

Sebdenia cerebriformis sp. nov. (Sebdeniaceae, Sebdeniales) from the south and western Pacific Ocean

Antoine D.R. N'Yeurt^{1*} and Claude E. Payri^{1,2}

¹Unité Mixte de Recherche 7138 Systématique, Adaptation, Evolution, Institut de Recherche pour le Développement-Nouméa – BPA5, 98848 Nouméa cedex, New Caledonia and ²Université de la Polynésie française, BP6570 Faa'a, 98702 Tahiti, French Polynesia

SUMMARY

A new species of red alga, *Sebdenia cerebriformis* N'Yeurt et Payri sp. nov. (Sebdeniaceae, Sebdeniales), is described from various localities in the south and western Pacific including Fiji, New Caledonia, the Solomon Islands, Vanuatu, and Indonesia (Java Sea). The new species is characterized by a ruffled thallus with multiple perennial stipitate holdfasts, large conspicuous inner cortical stellate cells, and a lax filamentous medulla.

Key words: Fiji, New Caledonia, new species, Rhodophyta, *Sebdenia cerebriformis* sp. nov., Sebdeniaceae, Solomon Islands, South Pacific, taxonomy, Vanuatu.

INTRODUCTION

The family Sebdeniaceae (Kylin 1932; Schneider *et al.* 2006) currently consists of two described genera, *Sebdenia* and *Crassitegula* C. W. Schneider, C. E. Lane et G. W. Saunders, and a further yet undescribed *nomen nudum*, *Lesleigha* General ined. (Schneider *et al.* 2006). The Sebdeniaceae is distinguished from the Halymeniaceae mainly by the usual presence of medullary gland cells (Norris & Aken 1985; Schneider & Wynne 1991), the absence of periclinal filaments, and the nonampullar nature of the auxiliary cell and carpogonial branches (Lewis & Kraft 1992). Recent *rbcl* molecular sequence analyses (Gavio *et al.* 2005) have shown the position of the Sebdeniaceae to be equivocal, nested in between the newly reinstated order Cryptonemiales and the order Rhodymeniales, and these preliminary findings were later confirmed by Withall and Saunders (2006), who erected the new order Sebdeniales to accommodate the Sebdeniaceae based on new molecular results. The Kallymeniaceae is distinguished from the Sebdeniaceae by the characteristic presence of large, often prominently lobed lower cells of the carpogonial branch system, and auxiliary cell systems with several chains of subsidiary cells (Womersley 1994). *Crassitegula* differs mainly from *Sebdenia* by its dorsoventral habit and nematocyst tetrasporangia. Its posi-

tion in the Sebdeniales is further supported by molecular small subunit ribosomal DNA genes (SSU) sequence analyses (Schneider *et al.* 2006).

After a tortuous taxonomic history (Guiry 2006), the genus *Sebdenia* was erected by Berthold (1882) with two species: *S. monardiana* (Montagne) Berthold and *S. dichotoma* Berthold (*nomen nudum*). *Sebdenia dichotoma* was later validated by Berthold (1884). Schmitz (1889) then designated *S. monardiana* as the type species of the genus. *Sebdenia dichotoma* (J. Agardh) Berthold is an illegitimate combination erroneously attributed to Berthold by Codomier (1973), and later attributed to Codomier by Parkinson (1980). However, it is a later homonym of *S. dichotoma* Berthold (1884). Reproduction in *Sebdenia* was documented in detail by Codomier (1972, 1973) and Hansen (1989).

The genus *Sebdenia* currently consists of 13 species (Table 1), ranging from tropical to subtropical regions of the world. Four additional species, *S. actinophysa* (Howe) E. Soler-Onís (de Jong 1998), *S. amoena* (Bory) E. Soler-Onís (de Jong 1998), *S. macaronesica* Soler-Onís, Haroun et Prud'homme van Reine (Guiry 2001) and *S. senegalensis* (M. Bodard) E. Soler-Onís (de Jong 1998) are as yet formally unpublished manuscript names requiring verification; the poor taxonomic practices used in creating these names suggest that they may never be published and could not be considered in the interim as valid species. Kylin (1956) was of the opinion that *Sebdenia yamadae* Okamura et Segawa (Segawa 1938) could represent a species of *Sarcodia* J. Agardh. N'Yeurt (2001) examined Japanese material of *S. yamadae* in SAP, finding zonate tetrasporangia and several other characteristics different from *Sebdenia*, indicating that the species does not belong in the Sebdeniaceae.

