

A New *Cladonia* from California

SAMUEL HAMMER

College of General Studies, Boston University, 871 Commonwealth Avenue, Boston, MA 02215, U.S.A.
e-mail: cladonia@bu.edu

Abstract. *Cladonia lacryma* sp. nov., a previously overlooked species from north coastal California and adjacent Oregon, is characterized by the teardrop-like shape of its podetium. The unusual shape develops when the indistinct, immature cup is deformed by the vertical growth of a single proliferation along its margin. *Cladonia lacryma* is similar to other species in section *Cladonia*, which are characterized by closed cups and the presence of fumarprotocetraric acid. The pattern of growth dynamics of *C. lacryma* suggests its affinity with *C. prolifica*, which grows on similar soil types in California.

As part of a recent continuation to a major treatment of the genus *Cladonia* Browne in western North America (Hammer 1995), a field trip to north coastal California was undertaken. During the trip a new lichen was collected in the Pygmy Forest of Mendocino County, an area with unusual, azonal edaphic conditions. Disjunct lichens such as *C. carneola* (Fr.) Fr. (see Hammer 1989a) and several new *Cladonia* species (Hammer 1993a,b) have been reported from the region. *Cladonia lacryma* was collected during previous field seasons in the western United States, but was not recognized as distinct. As discussed below, it was misidentified as *C. phyllophora* Hoffm., a species that is not found in California. The purpose of this study is to expand the knowledge of *Cladonia* in a part of California that is particularly rich in the genus.

MATERIALS AND METHODS

Several hundred packets of lichen specimens were collected from habitats in the Pygmy Forest with particular attention paid to lichens growing on organic matter under ericaceous shrubs, where *Cladonia* species are abundant. The specimens were studied using dissecting and light microscopes. Notes and sketches were prepared, and the material was compared with specimens at the Farlow Herbarium (FH).

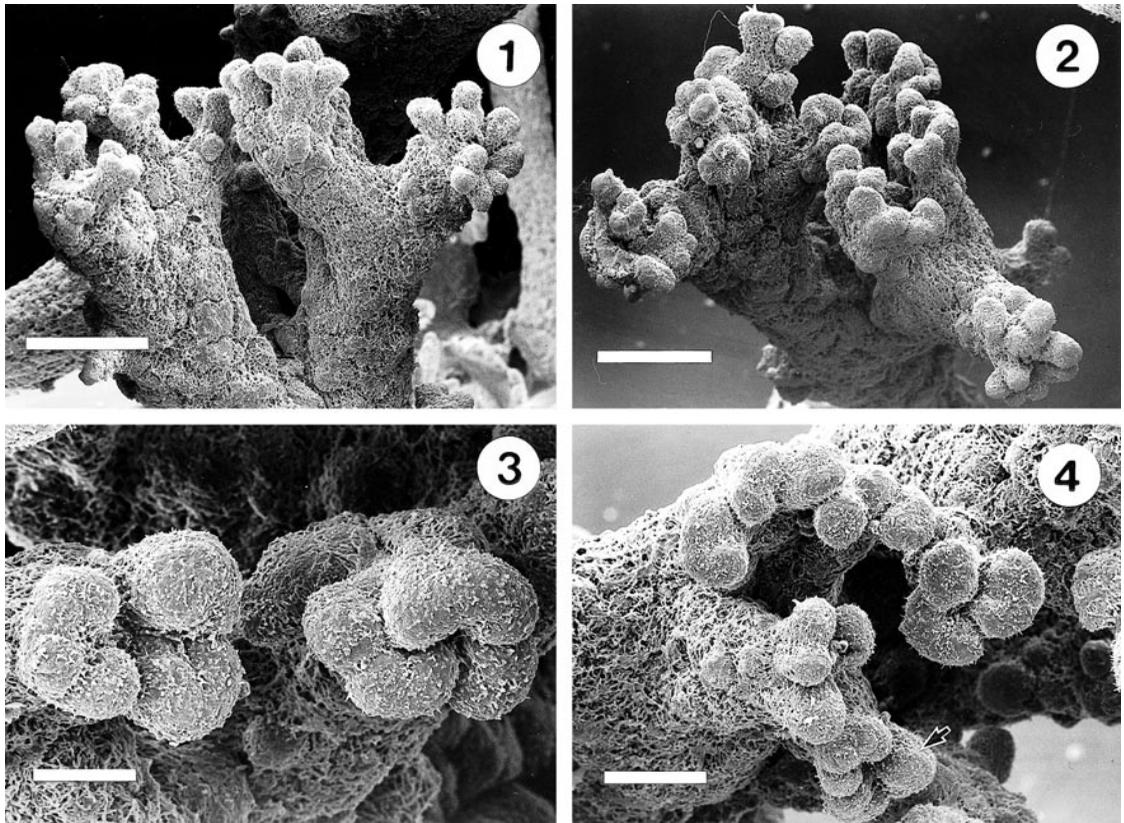
Material of *C. lacryma* was prepared for scanning electron microscopy (SEM), in order to help distinguish the species through an understanding of its microscopic characters and growth dynamics. Air dried specimens were mounted on aluminum stubs and sputter-coated with gold. They were displayed and photographed on the Cambridge Instruments Stereoscan 360 lanthium hexa-boride transmitter at 50 pico amps of electron beam current at 20.0 kv at the Australian National University Electron Microscopy Unit (Canberra), where the author conducted sabbatical year research immediately following the California field trip.

