent nodular thickening on medial walls, walls orange pigmented, basal cells forming zone in medial base of leaf above stem insertion. **Oil-bodies** not seen. **Asexual reproduction** absent. **Dioicous**. **Gynoecia** terminal on secondary shoot, female bracts in three or four pairs, increasing in stature toward gynoecium, closely adherent to perianth when wet and dry, air cells present in outer third of bract lobe only. Middle and ventral lobes on bracts transitioning from horn-like to plane, fused for one third their length in lower bracts, to fused for nearly their entire inner margin in upper bracts, upper bract folded, along lamina joining dorsal and medial lobes, dorsal lobe ligulate 1700–2400 µm long, 800–1100 µm wide, apex rounded, middle and ventral lobes ligulate, separated by a shallow sinus, concave, apex of both lobes rounded. Bracteole ligulate, folded medially, lamina either side of fold appressed to ventral perianth keel, bracteole apex rounded, around 2300 µm long and 700 µm wide, margins below midpoint recurved, insertion linear, broad. **Perianth** trigonous, ventral and lateral keels sharp and pronounced in upper half, perianths around 3450–4100 µm long and 950 µm wide at widest point, narrowing slightly in upper half toward mouth where 400 µm wide, mouth bordered by rectangular, thin-walled, hyaline cells plate-like appendages comprised of thin walled hyaline cells present; dorsal perianth surface with conspicuous medial furrow extending from the basal quarter to the mouth; incipient shoot calyptra present below perianth, sporophyte foot penetrating the stem apex to the level of the second leaf pair preceding the perianth; calyptra bistratose. **Androecia** not seen.

Distribution: *Goebeliella cornigera* is endemic to New Zealand, where it widespread in cool hyper-humid environments from around 100 m to more than 1200 m asl. *Goebeliella cornigera* is particularly common on the West Coast of the South Island, and is also common at higher elevations on ranges in the North Island.

Habitat: *Goebeliella cornigera* grows in all major forest types in New Zealand, including *Nothofagus* dominated, podocarp-broadleaf, broadleaf-dominated, and podocarp-dominated forests. It also grows above the treeline in alpine scrub and shrublands. Throughout its range *G. cornigera* is an epiphyte on the trunks and branches of a wide range of hosts including *Nothofagus* species, species of Podocarpaceae, and many broadleaf species. It may, in situations of suitable insolation grow as a lithophytic and even a terrestrial, for example on exposed banks in full sun. *Goebeliella cornigera* co-occurs with a suite of bryophytes typical of well-lit, epiphytic habitats, including species of the moss family Orthotrichaceae, and the liverwort genera *Lepicolea attenuata*, *L. scolopendra, Radula multiamentula, R. pseudoscripta, R. uvifera*, *Frullania ptychantha*, *Lepidolaena* spp., *Plagiochila circumdentata*, and on rock and soil with *Adelanthus occlusus*, *Kurzia calcarata*, and *Lepidozia obtusiloba* (as in *Engel 18548B*).

Recognition: *Goebeliella cornigera* is distinctive in its leaf margin with long-rectangular, thin-walled cells in the outer of two tiers of hyaline cells, the inner tier cells are similar in size, shape, and cell wall thickening to the adjacent medial cell walls but are hyaline. The horns lack a long stalk, the longest stalks on the antical horn are up to 30 µm long. The antical horn has at its base a small pseudo-stylus. The female bracts are closely appressed to the perianth in both wet and dry states.

Goebeliella cornigera can be separated from *G. glauca* by a suite of characters, listed below in order of decreasing accessibility.

1. The plants not having a glaucous bloom, which is a conspicuous feature of *G. glauca*.
2. In dry shoots the lateral leaves of *G. cornigera* are rolled inward and contact the underleaves, so completely obscuring the horns in ventral view; while in *G. glauca* no contact between leaves and underleaves is made in dry shoots, and the horns are visible in the intervening space as they project well beyond the underleaf margin.
3. The female bracts of *G. cornigera* are closely apressed to the perianth in both wet and dry shoots and the female bract dorsal lobe is ligulate, in *G. glauca* the female bracts are not appressed to the perianth, the dorsal lobe is falcate and strongly concave so spirals downward around the perianth.
4. The horns of *G. cornigera* are falcate, the antical margin is evenly curved and the horn turns through around 90° in the upper half; the horns of *G. glauca* are more sickle-shaped, the antical margin increases curvature in the upper half, and the horn turns through anything between 90° and 180° in the upper half.
5. The hyaline margin on the leaf lobe is two cell tiers deep in *G. cornigera*, cells of the outer tier are long rectangular and thin-walled; the hyaline margin in *G. glauca* is 2 or 3 tiers deep and cells in the outer tier are rectangular and thick-walled.
6. The walls of lobe medial cells of *G. cornigera* are sinuous due to their bearing pronounced, alternating, rounded medial thickenings, in *G. glauca* the lobe medial cell walls are evenly thickened.
7. Under light microscope, the leaf lobe medial cell surfaces of *G. cornigera* appear densely, yet irregularly, granular; in *G. glauca* the cell surfaces appear to have conspicuous ruminate ornamentation. Note that the causative structures are associated with the wall internal structure, rather than its surface.
8. The horns of *G. cornigera* are nearly sessile, their basal stalks are short and inconspicuous in both horns in each pair; in *G. glauca* the stalk on the antical horn is conspicuous, up to 90 µm long.
9. The pseudo-stylus at the base of the horn pair has a distinct lamina in *G. cornigera*, but in *G. glauca* consists of a three or four-celled spur only.
10. In *G. cornigera* cells of the horn are long rectangular cells, while in *G. glauca* they are short rectangular cells.

Goebeliella cornigera is more similar to *G. bicornuta* than *G. glauca*, both being green to wine-red plants whose horns are obscured by the underleaves, and leaves in dry shoots, and having female bracts adherent to the perianths. As such *G. cornigera* and *G. bicornuta* share the same state in the three most accessible characters described above. Closer examination, and accessing micromorphological characters is necessary to differentiate *G. cornigera* and *G. bicornuta*, in order of decreasing accessibility these characters and their states are:

1. The hyaline margin on the leaf lobe is two cell tiers deep in *G. cornigera*, the outer cells of which are long rectangular with thin walls; in *G. bicornuta* the margin is one cell thick, and the cells are quadrate to rectangular and have heavily thickened radial walls and a contrasting unthickened external wall.
2. The horns of *G. cornigera* have the antical and to a lesser degree the postical, margins of the horn continuously and nearly evenly curved from their base to their apex; in *G. bicornuta* the antical and postical margins are shallowly curved in the basal half, and have pronounced curvature in their apical half.
3. The horn apex of *G. cornigera* is bounded by cells whose surfaces are all plane; in *G. bicornuta* two cells above the opening are mamilliform, these two cells are orientated at around 45° to the horns line of bilateral symmetry on either side.
4. The stalk on both horns in *G. cornigera* is short, the horns are nearly sessile against the stem; in *G. bicornuta* the antical horn is stipitate, the stalk is long and distinct, being up to 90 µm long.
5. Female bract medial and ventral lobes rounded to obtuse in *G. cornigera*; obtuse to acute in *G. bicornuta*.
6. Underleaves are contiguous to loosely imbricate in *G. cornigera*, while they are closely imbricate in *G. bicornuta*.

Representative specimens examined: NEW ZEALAND: NORTH ISLAND: Auckland Province, Kaimai-Mamaku Forest Park, Mt Te Aroha, 37°32'S 175°44'E, 880–890 m, 15 Feb 2003, *J.J. Engel 23821 & M.J. von Konrat* (F); South Auckland Province, Southern extent of Herangi Range, W of cushion bog in vicinity of plateau area south of Te Whakapatiki, 38°29.9'S 174°46.2'E, 720–750 m, 18 Mar 2003, *J.J. Engel 25173*, *M.J. von Konrat & J.E. Braggins* (F); Gisborne province, Urewera National Park, Panekiri Range, summit area of Pukenui in vicinity of Punekiri Bluff, south of Lake Waikaremoana, 38°47'S 177°4'E, 1180 m, 24 Mar 1997, *J.J. Engel 23319* (F); Wellington Province, Ruahine Range, Pohangina Valley, 40°10'S 175°50'E, 16 Nov 1969, *J. Child H199* (F1033440); Wellington Province, northern Tararua Mountains Schormanns Track, eastern slopes of Mt

Hines, 10–12 miles west of Eketahuna, c. 1000 m, 15–16 Nov 1961, *R.M. Schuster 49163a* (F); South Island: Nelson Province, Paparoa National Park, Inland Pack track, SW of terminus of Bullock Creek Road, 42°7'S 171°24'E, 35 m, 24 Feb 1995, *J.J. Engel 21641* (F); Westland Province, Paparoa Range, road to Sewell Peak, 42°25'S 171°20'E, 710 m, 3 Feb 1983, *J.J. Engel 19062* (F); Paparoa Range, ridge immediately north of Sewell Peak, 42°24'S 171°20'E, 910 m, 3 Feb 1983, *J.J. Engel 19051* (F); Camp Creek, west of the Alexander Range, 42°42'S 171°33'E, 1010 m, Dec 1982, *A. Reif C129F* (F1062836); Westland Province, Jacksons Bay, between confluence of Jackson River and Arawata River and Lake Ellery, off Jackson River Road, 44°4'S 168°E, 30 m, 21 Dec 1982, *J. Child H4224* (F1086604); Cascade Road, Cascade ultramafic moraine, west of Martyr Saddle, 44°9'S 168°36'E, 135 m, 9 Mar 1997, *J.J. Engel 23011* (F); Arthurs Pass National Park, Kelly Range, off track to Carroll Hut, above Kellys Creek, north of Otira, 42°47'S 171°33'E, 1040–1110 m, 6 Jan 1983, *J.J. Engel 18418* (F); Arthurs Pass National Park, Bealey Valley track, 42°55'S 171°33'E, 875–900 m, 5 Mar 1997, *J.J. Engel 22858* (F); Canterbury Province, Arthurs Pass National Park, Scotts track to Avalanche Peak, w of Arthurs Pass township, 42°56'S 171°33'E, 950 m, 5 Mar 1995, *J.J. Engel 22084* (F); Southland Province, Fiordland National Park, Stuart Mountains, western shore of Lake Thomson north of stream draining from Lade Wade, 45°02'S 167°32'E, 300 m, 22 May 1986, *A.J. Fife 7665* (F1096273); Stewart Island (Rakiura), Rakiura National Park, Mt Rakeahua summit area, 46°56'S 167°52'E, 600–690 m, *J.J. Engel 24560A, M.J. von Konrat & J.E. Braggins* (F1173079).

Goebeliella bicornuta Steph., *Hedwigia* 51: 64. 1911.

Type: Mt Mou, Jul 1909, *Le Rat 156*, ex herb Steph. as *Goebeliella bicornuta St.* (lectotype here designated: G00051143!); Mont Mou, *Le Rat 271*, as *Goebeliella bicornuta* St. n.sp., (paralectotype: G00067854!).

Shoot systems green to orange-red to red, pinnately branched with closely spaced secondary shoots, dried primary shoots 950–1300 µm wide, dried secondary shoots 635–910 µm wide; branching of *Frullania*-type, first branch leaf with a pair of horns. **Stems** elliptic in transverse section around 200 µm diameter on primary shoots, with medial furrow on dorsal surface, cortical cells in 1 tier, smaller than medulla cells, walls bearing heavy, warm-brown pigmented thickenings contricting the lumen to a narrow cylinder, medulla cells with bulging, confluent yellow to orange-brown pigmented thickenings more or less continuous over cell walls. **Leaf-lobes** on primary shoots elliptic, 1280–1460 µm long by 960–1010 µm wide, postical margin straight other margins curved, densely imbricate, concave, margin entire, differentiated marginal cells continuous around the margin except in antical and postical base, insertion J-shaped. Leaf-lobe cells divided into three zones. Marginal cells in a single tier of hyaline cells devoid of contents, quadrate to rectangular, 7.1–12.1 µm long 6.8–10.7 µm wide, long axis oriented perpendicular to lobe margin, walls hyaline, external wall unthickened, thin and often partly collapsed, radial walls heavily and continuously thickened by colourless secondary thickening that tapers toward the lobe margin; medial cell walls often differentially thickened at middle, sinuous, long axis orientated perpendicular to lobe margin; occupying antical half of lobe between marginal cells above and basal cells below, dimorphic, with air-cells scattered among normal chlorophyllous cells, air-cells clear, devoid of content, rounded-oblong to elliptic, 14.9–21.6 µm long, 7.8–10.8 µm wide, walls sinuous or evenly and continuously rounded; normal cells 10.9–23.4 µm long, 9.1–12.2 µm wide, walls heavily thickened and sinuous due to pronounced rounded medial thickenings, typically one thickening present on each side of the medial wall, either alternating or opposing the thickening on the other side, long axis of cell orientation variable, but often parallel with radial lines from leaf base to margin; lobe basal cells long rectangular, 35.7–64.4 µm long, lumen 6.5–8.9 µm wide between heavily and evenly thickened radial cell walls, secondary thickenings orange pigmented, transverse walls unthickened. Cell walls of leaf-lobe medial portion granular, basal and marginal cells without texture. **Horns** falcate, antical margin shallowly curved or straight between bulbous base and apex, curvature increasing at apex where curved abruptly through 90°, 389–540 µm long, postical margin straight nearly its entire length or shallowly curved above the bulbous base, then abruptly curved through 90° at the apex, 251–344 µm long, base 85–118 µm wide, stalks differing in length, antical horn stalk longer, to 51–81 µm, postical horn nearly sessile, cells of mouth thin-walled and hyaline or orange pigmented, long rectangular, two papilliform cells above mouth present, orientated at 45° either side of the line of bilateral symmetry, cells of horn body rectangular, cell surfaces with pitted sculpting along cell walls. Pseudo-stylus at base of antical horn leaf-like, small, 3–4 cell tiers tall and wide, capped by a papilla. **Underleaves** transversely broad-elliptic, imbricate, plane or concave particularly in upper half in ventral view when wet, fan-shaped when dry due to recurving of lateral and basal margins, 375–416 µm long, 697–851 µm wide on dry primary shoots, 299–358 µm long, 394–606 µm wide on dry secondary shoots, insertion shallowly curved, base on either side of insertion with small auricle, marginal cells in two or three tiers, outer cells quadrate to long rectangular, 7.9–17.8 µm long, 5.5–10.5 µm wide, thin-walled, hyaline, long axis oriented perpendicular to margin, inner cells quadrate to rectangular, with weakly thickened, sinuous, hyaline walls; median cells narrow oblong 12.5–14.6 µm long, 5.7–8.9 µm wide, walls heavily thickened and sinuous due to pronounced rounded medial thickenings, orientation of long axis variable, air cells present, scattered throughout medial portion, basal cells forming zone in median and basal region of underleaf, cells long rectangular, 21.7–44.9 μm long, 6.1–8.4 μm wide, lumen constructed by heavily and continuously thickened, orange-brown pigmented cell walls. **Oil-bodies** not seen. **Asexual reproduction** absent. **Dioicous**. **Gynoecia** terminal on secondary shoot, female bracts in three or four pairs, increasing in stature toward gynoecium, spreading from the perianth when wet and dry, air cells present in outer third of bract lobe only. Middle and ventral lobes on bracts transitioning from horn-like to plane, fused for one third their length in lower bracts, to fused for nearly their entire inner margin in upper bracts, upper bract folded along lamina joining dorsal and medial lobes, dorsal lobe ligulate 2820–2900 μm long, 820–980 μm wide, obtuse or acute, middle and ventral lobes ligulate, separated by a shallow sinus, concave, apex of both lobes obtuse. Bracteole ligulate, folded medially, lamina either side of fold appressed to ventral perianth keel below but spreading ventrally from perianth in upper half, bracteole apex rounded, to 2300 μm long and 800 μm wide, margins below midpoint recurved, insertion linear, broad. **Perianth** trigonous, ventral and lateral keels sharp and pronounced in upper half, perianths at least 2500–3000 μm long and 860–940 μm wide at widest point, narrowing slightly in upper half toward mouth where 200–400 μm wide, mouth bordered by rectangular, thin-walled, hyaline cells plate-like appendages comprised of thin walled hyaline cells absent; mature perianths not seen. **Androecia** not seen.

Distribution; *Goebeliella bicornuta* is endemic to New Caledonia, where it grows in forests on and around mountain summits between 1000 and 1300 m asl.

Habitat: *Goebeliellla bicornuta* is an epiphyte on tree trunks and branches, and has been collected on trees with trunks as small as 2 cm dbh. *Goebeliella bicornuta* co-occurs with a wide range of epiphytic bryophytes, including species of the genera *Bazzania*, *Drepanolejeunea, Frullania*, and *Microlejeunea*.

Recognition: *Goebeliella bicornuta* is distinctive in the hyaline border on leaf lobe being 1 cell tier deep; the horns straight, or nearly so, in their lower half; the horns have a pair of papilliform cells above the mouth; the female bract lobes have an obtuse to acute apex.

Goebeliella bicornuta can be separated from *G. glauca* by many of the same characters that separate the latter from *G. cornigera*, and these are listed below in order of decreasing accessibility.

1. The plants do not have a glaucous bloom, which is a conspicuous feature of *G. glauca*.
2. In dry shoots the lateral leaves of *G. bicornuta* are rolled inward and contact the underleaves, so obscuring the horns in ventral view; while in *G. glauca* no contact between leaves and underleaves is made in dry shoots, and the horns are visible in the intervening space as they project well beyond the underleaf margin.
3. The female bracts of *G. bicornuta* are falcate and spread away from the perianth, but are plane; in *G. glauca* the female bracts are not appressed to the perianth, the dorsal lobe is falcate and cochleariform so envelops the perianth.
4. The horns of *G. bicornuta* are weakly falcate, the antical margin is nearly straight, but turns through about 90° in the upper half; the horns of *G. glauca* are more sickle-shaped, the antical margin increases curvature in the upper half, and the horn turns through anything between 90° and 180° in the upper half.
5. The hyaline margin on the leaf lobe is one cell tier deep in *G. bicornuta*; the hyaline margin in *G. glauca* is 2 or 3 tiers deep.
6. The walls of lobe medial cells of *G. bicornuta* are sinuous due to their bearing pronounced, alternating, rounded medial thickenings, in *G. glauca* the lobe medial cell walls are evenly thickened.
7. Under light microscope, the leaf lobe medial cells of *G. bicornuta* appear densely, yet irregularly, granular; in *G. glauca* the cell surfaces appear to have conspicuous ruminate ornamentation.
8. The horns of *G. bicornuta* have a pair of papilliform cells above the mouth; papilliform cells are absent from the horns of *G. glauca*.
9. The pseudo-stylus at the base of the horn pair has a small but distinct lamina in *G. bicornuta*; in *G. glauca* it consists of a three or four celled spur only.

Typification: No type indicated by Stephani (1911). The only detail given in the protologue regarding specimens examined is 'Hab. Novae-Caledoniae'. There are three specimens from New Caledonia in Stephani's herbarium in Geneva annotated '*G. bicornuta* St.' or '*G. bicornuta* St. n.sp.' by Stephani, all collected by Le Rat, probably on the same trip given the proximity of Le Rat's specimen numbers, which have a range of 120 across the specimens. One specimen bears the date 'July 1909'. The most reasonable assumption regarding Stephani's receipt of these specimens, in the absence of other evidence, is that all three were received in the same consignment, as all three had been collected by Le Rat in New Caledonia, and bear a range of numbers compatible with collection within a short space of time. Stephani probably had access to all three specimens when composing his protologue.

Two morphological entities are represented in the following three specimens:

1. Mt Mou, leg. *Le Rat 271*, G00067854. This specimen contains both a fuscous and a glaucous element.
2. Pic du Sources, *Le Rat 264*, G00067853. This specimen contains only the glaucous element.
3. Mt Mou, July 1909, leg. *Le Rat 156*, G00051143. This specimen comprises the fuscous element only.

Do characters described and illustrated in the protologue identify one morphological entity, or are they a mixture of features from both? Considering the major elements of the description: sterilis – ambiguous; fusca – an unambiguous reference to the red-brown element, rather than the glaucous element; irregularly pinnately branched – ambiguous; branches simple – ambiguous; rarissime pinnula auctis [very rarely branches increasing in stature] – ambiguous; leaf description – mostly ambiguous, though "hyalinae uniseriatae rectangulares (18 µm)" unambiguously refers to the fuscous plant; the description of horns could refer to either element; the underleaf description 'gigantea reniformia' and '1.21 mm lata' both suggest the fuscous plant, the measurement was probably taken from hydrated, slide mounted material, so is larger than the measurement from dehydrated material in the description above.

The figures in the protologue provide additional evidence. Figure 2 shows a leaf and adjacent underleaf attached to a short stem sector, within which the underleaf obscures the horns. This is consistent with the fuscous plant. The horns in Figure 2 have straight or nearly straight antical and postical margins in their lower halves, they are not S-shaped, and the apex does not curve through more than 90°, again consistent with the fuscous element. Figure 3 is ambiguous. Figure 4 again shows horns with nearly straight lower antical and postical margins, and an abrupt curve through around 90° close to the apex, all consistent with the fuscous element.

In summary, several features described and illustrated in the protologue of *G. bicornuta* unambiguously match the fuscous element. These include the width of the hyaline lobe margin, and horn shape. A couple of additional characters *suggest* the fuscous plant, but are not definitive, including underleaf size, and the horns obscured behind the underleaf in ventral view. Many characters are ambiguous and fit both plants equally as well. Critically, no character fits the glaucous element better than the fuscous element. I conclude that the protologue is a better match with the fuscous element and the name *G. bicornuta* must be lectotypified accordingly. The Pic du Sources specimen does not match the protologue, leaving two specimens, *Le Rat 156* and *271*, from which to select a lectotype. We may choose among these two specimens on their merits. *Le Rat 156* contains more copious material and is pure, and on these bases is selected as lectotype. This lectotypification leaves the glaucous element without a name.

Frullania bicornuta Steph. ex Paris was published in 1910, so a year before Stephani's name (Paris 1910). Paris cited specimens from Pic du Source and Mt Mou, in that order. Though the specimens cited are both *Goebeliella*, the name is invalid because no description was presented. Even if validly published, and based on the first cited specimen (which contains only the glaucous element) a combination for this species under *Goebeliella* would be blocked by Stephani's *Goebeliella* species published the following year.

Frullania bicornuta Steph. was published in 1911. The protologue of *Frullania bicornuta* Steph. describes a fairly typical *Frullania* subg. *Microfrullania* or subg. *Australes* species (Stephani 1911). Stephani's choice of epithet in this instance can be found in the second to last sentence of the diagnosis 'laciniae apicales anguste lanceolatae, torte valide dentatae quasi cornutae' [apical laciniae (on the female bracteole lobes) narrowly lanceolate, twisted strongly toothed resembling horns]. The lobes on the bifid female bracteole resemble horns, hence *bicornuta*. Stephani's descriptions and derivation of the same epithet from quite different structures emphasise the fact that he regarded his *Goebeliella bicornuta* and *Frullania bicornuta* as different species. Confusion between the two species sharing the same epithet seems to originate with Paris, and is probably due to the fact that his name was published before the genus *Goebeliella* had been described. Possibly it was published before Stephani had reached a decision to describe a new genus, and this late decision may explain the absence of *Goebeliella* from his *Species Hepaticarum*, a fact noted with some derision by Schuster (1965).

Specimens examined: NEW CALEDONIA: Epiphyte, le long d'un tronc entre 0.5 et 1.8 m au-dessus du sol, foret hygrophile de montagne, chaine de l'Ignambi pres du point culminant de la "Route do Gomen", 1200 m, 17 Aug 1951, *H. Hurlimann*, Franco Suisse Expédition botanique en Novell Calédonie No. 2849 (G); NORTHERN PROVINCE: trail to the summit of Mont Panié by southern slopes, 20°35'44"S 164°45'34"E, 1280 m, 9 Oct 2012, *J. Larraín 35904* (F); Reserve Speciale Botanique du Mont Panie, along ridge trail between hut (Blaffart Refuge) and Bwa Tean, 20.62446°S 164.77503°E, 780 m, 9 Oct 2012, *B. Shaw 17204* (DUKE, NSW); Mont Panié, Aufsteig entland de Wanderwegs von der Straße RPN 3 bis zum Gipfel, c. 1100 m, 13 Sep 2001, *F. Müller NC144* (DR); SOUTHERN PROVINCE: near summit of Mont Dzumac, by the vehicle road, 22°00'32"S 166°27'36"E, 1100 m, 26 Sep 2012, *J. Larraín 35388* (F); Province Sud, near summit of Mont Dzumac, 22°00'33"S 166°27'36"E, 1100 m, 26 Sep 2012, *J. Larraín 35379B* (F); sur le tronc d'un Weinmannia monticola, foret hygrophile de montagne, crete entre le Mt Dzumac et la Mt Ouin, 1000 m, 17 May 1951, *H. Hurlimann*, Franco Suisse Expédition botanique en Novell Calédonie No. 2591b (G); sur la tige d'un Dracophyllum, forest hygrophile de montage, au NW du sommet du Mt Dzumac, 1150 m, 19 May 1951, *H. Hurlimann*, Franco Suisse Expédition botanique en Novell Calédonie No. 2627 (G); New Caledonia, Epiphyte, sure une tige de Freycenitia sp. pea au-dessus du sol, foret meso-hydorophile de montagne, crete Sud-Ouest du Mt. Colnett, 1300 m, 13 Sep 1951, *H. Hurlimann* Franco Suisse Expédition botanique en Novell Calédonie No. 2941 (G-073699).

Goebeliella glauca M.A.M.Renner *sp. nov.*

Diagnosis: *Goebeliella glauca* differs from *G. bicornuta* and *G. cornigera* by its distinct glaucous hue, which overlays green, red-green, red or even purple-red shoot colour; by the horns visible between the underleaves and leaf lobes in dry shoots of primary and secondary order; by the horns evenly curved through 90–180° in their upper halves and having S-shaped antical and postical margins, and lacking papilliform cells above the mouth; by the round to transversely elliptic, remote to contiguous underleaves whose hyaline border is 2–4 cell tiers wide; by the leaf lobe cell walls evenly and continuously thickened in medial and basal divisions; by the hyaline border on the leaves 2 or 3 cell tiers wide; by the walls appearing to bear distinct ruminate ornamentation; by the cochleariform female bracts that envelope the perianth base when a perianth is present, or wrap around each other to form a structure resembling a strobilus that projects above the patch.

Type: New Caledonia, Southern Province, Noumea area, Montagne du Sources, along road to Pic Buse area, 22.14966°S 166.59033°E, 600 m, 28 Sep 2012, *B. Shaw 16737* (holotype: NOU; isotypes: DUKE, F, NSW)

Shoot systems glaucous-green to glaucous-purple, irregularly pinnately branched, dried primary shoots 850–1400 µm wide, dried secondary shoots 735–1025 µm wide; branching of *Frullania*-type, first branch leaf with a pair of horns. **Stems** elliptic in transverse section around 200 µm diameter on primary shoots, with medial furrow on dorsal surface, cortical cells in 1 tier, smaller than medulla cells, walls bearing heavy, warm-brown pigmented thickenings constricting the lumen to a narrow cylinder, medulla cells with bulging, confluent yellow to orange-brown pigmented thickenings more or less continuous over cell walls. **Leaf-lobes** on primary shoots elliptic, 1120–1220 µm long by 660–760 µm wide, postical margin straight other margins curved, densely imbricate, concave, margin entire, differentiated marginal cells continuous around the margin except in antical and postical base, insertion J-shaped. Leaf-lobe cells divided into three zones. Marginal cells in two or three tiers of hyaline cells devoid of contents, outer cells variable in shape, quadrate to long rectangular, 9.9–21.3 µm long 9.1–15.9 µm wide, long axis oriented perpendicular to lobe margin, walls hyaline, external wall unthickened, thin and often partly collapsed, radial walls heavily and thickened, bulging trigones present at cell angles, confluent with adjacent trigones across thickened medial walls, thickening colourless, inner cells round, elliptic or ovate with evenly thickened hyaline walls, similar in size to medial cells; medial cells occupying antical half of lobe between marginal cells above and basal cells below, dimorphic, with air-cells scattered among normal chlorophyllous cells, air-cells clear, devoid of content, rounded-oblong to elliptic, 10.9–14.4 µm long, 7.1–10.3 µm wide, normal cells variously round, elliptic, ovate or rounded-oblong, 14.4–21.9 µm long, 8.0–12.9 µm wide, walls in both cell types evenly and continuously thickened, occasionally weak medial thickening present, long axis of cell orientation variable, but often parallel with radial lines from leaf base to margin; lobe basal cells long rectangular, 23.1–40.1 µm long, lumen 6.8–9.7 µm wide between heavily and evenly thickened radial cell walls, secondary thickenings pale tan pigmented, sinuous, transverse walls unthickened or weakly thickened. Cell walls of leaf-lobe medial portion ruminate, including internal walls, basal and marginal cell walls without texture. **Horns** falcate, antical margin shallowly curved or straight between bulbous base and half way, then evenly curved through 90–180° in upper half, 445–622 µm long, postical margin S-shaped never straight, or straight only close to the middle, curved below, and above evenly curved through 90–180°, 311–428 µm long, base 97–115 µm wide, stalks differing in length, antical horn stalk longer, to 60–87 µm, postical horn sessile, cells of mouth thin-walled and hyaline or orange pigmented, long rectangular, papilliform cells above mouth absent, cells of horn body rectangular, cell surfaces with pitted sculpting along cell walls. Pseudo-stylus at base of antical horn a spur of, 3-4 cells, capped by a papilla. **Underleaves** rotund to transversely elliptic, imbricate, plane, 245–346 µm long, 469–540 µm wide on dry primary shoots, 203–323 µm long, 344–421 µm wide on dry secondary shoots, insertion shallowly curved, base on either side of insertion with small auricle, marginal cells in two to four tiers, outer cells quadrate to elliptic, 7.1–14.3 µm long, and wide, thin-walled, hyaline, long axis oriented perpendicular to margin, inner cells quadrate to rectangular, with continuously thickened, hyaline walls with bulging trigones; median cells narrow oblong 10.5–22.2 µm long, 7.9–11.5 µm wide, walls evenly and continuously thickened, orientation of long axis variable, air cells present, scattered throughout medial portion, basal cells forming zone in median and basal region of underleaf, cells long rectangular, 17.6–27.7 µm long, 8.8–12.4 µm wide, lumen not constructed, cell walls evenly and continuously thickened. **Oil-bodies** not seen. **Asexual reproduction** absent. **Dioicous**. **Gynoecia** terminal on secondary shoot, female bracts in three or four pairs, increasing in stature toward gynoecium, spreading from the perianth when wet and dry, air cells present in outer third of bract lobe only. Middle and ventral lobes on bracts transitioning from horn-like to plane, fused for one third their length in lower bracts, to fused for nearly their entire inner margin in upper bracts, upper bract folded along lamina joining dorsal and medial lobes, dorsal lobe ligulate, falcate, and cochleariform 2000–2540 µm long, 760–860 µm wide, apex rounded, middle and ventral lobes ligulate, separated by a shallow sinus, concave, apex of both lobes rounded. Bracteole ligulate, folded medially, lamina either side of fold appressed to ventral perianth keel below but spreading ventrally from perianth in upper half, bracteole apex rounded, to 1800 µm long and 800 µm wide, margins below midpoint recurved, insertion linear, broad. **Perianth** trigonous, ventral and lateral keels sharp and pronounced in upper half, perianths 2200–3000 µm long and 780–900 µm wide at widest point, narrowing close to mouth where 250–400 µm wide, mouth bordered by rectangular, thin-walled, hyaline cells plate-like appendages comprised of thin walled hyaline cells present; dorsal perianth surface plane. **Androecia** not seen.

Etymology: glaucous, in reference to the distinctive colour of this species.

Distribution: *Goebeliella glauca* is endemic to New Caledonia.

Habitat: *Goebeliella glauca* has been collected between 500 and 900 m asl, generally at lower altitudes than *G. bicornuta*. *Goebeliella glauca* grows as an epiphyte on tree trunks and branches with a wide range of xerophytic associates such as mosses of the family Orthotrichaceae, and many other liverworts including *Radula scariosa*, *Chiastocaulon caledonicum*, *Mastigophora caledonica*, many species of Lejeuneaceae, and *Frullania*. *Goebeliella glauca* also grows as a lithophyte on naked rocks or on thin humus over rock, again with xerophytic species including *Herbertus leratii*, *Mastigophora caledonica*, and *Acromastigum adaptatum* among others.

Recognition: *Goebeliella glauca* is distinctive in its glaucous hue, which overlays green, red-green, red or even purple-red shoot colour. The horns are visible between the underleaves and leaf lobes in dry shoots, and are evenly curved through 90–180° in their upper halves. The underleaves are round to transversely elliptic, and remote to contiguous on primary and secondary shoots. Leaf lobe cell walls are evenly and continuously thickened in medial and basal divisions, and the walls appear to bear distinct ruminate ornamentation, though this texture seems integral to wall structure rather than wall ornamentation. The female bracts are cochleariform, and envelope the perianth base if a perianth is present, otherwise they wrap around each other to form a structure resembling a strobilus, and this is held above the patch. See the recognition sections of *Goebeliella bicornuta* and *G. cornigera* for more detailed descriptions of character states differentiating *G. glauca* from these two species.

Remarks: With light microscope conspicuous rugose cell 'ornamentation' is visible. Under SEM no ornamentation was noted. In transverse sections of the leaf these "laminations" are observable in all walls, above, below and between adjacent cells in internal walls. This suggests these structures are integral to the wall, rather than deposits on the external walls only. Plants from New Caledonia illustrated by Schuster (1965) belong to *G. glauca*.

Specimens examined: NEW CALEDONIA: Montagne des Sources, in *Araucaria muelleri* forest, 800–850 m, 30 Mar 1962, *R.M. Schuster 52309a* (F); South Central, Pic Buse near Montagne des Sources, above St Louis, 650–750 m, open burned *Dacrydium araucarioides-Callitropsis* scrub forest, 30 Mar 1962, *R.M. Schuster 52273b* (F); ibid, *R.M. Schuster 52273c* (F); Sur un tronce en forest mesophile d'altitude moyehne, crete au NE du P. 576 a l'Ouest de la vallee du Boulari vers le P. 784, env. 530 m, 5 Feb 1951, *H. Hurlimann* Franco Suisse Expédition botanique en Novell Calédonie No. 2347 (G); Epiphyte sur lat tige d'une Scaevola, forest hygrophile de montagne, vallée derrière la mine Sunshine (Dumbea), 700 m, 15 Mar 1951, *H. Hurlimann*, Franco Suisse Expédition botanique en Novell Calédonie No. 2416 (G); Sur un tronce de *Podocarpus*, en forest hygrophile de montagne, fond de la vallée derrière la mine Sunshine (Dumbea), 730 m, 15 Mar 1951, *H. Hurlimann*, Franco Suisse Expédition botanique en Novell Calédonie No. 2431 (G); Epiphyte, ave *Mastigobryum* et *Radula* sur le tronc d'un *Calophyllum caledonicum* en foret mesophile, pente N des collines entre la Riviere Bleue et la Riviere Blanche (Yate), 500 m, 14 Jun 1951, *H. Hurlimann*, Franco Suisse Expédition botanique en Novell Calédonie No. 2692 (G); Pic du Sources, *Le Rat 264*, (syntype of *G. bicornuta* G00067853).

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Figs 2–25. *Goebeliella cornigera* (Mitt.) Steph. 2: Shoot systems. **3**: Single shoot system in dorsal view. **4**: Single shoot system in ventral view. **5**: Primary shoot dorsal view. **6**: Primary shoot ventral view. **7**: Secondary shoot dorsal view. **8**: Secondary shoot ventral view. **9**: Leaf-lobe cell wall texture. **10**: Transverse section of primary shoot stem. **11**: SEM of primary shoot ventral view. **12**: Horn mouth. **13**: Cell surface of horn body. **14**: Three horn-pairs. **15**: Stalks. **16**: Pseudostylus. **17**: SEM of horn mouth. **18**: Branches in ventral view. **19**: Perianth and female bracts, dorsal view. **20**: Perianth and female bracts, ventral view. **21**: SEM of perianth and female bracts, ventral view. **22**: Leaf lobe marginal cells. **23**: Leaf lobe medial cells. **24**: Leaf lobe basal cells. **25**: Underleaf marginal cells. All from *Schuster 49163a* (F).

Figs 26–49. *Goebeliella bicornuta* Steph. 26: Shoot systems. **27**: Single shoot system in dorsal view. **28**: Single shoot system in ventral view. **29**: Primary shoot dorsal view. **30**: Primary shoot ventral view. **31**: Secondary shoot dorsal view. **32**: Secondary shoot ventral view. **33**: Leaf-lobe cell wall texture. **34**: Transverse section of primary shoot stem. **35**: SEM of primary shoot ventral view. **36**: Horn mouth. **37**: Cell surface of horn body. **38**: Three horn-pairs. **39**: Stalks. **40**: Pseudostylus. **41**: SEM of horn mouth. **42**: Branches in ventral view. **43**: Perianth and female bracts, dorsal view. **44**: Perianth and female bracts, ventral view. **45**: SEM of perianth and female bracts, ventral view. **46**: Leaf lobe marginal cells. **47**: Leaf lobe medial cells. **48**: Leaf lobe basal cells. **49**: Underleaf marginal cells. All from *Shaw 17204* (NSW).

Figs 50–73. *Goebeliella glauca* M.A.M.Renner. 50: Shoot systems. **51**: Single shoot system in dorsal view. **52**: Single shoot system in ventral view. **53**: Primary shoot dorsal view. **54**: Primary shoot ventral view. **55**: Secondary shoot dorsal view. **56**: Secondary shoot ventral view. **57**: Leaf-lobe cell wall texture. **58**: Transverse section of primary shoot stem. **59**: SEM of primary shoot ventral view. **60**: Horn mouth. **61**: Cell surface of horn body. **62**: Three horn-pairs. **63**: Stalks. **64**: Pseudostylus. **65**: SEM of horn mouth. **66**: Branches in ventral view. **67**: Perianth and female bracts, dorsal view. **68**: Perianth and female bracts, ventral view. **69**: SEM of perianth and female bracts, ventral view. **70**: Leaf lobe marginal cells. **71**: Leaf lobe medial cells. **72**: Leaf lobe basal cells. **73**: Underleaf marginal cells. All from *Larraín 35388* (NSW).

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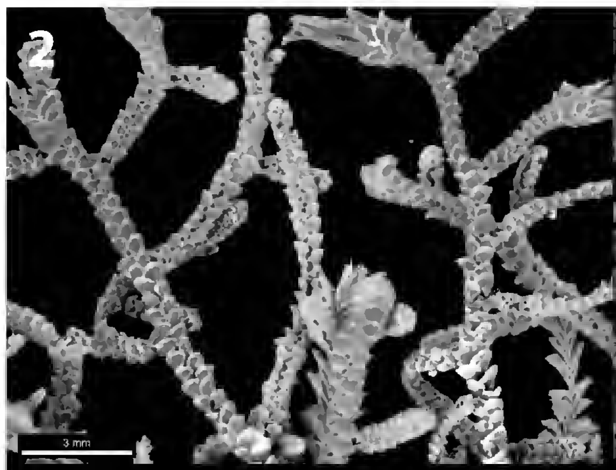

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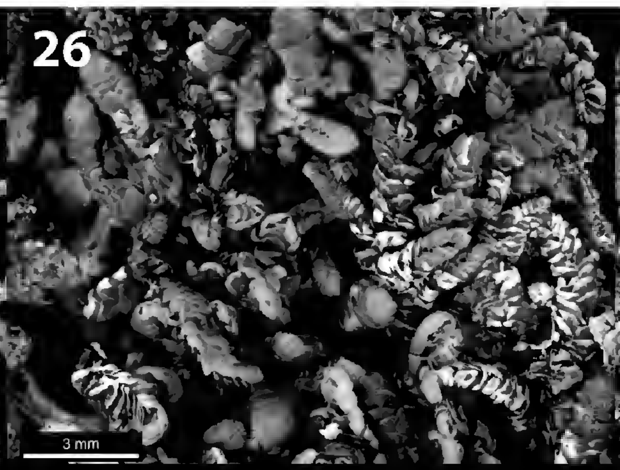

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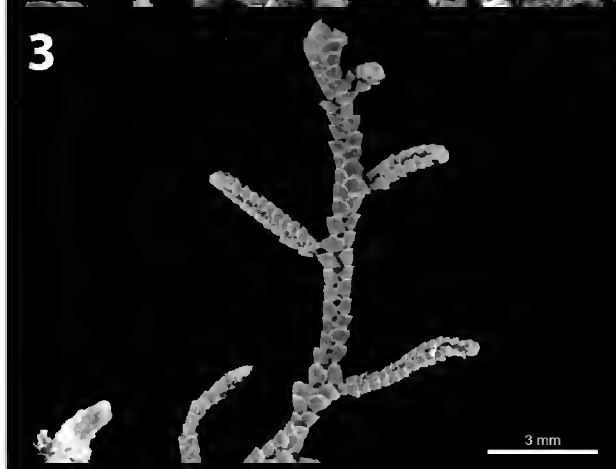

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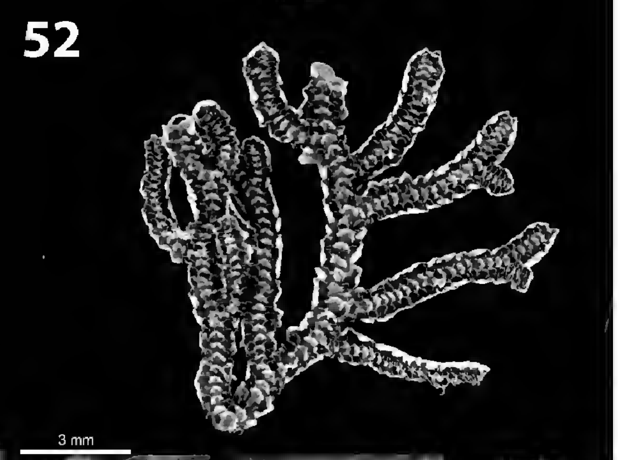

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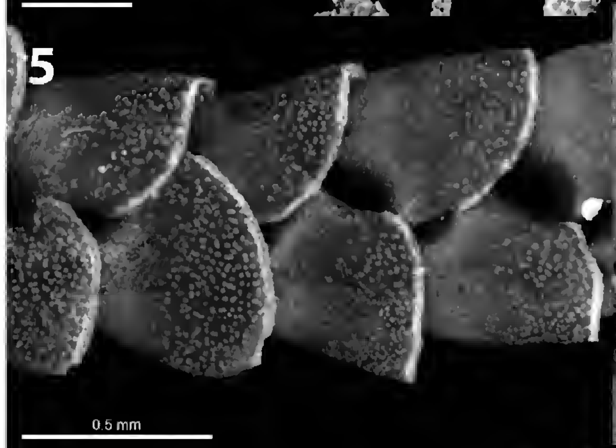

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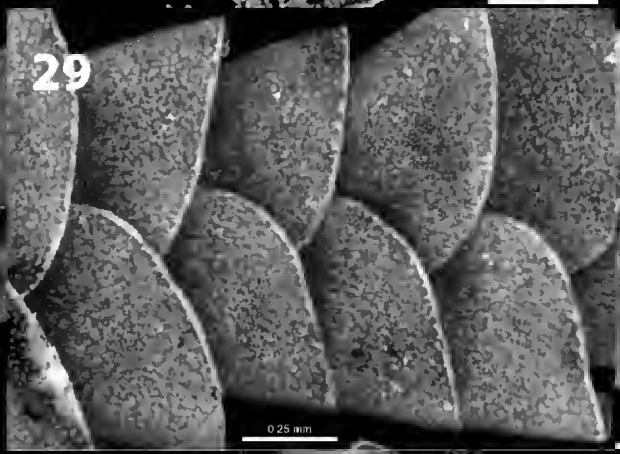

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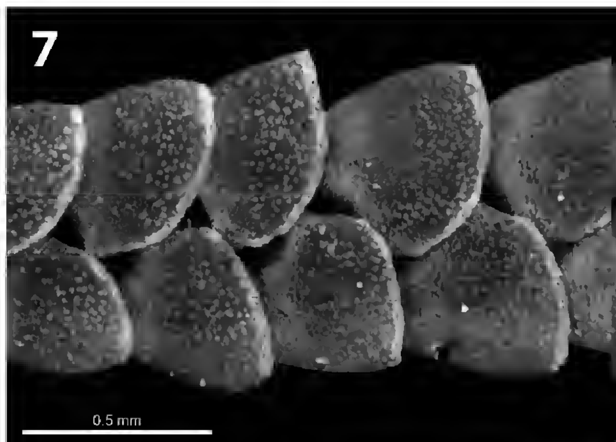
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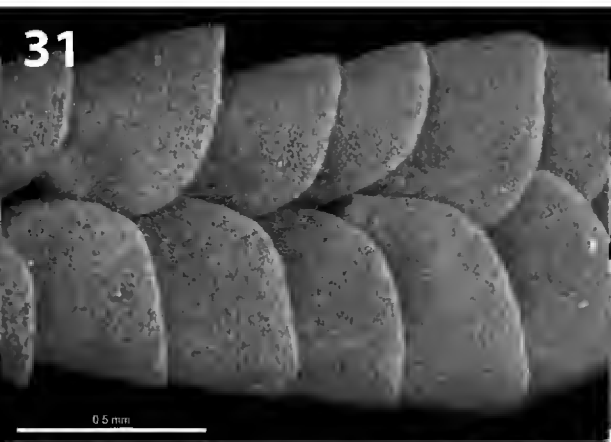
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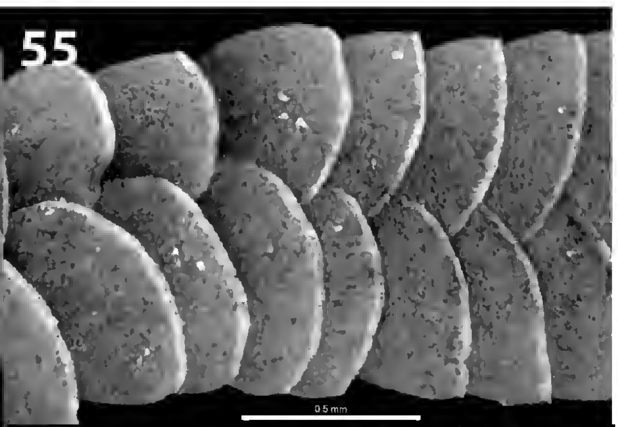
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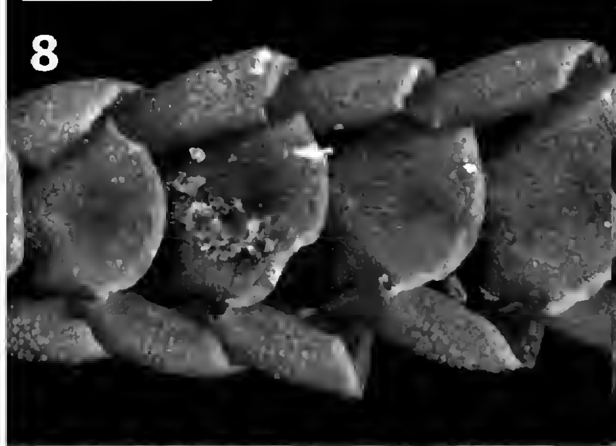
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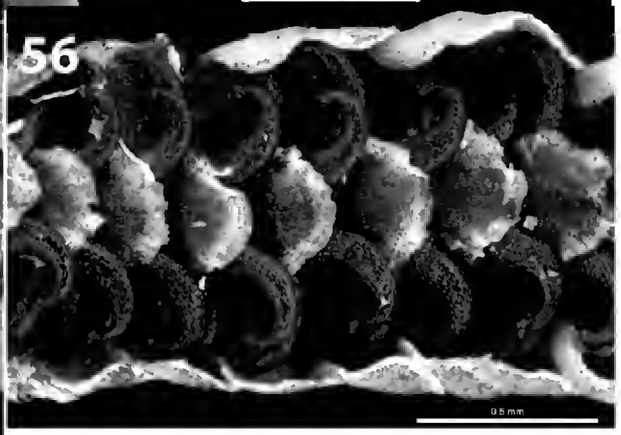
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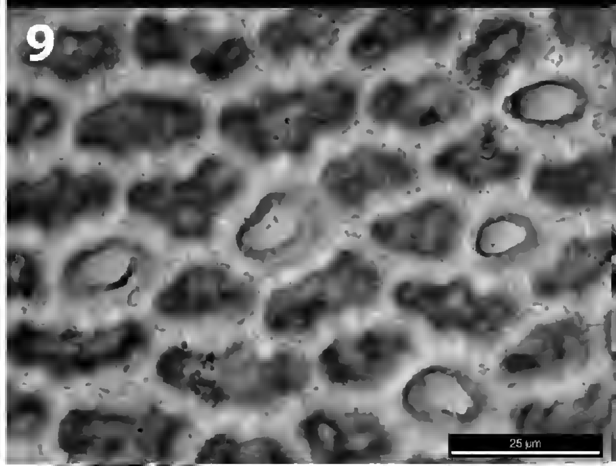
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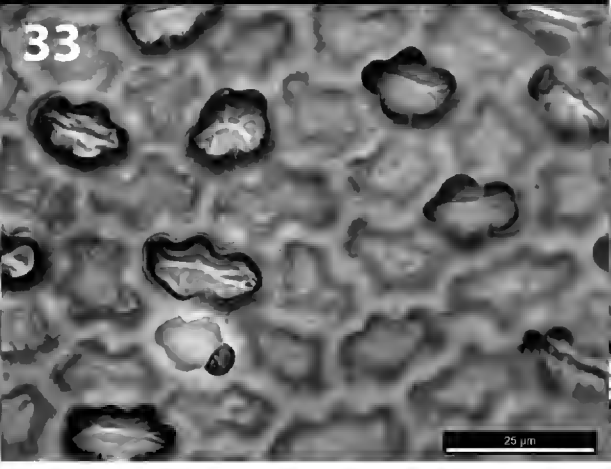
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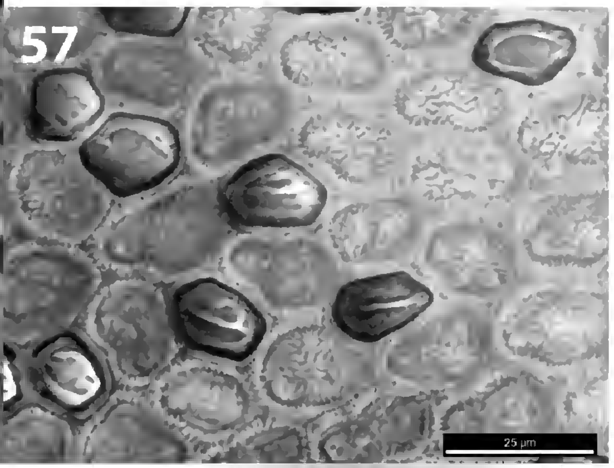
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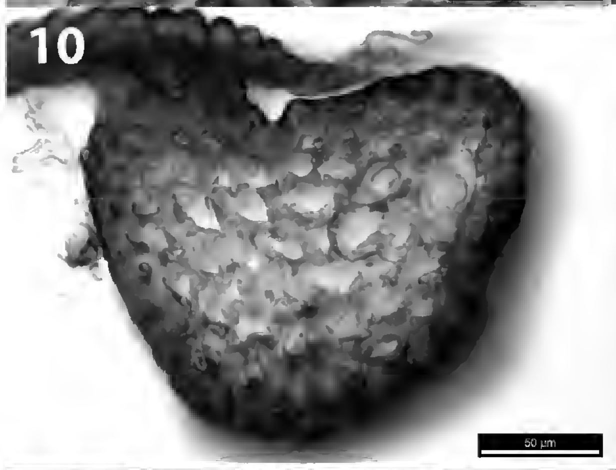
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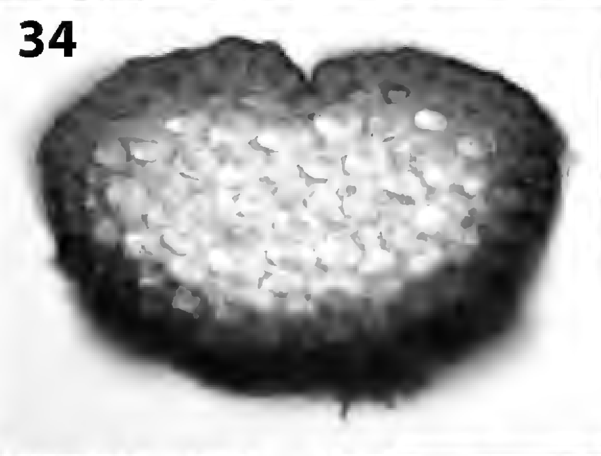
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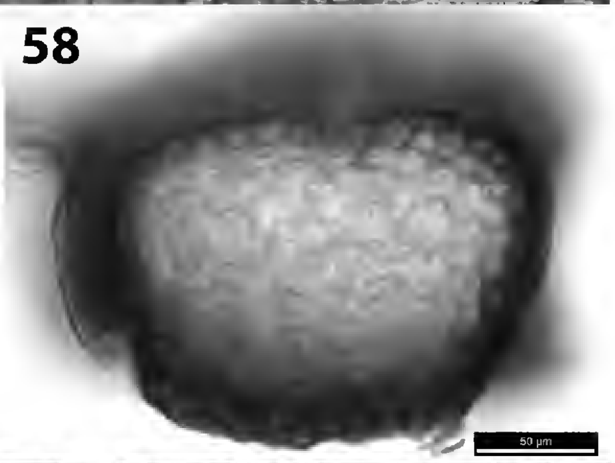
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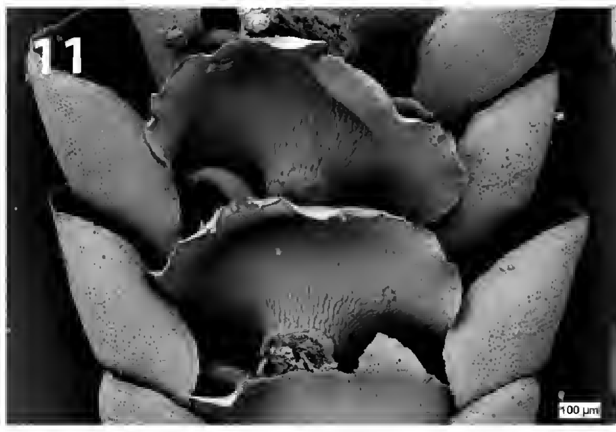
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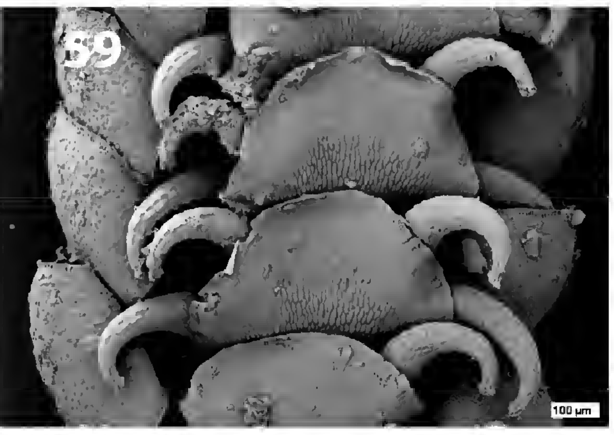
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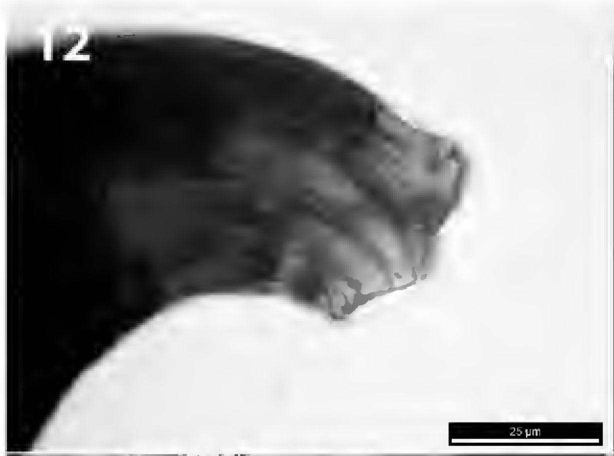
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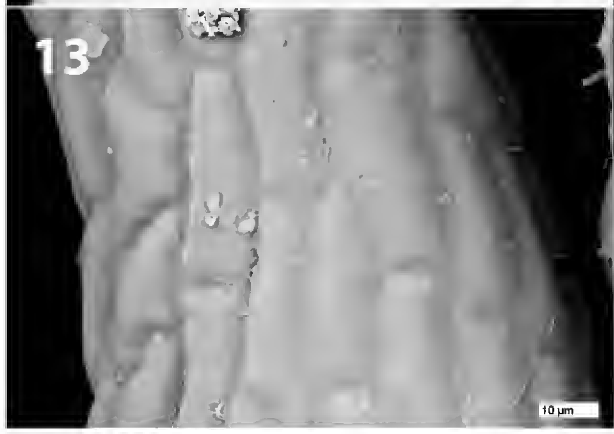
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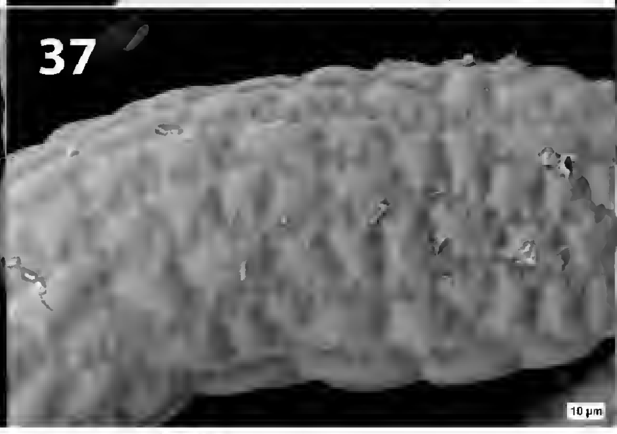
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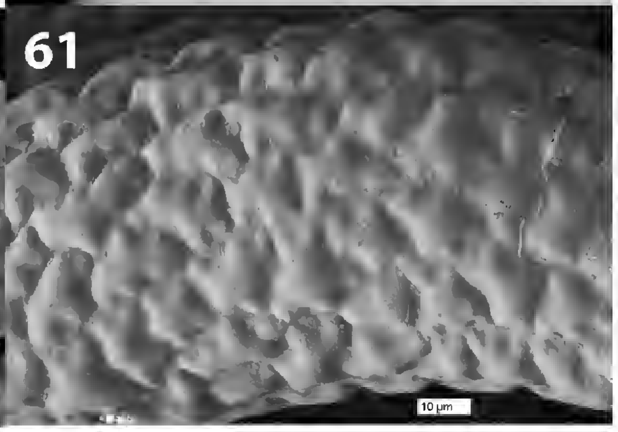
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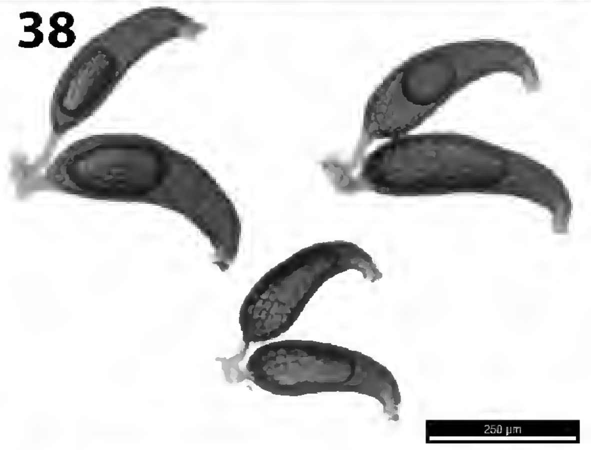
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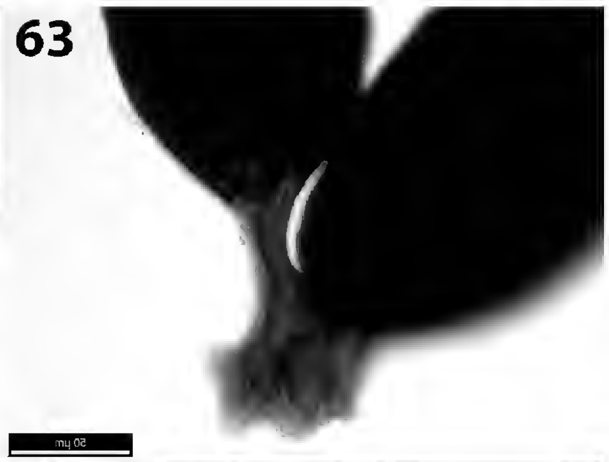
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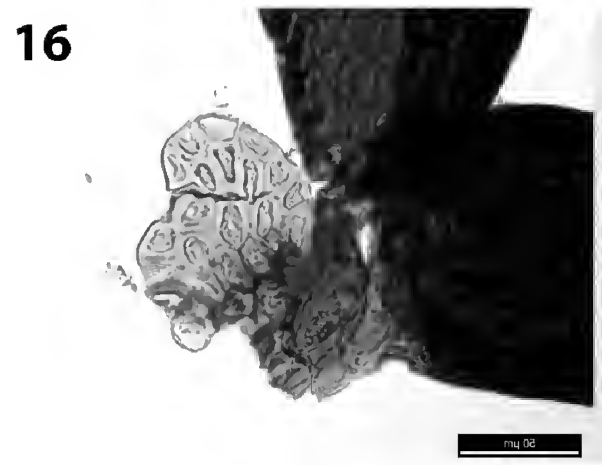
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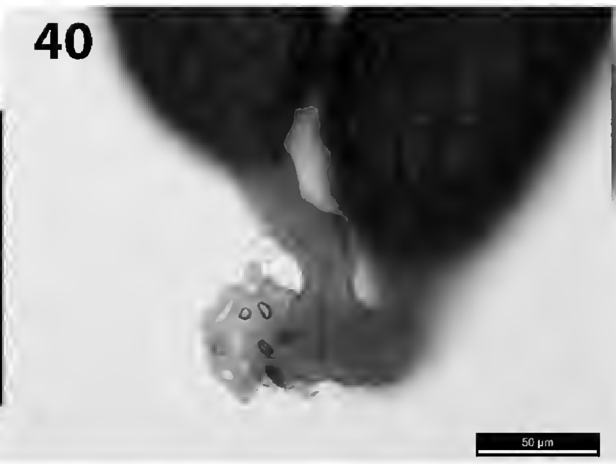
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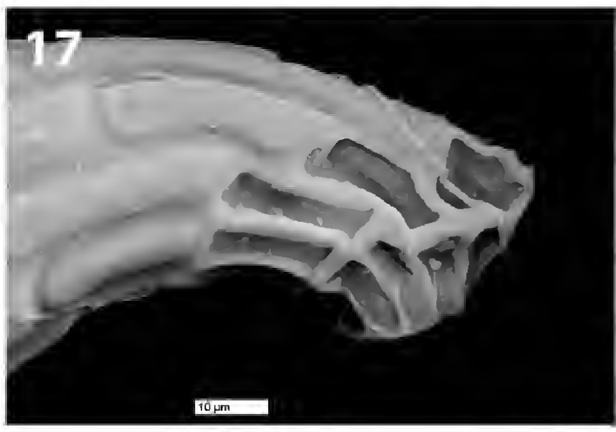