In the present study we report a new species of marine Rhodophyta from the Fiji Islands, New Caledonia, the Solomon Islands, Santo Island (Vanuatu) and

*To whom correspondence should be addressed.

Email: nyeurt@gmail.com

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Table 1. A comparison of selected characteristics between *Sebenia cerebriformis* and other current *Sebenia* species

Species and sources	Type locality	Habit	Surface infoldings	Holdfast(s)	Adhesion to paper	Margin	Subtending cells	Medulla
<i>Sebenia cerebriformis</i> (this study)	Suva Reef, Fiji	Compressed to aplanate, irregularly lobed	Abundant	Multiple, distinct, perennial	Good	Smooth to slightly undulate	Stellate, 50–70 µm in diameter	Lax, broad filaments 15–30 µm in diameter
<i>Sebenia afuerensis</i> Taylor (1945a) pl. 10 fig. 2	Lobos de Afuera Island, Peru	Strap-shaped, irregularly subdichotomous axes	Absent	Single, small, discoid	Poor	Irregular	Oval, 7–15 µm in diameter	Lax, slender filaments 3–7 µm in diameter
<i>Sebenia chichensis</i> Taylor (1945a) pl. 10 fig. 1	Chinchas Island, Peru	Cuneate-expanded blade	Absent	Single, small, discoid	Poor	Crenate, crisped	Rounded, 10–20 µm in diameter	Narrow, compact filaments
<i>Sebenia dawsonii</i> (L. A. Abbott) Hansen (1989) (= <i>Schizymenia dawsonii</i> Abbott 1967 = <i>Sebenia rubra</i> Taylor (1945b) pl. 73 fig. 1; see Hansen 1989)	Santo Tomás, Baja California	Entire to deeply cleft, ovate to obovate thallus	Absent	Single basal stipe	Not seen	Smooth	Stellate, 40–50 µm in diameter	Lax, filaments 7–18 µm in diameter
<i>Sebenia dichotoma</i> Berthold (1884) pl. 2	Marseille, France	Terete to compressed, dichotomously branched axes	Absent	Single, basal disc	Not seen	Smooth	Stellate, 40–70 µm in diameter	Lax, filaments 8–12 µm in diameter
<i>Sebenia fiabellata</i> (J. Agardh) Parkinson (1980)	Guadeloupe	Terete to compressed, fastigiate branched	Absent	Single, inconspicuous	Good	Smooth	Stellate, 13–20 µm in diameter	Lax, filaments 3–5 µm in diameter
<i>Sebenia heteronema</i> Howe (1914) pl. 58	Bay of Secura, Peru	Subpalmitate, elliptic oblong	Absent	Single, basal	Poor	Profusely innovate	Substellate, 40–50 µm in diameter	Compact, slender filaments 5–10 µm in diameter
<i>Sebenia integra</i> Gavio et al. (2005)	Offshore Louisiana, Gulf of Mexico	Subspherical, entire flat thallus	Absent	Single, basal, discoid	Not seen	Smooth	Stellate, 20–30 µm in diameter	Relatively compact, filaments 5–6 µm in diameter
<i>Sebenia lapathifolia</i> (Kützinger) Howe (1914) 162	Lima, Peru	Elongate-lanceolate, pertuse	Absent	Single, discoid	Not seen	Undulate, sometimes dentate or proliferate	Ellipsoidal, 10–20 µm in diameter	Lax, slender filaments 3–7 µm in diameter
<i>Sebenia limensis</i> (Sonder) Howe (1914) 160	Lima, Peru	Palmitifid-orbicular	Absent	Single, short-stipitate	Not seen	Sparingly proliferate, undulate or dentate	Ovate, 10–25 µm in diameter	Compact, filaments 4–8 µm in diameter
<i>Sebenia lindaueri</i> Setchell ex V.J. Chapman (1979) 290, fig. 79	Long Beach, Bay of Islands, New Zealand	Repeatedly dichotomous blade	Absent	Single, discoid	Not seen	Smooth	10–22 µm in diameter	5.0–7.5 µm in diameter
<i>Sebenia monardiana</i> (Montagne) Berthold (1882) 530	Gulf of Naples, Italy	Palmitifid to fan-shaped, irregularly di- to trichotomous blade	Absent	Single, basal disc	Not seen	Smooth	Not seen	Not seen
<i>Sebenia okamurae</i> Yamada (1938) pl. 29 ('Okamura')	Hayama, Sagami Province, Japan	Palmitifid, dichotomously to pinnately branched blade	Absent	Single, basal disc	Not seen	Smooth	Not seen	Not seen
<i>Sebenia rodrigueziana</i> (Feldmann) Parkinson (1980)	Banyuls-sur-Mer, France	Erect cuneate blade	Absent	Single, basal disc	Not seen	Proximally smooth, distally lacinate	Oval to stellate, 50–80 µm in diameter	Lax, filaments 10–20 µm in diameter