CLADONIA LACRYMA S. Hammer, *sp. nov.* FIGS. 1–8
Thallus primarius squamulosus, persistens aut evanescens, incisus, esorediatus. Podetia lacriforma, ascyphifera aut

obtusa scyphifera aut sparsa ramula, corticata, esorediata. Acidum fumarprotocetraricum continens.

TYPE: U.S.A. CALIFORNIA. Mendocino CO., Pygmy Forest, Van Damme State Park near Albion-Little River Road, 39°15' N, 123°40' W, elev. ca 50 m. On rotting twigs and leaves of ericaceous shrubs, also on evergreen needles and cones over acidic laterite hardpan soil. *Hammer 7810*. (FH, holotype; H, SFSU, isotypes). **PARATYPES** (all at FH): CALIFORNIA. DEL NORTE CO., *Hammer 2162, 2168, 3303*; MARIN CO., *Hammer 1664a*; MENDOCINO CO., *Hammer 7813, 7814*. OREGON. CURRY CO., *Hammer 3367*.

Prothallus diffuse, hyaline, appearing white, attached to and invested within top 5 mm of organic substratum, forming hyphal mats within the substratum. *Primary thallus* squamulose, attached by thick (0.5–1.5 mm wide) basal rhizinae to white prothallus, persistent or evanescent, deeply incised to crenate-lobate, 1.0–2.5 mm long, 0.5–1.5 mm wide, involute to erect, glaucescent greenish above, whitish beneath, underside darkening with age, esorediate. *Podetia* arising from primary squamules, esorediate, rarely with sparse squamules, smooth to minutely verruculose, ashy green to glaucescent green, rarely yellow green, narrowly cup-forming, unbranched or very sparingly branched, primarily from cup margins, 14–42 mm tall, 1.0–1.5 mm wide, narrow beneath cups, cups barely exceeding width of podetial support but in some specimens exceeding the width of the podetium (to 4 mm wide), cups shallow, deforming and sometimes deepening, giving rise to one, rarely more proliferations along the margin, proliferations narrow, generally shorter than supporting podetium, simple or very sparingly branched, lower portion of proliferations concave, comprising part of deformed cup, upper portion terete or slightly flattened, occasionally bearing narrow cup and one or more series of similar proliferations, concave bases of succeeding proliferations generally oriented in same direction, toward inner part of initial cup, apical proliferations bearing brown apothecia. *Apothecia* convex, hemispheric, toroidal, or reniform, generally exceeding width of supporting podetium. *Podetial wall* 100–230 µm; cortex (including algal component) 36–87 µm, medulla 58–130 µm. *Pycnidia* 0.1–0.4 mm in diam., borne on cup margins, sessile or on short fungal stalks, light brown to black-carbonaceous, narrowly obconic with indistinct ostiole, sometimes irregularly inflated and nearly globose with distinctly darker ostiole margin. *Conidia* hyaline, aseptate, filiform, straight



FIGURES 1–4. Early ontogeny of *C. lacryma* podetia (SEM). — 1. Habit of young podetia with numerous meristem bundles before cups have formed. — 2. Morphologically undifferentiated meristem bundles on podetium that has not formed a cup. — 3. Early meristem bundles with characteristic pattern of splitting. — 4. Undulating series of meristem bundles. Arrow indicates possible cup-forming group. Scale bars Figs. 1–2: 500 μm . Fig. 3; 100 μm . Fig. 4; 200 μm .

to arcuate, 4–7 μm long, 1–2 μm wide. *Asci* and *ascospores* not seen.