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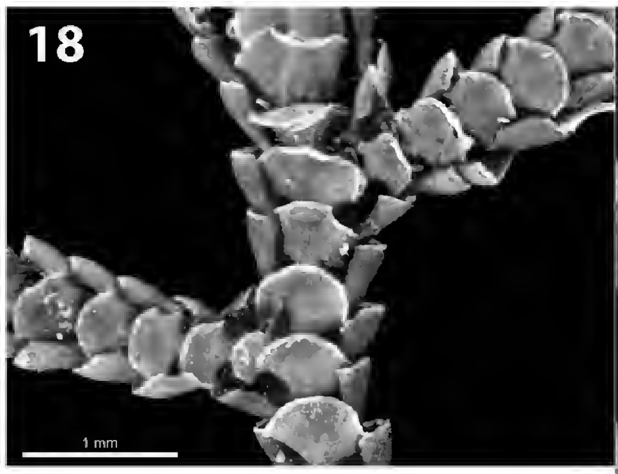

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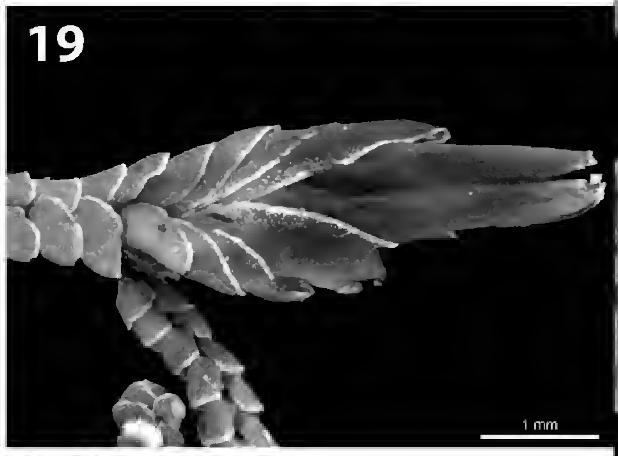

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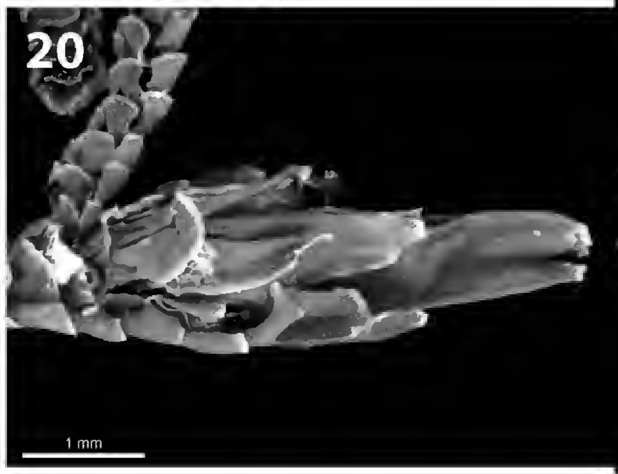

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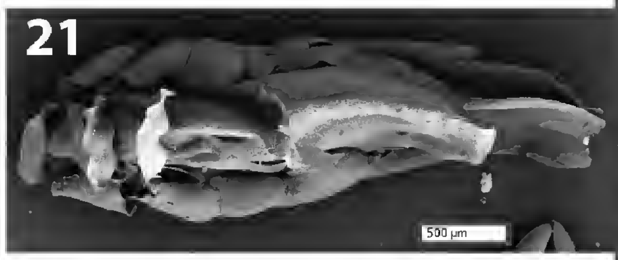

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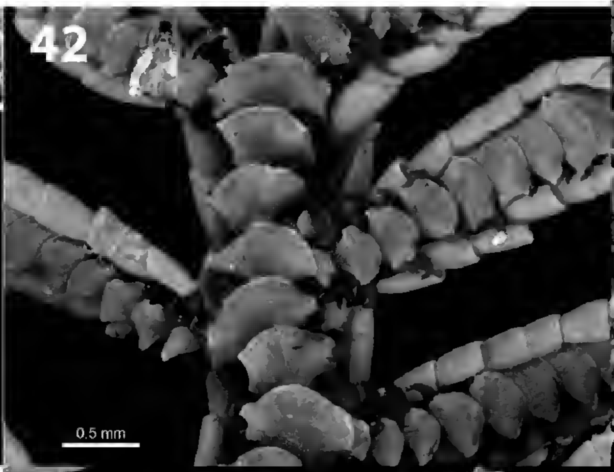

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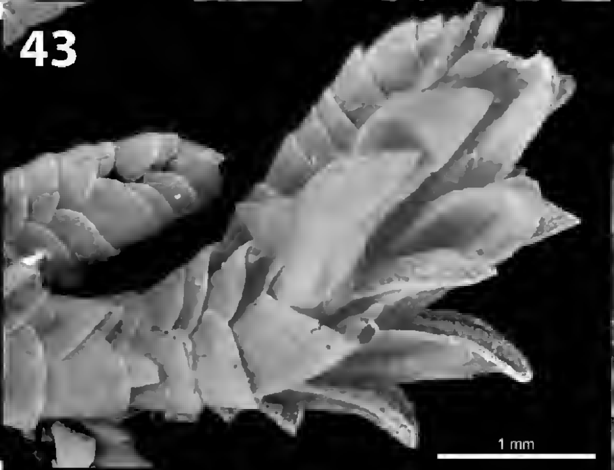

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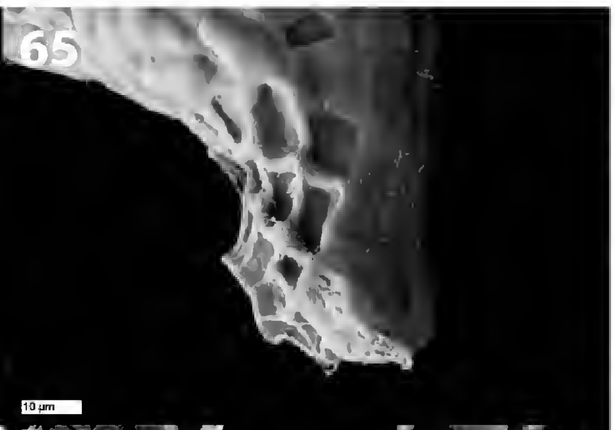

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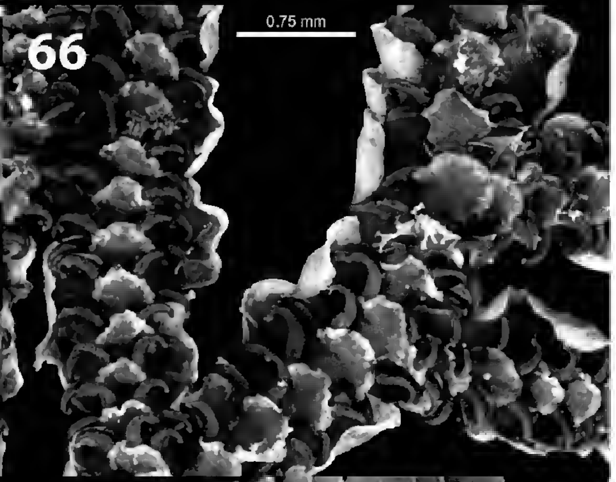

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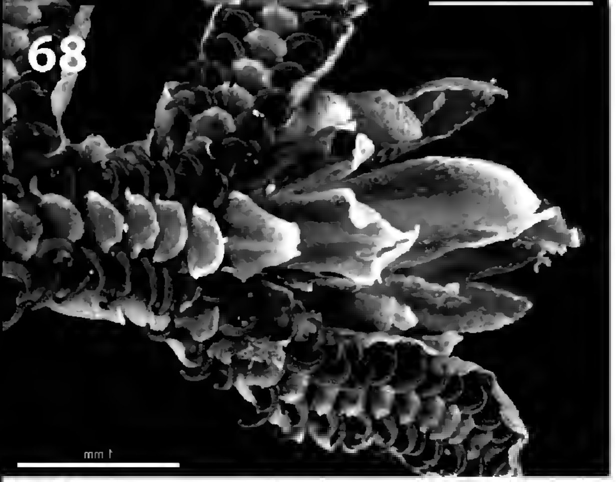

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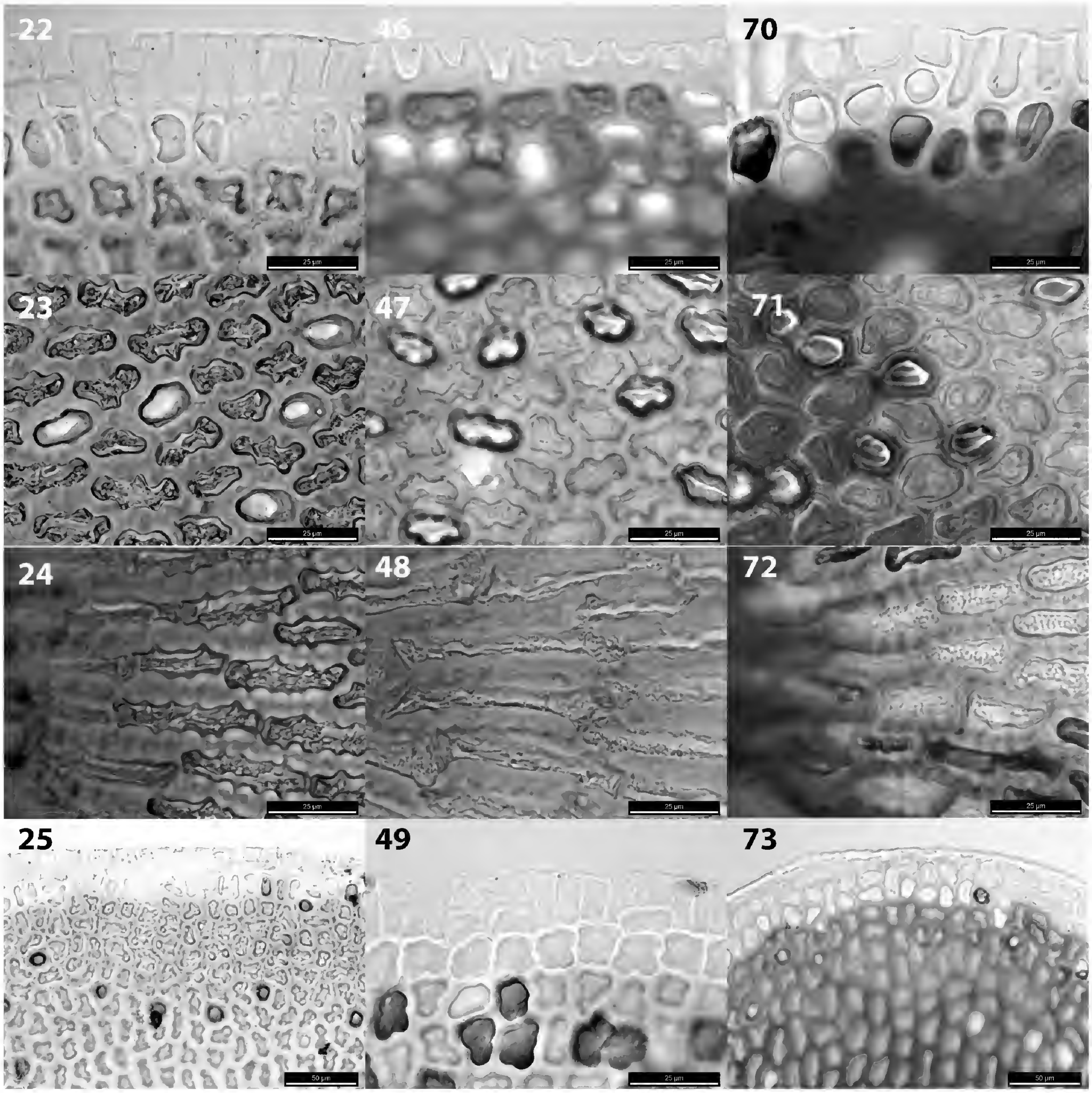

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Genus *Ensete* (Musaceae) in India

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Abstract

A detailed account of the genus *Ensete* (Musaceae) in India is presented, including a key to the two species known from the country. Updated descriptions and colour photographs of each species are provided, with notes on the phenology, ecology, distribution, cytology, morphological variation and uses. We also provide a brief history of the genus and descriptions of the two species present in India. *Ensete lecongkietii* is treated here as a synonym of *E. superbum.*

Introduction

Ensete is a unique genus characterized by its non-stoloniferous habit, chromosome count of n = 9, and its inability to be propagated in any way other than via seed. The name *Ensete* was first used by Bruce (1862) who described and illustrated a plant from Abyssinia under its native name *Ensete*. The name was originally used by Gmelin (1791) as a specific epithet in the Linnaean genus *Musa* in the 13th edition of *Systema Naturae*. Horaninow (1862) noted its marked difference from *Musa*, and treated it as a separate genus, renaming *M. ensete* as *Ensete edule*, but failed to treat some species that shared the characters of his genus. In subsequent treatments the genus *Musa* has been surveyed by Sagot (1887a, b), Baker (1893), Schumann (1900) and many other botanists who failed to adopt Horaninow's generic classification. Baker (*l.c.*) followed by Schumann (*l.c.*) treated Gmelin's species under the subgenus *Physocaulis* of *Musa*. The genus *Ensete* was in obscurity until the work of Cheesman (1947), who resurrected the genus based on genetic, cytological, and taxonomic data, while establishing a banana breeding program. Cheesman resolved problems created by earlier taxonomists by transferring twenty five species of *Musa* into *Ensete*; this included the whole subgenus *Physocaulis* of Baker. Cheesman pointed out that these taxa differed from *Musa* in being a group of single stemmed monocarpic herbs with the haploid chromosome number of 9, pseudostems dilated at the base, relatively fewer fruits with larger seeds that are irregularly globose and smooth. Baker and Simmonds (1953) revised the genus in Africa and placed most of the species treated by Cheesman (1947) in synonymy. However, they wrongly made *E. ventricosum* a synonym of *E. edule*, which was subsequently corrected by Simmonds (1953) since *E. ventricosum* was the older name. The basionym of *E. ventricosum*, *Musa ventricosa* Welw., predates *E. edule*. In the protologue of the genus, Horaninow included only *E. edule*, and for this reason it remained the obligate type species.

Simmonds (1960) listed six species under the genus, whereas Kress (1990) listed seven. Väre and Häkkinen (2011) provided a checklist of *Ensete* with nomenclatural notes and recognized eight species and one variety. Of the eight species, *E. agharkarii* (Chakravorti) Hore et al., is treated as a synonym in this work. *Ensete lecongkietii* Luu et al., was published after the checklist of Väre and Häkkinen (2011), and was diagnosed based on the difference in size, and number of anthers in the male flower. *Ensete lecongkietii* is here determined to be a synonym of *E. superbum*, and therefore we consider *Ensete* to contain seven species, with a distribution primarily in Africa and Asia.

Of the two species recorded for India, *E. glaucum* has a restricted distribution in the north-eastern states, while *E. superbum* is mainly restricted to Peninsular India (Joe 2015). There are also reports of *E. ventricosum* in cultivation at Kodaikanal, in the Palni Hills of southern India (Matthew 1969, 1996, 1999). Even though Matthew (1969) included *E. edule* in 'The Exotic Flora of Kadaikanal, Palni Hills' as an introduced garden plant, we could find only a few plants cultivated in home gardens and therefore in the current study we do not consider it an introduced plant.

Taxonomy

Ensete Bruce *ex* Horan., Prodr. Monogr. Scitam. 40. 1862.

Type: *Ensete edule* Bruce *ex.* Horan., Prodr. Scitam. 40. 1862.

Distribution: *Ensete* occurs primarily on the African continent, but is also known from India, southern China, Thailand, Myanmar, Philippines, Indonesia, and New Guinea.

Ecology: The majority of species grow in open, moist habitats, along rivers and swamps, and in forest clearings. Also common in grasslands or in rock crevices, and in forest shades or margins.

Cytology: 2n = 18 (White 1928, Cheesman and Larter 1935, Agharkar and Bhaduri1935, Chakravorti 1948).

Pollination vectors: Insects, birds and bats (Majumdar et al. 2013).

Uses: The type species, *E. edule* (=*E. ventricosum*), is a staple food crop in parts of southern Ethiopia. Edible starch is extracted from the corm and pseudostem and fermented to make 'kocho', an important food for several million people in the region (Demeke 1986, Sharrock 1997). In northern Uganda flower buds and seeds are cooked and eaten, while seeds are used as decorative beads (Mabberley 2005). With its large conical pseudostem *Ensete edule* has a high aesthetic value and is used as a garden ornamental.

Morphological variation: The size and shape of vegetative and reproductive parts varies depending on soil type, availability of water, and climatic conditions. The basal flowers are either female or bisexual. The number of stamens varies with the sixth rudiment staminode sometimes developing into a complete fertile stamen. Fruit size is dependent on pollination and fertilization.

Key to *Ensete* species in India

1. Pseudostem circumference to c. 2 m at base; outer leaf sheaths green, not dry; leaves arranged in a terminal tuft at the apex of pseudostem .... ***E. glaucum***

1. Pseudostem circumference to c. 1.5 m at base; outer leaf sheaths fully dry giving the trunk a dry brown appearance; leaves not tufted, well-spaced from c. middle of pseudostem to the apex .... ***E. superbum***

1. *Ensete glaucum* (Roxb.) Cheesman, Kew Bull. 2(2): 101. 1947

Musa glauca Roxb., Hort. Bengal. 19. 1814. *nom. nud.*, Pl. Coromandel 3: 96, t. 300. 1819. *descr.*, Fl. Ind., ed. Carey & Wall. 2: 490. 1824.

Type: Roxb.,Pl. Coromandel 3: t. 300. 1819 (Lectotype, designated by Argent 1976).

Ensete calospermum (F.Muell.) Cheesman, Kew Bull. 2(2): 102. 1947.

Musa calosperma F.Muell. ex Mikl.-Maclay, Proc. Linn. Soc. New South Wales 10: 348. 1885.

Type: Papua New Guinea: Northern New Guinea, Moresby [Basilaki] Island, *N. Miklouho-Maclay s.n.* (MEL 588768, lectotype designated by Häkkinen & Väre 2008).

Ensete agharkarii (Chakravorti) Hore, Baldev D. Sharma & G.Pandey, J. Econ. Taxon. Bot. 16(2): 450. 1992.

Musa agharkarii Chakravorti, J. Indian Bot. Soc. 27: 93. 1948.

Type: Chakravorti, Journ. Ind. Bot. Soc. 27: pl. 1, figs 1–5. 1948 (Lectotype designated by Väre & Häkkinen 2011).

Musa nepalensis Wall., in Roxb., Fl. Ind., ed. Carey & Wall., 2: 492. 1824.

Monocarpic non-stoloniferous herbs, plants not suckering. *Pseudostem* conical with distinctly swollen base, elongated, mature pseudostems 1.5–5 m tall, stout, 0.8–1.5 m circumference at the base, with loosely packed outer leaf sheaths that are not dry, green in colour, glaucous, more glaucous towards apex region, prominent at young stages, sap orange coloured. *Leaf* habit erect to intermediate or drooping, leaves arranged as a terminal tuft at apex of pseudostem, laminae 150–210 × 40–60 cm, oblanceolate, apex acute, adaxially green, dull, abaxially medium green, glabrous, leaf bases symmetric, both sides pointed, midrib adaxially green, abaxially yellowish green. *Petiole* 35–65 cm long, green or yellow-green, glaucous, margins open and spreading, without any blotches at base, bases winged, smooth, loosely or not clasping the pseudostem. *Inflorescence* pendulous, peduncle 35–90 cm long, green, glaucous, arched. Sterile bracts 5–7, ovate to rotund, persistent and greenish till the maturity of fruits, 25–40 × 14–19 cm, adaxially light green, glaucous, abaxially green, glaucous. Female bud lanceolate, imbricate. Female bracts ovate to rotund, 25–36 × 12–24 cm, adaxially and abaxially green, glaucous, apex cuspidate, lifting 1–2 bracts at a time, just open, persistent, greenish till fruits ripe, basal 5–14 bunches female or variably bisexual. *Bracts* and flowers integral with each other and with axis. *Flowers* 13–22 per bract in two rows, 6.8–7.5 cm long. Compound tepal 3–3.3 × 0.6–0.7 cm, creamy, lobes 5, divided nearly to the base, outer three lobes much longer and broader, 2.3–2.4 cm long, inner two lobes, linear, 1.9–2.1 cm long. Free tepal with two lateral sub-orbicular lobes (wing-like) and a narrow elongated central lobe (acumen), 1.5–1.6 × 1.2–1.3 cm, translucent cream or white, acumen 0.8–1 cm long. *Stamens* 0–5, 3–3.5 cm long, filaments 1.9–2.1 cm long, cream, anthers golden yellow, 1.5–1.8 cm long. *Staminodes* 4–5 with a much small rudiment sixth staminode, 1.2–1.9 cm long, cream. *Ovary* 3.8–4.2 cm long, straight, cream or creamy-green with purple patches, glaucous, with ovules in two rows per locule, style 2.5–2.8 cm long, straight, inserted, cream, stigma globose, cream, sticky. Male bud lanceolate, imbricate, rachis falling vertically, green, glabrous. Male bracts ovate to rotund or lanceolate, 20–29 × 11–15 cm, adaxially and abaxially green, glaucous, apex cuspidate, lifting 1–2 bracts at a time, just open, persistent, greenish till the maturity of fruits or dry, male bud continues to grow even after the ripening of the fruits. Bracts and flowers integral with each other and with axis. Male flowers 18–22 per bract in two rows, 5.9–6.2 cm long. Compound tepal 3.6–3.9 cm long, creamy, lobes 5, divided nearly to the base, outer lobes much longer and broader, 2.3–2.4 cm long, inner lobes 1.9–2.1 cm long. Free tepal with two lateral sub-orbicular lobes (wing-like) and a narrow elongated central lobe (acumen), 1.3–1.5 × 1.8–2.1 cm, creamy translucent. *Stamens* 5–7, 3.2–3.8 cm long, filaments white, exserted, 1.9–2.4 cm long, anther cream, 1.2–1.7 cm long, curved backwards. *Pollen* grains with regularly warty surface, cream. *Ovary* rudiment, straight, 2.2–2.6 cm long, creamy-white or creamy, style much reduced, cream, stigma not developed. Fruit bunch compact, with 5–14 hands and 13–22 fruits per hand, in two rows, fingers almost perpendicular to the axis. *Fruits* straight, 7.4–8.2 cm long, slightly ridged, apex blunt tipped or acuminate in less fertilized fruits, with floral relicts, pedicel absent, pericarp green, slightly glaucous, yellow when ripen, pulp cream. *Seeds* many, variable according to the fertilization, 7–21 per fruit, 1–1.3 × 0.8–1.2 cm, round or irregularly round, black except hilum region, surface smooth. **Figs 1, 2, 6A–H**.

Flowering and Fruiting: Flowers mainly during the rainy season (May–August). Male buds continue growth after fruit maturation, and until at least March.

Distribution: China, India, Indonesia, Laos, Myanmar, Philippines, Papua New Guinea, and Thailand. In India it is found in Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura. In various parts of India it is also cultivated in home gardens as an ornamental.

Ecology and habitat: *Ensete glaucum* is commonly found in open places near dry deciduous forest margins and grasslands. It occasionally grows near small streams and on river banks, and in moist soil, sometimes co-occuring with *Musa balbisiana* and *M. thomsonii*. During the dry season plants will be in a dormant state without any leaves. Flowering occurs within one or two years post germination if water and nutrients are sufficient, and may take over five years under less fertile conditions.

Etymology: The specific epithet refers to the glaucous pseudostem.

Cytology: 2n = 18 (Agharkar and Bhaduri 1935; Cheesman and Larter 1935; Chakravorti 1948).

Pollination vectors: Insects, birds and bats (Majumdar et al. 2013).

Uses: Due to its conical stem and mostly persistent green bracts, *E. glaucum* has ornamental potential. The Mizo people of north-eastern India once prepared different dishes with the buds and sheaths. The pseudostem is used as a vegetable in Meghalaya (Rao and Hajra 1976), while the orange sap from the pseudostem has known medicinal properties (Uma 2006).

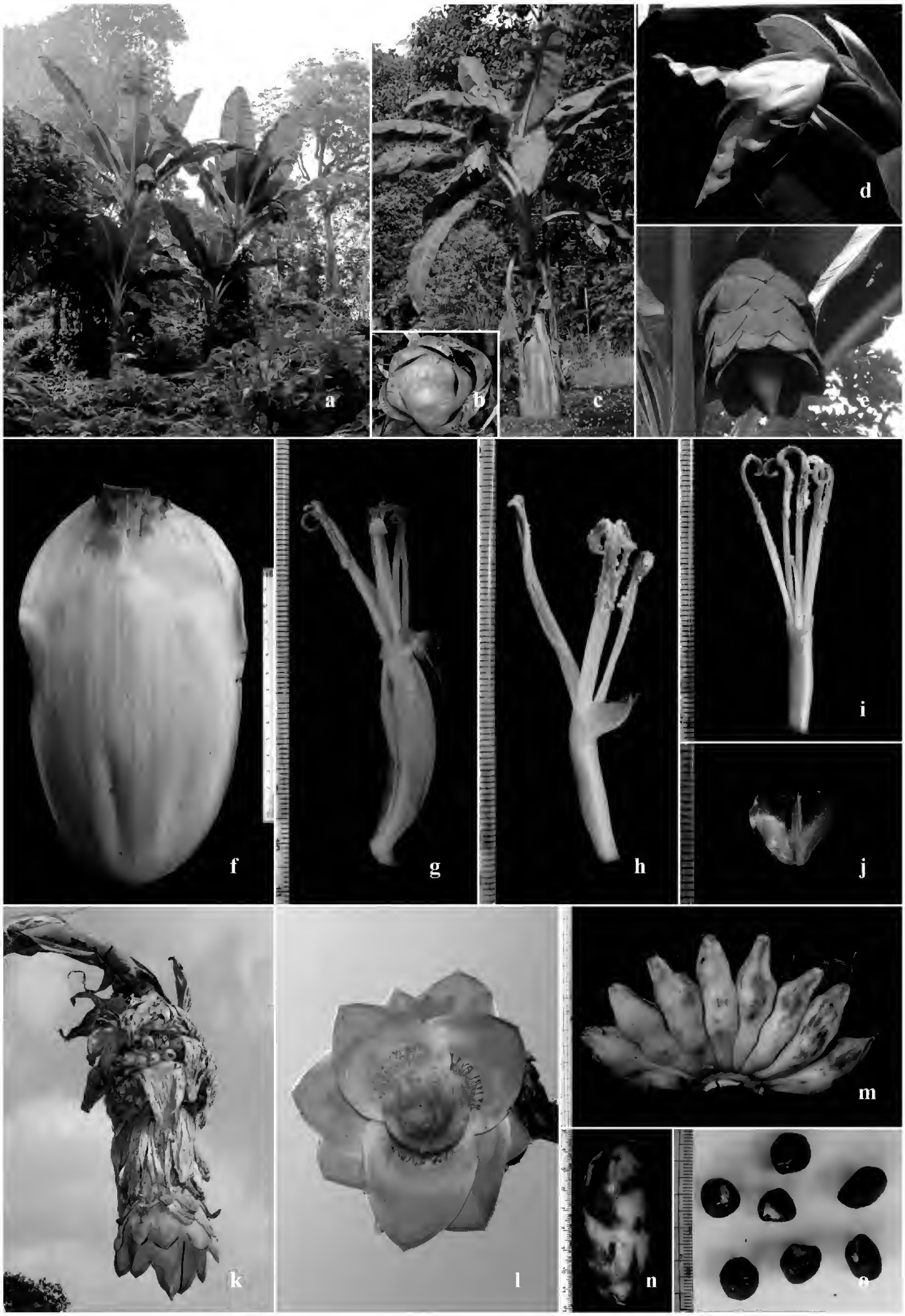

Fig. 1. *Ensete glaucum*. **a,** habitat; **b,** cross section of pseudostem showing orange sap; **c,** habit; **d–e,** inflorescences at early stages; **f,** bract; **g,** female flower; **h–j,** male flower parts; **h,** entire flower; **i,** flower without tepals; **j,** free tepal; **k,** infructescence with advanced stages of male bud; **l,** male bud; **m,** fruit bunch (produced from non-fully fertilized ovaries); **n,** single fruit produced from fully fertilized ovary; **o,** seeds. Photos by Alfred Joe (**a** from *A. Joe & Ashfak 121773*; **b–o** from *A. Joe & M. Sabu 130897*).

Morphological variation: The plant shows much variation in size depending upon the climatic and soil conditions and availability of water. The basal flowers are female with five staminodes and one much reduced rudiment staminode, but hermaphrodites with 2–5 fertile stamens and staminodes also occur. The male bud continues growth in some plants, even after the ripening of fruits, but sometimes degenerate before fruits mature. Fruits are uneven in size or undeveloped when the flowers are partially fertilized. In such cases, fruits have an acuminate apex and a lower number of seeds, while the fruits filled with seeds are almost rounded at the apex.

Notes: *Musa glauca* was first listed in Roxburgh's *Hortus Bengalensis* (Roxburgh 1814) and the detailed description appeared in *Plants of the Coast of Coromandel* (Roxburgh 1819). Subsequently, Roxburgh included the species in his *Flora Indica* (Roxburgh 1824). Horaninow (1862) followed Roxburgh and failed to place *M. glauca* under *Ensete* inspite of its close resemblance to the latter. Subsequently, Baker (1893) placed *M. glauca* in his subgenus *Eumusa* [=*Musa*], though all characters agreed with the subgenus *Physocaulis* and he himself admitted that it "has flowers like *M. superba*". Sagot (1887a), who divided the genus *Musa* into different groups, and from whom Baker formalized his subgeneric classification, included it correctly under 'Bananiers Géants' (Giant Bananas), but subsequent authors followed Baker. Cheesman (1947), who revived the genus *Ensete*, treated this species under it. Argent (1976) designated the icon of *M. glauca* in '*Plants of the Coast of Coromandel*' as lectotype. He also synonymised *E. calospermum* (F.Muell.) Cheesman under *E. glaucum*.

The status of *M. nepalensis* Wall., has been in a state of flux for a long time. Wallich described the plant from Nepal in Roxburgh's (1824) *Flora Indica*. According to Baker (1893), Wallich described the species principally from "two large unpublished drawings by Wallich, now at Kew". Anonymous (1894) included a letter by Dr. King, dated Calcutta, 22nd August 1893, which said: "I do not believe in the existence of the species which Wallich called *M. nepalensis*. I have never been able to hear of, or find, any specimens of a big non-stoloniferous plantain on the lower slopes of the Himalaya. I have made inquiries in Nepal where Wallich says it grows. Wallich must have described Roxburgh's *M. glauca* under the name *M. nepalensis*". Simmonds (1960) also supported King's view mentioned above. The existence of the taxon has also been questioned by Cheesman (1947), Moore (1957), Väre and Häkkinen (2011), but no one has confirmed its identity. Väre and Häkkinen (2011) considered the name to be illegitimate because Wallich himself thought it was either doubtfully distinct from *M. superba* or intermediate between that species and *M. glauca*. However, expressions of doubt do not invalidate names. In the course of this study, we could not find any specimen or illustration of *M. nepalensis* at K or CAL and agree with Simmonds (1960) that *M. nepalensis* and *E. glaucum* should be considered conspecific.

Musa agharkarii was described by Chakravorti (1948) who placed it in the subgenus *Physocaulis* of Baker. He distinguished it from the other species in Asia based on its geographic distribution. He was well aware of *M. glauca* but he neglected the icon of Roxburgh, which shows the inflorescence at advanced blooming, whereas *M. agharkarii* was described in its female stage, or during early development of the inflorescence, which can be confusing to those who are unfamiliar with the early flowering stages of *E. glaucum*. Some workers treated *M. agharkarii* as a synonym of the latter (Rao and Hajra 1976, Majumdar et al. 2013) but this was overlooked by Hore et al. (1992) who made a new combination for it under *Ensete*. Väre and Häkkinen (2011) followed Hore et al. (1992) and lectotypified the species using Chakravorti's plate. From our study we are convinced that these taxa are conspecific and treat *E. agharkarii* as a synonym of *E. glaucum*.

The existence of *E. glaucum* in India was reported by Simmonds (1960) and Rao and Hajra (1976) from Meghalaya. Giri et al. (2009) confirmed its presence from Arunachal Pradesh. Uma et al. (2005) mentioned its widespread distribution in many districts of Mizoram and in some parts of Assam nearer to Mizoram, both wild and domesticated. Recently, Majumdar et al. (2013) recorded its occurrence from Tripura. The present study has extended the known distribution of this species to Manipur and Nagaland and concluded that, in India, wild populations of *E. glaucum* are restricted to the north-eastern region, although plants are also found in home gardens throughout India as ornamentals. Rao and Kumari (1967, 2008) recorded the natural occurrence of *E. glaucum* from Andhra Pradesh in Eastern Ghats of India, but these occurrences are of *E. superbum*, which is commonly found in Peninsular India; this has been confirmed from specimens held at the Madras Herbarium.

IUCN Status: Based on intensive field surveys during the past several years, it is estimated that *E. glaucum* in India comes under the Critically Endangered (CR A2 a,c,d) criteria of IUCN (IUCN 2011). The populations are restricted to some pockets of natural vegetation, and continuous destruction of the habitat for Jhum (slash-and-burn) cultivation may adversely affect existing populations.

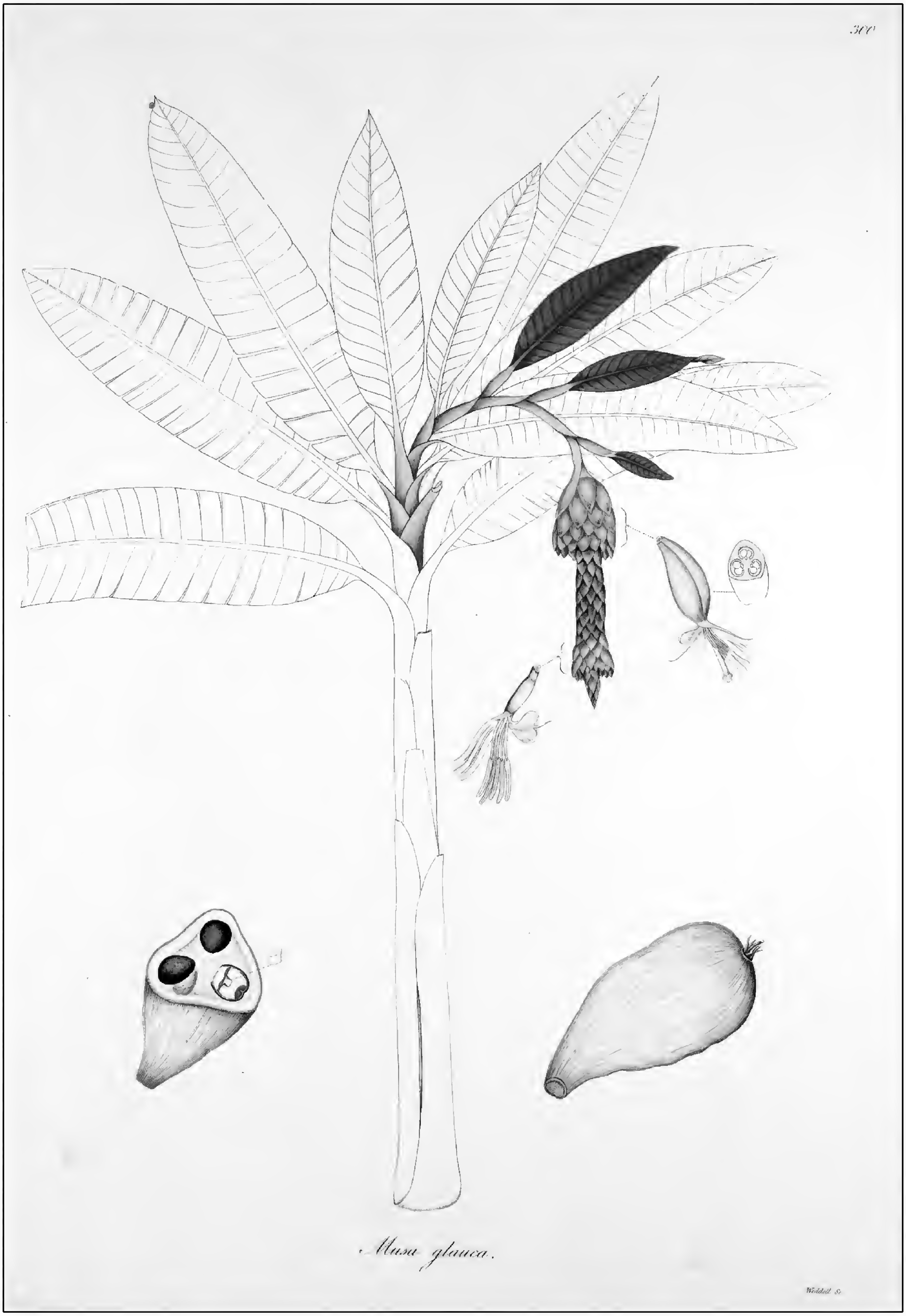

Fig. 2. Lectotype of *Ensete glaucum* (Roxb., Pl. Coromandel 3: t. 300. 1819).

Additional specimens examined: INDIA: KERALA: Malappuram Dist., Calicut University Botanical Garden (Cultivated), 25 Jan 2014, *A. Joe & M. Sabu 130897* (CALI). MANIPUR: Ukrul Dist., on the way to Kamjong, Nungou Village, N24°27.916′ E094°23.750′, 1189 m alt., 07 Dec 2012, *A. Joe & Ashfak 121640* (CALI). MEGHALAYA: Khasi Hills, Umdihar, 5 miles from Nongpoh, 20 Jun 1973, *P.K. Hajra 45683* (ASSAM, CAL); Khasi Hills, Umdihar, 5 miles south of Nongpoh, 30 Jun 1973, *A.S. Rao 45684* (ASSAM); Khasi Hills, Barnihat Citrus Research Station, 31 Jul 1973, *P.K. Hajra 45685* (ASSAM);West Garo Hills, Tura Peak, N25°30.494′ E090°13.723′, 471 m alt., 27 May 2013, *A. Joe & Ashfak 121773* (CALI). MIZORAM: Lengpui, Modal, near Zero Point, N23°49.740′ E092°37.989′, 277 m alt., 15 Mar 2012, *A. Joe & Sreejith 130817* (CALI); Champai Dist., Zote, 5 kms from New Champai, N23°28.579′ E093°20.867′, 1261 m alt., 16 May 2013, *A. Joe & Ashfak 121730* (CALI). NAGALAND: Tuensang Dist., near Noklak town, Noklak, 01 Dec 2012, *A. Joe & Ashfak 121628* (CALI).

2. *Ensete superbum* (Roxb.) Cheesman**,** Kew Bull. 2(2): 100. 1947

Musa superba Roxb., Hort. Bengal. 19. 1814, *nom. nud*., Pl. Coromandel 3: 17, t. 223. 1819, *descr*., Fl. Ind., ed. Carey & Wall., 2: 489. 1824

Type: East India, Roxburgh *s.n.* (K [barcode K000309030] image!, lectotype designated by Väre and Häkkinen 2011).

Ensete lecongkietii Luu, N.L.Vu & Q.D.Nguyen, Folia Malaysiana 13(2): 44. 2012. ***syn. nov***.

Type: VIETNAM, Binh Thuan Province: Ham Thuan Nam District, Thuan Nam Township, Nhan Hill, 48P815678.37m & E1200329.68 m., 5 June 2012, *Luu 872* (Holotype: VNM); *Luu 873* (Paratype: VNM).

Ensete glaucum auct. non. (Roxb.) Cheesman, Subba Rao & Kumari, Fl. Visakhapatnam Distr. (Andhra Pradesh) 2: 266. 2008.

Vernacular Names: Malayalam: Kalluvazha, Malavazha; Tamil: Kalluvazhai; Kannada: Kallu bale, Kalbale; English: Cliff banana, rock banana.

Monocarpic non-stoloniferous herbs, plants not suckering, suckers produced when the pseudostem cut from the base. *Pseudostem* conical with distinctly swollen base, congested, with tightly packed outer leaf sheaths that are full dry giving trunk dry appearance, mature pseudostems 1–4 m tall, stout, 0.6–2 m circumference at the base, green only towards apex, glaucous, more glaucous towards apex region, prominent at young stages, sap orange coloured. Leaf habit erect to intermediate or drooping, leaves spatially arranged from middle to apex of pseudostem, laminae 90–320 × 28–58 cm, oblanceolate, apex acute, adaxially green, dull, abaxially green, glabrous, leaf bases symmetric, both sides pointed, midrib adaxially green or purple, abaxially yellowish-green. *Petiole* 15–42 cm long, upper half green, lower half yellow- green with black dots, slightly glaucous, margins open with spreading, with black blotches at base, bases winged with smooth margins and clasping the pseudostem. *Inflorescence* pendulous or sub-horizontal, peduncle 30–60 cm long, green or green with black patches, glabrous, arched. Sterile bracts 4–7, ovate to rotund, persistent and dry before the maturity of fruits, 15–28 × 5–15 cm, adaxially light green or pink-purple or dark brown-purple, highly glaucous, abaxially pink-purple, glaucous. Female bud lanceolate, imbricate. Female bracts ovate, 14–25 × 5–16 cm, adaxially greenish or pink-purple or brown-purple, glaucous, pink-purple or brown-purple abaxially, glaucous, apex round, lifting 1–2 bracts at a time, open and reflexed, not revolute, persistent, dry before fruits mature, basal 3–14 bunches female or variably bisexual. *Bracts* and flowers integral with each other and with axis. *Flowers* 6–15 per bract in two rows, 7–10.2 cm long. Compound tepal 2.9–3.6 × 0.7–1.1 cm, creamy, divided nearly to the base, lobes five, outer three lobes much longer and broader, 2.3–2.4 cm long, inner two lobes linear, 1.9–2.1 cm long. Free tepal with two lateral sub-orbicular lobes (wing-like) and a narrow elongated central lobe (acumen), 0.9–1.8 × 1.2–1.4 cm, translucent cream or white, acumen 0.5–1 cm long. *Stamens* 0–5, 3–3.8 cm long, filaments cream, anthers creamy yellow. *Staminodes* 4–5 with a much smaller rudimentary sixth staminode, 0.7–1.7 cm long, cream to creamy orange. *Ovary* 4.5–6.9 cm long, straight, grayish green or dull brownish green, glaucous, with ovules in 2 rows per locule, style 2.3–2.7 cm long, straight or slightly curved, inserted, cream or creamy orange with pink-purple patches towards base, stigma globose, cream, sticky. Male bud lanceolate, in advanced blooming ovoid to top-shaped or lanceolate, imbricate, rachis falling vertically, brown, glaucous. Male bracts ovate to rotund or lanceolate, 15–23 × 12–15 cm, adaxially greenish or pink-purple or brown-purple towards apex, highly glaucous, abaxially red-purple or brown purple, glaucous, apex rotund, not revolute, lifting 1–2 bracts at a time, just open, deciduous, sometimes persistent near male bud at advanced blooming, male bud continues to grow even after ripening of the fruits. *Bracts* and flowers integral with each other and with axis. Male flowers 12–28 per bract in two rows, 5.9–7.8 cm long. Compound tepal 3.8–4.7 cm long, creamy, divided nearly to the base, lobes five, outer three lobes much longer and broader, inner two lobes linear, sometimes absent. Free tepal 0.8–1.3 × 0.8–1.2 cm, with two lateral sub-orbicular lobes (wing-like) and a narrow elongated central lobe (acumen), creamy translucent. *Stamens* 3–6, 3.5–4.1 cm long, exserted, filaments cream, 4–4.4 cm long, anther creamy white with cream pollen, orange-red to purple opposite to thecae, 2.5–3 cm long, curved backwards, pollen grains with regularly warty surface, cream. *Ovary* rudiment, straight, 2.2–3.5 cm long, creamy white or creamy orange, style much reduced, cream, 1.3–1.7 cm long, stigma not developed. Fruit bunch compact, with 3–14 hands and 6–15 fruits per hand, in two rows, fingers almost perpendicular to the rachis. *Fruits* straight, 5.5–9.5 cm long, slightly ridged, apex slightly pointed, 0.5–1 cm long, with floral relicts, pedicel 0.5–0.8 cm long, pericarp green, slightly glaucous, yellow when ripe, pulp cream. *Seeds* many, 20–90 fruits, variable according to the fertilization, 0.6–1.1 × 0.6–1 cm, round, black except hilum region, surface smooth. **Figs 3, 4, 5, 6 I–S.**

Fig. 3. *Ensete superbum*: **a,** habitat; **b,** habit; **c,** leaf apex; **d,** leaf base; **e,** cross section of petiole; **f–g,** inflorescences at early stages; **h–k,** female flower parts; **h,** entire flower; **i,** compound tepal; **j,** free tepal; **k,** cross section of ovary; **l,** infructescence with advanced advanced stage of male bud; **m,** bract-adaxial surface; **n,** bract-abaxial surface with male flowers; **o,** male flower; **p,** fruit bunch; **q,** single fruit; **r,** seeds. Photos by Alfred Joe (a–r from *A. Joe & M. Sabu 130896*).

Flowering and fruiting: Mainly during the rainy season (May–September) and male bud continues to grow and extends to the following year.

Distribution: India, Myanmar, Thailand and Vietnam. In India *Ensete suberbum* is mainly distributed throughout Peninsular India and some parts of Gujarat. It is also cultivated as an ornamental throughout India. There are some reports of its occurrence from Myanmar (Kress et al., 2003) and from Thailand (De Langhe et al. 1999) and as it commonly occurs near human populated areas, may have become naturalized from an introduced plant.

Ecology and habitat: Found mostly in rocky areas or in moist soils. Sometimes present in rock crevices and steep rocky cliffs. It is a monocarpic herb that dies after flowering. It takes one to more than six years to flower depending upon the availability of water and nutrients.

Etymology: The specific epithet refers to the superb nature in regards to the stout form of the pseudostem and inflorescence.

Cytology: 2n = 18 (Agharkar and Bhaduri 1935).

Uses: Reportedly the seeds of *E. superbum* are used for various human ailments such as diabetes, leucorrhoea, kidney stones, dysuria, etc. (Kumar et al. 2010). Seed powder is used to relieve kidney stones and painful urination (Yesodharan and Sujana 2007, Diana and George 2013). As a result, seeds have a high market value ranging from 200–400 rupees per kg across various states in South India (Kumar et al. 2010). Tribal people use the fruits, flowers and pseudostem as a vegetable in South India. *Ensete superbum* is also used as an ornamental because of its large conical pseudostem and leaf arrangement. The flower juice is used to treat dysentery and excess bleeding during menstruation in young girls (Padal et al. 2010).

Morphological variation: This taxon shows much variation in the size of vegetative as well as reproductive parts. At high altitudes the bracts sometimes develop a slightly greenish colour, and the number of flowers and fruits in a bunch can vary greatly. The number of stamens per flower can also vary from three, four and six.

Notes: *Musa superba* was first listed in Roxburgh's (1814) *Hortus Bengalensis* and a detailed description appeared in *Plants of the Coast of Coromandel* (Roxburgh 1819). Horaninow (1862) followed Roxburgh and failed to place *M. superba* under *Ensete* inspite of its close resemblance to the latter. Later, Cheesman (1947) correctly placed the species in *Ensete* when he reviewed and resurrected the genus.

Recently Luu et al. (2012) described a species, *E. lecongkietii*, from close to human habitation in Vietnam, based mainly on differences in size and number of anthers in male flowers compared with those of *E. superbum*. During this study we became convinced that this taxon is the same as *E. superbum* and we have treated it as conspecific. *Ensete superbum* is a species with a wide range of variation in size, number of fruits, flowers, and stamens in male flowers. *Ensete superbum* was earlier considered an endemic to the Western Ghats, India. There are some reports of it growing near temples and houses in Myanmar and Thailand. These plant might be disjunct populations or escapees from gardens since they were reported from populated areas.

IUCN status: Under IUCN criteria *Ensete superbum* should be listed under the category of Least Concern (IUCN 2011). It is very common in Western Ghats, and is also distributed throughout Peninsular India.

