The Lichenologist **44**(4): 457–463 (2012) © British Lichen Society, 2012
doi:10.1017/S0024282912000047

Pannaria howeana and *Pannaria streimannii*, two related new lichen species endemic to Lord Howe Island, Australia

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Abstract: *Pannaria howeana* and *P. streimannii* are described here as new to science. Both species are restricted to the isolated Lord Howe Island in Australia. The former is known only from one collection and the latter from two sites. *Pannaria howeana* is a primarily fertile species, with rather broad lobes and few rhizines restricted to the central part of the lower side of the thallus. The lower sides of the lobes have a pattern of characteristic radiating hyphae and narrowly recurved margins similar to the New Zealand lichen *P. araneosa* (C. Bab.) Hue, which is considered to be its closest relative. *Pannaria streimannii* is a phyllidiate counterpart of *P. howeana*. Both species share a new chemosyndrome consisting of porphyrilic acid in combination with vicanicin and leprolomin. Local endemic species are uncommon among tripartite *Pannaria* species, and the coarse vegetative propagules of both species appear to be an adaptation to local dispersal on a small, isolated island.

Key words: biogeography, chemistry, gigantism, lichenized Ascomycota, *Pannariaceae,* rare species, taxonomy, vegetative dispersal

Accepted for publication 15 *December* 2011

Introduction

Tripartite foliose *Psoroma* species have now been transferred to the genus *Pannaria* (Jørgensen 2001; Elvebakk & Galloway 2003; Passo & Calvelo 2006). Many can preliminarily be referred to species groups characterized by morphology, anatomy and chemistry. Species related to *P. pallida* (Nyl.) Hue have pannarin as the major secondary compound (Passo & Calvelo 2006; Elvebakk & Elix 2006), those related to *P. sphinctrina* (Mont.) Tuck. ex Hue have vicanicin (Lumbsch *et al*. 2011), and those related to *P. leproloma* (Nyl.) P. M. Jørg. have vicanicin and leprolomin, in part also scabrosin esters (Elvebakk *et al*. 2007). Some additional species with vicanicin or isovicanicin and species not thoroughly re-examined recently cannot yet be assigned to the groups listed above. The recent phylogenetic studies by Passo *et al*. (2008) and Elvebakk *et al*. (2010) both included ten sequenced samples of foliose, tripartite *Pannaria* species. These were grouped differently in comparison with the bipartite *Pannaria* species. However, a comparison of these two groups was not the target of either of these phylogenetic studies, and the relationship between these species has not been resolved, except that they are clearly within *Pannaria* s. lat. and not included in the *Psoroma* clade.

Among the 17 species currently accepted, seven species are panaustral, whereas another seven species are widely distributed endemics in New Zealand, South-East Australia, or southern South America, respectively, except for *P. euphylla* (Nyl.) Elvebakk & D. J. Galloway, which occurs in both New Zealand and Australia. In addition, both *P. isidiosa* Elvebakk and *P. phyllidiata* Elvebakk are regional endemics in New South Wales, Australia (Elvebakk & Elix 2006; Lumbsch *et al*. 2011), whereas *P. lobulifera* Elvebakk is known only from three collections in a restricted area of New Caledonia (Elvebakk 2007).

During herbarium studies of *Pannariaceae*, two new tripartite, foliose *Pannaria* species were discovered from the small and isolated Lord Howe Island. The aim of the present

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study is to describe these species and discuss their affinity to other known species.

Materials and Methods

Collections were found only in the herbaria BG, H and CANB. However, the species were sought in material from the herbaria AK, BM, PC, S, TROM, UPS, and WELT. When studied microscopically, iodine+reactions were examined by adding IKI to mounts pretreated with KOH (Orange *et al.* 2001). Perispore structures were studied in water mounts and restricted to spores liberated from their asci. Thin-layer chromatography of acetone extracts followed standardized procedures and included solvents A and C (Culberson 1972; Orange *et al.* 2001). HPLC analyses were carried out according to Feige *et al.* (1993) and Bjerke *et al.* (2002). Nomenclature of ascospore structures follows Nordin (1997).

The Species

Pannaria howeana Elvebakk sp. nov.

MycoBank No: MB 563995

Pannariae araneosae similis, sed lobis tenuioribus, secundariis lobis suberectis et tenuibus, tomento laminali minus evoluto, praesentiaque leprolominis et acidi porphyrolici differt.