the Java Sea of Indonesia, belonging to the genus *Sebdenia* but with a suite of characteristics unlike any previously described species.

MATERIALS AND METHODS

Collection and analysis of material

Material was collected by underwater breathing apparatus; part was stored in 5% buffered formalin in sea-water, and the rest was dried as herbarium specimens. Dried material was rehydrated in weak detergent solution prior to sectioning using a freezing microtome. Sections were stained using either cotton blue/lactophenol or 1% aniline blue in 60% clear corn syrup, and made permanent if necessary by mounting in 60% clear corn syrup.

Drawings and photography

Drawings were made using a microscope with a camera-lucida attachment. Macrophotographs were either taken with a Canon EOS 350D digital camera (Canon Inc., Tokyo, Japan) or a Nikon E-995 digital camera (Nikon Corporation, Tokyo, Japan); photomicrographs were obtained using an Olympus BH2 compound microscope fitted with an Olympus C-5050 digital camera (Olympus Optical Co. Ltd, Tokyo, Japan), and the resulting files processed into figures by computer software (Adobe Illustrator, San José, CA, USA).

Herbarium specimens

Voucher specimens have been deposited in the herbaria of Phycological Herbarium, Institut de Recherche pour le Développement, Nouméa, New Caledonia (NOU-IRD), PC and Phycological Herbarium, The University of the South Pacific School of Marine Studies, Suva, Fiji (SUVA-A). Herbarium abbreviations are in accordance with Holmgren *et al.* (1990). Accession numbers preceded by the letter 'S' refer to microscope slide collections.

RESULTS

Order Sebdeniales: Family Sebdeniaceae

Sebdenia cerebriformis N'Yeurt *et* Payri sp. nov. (Figs 1–16)

Thallus atroruber, 3–10 cm latus, compressus vel applanatus, mollis lubricusque, ex lobis mamillatis irregulariter ramosis, cerebriformis ubi vivus, ad substratum per hapteron multiple, perennial teretem basalem; in arescendo papyro bene adhaerens. Cortex uni-vel bistratus, pseudoparenchymatus, cellulis extimis ovoideis subrectangularibusve, 3–5 μ m diametro; cellulae interiores subsphaericae, 12–25 μ m diametro, foveis conjungentibus secundariis numerosis