Additional specimens examined: INDIA, ANDHRA PRADESH: East Godavari Dist., Errakonda, 400 m alt., 05 Jul 1965, *G.V. Subba Rao s.n.* (MH); Vishakapatnam Dist., Arakku, Adapavalasa block, 950 m alt., 20 May 1964, *G.V. Subba Rao s.n.* (MH). GUJARAT: Waghai, Dangi Forest, 12 Feb 1956, *N.A. Irani 1716B* (BLAT). KERALA: PalghatDist., Mukkali forest, 300 m alt., 25 Aug 1966, *E. Vajravelu 27823* (MH); Thrissur Dist., Sholayar, 725 m alt., 21 Mar 1989, *N. Sasidharan 5357* (KFRI); Thrissur Dist., on the way to Sholayar from Athirapilly, 10 Jul 2012, *A. Joe & Sreejith 130888* (CALI); Malappuram Dist., Villunniyal (cultivated), 16 Nov 2010, *A.Joe & Sreejith 116101* (CALI); Malappuram Dist., Calicut University Botanical Garden (Cultivated), Near West Gate, 15 Sep 2012, *A. Joe & M. Sabu 130896* (CALI); Malappuram Dist., Calicut University Botanical Garden (cultivated), Near West Gate, 18 Jul 2013, *A. Joe & M. Sabu 121683* (CALI); Malappuram Dist., Calicut University Botanical Garden (Cultivated), Ginger Zone, 28 Apr 2013, *A. Joe & M. Sabu 130778* (CALI). MAHARASHTRA: Khandala, Behrams Plateau, 18 Jul 1953, *H. Santapau 15698* (BLAT); Purandar Path, above camp, 08 Oct 1950, *H. Santapau 11390* (BLAT); Sindhudurgh Dist., Sawanthawadi, 19 Aug 2014, *Kabeer & K.M. Manudev 143027* (CALI). TAMIL NADU: Coimbatore Dist., Poonachi Ghat, Oct 1900, *Dr. C.A. Barber s.n.* (MH); Coimbatore Dist., 17 Mar 1931, *V. Narayanaswami 5434* (MH). WEST BENGAL: Calcutta Botanical Garden (cultivated), *s.c.*, *s.n.* (CAL). UNKNOWN LOCALITY: 1880, *R.A. Beddome s.n.* (MH); Museum compound, 1881, *G. Biddie s.n.* (MH).

Fig. 4. Lectotype of *Ensete superbum*: Roxburgh s.n. (K). Image courtesy of the Board of Trustees of Royal Botanic Garden, Kew.

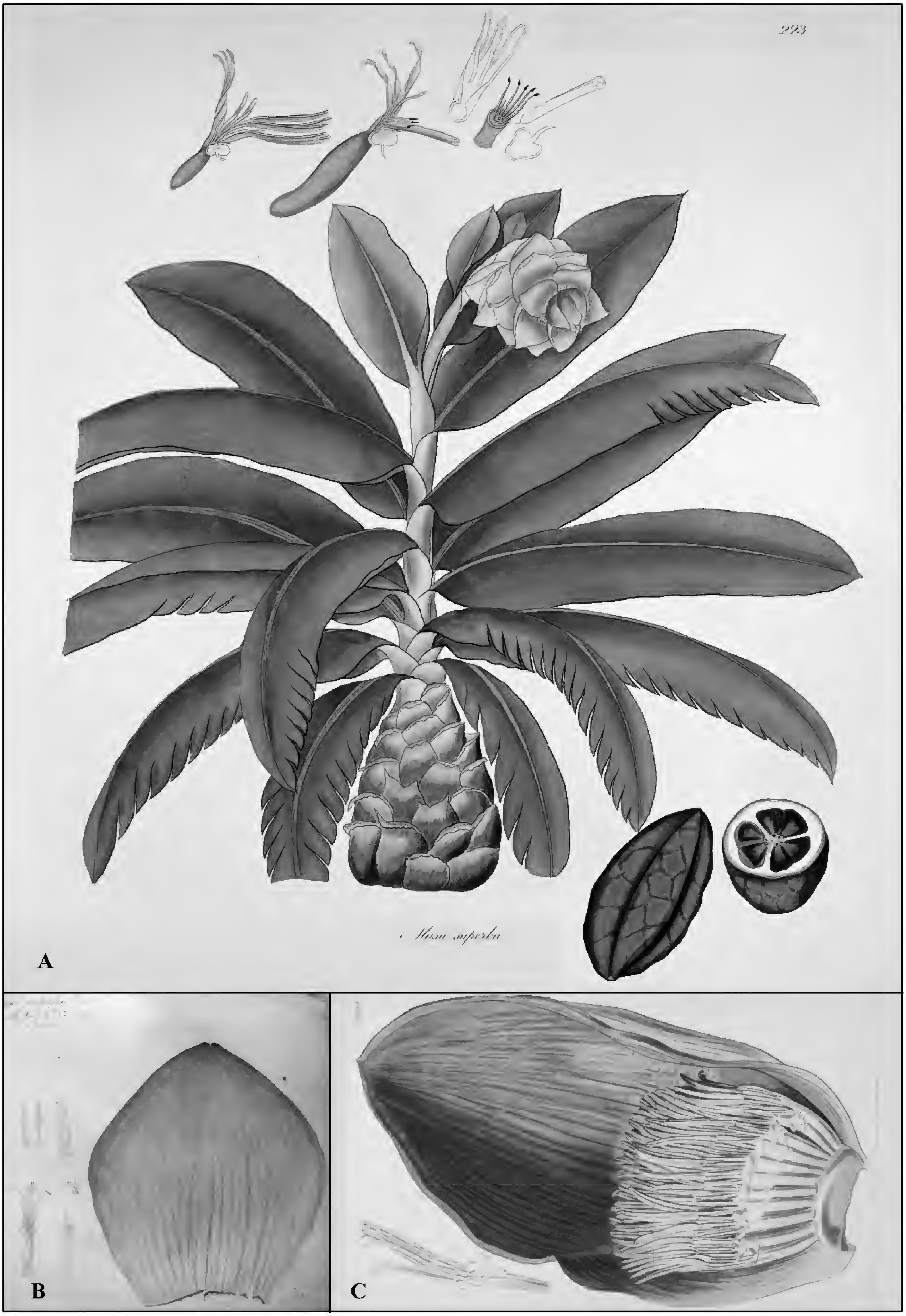

Fig. 5. a, original painting of *Ensete superbum* from Roxb., Pl. Coromandel 3: t. 223(1819); **b,** painting found along with specimens at CAL; **c,** painting in Curtis' Bot. Mag. 67: t. 3850 (1841).

Fig. 6. *Ensete glaucum*: **a–c,** variations across inflorescences; **d,** partially cylindrical pseudostem after removal of outer sheath for food (from Mizoram); **e,** seedling growing epiphytically in tree canopy; **f,** seedling; **g–h,** female flowers with 3 and 1 fertile stamens respectively; *Ensete superbum*: **i,** bract containing male flowers with 3 fertile stamens; **j,** male flower with 3 stamens; **k,** variation in fruits size and shape; **l,** undeveloped fruits; **m–s,** form variation across inflorescences and infructescences. Photos by Alfred Joe.

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Revision of *Goodyera rubicunda* (Orchidaceae: Goodyerinae)

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Abstract

The *Goodyera rubicunda* complex has broad morphological variation of the floral parts. A revision of the *G. rubicunda* complex was conducted and three intraspecific groups were recognised; *G. rubicunda* var. *rubicunda* which is the widespread variety, *G. rubicunda* var. *triandra*, and *G. rubicunda* var. *australis* var. nov. Herein, we propose the variety *G. rubicunda* var. *australis* from Australia and Papua New Guinea as newly described.

Introduction

Goodyera R.Br. is classified as belonging to subfamily Orchidoideae, tribe Cranchideae, subtribe Goodyerinae (Pridgeon 2003), containing approximately 98 species that are currently recognised as belonging to the genus (www.theplantlist.org, accessed 2 Jan 2014). Schlechter (1911) classified *Goodyera* as part of subfamily Monandrae, division Acrotonae, subdivision Polychondreae, and group Physurinae (subtribe Goodyerinae, Dressler and Dodson 1960; Pridgeon et al. 2003).

Goodyera species are characterised by their terrestrial habit, horizontal creeping stems, a rhizome about as thick as the stem, rather thick pubescent roots, leaves either in rosettes or spread laxly along the stem, a terminal, often pubescent inflorescence, and a generally pubescent, saccate labellum often with internal fleshy hair-like glands (Comber 1990; Dockrill 1992). However, some of these characters are not useful for differentiation of genera within subtribe Goodyerinae, and for this reason delimitation within the subtribe still remains problematic. Members of the genus are widely distributed throughout North America, Europe, Africa, South Asia, South East and East Asia including Japan, New Guinea, Pacific islands and Australia (Brown 1813; Blume 1825; Thwaites 1858; Ridley 1886; Hooker 1894; Schlechter 1906, 1932; Smith 1905, 1917; Ohwi 1937; Seidenfaden and Smitinand 1959; Garay and Sweet 1974; Halle 1977; Cornell 1978; Kores 1989; Lewis and Cribb 1989; Comber 1990; Lewis and Cribb 1991; Dockrill 1992; Seidenfaden and Wood 1992; Cribb and Whistler 1996).

Robert Brown (1813) first described *Goodyera* and included it under *Neottia pubescens* Willd. (North America), and *Satyrium repens* L. (Europe). Soon after, the genus was expanded with addition of other species described from the tropics and subtropics (Wallich 1822; Loddiges 1824; Blume 1825; Lindley 1839). Blume (1825) described seven species for the genus *Neottia* Guett., section 3 *Erporchis*. In the generic treatment of Lindley (1839), *Neottia rubicunda* was transferred to *Goodyera* (as *G. rubicunda*) based on similarity of its habit and floral characters with *G. procera* (Ker Gawl.) Hook. from Nepal (Wallich 1822). Lindley (1839) noted that all two species within *Neottia* sect. 3 *Erporchis* belonged to *Goodyera*, although a type for the genus had not been designated. Of the original two species *G. repens* (L.) R.Br. and *G. pubescens* from North America, Britton and Brown designated *G. repens* as the lectotype.

In the treatment of the orchids of former German New Guinea (now part of Papua New Guinea), Schlechter (1911) divided *Goodyera* into the two sections *Eu-Goodyera* (=sect. *Goodyera*) and *Otosepalum*. The diagnostic character separating these two sections is the position of the lateral sepals, which are parallel in section *Goodyera,* and widely spreading in section *Otosepalum*. Jones and Clements (2004) designated *Goodyera rubicunda* (Blume) Lindl. as lectotype of section *Otosepalum*. At least 15 species in *Goodyera* share the character of spreading lateral sepals, although for several vegetative characters, taxa such as *G. procera* (Ker-Gawl.) W.J.Hook., *G. scripta* (Rchb.f.) Schltr., and *G. viridiflora* (Blume) Lindl. ex D.Dietr. appear to be distantly related to each other (LSJ pers. observation). Further morphological and molecular studies are needed in *Goodyera* to determine whether Schlechter's sectional divisions require further refinement, or whether they should be abandoned. Clements and Jones (2006a), with limited transfers, placed section *Otosepalum* in a reinstated *Salacistis* Rchb.f., whilst also accepting *Eucosia* Blume as a genus for *G. viridiflora* and allied taxa (Clements and Jones 2006b).

The most widespread and taxonomically complex member of section *Otosepalum* is *Goodyera rubicunda*. It has been reported from north eastern India, South West China, Vietnam, Taiwan, Japan, the Philippines, Malaysia, Indonesian New Guinea, north eastern Australia, Solomon Islands, Vanuatu, Fiji, Samoa, Tonga, and Tahiti (Blume 1825, 1858; Thwaites 1858; Ridley 1886; Hooker 1894; Schlechter 1906; Ohwi 1937; Seidenfaden and Smitinand 1959; Garay and Sweet 1974; Hallé 1977; Kores 1989; Lewis and Cribb 1989, 1991; Comber 1990; Dockrill 1992; Seidenfaden and Wood 1992; Cribb and Whistler 1996). It is also expected that its distribution may extend into Bhutan, Thailand, Laos, and Cambodia (Pearce and Cribb 2002; Schuiteman and de Vogel 2000).

The primary aim of the present study is to clarify the patterns of variation found within *G. rubicunda* as interpreted in the broad sense. Taxonomic descriptions for all three varieties of the *G. rubicunda* complex are provided along with a key to aid identification. Here, we also attempted to resolve problems regarding typification, and propose recognition of a new variety for *G. rubicunda* based on the overall labellum structure and the shape of the base of the labellum.

Materials and methods

Herbarium specimens of the *Goodyera rubicunda-grandis* complex were borrowed from A, BISH, BM, BO, BRI, CANB, E, K, KYO, L, LAE, NSW, NY, P, QRS, and US. Examination of about 100 herbarium specimens showed considerable variation of form.

Dried herbarium specimens were examined and vegetative and floral characters measured and recorded. Specimens with similar morphology were grouped with the relevant type specimen for assignment of the appropriate variety. In cases where the number of type specimens was greater than one, one name was accepted as having nomenclatural priority and the others as synonyms. To decide which nomenclatural rank was to be assigned, information on how much morphological variation existing within a group was recorded along with details on geographic distribution (Table 1).

Results

Several characters vary within and between groups in the *Goodyera rubicunda* complex, however only three identified groups could be recognised based on several floral characteristics (Table 1; Figs 1, 3-5). Geographic distribution of the three designated groupings was examined to determine the taxonomic status of the groups (Table 1; Fig. 2). Taxa are recognised at variety rank because we regarded the morphological variation between them as minor, with two of the varieties found to be broadly sympatric in the Milne Bay Province of Papua New Guinea. We observed no significant between-group variation in general habit.

Table 1. Morphological and geographic characters used to differentiate three varieties in the *Goodyera rubicunda* complex.

Characters	*G. rubicunda* var. *rubicunda*	*G. rubicunda* var. *triandra*	*G. rubicunda* var. *australis*
Labellum shape	ovate to oblong	ovate	triangular
Shape of labellum base	obtuse	obtuse	cordate
Rostellum	well developed	well developed	not developed
Number of anthers	one	three	one
Labellum apex	recurved to revolute	recurved to revolute	recurved
Geographic distribution	Indonesia (Sumatra, Java, Borneo, Sulawesi), Pacific Islands region (Tahiti), Malaysia, India, Philippines, New Guinea, Taiwan, Japan	Pacific Islands region, as far East as Fiji, Samoa	Australia, Papua New Guinea

Taxonomic History

Several names are available for taxa in the *Goodyera rubicunda-grandis* complex: *G. rubicunda* (Blume) Lindl., *G. yaeyamae* Ohwi, *G. hispidula* R.S.Rogers & C.T.White, *G. papuana* Ridl., *G. celebica* Blume, *G. rubens* Blume, *G. triandra* Schltr., and *G. grandis* King & Pantl. Types of *Goodyera grandis* (Blume) Lindl. ex. Dietr., *G. celebica* Blume, *G. rubens* Blume were loaned from (L). Those of *G. papuana* Ridl. and *G. grandis* King & Pantl. (BM), *G. triandra* Schltr. (K, AMES), *G. hispidula* R.S.Rogers & C.T.White (BRI), *G. rubicunda* (Blume) Lindl. (P), *G. yaeyamae* (KYO), and *G. anomala* Schltr. (W).

Neottia rubicunda was described by Blume (1825) based on specimens from Mount Salak and Mount Gede, however a type specimen could not be located during this study. Blume's specimens usually lack precise location and collection date details which caused some uncertainty regarding their exact status. Simultaneously, another name *Neottia grandis* was proposed by Blume (1825), with Smith (1905) subsequently determining that the two are conspecific, choosing the name *Goodyera rubicunda*.

Another entity, *Goodyera grandis* King & Pantl. was described from Sikkim, India by King and Pantling (1898). However, these authors overlooked the fact that this name was already in use by David Dietrich after he transferred *Neottia grandis* to *Goodyera* in his treatment (Dietrich 1852). Later, Pearce and Cribb (2001, 2002) noticed what they considered to be significant differences between *G. rubicunda* and *G. grandis*, renaming the latter *G. clavata*. Ormerod (2003) initially accepted *G. clavata* as distinct, based on the raised ventral callosity on the column. However, reexamination of other materials from Java, Sumatra, Borneo, the Philippines, and elsewhere convinced him that the thickening of the ventral callosity was variable across the material examined. This led to the conclusion that *G. clavata* was conspecific with *G. rubicunda* (Ormerod 2004). Garay and Sweet (1974) reduced *G. grandis* King & Pantl. to *G. rubicunda*, and the current study supports this placement. *Goodyera rubicunda* specimens from Sikkim appear to be geographically isolated, but Ormerod (2004) suggested that there are scattered records of the species from the Naga Hills (near the Myanmar border) in North East India, Yunnan Province in South West China, and Vietnam (specimens not examined).

Reichenbach (1857a) transferred *Neottia rubicunda* Blume to *Georchis rubicunda*, and at the same time described *Goodyera zollingeri* as a new species. However, based on our observations *G. zollingeri* and *G. rubicunda* appear to be conspecific (Reichenbach 1857b). Unfortunately, the type specimen of *G. zollingeri* could not be located, although its description indicates it is likely a synonym of *G. rubicunda* (LSJ pers. observation).

Blume (1858) described two more supposedly similar *Goodyera* species, *G. celebica* from Celebes (Sulawesi) and *G. taitensis*. The geographic origin of Blume's specimen of *G. taitensis* is unclear. Based on the voyage of Hombron 1837-1840 (Van Steenis 1950), there is no evidence that Hombron had ever collected in the Pacific Islands region. It is possible that the specimen was collected in Ambon, Maluku province, or somewhere where Hombron collected other specimens during the expedition. Both these specimens fit descriptions of material of var. *rubicunda* as circumscribed in the current study, but not with our var. *triandra* from the Pacific Islands.

Goodyera papuana was described by Ridley in 1886 from a collection from British New Guinea. The description of the type specimen (*Forbes 64*), fits the description of var. *rubicunda* (current study).

Rogers and White (1920) described *G. hispidula* using material from Papua New Guinea collected by C.T. White, but the isotype (deposited at BRI) confirmed its synonymy with *G. rubicunda*.

Finally, *G. yaeyamae* was described from Ryuku Islands by Ohwi in 1937. Although his specimen has a longer, spur-like labellum base than most other members, it fits within our circumscription of var. *rubicunda*.

The *Goodyera anomala* type is sterile so we were unable to examine floral morphology, however specimens of *G. triandra* are comparable to the description of *G. anomala* in most other respects. Type specimens of *G. triandra* were collected from the Pacific Islands, but the flowers and whole plants of *G. triandra* are smaller than those of *G. anomala*. Differences between *Goodyera rubicunda* and *G. triandra* include the number of anthers, and for this reason *G. triandra* is treated below the species level as *G. rubicunda* var. *triandra*.

In summary, after examination of available operational taxonomic units it is clear that the names in question should not be maintained at the species level. *Goodyera rubicunda* is the oldest legitimate name for the group, and comparison of floral parts among the available type specimens shows that specimens from Australia and Papua New Guinea represent an unnamed taxon and require description. This taxon has a triangular labellum, cordate labellum base, and an undeveloped rostellum, with these characters not occurring in the other groups. Based on these characters we here propose the new variety *Goodyera rubicunda* var. *australis*.

Nomenclature

Goodyera R.Br. in W. Aiton & W.T. Aiton, Hortus Kewensis (ed. 2) 5: 197 (1813).

Lectotype: *Goodyera repens* (L.) R.Br. *Satyrium repens* L. Species Plantarum (1753); N.L. Britton & A. Brown, An Illustrated Flora of the Northern United States and Canada (ed. 2) 1: 569 (7 Jun 1913).

Description of *Goodyera rubicunda* Lindl.

Herb, terrestrial, 20.5–42.7–(54) cm tall; *rhizome* decumbent, rooted at nodes; *stem* ascending, leafy in the proximal half, racemose above. *Leaves* with petiole and sheath, spreading; blade obliquely ovate-elliptic, 5.8–37.0 cm × 3.4–6.3 cm, apex acute or sub-acuminate; petiole 2.4–9.3 cm long. *Inflorescence* terminal, sub-densely many-flowered, 8.0–23.0 cm long; peduncle 9.0–29.5 cm long with 2–3 remote sterile bracts. *Flowers* opening widely, brownish to whitish; *pedicel* with sessile ovary, 0.5–1.2 cm long; *floral bract* linear-lanceolate, 11–20 mm × 2–4.25 mm. *Sepals* hairy; lateral sepals spreading, cucullate, narrowly ovate or ovate-lanceolate, somewhat oblique, 5.5–10.3 mm long 1.8–4 mm wide, acute; dorsal sepal ovate-lanceolate, up to 5.8–9.3 mm long and (1.5)–1.8-3.3–(4) mm wide. *Petals* obliquely rhombic to narrowly spatulate, (4)–6–10.5 mm long, (0.9)–1–2.7 mm wide.

1. *Goodyera rubicunda* Lindl. var. *rubicunda*

Goodyera rubicunda (Blume) Lindl., Edwards's Botanical Register 25: Misc. 61 (1839).

Basionym: *Neottia rubicunda* Blume, Bijdragen tot de Flora van Nederlandsch Indië 8: 108 (1825).

Synonyms: *Georchis rubicunda* (Blume) Rchb. f., Bonplandia 5: 35 (1857a); *Rhamphidia rubicunda* (Blume) F. Müll,. Fragment, 7: 30 (1869), [non (Rchb.f.) Rchb.f.) 1868]; *Orchiodes rubicundum* (Blume) Kuntze, Revision Generum Plantarum 2: 675 (1891); *Epipactis rubicunda* (Blume) A.A. Eaton, Proceeding of the Biological Society of Washington 21: 64 (1908). *Goodyera rubens* Blume, Collection des Orchidees les Plus Remarquable de l'Archipel Indien et du Japon nov. ser. 36, t. 9d, f. 1 (1858), *nom. illeg.* Type: Java, Mt. Salak and Mt. Gede, *Blume s.n.* (holotype: L!, isotypes: K not seen, P!).

Neottia grandis Blume, Bijdragen tot de flora van Nederlandsch Indië 8: 107 (1825); *Goodyera grandis* (Blume) Lindl. ex D. Dietrich, Synopsis Plantarum 5: 165, (1852); *Orchiodes grande* (Blume) Kuntze, Revision Generum Plantarum 2: 675 (1891). Type: Java, *Blume s.n.* (holotype: L!).

Goodyera zollingeri Rchb. f., Bonplandia 5: 36 (1857b) *syn. nov.* Type: Java, Bandong. *Zollinger 196* (holotype: not found).

Goodyera celebica Blume, Collection des orchidees les plus remarquable de l'Archipel Indien et du Japon 43 (1858). *Orchiodes celebicum* (Blume) Kuntze, Revision Generum Plantarum 2: 675 (1891). *Goodyera rubicunda* var. *celebica* (Blume) Schltr., Repertorium Specierum Novarum Regni Vegetabilis 10: 9 (1911a). Type: In sylvis circa Tondano insulae Celebes, *Forsten s.n.* (holotype: L!).

Goodyera taitensis Blume, Collection des orchidees les plus remarquable de l'Archipe Indien et du Japon 44 (1858). Type: Tahiti, *Hombron s.n.* (holotype: L!).

Goodyera papuana Ridl., J. Bot. 24: 355 (1886). *Epipactis papuana* (Ridl.) A.A. Eaton, Proceedings of the Biological Society of Washington 21: 65 (1908). Type: New Guinea, *Forbes 64* (holotype: not seen).

Goodyera rubicunda var. *amboinensis* J.J.Sm., Philippine Journal of Science, C. Bot. 12: 254, 1917. Type: Indonesia, Maluku, Ambon, Mahija, 1913, *Robinson 1615* (holotype: L!).

Goodyera grandis King & Pantl., Annals of the Royal Botanic Garden Calcutta 8: 284, plate 379 (1898), nom. illeg., non (Blume) Lindl. ex D. Dietr. (1852); *Epipactis grandis* (King & Pantl.) A.A. Eaton, Proceedings of the Biological Society of Washington 21: 64 (1908); *Goodyera clavata* N.Pearce & P.J.Cribb Edinburgh Journal of Botany 58, 1: 116, 2001. Type: India, Sikkim, at Rumtek in the valley of the Teesta, at an elevation of 4,000 feet, 1898, *Pantling 460* (holotype: CAL!, isotypes BM!, K!).

Goodyera hispidula R.S.Rogers & C.T.White, Transactions and Proceedings of the Royal Society of South Australia 44: 112-4, t. 6 (1920). Type: New Guinea, Dilava, *White 603*, Jul-Aug 1918 (holotype: AD n.v., isotype: BRI!).

Goodyera yaeyamae Ohwi, Journal Japanese Botany 13:439 (1937). Type: Japan, Ryukyu Islands, Yonakuni, *G. Koidzumi* (holotype: KYO!).

Goodyera rubicunda (Blume) Lindl. ex D. Dietr. var. *amboinensis* J.J. Sm. Philippine Journal of Science (1917). Type: Maluku, Ambon, Mahija, *Robinson 1615* (holotype: L, not seen).

Description: *Labellum* ovate to oblong, 3–7 mm long; base obtuse, rarely spur like, spur sometimes not present, if present up to 0.7 mm long from the back of the saccate labellum at the attachment to the pedicel to the lowest base of the spur; apex more or less recurved and revolute, triangular to linear and oblong; disc hairy inside. *Column* clavate, 4–7.5 mm long, 1–2 mm wide. *Rostellum* bifid. *Anther* 1, attached at its base to the apex of the column. **Fig. 1.**

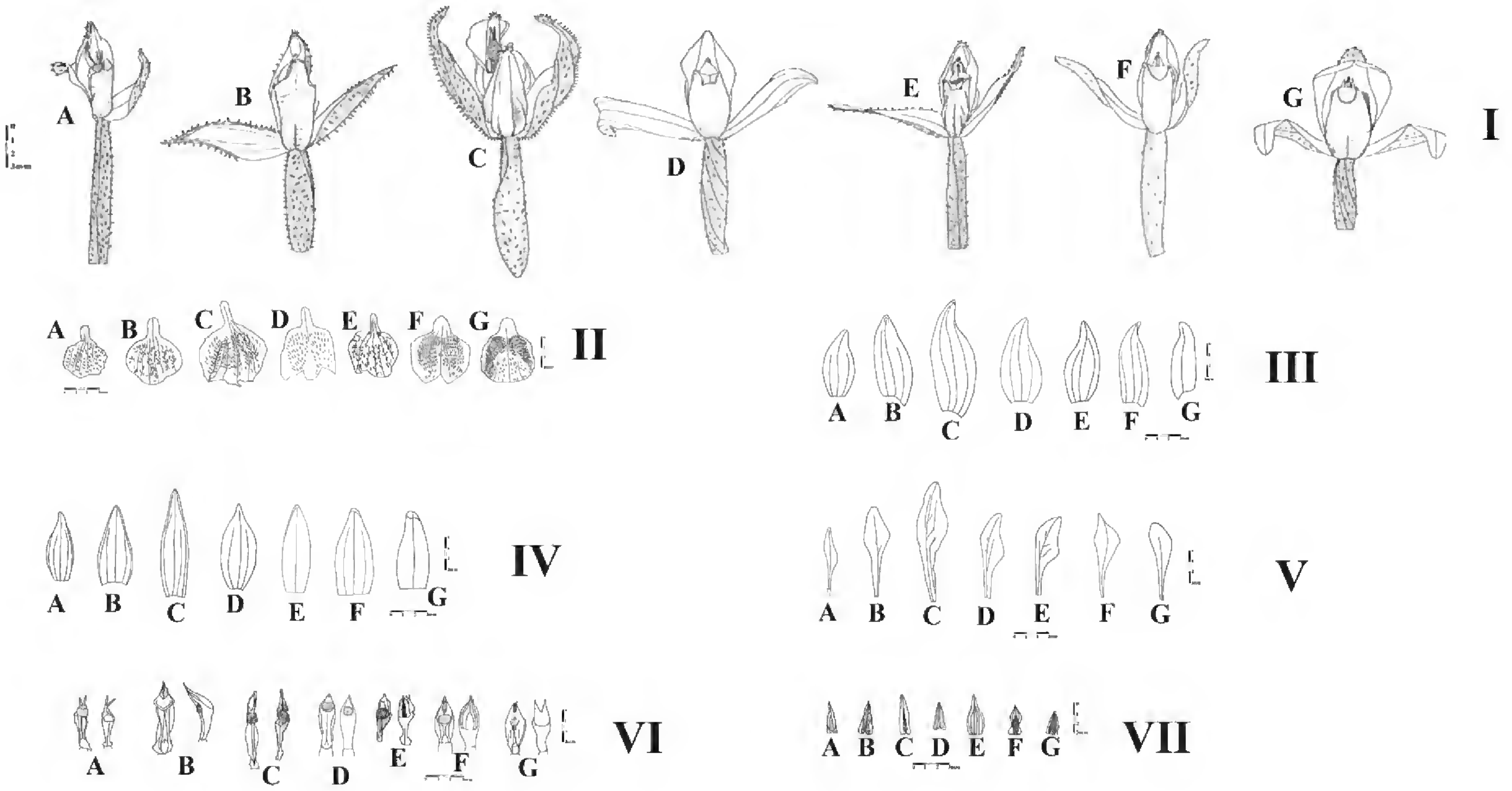

Fig. 1. *Goodyera rubicunda* var. *rubicunda*: **I,** Flower, frontal view; **II,** labellum; **III,** lateral sepal; **IV,** dorsal sepal; **V,** petal; **VI**, column; **VII**, anther cap. Specimens used: **A**, Blume sn, dried specimen (L0061296); **B**, *Blume sn*, dried specimen (L0061167); **C,** *Clements J & MS 26997 (=26832)*, dried specimen; **D**, *Clements MA 6354c*, living plant; **E**, *Blume sn*, dried specimen (L0061295); **F**, *Samsul & Entim 86*, spirit preserved; **G**, *Forbes FR 38078*, dried specimen. Scale bars shown. Illustration: L.S. Juswara.

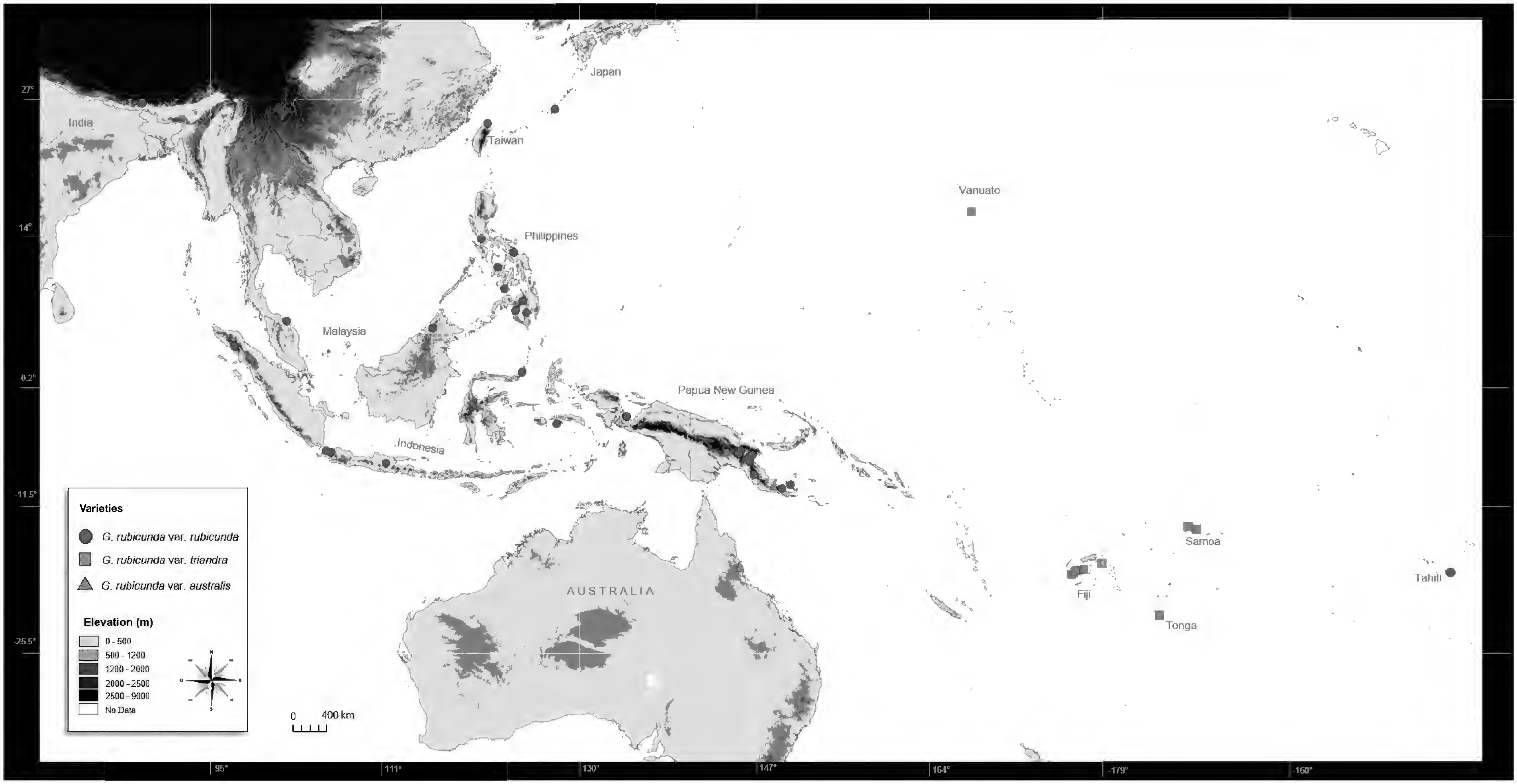

Fig. 2. Distribution of the three varieties of *Goodyera rubicunda*. Key to varieties shown on map.

Additional specimens examined: INDONESIA: West Papua Province: Division Geelvinkbay, Wandamen Peninsula, Mt. Wondiwoi, *Schram 10745*, 28 Feb 1962 (L, LAE). West Java: Karang Gelekung, *Blume 45* (L). Sumatra: W. Helling Talomun elevation 700 m, *Bunnemeijer 463*, 27 Apr 1917 (BO, L); Central Aceh: *Samsul & Entim 86* (CANB). MALAYSIA: North Borneo: Near Dalas, *Carr 3757*, Aug 1933 (K); Kinabalu: Dallas, *Clemens 26896*, Nov 1931 (BO, BM, E, K, L, NY); Sabah: Keningau, Near Laing Cave Apin-Apin, elevation 700 m, *Lajangah 44565*, 4 Aug 1965 (K); Keningau, Interior zone, *Lamb & Lohok 1158/89*, Aug 1989 (K); Pun Batu Interior zone, elevation 600 m, *Vermeulen 448*, Sep 1986 (L); Bukit Maripit, elevation 600 m, *Winkler 111028*, Dec 1924 (E). PAPUA NEW GUINEA: Central PNG: Dilava, *White 603*, Jul-Aug 1918 (BRI); East Papua: Milne Bay District, c. 8 miles W of Rabaraba, *Pullen 7724*, 5 Jul 1969 (CANB, LAE); Milne Bay Province, Agamoia, Fergusson Isl., *Brass 27250*, 20 Jun 1956 (L); Eastern Highlands district: Kassam Pass, Kainantu Subdistrict, *Dockrill & Coode 34167*, 12 Jan 1968 (LAE); Ilafo: about 2 miles SE of Okapa, *Brass 31784*, 28 Sep 1959 (L, LAE, NY, US); Kaiser Wilhelmsland In den Waldern am Kaulo, *Schlechter 16873*, Sep 1904 (L, NSW); Morobe District, Wau Sub district, Kauli Creek Waterfall, *Womersley & A. Dockrill 24977*, 3 Jun 1967 (LAE); Schumann River, 300 m, *Schlechter 13844*, Jan 1902 (AMES, BRI); Morobe District, Bulolo to Wau road, *Woods 104*, 13 Oct 1962 (E); Morobe District, Trans-Busu Timber Lease near LAE, *Floyd 5743*, 17 Jun 1954 (BRI, LAE). PHILLIPPINES: Babuyanes: Camiguin Is., Mt. Malabsing, *Edano 79590*, Mar 1930 (AMES). Luzon: Province Sorsogon, Irozin, Mt. Bulusan, *Elmer 14867*, Nov 1915 (AMES, BM, L, NSW, NY); Tagaytay, *R.S. Davis 49-12*. Jamindan: Capiz Province, Panay, *Ramos & Edano 31096*, Apr-May 1918 (AMES). Mindanao: Cottabato Umbungan, *Weber 201*, (AMES); District of Davao: Todaya, Mt. Apo, *Elmer 11150*, Jul 1909 (AMES, NY); Bukidnon: Mt. Katanglad-S slope of middle peak, upper source of Alanib R. Vicinity of Bo Songes, *Sulit 10207*, 16 Apr 1949 (AMES). Negros Is.: Province of East Negros, Dumaguete, Cuernos Mt., *Elmer 10173*, May 1908 (AMES, NY). TAIWAN: Taipei Country: forest on steep slope near Cascade, *Van Steenis 20589*, - (L).

Habitat and Ecology: Stony, limestone soil near river banks within rain-forests.

Distribution: India, Indonesia (Sumatra, Java, Borneo, and Celebes), Malaysia, Papua New Guinea, Philippines, Taiwan, Japan, and Pacific Islands (e.g., Tahiti) (Fig. 2).

Notes: This variety is variable in the shape of the labellum and labellum apex and for this reason there remains some doubt as to whether it is a single entity. Further research is needed on living and pickled specimens from Indonesia, Papua New Guinea, Philippines, Malaysia, India, Taiwan, and Japan.

2. *Goodyera rubicunda* var. *triandra* (Schltr.) N. Hallé.

Goodyera rubicunda var. *triandra* (Schltr.) N. Hallé. Flore de la Nouvelle Caledonie. Depend. 8: 532, 1977.

Basionym: *Goodyera triandra* Schltr., Bulletin De l'Herbier Boissier Ser. II, 6: 298 (1906); *Epipactis triandra* (Schltr.) A.A. Eaton, Proceeding of the Biological Society of Washington 21: 66 (1908).

Type: New Hebrides: Efate: near Mt. MacDonald, *Morrison s.n.*, 18 Aug 1896 (Holotype: B†, isotype: AMES!, K!).

Synonym: *Goodyera anomala* Schltr., Repertorium Specierum Novarum Regni Vegetabilis 9:86 (1910). Type: Savai'i, Samoa: *Vaupel 405* (*syn* B†). Samoa: Sassina, 1905, *K. & L. Rechinger 96* (isosyntype: W!).

Description: *Labellum* ovate, to 2.5–4.5 mm long; base obtuse, mentum not visible; apex linear recurved to revolute; disc hairy inside. *Column* clavate, up to 3.5–5.5 mm long, 1.5–2.5 mm wide. *Rostellum* bifid. Anthers 3; the median anther attached at its base to the apex of the column; lateral anthers attached at their bases on the distal half of the column. **Fig. 3.**

Additional specimens examined: SAMOA: Upolu: Lanutoa, Raunyebit, Erolbevoduer, *Rechinger 2506*, 1-11 Aug 1905 (BM). Savaii: locally abundant in lower rain forest: Ssalailua, *Bryan 162*, 19 May 1924 (NY). TONGA: Eua Islands: in forest near Mt. Esi-o-Moheofo, E of Pangai village, *Hotta 5272*, 3 Sep 1960 (KYO). NEW CALEDONIA: Kone: Mt. Tanji (Pente Sud), *Mackee 196*, 30 Jul 1976 (K). VANUATU: New Hebrides, *Morrison*, 20 Aug 1896 (K). FIJI: Ovalau: Slope of Mt. Korotolutolu, W of Thawathi, *Smith 8004*, 11 Jul 1953 (AMES, L, NY). Taveuni: Slope of Mt. Manuka, E of Wairiki, *Smith 8130*, - (AMES, L, NY). Southern portion of Seatovo Range, *Smith 1576*, 20 Apr-2 May 1934 (NY). Viti Levu: Tholo West, Vicinity of Mbelo, near Vatukarasa, *Degener 15253*, 8-24 May 1941 (AMES); Mba, Slope of Mt. Nairosa, E flank of Mt. Evans Ranges, *Smith 4015*, 26 Apr-14 May 1947 (AMES); Nandronga & Navosa: North portion of Rairaimatuku Plateau, between Nandrau and Rewasau, *Smith 5623*, 31 Jul -11 Aug 1947 (AMES, BRI).

Habitat and Ecology: Dense rainforest, lowland forest.

Distribution: Pacific Islands: Vanuatu, New Caledonia, Tonga, Samoa and Fiji (Fig. 2).

Notes: This variety is confined to the Pacific Islands. It differs from the other varieties in having three anthers attached inside the bifid rostellum.

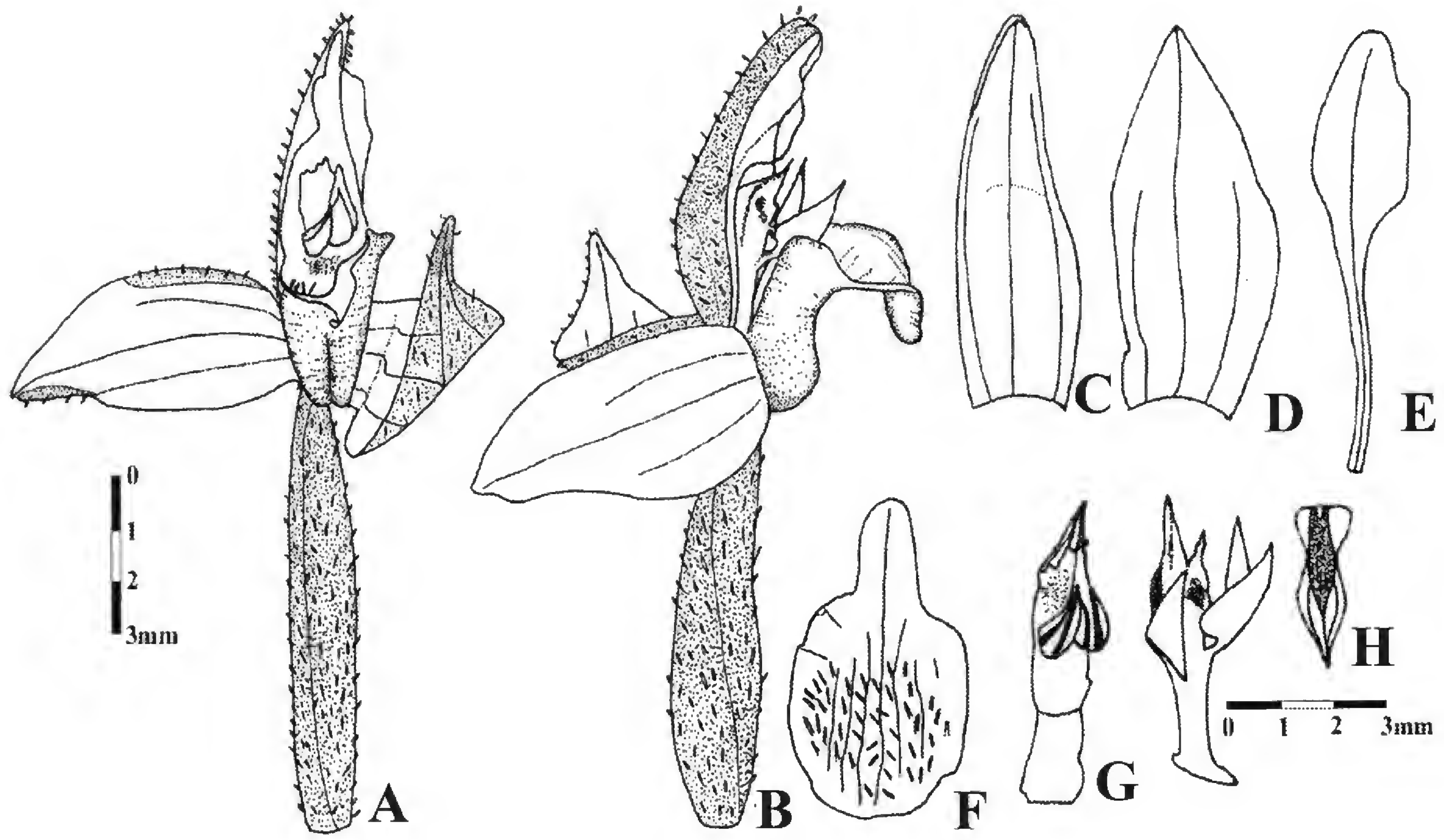

Fig. 3. *Goodyera rubicunda* var. *triandra*: **A**, flower, front view; **B**, flower, side view; **C**, dorsal sepal; **D**, lateral sepal **E**, petal; **F**, labellum; **G**, column; **H**, anther cap. Scale bars shown. Illustration: L.S. Juswara, from *Morrison sn*, dried specimen (HUH 00070595).

3. *Goodyera rubicunda* var. *australis* Juswara var. nov.

Type: Australia: Queensland, Cook District, Wallicher Falls track, Palmerston National Park, *Jones 4150 & Clements*, 20 May 1989 (holotype CANB!).

Synonyms: *Goodyera rubicunda* auct. non (Blume) Lindl.; Dockrill, Australian Indigenous Orchids 1: 100-101, f. (1969).

Goodyera grandis auct non (Blume) Lindl. ex D.Dietr.: Dockrill, Australian Indigenous Orchids 1: 30-32, f. (1969).

Description: *Labellum* triangular, 5 mm long; base cordate, mentum not visible; apex linear, more or less recurved; disc hairy inside. *Column* clavate, up to 3 mm long, 0.6–1 mm wide. *Rostellum* absent. *Anther* 1, attached at its base to the apex of the column. **Figs 4, 5.**

Additional specimen examined: PAPUA NEW GUINEA: East Papua: Milne Bay Province, 15 km WNW of Biniguni airstrip, East of Mount Suckling, Mayu River, *R. Pullen 8367*, 27 Jun 1972 (CANB).

Habitat and Ecology: Rain forest near rivers on stony terraces, in red clay loam.

Distribution: Australia and Papua New Guinea (Fig. 2).

Notes: In *Goodyera rubicunda* var. *australis*, the rostellum is absent. This variety also differs from the others in having a triangular labellum with cordate base and more or less recurved linear labellum apex. *Goodyera ochroleuca* (FM Bailey) M.A.Clem & D.L.Jones (2004) was claimed to be the same as var. *australis*. However, in *G. ochroleuca* a rostellum is present thus the two are not conspecific.

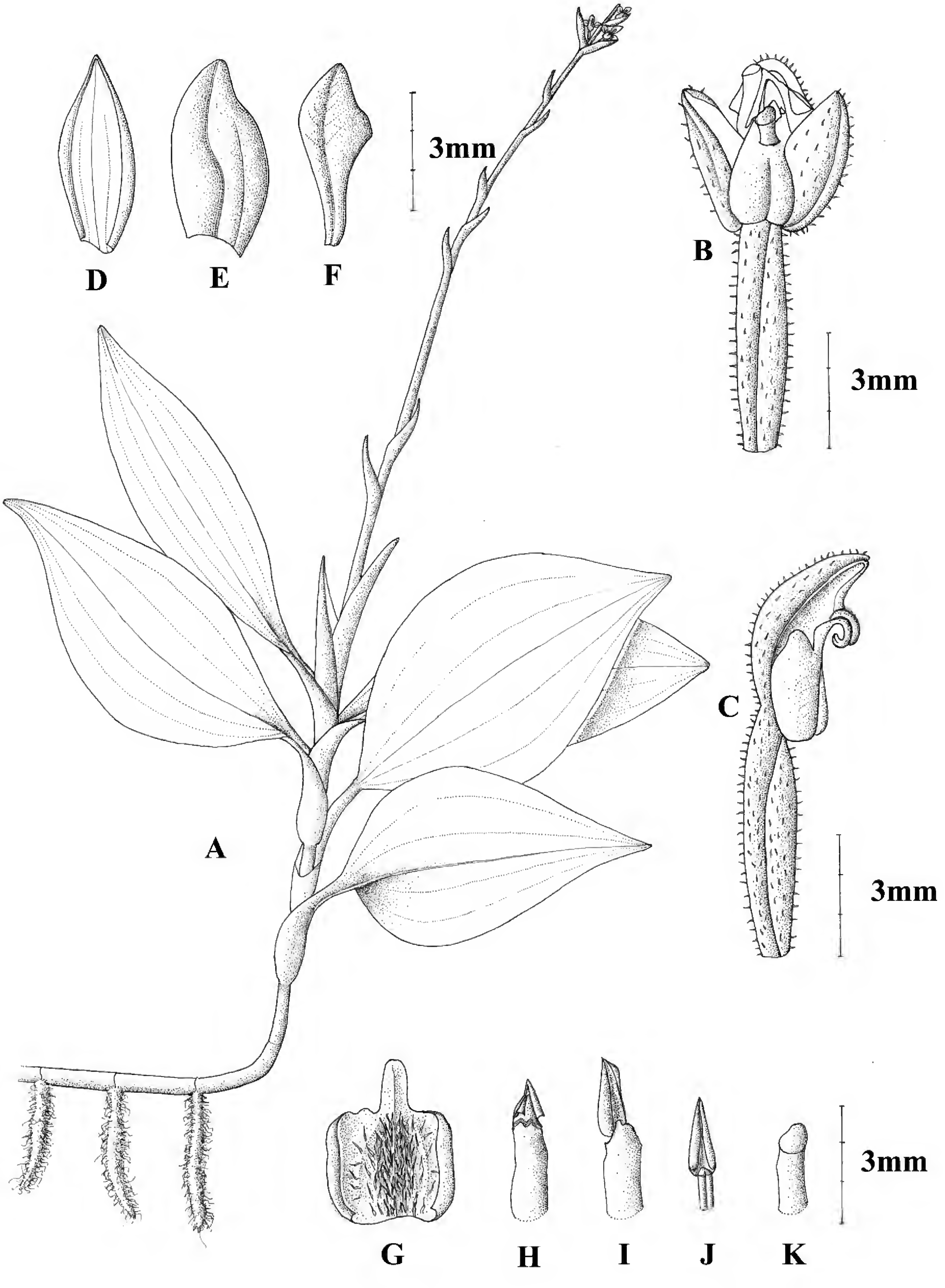

Fig. 4. *Goodyera rubicunda* var. *australis*: **A,** habit; **B,** front side of the flower; **C,** front side of the flower; **D,** dorsal sepal; **E,** lateral sepal; **F,** dorsal petal; **G,** labellum; **H-I,** column with the anther cap (note lack of rostellum); **J,** anther cap; **K,** column. Scale bars shown. Illustration: Anne Kusumawaty, based on sketches by L.S. Juswara from *Jones 4150* (dried specimen).

Fig. 5. *Goodyera rubicunda* var. *australis*, mid-region of inflorescences. Refer to description for scale. Image: M.A. Clements.

Key to the varieties of *Goodyera rubicunda*

1a. Anthers 3; anther cap attachment on clinandrium with distinct dorsal filament and the rostellum well developed extending from the stigma; Pacific Islands .... ***G. rubicunda* var. *triandra***

1b. Anther 1 .... **2**

2a. Labellum triangular, base cordate, apex ± recurved; anther cap attached on clinandrium by a dorsal filament without a well-developed rostellum; Australia and PNG.................. ***G. rubicunda* var. *australis***

2b. Labellum ovate to oblong, base is ± obtuse; the anther cap attached on clinandrium without a distinct filament and with a well-developed rostellum, extending from the stigma; Indonesia (Sumatra, Java, Borneo, Sulawesi), Malaysia, India, Philippines, New Guinea, Pacific Islands, Taiwan, and Japan .... ***G. rubicunda* var. *rubicunda***

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Paraboea yunfuensis: a new calcicolous species of Gesneriaceae from Yunfu, Guangdong Province, China

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Abstract

Paraboea yunfuensis F. Wen & Y.G. Wei (Gesneriaceae) is described as a new species endemic to the Guangdong Province, China. This species is one of two peltate-leaved *Paraboea* species in China. It is distinguished from the similar-looking *P. peltifolia* by the presence of longer pedicel and filaments, shorter staminodes, linear-lanceolate calyx lobes, and an indumentum on peduncles, pedicels, and calyx lobes. A detailed description, photographs of a specimen from the type location, and a table of comparative characters are provided.

Introduction

Paraboea (Clarke) Ridley (Gesneriaceae) is one of the largest genera of the Old world Gesneriaceae (Weber 2004). All species in this morphologically diverse genus are herbs, with wide variation in habit, floral indumentum, inflorescence form, and seed capsule shape (Xu and Burtt 1991; Xu et al. 2008). The genus, originally described as a section of *Didymocarpus* (section *Paraboea* Clarke: Clarke 1883), was subsequently upgraded to the generic level by Ridley (1905). Since then, the name *Paraboea* has been maintained despite significant taxonomic changes in the Gesneriaceae over the last decade, where monotypic *Phylloboea* Benth. and *Trisepalum* C.B.Clarke have been synonymized within *Paraboea* (Puglisi et al. 2011; Middleton et al. 2010).

Paraboea includes at least 130 species distributed from South to Southwest China, Indo-China Peninsula to Malaysia, Indonesia, and the Philippines (Burtt 1948, 1984; Xu and Burtt 1991; Xu et al. 2008, 2012; Chen et al. 2008, 2012; Kiew 2010; Puglisi et al. 2011; Triboun and Middleton 2012; Triboun 2013; Xu et al. 2012). Several species of *Paraboea* have recently been described from South and Southwest China, namely *P. trisepala* W.H. Chen & Y.M. Shui, *P. hekouensis* Y.M. Shui & W.H. Chen, *P. manhaoensis* Y.M. Shui & W.H. Chen, *P. angustifolia* Yan Liu & W.B. Xu and *P. tetrabracteata* F.Wen, Xin Hong & Y.G.Wei (Chen et al. 2008, 2012; Xu et al. 2012; Wen et al. 2013). This region includes the Guangdong province, a global plant diversity hotspot, whose karst formations contribute to 3.5% (6, 208 km^2) of its total area (Davis et al. 1995). The high solubility of limestone combined with variable temperatures (6–39 °C) and precipitation (1350–1920 mm per annum) of the region influence its highly variable geomorphology (Cen et al. 1990). This, combined with a high level of edaphic variability, appears to be associated with its correspondingly high levels of biodiversity and endemism (Tao et al. 2015; Clements et al. 2006; Li and Wang 2012).

An area with particularly high biodiversity within Guangdong, Yunfu city, harbours 130 plant families, consisting of 373 genera and >600 species (Wang 2015). In an effort to improve our floristic understanding of the region, a botanical survey was conducted in Aug 2014. During the survey, a specimen of an undescribed *Paraboea* species was discovered and collected from a single population on a limestone cliff. Using this specimen, we here provide a description and images of the new species *P. yunfuensis*.

Taxonomic Treatment

Paraboea yunfuensis F. Wen & Y.G. Wei ***sp. nov.***

Diagnosis: *Paraboea yunfuensis* is morphologically most similar to *P. peltifolia* because they both have a peltate leaf base. The leaf blade apex of *P. yunfensis*, however, is acuminate to obtuse, lateral veins are 5–7 on each side of midrib (vs. 11–18), peduncle nearly glabrous but with reddish-brown matted indumentum near its base (vs. densely woolly and brownish), bracts 4.6–5.2 mm long and glabrous outside (vs. 2–3(–4) mm long and outside densely woolly and brownish), pedicel 1.2–2 cm long and glabrous (vs. c. 6 mm long and densely woolly and brownish), filaments 4–4.5 mm long (vs. c. 3 mm long), staminodes 1–1.2 mm long (vs. c. 2 mm long).

Type: China. Guangdong Province: Yunfu City, Yuncheng District, Luoshi Village, Hongyan, 22.901024 N, 112.011613 E, alt. ± 164 m, 28 Nov 2013, *Fang Wen 141128-01* (flowering) (holo: IBK, iso: ANU).