Typus: Australia, New South Wales, Lord Howe Island, Mt. Gower summit area, 31°35′12″S, 159°04′38″E, 820 m alt. Low vegetation dominated by *Metrosideros nervulosa, Zygogynum howeanum, Dysoxylum pachyphyllum, Dracophyllum*, tree ferns and palms, on shaded shrub (*Dracophyllum*) stem, 11 February 1995, leg. *H. Streimann* 56126 (CANB—holotypus!; H!, B, NY—isotypi).

(Fig. 1)

Thallus foliose, corticolous, forming rosettes 5–10 cm diam., very loosely attached to the substratum. *Lobes* 180–250 μm thick, irregularly branched, discrete to slightly overlapping in peripheral parts, coalescing centrally, weakly concave, 1·5–3·0 mm broad; ascending and partly incurved lobules, without basal constrictions, *c.* 0·5 × 2·0 mm, also present; margins distinctly and very narrowly recurved. *Prothallus* not observed. *Upper surface* probably pale greenish grey when fresh and dry, changing to pale yellowish brown after storage in herbaria, glossy and glabrous, except very weakly tomentose close to margins. *Upper cortex* 50–60 μm thick, without pigmentation and without colour change after application of water to old herbarium specimens, paraplectenchymatous, surface layer sclerenchymatous, lumens globose and small above, elongated and 7–12 μm long below, walls 3–5 μm thick. *Photobiont* layer 20–30 μm thick, of globose to subglobose very small cf. *Myrmecia* cells, 2·5–3 × 2·5–5 μm in size. *Medulla* 100–140 μm thick. *Lower cortex* lacking, but lowermost part of the medulla forming a distinct pattern of longitudinally radiating and pale brown hyphae; *rhizines* sparse, pale brown and simple, 2–3 mm long, mostly arranged in central parts of lobe systems.

Cephalodia common, laminal on the upper side, 1·0–2·5 mm long, placodioid and pulvinate, lobes irregularly arranged and convex; *upper cortex* as in the chlorobiont; *cyanobiont* cf. *Nostoc*, cells bluish green, subglobose to ellipsoid, 3–6 × 3–4 μm, organized within indistinct spherical glomeruli, 10–20 μm wide, delimited by a mucilaginous sheath; no chain structures observed.

Apothecia common, laminal, substipitate, 1·0–2·5 mm broad, discs rufous brown, plane to weakly concave, occasionally with a deposited thalline granule; *thalline excipulum* crenulate-striate, distinctly incurved; *epithecium* brown, 15–20 μm thick, IKI–; *hymenium* colourless, but IKI+ blue, 100–120 μm thick; *hypothecium* light brown, IKI–, 60–90 μm thick; *paraphyses* simple to sparingly branched, *c.* 2·5 μm thick, multiseptate, slightly swollen near the septa; *asci* clavate, 100–120 × 15–20 μm, no internal amyloid structures observed, with eight ascospores. *Proper ascospores* ellipsoid, 13·5–17·0 × 8–10 μm, irregularly verrucose; *perispores* ellipsoid, 14–18 × 9–11 μm, smooth when immature, gradually developing verrucae on a *c.* 0·5 μm thick wall, without apical extensions.

Chemistry. TLC: porphyrilic acid and vicanicin (major), leprolomin (nil to minor), unidentified terpenoids (trace). HPLC (isotype at H): porphyrilic acid (major), vicanicin minor), leprolomin (very weak trace).

Etymology. Named after Lord Howe Island, which is the only known locality of this species.

FIG. 1. *Pannaria howeana* (holotype). A, general habit; B, detail, showing suberect lobules and one cephalodium; C, lower side of lobes with radially arranged hyphae.

https://doi.org/10.1017/S0024282912000047 Published online by Cambridge University Press

Pannaria streimannii Elvebakk sp. nov.

MycoBank No: MB 563996

Pannariae howeanae similis, nisi quod apotheciis destituta et phyllidiis instructa est.

Typus: Australia, New South Wales, Lord Howe Island, Mt. Gower summit area, 31°35′12″S, 159°04′38″E, 820 m alt. Low vegetation dominated by *Metrosideros nervulosa, Zygogynum howeanum, Dysoxylum pachyphyllum, Dracophyllum*, tree ferns and palms, on treelet (*Atractocarpus stipularis*) stem, 11 February 1995, leg. *H. Streimann* 56128 (CANB—holotype!; B, H—isotypi).