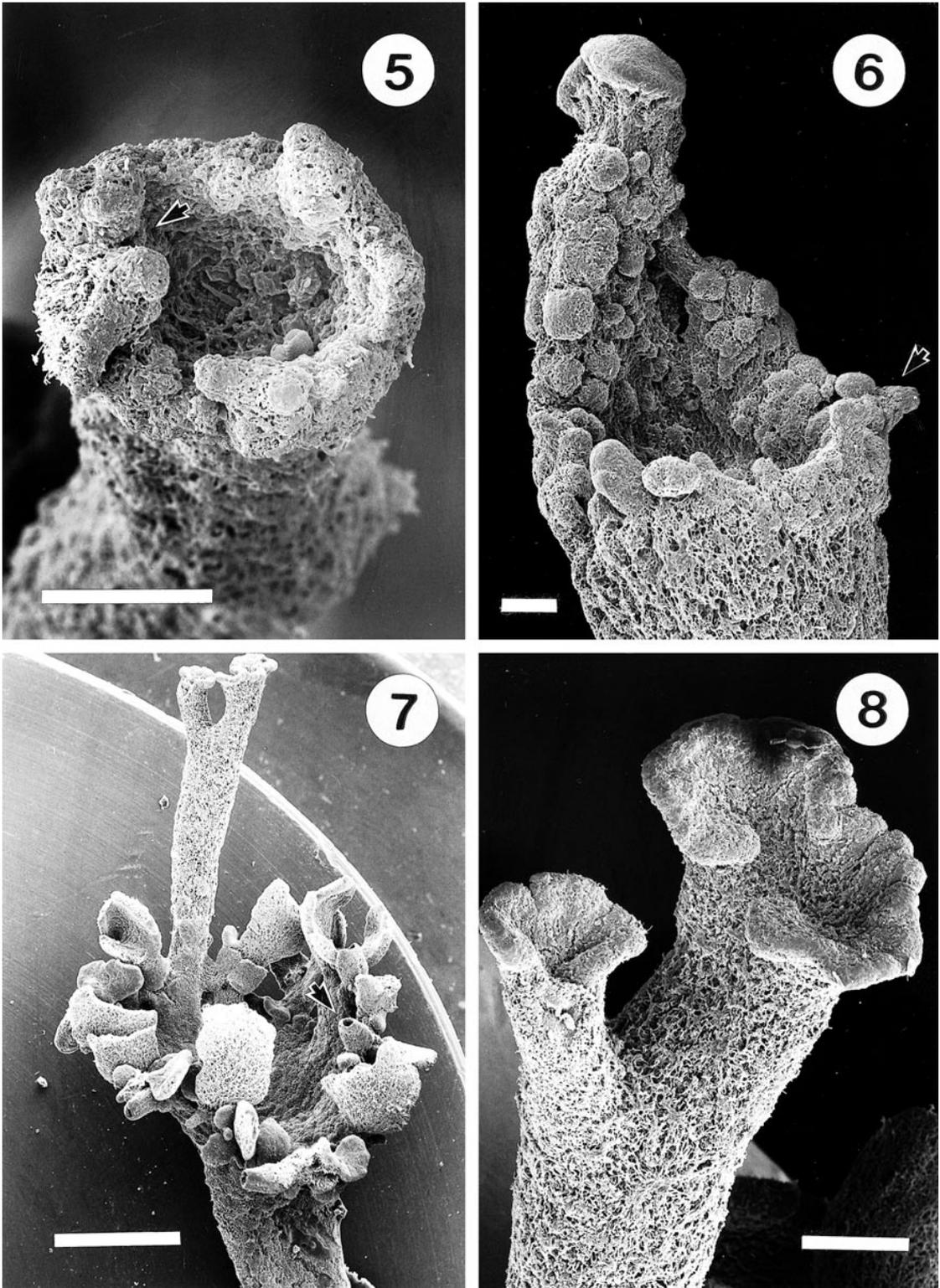
Chemistry.—K–, P+ orange to red. Fumarprotocetraric acid.

Distribution.—North coastal California and adjacent Oregon.

Cladonia lacryma is generally found on acidic substrata such as decomposing ericaceous twigs and leaves, and on rotting pine needles and twigs. At the type locality, *C. lacryma* was found growing on small mounds of leaves and twigs beneath ericaceous shrubs. The apparent dependence of this species upon organic substrata suggests that it requires relatively persistent moisture. Increased moisture availability is provided by fog drip from the shrubs and by the spongy organic substratum. Conversely, *C. lacryma* may avoid prolonged inundation by undrained water on top of the hardpan soil by growing on small mounds that are several cm above the soil. Other *Cladonia* species that grow in the pygmy forest, notably *C. artuata* Hammer and *C. cervicornis* (Ach.) Flotow inhabit the same micro-environment.