Terrestrial, rosulate, perennial herb. *Rhizomes* stout and lignified, subterete, 5–8 cm long, 5–12 mm in diameter. *Roots* slender, fibrous. *Leaves* 8–12, congested at the apex of the rhizome, with a short petiole up to 3 cm long, leaf blade 8.0–11.5 × 1.6–5.0 cm, obovate, oblanceolate to narrowly oblanceolate, spatulate, or subpandurate, chartaceous, bases attenuate but becoming peltate-auriculate, margins ± irregularly serrulate, rarely entire, fawn-coloured, matted indumentum, apices acuminate to obtuse, upper leaf surfaces covered with greyish arachnoid hairs when young and glabrescent in age, lower leaf surface indumentum matted, fawn-coloured, lateral veins 5–7 on each side of midrib, adaxially sunken and abaxially prominent. *Inflorescences* cymose, axillary, 1–3-branched, 3–12-flowered; peduncles slender, 4–7 cm long, 1–1.5 mm in diameter, reddish-brown, glabrous with indumentum matted, reddish-brown near base; bracts two, 4.6–5.2 × 0.8–0.9 mm, linear-lanceolate, margins entire, apices obtuse, with sparsely greyish matted indumentum outside, glabrous inside; pedicels 1.2–2 cm long, 0.6–0.7 mm in diameter, reddish-brown, glabrous. *Calyx* 3.2–3.7 × 0.7–0.8 mm, 5-lobed nearly to the base, lobes linear-lanceolate, greenish-brown, glabrous outside and inside, margins entire. *Corolla* 1.4–1.6 cm long, pinkish-purple to reddish-purple, outside and inside glabrous; tube 5.5–7 mm long, 4.5–5.2 mm in diameter at the mouth; the limb distinctly 2-lipped, adaxial lip 2-lobed from its base, lobes broadly ovate, 4.0–4.2 × 3.5–3.9 mm, abaxial lip 3-lobed for more than half of length, lobes broadly ovate, 4.0–4.5 × 5.0–6.0 mm. *Stamens* 2, adnate to the corolla base; filaments 4–4.5 mm long, glabrous; anthers semicircular, c. 3.0 mm long; staminodes two, glabrous, 1–1.2 mm long, adnate to the corolla tube base. *Pistil* glabrous; ovary 3.5–4.0 mm long, c. 1.5 mm in diameter at middle, style c. 4.5 mm long, stigma capitate. *Capsule* straight, glabrous, not twisted, 2.5–3.0 cm long, c. 3 mm diameter. **Fig. 1**.

Etymology: The specific epithet is derived from the type locality, Yunfu city, Guangdong, China.

Vernacular name: Yún Fú Zhū Máo Jǔ Tái (Chinese pronunciation); 云浮蛛毛苣苔 (Chinese name).

Phenology: Flowering in November; fruit develop late January and throughout February.

Ecology and habit: *Paraboea yunfuensis* grows in the Yunfu region, that has a annual average temperature of 21.5 °C, average annual rainfall of 1,600 mm, and frosts occurring 15 to 34 days per year. Plants grow in the shaded crevices of damp limestone cliffs at c. 164 m alt. Subtrate consists of terra rossa and rendzina with pH 7.0–7.5 (Cen et al. 1990). Surrounding vegetation is subtropical evergreen broad-leaved forest consisting of *Pterospermum heterophyllum* Hance, *Dalbergia benthamii* Prain, *Cratoxylum cochinchinense* (Lour.) Bl., *Glycosmis pentaphylla* (Retz.) Correa, *Toddalia asiatica* (L.) Lam., *Sageretia thea* (Osbeck) Johnst., *Alchornea trewioides* (Benth.) Muell. Arg., *Allocasia macrorrhiza* (Linn.) Schott, and *Primulina bicolor* (W.T. Wang) Mich. Möller & A. Weber (Huang 2005).

Proposed IUCN Conservation Status: A search around the type location (c. 5 km^2) revealed no other populations. The type location consists of approx. 500 mature individuals growing on a limestone hill. The population does not occur in a protected area, and future protection measures are required. The area has been relatively undisturbed due to its significance to the surrounding village, although locals continue to forage in it for firewood. Considering the small population size and fragile habitat, we propose that *Paraboea yunfuensis* requires classification as Endangered (EN C2b) under IUCN criteria (2011).

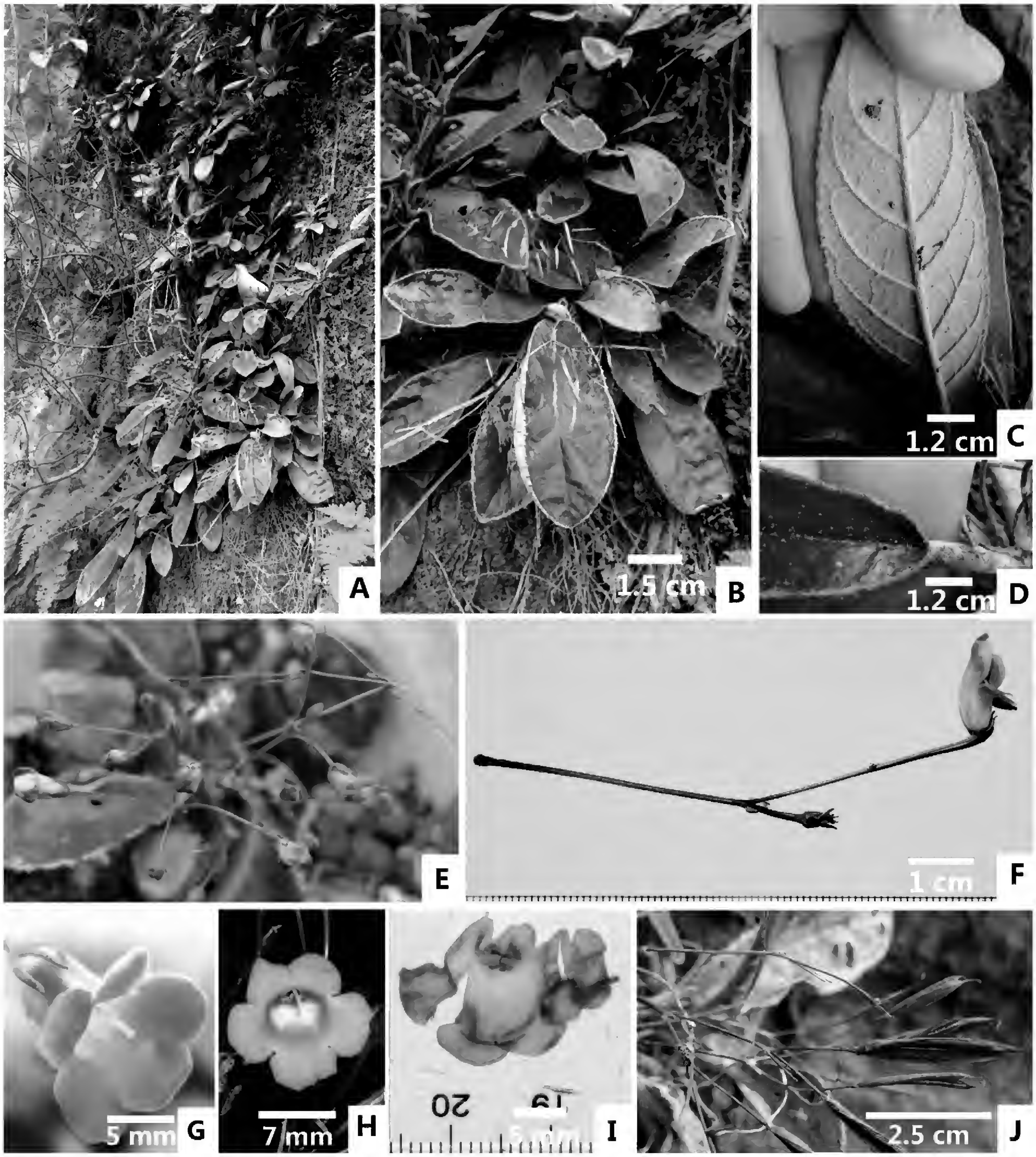

Fig. 1. *Paraboea yunfuensis* F. Wen & Y.G. Wei: **A,** habit; **B,** habit showing infructescence and adaxial view of leaves; **C,** leaf, abaxial view; **D,** peltate base of leaf lamina; **E,** inflorescence with unopened buds; **F,** inflorescence stem showing glabrous surface and flower in profile view; **G,** corolla oblique view; **H,** corolla frontal view; **I,** dissected corolla showing stamens; **J,** infructescence with dehisced capsules. Images taken at type location by F. Wen.

Notes and affinities: There are two patterns of capsule development in *Paraboea*: (1) the capsule forms a spirally twisted valve; and (2) the capsule forms a linear valve. All *Paraboea* species with non-twisted and nearly straight capsules have axillary cymes. As *Paraboea yunfuensis* possesses a linear valve and axillary cyme, it is likely that it is a member of group 2. Although *P. yunfuensis* is most similar to *P. peltifolia* from Mashan County, Guangxi Province (as described in the diagnosis), it also shares a lax cyme and numerous flowers with *P. filipes* and *P. guilinensis*. *Paraboea yunfuensis* can be distinguished from *P. filipes* by its larger vegetative size (*P. yunfuensis*: 1.4–1.6 cm long vs. *P. filipes*: c. 1 cm long) and numerous flowers (3–12-flowered vs. 1–2-flowered). *Paraboea yunfuensis* differs from *P. guilinensis* by having a rosulate growth form vs. erect stem growth habit, and possessing unequal vs. equal length calyx lobes. Diagnostic character differences between *P. paraboea* and similar species are presented in Table 1.

Table 1. Morphological comparison between *Paraboea yunfuensis, P. peltifolia, P. guilinensis* and *P. filipes*.

Characters	*P. yunfuensis*	*P. peltifolia*	*P. guilinensis*	*P. filipes*
Leaf margin	± irregularly serrulate, occasionally entire	irregularly crenate-serrate	entire to slightly denticulate, involute	nearly entire, involute
Lamina apex	acuminate to obtuse	obtuse to rounded	rounded	obtuse to rounded
Lateral veins	5–7 on each side of midrib	11–18 on each side of midrib	5–6 on each side of midrib	4–6 on each side of midrib
Peduncle	glabrous except near base with matted reddish-brown indumentum	densely woolly, brownish indumentum	glabrous	glabrescent
Bracts	4.6–5.2 mm long, glabrous outside	2–3(–4) mm long, densely brownish woolly outside	c. 0.5 mm or not present	c. 1 mm or not present
Pedicel	1.2–2 cm long	c. 6 cm long	1–2 cm long	1.5–3.5 cm long
Corolla colour	pinkish-purple to reddish-purple	white to pale pink	white to purple	purplish
Filaments	4–4.5 mm long	c. 3 mm long	4.5–5 mm long	c. 2.5 mm long
Staminodes	1–1.2 mm long	c. 2 mm long	≤1.2 mm long	c. 0.2 mm long
Anthesis	Nov	Jan–Feb	Apr	Sep–Oct

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Dendrobium armeniacum P.J.Cribb, a new record for Indonesian New Guinea

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Abstract

Dendrobium armeniacum P.J.Cribb is recorded from Papua Province, Indonesia, for the first time. A description, illustration, and images of this rarely collected species are here presented.

Introduction

After *Bulbophyllum*, *Dendrobium* is the second largest orchid genus in New Guinea, with approximately 560 known species (Schuiteman 2013). Undoubtedly, many species of *Dendrobium* still await discovery in New Guinea, particularly in the more poorly explored western part of the island, and for most species the distribution is incompletely known.

In May 2014, LSJ conducted fieldwork in two regencies in Papua Province, Lanny Jaya and Jayawijaya. One of the sites visited was the heritage tropical rainforest of the Dani people from the village of Meagama, Ilaga, Ukuloba, Hubikosi District, near Wamena, the capital city of Kabupaten Jayawijaya, in the famous Baliem valley. In this orchid-rich forest, LSJ collected a living specimen of an epiphytic *Dendrobium* species that was not seen in flower at the time. The specimen was subsequently cultivated in the Biology Botanical Garden (Kebun Raya Biologi) in Wamena, where it flowered in April 2015, producing a single stem with two inflorescences. In May 2016, the specimen re-flowered producing more than two stems with 8 to 10 flowers per inflorescence.

After examination it was determined that the specimen belonged to *Dendrobium* section *Latouria*, of which most species are endemic to New Guinea (Cribb 1982). Using the revision of this section by Cribb (1982) we initially identified the specimen as the rare *D. euryanthum* Schltr., since the callus structure seemed to match that species better than that of the similar *D. armeniacum*. According to Cribb (1982), there is a large solid callus at the base of the lip of *D. armeniacum*, whereas in our plant we find three ridges, more or less as in Schlechter's illustration of *D. euryanthum* (Schlechter, 1923–1928, t. 164, fig. 615). In addition, the length of the floral mentum, after preservation in spirit, was 8–10 mm (slightly longer when fresh), which is intermediate between *D. armeniacum* (6–7mm) and *D. euryanthum* (10–13 mm).

In other respects, however, notably the distinctly shorter lobes of the lip, and consequently the shallower sinuses between the lobes, as well as in the straight mentum and the larger maximum number of flowers, our specimen fits better the description of *D. armeniacum*. Assuming the callus structure and mentum length in this species is somewhat variable, and that *D. euryanthum* and *D. armeniacum* are indeed distinct species, we believe that our specimen is best identified as *D. armeniacum*. This species, like *D. euryanthum*, was previously known only from Papua New Guinea. Considering that in some respects our plant appears to be intermediate between the two taxa, we cannot rule out that *D. euryanthum* and *D. armeniacum* are forms of the same species, in which case the name *D. euryanthum* would have priority.

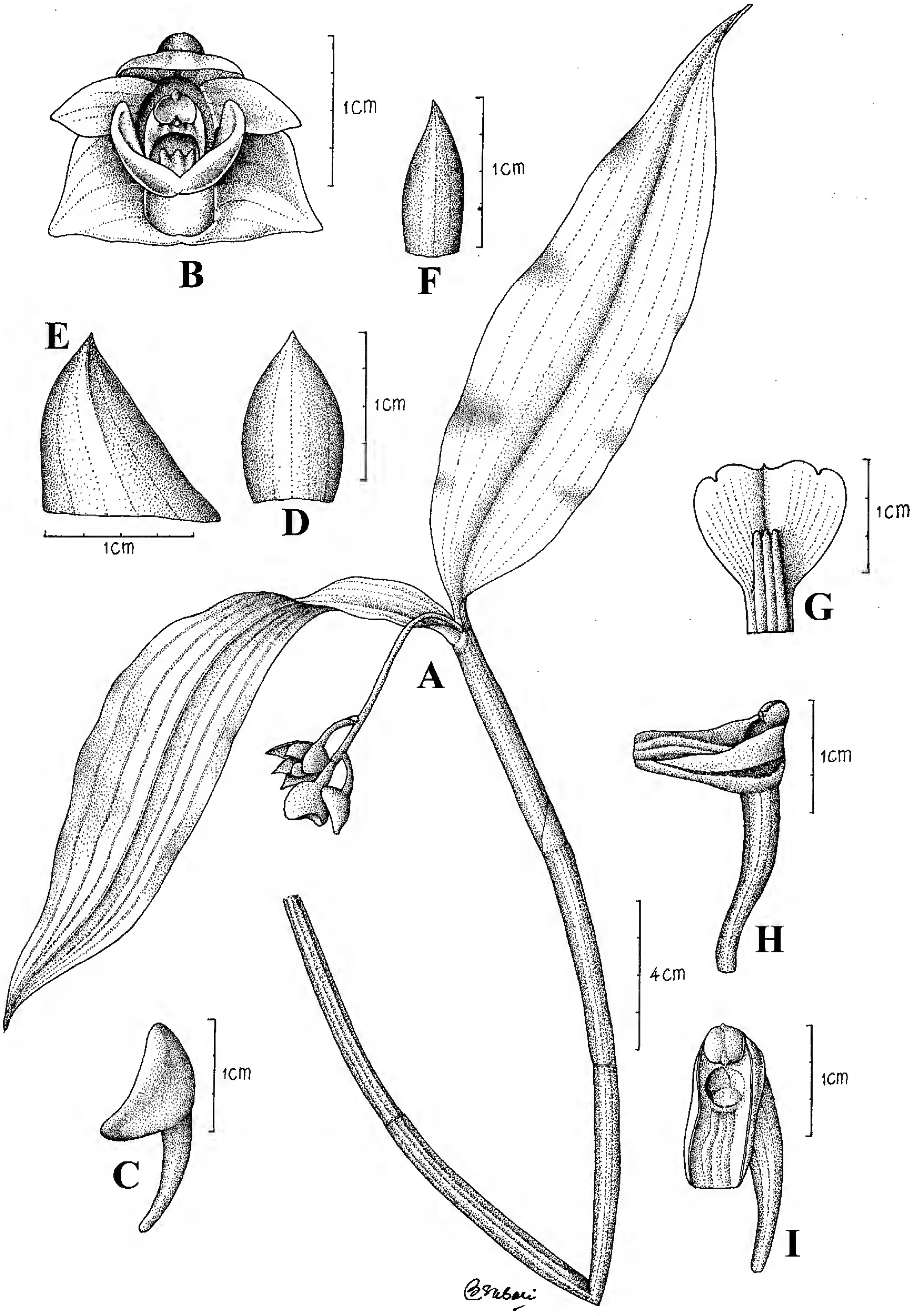

Fig. 1. *Dendrobium armeniacum* Schltr. A, habit; B, flower; C, floral bud; D dorsal sepal; E, lateral sepal; F, petal; G, lip; H, column, side view; I column, front view. Drawn by Subari from *Juswara 928*.

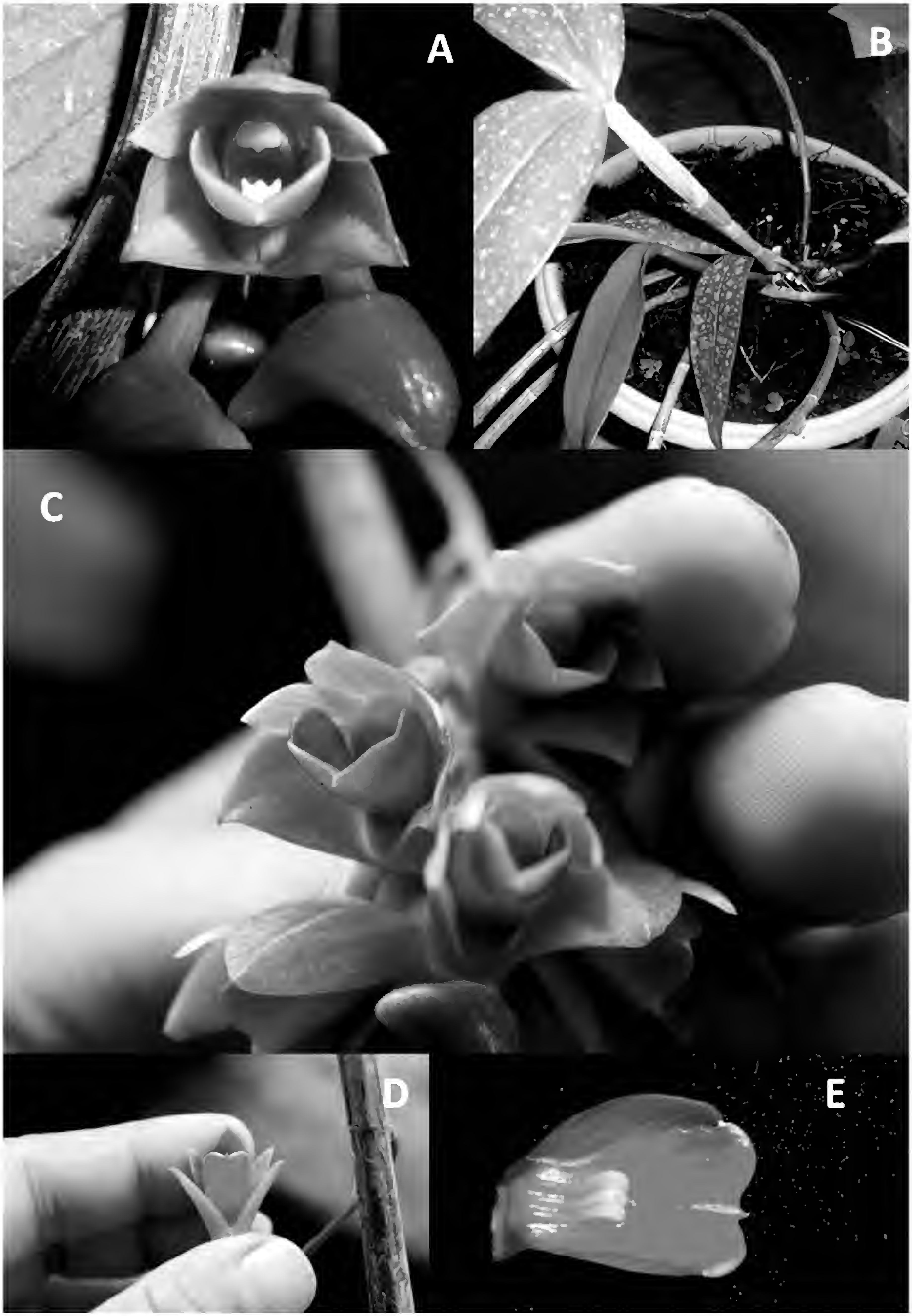

Fig. 2. *Dendrobium armeniacum* Schltr.: A, flower and buds; B, habit; C, flowers with all color variations; D, a flower showing mid-lobe of the labellum; E, labellum. For scale refer to description. Images from *Juswara 928*.

Taxonomy

Dendrobium armeniacum P.J.Cribb, *Orchadian* 6: 279, fig. 1 (1981). Type: Papua New Guinea, Enga Prov., Paiela Census Div., Lagaip Dist., Komanga, alt. 1500–1600 m, *Reeve 397A*, Oct 1979, (holotype K!; isotypes AMES, CBG, E, L, LAE).

Sayeria armeniaca (P.J.Cribb) Rauschert, in *Feddes Repert.* 94(7–8): 466 (1983).

Description: Pendent epiphytic herb. *Pseudobulbs* slender, slightly dilated above, 10–17.5 long, 0.3–0.8 cm diam., 2-leaved at apex. *Leaves* twisted at base to lie in one plane, subcoriaceous, elliptic, acuminate, up to 10 × 3–5 cm, bluish green. Inflorescence about 8 cm long, from terminal and subapical nodes of pseudobulb, 3–10-flowered; peduncle slender; peduncle-scales absent; floral bract of flaky looking scales, thin, triangular, subacute, appressed, 2–3 mm long. *Flowers* fleshy, greenish white, lip yellowish green, dull orange-brown in apical part of the mid-lobe with red-brown or purple veins. Dorsal sepal ovate, apiculate, 10–13 × 9 mm; lateral sepals obliquely triangular, subacute, 10–13 × 12–15 mm; mentum incurved-conical, 10–13 mm long. *Petals* elliptic, apiculate, 11.5 × 5.0 mm. Lip clawed, geniculate at base and slightly reflexed at apex, 3-lobed near apex, 15 × 11–13 mm when flattened; side-lobes erect-incurved, rounded in front; mid-lobe conduplicate, transversely oblong, slightly apiculate; callus 3-ridged, undulate at base (in lateral view), strongly raised at apex. *Column* 3 mm long, apex entire; foot 8–9 mm long. (Based on *Juswara 928*). **Figs 1, 2.**

Specimen examined: Indonesia, Papua Province, Jayawijaya Regency, Wamena, Hubikosi District, Ukuloba, Osinakma Forest, heritage forest of Meagama Village, 30 May 2014, flowered in cultivation Apr 2015 and May 2016 at Kebun Raya Biologi, Wamena (Z2014050030 RA), *Juswara 928* (BO, spirit material) (Fig. 3).

Habitat and ecology: Montane forest at c. 1790 m elevation, epiphyte on tree trunk, uncommon within a shady forest in a small valley, with two living specimens of *Dendrobium capituliflorum* Rolfe collected from nearby grassland. A single specimen of *D. armeniacum* was collected in May 2014, but was not seen when the site was revisited in May 2016.

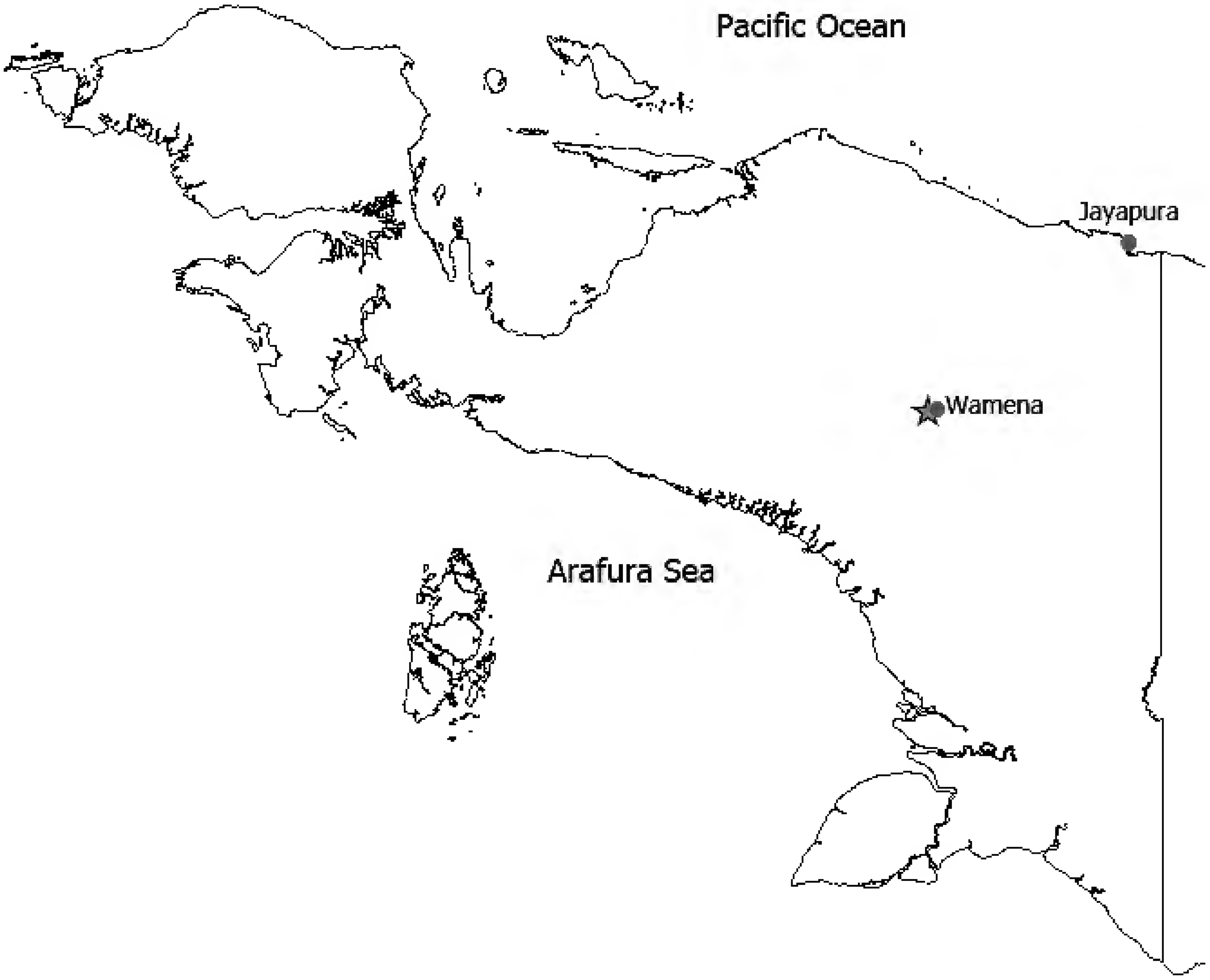

Fig. 3. The location of *Dendrobium armeniacum* collection site (red star) near Wamena in Papua, Indonesia.

Notes: During this study we did not examine any material of *D. euryanthum*, and as Cribb (1982) cites only two collections, it is likely to be uncommon in the Southern Highlands and Enga Provinces of Papua New Guinea. Schlechter's type material from the Torricelli Mountains in PNG is missing and was probably lost. Mark Clements (CANB) kindly sent us a photo of a floral dissection from a specimen he collected in the Torricelli Mountains (Fig. 4). This image aided our identification process. *Dendrobium armeniacum* is a more frequently collected species in Papua New Guinea and has been found in several Highland provinces and in the Sarawaket Mountains.

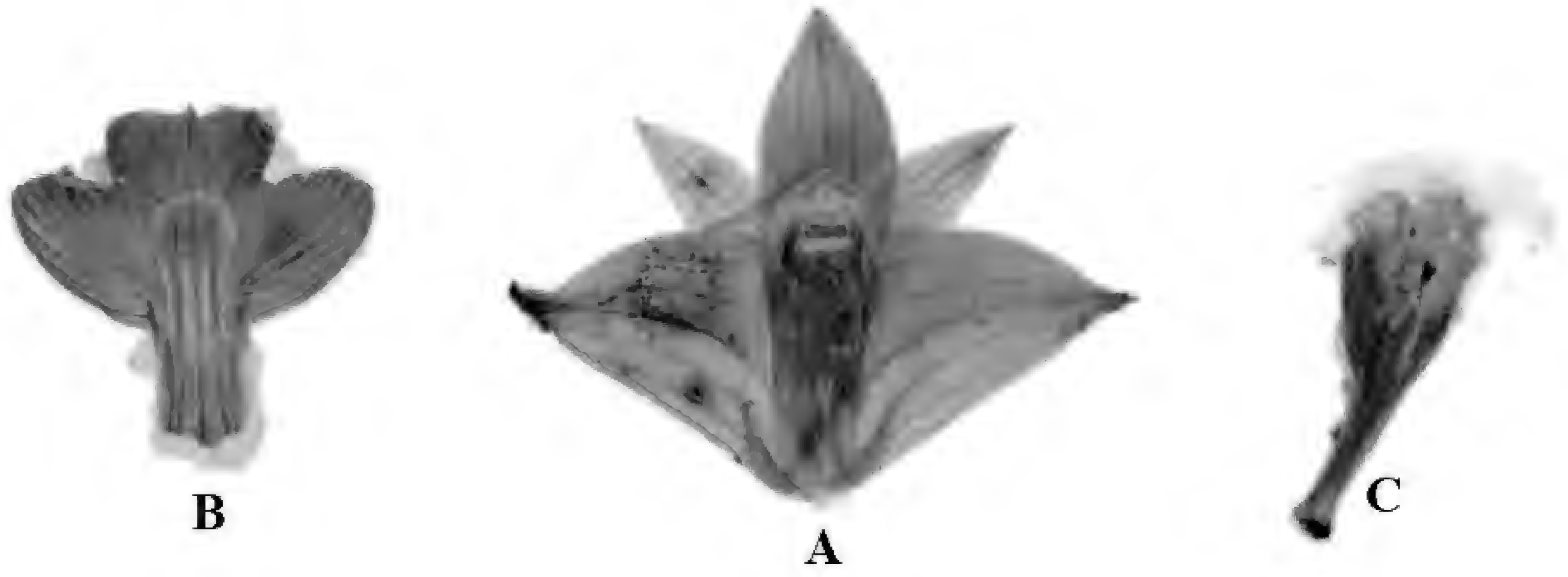

Fig. 4. Floral dissection of *Dendrobium euryanthum* from near the locus classicus in Papua New Guinea, West Sepik Province, Torricelli Mountains: A, flower; B, lip; C, pedicel with ovary. From *Clements s.n.* (CANB).

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Five new lichen species (Ascomycota) from south-eastern Australia

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Abstract

Five lichens (Ascomycota) are described as new from south-eastern Australia: *Enterographa cretacea* P.M.McCarthy & Elix (Roccellaceae; southern New South Wales), *Eugeniella farinosa* P.M.McCarthy & Elix (Pilocarpaceae; Tasmania), *E. usnica* P.M.McCarthy & Elix (southern New South Wales and eastern Victoria), *Megalaria montana* P.M.McCarthy & Elix (Ramalinaceae; central-western New South Wales) and *Micarea eucalypti* P.M.McCarthy & Elix (Pilocarpaceae; Australian Capital Territory). *Megalaria orokonuiana* Fryday & A.Knight is reported for the first time from Australia (New South Wales and Victoria).

Introduction

Field studies and laboratory investigations continue to expand our understanding of Australian lichen diversity. In early 2016 the number of species and infra-specific taxa in the six states and two mainland territories stood at 3578, including 1269 endemic taxa (McCarthy 2016).

In this contribution, five new lichen species are documented from south-eastern Australia, representing the genera *Enterographa* Fée (Roccellaceae), *Eugeniella* Lücking, Sérus. & Kalb and *Micarea* Fr. (Pilocarpaceae) and *Megalaria* Hafellner (Ramalinaceae). *Megalaria orokonuiana* Fryday & A.Knight, is reported for the first time from Australia, while *Rimularia campestris* Kantvilas & Elix (Trapeliaceae) is a new record for New South Wales.

Methods

Observations and measurements of photobiont cells, thalline and apothecial anatomy, asci, ascospores, pycnidial anatomy and conidia were made on hand-cut sections mounted in water and treated with 10% potassium hydroxide (K), 50% nitric acid (N) and 10% hydrochloric acid (H). Calcium oxalate was detected by treatment of apothecial margins and medullary tissue with a 10% aqueous solution of sulfuric acid. It forms colourless, needle-shaped crystals that are readily observed under the stereomicroscope. Asci were also observed in Lugol's Iodine (I), with and without pre-treatment in K. Chemical constituents were identified by thin-layer chromatography (Elix 2014) and comparison with authentic samples.

New Species

1. *Enterographa cretacea* P.M.McCarthy & Elix, **sp. nov.**

MycoBank No.: MB 817592

Characterized by a chalky white, ecorticate, saxicolous thallus containing dehydroconstipatic acid (major), scattered, markedly convex to subglobose-bullate, fertile areoles of (0.8–)1–1.8(–2.5) mm, immersed, black-punctate ascomata that merge into lirelliform aggregations 0.3–1.2 × 0.1–0.3 mm, but do not form pseudostromata, a thin, brown, divergent proper excipulum, a non-amyloid hymenium, 7-septate ascospores of 18–30 × 4–5.5 µm, and pycnidia that are solitary, black, punctate, immersed and produce simple, filiform conidia of 10–16(–20) × 0.5 µm.

Type: Australia. New South Wales: South Coast (Jacobs and Pickard 1981): 5 km N of Bermagui, Camel Rock, 36°22'41"S, 150°04'37"E, alt. c. 3 m, on sheltered quartzitic sandstone on the seashore, above the splash zone, *P.M. McCarthy 4475*, 10 Feb 2016; holotype: CANB.

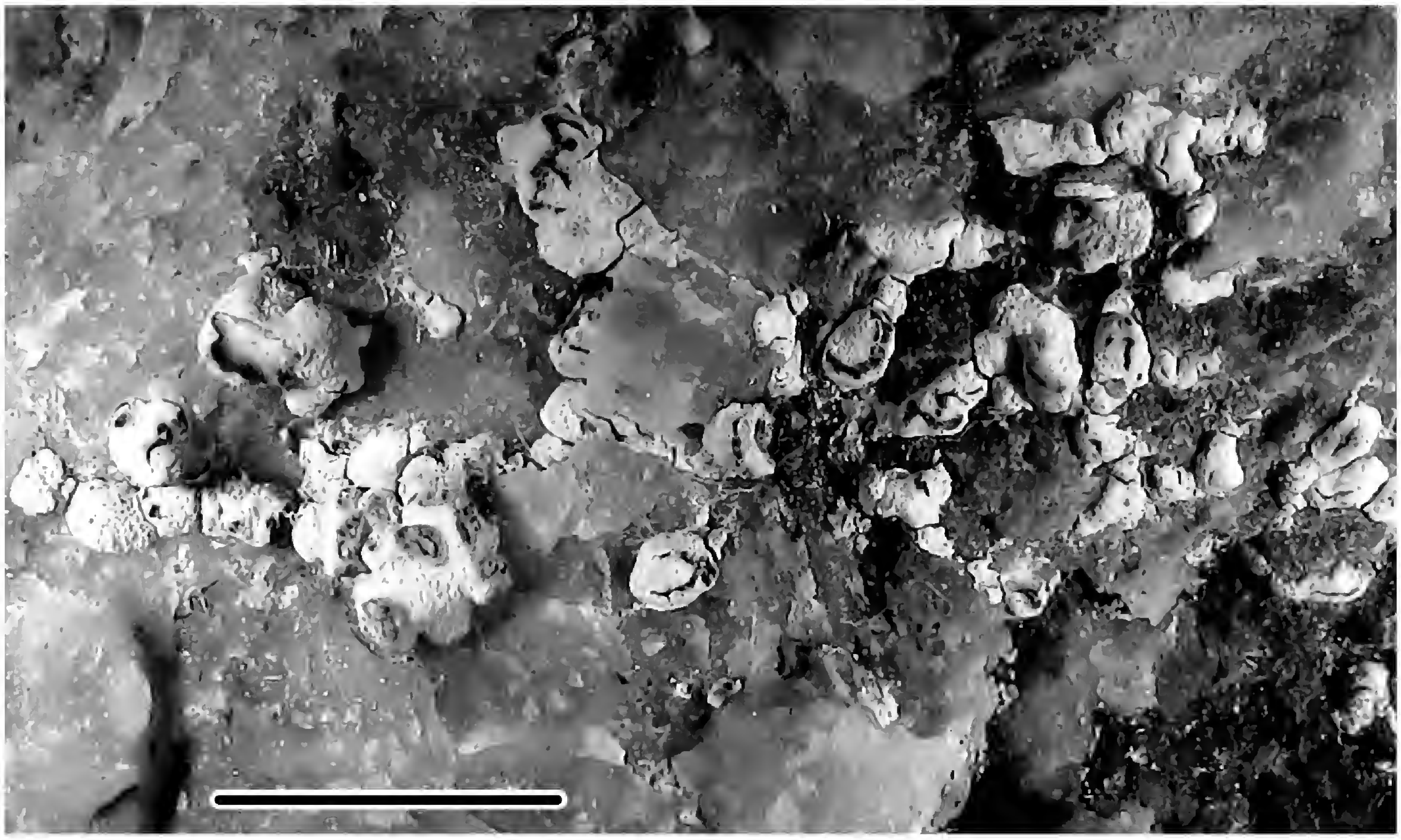

Fig. 1. *Enterographa cretacea* (holotype). Scale bar = 5 mm.

Thallus epilithic, crustose, diffuse, dull chalky white, scarcely forming continuous colonies to 1 cm wide, areolate, the areoles at first solitary, usually in small scattered clusters, or in rows following microfissures in the rock surface, or developing and maturing around other irregularities in the substratum, not water-repellent, with an uneven, 30–50 µm thick frosting of white pruina (just visible under a hand lens). *Areoles* initially plane to slightly convex, rounded, angular or irregular, increasing in size and thickness; mature fertile areoles (0.8–)1–1.8(–2.5) mm in maximum extent, to 0.7 mm thick, strongly convex or forming large irregular verrucae or subglobose-bullate; persistently sterile areoles plane to strongly convex, 0.2–0.8 mm wide, 0.08–0.4 mm thick. *Cortex* absent. *Algae Trentepohlia*, occupying a layer 80–150 µm thick in larger and fertile areoles, commonly scattered vertically throughout immature areoles; cells 10–21 × 8–14 µm, solitary or in filaments of up to 6 cells; interstitial hyphae 3–4 µm thick. *Medulla* white, densely packed with small to large calcium oxalate crystals (as is the algal layer); hyphae 2–4 µm thick, inconspicuous. *Prothallus* not apparent. *Ascomata* numerous, immersed, initially black-punctate and 0.08–0.12(–0.16) mm wide, merging to form lirelliform aggregations 0.3–1.2 mm long and 0.1–0.3 mm wide [*n* = 40, solitary and aggregated ascomata], the 'lirellae' simple or with 1 or 2 branches, straight or curved to arcuate, occasionally sigmoid, not in pseudostromata. *Thalline excipulum* absent. *Proper excipulum* visible only in thin section, divergent; in solitary ascomata medium to dark olive-brown above and 15–20 µm thick, pale brown or hyaline laterally and below, 10–15 µm thick; in aggregated ascomata the basal excipulum becoming obscured or possibly excluded; disc open, plane, smooth, dull, occasionally hyaline to dark pinkish grey, but usually blackish, epruinose or patchily white-pruinose. *Hypothecium* hyaline, poorly defined, c. 25–40 μm thick, with oily inclusions, K–, I–, often becoming indistinguishable from the base of the proper excipulum. *Hymenium* 55–70 μm thick, not inspersed with granules or oil globules, non-amyloid, K–, I+ orange-red or wine-red. *Epihymenium* bilayered, K–, I–, 10–15 μm thick and hyaline above, 15–20 μm thick below and medium grey-brown to dark brown. *Paraphysoids* moderately conglutinate, not separating in K, branched and anastomosing above, simple or sparingly branched below, rather long-celled, 0.8–1.5 μm thick; apical cells to 2 μm thick, not pigmented. *Asci* structurally *Opegrapha*-type, but completely non-amyloid, broadly cylindrical or cylindroclavate, laterally thin-walled, 8-spored, 52–65 × 11–14 μm; apex rounded, with a 2–3 μm thick tholus and a minute ocular chamber at maturity. *Ascospores* colourless, irregularly massed in the ascus, 7-septate at maturity, narrowly oblong to fusiform, usually straight, occasionally slightly curved, faintly constricted at the septa or not, (18–)25(–30) × (4–)5(–5.5) μm excluding the perispore [*n* = 25]; cells of ± equal size throughout spore ontogeny (i.e. microcephalic); perispore to 1(–1.5) μm thick around immature and submature spores; apices rounded or subacute; contents clear or granular-guttulate. *Pycnidia* moderately numerous, immersed, solitary, 80–120 μm wide; apex black, punctate, plane, rounded, epruinose; internal wall medium to dark brown (thin section), with a simple conidiogenous layer; conidiogenous hyphae 10–15 μm long. *Conidia* hyaline, simple, filiform, usually curved, arcuate or sigmoid, 10–16(–20) × 0.5 μm. **Figs 1, 2.**

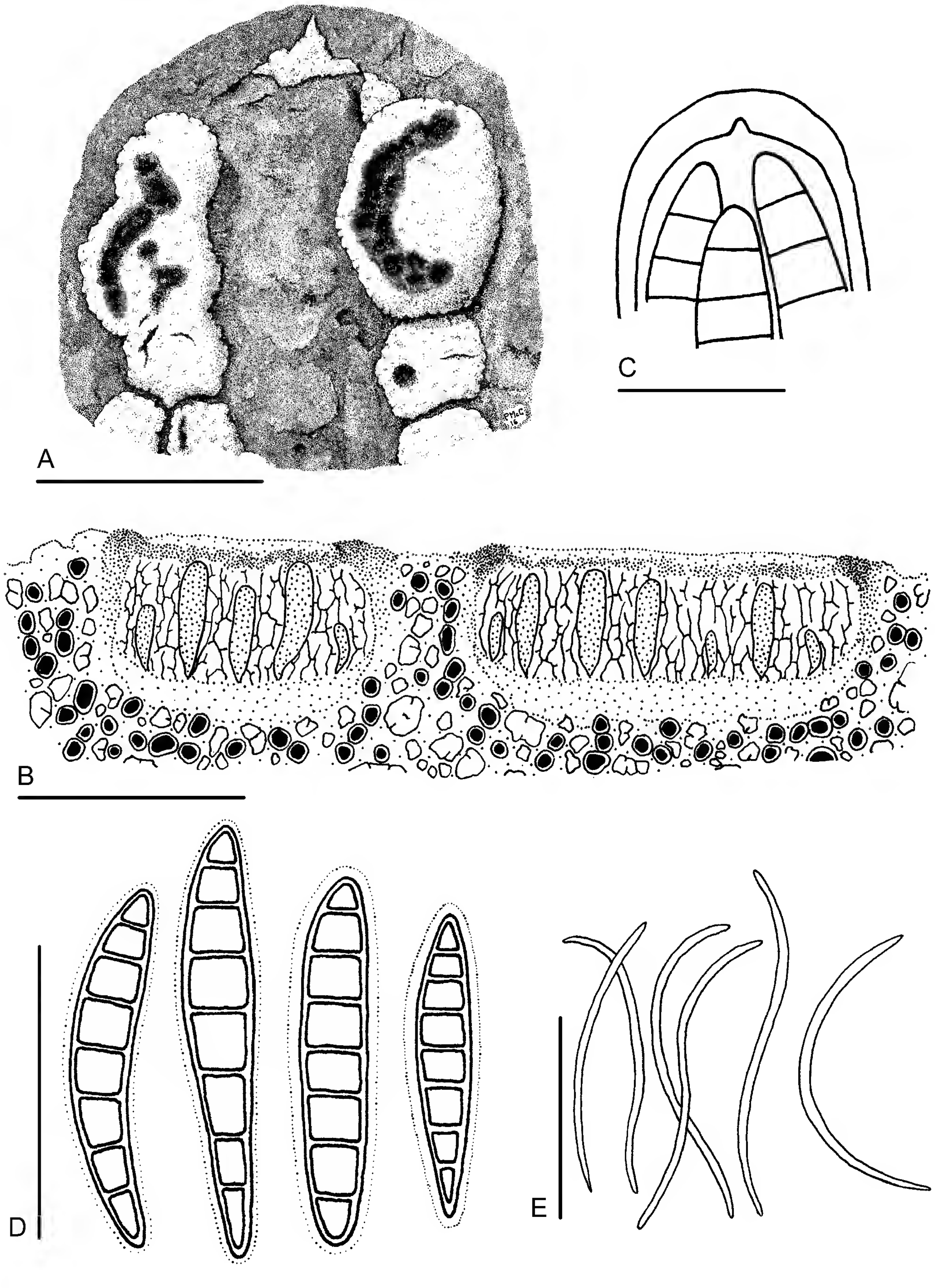

Fig. 2. *Enterographa cretacea* (holotype). A, habit of thallus and ascomata; B, sectioned ascomata (semi-schematic); C, ascus apex; D, ascospores; E, conidia. Scale bars: A = 1 mm; B = 0.1 mm; C, E = 10 μm; D = 20 μm.

Chemistry: Thallus K–, C–, KC–, PD–, UV–; dehydroconstipatic acid (major) by TLC. Medulla and algal layer H_2SO_4+, containing calcium oxalate.

Relationships: The genus *Enterographa* Fée (Roccellaceae) includes 56 species that grow on bark, rock or leaves, or as parasites of other lichens, mainly in tropical and subtropical latitudes, but with a significant minority found in temperate regions of both hemispheres (Sparrius 2004, Seavey and Seavey 2014). Ten species are known from Australia and its oceanic island territories (McCarthy 2016) where most are corticolous or foliicolous, except for *E. subgelatinosa* (Stirt.) Redinger which occurs on coastal rock in the south-west of Western Australia and in a similar habitat at the type locality in northern New Zealand.

The diagnostic characters of *E. cretacea* (see above), especially those of thalline habit and chemistry, ascomatal anatomy and the absence of pseudostromatic tissues, the non-amyloid hymenium, ascospore size and septation and pycnidial attributes, set it apart from all other species (Sparrius 2004; Seavey and Seavey 2014). For example, while the Australasian *E. subgelatinosa* has similar ascospores and conidia, its thallus forms 2–5 cm wide, cream-coloured, rimose-areolate colonies with a PD+ yellow colour reaction [“probably psoromic acid” *fide* Sparrius (2004)], and the pycnidia are orange-brown. The corticolous, Neotropical *E. sipmanii* Sparrius has similar ascomatal anatomy and ascospores, but the thallus lacks lichen substances, and the conidia are short-bacilliform and 3–5 × 1 µm (Sparrius 2004). The northern-temperate *E. hutchinsiae* (Leight.) A.Massal. also grows on rock and has an ascomatal anatomy similar to that of *E. cretacea*, but the olive-grey to dark brown thallus contains confluentic acid, and the bacilliform conidia are 5–6 × 1.2–1.5 µm (Coppins and James 1979; Sparrius 2004).

Etymology: The epithet *cretacea* (chalky) refers to the white thallus of the new species.

Distribution and habitat: This species is known only from the type locality, an exposed rocky seashore on the south coast of New South Wales, Australia. It grows on the moderately shaded, landward side of a quartzitic sandstone pinnacle among lichens that include *Buellia halonia* (Ach.) Tuck., *Caloplaca* spp., *Diploicia canescens* subsp. *australasica* Elix & Lumbsch, *Opegrapha* sp. and *Porina guentheri* (Flot.) Zahlbr.

2. *Eugeniella farinosa* P.M.McCarthy & Elix, sp. nov.

MycoBank No.: MB 817593

Characterized by the predominantly farinose, pale grey-green, epiphloeodal thallus containing usnic acid, adnate or basally constricted, biatorine apothecia 0.25–0.60 mm diam., with an epruinose, greenish brown disc, a thin but usually persistent and off-white proper margin of moniliform hyphae encrusted with crystals of calcium oxalate, the proper excipulum partially subtending the medium to dark reddish brown hypothecium, an inconspicuous epihymenium, simple to sparingly branched paraphyses and *Byssoloma*-type asci containing 3-septate ascospores of 10–15 × 2.5–4 µm.

Type: Australia. Tasmania: 1 km SE of Wiltshire along Bass Highway, 40°50'S, 145°17'E, alt. 5 m, on bark of *Melaleuca ericifolia* in a swamp, *G. Kantvilas 272/99*, 28 Jun 1999; holotype: HO 445376.

Thallus crustose, epiphloeodal, continuous and farinose (the granules 30–60 µm wide), or rimose to indistinctly areolate and smooth to minutely rugulose-verruculose, pale grey-green, to 0.1(–0.2) mm thick, ecorticate, forming colonies to 4 cm wide. *Algal cells* green, globose, chlorococcoid, 8–18 µm diam., thick-walled. *Medulla* not delimited, a loose hyphal reticulum; hyphae long-celled, 2–3(–4) µm wide. *Prothallus* absent. *Apothecia* numerous, adnate or basally constricted, solitary and rounded or shallowly to deeply lobate, often subdividing into rounded clusters or short rows of apothecia, their shape distorted by mutual pressure; individual apothecia (0.25–)0.46(–0.60) mm diam. [*n* = 60]; disc medium greenish brown, smooth, epruinose, at first ± plane, becoming moderately to strongly convex; proper margin biatorine, off-white, thin but distinct, usually persistent, initially 25–40 µm thick in surface view, entire and even to delicately flexuose. *Proper excipulum* partially subtending the hypothecium and up to 60 µm thick, heavily impregnated with rounded, squarrose or irregularly shaped crystals of calcium oxalate which are interspersed with radiating moniliform hyphae; cells ellipsoid to subglobose, constricted at the septa, 4–6 µm long and 3–4 µm wide. *Hypothecium* medium to dark reddish brown, 50–80 µm thick, not inspersed with granules or oil droplets, non-amyloid, K–; subhypothecial tissue hyaline to pale brown, lacking an “apothecial base” *sensu* Lücking (2008) and Breuss and Lücking (2015). *Hymenium* 50–70 µm thick, not inspersed, I+ dark blue, K–, occasionally with a faint brownish tint. *Epihymenium* 10–15 µm thick, inconspicuous, pale grey-green to pale greenish brown, often scarcely distinguishable from the hymenium. *Paraphyses* simple to sparingly branched, long-celled, conglutinate, 0.8–1.5 µm thick; apical cells not swollen and not pigmented. *Asci* narrowly to broadly clavate or clavate-cylindrical, 8-spored, 36–47 × 10–13 µm [*n* = 20], *Byssoloma*-type (Hafellner 1984), with or without a thin amyloid outer coat; tholus well-developed, uniformly amyloid, but with a very inconspicuous *masse axiale* bordered by a more intensely amyloid zone; ocular chamber conical or not apparent. *Ascospores* colourless, 3-septate at maturity, narrowly ellipsoid to oblong or fusiform, irregularly biseriate or obliquely massed in the upper half of the ascus, straight or slightly bent, with rounded or subacute apices, not or only very slightly constricted at the septa, (10–)13(–15) × (2.5–)3.5(–4) µm [n = 50], thin-walled; perispore lacking. *Pycnidia* not seen. **Figs 3A, 4.**

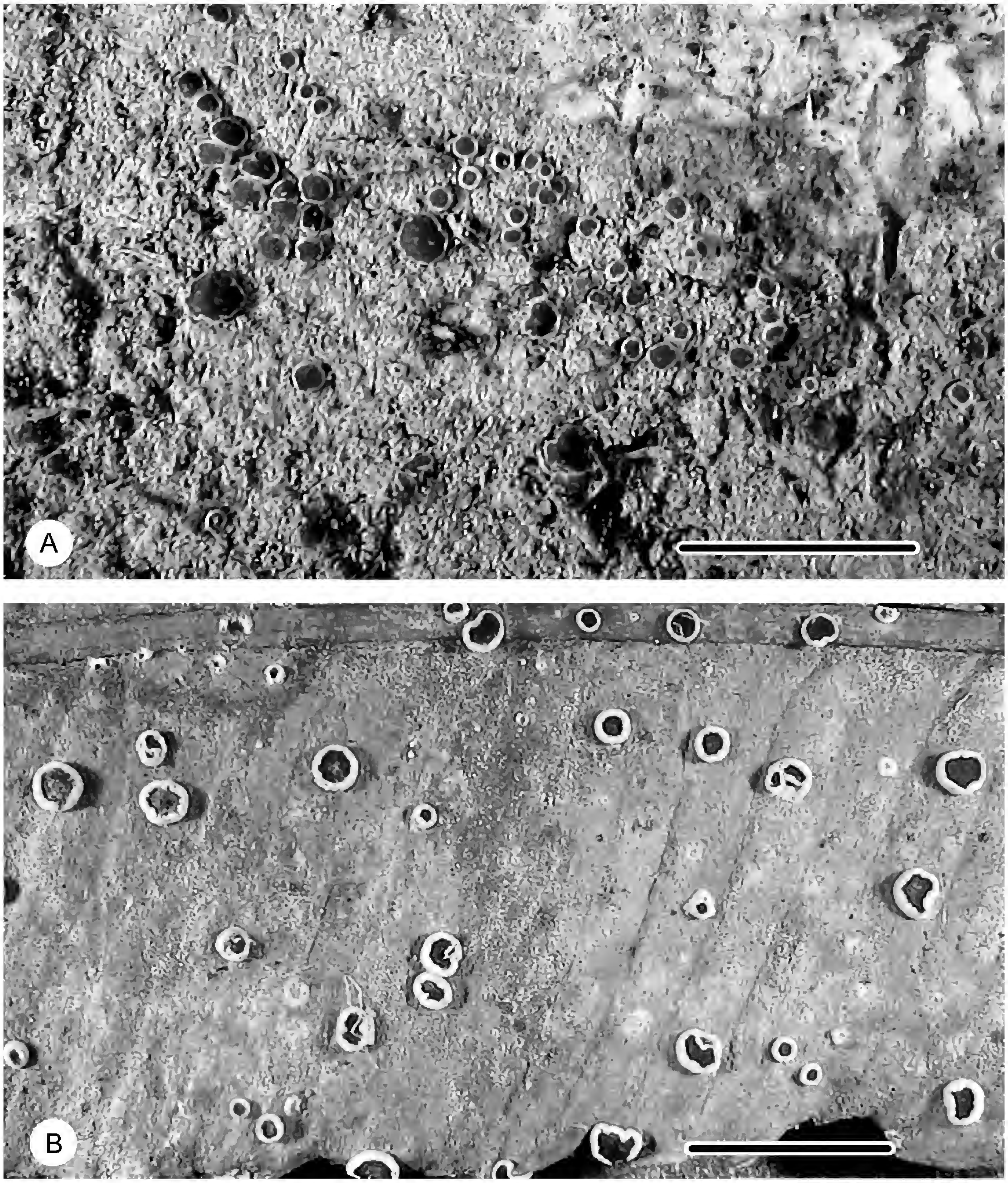

Fig. 3. *Eugeniella* species. A, *E. farinosa* (holotype); B, *E. usnica* (holotype). Scale bars = 2 mm.

Chemistry: Thallus K–, C–, KC–, PD–, UV–; usnic acid [major] by TLC; H_2SO_4+, thallus and apothecial margin containing calcium oxalate.

Relationships: *Eugeniella* was first described to accommodate several species previously included in *Bacidia sens. lat.* and *Byssoloma* Trevis. (Lücking 2008). Its circumscription emphasises an excipular anatomy of moniliform hyphae heavily encrusted with calcium oxalate crystals in conjunction with mostly unbranched paraphyses, *Byssoloma*-type asci and transversely septate to muriform ascospores (Breuss and Lücking 2015). The genus includes nine species, most of which are foliicolous and exclusively Neotropical (Lücking 2008, Breuss and Lücking 2015), with one pantropical taxon, *E. micrommata* (Kremp.) Lücking, Sérus. & Kalb, which has previously been reported from north-eastern New South Wales (Lücking et al. 2001).