(Fig. 2)

Similar to *P. howeana*, except for the following:

Lobes partly covered laminally with a sparse tomentum. *Phyllidia* common, semierect, 0·2–1·0 mm wide, occasionally up to 2·5 mm, orbicular or nearly so, constricted at base, other ascending lobules not seen.

Apothecia not seen.

Etymology. Named after Heinar Streimann (1938–2001), an outstanding collector and student of bryophyte and lichen biodiversity, particularly within Australasia, who collected both this species and *P. howeana* on Mt. Gower.

Additional collection. **Australia:** *New South Wales*: Lord Howe Island, slope of Mt. Gower, August 1981, *P. M. Jørgensen* s. n. (BG L-44187).

Discussion

The two new species are obviously closely related, with *P. streimannii* considered to be a phyllidiate counterpart of *P. howeana*. Both differ considerably from other known tripartite *Pannaria* species. The most distinctive feature is their exclusive chemosyndrome, combining vicanicin and leprolomin with porphyrilic acid. The last substance is known from several pannarin-containing species within *Pannariaceae*, in addition to being known from a number of *Psoroma* species as a related compound, mostly referred to as porphyrilic acid methyl ester (methyl porphyrilate). There are no reports in the literature of porphyrilic acid co-occurring with vicanicin/leprolomin, nor is this combination known from numerous unpublished TLC analyses of *Pannariaceae* specimens made by the present author.

It has been established that secondary chemistry is of particular taxonomic importance in tripartite *Pannaria* species (see review by Elvebakk & Elix 2006). One might speculate that the occurrence of porphyrilic acid here represents an occasional divergence to its usual association with pannarin in several *Pannaria* species. However, the HPLC analysis of *P. howeana* showed that porphyrilic acid, including a twin peak with slightly higher retention value, had a peak six times higher than vicanicin. Although the peak height is not an accurate indication of relative concentrations of these two substances, this result makes it unlikely that porphyrilic acid is an accessory compound.

Morphologically, the two species appear most strongly related to the New Zealand species *P. araneosa* (C. Bab.) Hue. The lobes are large and broad, although not as broad as in *P. araneosa*. Their tomentum is either sparse or rudimentary along margins, in contrast to its more prominent development in *P. araneosa*.

However, all these species have just a few rhizines in older parts of their thalli, and are therefore loosely attached to the substratum. Their lower sides have a very characteristic pattern of long, adpressed, longitudinal and radiating hyphae following the branching of the lobes, similar to the morphology of many *Heterodermia* species (Fig. 1C). Their lobes also have a characteristic very narrow and distinct recurved margin representing the growth zone.

Pannaria araneosa is currently being studied (A. Elvebakk, J. A. Elix & T. Dahl, unpublished data), and details of its anatomy, chemistry and distinguishing features compared with other, mostly undescribed, species are not known, although its chemosyndrome consists of compounds in the vicanicin complex. Further studies involving molecular analyses are needed to support the hypothesis presented here that these three species form a phylogenetically distinct clade within the group of tripartite foliose *Pannaria* species. Although stated to be widely distributed in New Zealand by Galloway (2007),

FIG. 2. *Pannaria streimannii* (holotype). A, general habit; B, detail showing phyllidia.

https://doi.org/10.1017/S0024282912000047 Published online by Cambridge University Press

unpublished data suggests that *P. araneosa* is restricted to northern areas of the country. This would be consistent phytogeographically, given the occurrence of *P. howeana* and *P. streimannii* on subtropical Lord Howe Island.

The chlorobiont cells of both Lord Howe Island species are myrmecioid, but significantly smaller than those of all other *Pannaria* species studied by the present author. Another interesting aspect is that the thalli of the herbarium specimens, now 16 to 30 years old, are pale olive green, without the strong dark brown or yellowish brown pigmentation observed in other old tripartite *Pannaria* specimens. In addition, the dead *P. howeana* and *P. streimannii* thalli do not change colour to violet-brown immediately after exposure to water, as is the case with most other tripartite *Pannaria* species. It is still not known whether this is due to the breakdown of specific chlorobiont strains, or whether it is due to the particular mycobionts or their symbioses.