Cladonia lacryma, which is characteristically cup-forming at maturity, does not possess distinct cups in earliest ontogeny. The youngest podetia bear undulating series of fungal meristem bundles at their apices (Figs. 1–2), most of which do not grow further. The meristem bundles are morphologically undifferentiated in early ontogeny (Fig. 3), and relatively few of them become activated to form cup-bearing podetia (Fig. 4). In general, the podetia of *C.*

lacryma are only sparingly branched, and the few branches usually form around the cup margins. However, inactive meristem bundles may extend upward along the axis of the vertically developing podetium, later forming proliferating branchlets below the cup. These are most apparent later in ontogeny when the cup has begun to deform due to the growth of the single vertical proliferation. Cups may begin to form at any stage of ontogeny. They may be present on rather short podetia (<1 mm) but in general, they form on taller (>2 mm) podetia. Very early in cup ontogeny, one or more proliferations arise from the meristem bundles that surround the margin (Fig. 5). Generally, only one of these becomes the dominant (largest), vertical proliferation. Other meristem bundles generally remain quiescent. Alternatively, they may form squamules or pycnidia around the cup margin. The cup generally grows vertically concomitant with the vertical growth of a single proliferation. This results in the characteristic “teardrop” morphology for which the species is named (Fig. 6), which is especially apparent when viewed obliquely. The cup diameter tends not to increase during further growth of the proliferation. Rather, the cup deforms longitudinally (occasionally laterally), and the base of the resulting proliferation is generally concave. Successive tiers of proliferations result in similarly oriented deformations along the vertical axis of the podetium. Thus, specimens with more than one tier of proliferations appear to possess one to several shallow indentations along the podetium (usually on the same side of the po-



FIGURES 5–8. Later ontogeny of *C. lacryma* (SEM). — 5. Early cup ontogeny with marginal proliferation arising from one of the meristem bundles (arrow). — 6. Habit of upper portion of podetium, showing mature cup with characteristic, vertically elongating proliferation and apothecium at apex. Arrow indicates developing pycnidium. — 7. Cup with podetial proliferation, squamules, and pycnidium along the margin (arrow). — 8. Enlargement of apex from previous figure. Note undulating, elongate meristem bundles along margins of deforming cups. Scale bars Figs. 5, 8; 200 μ m. Fig. 6; 100 μ m. Fig. 7; 1 mm.

detium), which indicate the presence of cups during earlier ontogeny of the proliferations. The cup generally does not deform during the early development of the proliferation (Fig. 7). However, if the proliferation gives rise to further vertical growth, stretching of the initial cup occurs. Further growth is initiated by meristem tissue at the cup margin of the apical proliferation. The tissue is composed of several fused bundles that incompletely surround the margins of cup-like formations (Fig. 8).

Cladonia lacryma possesses morphological and chemical affinities with the large, diverse section *Cladonia* Browne, in which many of the species possess imperforate, cup-forming podetia and fumarprotocetraric acid. It is similar to *C. ramulosa* (With.) Laundon, a species with a worldwide distribution (see Ahti 2000), but which was not reported in western North America by Hammer (1995). The present species can be distinguished from *C. ramulosa* by its consistently smooth outer surface and the absence of squamules borne laterally along the podetium. Some podetia do bear squamules along the margin of the cups (see Fig. 7), and these may be involved in vegetative reproduction. Like many of the species in section *Cladonia*, the apothecia of *C. lacryma* are not regularly spore-bearing. None of the apothecia examined for this study contained ascospores. It is noteworthy that the podetia of *C. lacryma* produce cups relatively late in ontogeny, which is not characteristic within section *Cladonia* (see Hammer 1993c, 1997a). Cup production in *C. lacryma* begins when certain meristem bundles become committed to develop cup-like formations. Cup formation then proceeds through the development of a toroid-annular meristem shape, similar to other cup-forming species as discussed in Hammer (2000). Many meristem bundles remain quiescent however, and their development during later ontogeny is a significant source of variability in *C. lacryma*. Asynchronous meristem development is an important source of variability in the genus *Cladonia*, and it has been reported in several species, notably *C. cristatella* Tuck. (Hammer 1997b) and *C. subcervicornis* (Vain.) Kernst. (Hammer 1998). The fused, undulating meristem bundles of *C. lacryma* suggest affinities with other taxa. For example, similar structures were reported in *C. prolifica* Ahti & Hammer (Hammer 2000, 2001). *Cladonia prolifica* was described from a habitat in California with edaphic features similar to those of the pygmy forest (Hammer & Ahti 1990). The present species is distinguished from *C. prolifica* by narrower podetia with fewer proliferations. The abundant proliferations of *C. prolifica* develop in a helical pattern while those of *C. lacryma* are usually linear. Both *C. prolifica* and *C. lacryma* were misidentified in an earlier paper (Hammer 1989b) as *C. phyllophora* Hoffm., but the latter species, with its arachnoid outer cortex, is not found in California or southern Oregon.

The California (or "Oregonian") floristic province (see Munz & Keck 1959) is a center of endemism for many plant and fungal groups. In the lichen genus *Cladonia*, section *Perviae* (Del.) Matt. (Hammer 1993b) and sect. *Cladonia* (Hammer 1991) have apparently undergone ex-

tensive radiation in the region, and it is likely that more species are still undiscovered. Both *C. prolifica* and *C. lacryma* represent radiation within the more speciose section *Cladonia* (Hammer 1996).

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