Eugeniella farinosa and *E. palleola* Breuss & Lücking are the only two obligately corticolous species in the genus (see couplet 2 of the key, below). The new species is characterized by a pale grey-green, mainly farinose thallus containing usnic acid, adnate or basally constricted apothecia with an epruinose, greenish brown disc, a thin but usually persistent and off-white proper margin that, in section, partially subtends the medium to dark reddish brown hypothecium and small, 3-septate ascospores. A key to the eight species of *Eugeniella* with 3-septate ascospores is provided below.

Etymology: The epithet *farinosa* refers to the powdery thallus of the new species.

Distribution and habitat: *Eugeniella farinosa* is currently represented only by the type collection from the bark of *Melaleuca ericifolia* in a coastal swamp in north-eastern Tasmania.

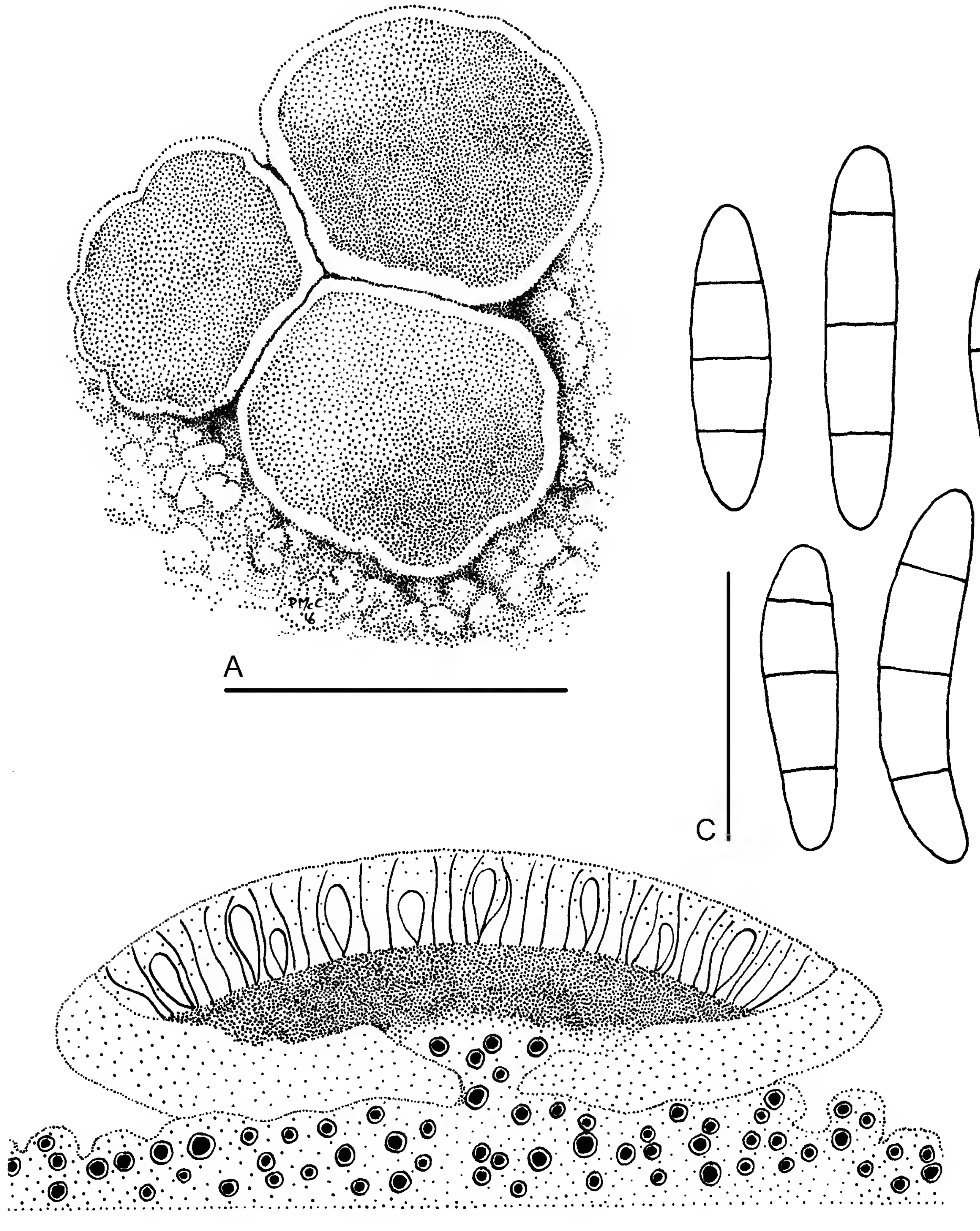

Fig. 4. *Eugeniella farinosa* (holotype). A, habit of thallus and apothecia; B, sectioned apothecium (semi-schematic); C, ascospores. Scale bars: A = 0.5 mm; B = 0.2 mm; C = 10 μm.

3. *Eugeniella usnica* P.M.McCarthy & Elix, sp. nov.

MycoBank No.: MB 817594

Characterized by a very thin, often smooth, pale to medium green or pale greyish green, epicuticular thallus on herb and tree leaves and on fern pinnae, highly conspicuous, sessile, biatorine apothecia 0.24–0.62 mm diam. with a plane, epruinose, dark olive-brown to blackish disc, a persistent, white to pale yellowish proper margin of moniliform hyphae encrusted with crystals of calcium oxalate and containing usnic acid (major), the excipulum cupulate or partially subtending the medium to dark reddish brown hypothecium, a hyaline to pale greenish brown epihymenium, simple paraphyses and *Byssoloma*-type asci containing 3-septate ascospores of 11–16 × 3.5–5 µm.

Type: Australia. New South Wales: South Coast: Box Cutting Rainforest Walk, off Kianga Forest Drive, Bodalla State Forest, near Narooma, 36°10'57"S, 150°04'05"E, alt. 140 m, on pinnae of *Blechnum* sp. in a wet forest gulley, *P.M. McCarthy 4477*, 10 Feb 2016; holotype: CANB.

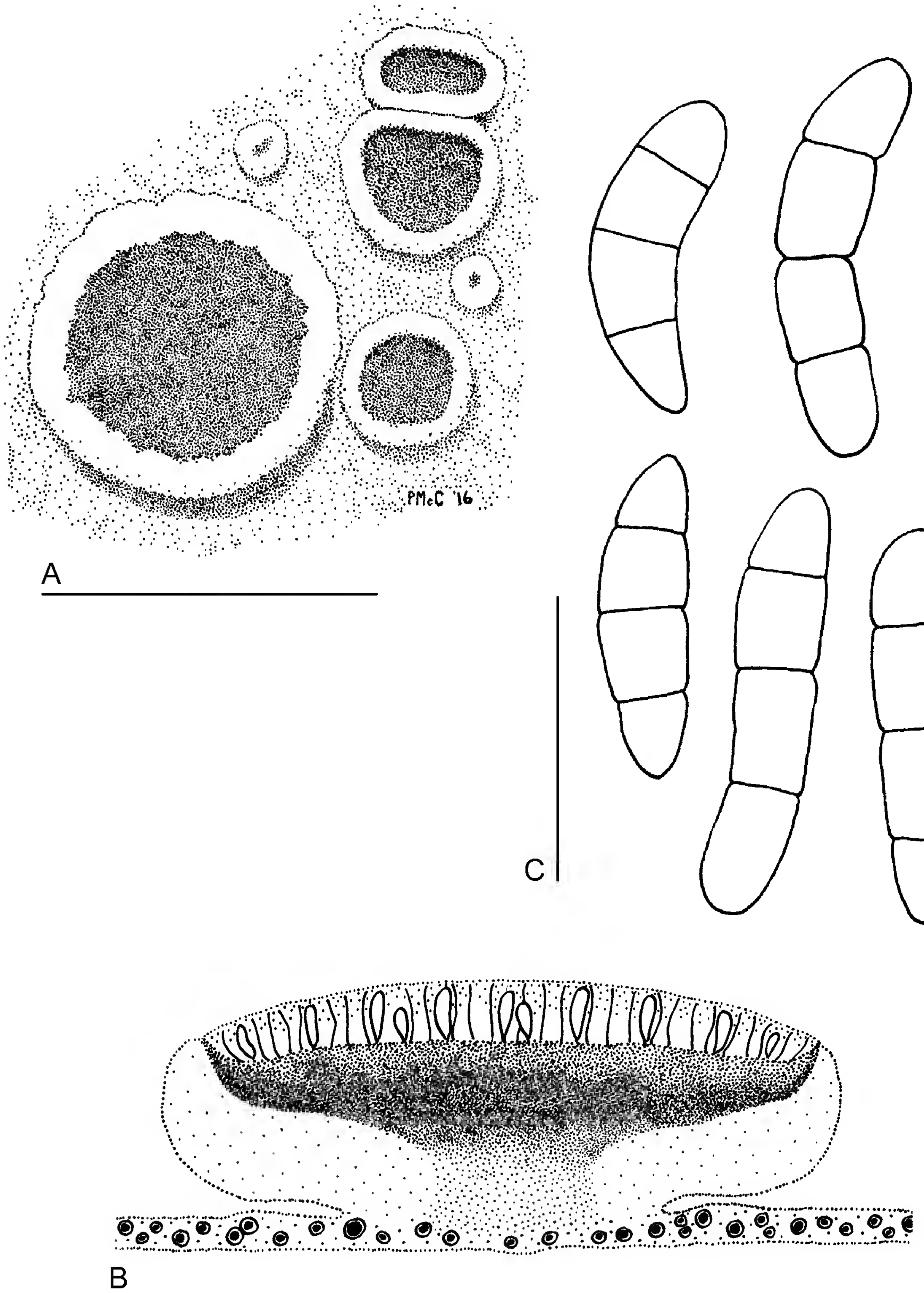

Fig. 5. *Eugeniella usnica* (holotype). A, habit of thallus and apothecia; B, sectioned apothecium (semi-schematic); C, ascospores. Scale bars: A = 0.5 mm; B = 0.2 mm; C = 10 µm.

Thallus crustose, epicuticular on the upper surfaces of fern pinnae, the leaves of wet forest trees and a perennial herb (*Lomandra* sp.), diffuse or continuous, not areolate, smooth to minutely and irregularly uneven, 18–30 µm thick, pale to medium green or pale greyish green, ecorticate, forming colonies to 5–10(–15) mm wide. *Algal cells* green, globose, chlorococcoid, 8–15 µm diam., thick-walled; interstitial hyphae long-celled, 1.5–2 µm wide. *Prothallus* pale grey and effuse, or not apparent. *Apothecia* usually numerous, sessile, solitary and rounded or shallowly to deeply and irregularly lobate, or paired, or in small clusters, the apothecial shape then usually distorted by mutual pressure, (0.24–)0.45(–0.62) mm diam. [*n* = 100], often leaving a round, 0.2–0.35 mm wide scar when detached from the thallus; disc plane, smooth, epruinose, dark olive-brown to blackish; thalline margin absent; proper margin 40–80(–100) µm thick, biatorine, entire, white to pale yellowish, persistent, often translucent when wet. *Proper excipulum* partially subtending or continuous beneath the hypothecium, heavily encrusted with hyaline, squarrose or irregular crystals that largely obscure the moniliform hyphae; cells 3–5 µm long and 2–3(–4) µm wide; excipulum base 90–130 µm thick, subtending the hypothecium with a loose reticulum of 2–3 µm thick hyphae, I+ pale yellowish brown, K–. *Hypothecium* medium to dark reddish brown, 40–65 µm thick, not inspersed with granules or oily inclusions, I–, K+ dark olive-brown; subhypothecial tissue [the "apothecial base" *sensu* Lücking (2008), Breuss and Lücking (2015)] hyaline to pale brown, 40–60 µm thick, I–, K–. *Hymenium* 50–60 µm thick, not inspersed, I+ dark blue, K–. *Epihymenium* 10–15 µm thick, this layer and adjacent parts of hymenium hyaline to pale greenish brown, K–. *Paraphyses* simple, long-celled, conglutinate, 0.8–1.5 µm thick; apical cells not or slightly swollen (2–3 µm thick), not pigmented. *Asci* narrowly clavate to cylindrical, 8-spored, 40–55 × 9–12 µm [*n* = 15], *Byssoloma*-type, with or without a thin amyloid outer coat; tholus well-developed, uniformly amyloid, but with an inconspicuous *masse axiale* bordered by a more intensely amyloid zone; ocular chamber not apparent. *Ascospores* colourless, 3-septate at maturity, narrowly ellipsoid to oblong, irregularly biseriate in the ascus, straight or bent, occasionally faintly sigmoidal, with rounded apices, or the proximal apex more pointed, slightly constricted at the septa, especially the primary septum, (11–)14(–16) × (3.5–)4(–5) µm [*n* = 100], thin-walled; perispore lacking or up to 1 µm thick. *Pycnidia* not seen. **Figs 3B, 5.**

Chemistry: Thallus K–, C–, KC–, PD–, UV–; usnic acid (major), atranorin (minor or trace), chloroatranorin (minor or trace) by TLC; H_2SO_4+, apothecial margin containing calcium oxalate.

Relationships: *Eugeniella usnica* is a very distinctive lichen, even at a distance in the field, and its dark olive-brown to blackish apothecial discs and white to pale yellowish margins are particularly noticeable. Its habit, the presence of usnic acid in the proper margin of the apothecium and 3-septate ascospores of 11–16 × 3.5–5 µm set it apart from all other species. Thus, the Neotropical *E. atrichoides* (Malme) Lücking, Sérus. & Kalb has a pale grey to brownish grey apothecial margin and ascospores that are only 2.5–3.5 µm wide (Lücking 2008), while the more widely distributed *E. leucocheila* (Tuck.) Lücking, Sérus. & Kalb has dark brown to brownish black hypothecial and subhypothecial tissues, a white to pale brown apothecial margin (Lücking 2008) and a thallus that can contain perlatolic acid, stenosporic acid and glomelliferic acid.

Etymology: The epithet *usnica* refers to usnic acid, the dominant lichen substance in this species.

Distribution and habitat: *Eugeniella usnica* is locally abundant on the upper surfaces of fern pinnae, the leaves of wet forest trees and a perennial herb (*Lomandra* sp.) at two localities in rainforest and warm-temperate forest in south-eastern New South Wales and far-eastern Victoria. Associated lichens at the type locality included many of the foliicolous species typical of wet, coastal forest in south-eastern New South Wales, *viz. Arthonia trilocularis* Müll.Arg., *Aulaxina dictyospora* R.Sant., *Byssoloma leucoblepharum* (Nyl.) Vain., *B. subdiscordans* (Nyl.) P.James, *Fellhanera bouteillei* (Desm.) Vězda, *Gyalectidium microcarpum* (Vězda) Lücking, Sérus. & Vězda, *Mazosia phyllosema* (Nyl.) Zahlbr., *Sporopodium flavescens* (R.Sant.) Vězda, *Strigula nitidula* Mont., *S. smaragdula* Fr.: Fr., *Tapellaria phyllophila* (Stirt.) R.Sant. and *Trichothelium alboatrum* Vain.

Additional specimens examined: NEW SOUTH WALES: type locality, *P.M. McCarthy 2809*, 10 Apr 2009 (CANB). **VICTORIA:** East Gippsland (Foreman and Walsh 1993): 10 km E of Cann River, Drummer Rainforest Walk, 37°34'05"S, 149°16'26"E, alt. 80 m, on leaves of trees at margin of warm-temperate forest, *J.A. Elix 39368*, 11 Nov 2008 (CANB); *loc. id.*, on leaves of *Lomandra*, *J.A. Elix 39367*, 11 Nov 2008 (CANB).

Key to the species of *Eugeniella* with 3-septate ascospores

[Based on Lücking (2008), Breuss & Lücking (2015) and the two newly described species]

1 Apothecial disc pale brown to grey or medium greenish brown; growing on bark **2**

1: Apothecial disc dark brownish grey, dark olive-brown or blackish; usually growing on leaves, bark or wood **3**

2 Thallus farinose; apothecial margin containing usnic acid; hypothecium medium to dark reddish brown, not subtended by a pigmented "apothecial base"; ascospores 10–15 µm long .... ***E. farinosa***

2: Thallus minutely uneven but not farinose; apothecial margin containing norstictic acid; hypothecium brown-black, subtended by a concolorous "apothecial base"; ascospores 13–17(–20) µm long [Central America] .... ***E. palleola***

3 Thallus distinctly verrucose 4

3: Thallus lacking verrucae 5

4 Thallus greenish; verrucae white, 0.07–0.15 mm wide; paraphyses unbranched [Neotropics] .... ***E. psychotriae***

4: Thallus bluish grey or white; verrucae concolorous, 0.1–0.2 mm wide; paraphyses branched and anastomosing [pantropical] .... ***E. micrommata***

5 Apothecial margin evanescent; tubular pycnidia usually present [Neotropics] .... ***E. corallifera***

5: Apothecial margin well-defined and persistent; pycnidia absent 6

6 Apothecial margin pale grey to brownish grey; ascospores 2.5–3.5 µm wide [Neotropics .... ***E. atrichoides***

6: Apothecial margin white, pale yellowish white or pale brown; ascospores 3–5 µm wide 7

7 Hypothecium and subhypothecial tissues dark brown to brownish black; apothecial margin white to pale brown; chemistry: perlatolic acid (major), stenosporic acid (minor), glomelliferic acid (minor) (J.A.Elix, unpublished) [Neotropics, SE United States and tropical Africa] .... ***E. leucocheila***

7: Hypothecium medium to dark reddish brown; subhypothecial tissue hyaline to pale brown; apothecial margin white to yellowish; chemistry: usnic acid (major), atranorin (minor or trace), chloroatranorin (minor or trace) .... ***E. usnica***

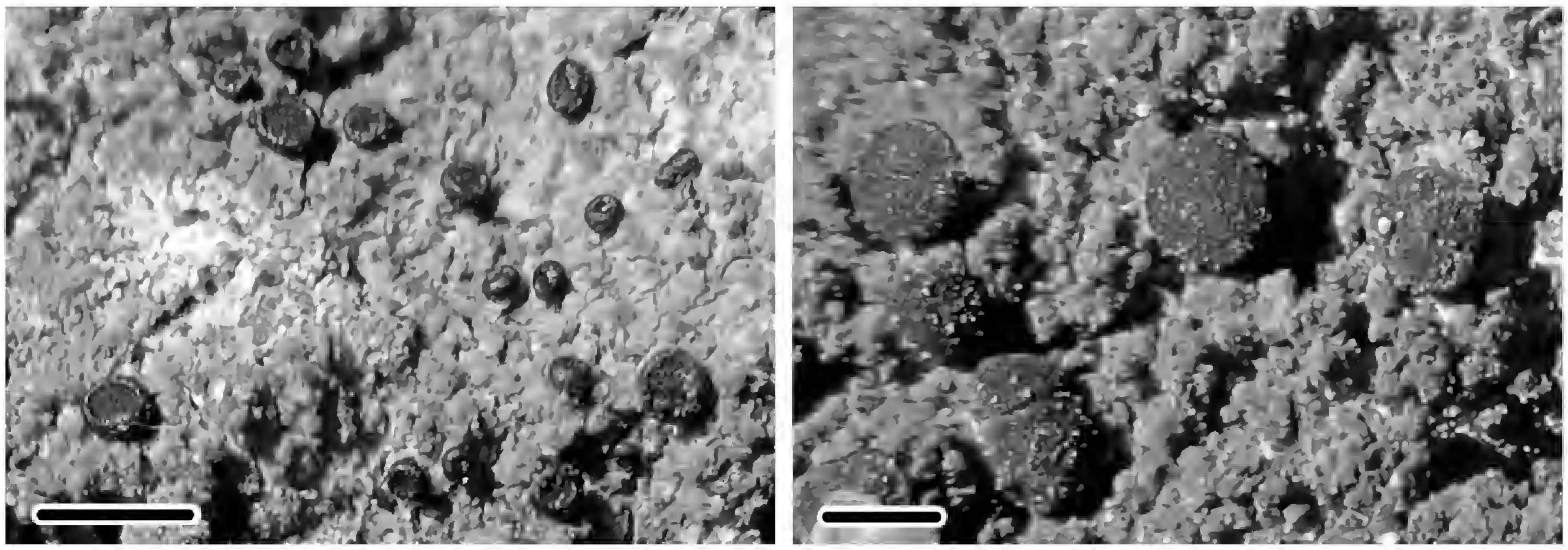

Fig. 6. *Megalaria montana* (holotype). Thalli with immature (left) and mature apothecia. Scale bars = 1 mm.

4. ***Megalaria montana*** P.M.McCarthy & Elix, **sp. nov.**

MycoBank No.: MB 817595

Characterized by a thick, green, granulose-isidiate to coralloid-isidiate thallus growing on rock and lacking lichen substances, apothecia that are adnate to sessile, black, 0.5–1.5 mm diam., with a persistent margin, a thick, laterally violet-grey to bluish black proper excipulum (N+ violet or purple) that is cupulate and paler at the base, a pale, bilayered hypothecium (N+ pale pink above), a blackish epihymenium, simple to sparingly branched paraphyses with occasional anastomoses mainly towards their base, mostly 8-spored, ± *Biatora*-type asci of 88–110 × 11–30 µm and narrowly ellipsoid to oblong-ellipsoid, 1-septate ascospores 19–40 × 8–13 µm.

Type: Australia. New South Wales: Central Tablelands: Mount Canobolas State Conservation Area, W face of Mt Canobolas, c. 12 km SW of Orange, 33°20'13"S, 148°58'51"E, alt. c. 1115 m, on weathered trachytic rhyolite in heath with scattered *Eucalyptus* and *Acacia*, *P.M. McCarthy 4480*, 6 Apr 2016; holotype: CANB.

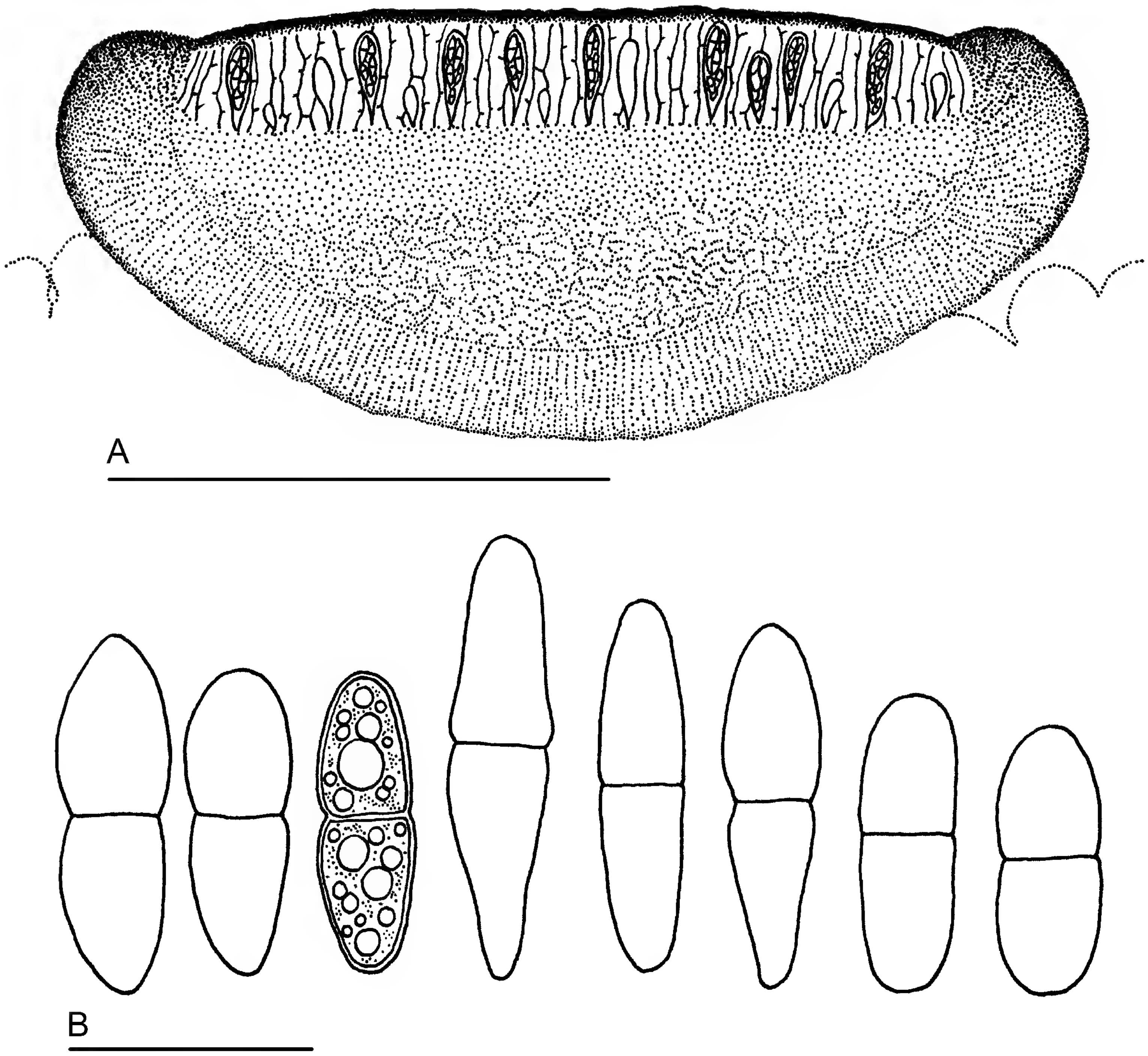

Fig. 7. *Megalaria montana* (holotype). A, sectioned apothecium (semi-schematic); B, ascospores. Scales bars: A = 0.5 mm; B = 20 μm.

Thallus crustose, epilithic, pale to medium green or greyish green, 0.2–1.5(–2) mm thick, forming colonies to 5 cm wide, granulose-isidiate to coralloid-isidiate, in places verruculose and with coralloid lobules, patchily and thinly corticate on granules to distinctly corticate on coralloid outgrowths, then the cortex hyaline, prosoplectenchymatous or subparaplectenchymatous and 10–15 μm thick; granulose isidia globose or somewhat irregular, 0.1–0.3(–0.4) mm wide; lobules and coralloid isidia ±terete, or plane to convex, erect, spreading or contorted, simple to irregularly and short-branched, 0.1–0.3 mm wide, forming pulvinate, areole-like clumps up to 2 mm wide; thallus friable when dry, readily crumbling, becoming detached from the substratum and exposing the white prothallus. *Photobiont* chlorococcoid, forming a subcortical layer 40–80(–100) μm thick; cells mostly globose, 8–14(–18) μm wide, thin- or thick-walled. *Medulla* loose, almost byssoid in places; hyphae variously orientated, long-celled, 3–5(–6) μm wide. *Prothallus* thin, white, discontinuous and byssoid under the thallus, up to 1.5 mm wide at the thallus margin where the inner part is white and minutely radially rimose, the outer zone silvery grey and fimbriate. *Apothecia* rounded or slightly irregular in outline, or more contorted when immature and wedged between 'areoles', (0.5–)0.9(–1.5) mm diam. [*n* = 44], usually solitary and scattered, adnate or basally constricted; margin at first glossy black, smooth, entire, later dull black, persistent, 80–120 μm thick, occasionally a little paler than the disc; disc initially slightly concave or plane, becoming moderately convex, matt black, smooth, epruinose, roughened or pock-marked in post-mature apothecia and internally becoming uniformly blackish and anatomically amorphous, the hymenium disappearing. *Proper excipulum* cupulate in section, 75–125(–150) μm thick laterally, 70–120 μm thick at the base, laterally uniformly medium violet-grey to bluish black, or pigmented towards the outside and hyaline within, suprabasal and basal excipulum uniformly hyaline or with a thin, external violet-grey zone; pigmented parts K– or K+ greenish blue, H+ bluish, I–, N+ violet or purple; excipular hyphae radiating outwards laterally and downwards basally, anastomosing, tightly coherent, 6–11 µm wide, very thick-walled (the lumina c. 1 µm thick), the outermost/lowermost cells not swollen. *Hypothecium* bilayered, not inspersed with oil droplets or granules, or with sparse granules distally; upper layer paraplectenchymatous, hyaline to pale straw-coloured or pale greenish brown, 60–130 µm thick, K–, H–, I+ pale yellowish, N+ pale pink, the uppermost 10–20 µm (adjacent to the hymenium) occasionally very pale bluish green; lower layer 90–160 µm thick, a well-defined, hyaline zone of prosoplectenchymatous or very loose and randomly orientated hyphae 3–5 µm wide, K–, H–, I–, N–. *Hymenium* 90–150 µm thick, not inspersed with granules or oil globules, hyaline, K–, H–, I+ blue, N–. *Epihymenium* inky black, blue-black or dark bluish green, 15–20(–25) µm thick, K+ greenish, H+ deep cobalt blue, I–, N+ violet or purple. *Paraphyses* simple to sparingly branched, with occasional anastomoses especially towards the base of the hymenium, 1–1.5(–2) µm thick, separating in K but conglutinate at the epihymenium; apices swollen, 3.5–4 µm wide, with or without a cap of blue-black pigment and a diffuse, internal blue-green pigment; short paraphyses occasionally intermixed, only c. half the height of the hymenium, with numerous short branches. *Asci* narrowly clavate to clavate-cylindrical, mostly 8-spored, occasionally with 2 or 3 spores aborted, the spores biseriate, irregularly arranged, or massed in the distal half of the ascus, 88–110 × 11–30 µm [*n* = 25], ± *Biatora*-type; tholus well-developed, weakly amyloid, penetrated almost to the ascus wall by a conical *masse axiale*, this bordered by a narrow, more deeply amyloid zone; ocular chamber stunted-convex or not apparent; ascoplasma non-amyloid. *Ascospores* narrowly ellipsoid or oblong-ellipsoid, hyaline, 1-septate, slightly constricted at the septum or not, straight, (19–)31(–40) × (8–)11(–13) µm [*n* = 100]; apices rounded or subacute; wall 1–1.5 µm thick, lacking all traces of an epispore; contents usually guttulate, frequently also minutely granular. *Pycnidia* not seen. **Figs 6, 7.**

Chemistry: Thallus K–, C–, KC–, PD–, UV–; no substances detected by TLC.

Relationships: With a circumscription that has varied considerably over the last 30 years, *Megalaria* (including *Catillochroma* Kalb and *Lopezaria* Kalb & Hafellner) is recognised by its usually pale and variously crustose thallus with a unicellular green photobiont, large, mainly black apothecia lacking a thalline margin but with a thick proper excipulum of anticlinal hyphae, an amyloid hymenium with *Biatora*- or *Bacidia*-type asci or a variant of the *Lecanora*-type (*sensu* Hafellner 1984), simple, sparingly branched or somewhat anastomosing paraphyses, the apices with or without dark, pigmented caps, and 1-septate ascospores (Hafellner 1984; Ekman and Tønsberg 1996; Kantvilas 2008, 2016; Sanderson 2009; Fryday and Lendemer 2010; Fryday 2016). This almost cosmopolitan genus includes at least 35 species, and while most are corticolous, several are facultatively or exclusively saxicolous (Lendemer 2007; Kantvilas 2008; Sanderson 2009; Fryday 2016).

Megalaria montana has a thick, green, corticate and mainly granulose- or coralloid-isidiate thallus, large black apothecia with a blackish epihymenium, a hyaline or very pale hypothecium, a partly violet-grey to blue-black and partly hyaline, cupulate excipulum and moderately large 1-septate ascospores. Six other species, all known only from bark or epiphytic on bryophytes, have a granulose- or coralloid-isidiate thallus. *Megalaria brodoana* S.Ekman & Tønsberg, from north-western North America, has a bluish green thallus, a red-brown hypothecium and inner excipulum and broadly ellipsoid to almost subglobose ascospores of c. 17–21 × 9–11 µm (Ekman and Tønsberg 1996), while *M. bryophila* (Müll.Arg.) Elix from south-eastern Australia (Elix 2012), *M. bengalensis* Jagadeesh, Aptroot, G.P.Sinha & Kr.P.Singh from India (Jagadeesh Ram et al. 2007) and *M. spodophana* (Nyl.) D.J.Galloway from New Zealand (Galloway 2007) all have ascospores less than 20 µm long. The possibly pantropical *M. isidiza* (Makhija & Nagarkar) Fryday & Lendemer has considerably larger ascospores in 1- or 2-spored asci (Sipman 1983; Fryday and Lendemer 2010).

The recently described *M. orokonuiana* Fryday & A.Knight, from southern New Zealand, is rather similar to *M. montana* in outward appearance and in the dimensions of its ascospores. However, it has a very different pattern of apothecial pigmentation (Fryday and Knight 2012); the epihymenium is dark grey to blue-black and N+ red or violet, the upper hypothecial zone is reddish brown to dark chestnut-brown and N+ orange-brown or red-brown, while the cupulate excipulum has a hyaline, outer, basal zone and is bluish black within. It is reported here for the first time from Australia (see below).

Etymology: The epithet *montana* refers to the discovery of the new species on the upper slopes of Mount Canobolas, New South Wales.

Distribution and habitat: *Megalaria montana* is known only from weathered outcrops of hard trachytic rhyolite in montane heath with scattered *Eucalyptus* and *Acacia* below the summit of Mount Canobolas in central-western New South Wales. This habitat supports a diverse and distinctive saxicolous lichen flora including the recently described *Sarcogyne sekikaica* P.M.McCarthy & Elix (McCarthy and Elix 2014), along with *Acarospora fuscata* (Nyl.) Arnold, *A. veronensis* A.Massal., *Aspicilia* spp., *Buellia homophylia* (C.Knight) Zahlbr., several *Caloplaca* spp., *Candelariella vitellina* (Hoffm.) Müll.Arg., *Ingvariella bispora* (Bagl.) Guderley & Lumbsch, *Lecidea capensis* Zahlbr., numerous Parmeliaceae, *Pertusaria* spp., *Paraporpidia leptocarpa* (C.Bab. & Mitt.) Rambold & Hertel, *Ramboldia petraeoides* (Nyl. ex C.Bab. & Mitt.) Kantvilas & Elix, *R. plicatula* (Müll.

Arg.) Kantvilas & Elix, several species of *Rhizocarpon*, *Rimularia campestris* Kantvilas & Elix (reported here for the first time outside of Tasmania; *P.M. McCarthy 4482*, CANB), *Rinodina oxydata* (A.Massal.) A.Massal. and *Tephromela atra* (Huds.) Hafellner.

Additional specimen examined: c. 100 m from the type specimen, on weathered trachytic rhyolite in heath with scattered *Eucalyptus* and *Acacia*, *P.M. McCarthy 4481*, 6 Apr 2016 (CANB).

5. *Micarea eucalypti* P.M.McCarthy & Elix, **sp. nov.**

MycoBank No.: MB 817596

Characterized by a moderately thick, greenish, granular, corticolous thallus that lacks lichen substances, black, convex apothecia 0.21–0.42 mm diam. with a K– and C– hymenium, a hyaline hypothecium and 3-septate ascospores of 16–28 × 2.5–4 µm. Pycnidia produce either short-acicular microconidia 4–7 × c. 0.5 µm or elongate-filiform, (1–)3-septate macroconidia 12–22 × 0.5–1 µm.

Type: Australia. Australian Capital Territory: Namadgi National Park, Mt Scabby, summit, 35°45'08"S, 148°54'35"E, alt. 1809 m, on twigs of *Eucalyptus pauciflora*, *P.M. McCarthy 4200*, 9 Dec 2013; holotype: CANB.

Thallus crustose, epiphloeodal, diffuse or forming a continuous colony to 16 mm wide in microfissures in the twig surface, 80–140 µm thick, dull medium greenish grey to darker grey-green, granular and forming irregular and poorly defined areoles; granules 50–100(–130) µm wide, ±globose to tuberculate, ecorticate. *Algae* scattered or well-delimited and occupying a layer 50–80 µm thick; cells micareoid, yellowish green to grey-green, globose to subangular (when tightly aggregated), 5–8 µm wide. *Medulla* poorly defined; hyphae 2–3 µm wide, thin-walled. *Prothallus* absent. *Apothecia* dull black, adnate, rounded to irregular, solitary or in groups of 2–4, (0.21–)0.29(–0.42) mm diam. [*n* = 20]; disc smooth, moderately to strongly convex, epruinose; proper margin initially 15–25 µm thick, but scarcely visible in surface view, entire, concolorous with the disc, soon becoming excluded. *Proper excipulum* dark brown in section, 10–12(–15) µm thick laterally, 15–25 µm thick and paler brown at the base, partially subtending the hypothecium. *Hypothecium* hyaline, 60–90 µm thick, paraplectenchymatous, with cells 3–5 µm wide, not inspersed with granules or oil globules, K–, I+ blue. *Hymenium* 40–50 µm thick, not inspersed, I+ dark blue, K–, C–; upper parts greenish black, the pigmentation continuous with the epihymenium. *Epihymenium* dark olive-green to greenish black, 10–20 µm thick, K–, N–. *Paraphyses* loosely to tightly conglutinate, sparingly branched and anastomosed, long-celled, 0.8–1.2(–1.5) µm thick; apical cells not swollen. *Asci* narrowly to more broadly clavate, 40–58 × 9–13 µm, 8-spored, with an amyloid outer coat; tholus well-developed, predominantly amyloid, with a short, conical, ocular chamber subtending a non-amyloid, apical cushion that broadens distally. *Ascospores* colourless, irregularly massed in the ascus, 3-septate at maturity, narrowly oblong to oblong-fusiform or bacilliform, usually slightly or strongly curved, occasionally straight or faintly sigmoid, not constricted at the septa, (16–)21(–28) × (2.5–)3.2(–4) µm [*n* = 40], thin-walled, lacking a perispore; apices rounded to subacute. *Pycnidia* moderately numerous, semi-immersed and hemispherical to superficial and tuberculate, dark greenish grey to black, 40–80 µm diam.; conidiogenous layer simple or convoluted. *Conidia* of 2 types: microconidia short-acicular, simple, 4–7 × c. 0.5 µm, with pointed apices; macroconidia elongate-filiform, curved, arcuate, uncinate, sigmoid or otherwise contorted, (1–)3-septate, 12–22 × 0.5–1 µm, with rounded or subacute ends; mesoconidia not seen. **Fig. 8.**

Chemistry: Thallus K–, C–, KC–, PD–, UV–; no substances detected by TLC.

Relationships: The crustose lichen genus *Micarea* Fr. (Pilocarpaceae) is mainly northern-temperate in its distribution, with approximately 100 species growing on bark, rock and soil. Twenty-three taxa are known from Australia (McCarthy 2016), mostly at southern latitudes, but this diversity is likely to increase substantially as unresolved herbarium specimens are clarified and further collections become available.

Micarea eucalypti is a diminutive, but highly distinctive species. Ascomatal anatomy, pigmentation and lack of chemistry confirm its place in the *M. lignaria*–*M. ternaria* species group (Coppins 1983, 2009; McCarthy and Elix 2016) where it aligns with *M. lignaria* (Ach.) Hedl. var. *lignaria* by virtue of its narrowly elongate ascospores. However, the latter has longer ascospores with up to 7 septa, and the thallus contains argopsin. Ascospores of a rather similar shape and septation occur in *M. globulosella* (Nyl.) Coppins and *M. synotheoides* (Nyl.) Coppins, corticolous species with a very scattered Northern Hemisphere distribution (Coppins 1983, 2009). In contrast to *M. eucalypti*, both have a K+ violet upper hymenium, *M. globulosella* also has a C+ red upper hymenium (presumably due to the presence of gyrophoric acid), and the microconidia of both species are shorter and broader (Coppins 1983, 2009).

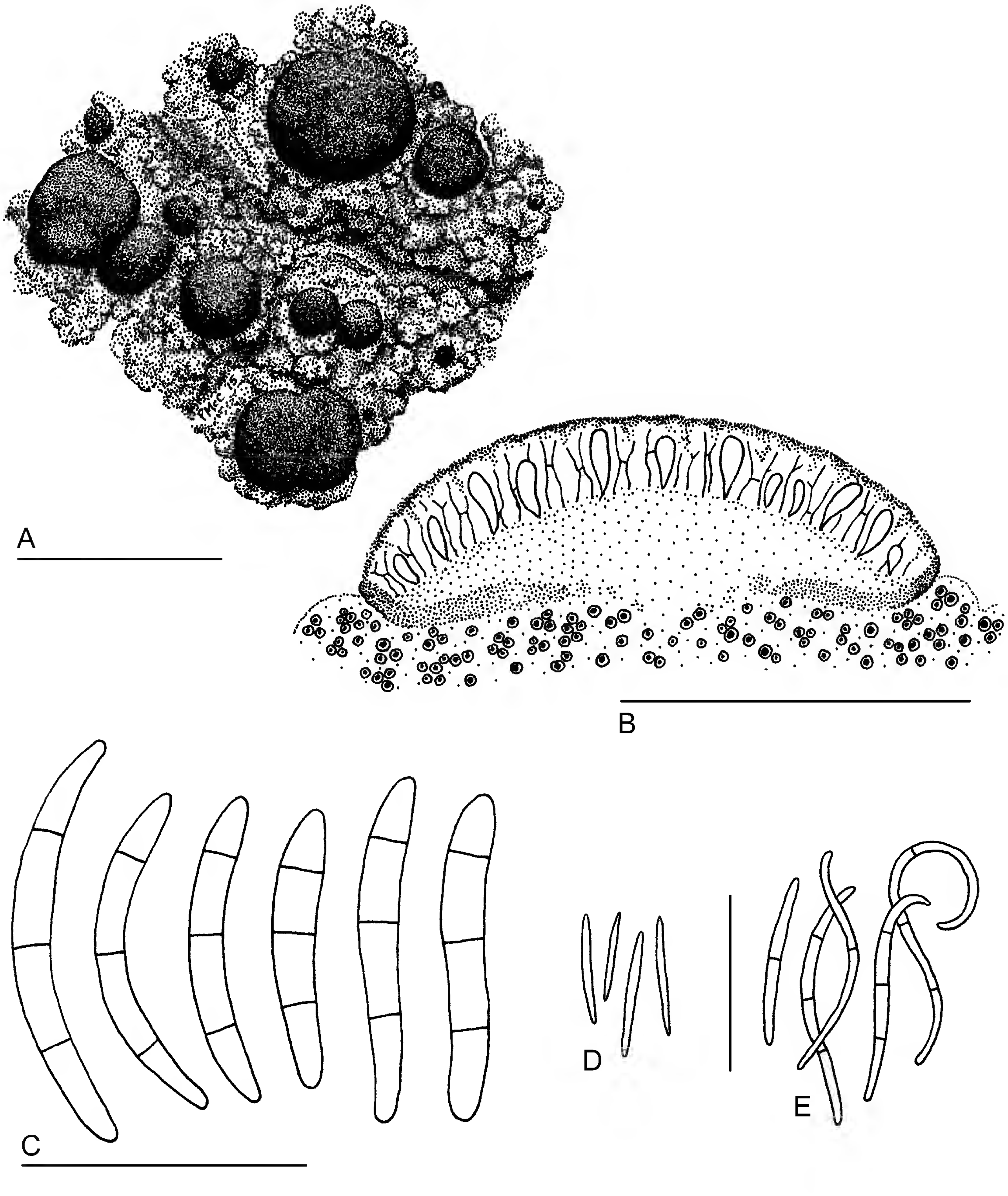

Fig. 8. *Micarea eucalypti* (holotype). A, habit of thallus, apothecia and pycnidia; B, sectioned apothecium (semi-schematic); C, ascospores; D, microconidia; E, macroconidia. Scale bars: A = 0.5 mm; B = 0.2 mm; C–E = 10 μm.

Etymology: The epithet *eucalypti* refers to the host tree of the new species, *Eucalyptus pauciflora*.

Distribution and habitat: *Micarea eucalypti* is currently represented only by the small type specimen that grew on a centimetre-wide twig of snowgum (*Eucalyptus pauciflora*) on the summit of Mount Scabby near the southern border of the Australian Capital Territory. These twigs support a surprisingly diverse community of lichens in an environment not ideally suited to corticolous species or their hosts (McCarthy 2015). Species on twigs of the same and nearby trees at the type locality include *Caloplaca wilsonii* S.Y.Kondr. & Kärnefelt, *Candelariella xanthostigma* (Ach.) Lettau, *Lecidella destituta* Kantvilas & Elix, *L. xylogena* (Müll.Arg.) Kantvilas & Elix, *Ramboldia laeta* (Stirt.) Kalb, Lumbsch & Elix and *R. stuartii* (Hampe) Kantvilas & Elix. A careful examination of hundreds of snowgum twigs from the summit areas of Mount Scabby, Mount Murray, Mount Ginini, Mount Bimberi and Sentry Box Mountain in the southern A.C.T., and among the subalpine vegetation on Mount Canobolas in the Central Tablelands of N.S.W. failed to yield further collections of *M. eucalypti*.

New Record for Australia

Megalaria orokonuiana Fryday & A.Knight, *Australasian Lichenology* 70: 27 (2012)

Type: New Zealand. South Island: Otago: Dunedin, Orokonui Ecosanctuary, 45°46'S, 170°36'E, alt. 236 m, on bark at base of trunk in kanuka grove, *A. Knight s.n.*, 12 Jul 2010; holotype: OTA 60695 *n.v.*; isotypes: CANB!, MSC *n.v.*

Thallus crustose, epiphloeodal, olivaceous, grey-brown or pale greyish green, (0.05–)0.2–0.5(–1) mm thick, granulose-isidiate to coralloid-isidiate. *Photobiont* chlorococcoid; cells mostly globose, 5–10(–12) µm wide. *Medulla* loose, almost byssoid in places; hyphae variously orientated, long-celled, 4–6 µm wide. *Prothallus* thin and white, or not apparent. *Apothecia* sparse to numerous, rounded or slightly irregular in outline, adnate or basally constricted, uniformly dull black, rarely with slightly paler patches, (0.5–)1.5(–2.7) mm diam. [*n* = 50], usually solitary and scattered, occasionally clustered; proper margin often prominent, entire or flexuose, persistent or becoming excluded around the most convex apothecia; disc initially slightly concave or plane, becoming slightly to moderately convex, smooth, epruinose. *Proper excipulum* cupulate in section, 50–150 µm thick laterally, 100–180 µm thick at the base, laterally uniformly dark violet-grey to blue-black, or pigmented internally and with hyaline outer layer 10–25 µm thick; basal excipulum bilayered, internally blue-black and 50–80 µm thick, externally hyaline and 20–50 (–70) µm thick; hyphae radiating outwards laterally and downwards basally, anastomosing, tightly coherent, very thick-walled; pigmented parts K+ greenish blue or green, H+ bluish, N+ violet or purple. *Hypothecium* bilayered, not inspersed with oil globules or granules; upper layer of compacted hyphae, dark reddish brown or chestnut-brown, 50–100(–150) µm thick, K+ slightly darker or purple-brown, N+ red or deep red-brown; lower layer of loose, randomly orientated hyphae, hyaline to pale brown, 80–160 µm thick. *Hymenium* 120–180 µm thick, not inspersed. *Epihymenium* dark olive-grey to blue-black, 10–20(–25) µm thick, K+ blue-green or blue-grey, H+ deep blue, I–, N+ violet or red. *Paraphyses* simple, 1–1.5(–2) µm thick, separating in K but conglutinate at the epihymenium; apices not or only slightly swollen, with a cap of dark olive-grey to blue-black pigment. *Asci* narrowly clavate to clavate-cylindrical, ± *Biatora*-type, mostly 8-spored, occasionally with 2–4 spores aborted, 100–125 × 27–35 µm. *Ascospores* narrowly ellipsoid or oblong-ellipsoid, rarely more broadly ellipsoid, 1-septate, hyaline, straight or slightly curved, (20–)31(–41) × (9–)14(–17) µm [*n* = 115]; apices rounded or subacute; wall 1–2(–3) µm thick. *Pycnidia* not seen.

Chemistry: Thallus K–, C–, KC–, PD–, UV–; no substances detected by TLC.

Relationships: For a comparison with other isidiate species of *Megalaria*, see the discussion of *M. montana* (above).

Distribution and habitat: Previously known only from bark at the type locality in southern New Zealand (Fryday and Knight 2012), *Megalaria orokonuiana* is reported here from forest trees in the Northern and Southern Tablelands of New South Wales and from the Gippsland Plain and East Gippsland, Victoria.

Additional specimens examined: NEW SOUTH WALES: Northern Tablelands: Barrington Tops Forest Road, Barrington Tops State Forest, 42 km WNW of Gloucester, 31°55'S, 151°30'E, alt. 1340 m, on bark of Proteaceae species in disturbed *Nothofagus* forest bordering *Eucalyptus* forest, *J.A. Elix 24874*, 26 Apr 1990 (CANB); Southern Tablelands: along the Mongarlowe River, 3.5 km S of Monga, 35°37'S, 149°55'E, alt. 665 m, on bark of *Leptospermum* sp. in wet-sclerophyll forest, *J.A. Elix 30247*, 19 Sep 1993 (CANB). **VICTORIA:** East Gippsland: Spring Creek, 1 km W of Buchan, 37°30'S, 148°10'E, alt. 250 m, on stem of *Telopea* sp. in disturbed wet-sclerophyll forest in valley, *J.A. Elix 39755*, 2 Oct 1988 (CANB); Gippsland Plain: Fosters Gully Nature Walk, Morwell National Park, c. 16 km S of Morwell, on bark in wet-sclerophyll forest, *I.M. Chang 4*, 2016 (CANB).

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We are grateful to Dr Gintaras Kantvilas for the specimen of *Eugeniella tasmanica*. Dr Allison Knight kindly provided an isotype of *Megalaria orokonuiana*, and Ms I Mei Chang contributed a Victorian specimen of the same species. *Micarea eucalypti* was collected during a Bush Blitz survey of the southern A.C.T. co-funded by the Australian Government and BHP Billiton.

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Lysimachia nummularia (Primulaceae) naturalised in New South Wales, Australia

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Abstract

In November 2015 the first naturalised collection of *Lysimachia nummularia* L. (Primulaceae) was made for New South Wales from the Apsley River in the Northern Tablelands. This creeping, perennial herb is native to Eurasia and previously recorded as naturalised in Australia in Victoria and Tasmania. It has the potential to be an invasive weed, particularly in wetland and other damp habitats. A description of *L. nummularia* is provided as well as a key to *Lysimachia* taxa occurring in New South Wales.

Introduction

Lysimachia nummularia L. (Primulaceae), commonly known as Creeping Jenny or Moneywort, is a creeping perennial herb native to Eurasia where it grows near water bodies and in swamps and other damp habitats. Introduced to North America, where it is an invasive species in some areas, it aggressively spreads in favourable conditions such as wet ground and near water bodies. In Australia, *L. nummularia* has previously been recorded as naturalised in Victoria (Walsh 1996) and Tasmania (Curtis 1967). The earliest herbarium specimen was collected in 1884 from Sandhurst near Bendigo, Victoria (MEL; CHAH 2016a), although whether or not the specimen is from a naturalised or cultivated plant is unknown; the second herbarium collection, made in 1955, is from near Macquarie River at Ross, Tasmania (HO; CHAH 2016a). Most subsequent specimens are likely to be from naturalised plants and were collected from the 1980s onwards. It has now been found naturalised in New South Wales with a collection made by RWJ in November 2015 from the Apsley River in the Northern Tablelands.

Lysimachia taxa in New South Wales have previously been described by Makinson (1990), Kodela (2006) and Kodela et al. (2014). This paper provides an account of the first naturalised record and weed alert of *Lysimachia nummularia* in the State, providing information for its presence in New South Wales for the *Australian Plant Census* (CHAH 2016b).

Methods

The description of *Lysimachia nummularia* is based on morphological observation and assessment of specimens from Australia, Europe and the United States of America held at NSW, and from images provided by HO and MEL. Additional data was obtained from Australian flora treatments, including Walsh (1996).

Botanical regions cited for New South Wales follow those of Anderson (1961) and Jacobs and Pickard (1981), and Walsh (1996) for Victoria.

Description

Lysimachia nummularia L., *Species Plantarum* 1: 148 (1753)

Lysimachusa nummularia (L.) Pohl, *Tentamen Florae Bohemicae. Prag* 1: 163 (1809); *Ephemerum nummularia* (L.) Schur, *Enumeratio Plantarum Transsilvaniae* 549 (1866)

?*Lysimachia zawadzkii* Wiesn., *Oesterreichisches Botanisches Wochenblatt. Gemeinnütziges Organ für Botanik* 4: 257 (1854)

Creeping, stoloniferous perennial herb; stems prostrate, rooting at nodes, to 40 cm or more long, grooved, narrowly winged (wings decurrent along stem), glabrous, with scattered minute reddish glandular dots and short streaks (papillae). Leaves opposite; lamina (ovate–) broadly ovate to orbiculate, with round or ± cordate base, entire, mostly 10–25 (–35 in lit.) mm long and (5–) 10–26 (–35 in lit.) mm wide (sometimes wider than long), glabrous, minutely dotted with reddish or orange-brown sessile glands; petiole (1–) 2–6 mm long, glabrous, narrowly winged, shallowly grooved adaxially. Flowers simple, solitary in leaf axils, axillary (although solitary in leaf axils they often appear as pairs from the stem nodes where the opposite leaves meet); pedicel 5–35 mm long, glabrous, without a basal bract; sepals 5(6), virtually free, green, 4–10 mm long, 3–7 mm wide, ovate with acute (to acuminate) apex, cordate base, scattered minute sessile glands; petals 5(6), shortly fused (united at base forming short corolla tube), exceeding the sepals, ovate, c. 10–15 mm long, yellow, glandular-spotted, margin minutely glandular puberulent, apex acute or obtuse/rounded; stamens 5(6); filaments often minutely glandular puberulent. Capsule globose or subglobose, 2–3(–4) mm diam., much shorter than persistent calyx, longitudinally dehiscing from apex by 5 valves, many-seeded. **Fig. 1a, b**.

Phenology: Flowering mostly in summer; November–February (–April) in Australia, c. June–July in Northern Hemisphere.

Common names: Creeping Jenny, Moneywort, Creeping Loosestrife, Herb Twopence, Twopenny Grass, Creeping Penny, Wandering Jenny, Creeping Charlie, Yellow Myrtle.

Habitat: in the Northern Hemisphere grows on margins of water bodies, on stream and river banks, floodplains, in wetlands, wet meadows, forests, on wet ground, ditches; also a weed in lawns, parks, ponds, pastures, yards and waste ground (Cholewa 2009, Innes 2011, Cao and Berent 2014, NatureGate 2016). In New South Wales only recorded as occasional on basalt, growing in a wet river bed among *Schoenoplectus* sp. and *Bulboschoenus* sp., with *Potamogeton australiensis* and *Azolla* sp. occupying deeper pools (**Fig. 1c**).

Distribution: Native to Eurasia; naturalised in North America (including Canada and the United States of America), New Zealand and south-eastern Australia, as well as sometimes escaping from cultivation as a weed in Europe. In Australia, *Lysimachia nummularia* is naturalised in north-east Tasmania, central-south Victoria, and now known from a single locality at Apsley River in the Northern Tablelands of New South Wales.