The perispores are verrucose in *P. howeana*, a feature shared by many tripartite *Pannaria* species. However, in *P. howeana* the proper spore wall is also verrucose, which is a far less common feature in this group of lichens.

In an evolutionary context, the presence of two related, locally endemic species from this isolated island is interesting. The small (10 km^2) and isolated Lord Howe Island is situated 600 km east of continental Australia and more than twice that distance from New Zealand, is of volcanic origin and is estimated to be 6·9 million years old. Its vascular flora comprises 249 species, of which 103, or 40 %, are endemic, and mostly with relationships to species in adjacent territories (Hutton 2002). The vascular flora also includes several endemic genera.

The present study has established that a corresponding evolutionary process has taken place within the genus *Pannaria* leading to local endemism. The situation is similar to that of the Juan Fernández Archipelago in the eastern Pacific, islands which are only slightly younger, and of similar distance from the nearest continent. Their level of vascular plant endemism at species and generic level is in the same range, although higher at Juan Fernández, an archipelago which has higher habitat diversity. According to our current knowledge, the Juan Fernández Archipelago houses three local endemic species of *Pannaria* and *Psoroma*, in addition to a higher number of several widespread species present on the South American mainland.

Lord Howe Island provides another site to study the balance between long-distance dispersed and local endemic taxa within this group of lichens. *Pannaria howeana* probably required a long evolutionary period to develop from its presumed ancestors, which could be the *P. araneosa* lineage in New Zealand or an unknown group in Australia. *Pannaria sphinctrina* (Mont.) Tuck. ex Hue is a well-known primarily fertile, foliose tripartite *Pannaria* species which appears to be evolutionarily old based on its panaustral distribution pattern, whereas other primarily fertile species in this group either have more restricted distribution patterns, or are not well understood. Interestingly, no primarily fertile species other than *P. howeana* are known to be local endemics, except *P. rolfii* Elvebakk in ed. (Elvebakk 2012). *Pannaria streimannii* is presumed to be a secondary species that evolved from *P. howeana*. The co-occurrence of two related species with different vegetative propagules matches the situation both in the *P. leproloma* and in the *P. sphinctrina* complexes (Elvebakk *et al.* 2007; Lumbsch *et al.* 2011).

Both species have conspicuous vegetative propagules. The phyllidia of *P. streimannii* become so large that it was tempting to refer to them as lobules, although they maintain the same basal constrictions as normally sized phyllida (Fig. 2B). In addition to its abundant apothecia and primary thallus lobes, *P. howeana* produces brittle, erect to recurved secondary lobes which evidently function as vegetative propagules (Fig. 1B), an adaptation which is not known from other primarily fertile tripartite *Pannaria* species. The particularly large diaspores developed during the evolution of these two species parallels the development of gigantism in vascular plant diaspores on isolated islands. Such evolutionary adaptation to short-distance dispersal

is a classical aspect of island biogeography (see e.g. Carlquist 1966). This is particularly pronounced in small, moist forests of evolutionarily old islands, a situation which matches Lord Howe Island.

Obviously, there is a great need to investigate the population status of these two species, both with holotypes originating from the summit area of Mt. Gower. The additional specimen of *P. streimannii* collected by Jørgensen was growing on rock on the slopes of Mt. Gower, where it was probably common (P. M. Jørgensen, pers. comm.). The populations collected by Streimann were probably quite large, given that duplicates of both were sent to the herbaria B and H, as well as to NY in the case of *P. howeana*. Both collections at B had been determined as *Psoroma microphyllizans* (Nyl.) D. J. Galloway. Care should be taken when new species are described based on one or two collections only. However, these two species were found to be very distinct, and they are considered here to doubtlessly represent new species, although there is a need to study their variation, for example in propagule size, from a larger number of samples.

Curators of the herbaria AK, BG, BM, CANB, H, PC, S, TROM, UPS, and WELT are acknowledged for permitting study visits, and CANB and H for loans of material presented here. Tina Dahl, then at the Department of Biology, University of Tromsø, is acknowledged for the HPLC analysis of one sample, Per P. Aspaas, University of Tromsø Library, kindly translated the texts in Latin, and Professor P. M. Jørgensen, University of Bergen, kindly supplied information about the collection on the slope of Mt. Gower, and, together with an anonymous referee, commented on the manuscript.

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