Specimens examined: AUSTRALIA: NEW SOUTH WALES: NORTHERN TABLELANDS: Apsley River, c. 150 m W of Apsley Falls carpark, *R.W. Jobson 3018*, 11 Nov 2015 (CANB, NE, NSW848185). **VICTORIA: EASTERN HIGHLANDS**: Millgrove, W side of Warburton Highway, *J.C. Reid 2399*, 5 Dec 2000 (MEL2089344); **VICTORIAN VOLCANIC PLAIN**: Ballarat, northwest side of Lake Wendouree, *V. Stajsic 3648*, 22 Feb 2004 (MEL2280562); **VICTORIAN MIDLANDS**: Sandhurst, *R. Thom 14*, 1884 (MEL2234755). **TASMANIA: MIDLANDS:** West Tamar Fitness Trail, *R. Schahinger s.n.*, 7 Feb 2002 (HO521685), Mersey River at Kimberley, *P. Milner s.n.*, 17 Feb 2002 (HO521686), Macquarie River at Ross bridge, *M. Allan s.n.*, 12 Feb 1981 (HO515542); **NORTH EAST**: Ringarooma River, *M. Wapstra 136*, 27 Jan 2007 (HO555073). **U.S.A.: ILLINOIS**: Naperville, *L.M. Umbach s.n.*, 13 Jul 1897 (NSW). **HOLAND: VULKENBURG**: near Wassenaar prov, *P. van Ryen s.n.*, 27 Jun 1947 (NSW); **RIJSENBURG**: Utrecht, Beverweert Castle, *R.C. Bakhuizen s.n. & D. Brink*, 5 Jul 1937 (NSW); **KRANENBURG**: Den Haag, *M.R.S. Boetje van Ruyven s.n.*, 1899 (NSW). **DENMARK**: Peninsula Mols, Kalo, *L. Holm-Nielsen s.n. & S. Jeppesen*, 18 Jul 1969 (NSW). **ROMANIA**: Transilvania district, *E.I. Nyarady s.n.*, 5 Jul 1929 (NSW). **UNITED KINGDOM**: **GLOUCESTERSHIRE**: Dursley *s.n.*, 12 Jul 1850 (NSW).

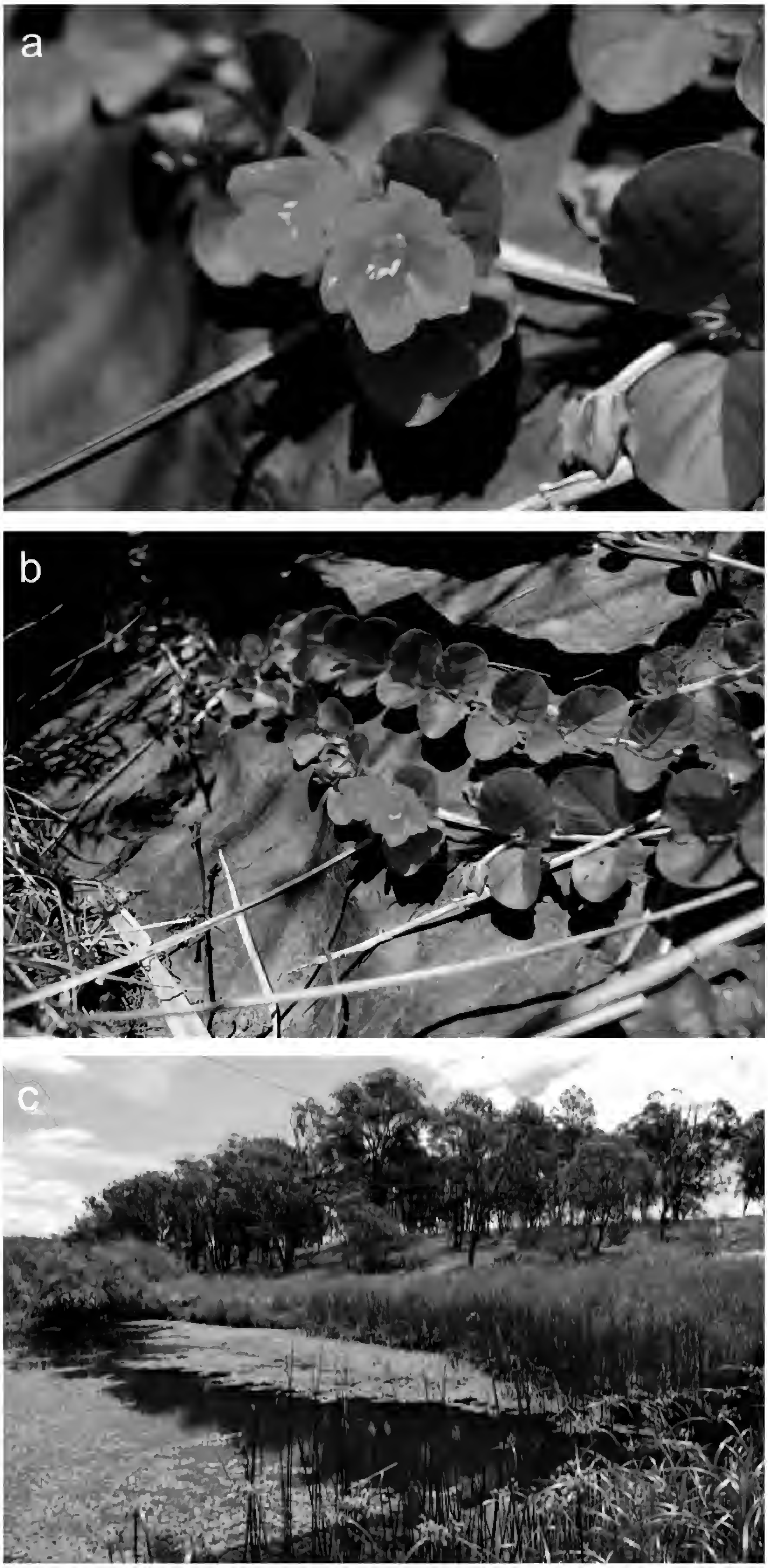

Fig. 1. *Lysimachia nummularia* in situ at Apsley River, Northern Tablelands: **a**, flowers and developing fruit capsule; **b**, trailing habit; **c**, river bed habitat. Images represent specimen and habitat of *R.W. Jobson 3018*.

Weed status: *Lysimachia nummularia* was introduced to North America where it is a naturalised invasive weed species (Innes 2011, Randall 2002, 2012 and references therein). In Australia it has been reported as a weed in Tasmania and sparingly naturalised in Victoria (Randall 2002, CHAH 2016b, Richardson et al. 2011), and although only recently recorded in New South Wales it has the potential to be distributed to other wetland habitats, with the ability to spread vegetatively via fragmentation within waterways especially during flooding. Once established, under favourable conditions, it can spread rapidly as a groundcover and form dense mats that crowd out or outcompete with native species, as seen in places overseas where it has become a significant weed (references herein). Hence, this species has the ability to form monocultures and reduce biodiversity. If seeds are produced they could be spread via water, although it appears that seeds are often not produced, e.g. North American populations of *L. nummularia* rarely, if ever, produce capsules (Cholewa 2009). In North America and New Zealand, plants most commonly reproduce vegetatively with dispersal mostly by stem fragments spread by water movement, deliberate planting, or garden discards (Innes 2011, Champion and Hofstra 2014).

The origin/source of the plants at Apsley River is unknown, however the species has often been introduced as an ornamental for water gardens, borders, containers and a dense groundcover for moist areas, from where it can become a garden escapee. The collection site is c. 150 m from the carpark for the popular tourist attraction Apsley Falls, and close to a walking track from which seed or propagules may have been introduced. *Lysimachia nummularia* has been developed and distributed as a horticultural ornamental groundcover and is available in Australia for cultivation from nurseries, including online suppliers, especially cultivars such as 'Aurea', 'Gold Clusters' and 'Golden Creeping Jenny'; often promoted for the plant's attractiveness, cascading habit, ability to grow rapidly in moist areas, and ease of propagation via cuttings.

Lysimachia nummularia is not listed as a declared noxious or invasive weed species in New South Wales. However, the species has the ability to become a potential problem weed, as indicated by its status as a sleeper weed species (Randall 2001, WWF 2006), and its inclusion in national and international weed lists (e.g. Randall 2007, HEAR 2015). This alert to the presence of a naturalised population of *Lysimachia nummularia* in New South Wales is a step towards increasing awareness of its presence in natural habitats and will assist in the identification and control of other naturalised occurrences.

Key to the *Lysimachia* taxa of New South Wales

(Modified from Kodela 2006)

1 Flowers yellow 2

1: Flowers white to pinkish 4

2 Stems ± prostrate; leaves ovate to broadly ovate or ± spatulate or orbiculate, to 3.5 cm long; flowers simple 3

2: Stems erect; leaves elliptic to narrowly elliptic, lanceolate or oblanceolate, mostly 4–9 cm long; flowers in panicles or racemes .... ***L. vulgaris*** **var.** ***davurica***

3 Stems and leaves with hyaline, septate hairs; corolla close to or barely exceeding length of the calyx; sepals and peduncles with hairs .... ***L. japonica***

3: Stems and leaves glabrous; corolla distinctly exceeding the calyx; sepals and peduncles glabrous .... ***L. nummularia***

4 Leaves not fleshy; pedicels 1–5 mm long; petals white to pinkish .... ***L. fortunei***

4: Leaves slightly fleshy; pedicels usually 5–15 mm long; petals white .... ***L. mauritiana***

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Additional taxa and new reports in the genus *Pertusaria* (Pertusariales, lichenised Ascomycota) from Queensland and Norfolk Island (Australia)

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Abstract

Five new species, *Pertusaria dayi*, *P. glabra*, *P. heinarii*, *P. montoensis*, *P. stenospora* and a new combination, *Pertusaria aphelospora*, are reported from Australia. In addition, *Pertusaria phulhuangensis* described from Thailand, *P. karkarensis*, described from Papua New Guinea, and *P. virensica,* described from Florida, are reported from Australia for the first time.

Introduction

The lichen genus *Pertusaria* in Australia has been studied for over 150 years, since G.W. Körber, Professor of Botany, Breslau [now Wrocław, Poland] described *Pertusaria lophocarpa* from Victoria (Körber 1862). From that time additional species have been reported from Australia by, for example, Stirton (1876), Müller (1882), Knight (1882), Kantvilas (1990) and Archer (1991). A recent account of the genus in Australia (Archer & Elix 2016) listed 170 taxa, including 12 varieties. Worldwide the number of taxa in the genus is not known with any certainty but an estimate of 1,550 has been suggested (Messuti & Archer 2009) based on various combinations of the characters used for the systematic separation of the taxa, such as chemistry, morphology and ascospore number and structure. The lichen compounds, such as xanthones, depsides and depsidones that may be present in a specimen, are important characteristics for identification. Accounts of the genus in Japan (Oshio 1968) and North America (Dibben 1980) used chemistry extensively for identification.

The genus has been divided into 3 subgenera; *Monomurata*, *Pionospora* and *Pertusaria* (Archer 1997) but recent molecular work on the phylogeny of *Pertusaria* and allied taxa indicate that *Pertusaria* is polyphyletic, comprising three well-supported clades viz: (1) *Pertusaria* sens. str. group (including the subgenera *Pertusaria* and *Pionospora*); (2) *Monomurata* group; and (3) *Varicellaria* group (Schmitt 2002; Schmitt & Lumbsch 2004). The two subgenera, *Pertusaria* and *Monomurata*, are distinguished by the morphology of the apothecia (verruciform in *Pertusaria* and disciform in *Monomurata*) and chemistry (chloroxanthones sometimes present in *Pertusaria* and absent in *Monomurata* and β-orcinol depsides absent from *Pertusaria* and present in *Monomurata*). The morphology and chemistry [except *P. heinarii*] of the new species indicate that they belong in subgenus *Pertusaria* sens. str.

Materials and Methods

The specimens studied were collected in northern Queensland by J.A. Elix, H. Streimann and H.T. Lumbsch in the 1990's and on Norfolk Island by H. Streimann in 1984. The specimens are held in CANB. In the present work chemical constituents were identified by thin-layer chromatography (Elix 2014), and by comparison with authentic samples. Specimens were photographed at a magnification of ×4 with a Canon EOS 450D camera fitted with a Canon MP-E65 mm, F2.8 1–5× lens.

New Taxa

1. *Pertusaria aphelospora* (A.W. Archer) A.W. Archer & Elix, **comb. nov.** MycoBank no. 817381

Basionym: *Pertusaria wilsonii* var. *aphelospora* A.W. Archer, *Mycotaxon* **41**: 251 (1991).

Type: Australia, Queensland, Black Mountain, 25 km NW of Kuranda, 16°40'S, 145°29'E, alt. 500m, on *Acacia*, *J.A. Elix 17507*, 7 Jul 1984 (holotype: CANB).

Thallus corticolous, pale olive-green; surface smooth and cracked, corticolous, lacking isidia and soredia. Apothecia verruciform, numerous, crowded, flattened-hemispherical, rarely confluent, concolorous with the thallus, 0.4–0.8 mm diam. Ostioles inconspicuous, black-punctiform, *c.* 0.1 mm diam., 1–2 per verruca. Asci 2-spored. Ascospores elongate-ellipsoid, hyaline, with smooth inner walls, 100–112 µm long and 30–35 µm wide. **Figs 1 & 2**.

Chemistry: protocetraric acid (major) ± 4,5-dichlorolichexanthone (minor).

Additional specimens examined: Queensland, Leichardt Highway, 8 km NNW of Taroom, 25°35'S, 149°46'E, alt. 200 m, on tree trunk in poor monsoon forest, *J.A. Elix 35076*, 30 Aug 1993 (CANB); Isla Gorge National Park, 27 km NNE of Taroom, 25°10'S, 149°59'E, alt. 220 m, on fallen branch in dry monsoon scrub with *Brachychiton* on gently sloping terrace above stream, *J.A. Elix 35114*, 31 Aug 1993 (CANB). Further specimens were listed in Archer (1991).

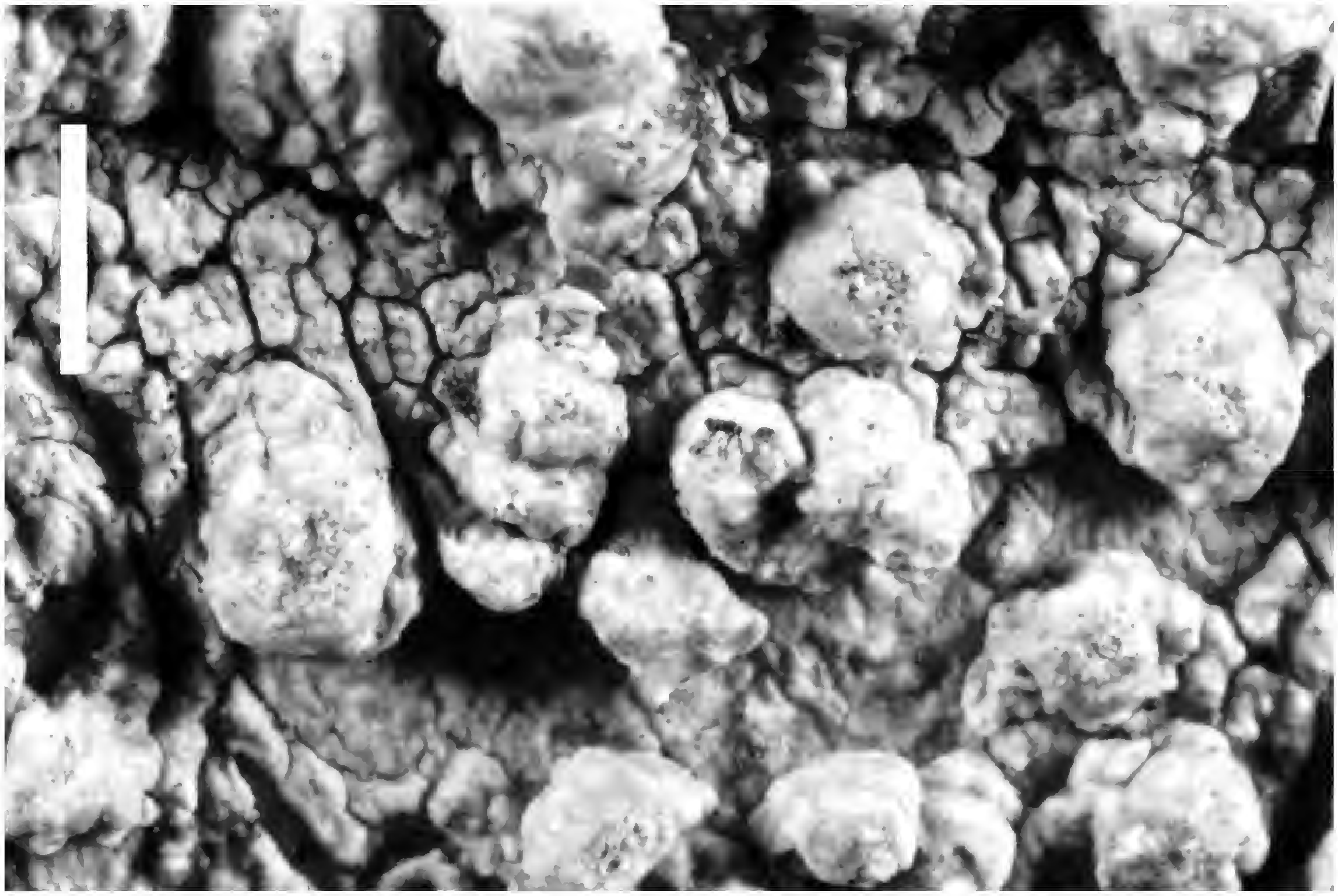

Fig. 1. *Pertusaria aphelospora* (A.W. Archer) A.W. Archer & Elix; *Elix 35076* (CANB); bar = 1 mm.

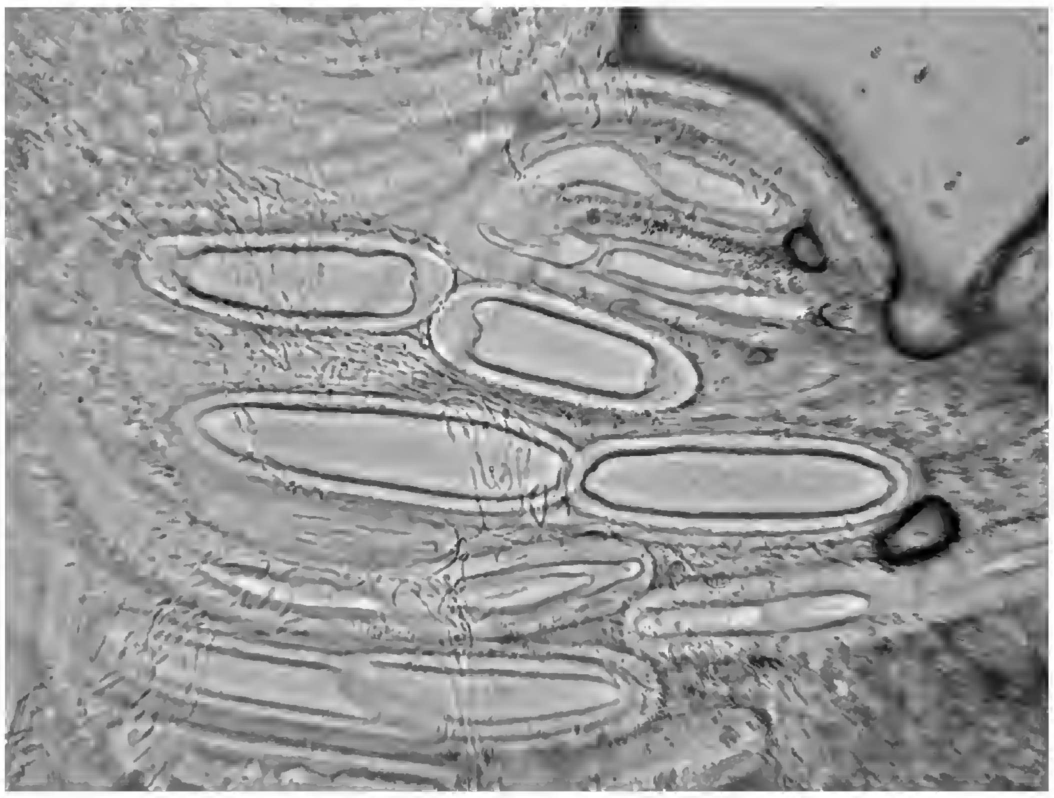

Fig. 2. *Pertusaria aphelospora* (A.W. Archer) A.W. Archer & Elix; *Elix 35076*; ascospores (CANB).

Relationships: *Pertusaria wilsonii* var. *wilsonii* and *P. wilsonii* var. *aphelospora* were published in the same paper (Archer 1991). Subsequently *P. wilsonii* var. *wilsonii* was found to be a later name for *P. thwaitesii* Müll. Arg., a species characterised by the presence of protocetraric acid and bisporous asci, the ascospores having rough inner walls. Although *P. wilsonii* var. *aphelospora* also has 2-spored asci, the ascospores differs in having smooth inner walls, and this taxon lacks the multi-ostiolate, flattened apothecia present in *P. thwaitesii* (Fig. 3).

Protocetraric acid is widely distributed in the genus *Pertusaria*; it is found as the sole lichen compound present in the following fertile species: *P. thwaitesii* Müll. Arg., *P. huanicola* Messuti & A.W. Archer, from Argentina, in *P. errinundrensis* A.W. Archer and *P. lacericans* A.W. Archer from Australia, *P. leeuwenii* Zahlbr. from Indonesia, *P. composita* Zahlbr. from Japan, *P. macloviana* Müll. Arg., from South America and *P. pseudoparotica* Sipman from Greece, and in the sterile species, *P. acroscyphoides* Sipman, *P. corallophora* Vain., *P. leucosora* Nyl. and *P. umbricola* A.W. Archer & Elix.

Fig. 3. *Pertusaria thwaitesii* Müll. Arg.; *A.W. Archer P177* (NSW); bar = 1 mm.

Distribution: *Pertusaria aphelospora* has been found in eastern New South Wales and eastern Queensland.

Etymology: The epithet *aphelospora*, is derived from the Greek *apheles* (smooth), and Greek *spora* (a seed), a reference to the smooth-walled ascospores present in this species.

2. *Pertusaria dayi* A.W. Archer & Elix, sp. nov. MycoBank no. 817382

Similar to *Pertusaria dussii* Vain. but differs in having smaller ascospores with smooth walls.

Type: Australia, Queensland, Finch Hatton Gorge, 21°07'S, 148°38'E, alt. 750 m, on dead wood in tropical rainforest, *M.F. Day 87.21*, Jul 1987 (holotype: CANB).

Thallus corticolous, pale greyish green; surface glossy and somewhat cracked, lacking isidia and soralia. Apothecia verruciform, conspicuous, scattered, concolorous with the thallus, flattened-hemispherical, conspicuously concave, 0.9–1.5 mm diam. Ostioles inconspicuous, black, punctiform, 2–4 per verruca. Asci 4-spored. Ascospores ellipsoid, hyaline, with smooth inner walls, 75–82 µm long and 30–32 µm wide. **Figs 4 & 5**.

Fig. 4. *Pertusaria dayi* A.W. Archer & Elix; *M.F. Day 87.21* (holotype: CANB); bar = 1 mm.

Fig. 5. *Pertusaria dayi* A.W. Archer & Elix, showing ostioles; *M.F. Day 87.21* (holotype: CANB); bar = 1 mm.

Chemistry: stictic acid (major) and menegazziaic acid (minor).

Relationships: *Pertusaria dayi* is characterised by large, concave, verruciform apothecia, asci with four ascospores and the presence of stictic acid. The new species is somewhat similar to *P. dussii* (Fig. 6) in that both have large verruciform apothecia and contain stictic acid. However, the asci in *P. dussii* can contain 2–8 ascospores and the spores differ from those of *P. dayi* in having rough inner walls and being up to 125 µm long (Vainio 1899). *Pertusaria aspera* Müll. Arg. from East Africa (Müller 1885) is also somewhat similar to *P. dayi*; this species has asci with 2–4 ascospores per ascus, *c.* 80 µ long and 30 µm wide, but differs in the smaller apothecia (Fig.7), and it contains constictic acid as the major lichen acid.

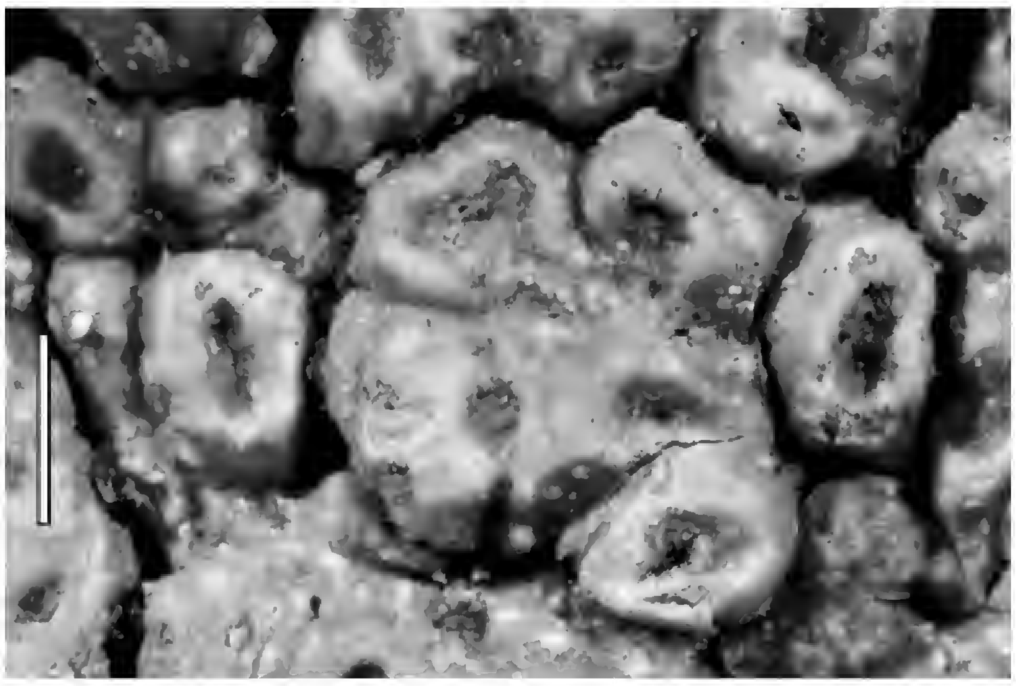

Fig. 6. *Pertusaria dussii* Vainio; *P. Dussi 561*, (holotype: TUR-V 6873); bar = 1 mm.

Fig.7. *Pertusaria aspera* Müll. Arg.; *Hildebrandt 2350* (holotype: G); bar = 1 mm.

Distribution: At present this new species is known only from the type collection at Finch Hatton Gorge, Queensland.

Etymology: The species is named after the collector, Dr M.F. Day.

3. *Pertusaria glabra* A.W. Archer & Elix, **sp. nov**. MycoBank no. 817383

Similar to *Pertusaria subisidiosa* A.W. Archer but differs in having smaller ascospores and in lacking isidia.

Type: Australia, Queensland, Mount Archer Environmental Park, 8 km NE of Rockhampton, 23°20'S, 152°34'E, alt. 780 m, on dead wood in dry sclerophyll forest on moderately steep slope, *J.A. Elix 34490*, 24 Aug 1993 (holotype: CANB; isotype: B)

Thallus corticolous, off-white to pale grey; surface smooth and dull; isidia and soredia absent. Apothecia verruciform, conspicuous, scattered, not confluent, sessile, flattened-hemispherical, concolorous with the thallus, 0.6–1 mm diam. Ostioles conspicuous, black, 1 per verruca, 0.2–0.5 mm diam. Asci (2–)3–4-spored.

Ascospores ellipsoid, hyaline, with rough inner walls, 55–75 µm long and 20–35 mm wide, or when 2 per ascus [in the same apothecium], 95–100 µm long and 25–30 µm wide. **Figs 8 & 9**.

Fig. 8. *Pertusaria glabra* A.W. Archer & Elix; *Elix 34490* (holotype: CANB).

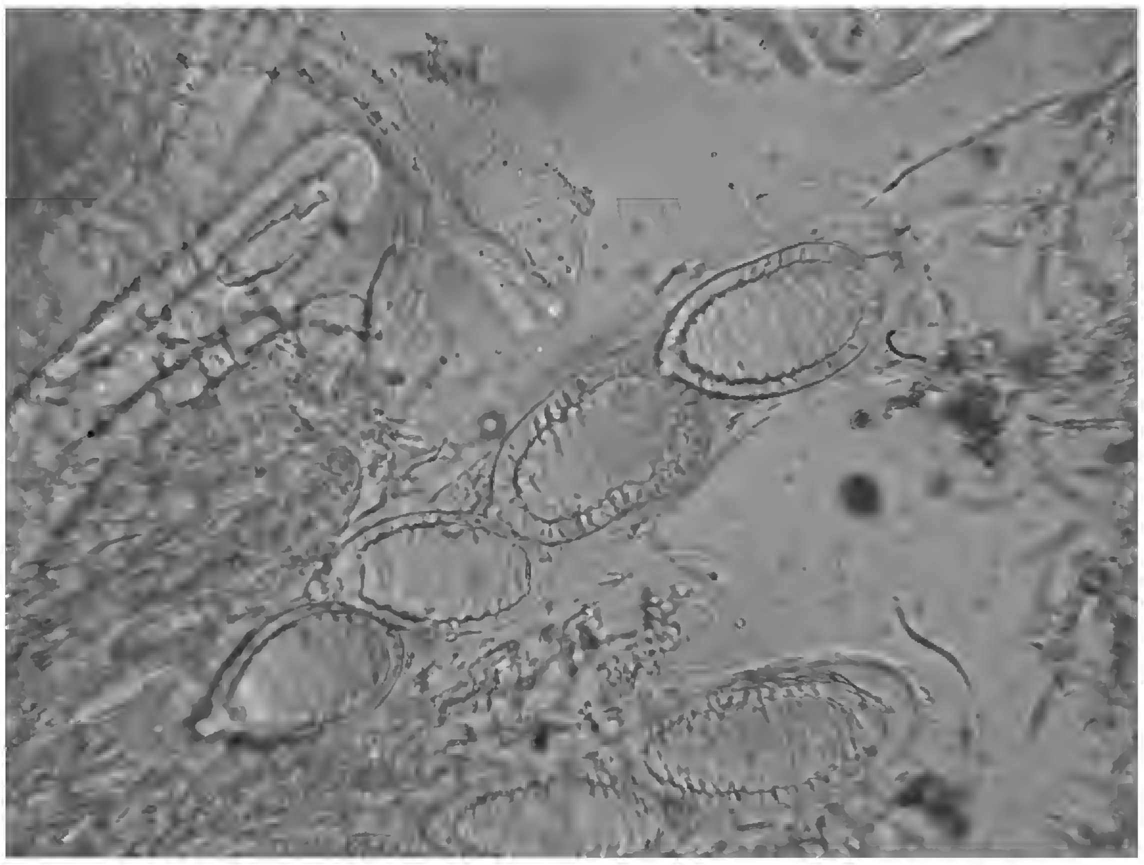

Fig. 9. *Pertusaria glabra* A.W. Archer & Elix; ascospores, *Elix 34490* (holotype: CANB).

Chemistry: 2,4-dichlorolichexanthone (minor), 2,5-dichlorolichexanthone (minor), 2,4,5-trichlorolichexanthone (minor) and stictic acid (major).

Relationships: The new species is characterised by the conspicuous black ostioles, asci with (2–)3–4 rough-walled ascospores and by its chemistry. The lichen substances are identical to those present in *P. subisidiosa*

(Archer 1991) (Fig. 10) and the ascospores are similar, in having rough inner walls. However, the ascospores are shorter than in *P. subisidiosa* (80-95 µm long) and thallus lacks isidia. Superficially the new species resembles *P. nebulosa* A.W. Archer (Archer in Elix *et. al.* 1992) (Fig. 11) but the latter can be distinguished by the smooth-walled ascospores and the absence of lichen compounds.

Distribution: At present this species is known only from the type specimen.

Etymology: The epithet *glabra*, is derived from the Latin *glaber*, (smooth), in reference to the smooth upper surface that lacks isidia.

Fig. 10. *Pertusaria subisidiosa* A.W. Archer; *Archer P382* (NSW); bar = 1 mm.

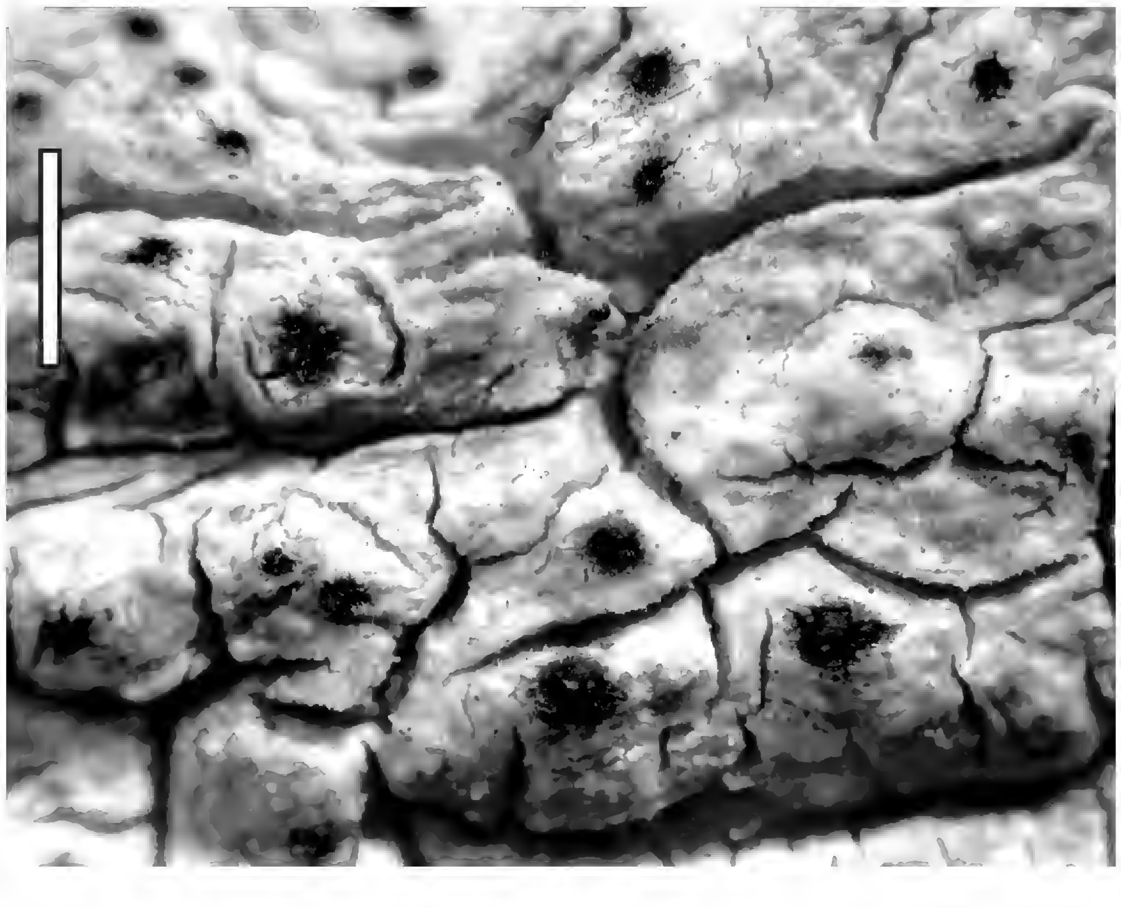

Fig. 11. *Pertusaria nebulosa* A.W. Archer; *Elix 18389* (holotype: CANB); bar = 1 mm.

4. *Pertusaria heinarii* A.W. Archer & Elix, **sp. nov.** MycoBank no. 817384

Similar to *Pertusaria salebrosa* A.W. Archer & Elix but differs by having larger soralia, by lacking lichen substances and by growing on bark.

Type: Norfolk Island, King Fern Valley, Mount Pitt Reserve, 29°01'S, 167°52'20"E, alt. 260 m, on treelet stem in poor lowland forest with palm regrowth, *H. Streimann 34519*, 7 Dec 1984 (holotype: CANB)

Thallus corticolous, pale olive-green; surface smooth, slightly cracked, isidia absent. Soralia white, numerous, scattered, rarely confluent, sessile, subglobose, 0.6–1 mm diam. Apothecia and ascospores not seen. **Fig. 12.**

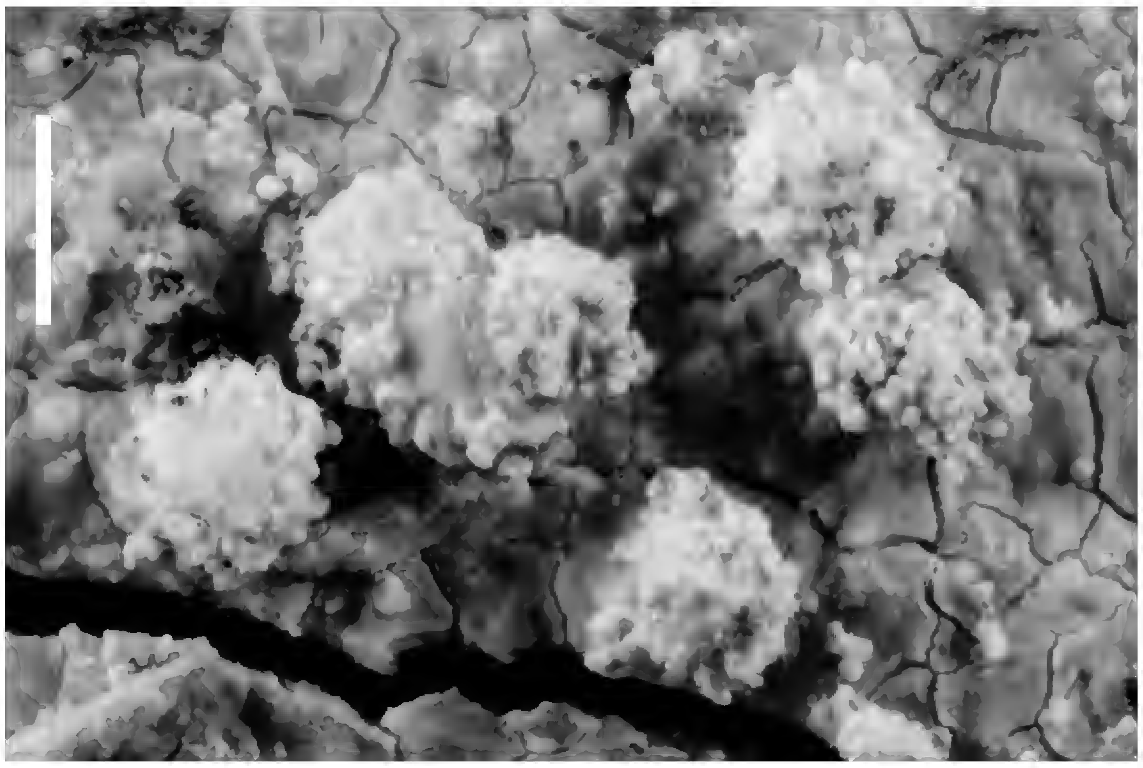

Fig. 12. *Pertusaria heinari* A.W. Archer & Elix; *Streimann 34519* (holotype: CANB); bar = 1 mm.

Chemistry: no lichen substances detected.

Relationships: *Pertusaria heinarii* is characterised by the numerous, subglobose, white soralia and the absence of lichen compounds. It resembles the sterile, sorediate, corticolous species *P. salebrosa* A.W. Archer & Elix (Archer 1997) (Fig. 13) from Queensland but the latter differs chemically in containing higher homologues of perlatolic acid and in growing on rocks. In addition, the soralia of *P. heinarii* are larger than those of *P. salebrosa* (0.3-0.5 mm diam.).

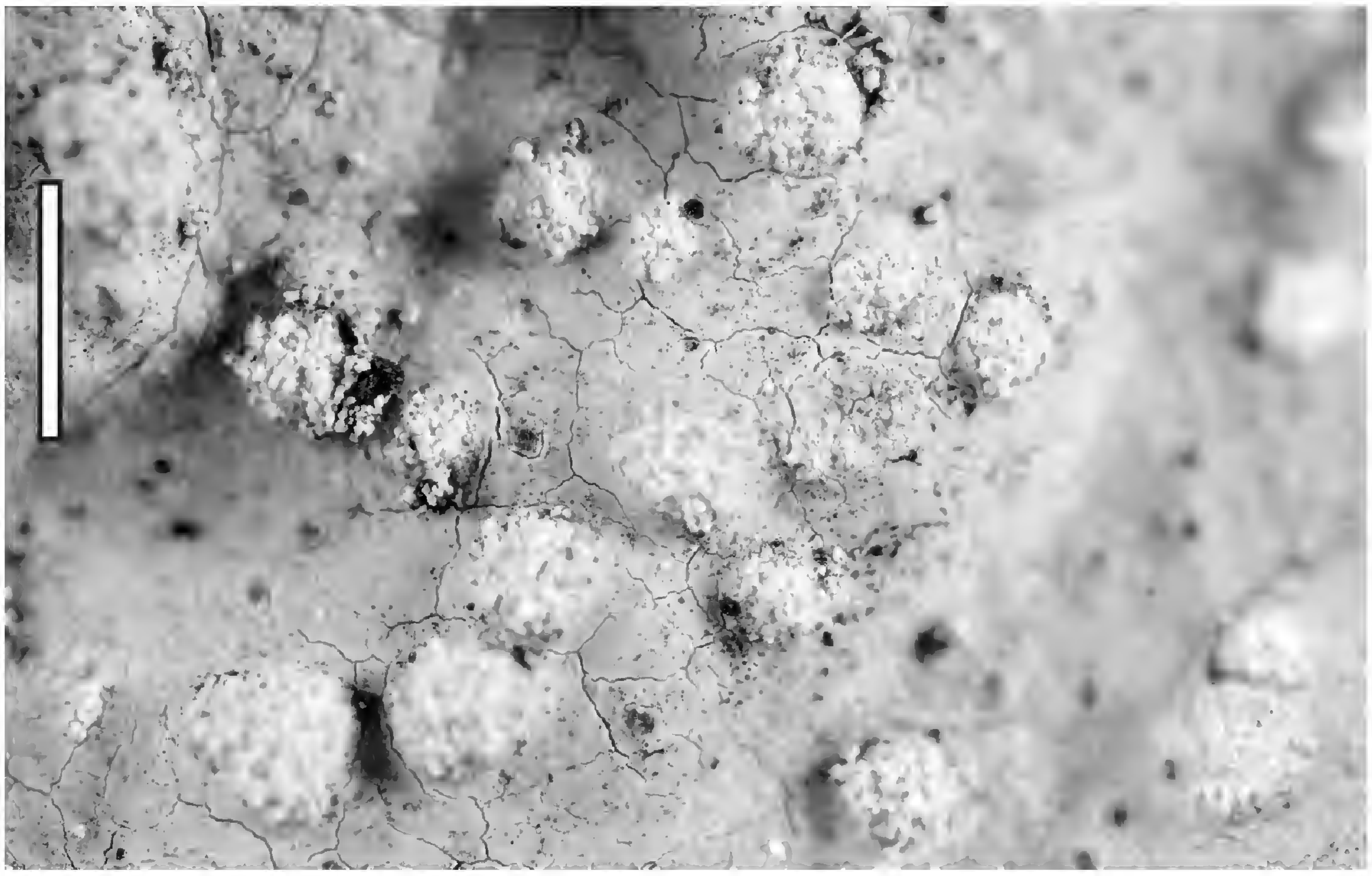

Fig. 13. *Pertusaria salebrosa* A.W. Archer & Elix; *Elix 34510* (holotype: CANB); bar = 1 mm.

Distribution: At present, *Pertusaria heinarii* is known only from the type specimen.

Etymology: The species is named after the collector, Heinar Streimann (1938–2001) who made important contributions to the study of Australian mosses and lichens.

5. *Pertusaria montoensis* A.W. Archer & Elix, sp. nov. MycoBank no. 817385

Similar to *Pertusaria platycarpa* Jariangprasert but differs in having smaller, uniseriate ascospores, 56–62 µm long and 20–26 µm wide.

Type: Australia, Queensland, Hurdle Gully, Coominglah State Forest, 14 km WSW of Monto, 24°54'S, 157°01'E, alt. 310 m, on canopy branches in monsoon forest with dense shrubby understory, *J.A. Elix 35465*, 3 Aug 1993 (holotype: CANB) **Fig. 14**.

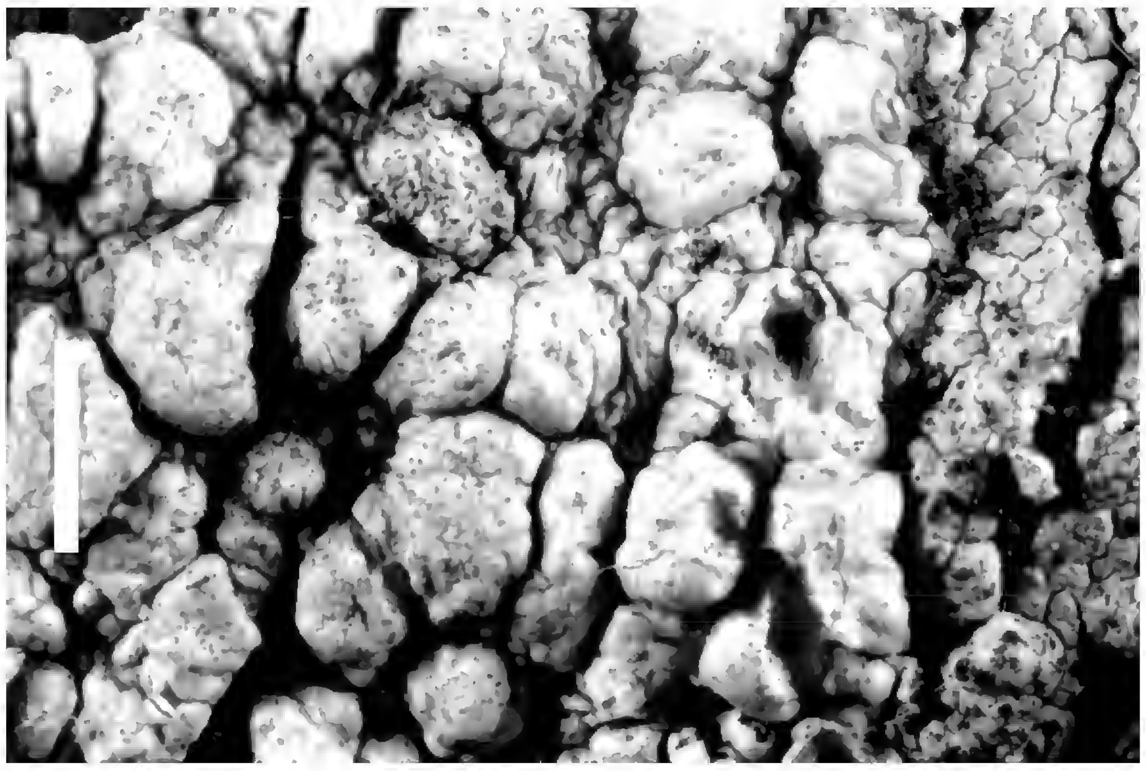

Fig. 14. *Pertusaria montoensis* A.W. Archer & Elix; *Elix 34565* (holotype: CANB); bar = 1 mm.

Thallus corticolous, pale olive-green; surface subtuberculate and slightly cracked, lacking isidia and soralia. Apothecia numerous, concolorous with the thallus, flattened-hemispherical, sometimes becoming distorted, 0.5–0.9 mm diam. Ostioles inconspicuous, pale brown, punctiform, 1 per verruca. Asci 8-spored. Ascospores 1-seriate, hyaline, ellipsoid, with smooth inner walls, 56–62 µm long and 20–26 µm wide.

Chemistry: lichexanthone (minor), 2'-*O*-methylstenosporic acid (major), stictic acid (major), cryptostoctic acid (trace), mengazziaic acid (trace) and skyrin (trace).

Relationships: *Pertusaria montoensis* is characterised by apothecia with pale punctiform ostioles, asci with eight ascospores per ascus and in containing lichexanthone, 2'-*O*-methylstenosporic and stictic acids. The chemically similar *P. platycarpa* Jariangprasert from north-eastern Thailand (Jariangprasert 2006) has larger, 2-seriate ascospores, 70-100 µm long and 36-46 µm wide, in contrast to the smaller, 1-seriate ascospores present in *P. montoensis*.

Distribution: At present this new species is known only from the holotype.

Etymology: The epithet is derived from Monto, the Queensland town nearest to the type locality and *ensis*, Latin for place of origin.

6. *Pertusaria stenospora* A.W. Archer & Elix, sp. nov. MycoBank no. 817386

Similar to *Pertusaria pycnothelia* Nyl. but differs by having conspicuous black ostioles and by containing 2'-*O*-methylstenosporic acid rather than 2'-*O*-methylperlatolic acid.

Type: Australia, Queensland, 3 km S of Forrest Beach, 16 km SE of Ingham, 18°43'S, 146°18'E, alt. 1 m, on a tree at the edge of mangrove and strand vegetation, *J.A. Elix 15899*, 22 Jun 1984 (holotype: CANB).

Thallus corticolous, pale fawn; surface smooth, lacking soralia and isidia. Apothecia verruciform, numerous, crowded, sometimes confluent, flattened-hemispherical, 0.4–0.7 mm diam. Ostioles black, conspicuous, 1 per verruca, *c.* 0.15 mm diam. Asci 2-spored. Ascospores elongate-ellipsoid, hyaline, with smooth inner walls, 100–110 µm long and 22–30 µm wide. **Figs 15 & 16**.

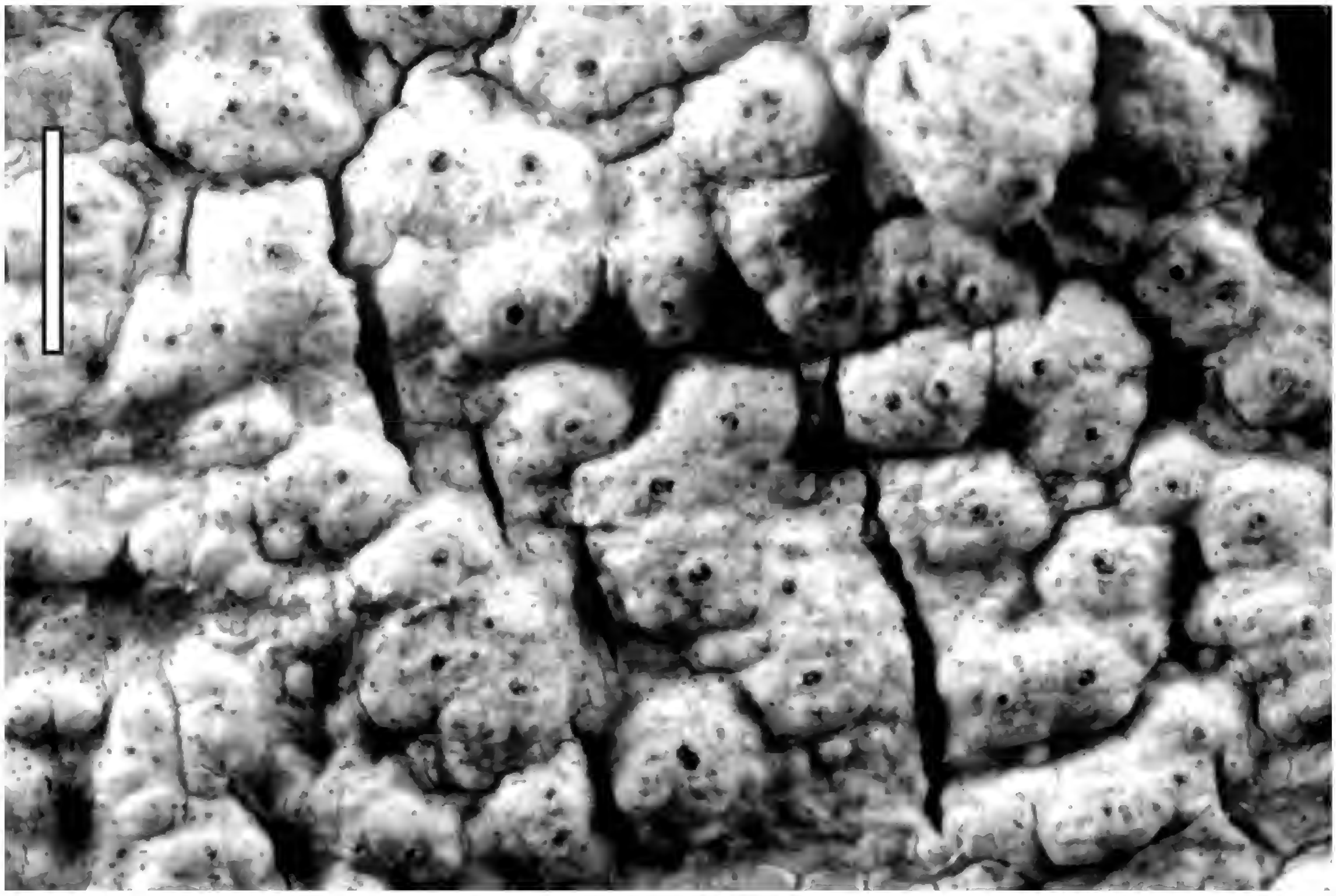

Fig. 15. *Pertusaria stenospora* A.W. Archer & Elix; *Elix 15899* (holotype: CANB); bar = 1 mm.

Fig. 16. *Pertusaria stenospora* A.W. Archer & Elix; ascospores, *Elix 15899* (holotype: CANB).

Chemistry: 4,5-dichlorolichexanthone (minor) and 2'-*O*-methylstenosporic acid (major)

Pertusaria stenospora is characterised by numerous small, verruciform apothecia with conspicuous black ostioles, asci containing two smooth-walled ascospores and the presence of 4,5-dichlorolichexanthone and 2'-*O*-methylstenosporic acid.

Relationships: It closely resembles *P. pycnothelia* described from New Caledonia (Nylander 1868), but differs in having conspicuous black ostioles and in containing 2'-*O*-methylstenosporic acid rather than 2'-*O*-methylperlatolic acid. The combination of 4,5-dichlorolichexanthone and 2'-*O*-methylstenosporic acid is rather uncommon in *Pertusaria* but is also present in *P. praetermissa* A.W. Archer & Elix from Australia (Archer & Elix in Archer 1997), and *P. kansriae* Jariangprasert from Thailand (Jariangprasert & Anusarnsunthorn 2005). However in contrast to *P. stenospora,* these species have four- and eight-spored asci respectively.

Etymology: The epithet *stenospora* is derived from the Greek *stenos*, (narrow) and *spora*, (a seed), a reference to the elongate-ellipsoid ascospores.

New Reports

Pertusaria karkarensis A.W. Archer & Elix, *Mycotaxon* **67**:162 (1998).

Type: Papua New Guinea, Madang Province, Karkar Island, NW side, S of airfield at Kinim Station, 4°35'S, 145°55'E, alt. 300m, on trunks of *Cocos* in plantation, *H.J.M. Sipman 24217*, 28 Feb 1987 (holotype: B).

Pertusaria karkarensis was reported as a corticolous, isidiate species with fertile verruciform apothecia with asci containing eight, biseriate ascospores, 80–95 µm long and 30–35 µm wide and containing thiophanic acid, arthothelin and asemone in the thallus (Archer and Elix 1998). The specimen from Queensland lacked apothecia but it has an isidiate thallus and contains thiophanic acid and arthothelin.

Additional specimen examined: Queensland, Pepina Falls, Middlebrook Creek, 8 km S of Millaa Millaa, 17°34'11"S, 145°36'32"E, alt. 760 m, on canopy branch in remnant montane forest, *J.A. Elix 44463*, 6 Aug 2006 (CANB).

Pertusaria phulhuangensis Jariangprasert, *Mycotaxon* 96: 116 (2006).

Type: Thailand, Loei Province, Phu Lhuang Wildlife Sanctuary, behind the Queen's palace, Pha Yueang Cliff, alt. 1470 m, on tree trunk in oak/chestnut forest, *S. Jariangprasert 2193*, 3 Feb 2002 (holotype: QSBG).

This taxon was originally reported as an un-named species from north-eastern Thailand, "*Pertusaria* sp. 10" (Jariangprasert 2005) and was formally published as *Pertusaria phuluangensis* in 2006. The species is characterised by large, verruciform apothecia, translucent ostioles, asci with (5-)6-8 uniseriate subfusiform-ellipsoid ascospores and the presence of 2'-*O*-methylperlatolic and stictic acids. This combination of lichen acids is also found in *P. minor* Müll.Arg. from Indonesia (Müller 1882) but that species has smaller biseriate ascospores (58–80 × 22–26 µm compared to 74–110 × 30–44 µm in *P. phuluangensis*) and by the presence of additional constictic acid as a major lichen acid. *Pertusaria novaeguineae* A.W. Archer & Elix (Archer & Elix 1998) also contains 2'-*O*-methylperlatolic and stictic acids but has asci with four larger ellipsoid ascospores, (115–)125–150 × 35–45 µm.

A number of *Pertusaria* taxa, originally described from Australia, have also been found in Thailand including: *P. alboaspera* A.W. Archer & Elix, *P. howeana* A.W. Archer & Elix, *P. lordhowensis* A.W. Archer & Elix, *P. pilosula* A.W. Archer & Elix, *P. umbricola* A.W. Archer & Elix and *P. xylophyes* A.W. Archer. **Fig. 17**.

Additional specimens examined: Queensland: Ninney Point, Bingil Bay, 20 km N of Tully, 17°50'S, 146°06'E, alt. 1 m, on coconut trunk; *H. Streimann 45487*, 1 Dec 1990 (CANB); Cow Bay, Cape Tribulation National Park, 26 km NNE of Mossman, 16°14'S, 145°29'E, alt. 2 m, on treelet stem; *H. Streimann 45989*, 6 Dec 1990; *ibid.* on *Calophyllum* stem, *H. Streimann 46011*, 6 Dec 1990 (CANB).

Pertusaria virensica R.C. Harris, *Some Florida Lichens*: 62 (1990).

Type: United States of America, Florida, Okaloosa County, 1.2 miles [1.9 km] W of Florida Highway 85 on Antioch Road (County Road 4) ca. 4 miles [6.4 km] S of Crestview, *R.C. Harris 25182*, 5 May 1990 (holotype: NY – not seen).

Pertusaria virensica is characterised by having verruciform apothecia, asci with eight, uniseriate ascospores (60–70 µm long and 28–35 µm wide) and in containing thiophaninic and virensic acids (Harris 1990). This combination of lichen compounds is, so far, unique for the genus. The Australian material has asci with eight, uniseriate ascospores, 60–80 µm long and 24–34 µm wide. A recent photograph of this species (Lücking *et al.* 2011, Fig. 45G) is very similar to the Australian specimen. The apparently disjunct distribution of *P. virensica* is unusual but *Graphis supracola* A.W. Archer (Archer 2001), described from Australia, also occurs in Florida (Seavey & Seavey 2011). **Fig. 18**.

Additional specimen examined: Queensland, Cook District, ca. 5 km W of Mount Molloy, near road from Cairns to Cooktown, 16°40'S, 145°18'E, in dry sclerophyll forest, on *Eucalyptus*, *H.T. Lumbsch 11168b*, 5 Aug 1996 (CANB).

Fig. 17. *Pertusaria phuluangensis* Jariangprasert, *Streimann 46011* (CANB); bar = 1 mm.

Fig.18. *Pertusaria virensica* R.C. Harris, *H.T. Lumbsch 11168b* (CANB); bar = 1 mm.

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Typification of ten taxa in the genus *Actinodaphne* Nees (Lauraceae) in India

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Abstract

Recent studies on the Indian genus *Actinodaphne* revealed that several names need typification. From the available syntypes, we designate lectotypes here for each of the following names: *A. bourdillonii*, *A. campanulata*, *A. campanualata* var. *obtusa*, *A. hookeri*, *A. hookeri* var. *glabrata, A. hookeri* var. *longifolia, A. lawsonii*, *A. madraspatana*, *A. salicina* and *A. tadulingamii.*

Introduction

The genus *Actinodaphne* Nees, commonly known as ray laurels, is a member of the family Lauraceae, comprising 100 species worldwide (Van der Werff 2001), and is predominantly found in Southeast Asia and Malaysia. The preferred habitats of these plants are semi-evergreen, evergreen, and shola forests. In India, the genus includes 15 species and a variety (Robi 2014). During studies towards a monograph of *Actinodaphne*, the type specimens of all taxa published in the genus have been studied. As a result, lectotypes are designated here for names of seven species and three varieties. Lectotypes are chosen following the principle outlined in Art. 9.2 of the International Code of Nomenclature (McNeill *et al.* 2012).

Lectotypifications

1. ***Actinodaphne bourdillonii*** Gamble, Bull. Misc. Inform. Kew 1925(3): 129 (17 Apr 1925) & Gamble, Fl. Madras 2(pt. 7): 1231 (Nov–Dec 1925)

Type citation: "S. India. Hills of Travancore, 200–1200 m. alt., in evergreen forest, *T.F. Bourdillon 19, 37, 504*, (Small tree 19, 37; large tree 504); S. Canara, forests, *Beddome*; Iyerpadi, Anamalai hills, April 1903, *C.A. Barber 5469*; Lord Hobart's road, Nilgiris, 2000 m. alt., June 1883, *J.S. Gamble 11800*"

Lectotype (designated here): Travancore, ±1200 m, 1890, *T.F. Bourdillon 504* (K000793026!). **Fig. 1**.

Residual syntypes: South India, hills of Travancore, 200–1200 m, *T.F. Bourdillon 37* (K000793025!, CAL!); Lord Hobart's road, Nilgiris, 2000 m, June 1883, *J.S. Gamble 11800* (K!).

Distribution: South India (Karnataka, Kerala & Tamil Nadu).

Notes: Gamble (1925) cited six collections, viz., T.F. Bourdillon, R.H. Beddome, C.A. Barber, and J.S. Gamble, and these constitute syntypes. Of these, the specimen *Bourdillon 504* (K) is selected here as the lectotype, which allows for a more complete comparison with the protologue. The specimen at K comprises a male flowering branch with several leaves.

Fig. 1. Lectotype of *Actinodaphne bourdillonii* (K000793026, © the Board of Trustees of the Royal Botanic Gardens, Kew. Reproduced with the consent of the Royal Botanic Gardens, Kew).

2. ***Actinodaphne campanulata*** Hook.f., Fl. Brit. Ind. 5(pt. 13): 148 (1886) var. ***campanulata***.

Type citation: "Tinnevelly, Beddome"

Lectotype (designated here): Tinnevelly, *R.H.Beddome 200* (K000778983!). **Fig. 2**.

Distribution: South India (Kerala & Tamil Nadu).

Notes: Hooker (1886) based his species on Beddome's collection from Tirunelveli, Tamil Nadu. As noted by Hooker, Beddome (1873) had incorrectly included his collection as *A. salicina* Meisn. Since the Kew Herbarium, wherein Hooker worked, has a single specimen of the Beddome collection, one may argue that the relevant specimen is the holotype. Nevertheless, Hooker did not use the term type or mention the name of the herbarium housing the type. Therefore, we recognize *Beddome 200* (K) as a lectotype. The type specimen comprises several leaves and immature fruits.

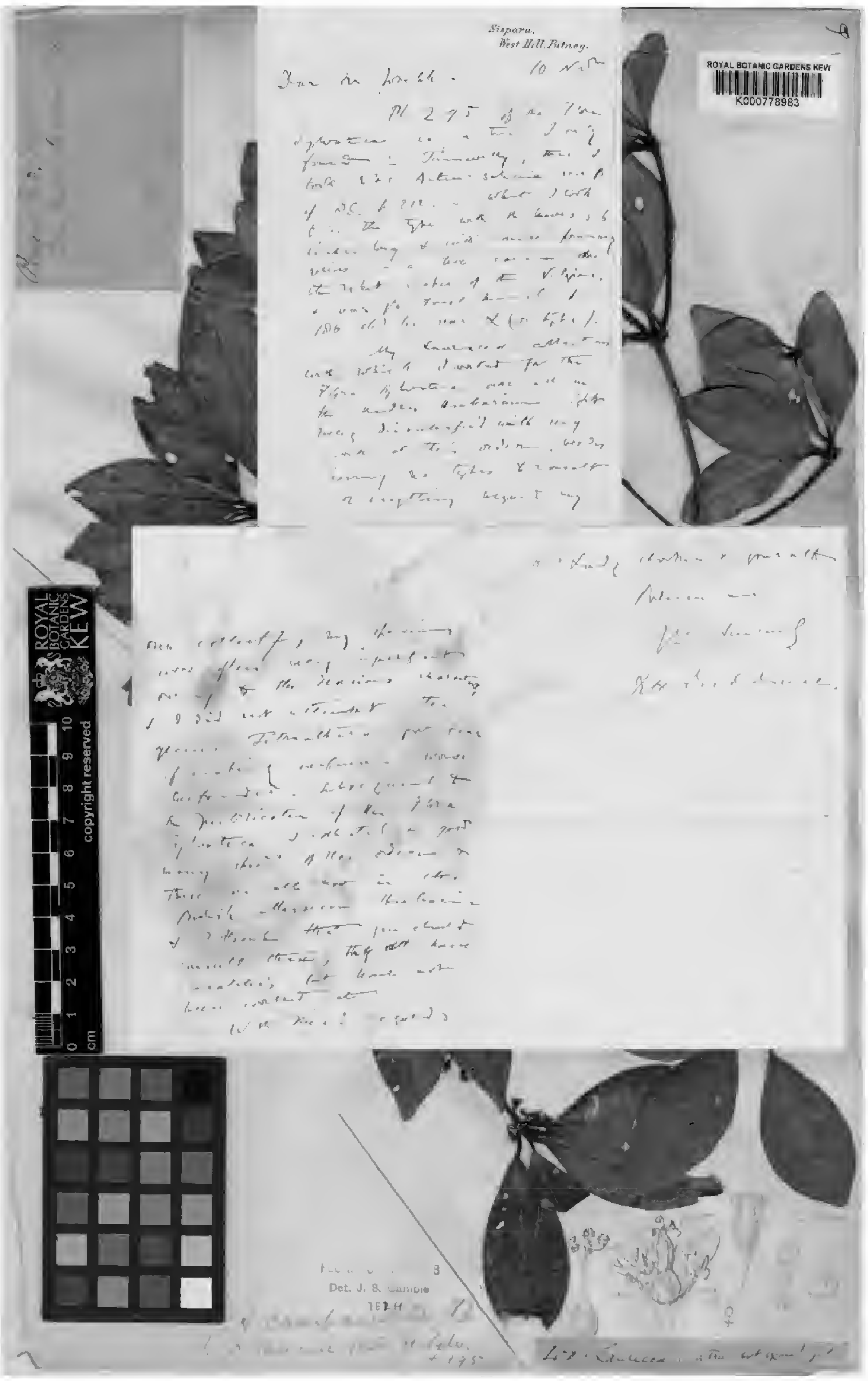

Fig. 2. Lectotype of *Actinodaphne campanulata* var. *campanulata* (K000778983, © the Board of Trustees of the Royal Botanic Gardens, Kew. Reproduced with the consent of the Royal Botanic Gardens, Kew).

3. ***Actinodaphne campanulata*** Hook.f. var. ***obtusa*** Gamble, Fl. Madras 2(pt. 7): 1230 (1925).

Type citation: "W. Ghats, evergreen forests of Travancore at 3,000-4,000 ft. (Bourdillon)".

Lectotype (designated here): Travancore, Chemunji, 3000–4000 ft, 7 March 1897, *T.F. Bourdillon 543* (K000778984!); isolectotypes: K000778985!, K000778986! **Fig. 3**.

Distribution: South India (Kerala & Tamil Nadu).

Note: Gamble (1925) based his varietal name on the collection by *Bourdillon 543* (K), which is mounted on three sheets all with immature fruits. Since Gamble did not designate a holotype, a lectotype needs to be selected; one specimen (K000778984!), which is more complete than the other two specimens, is selected as the lectotype, and the remaining two are therefore isolectotypes (K000778985! & K000778986!).

Fig. 3. Lectotype of *Actinodaphne campanulata* var. *obtusa* (K000778984, © the Board of Trustees of the Royal Botanic Gardens, Kew. Reproduced with the consent of the Royal Botanic Gardens, Kew).

4. ***Actinodaphne hookeri*** Meisn. in A.P. de Candolle, Prodr. 15(1): 218 (1864)

Lectotype (designated here): Concan, *J.S. Law s.n.* (K000778992!); isolectotype: K000778993! **Fig. 4.**

Actinodaphne hookeri Meisn. var. ***dasypoda*** Meisn. in A.P. De Candolle, Prodr.15(1): 218 (1864)

Type citation: "Circa Bombay, in Concan, Sikkim (Law! Hook. fil.!)

Lectotype: as for the species

Actinodaphne hookeri Meisn. var. ***glabrata*** Meisn. in A.P. De Candolle, Prodr.15(1): 218 (1864)

Type citation: "in Concan (Law!)"

Lectotype (designated here): Concan, *J.S. Law s.n.* (K000778995!); isolectotype: K000778996! **Fig. 5.**

Distribution: South India (Karnataka).

Notes: Under his new species *A. hookeri*, Meisner (1864) included three new varieties viz., *dasypoda, longifolia* and *glabrata*. Later, Hooker (1886), placed var. *longifolia* in synonymy under *A. madraspatana*. For *A. hookeri*, he cited its distribution as India and Sri Lanka ('Ceylon') but did not cite any specific specimen. We here select the specimen *J.S. Law s.n.* (K000778992) from Concan, cited by Meisner under var. *dasypoda*, as lectotype of *A. hookeri*. This sheet comprises two twigs; the first is a female with fruits, and the second has male flowers. This sheet has annotations and illustrations of male floral parts by Gamble. For *A. hookeri* var. *glabrata*, we here select the specimen *J.S. Law s.n.* (K000778995) from Concan as lectotype. This sheet bears Gamble's drawings and Meisner's annotations.

Fig. 4. Lectotype of *Actinodaphne hookeri* (K000778992, © the Board of Trustees of the Royal Botanic Gardens, Kew. Reproduced with the consent of the Royal Botanic Gardens, Kew).

Fig. 5. Lectotype of *Actinodaphne hookeri* var. *glabrata* (K000778995, © the Board of Trustees of the Royal Botanic Gardens, Kew. Reproduced with the consent of the Royal Botanic Gardens, Kew).

5. ***Actinodaphne lawsonii*** Gamble, Bull. Misc. Inform. Kew 1925 (pt. 3): 129 (17 Apr 1925): & Gamble, Fl. Madras 2 (pt. 7): 1231 (Nov–Dec 1925).

Type citation: "S. India. South-East Wynaad, Nilgiris, about 1500 m. alt., *M.A. Lawson* 1884; also probably, *C.B. Clarke 11079* from Coonoor Nilgiris, leaves only, a large tree!, the leaves obovate, thinner, 24 cm. by 10 cm."

Lectotype (designated here): Nilgiris, South-East Wayanad, ±1500 m, 1884, *M.A. Lawson s.n.* (K000793029!) **Fig. 6.**

Distribution: South India (Karnataka, Kerala & Tamil Nadu).

Notes: *Actinodaphne lawsonii* was based on two collections, which should be considered as syntypes, viz., *M.A. Lawson s.n.* (K000793029) and *C.B. Clarke 11079* (K000793028). The first collection bears an annotation by J.S. Gamble as new species, and the specimen gives a more complete comparison with the protologue; therefore, *M.A. Lawson s.n.* (K000793029) is here selected as the lectotype.

Fig. 6. Lectotype of *Actinodaphne lawsonii* (K000793029, © the Board of Trustees of the Royal Botanic Gardens, Kew. Reproduced with the consent of the Royal Botanic Gardens, Kew).

6. ***Actinodaphne madraspatana*** Bedd. ex Hook.f., Fl. Brit. India 5(pt. 13): 149 (1886)

Type citation: "Deccan Peninsula: On the Cudeppah Hills, *Wight*, *Beddome*".

Lectotype (designated here): Andhra Pradesh, Cuddapha hills, *R.H. Beddome 259* (K000778990!). **Fig. 7**.

Actinodaphne hookeri Meisn. var. ***longifolia*** Meisn. in A.P. De Candolle, Prodr.15(1): 219 (1864)

Type citation: "in Penins. Ind. or. (Wight!)"

Lectotype (designated here): Peninsula Indiae Orientalis, *Robert Wight 2537* (K000778991!); isolectotype: P01954955! **Fig. 8**.

Distribution: South India (Andhra Pradesh & Tamil Nadu).

Notes: As noted in Hooker's treatment, Beddome (1873) misapplied the name *A. hookeri* Meisn. However, he observed that this species was very common on the hills of the eastern side of the Presidency of Madras (North Arcot and Cuddapah), an area representing many Laurels. He also added that the species was poorly or not represented in the Western Ghats.

In spite of his misapplication of the name *A. hookeri*, it was Beddome who coined the name *A. madraspatana* on a herbarium specimen collected from Cuddapah hills in Andhra Pradesh. Later, Hooker (1886) validated the name *A. madraspatana*. Furthermore, both he and Gamble (1925) cited the locality as Cuddapah hills alone. In the protologue, Hooker cited two collections: R.H. Beddome (259; K000778990!) and R. Wight (2537; K000778991!). The first collection bears the annotation of Hooker, which is selected and designated here as the lectotype.

Meisner erected *Actinodaphne hookeri* Meisn. var. *longifolia* based on a collection by Robert Wight from Peninsular India (*Wight 2537*; K000778991!), which was later synonymised by Hooker (1886), and he suggested the type, as that of *A. madraspatana*. In fact, *A. hookeri* var. *longifolia* has two type sheets, one at Kew and another in the Paris Herbarium, both syntypes. Since the sheet at K is in good agreement with the protologue, it is here selected as lectotype.

Fig. 7. Lectotype of *Actinodaphne madraspatana* (K000778990, © the Board of Trustees of the Royal Botanic Gardens, Kew. Reproduced with the consent of the Royal Botanic Gardens, Kew).

Fig. 8. Lectotype of *Actinodaphne hookeri* Meisn. var. *longifolia* (K000778991, © the Board of Trustees of the Royal Botanic Gardens, Kew. Reproduced with the consent of the Royal Botanic Gardens, Kew)

7. ***Actinodaphne salicina*** Meisn. in A.P. De Candolle, Prodr. 15(1): 212 (1864)

Type citation: "In Ceylon (hb. Wight)".

Lectotype (designated here): 6 January 1860, *Hb. Wight 41* (NY00354778!) **Fig. 9**.

Distribution: South India (Kerala & Tamil Nadu).

Notes: *Actinodaphne salicina* was originally described by Meisner (1864) from a specimen of Robert Wight from Ceylon. However, the stated locality is incorrect, as is evident from Hooker's statement: "The supposed Ceylon specimens mentioned by Meisner are not so; they have no collector's name nor locality, and are no doubt Peninsular". At NY there is a vegetative specimen (NY00354778) that closely matches the description of *A. salicina*. We infer from the protologue that its fruits were undescribed. Later, Hooker (1886) described the fruits of it, based on the collections of Gardner (CAL!) from Nilgiris. We designate *Robert Wight 41* here as the lectotype of the *A. salicina*.

Fig. 9. Lectotype of *Actinodaphne salicina* (NY00354778, The C. V. Starr Virtual Herbarium of The New York Botanical Garden (http://sweetgum.nybg.org/science/vh/)).

8. ***Actinodaphne tadulingamii*** Gamble, Bull. Misc. Inform. Kew 1925 (pt. 3): 130 (17 Apr 1925) & Gamble, Fl. Madras 2(pt. 7): 1231 (Nov–Dec 1925).

Type citation: "S. India. Tinnevelly District, Mundanthorai to Kannikatti, March 1917, *C. Tadulingam 14640*; Anamalai Hills, *Beddome*; Murchison Estate, Travancore, 700 m. alt., *M.A. Lawson* Dec. 1893."

Lectotype (designated here): Tamil Nadu, Tinnevelly dist.: Mundanthurai to Kanikkatti, 17 March 1917, *C. Tadulingam 14640* (K000793032!). **Fig. 10**.

Distribution: South India (Karnataka, Kerala & Tamil Nadu).

Notes: Gamble (1925) described *A. tadulingamii* based on the collections by C. Tadulingam from Kannikatti, R.H. Beddome from Anamalays (K000793033!) and M.A. Lawson (CAL!) from Merchiston Estate, Travancore. Of the three collections, *Tadulingam 14640* agrees well with the original description and is selected here as lectotype.

Fig. 10. Lectotype of *Actinodaphne tadulingamii* (K000793032, © the Board of Trustees of the Royal Botanic Gardens, Kew. Reproduced with the consent of the Royal Botanic Gardens, Kew).

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Memecylon macneillianum (Melastomataceae), a new species from South Andaman, India

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Abstract

Memecylon macneillianum M. Das Das, G. S. Giri, A. Pramanik and D. Maity, a new species from the southern Andaman Islands in India, is described and illustrated. It differs from its closely related species *M. oleifolium* Blume by having both terminal and axillary inflorescences, a higher number (mostly 3–7) inflorescences per node, longer and acutely quadrangular, distinctly furrowed primary inflorescence axes, distinct calyx lobes, and globose fruits. Moreover, in *M. macneillianum* the leaves are thicker, coriaceous and yellowish on both surfaces when dry, whereas in *M. oleifolium* the leaves are thin, chartaceous and olive green with a distinctive rusty-red blush around the midvein on drying.

Introduction

The genus *Memecylon* L. comprises 343 species (Renner et al. 2007) distributed in the Old World tropics and is represented by about 49 species in India with the main concentration of species diversity in the Western Ghats (Das Das and Pramanik 2015). In the course of revisionary work on the family Memecylaceae (=Melastomataceae subfamily Olisbeoideae *sensu* APG IV 2016), the authors came across and critically studied about 18 specimens of 12 gatherings collected between 1891 to 1976 from South Andaman Islands deposited at Central National Herbarium (CAL). The study determined that these specimens were wrongly identified as *M. elegans* Kurz. *Memecylon elegans* is characterized by quadrangular branchlets, leaves obtusely rounded at apices, and inflorescences that arise from abscised leaf scar marked nodes, whereas the specimens under present study show terete to subterete branchlets, leaves caudate-acuminate at apices, distinctly terminal and axillary inflorescences. Though these specimens are morphologically akin to those of *M. oleifolium* Blume having similar habit, elliptic-lanceolate to broadly elliptic leaves and pedunculate inflorescences, a detailed analysis of the characters established that they are taxonomically different and represent a new species. The identity of the new taxon was also confirmed through the study of specimens of allied species deposited in herbaria, viz. CAL, MH, PBL, TBGT, XCH, CALI, and consultation of relevant literature (Blume 1851, Kurz 1872,Parkinson 1923, Maxwell 1980, Bremer 1983, Mathew and Lakshminarasimahan1992, Lakshminarasimahan and Ray 1995, Sinha 1999, Hughes 2013). The new species is here described and illustrated.

The floristic composition of Andaman and Nicobar Islands, in general, shows a striking affinity with that of Southeast Asian regions. About 10, 8 and 6 taxa of *Memecylon* are shared by Malaysia, Thailand and Borneo respectively with those of the Andaman and Nicobar Islands. The taxonomy of the genus in Malaysia had been covered by King (1900), Ridley (1922), Maxwell (1980) and Hughes (2013). Craib (1931) provided an enumeration of Thai taxa and Bremer (1983) published a revisionary account of the genus in Borneo.

Significant botanical work on the genus *Memecylon* in the Andaman and Nicobar Islands was carried out by Parkinson (1923) who recorded five species from the Andaman Islands. This was preceded by earlier accounts (Kurz 1872; King 1900) and subsequent workers (Mathew and Lakshminarasimhan 1992; Lakshminarasimhan and Mathew 1993; Lakshminarasimhan *et al.* 1993; Lakshminarasimhan and Ray 1995) published new names and new distribution records for the region. Sinha (1999) provided an account of the genus in a floristic study of Great Nicobar. Recently, Murugan (2011) recorded *M. minutiflorum* Miq., a Malayan species from South Andaman Islands. Pandey and Diwakar (2008) provided a comprehensive checklist of floristic elements of Andaman and Nicobar Islands which includes 14 taxa of *Memecylon*. However, their records of *M. amplexicaule* Roxb. and *M. angustifolium* Wight from this region are dubious.

To date, fifteen taxa, including the new species of the genus *Memecylon* have been recorded from Andaman and Nicobar Islands. As an aid to identification a taxonomic key is included for these taxa.

Taxonomic treatment

Memecylon macneillianum M. Das Das, G. S. Giri, A. Pramanik & D. Maity **sp. nov.**

Diagnosis: The new species is similar to *M. oleifolium* Blume but differs in having both terminal and axillary inflorescences, more inflorescences per node (usually 3–7), longer and acutely quadrangular, distinctly furrowed primary inflorescence axes, distinct calyx lobes and globose fruits. However, in *M. oleifolium* inflorescences arise from the leaf axils, peduncles only 1–2 per node, primary inflorescence axes terete, hypanthium truncate and fruits ellipsoid.

Furthermore, in *M. macneillianum* the leaves are thicker, coriaceous and yellowish on both the surfaces on drying, whereas in *M. oleifolium* the leaves are thin, chartaceous and olive green with a distinctive rusty-red blush around the midvein on drying. The hypanthium is campanulate, smooth throughout or papillate on outer side near base in *M. macneillianum* whereas in *M. oleifolium* it is smooth throughout.

Type: INDIA: Andaman & Nicobar Islands: S. Andamans: North Bay Hill Jungle, 9 Aug 1891, *King s. n.*, acc. no. CAL 174710 (holo: CAL 174710 A, barcode CAL 0000027203; iso: CAL 174710 B, barcode CAL0000027206; L 908132-60). Fig. 1.

Tree, 5–8 m high; branches woody, terete, ultimate branches often shallowly grooved or compressed. Leaves elliptic-lanceolate to broadly elliptic, 5–11 × 3–5 cm, glabrous, thick, coriaceous, yellowish on both the surfaces on drying; apex caudate-acuminate, occasionally retuse, margin slightly undulate and often revolute, base cuneate, often decurrent; secondary veins 8–10 pairs, originating at c. 45° angle from midrib, irregularly spaced at 6–10 mm intervals, lateral and intramarginal nerves usually prominent to subprominent on lower surface, faintly visible on upper surface; intramarginal nerves c. 2 mm away from margin; petioles canaliculate, 4–6 mm long, glabrous. Inflorescence terminal and axillary, umbel-like, many-flowered, pedunculate; primary axes 1–7, sometimes up to 9, 1–4 cm long, quadrangular, compressed with 2 opposite deep and 2 opposite shallow grooves, glabrous; secondary axes almost quadrangular, grooved, (2–) 3.0–4.5 (–6) mm long, glabrous; tertiary axes, if present, 2–3 mm long; pedicels 3–5 mm long, bracteate and bracteolate, both broadly ovate or ovate-oblong, caducous. Hypanthium campanulate, smooth throughout or papillate on outside near base, 2–3 × 1.5–2.7 mm, widened at mouth after anthesis; calyx lobes 4, broadly ovate-triangular, apex obtuse or acute, glabrous, smooth; disc-rays prominent. Petals 4, broadly ovate or elliptic-ovate, 1.5–2.5 × 1.25–2.0 mm, apex acute, membranous, margin hyaline, keel prominent towards apex. filaments terete, flattened near base, 2.0–3.5 mm long; anthers oblong, c. 0.5 mm long, thecae restricted to upper side of connective; anther connective elongated, C-shaped at maturity, c. 1.0 × 0.5 mm long, with centrally placed gland. Ovary inferior, subglobose; style columnar, 2.0–2.5 mm long; stigma pointed. Fruits globose, 10–12 mm diam.; persistent calyx crown distinct, c. 1 mm long, areoles c. 2 mm diam., septa 8, prominently raised; pericarp thick, rough. Seed solitary, globose, glossy brown. Fig. 2.

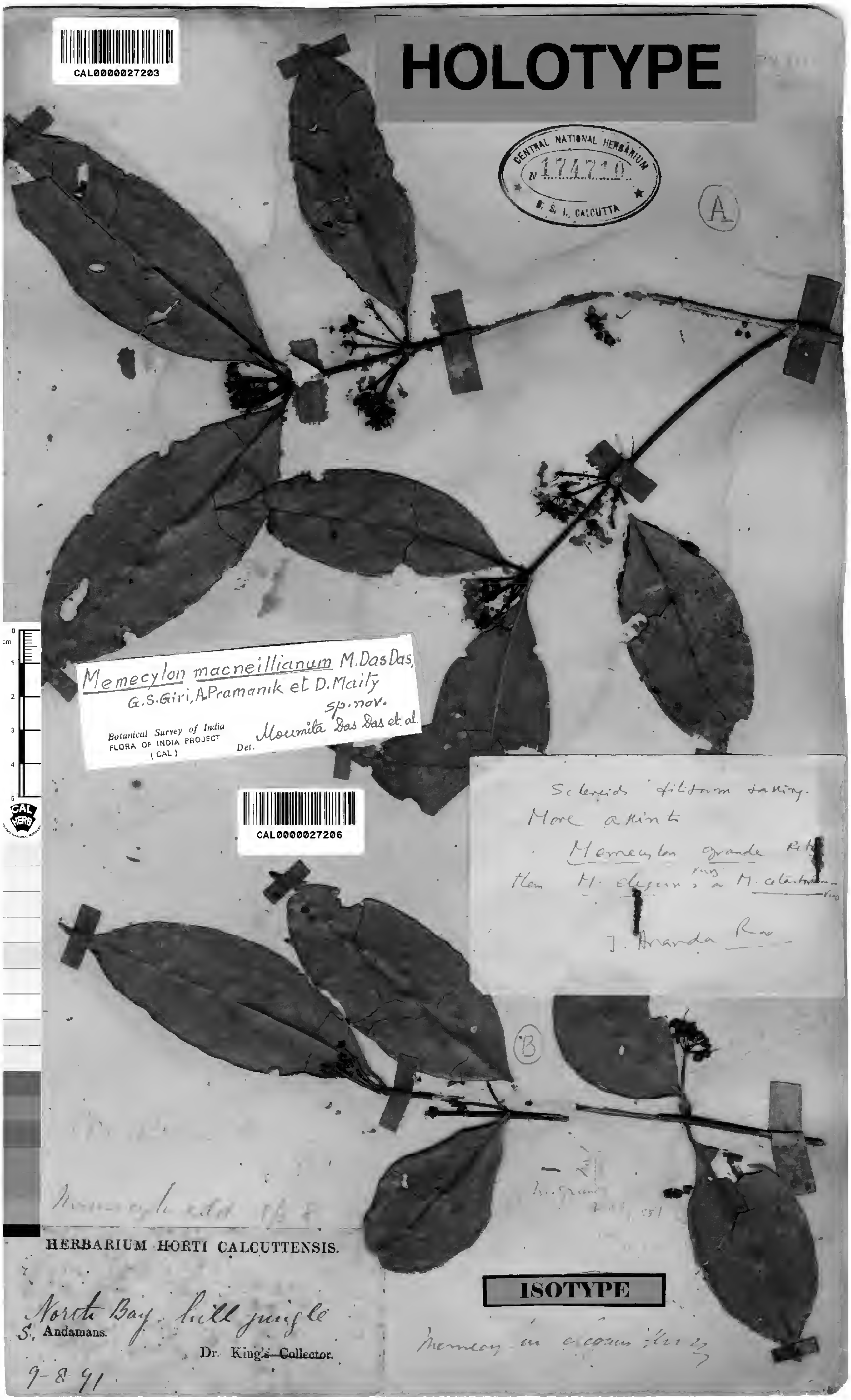

Fig. 1. Holotype and isotype of *Memecylon macneillianum* M. Das Das, G. S. Giri, A. Pramanik and D. Maity.

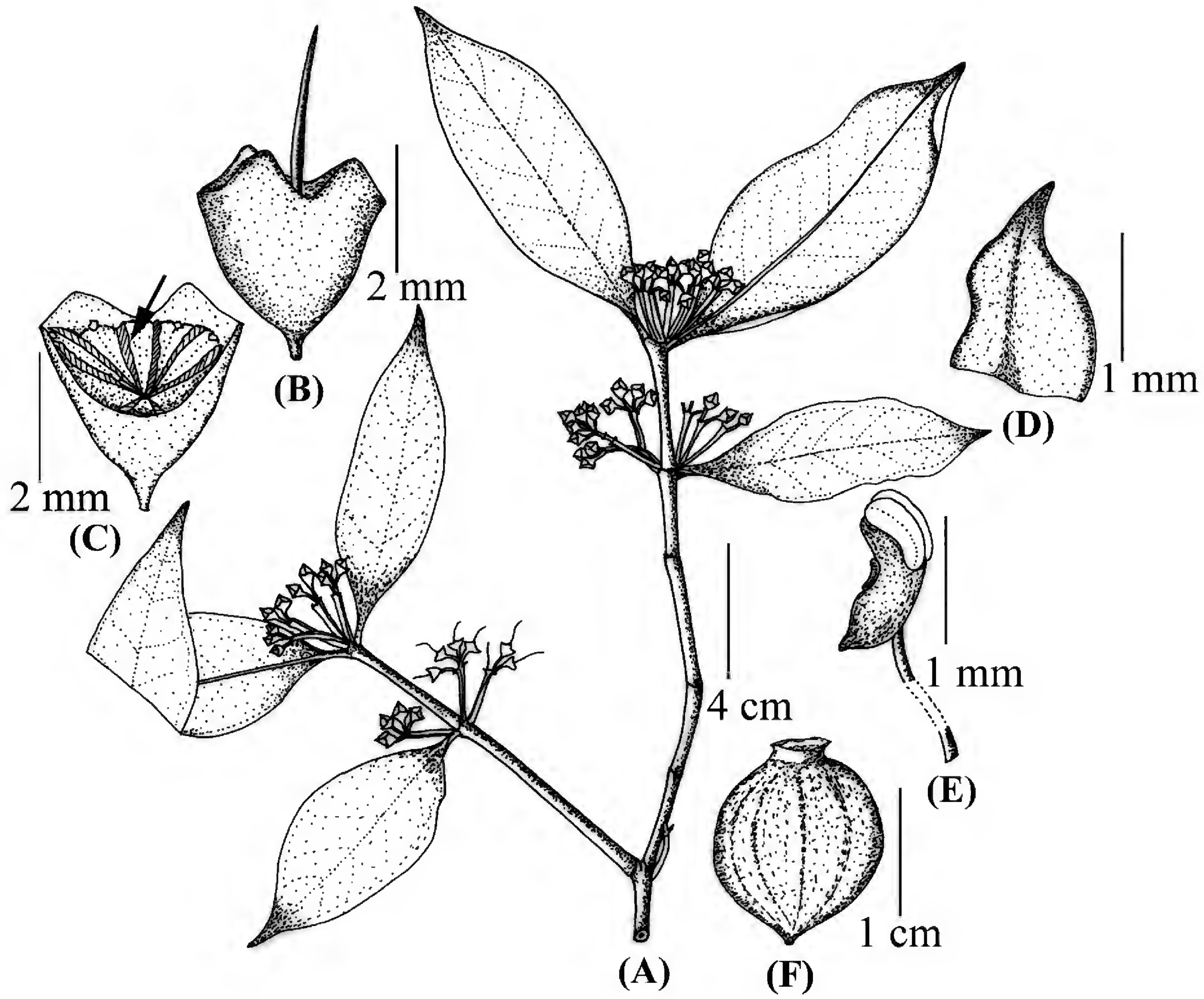

Fig. 2. *Memecylon macneillianum* M. Das Das, G. S. Giri, A. Pramanik and D. Maity: A. flowering branchlet, B. hypanthium showing distinct calyx), C. prominent disc rays marked with arrow (part of hypanthium removed), D. petal, E. stamen, F. fruit. Drawn from *King s.n.* (CAL 174710A).

Distribution: India: endemic to the South Andamans. Fig. 3.

Flowering and Fruiting: June–January.

Additional Specimens examined: INDIA: ANDAMAN AND NICOBAR ISLANDS: South Andamans: Anikhet-jungle Hill, 11 Aug 1894, *King's Collector s. n.* (CAL 174716); Ali Masjid Hill jungle, 28 Oct 1893, *King's Collector s. n.* (CAL 174712; fr.); Without precise locality, 15 Nov 1901, *R. L. Heinig 500*, (CAL; fl.); ibid. *R. L. Heinig 416*, (CAL; fl.); Port Mouat jungle Hill land, 03 Oct 1891, *King s. n.* (CAL 174709; fr.); Port Mouat jungle Hill land, 11 Jul 1891, *King s.n.*(CAL); between Garacherama and Monmai Bay Hill Jungle, 16 Jun 1894, *King's Collector s.n.* (CAL 174717; PBL 1646, barcode 0000008768; fl.); Sipighat-Jungle stream, 28 Nov 1893, *King's Collector s. n.* (CAL 174713; fr.); Baratang Island, 21 Jan 1904, *C.G. Rogers s.n.* (CAL; fr.); 10 km towards north from Poona Nallah, 100 m, 26 Jul 1976, *N. Bhargava 4243* (CAL).

Relationships: The presence of both terminal as well as axillary inflorescences is a diagnostic character of this new species. The genus *Memecylon* L. has axillary, cauliflorous or ramiflorous inflorescences. However, only two species in India, *M. terminale* Dalzell and the species described here, *M. macneillianum*, have terminal as well as axillary inflorescences. However, *M. terminale* is easily recognizable through its much smaller and narrower leaves with acute apices and cordate to rounded bases. Moreover, in the latter species the peduncles always arise singly. The new species is closely related to *M. oleifolium* Blume by tree habit, elliptic-lanceolate leaves, pedunculate inflorescences and pedicellate flowers. However, the presence of both terminal as well as axillary inflorescences makes the new species distinct from this as well as other species growing in the Andaman and Nicobar Islands. Notably, more peduncles per node, distinctly lobed calyx and globose fruits make it distinct from all known species in India and adjacent regions. The comparison of the new species and its close relatives for most of the important features is shown in Table 1.

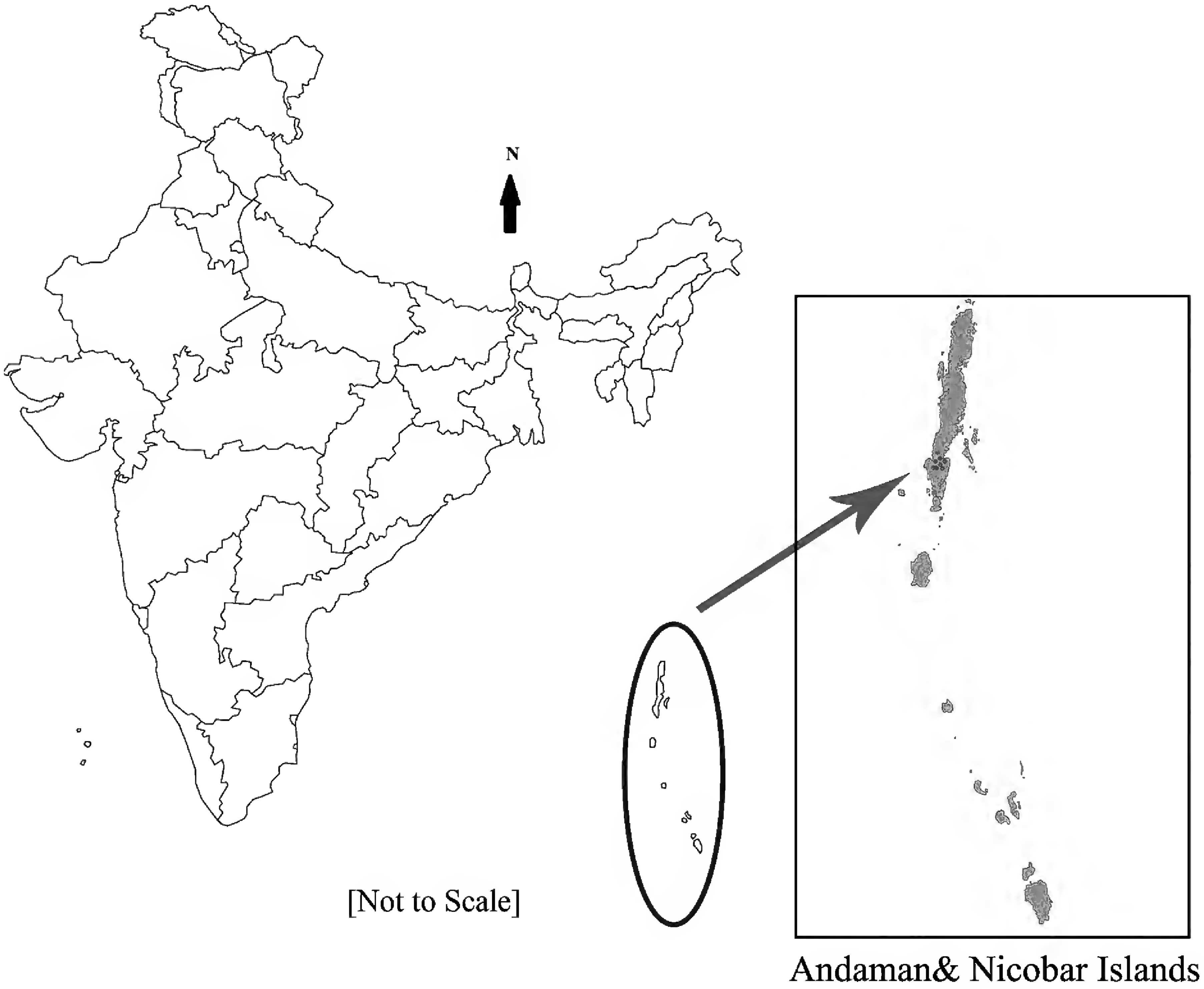

Fig. 3. Distribution of *Memecylon macneillianum* M. Das Das, G. S. Giri, A. Pramanik and D. Maity (blue dots indicate known localities).

Table 1. Comparison of major diagnostic morphological features of *Memecylon macneillianum* M.Das Das *et al.*, *M. oleifolium* Blume and *M. elegans* Kurz.

Characters	*M. macneillianum*	*M. oleifolium*	*M. elegans*
Leaf colour on drying	uniformly yellowish	olive green with a distinctive rusty-red blush around the mid-vein	yellowish green to greenish
Inflorescence position	terminal and axillary	axillary (very rarely terminal)	at leafless axils
Primary inflorescence axes	acutely 4-angular, grooved, compressed	terete (very rarely 2–grooved)	4-angular
Numbers of peduncles per node	(1–)3–7	1 (–2)	1–2
Hypanthium rim	distinctly 4–lobed; lobes ovate, ± acute	Truncate	entire or undulate
Fruit shape	globose	ellipsoid, rarely globose	globose

Etymology: The specific epithet honours Dr. John McNeill (E), a renowned taxonomist and nomenclature specialist. The orthography of the epithet follows Rec. 60C.5(a) of the ICN.

Conservation status: The species is known only from the old collections mentioned above. No recent collection has been located at CAL, PBL, MH, TBGT, XCH, CALI. Given the limited information on the present status of the species, we recommend treating it under the Data Deficient (DD) category (IUCN Standards and Petitions Subcommittee 2014). Further rigorous population study is needed to estimate its proper conservation status.

Key to the taxa of *Memecylon* occurring in Andaman & Nicobar Islands

1. Leaves small, ≤ 4.5 × 2.5 cm **2**

1: Leaves larger, mostly > 5 × 3 cm (sometimes leaves smaller in *M. edule* and *M. intermedium*, but then leaves always elliptic to ovate-elliptic with shortly caudate apices) **3**

2. Ultimate branchlets 4-angled; leaves rhomboid to ovate–rhomboid, drying dark brown above, slightly paler below; inflorescence 5–10-flowered .... ***M. pauciflorum***

2: Ultimate branchlets thinly 2-grooved; leaves suborbicular to obovate, drying coppery–brown to dark blackish brown on both surfaces; inflorescence 10–30-flowered .... ***M. scutellatum* var. *brevifolium***

3. Leaves larger, ≥ 14 × 5.5 cm **4**

3: Leaves smaller, mostly less than ≤11 × 5 cm **5**

4. Leaves oblong, olive-green on drying; secondary venation prominent; primary peduncles 2–3 mm long; secondary inflorescence axes up to 1 mm long .... ***M. kurzii***

4: Leaves ovate or ovate-elliptic, brownish on drying; secondary venation not prominent; primary peduncle 10–15 mm long; secondary inflorescence axes c. 10 mm long .... ***M. pulchrum***

5. Leaf–apices obtuse **6**

5: Leaf–apices acute or acuminate **7**

6. Ultimate branchlets terete or slightly 2-grooved; leaves brownish on drying, paler beneath; peduncles terete or lengthwise grooved, up to 1 cm long .... ***M. balakrishnanii***

6: Ultimate branchlets 4-angled; leaves yellowish to greenish-yellowish on both surfaces on drying; peduncles sharply 4-angled, usually > 1 cm long .... ***M. elegans***

7. Inflorescences both terminal and axillary .... ***M. macneillianum***

7: Inflorescences axillary and/or on bare nodes **8**

8. Leaves coriaceous, base rounded to cordate **9**

8: Leaves comparatively thin, base cuneate in most of the leaves **10**

9. Leaves sessile to subsessile, lower surface rusty-brown or yellowish on drying; peduncles shorter, less than 3 mm, few–flowered; pedicels up to 1.5 mm long, thick; fruits ellipsoid .... ***M. caeruleum***

9: Leaves distinctly petiolate, lower surface brown on drying; peduncles ≥ 5 mm long, many–flowered; pedicels > 2 mm long, slender; fruits globose .... ***M. ovatum***

10. Leaves lanceolate or narrowly ovate **11**

10: Leaves otherwise **12**

11. Leaves lanceolate with long acuminate apices .... ***M. andamanicum***

11: Leaves elliptic with obtuse to shortly caudate apices .... ***M. edule***

12. Anther connective subglobose with basally attached gland .... ***M. garcinioides***

12: Anther connective elongated with central gland **13**

13. Plants to 5 m high; fruits yellowish-green at maturity .... ***M. minutiflorum***

13: Plants to 25 m high; fruits reddish or blue at maturity **14**

14. Leaves ovate-elliptic, blackish-green above on drying; primary inflorescence axes 3–12 mm long; anther connectives 'J'-shaped; fruits globose, blue .... ***M. intermedium***

14: Leaves oblong-elliptic to oblong-lanceolate, olive-green above on drying; primary inflorescence axes 14–25 mm long; anther connectives oblong; fruits ellipsoid, reddish .... ***M. oleifolium***

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Free Axial Lobes: An Important Diagnostic Character in *Pteridium* (Dennstaedtiaceae)

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Abstract

The overall form of the lamina in the bracken fern (*Pteridium*) is a fractal series in which blade, pinnae, pinnules and pinnulets represent a hierarchy of repeated units of decreasing size. Distinctive lunate or semi-lunate lobes of laminal tissue between the divisions of the blade in an apical zone of some or all of its axes are an important diagnostic feature. These "free lobes" link *Pteridium esculentum* (G. Forst.) Cockayne subsp. *esculentum* from Australasia with *P. esculentum* subsp. *arachnoideum* (Kaulf.) J.A. Thomson from Central and South America and separate both from *P. aquilinum* (L.) Kuhn. The development, pattern of distribution on laminal axes and variation of form of the free lobes in *P. esculentum* subsp. *esculentum* are described here. Although basic frond architecture as reflected in pinna spacing on the rachis is largely independent of the size of the lamina, the number and pattern of occurrence of free lobes is significantly correlated with the length of axial intervals and hence with frond size and laminal dissection. Attention is drawn to the likelihood that a genetic polymorphism may underlie development of free lobes in *P. esculentum* subsp. *arachnoideum*. The presence or absence of free axial lobes may be a useful marker for detection of introgression following hybridisation of *P. esculentum* and *P. aquilinum*.

Introduction

The abundant cosmopolitan bracken ferns (*Pteridium* Gled. ex Scop.) with a diploid (2n = 104) chromosome complement group on many morphological and molecular features into two distinct clades (Der et al. 2009, Thomson 2012, Zhou et al. 2014, Wolf et al. 2015) between which there is evidence of reproductive incompatibility (Brownsey 1989, Thomson and Alonso-Amelot 2002, Thomson 2012). One of these clades comprises *P. aquilinum* (L.) Kuhn, predominantly from the northern hemisphere and Africa, considered to include 11 (Thomson 2004, 2008, 2012) or fewer (Zhou et al. 2014) subspecies. The second clade comprises *P. esculentum* (G. Forst.) Cockayne with two subspecies of predominantly southern hemisphere distribution, namely *P. esculentum* subsp. *esculentum* in south-east Asia, Australia and New Zealand and *P. esculentum* subsp. *arachnoideum* (Kaulf.) J.A. Thomson in Central and South America (Thomson 2012, Zhou et al. 2014). Although treatment of the diploid bracken ferns as only two species appears to be emerging as a consensus, this view is not universally accepted: Schwartsburd et al. (2014), for example, argue for retention of the name *P. arachnoideum* at specific rank.

Hybrids between *P. esculentum* s.l. and *P. aquilinum* s.l. have been recognised in two geographic regions where these taxa overlap in distribution. *P. semihastatum* (Wall. ex J. Agardh) S.B. Andrews is an allotetraploid

(4n = 208) between *P. esculentum* subsp. *esculentum* and *P. aquilinum* subsp. *wightianum* (Wall. ex J. Agardh) W.C. Shieh in South-East Asia/Australia while *P. caudatum* (L.) Maxon is an allotetraploid hybrid of *P. esculentum* subsp. *arachnoideum* with *P. aquilinum* (subspecies not identified) in Central and South America (Thomson and Alonso-Amelot 2002, Der et al. 2009, Zhou et al. 2014, Wolf et al. 2015). There is evidence in both of these cases that hybrids or introgressants other than the allotetraploids are also present (Brownsey 1989, 1998, Wolf et al. 2015), meriting additional cytological, molecular and morphological analysis.

The presence in *P. esculentum* s.l. and absence in *P. aquilinum* s.l. of two characters concerned respectively with the abaxial indumentum and laminal subdivision have been widely used as diagnostic of these taxa (e.g. Tryon 1941, Mickel and Beitel 1988, Mickel and Smith 2004, Thomson 2012). One of these critical characters is the presence of minute highly distorted hairs termed gnarled trichomes (Thomson and Martin 1996, Thomson and Alonso-Amelot 2002, Schwartsburd et al. 2014, Wolf et al. 2015) between veins on the abaxial surface of laminal segments of *P. esculentum* s.l. If sufficiently dense, these hairs are seen at low magnifications as a surface texture that has been described as farinaceous (Tryon 1941, Schwartsburd et al. 2014), mealy (Brownsey 1989), or farinose (Schwartsburd et al. 2014). The density of gnarled trichomes is highly variable and strongly reduced in shade-form fronds of *P. esculentum* subsp. *esculentum* (Thomson and Martin, 1996) although hairs of this type were present in all of a large series of specimens of this subspecies examined to date. In contrast, *P. esculentum* subsp. *arachnoideum* from Brazil and Uruguay was observed to be polymorphic for presence/absence of gnarled trichomes (Thomson and Martin 1996, Schwartsburd et al. 2014).

The second character widely regarded as diagnostic of *P. esculentum* s.l. is the presence of "lunate or semi-lunate, entire lobes along part of the rachis, costae and costules, between the divisions of the blade" (Tryon 1941, p. 8). Such free lobes of laminal tissue are found proximal to the apices of the axes to an extent differing widely depending on growth conditions affecting frond size and subdivision. A detailed study of the pattern of occurrence and development of free lobes in a bracken population is presented here to facilitate field assessment and collection of material appropriate for taxonomic study, and to provide background for use of this character in revealing possible hybridisation or introgression.

Spacing of laminal elements on the frond axes

The evolutionary origins, patterns of development and diverse morphology of fern leaves have been extensively reviewed by Vasco et al. (2013). Unlike seed plants, fern leaves typically show determinate (finite) growth (Imaichi 2008) with prolonged acroscopic extension due to meristematic activity of a cell at the leaf tip. More proximal elements of the leaf thus mature first.

The overall form of the bracken lamina is that of a Mandelbrot fractal series (Thomson 2000) in which blade, pinnae, pinnules and pinnulets represent a hierarchy of repeated units of decreasing size. A general feature at each level in this series in *Pteridium* is the consistently greater spacing between basal lateral axes compared with those more apically (distally) placed, whether between pinnae on the rachis, pinnules on the costae, pinnulets on the costules or segments on the costulets (terminology following Lellinger 2002). Although visually distinguishable at each level, this pattern is most evident in the spacing of the costae (pinna axes) on the frond rachis.

The pinnae of *P. esculentum* subsp. *esculentum* are generally paired and opposite on the rachis, although quite frequently sub-opposite, apparently due to unequal elongation of the two sides of the rachis (O'Brien 1963). In analysing the spacing pattern of costae on the rachis care was taken to measure the distance between each successive costa from the base (Pinna 1) towards the apex on the same side of the rachis, but the pinna numbers used here each refer to a pinna pair whether exactly opposite or not. The distances between costae of pinna pairs P1 to P2, P2 to P3 … to P12 to P13 are shown in Figs 1 and 2 which illustrate a typical frond of subsp. *esculentum* 750 mm in height from a mixed dry sclerophyll woodland at Epping (Sydney, NSW). These spacings form an approximately exponential series decreasing from the base of the rachis (insertion of costa of P1) towards its apex beyond P13 (Fig. 2). Bright (1928) established that a similar gradation in spacing of pinnae on the rachis in *P. aquilinum* subsp. *aquilinum* is largely independent of frond size (height) by comparing the distances between successive pinna pairs relative to that between pinna 1 and pinna 2, standardised to a value of 1.0 for each frond. For comparison with Bright's analysis, pinna spacings P1 to P2, P2 to P3, P3 to P4 and P4 to P5 were measured for a sample of 30 fully expanded fronds of *P. esculentum* subsp. *esculentum* ranging in height between 565 mm and 1380 mm that were collected contemporaneously from the same site as the specimen illustrated in Figs 1-2. These fronds show a consistent pattern of pinna spacing on the rachis similar to that observed by Bright (1928) in subsp. *aquilinum*. When the distances between successive pinna pairs P1 to P2 through P4 to P5 are standardised with reference to the spacing of P1 to P2 taken as 1.0, the medians are respectively 0.53 for P2 to P3 (range 0.40 to 0.77), 0.40 for P3 to P4 (range 0.27 to 0.65), and 0.29

for P4 to P5 (range 0.2 to 0.4). In none of the fronds in the sample does the distance on the rachis between two successive pinna pairs exceed the spacing between the two next lower pinna pairs. Thus, although there is considerable variability between fronds, the overall pattern of pinna spacing is consistent from frond to frond after controlling for frond size. Experimental studies of fern leaf development (reviewed by Vasco et al. 2013) have established that the final shape of the fern leaf is determined by the pattern of division of the apical initial and of marginal meristematic and sub-marginal cells. Inhibition of cell groups positioned regularly along the marginal meristem of the developing leaf determines the spacing of the developing pinnae (Wardlaw 1963).

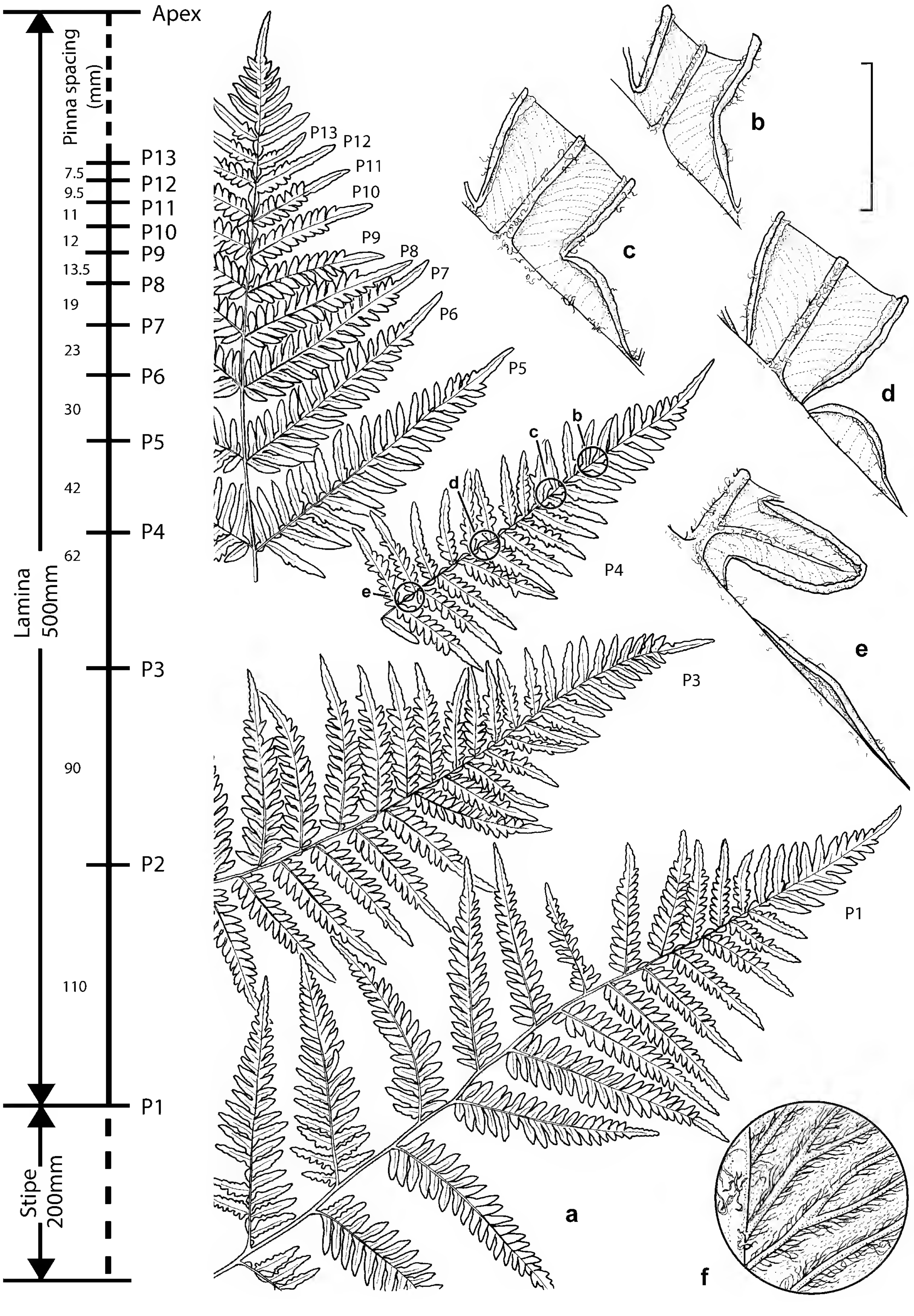

Fig. 1. Laminal dissection in a typical 3-pinnate to 3-pinnate-pinnatifid frond of *P. esculentum* subsp. *esculentum* from an exposed dry sclerophyll woodland site. **a.** Spacing of pinnae (mm) on the rachis is shown for the intervals between pinna pairs numbered acroscopically from the base of the lamina. One pinna (P) of each pair is shown removed from the rachis as P1, P3 and P4, while pinnae from P5 to the apex of the frond are shown in situ on the rachis. Note the reduced basal pinnule on P4. **b–e.** Different extents of separation of free lobes from decurrent segment bases along a pinna axis. **f.** Abaxial surface of a free lobe showing mealy appearance between veins at low magnification due to gnarled trichomes. Scale bar: **a** = 50 mm, **b–e** = 5 mm, **f** = 1.25 mm.

Origin, characteristics and position of free lobes

Proximal to the apices of the laminal elements in *P. esculentum* subsp. *esculentum,* segments may develop adnate decurrent bases that progressively lengthen to form a continuous narrow ledge on the side of the axis. This gives the appearance of "narrow wings on midribs of primary and secondary pinnae" (Brownsey 1989, see also Brownsey 1998). More frequently the apical segment bases gradually elongate and separate to form free lobes as illustrated for a pinna axis (costa) in Figs 1 b-d. Initially an indentation develops on the proximal side of a segment base close to the axis of that segment (Fig. 1b). In successive lobes down the axis, this cleft deepens and a gap opens on the axis as a more or less symmetrical semicircular lobe separates fully from its parent segment base (Fig. 1c). In a few of the more proximal axial intervals an elongated remnant of such a lobe forms a narrow flange on the side of the axis (Fig. 1d). In general, free lobes develop along both sides of the axial intervals over approximately 5-20 % of the length of the rachis just below the simple distal segments representing its apical pinnae (e.g. from P9 to P13 in Fig.1a), about 40% (P1)-70% (P3) of the length of the costae from a similar position but often along the full (P5), or nearly full (P4) length of the costae (Fig. 1a) as well as some basal intervals of costules (Fig. 1a, P1). Rarely, in the very largest 4-pinnate to 5-pinnatifid shade-form fronds (Fig. 3, and see below), free lobes are also present between a few of the most basal (proximal) laminal elements on the costulets. The contrasting absence of free lobes in *P. aquilinum* s.l. is illustrated for *P. aquilinum* subsp. *wightianum* (as *P. revolutum*) by Brownsey (1989, Fig. 2).

The distribution of the free lobes on laminal axes in *P. esculentum* subsp. *esculentum* varies widely, even between fronds of the same plant. The position (number from the base) of the most distal interval on each of these axes that carried free lobes, and the overall length of that axis from base to apex were recorded for a sample of 35 fronds. These specimens were collected at Epping (Sydney, NSW, same site as above) from a series of separate stands in a mixed dry sclerophyll woodland and are likely to represent a number of genets. The data are summarised in Table 1 where minimum, median and maximum values are shown. In each case the longer the axis overall, the further from its base is the axial interval carrying the lowest free lobe. The correlation between location of the lowest (most proximal) free lobe along the rachis and total rachis length is weak but significant (Spearman correlation coefficient, r = 0.4214, P = 0.0117). The correlation is stronger for the overall length of the basal costa and position of the most proximal free lobe along it (r = 0.5924, P = 0.0002) and for the overall length of the basal pinnule and location of its proximal basal free lobe (r = 0.7915, P = 0.0001). A large series of Herbarium specimens of subsp. *esculentum* from widespread localities in Australia and New Zealand shows patterns of free lobe distribution on the laminal axes consistent with those reported here.

Free lobes retain the characteristics of the ultimate segments which gave rise to them in relation to venation, the variable development of an apparently normal false indusium along the outer margin (Figs 1 b-e) and the presence/absence of gnarled trichomes between veins on the abaxial surface (Fig. 1f). Reflecting their origin as adnate segment bases, the veins of free lobes extend from the axis to which the lobe is attached to the outer margin of the lobe, i.e. at right angles to the lateral veins of the parent segment.

Table 1. Length of lamina, length of most basal pinna and length of most basal pinnule for a sample of 35 fronds of *P. esculentum* subsp. *esculentum* in relation to the most basal axial intervals carrying free lobes.

	Minimum	Median	Maximum
Length of lamina (mm)	341	676	1062
Basal free lobe on rachis (interval between costae)	8	11	13
Length of basal pinna (mm)	195	449	865
Basal free lobe on costa (interval between costules)	3	8	12
Length of basal pinnule (mm)	75	203	387
Basal free lobe on costule (interval between costulets)	1	2	7

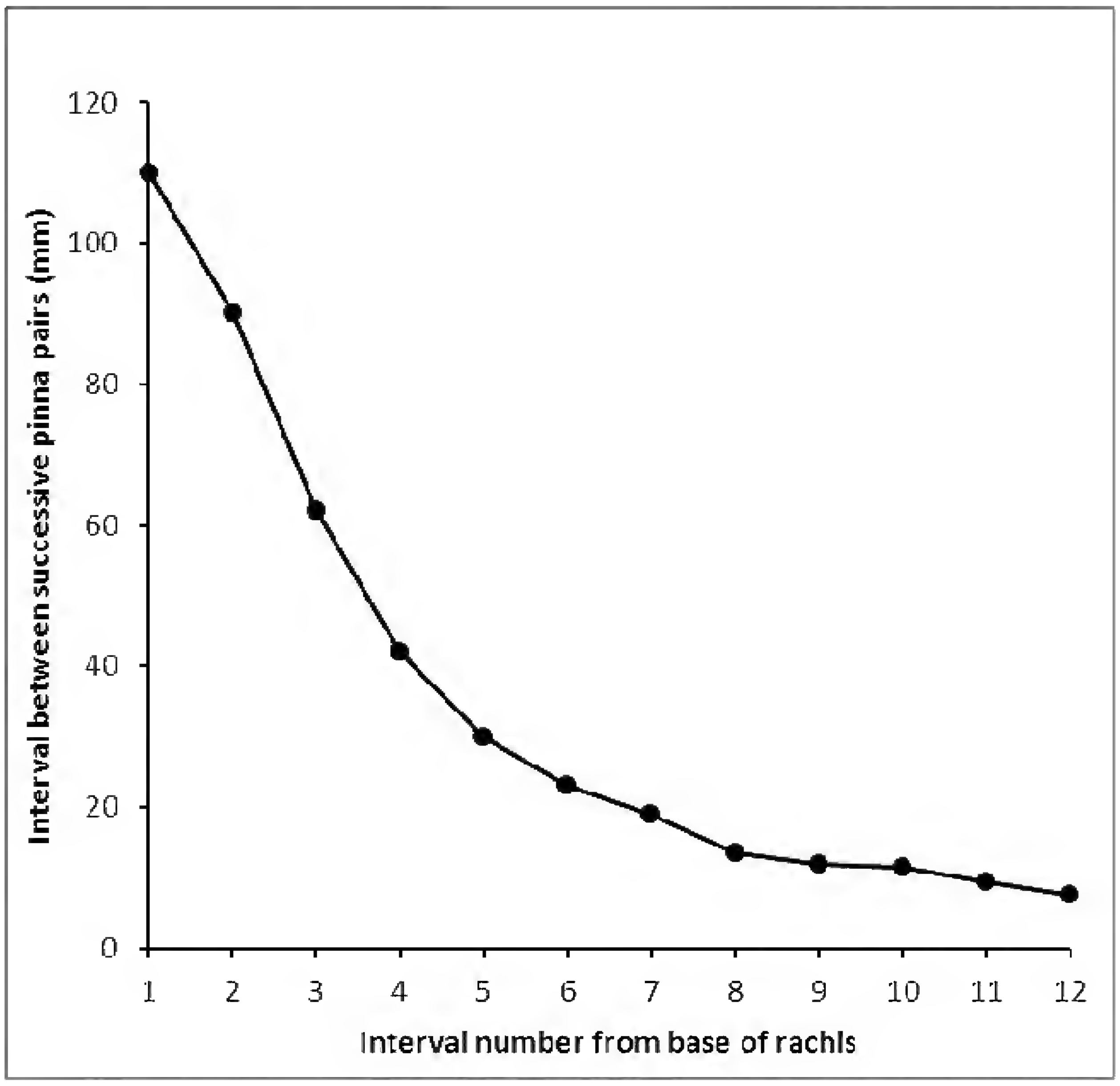

Fig. 2. Spacing of successive pinna pairs (P1–P13) on the rachis of the frond of *P. esculentum* subsp. *esculentum* shown in Fig.1. Intervals 1 to 12 correspond with the distances P1 to P2, P2 to P3….P12 to P13 respectively.

Factors affecting expression of the free-lobe character

The association between the length of major laminal axes and the presence/absence of free lobes on their basal intervals in *P. esculentum* subsp. *esculentum* suggests involvement of environmental factors affecting plant form and growth, whereas the general pattern of pinna spacing on the rachis (see above) is maintained across wide variation in size and dissection of the lamina, as in *P. aquilinum* subsp. *aquilinum* (Bright 1928).

In *P. aquilinum* subsp. *aquilinum* Bright (1928) reported marked reductions in the number of pinnae, the length of the lowest pinnae and laminal size with increased exposure of stands to sunlight, wind and frost compared to fronds from more sheltered positions. Boodle (1904) had earlier noted more highly divided laminae in sheltered-form compared with exposed-form fronds in this subspecies. Boodle also observed that different leaves of the same plant grown consecutively in two different environments, or different portions of the lamina of a single frond, show changes over the same range when transferred between contrasting environments, indicating that such aspects of phenotype are determined only late in development.

O'Brien (1963) observed fronds of *P. esculentum* subsp. *esculentum* growing in protected situations to a height of 2.5 to 3 m, compared with average frond heights at the other extreme of 15 to 25 cm in stands growing on poor coastal soils and exposed to strong winds and full sunshine. Laminae were found to be markedly more divided in fronds from sheltered positions with good soil nutrition, shading from hot sunshine, protection from strong wind and adequate soil moisture than fronds from more exposed microhabitats. The scale of variation in such division under different growth conditions in subsp. *esculentum* is evident in comparison of the basal pinnulets of a basal pinna (Fig. 1) from a frond of average size collected in an open woodland stand, with a basal pinnulet (Fig. 3) from a basal pinna of a large shade-form frond over 3 m high growing in a contiguous moist gully microhabitat. This shade-form pinnulet exemplifies 4-pinnate to 4-pinnate-pinnatifid laminal subdivision in contrast to the pinnulets of the frond in Fig. 1 that show 3-pinnate to 3-pinnate-pinnatifid subdivision with free lobes only on the basal few intervals on the costule of basal pinnules. In the large pinnulet of Fig. 3, there is again a gradation in spacing of segment axes on the costulet repeating the general trend at all levels of laminal subdivision, but here on a small scale. Segments are contiguous at the apex of the costulet but are slightly more widely spaced in the central and proximal zones where long segment bases and free lobes respectively have formed (Fig. 3). If development is relatively slow as in cool shady conditions, there is a reduced incidence of uncut long-adnate segment bases, laminal subdivision proceeds further (compare Figs 1 and 3), and typical lunate free lobes extend to more of the longer basal axial intervals. Conversely, relatively rapid development and frond expansion favours limited laminal subdivision (O'Brien 1963). This results in a higher incidence of axial intervals without free lobes and a relative increase in contiguous uncut adnate segment bases that contribute to a winged appearance in subapical axial intervals. Thus there are a number of indications that the rate of frond expansion defines a "window of opportunity" for the formation of free lobes. This model is consistent with Boodle's (1904) contention that laminal subdivision and other aspects of frond morphology are determined only late in the development and expansion of the bracken leaf. It is shown here that such morphological variability is restricted by over-riding control of the pattern of differential spacing of the laminal axes at each level.

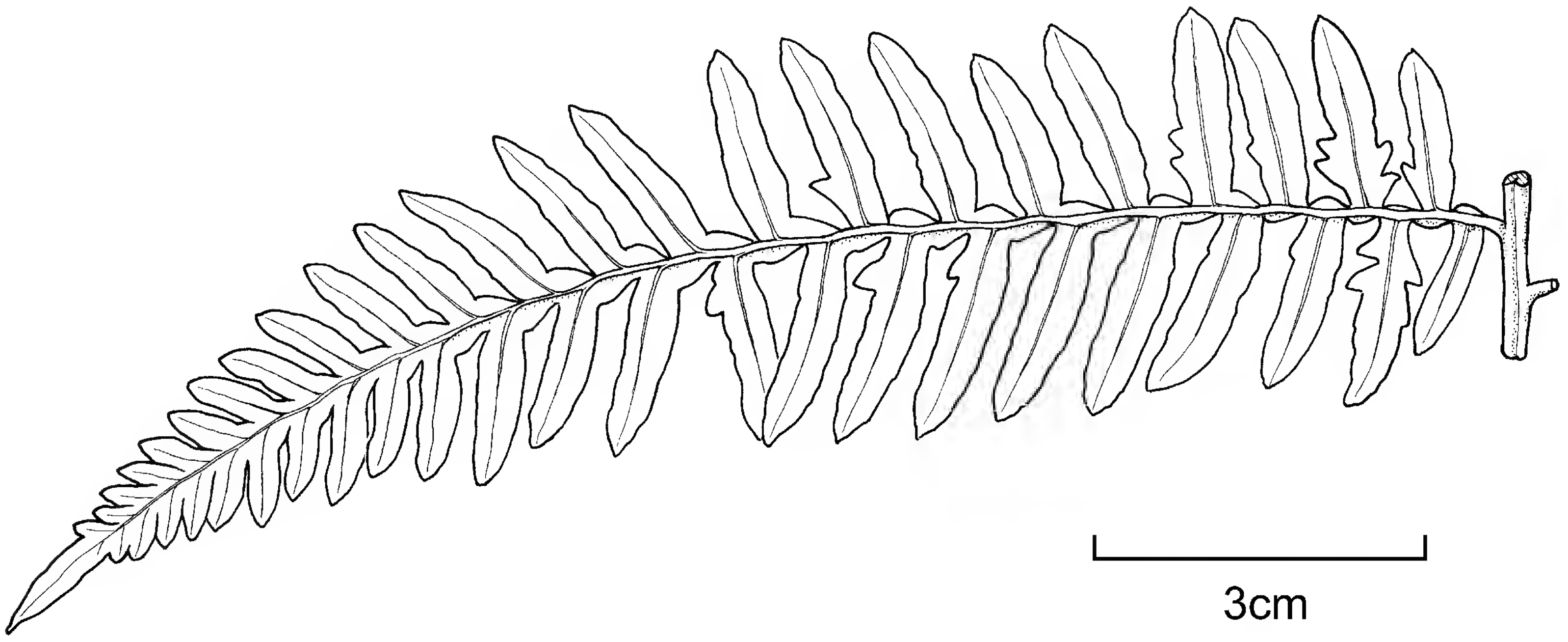

Fig. 3. Pinnulet of an exceptionally large sheltered-form frond of *P. esculentum* subsp. *esculentum* with 4 pinnate to 4-pinnate-pinnatifid laminal dissection showing free lobes on basal intervals of the costulet. Scale bar: 30 mm.

Genotypic basis of free-lobe expression

Detailed examination of the expression of free lobes is timely in view of a major recent study by Schwartsburd et al. (2014) who recognised three morphotypes in diploid South American brackens at subspecific rank within *P. arachnoideum* (Kaulf.) Maxon. These morphotypes are distinguished as showing (i) both free axial lobes and gnarled trichomes (morphotype "ined."), (ii) free axial lobes but not gnarled trichomes (morphotype "arachnoideum") or (iii) gnarled trichomes but not free lobes (morphotype "campestre"). Both morphotypes "arachnoideum" and "campestre" are apparently diploid based on stomatal guard-cell length (Schwartsburd et. al. 2014), as are many specimens of subsp. *arachnoideum* from Central and South America that have both free lobes and gnarled trichomes (Thomson 2000, Thomson and Alonso-Amelot 2002, Wolf et al. 2015). The study by Schwartsburd et al. (2014) was numerically large scale, established diploidy for a sample of the collections and revealed a coherent geographic distribution of sites for each morphotype. Considered together with the observation of an apparently diploid bracken accession with gnarled trichomes but without free lobes in the vicinity of typical subsp. *arachnoideum* in the Galapagos Islands (Wolf et al. 2015), these results suggest that a genetic presence/absence polymorphism may underlie this character. More large scale population studies of *P. esculentum* s.l. including genome size determination are required not only in the Galapagos Islands but also in Venezuela where Ortega (1990) reported a variant ecotype of subsp. *arachnoideum*. This variant form lacks free lobes and, perhaps significantly, shows unusually compact spacing of laminal axes, and may be of hybrid origin.

Conclusion

Development of free lobes in *P. esculentum* starts with extension basiscopically of an adnate lobe or wing of tissue decurrent to a simple distal segment proximal to the apex of the axis carrying it. As this axis extends, in successive intervals down it the greater part of the lobe becomes increasingly separated from the parent segment base as a lunate or semi-lunate portion of typical laminal tissue. The midrib of the segment that gave rise to this free lobe becomes the more apical of the two subordinate axes delimiting the axial interval to which that free lobe is attached. The basic hierarchy of spacing between the laminal axes at successive levels of blade dissection is similar in fronds of greatly different size. In contrast, the position of the most proximal free lobes on the laminal axes is significantly correlated with the length of axial intervals which is mediated by environmental factors influencing growth rate and laminal subdivision.

Plants intermediate in morphology between *P. esculentum* s.l. and *P. aquilinum* s.l. have been widely reported (e.g. Tryon 1941, Mickel and Beitel 1988, Mickel and Smith 2004), especially in locations such as the Galapagos Archipelago (Wolf *et al.* 2015) and northern Australia (Brownsey 1989, 1998) and may include both allotetraploids and introgressants of other ploidy. Fully discrete free lobes appear to be absent in all specimens for which tetraploid status (4n = 208) has been supported by nuclear genome analysis, determination of nuclear DNA content or by comparison of stomatal guard cell lengths (Tan and Thomson 1990, Thomson 2000, Thomson and Alonso-Amelot 2002, Der et al. 2009, Wolf et al. 2015). Importantly, however, Brownsey (1989) has observed that free lobes appear reduced in number and demarcation in some of the putative hybrids that may be diploid, as for instance in those between *P. esculentum* subsp. *esculentum* and *P. aquilinum* subsp. *wightianum* (as *P. revolutum*) in which "…. the free lobes on the midribs of the primary or secondary pinnae are less numerous and clearly defined" than those of *P. esculentum* subsp. *esculentum*. An improved understanding of the form and placement of free lobes should facilitate more positive identification of such hybrids, their parents, and their possible introgressants as, for example, in the Galapagos Islands (Wolf et al. 2015) and northern Australia. Clarification of recognition criteria for free axial lobes also contributes to validation of their potential use as a presence/absence polymorphism providing a genetic marker in further population and biogeographic studies building on the work of Schwartsburd et al. (2014).

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Additional new species of the lichen genus *Pertusaria* from China

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Abstract

Three *Pertusaria* species are described as new to science from China: *Pertusaria laceromarginata* Q. Ren has disciform apothecia with lacerate margins and slightly pruinose, pink disc; a K– epihymenium; 1-spored asci and the presence of hypothamnolic acid. *Pertusaria montana* Q. Ren has disciform apothecia with epruinose or slightly pruinose, pink disc; a K– epihymenium; 1-spored asci and the presence of gyrophoric acid. *Pertusaria yulongensis* Q. Ren has verruciform apothecia with concave, black apices; a K+ violet epihymenium; 8-spored asci with dominantly biseriate spores and the presence of fumarprotocetraric acid.

Introduction

Pertusaria is a large genus in the Pertusariaceae, a widely distributed family throughout the world. The diagnostic characters for species in the Pertusariaceae are the apothecial structure, the number of ascospores per ascus, and spore structure and chemistry (Archer 1997, Schmitt & Lumbsch 2004). During a survey of the Chinese *Pertusaria* lichen flora, we examined specimens collected from the high mountains in Yunnan and Shaanxi provinces and found three species, here described as new to science. Two of the newly described species were found from the northwestern corner of Yunnan Province belonging to Hengduan Mountains (the southeastern part of the Qingzang Plateau). The other one was found from Mt. Taibai at 3700 m, which is the tallest mountain of the Qinling Mountains in southern Shaanxi Province.

Material & methods

The specimens examined in the present study are preserved in the herbarium of Shandong Normal University, China (SDNU) and herbarium of Kunming Institute of Botany, CAS, China (KUN). The morphology and anatomy of all specimens were studied using an Olympus SZX16 stereomicroscope and an Olympus BX61 compound microscope and photographed using an attached Olympus DP72 digital camera. The chemical constituents were identified by spot tests and thin-layer chromatography (Orange et al. 2001).

New Species

Pertusaria laceromarginata **Q. Ren, sp. nov.**

Fungal Name No.: FN 570269

Similar to *Pertusaria wulingensis* Z. S. Sun & Z. T. Zhao but is distinguished by a 1-spored asci and it contains hypothamnolic acid.

Type: China: Yunnan: Gongshan County, Qiqi Natural Reserve, alt. 1900 m, on bark, *M. Zang s.n. (Herb. No. 4449)*, 19 Jul 1982 (holo: KUN).

Thallus grey or ash-grey, thin, the margin entire and unzoned; surface smooth or weakly tuberculate, generally matt, fissured in the older parts; isidia and soredia absent. *Fertile apothecia* abundant, disciform, crowded or well dispersed, rarely fused, concolorous with the thallus, initially closed and becoming ruptured with age, (0.3–) 0.5–1.0 mm diam., the margins crenulate or lacerate. *Disc* pink, slightly pruinose; the fruit center pink; epihymenium hyaline, K–; hypothecium hyaline. *Asci* 1-spored, clavate; ascospores hyaline, cylindric or ellipsoidal, 160–180 × 50–65 μm; spore wall single, 2–3 μm thick, smooth and not trimmed. *Pycnidia* not seen. **Fig. 1**.

Chemistry: Cortex K–, C–, KC–, Pd–; medulla K+ purple, C+ red (quickly fading), KC–, Pd–; containing hypothamnolic acid (TLC).

Etymology: *laceromarginata* from the Latin *lacer*, torn and *marginata*, margin, a reference to the lacerate margins of the disciform apothecia.

Ecology and distribution: *Pertusaria laceromarginata* is a rare, corticolous species, known only from Gongshan County, Yunnan Province in southwestern China. It grows on bark at altitudes between 1700 m and 1900 m.

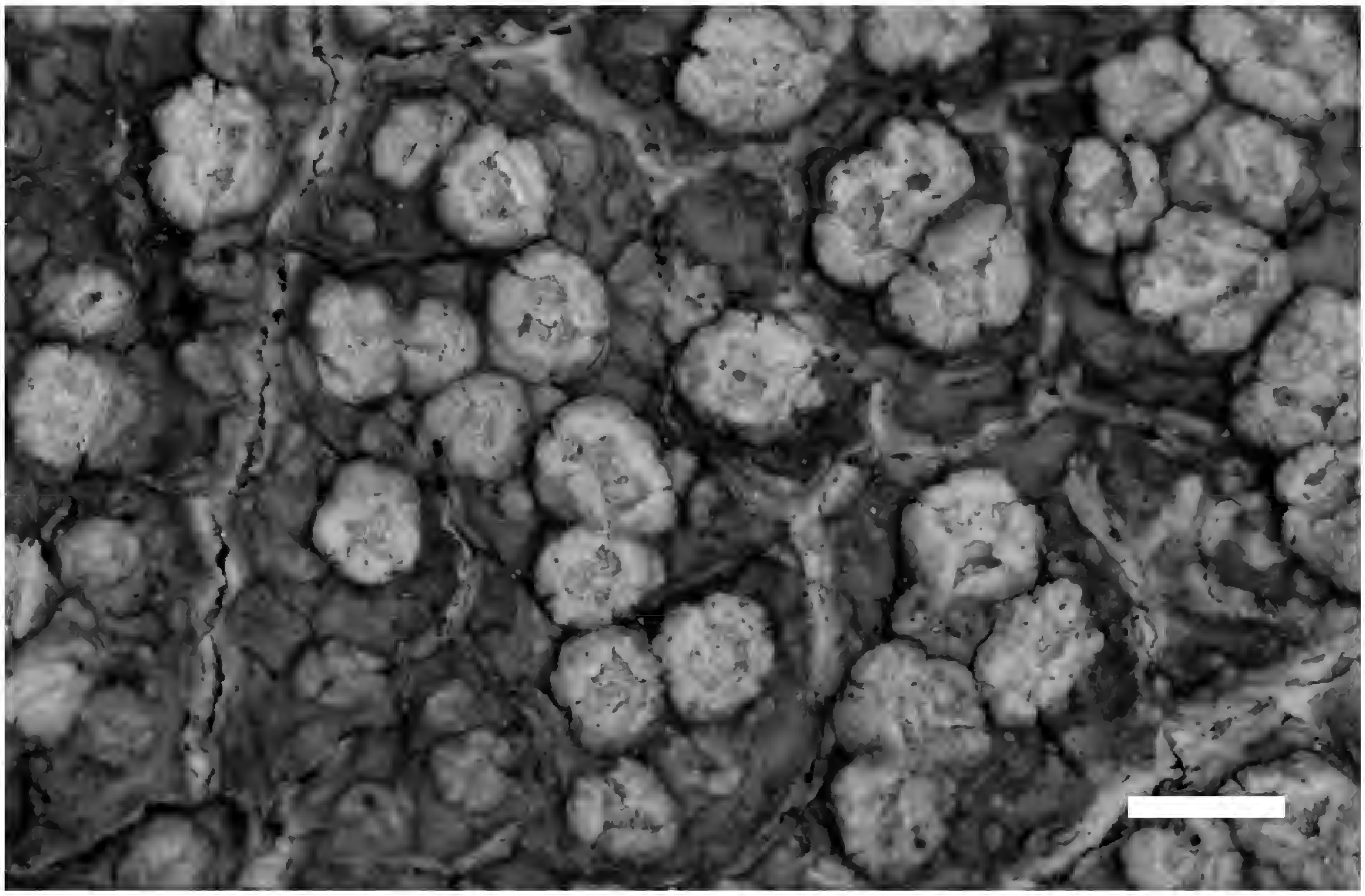

Fig. 1. *Pertusaria laceromarginata* (holotype). Image showing disciform apothecia with lacerate margins and pruinose, pink disc. Scale bar = 1 mm.

Comments: *Pertusaria laceromarginata* is characterized by a grey and matt thallus, lecanorine apothecia with 1–3 pink discs covered with weak pruina, 1-spored asci with cylindric or ellipsoidal spores, the walls of which are smooth and not trimmed, and the presence of hypothamnolic acid. Morphologically, the new species resembles *Pertusaria wulingensis*, but the latter species has 8 ascospores per ascus and contains psoromic acid (Ren et al. 2009). The new species is chemically identical to *Pertusaria novaezelandiae* Szatala, but the latter species occurs in south-eastern Australia and New Zealand from sea level to 1400 m elevation, and has a K+ violet epihymenium and heavily pruinose or sorediate disc, and possesses smaller spores that are 140–170 × 30–55 µm (Kantvilas 1990). *Pertusaria laceromarginata* resembles *Pertusaria hypothamnolica* Dibben (Dibben 1980) in that both species contain hypothamnolic acid and possess asci with a single ascospore. However, *P. hypothamnolica* is found in the south-eastern United States and contains additional lichexanthone, which is absent from *P. laceromarginata*.

Additional specimen examined: CHINA: YUNNAN: Gongshan County, Dulongjiang Town, Dizhengdang Village, alt. 1700 m, *Q. Ren 554,* 28 Aug 2002 (SDNU).

***Pertusaria montana* Q. Ren, sp. nov.**

Fungal Name No.: FN 570268

Distinguished from the closely similar *Pertusaria bryontha* (Ach.) Nyl. possessing a pink disc, having a K– epihymenium and lacking stictic acid.

Type: China: Shaanxi: Mt. Taibai, alt. 3700 m, on moss, *Y. J. Li & W. Fu L-134,* 5 Aug 2005 (holo: SDNU).

Thallus white or whitish grey, thin, margins indefinite, not zoned; surface smooth or slightly tuberculate, generally matt, continuous. Isidia and soredia absent. *Fertile apothecia* disciform, concolorous with thallus, numerous, solitary, subspherical to discoid, dispersed or occasionally crowded, (0.5–) 0.8–2.5 mm diam. *Disc* pink, plane, epruinose or slightly pruinose; the margins prominent, initially entire but later crenulate. *Epihymenium* dark brown, K–; hymenium hyaline. *Asci* 1-spored, clavate; ascospores hyaline, ellipsoidal or cylindric, (138–) 188–208 × 53–70 (–75) µm; spore wall single, 5–12 µm thick, smooth and trimmed, the end wall 17–25 µm thick. *Pycnidia* not seen. **Fig. 2**.

Chemistry: cortex K–, C+ yellow, KC+ yellow, Pd–; medulla K–, C–, KC–, Pd–; epihymenium K–, C+ red, KC+ red, Pd–; containing gyrophoric acid and trace of thiophaninic acid (TLC).

Etymology: From the Latin *montana*, mountain, a reference to the high mountain habitat.

Comments: *Pertusaria montana* resembles *P. bryontha* both in general appearance and habitat. Both are arctic-alpine species growing on mosses and plant debris and contain one ascospore per ascus. *Pertusaria bryontha* has a dark brown disc, contains stictic acid and its epihymenium is K+ purple (Chambers et al. 2009) whereas the new species has a pink disc, lacks stictic acid and has a K– epihymenium.

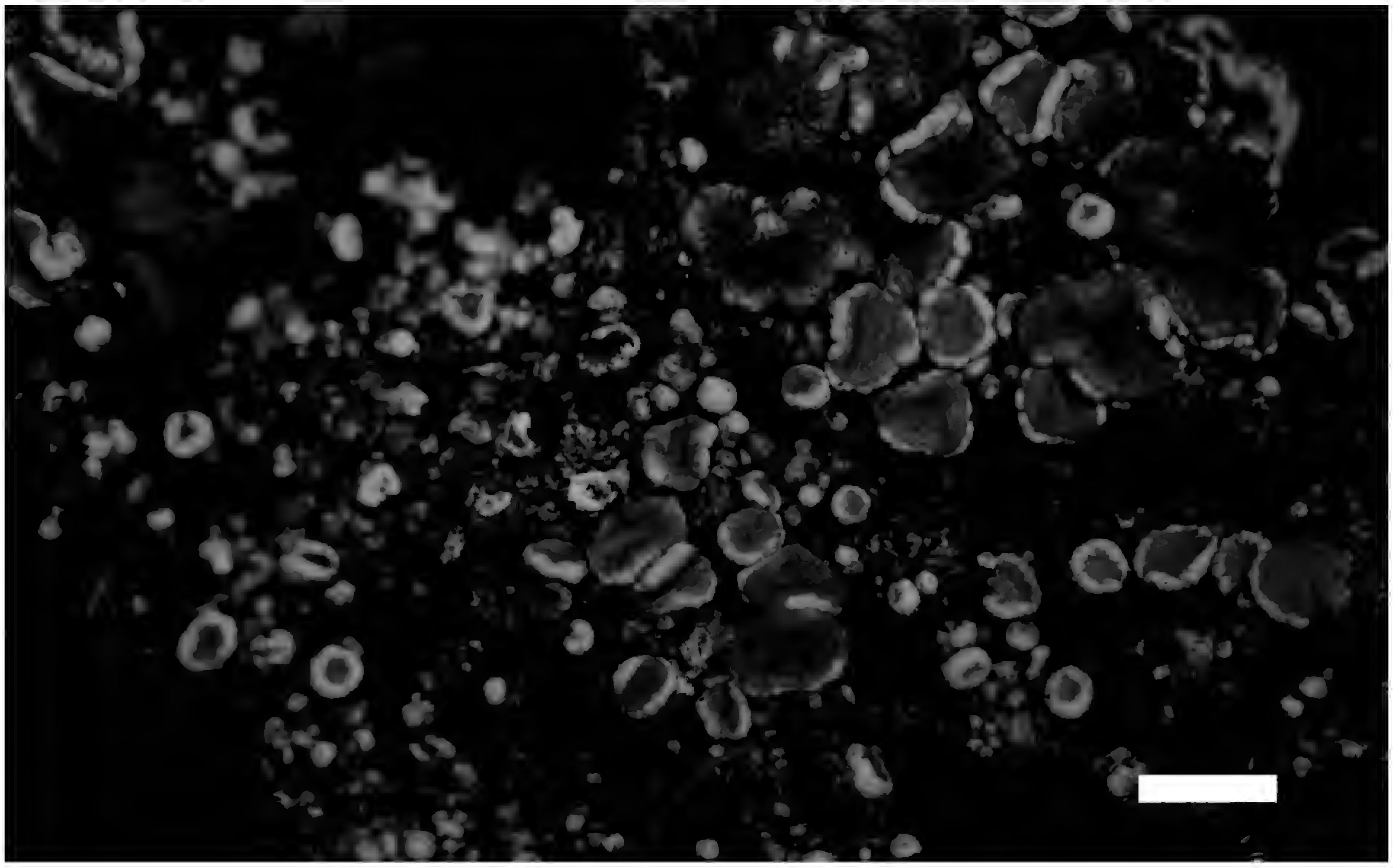

Fig. 2. *Pertusaria montana* (holotype). Image showing a muscicolous thallus and disciform apothecia with epruinose or slightly pruinose, pink disc. Scale bar = 2 mm.

***Pertusaria yulongensis* Q. Ren, sp. nov.**

Fungal Name No.: FN 570266

Similar to *Pertusaria leioplaca* DC. but differs in having 8-spored asci and in containing fumarprotocetraric acid.

Type: China: Yunnan: Yulong County, Yulong Snow Mountain, on branch, *L. S. Wang 88-353a*, 6 Nov 1988 (holo: KUN).

Thallus grey to black-grey, thin, prothallus absent; isidia and soredia absent. *Apothecia* verruciform, fertile verrucae abundant, concolorous with the thallus, globose, usually single, rarely 2–3 fused, 0.5–1.0 mm diam., with concave, black apices; ostiole 1 per verruca, inconspicuous; epihymenium K+ violet; hymenium hyaline. *Asci* 8-spored; ascospores mostly biseriate, 38–70 × 25–40 µm; spore wall double, smooth and not trimmed, 3–5 µm thick. *Pycnidia* not seen. **Fig. 3**.

Chemistry: Cortex K–, C–, KC–, Pd–; medulla K+ yellow, C–, KC–, Pd+ yellow; containing fumarprotocetraric acid (TLC).

Etymology: From the Latin *ensis*, place of origin, and Yulong County.

Comments: *Pertusaria yulongensis* is characterized by asci with eight mostly biseriate spores and the presence of fumarprotocetraric acid. *Pertusaria yulongensis* resembles *P. leioplaca* in morphology, but *P. leioplaca* usually has four spores per ascus and contains 4,5-dichlorolichexanthone (Chambers et al. 2009). The new species is distinguished from the chemically similar species *P. yunnana* G. L. Zhou & Lu L. Zhang, also from Yunnan Province, by the disciform apothecia and the larger ascospores (Zhao et al. 2014).

Additional specimen examined: CHINA: YUNNAN: Yulong County, Lidiping, alt. 3250 m, on branch, *J. X. Xi 0159(h),* 16 Jun 1984 (KUN 11537).

Fig. 3. *Pertusaria yulongensis* (holotype). Image showing verruciform apothecia with concave, black apices. Scale bar = 1 mm.

Acknowledgments

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A review of *Myriophyllum callitrichoides* (Haloragaceae)

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Abstract

Barrett, M.D., Moody, M.L. & Barrett, R.L. A review of *Myriophyllum callitrichoides* (Haloragaceae). *Telopea* 24: 207–211 (2016). The taxonomic status of *Myriophyllum callitrichoides* Orch. in Western Australia is reviewed. On the basis of new collections made across the Kimberley, a previously unknown taxon with unique mericarp ornamentation is documented, here described as the new species *Myriophyllum foveicola* M.D.Barrett, M.L.Moody & R.L.Barrett. *Myriophyllum foveicola* deserves the same rank as the two previously described taxa, although we prefer to treat them at the rank of species. The previously recognised *M. callitrichoides* subsp. *striatum* Orchard is elevated to species rank as *Myriophyllum striatocarpum* M.D.Barrett, M.L.Moody & R.L.Barrett *nom. nov.* (non *M. striatum* Orchard). Both species are endemic to the Kimberley region of Western Australia. The three species now recognised in the *M. callitrichoides* complex have morphological, ecological and / or geographic distribution to support their status as species. The two Western Australian species are of conservation significance. Illustrations are provided for both of the Kimberley species.

Introduction

Myriophyllum callitrichoides Orchard (1974) is an unusual aquatic plant found only in shallow rockpools in northern Australia, a habitat with transient and irregular hydroperiod that experiences multiple flooding / drying cycles per season, and requires extraordinary resilience to persist in the seed bank (Cross et al. 2015a, b). Plants of *M. callitrichoides* are annual, and posess dimorphic stems and leaves; the basal leaves are thick and spongy and are restricted to a short spongy stem, while upper leaves occur in floating rosettes on numerous long filiform stems. In addition to plant architecture, fruit are also unique within the genus *Myriophyllum* in having divergent mericarps that are cruciform and connate only at their bases (vs mericarps when more than one parallel and connate for > half their length in other *Myriophyllum*), erect subulate styles (sessile to shortly clavate in most other *Myriophyllum*), and unusual in having strictly hermaphroditic flowers (at least some flowers unisexual in most other species), states which prompted van der Meijden (1975) to establish a new genus *Vinkia* Meijden for *M. callitrichoides*. However, the genus *Vinkia* is not currently recognised. *Myriophyllum callitrichoides* has yet to be included in phylogenetic analyses (eg. Moody and Les 2007, 2010; Chen et al. 2014) to establish its synonymy, however ongoing research suggests it is included within *Myriophyllum* subg. *Brachythecum* (Moody and Les 2010; Moody, unpublished data).

Orchard (1986), in a revision of the Australian species of *Myriophyllum*, recognised two subspecies within *M. callitrichoides*, based on anther number, leaf dimension and fruit ornamentation differences. The two subspecies were considered geographically disjunct; *M. callitrichoides* subsp. *callitrichoides* from Western Arnhem Land and *M. callitrichoides* subsp. *striatum* Orchard from the north-west Kimberley. With the collection of further material, the leaf dimension differences between the subspecies described by Orchard (1986, 1990) have proven insufficient to distinguish these taxa. For example, Cowie et al. (2000) describe a larger size range for leaves of *M. callitrichoides* subsp. *callitrichoides* that completely encompasses the range reported by Orchard (1986) for both *M. callitrichoides* subsp. *callitrichoides* and *M. callitrichoides* subsp. *striatum*.

Even at the time of Orchard's 1986 revision, *M. callitrichoides* was poorly known, and the Kimberley *M. callitrichoides* subsp. *striatum* was known only from the type collection. Through extensive collecting across the Kimberley we have confirmed that all Kimberley material has 8 anthers (matching subsp. *striatum*), but discovered two types of mericarp ornamentation within Kimberley material, (1) the wholly striate mericarps typical of *M. callitrichoides* subsp. *striatum*, and (2) wholly verrucose mericarps distinct from either of the described subspecies, known informally in Western Australia by the phrase name *M.* sp. (Harding Range, *M.D. Barrett & R.L. Barrett MDB 1825*). In the north-west Kimberley, e.g. near Theda Station homestead and near the Lawley River mouth, plants containing one or other of the fruit types occur within 100–1000 m of each other, but so far they have not been found growing in the same rockhole, nor is there any evidence of hybridisation. The two forms at Theda differ in their seed dormancy and response to wetting/drying cycles (Cross et al. 2015a), suggesting a subtle ecological shift between them. We here recognise these forms formally as species. Other taxa in *Myriophyllum* differ by similar variation in mericarp ornamentation (e.g. *M. filiforme* and *M. costatum*; *M. echinatum*, *M. drummondii* and *M. limnophilum*), which have been corroborated in recent phylogenetic analyses (Moody and Les 2010; Chen et al. 2014). Consequently we describe the unnamed form with completely verrucose mericarps as the new species *M. foveicola* M.D.Barrett M.L.Moody & R.L.Barrett, and raise *M. callitrichoides* subsp. *striatum* to species rank. Unfortunately, the epithet *striatum* is preoccupied at species rank by *Myriophyllum striatum* Orchard (1986), a species only distantly related to the *M. callitrichoides* complex. We therefore provide the name *Myriophyllum striatocarpum* M.D. Barrett, M.L. Moody & R.L. Barrett as a nom. nov. for *M. callitrichoides* subsp. *striatum* at species rank, and provide a series of comparative photos (Figure 1F–I). Under this new taxonomy, *M. callitrichoides* sensu stricto is confined to Western Arnhemland in the Northern Territory.

Methods

Descriptions are based primarily on dried herbarium specimens although fresh field or cultivated material, or material preserved in 70% ethanol was also utilised. To produce Scanning Electron Microscope (SEM) images, dry material was mounted on stubs using double-sided or carbon tape with conductive carbon paint, coated with gold using an EMITECH K550X Sputter Coater and imaged at high vacuum and high voltage (15 KVa) using a Jeol JCM 6000 NeoScope bench-top SEM at Kings Park and Botanic Garden.

Taxonomy

Myriophyllum callitrichoides Orchard, Trans. R. Soc. S. Aust. 98: 173-177 (1974).

Vinkia callitrichoides (Orchard) Meijden, *Blumea* 22 (1975) 253, postscript.

Vinkia natans Meijden, *Blumea* 22 (1975) 251-253, nom. inval.

With the elevation of *M. callitichoides* subsp. *striatum* to species rank, the autonym *M. callitichoides* subsp. *callitrichoides* is superfluous.

Myriophyllum foveicola M.D.Barrett M.L.Moody & R.L.Barrett, **sp. nov.**

Type: Australia: Western Australia: Near Mt Agnes, [precise locality withheld for conservation reasons], 28 March 2010, *M.D. Barrett & R.L. Barrett MDB 2868* (holo: PERTH 08613699, *iso:* CANB, DNA).

Myriophyllum sp. Harding Range (*M.D.Barrett & R.L. Barrett MDB 1825*), Western Australian Herbarium, in FloraBase, http://florabase.dpaw.wa.gov.au [accessed 01 March 2014].

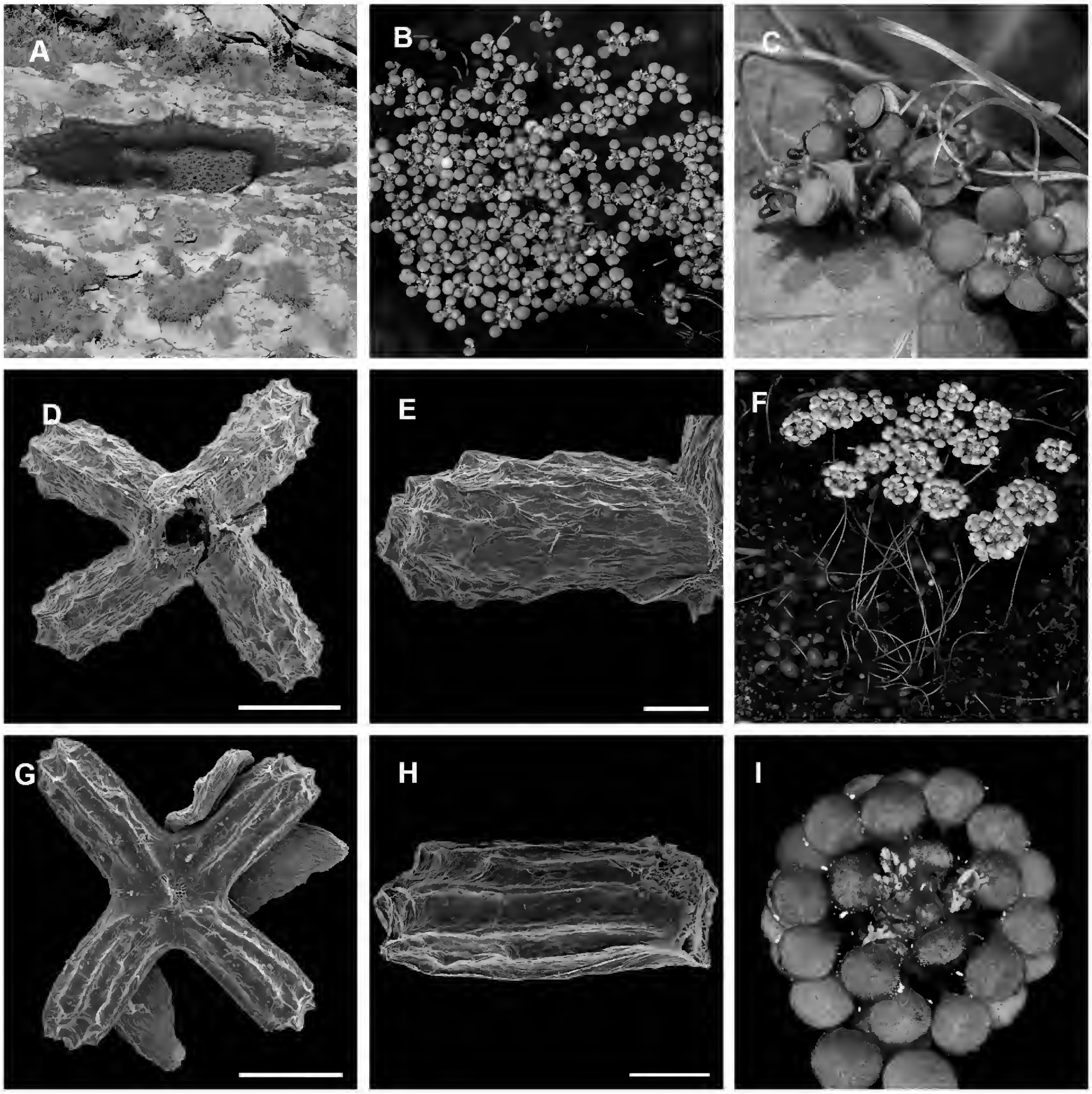

Figure 1. *Myriophyllum foveicola*. **a.** habitat; **b.** habit of floating leaves; **c.** floating leaf rosettes showing fruit held below leaves and flowers held above leaves; **d.** SEM of fruit with four fused verrucose mericarps; **e.** SEM of single verrucose mericarp. *M. striatocarpum*. **f.** habit with submerged leaves and floating leaves; **g.** SEM of fruit with four fused striate mericarps; **h.** SEM of single striate mericarp; **i.** floating leaf rosette with flowers. Scale bars = 500 µm (D, G); 200 µm (E, H). Images from *M.D. Barrett, R.L. Barrett & B.M. Anderson MDB 4281* (A–E) and *M.D. Barrett & R.L. Barrett MDB 2896* (E). Photographs by R.L. Barrett (A, C, F, I); M.D. Barrett (B, D, E, G, H).

Weak annual aquatic herb 20–40 cm tall; stems and leaves dimorphic. Primary stems thick, fleshy, ascending, rooting at base, 10–45 mm tall, 2–3 mm diam., not or sparsely branched; leaves of primary stems alternate, succulent, obovoid to shortly spathulate, 1.5–9 mm long, 1.2–4.0 mm wide, widest in upper half, tapering to 0.5–1.2 mm towards base, entire, slightly recurved, tip rounded with a dark brown terminal gland. Leaves flanked by 2 minute, filiform, deciduous, black-tipped hydathodes on stem at base of petiole. Secondary stems filiform, 1 per main stem branch, arising from axils of the upper primary leaves, 15–35 cm long, 0.2–0.4 mm diam., unbranched for most of length, at apex with a short zone (0.5–5 mm long) of dense short axillary branches, from axils of distant, alternate to subopposite bract-like, subulate, reduced leaves 0.2–0.5 mm long, each branch a single slightly thickened internode 0.5–1.5 mm long, terminating in a flower subtended by 2 opposite bracteoles and a fully formed floating leaf. Emergent floating leaves closely clustered at tips of secondary stems forming 'rosettes', alternate, petiolate, lamina thin, fleshy-succulent, circular to broadly ovate, 1.3–3.0 mm long, 1.2–2.8 mm wide, entire, tip rounded with black apical gland (often bluntly recurved and gland oriented on the lower side), base abruptly tapered to petiole, veins indistinct, ± parallel; petiole 1–2.5 mm long, with 2 black, filiform hydathodes at base. Plants monoecious, flowers bisexual, borne singly at apex of short branches and in axils of emergent floating leaves, sessile, flanked by 2 filiform ± crisped bracteoles 0.2–0.8 mm long with a tapering apex, hydathodes not found. Sepals 4, narrowly obovate, 0.3 mm long, 0.2 mm wide, entire, apex obtuse. Petals 4, 0.9–1.0 mm long, 0.7–0.8 mm wide, broadly obovate with rounded apex, slightly hooded, not keeled, non-unguiculate, persistent. Stamens uniformly 8, filaments 0.6–1.0 mm long; anthers elliptic, 0.6–0.8 mm long, 0.20–0.25 mm wide, not or very minutely apiculate. Styles 4, filiform, 0.8–1.1 mm long, erect, stigma occupying entire length, non-fimbriate. Ovary obturbinate, c. 0.5 mm long, c. 1.8 mm wide, 4-locular. Fruit red-brown to dark brown, cruciform, straddling the petiole, mericarps 4, diverging downwards and outwards at c. 30–70°. Mericarps fused only at bases, separating freely at maturity, narrowly obovoid to cylindrical, 1.0–1.8 mm long, 0.4–0.6 mm wide, verrucose over whole surface, verrucae sometimes slightly elongated longitudinally and aligned longitudinally, especially when immature, but lacking longitudinal striations even at base. **Figure 1A–E**.

Distribution: Endemic to the Kimberley Region, from Kimbolton Station north east to Theda Station, and a single isolated record in the Parker Range, East Kimberley. This range is more widespread, incorporating a wider rainfall gradient than either of the related taxa *M. callitrichoides* and *M. striatocarpum*.

Habitat: Entirely restricted to small, shallow rockholes (up to c. 10 m across) on sheeting sandstone, or once found in a rockhole on granite (*R.L. Barrett RLB 2126*).

Flowering and fruiting: recorded Jauary to April.

Additional specimens: WESTERN AUSTRALIA: [localities withheld for conservation reasons]: 19 January 2007, *M.D. Barrett & R.L. Barrett MDB 1825* (PERTH); 29 Mar. 2010, *M.D. Barrett & R.L. Barrett MDB 2888* (PERTH); 29 Mar. 2010, *M.D. Barrett & R.L. Barrett MDB 2889* (PERTH); 29 Mar. 2010, *M.D. Barrett & R.L. Barrett MDB 2892* (PERTH); 30 Mar. 2010, *M.D. Barrett & R.L. Barrett MDB 2945* (PERTH); 30 Mar. 2010, *M.D. Barrett & R.L. Barrett MDB 2956* (PERTH); 12 Mar. 2001, *R.L. Barrett RLB 2126* (PERTH); 19 Jan. 2010, *R.L. Barrett, M. Maier & P. Kendrick RLB 6260* (PERTH); 24 Jan. 2010, *R.L. Barrett & M.D. Barrett RLB 6402* (PERTH); 25 Jan. 2010, *R.L. Barrett & M.D. Barrett RLB 6423* (PERTH); 7 Apr. 2013, *M.D. Barrett, R.L. Barrett & B.M. Anderson MDB 4281* (PERTH).

Etymology: The epithet is derived from Latin *fovea*, a small pit, and *–cola*, dweller, in reference to the specific habitat in rockpools. The vernacular name Warty Rockpool Milfoil is recommended, along with Striped Rockpool Milfoil for *M. striatocarpum* and Kakadu Rockpool Milfoil for *M. callitrichoides*.

Conservation status: *Myriophyllum foveicola* is listed by Jones (2015) as Priority Three under Department of Parks and Wildlife Conservation Codes for Western Australian Flora, under the name *M.* sp. Harding Range (*M.D.Barrett & R.L. Barrett MDB 1825*).

Notes: Seeds of *M. foveicola* were found to germinate in high numbers after 2 and 3 years of simulated annual inundation / drought cycles by Cross et al (2015a, fig. 4), while seeds of co-occurring *M. striatocarpum* had a very low rate of emergence after the second year. These data suggest that *M. foveicola* seeds may be more resilient than *M. striatocarpum* to poor seasons that provide sufficient rainfall to germinate seeds, but insufficient rain to maintain rockpool levels through to flowering. This is in agreement with the observed greater climatic envelope for *M. foveicola*, which occurs widely through the Kimberley including the drier central and east Kimberley, while *M. striatocarpum* is apparently restricted to the highest-rainfall zone of the north-west Kimberley. On the Mitchell Plateau, *M. striatocarpum* co-occurs with *Nymphoides astoniae* M.D. Barrett & R.L. Barrett, a species also restricted to rockhole habitats in the high rainfall zone of the north-west Kimberley (Barrett and Barrett 2015).

Myriophyllum striatocarpum M.D.Barrett, M.L.Moody & R.L.Barrett, **nom. et stat nov**.

Basionym: *Myriophyllum callitrichoides* subsp. *striatum* Orchard, *Brunonia* 8(2): 252 (1986), non *Myriophyllum striatum* Orchard, *Brunonia* 8(2): 243 (1986). Type: Mitchell River, Western Australia, 22 February 1980, *C.R. Dunlop 5261* (holo: HO 34156; iso: DNA, MEL, NSW, PERTH 01000268).

Conservation status: *Myriophyllum striatocarpum* is listed by Jones (2015) as Priority Three under Department of Parks and Wildlife Conservation Codes for Western Australian Flora, under the name *M. callitichoides* subsp. *striatum*.

Key to species of the *Myriophyllum callitrichoides* complex

1. Stamens 4; mericarps weakly and irregularly striate with sharp downward pointing verrucosities in distal half .... ***M. callitrichoides***

1: Stamens 8 .... **2**

2. Mericarps strongly striate lacking sharp verrucosities, or a few weak verrucosities occasionally present at extreme apex .... ***M. striatocarpum***

2: Mericarps lacking striations, entirely verrucose .... ***M. foveicola***

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