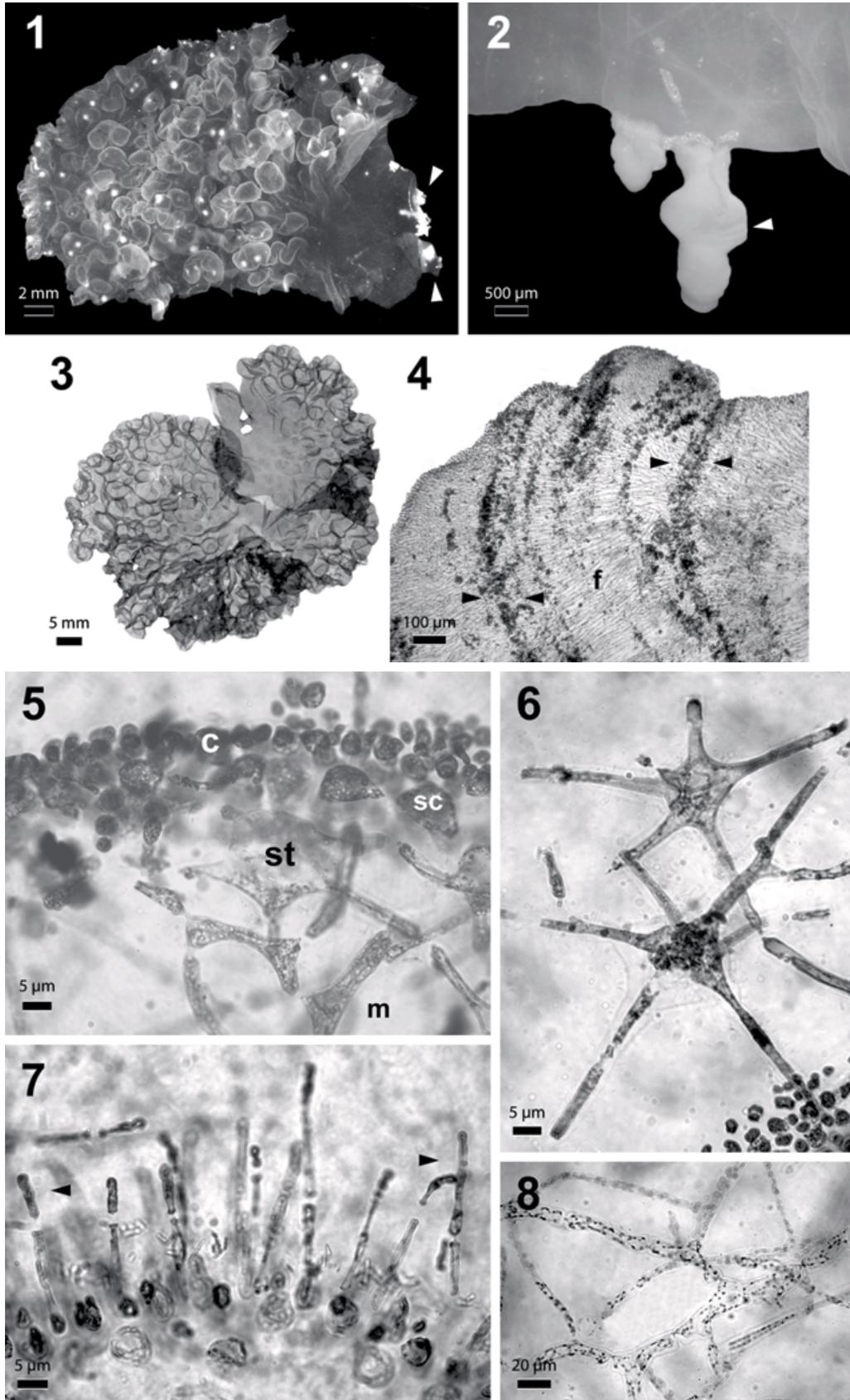
instructae, unaquaeque vulgo 3 cellulas extimas fulcrans. Sub cortice pars ex filamentis laxis (5) 10–20 (30) μ m diametro constans et medulla ex cellulis magnis stellatis (30) 35–50 (70) μ m diametro constans quae 4–5 conjunctiones filamentosas ad cellulas medullosas externas irregulariter stellatas 22–27 μ m diametro producunt. Rami carpogoniales tres-cellulares, extrinsecus evoluti, in cellulis corticalibus interior locati. Initia gonimoblastorum extrinsecus evoluta; carposporophyta sine involucris ampullaribus. Cystocarpia protuberentia, 1.0–1.2 mm diametro, in paginis laminarum, ostiola distincta destituta. Tetrasporangia 10–20 μ m diametro, cruciatim divisa, in cortice exteriore dispersa. Spermatangia globosa, 1.5–2.0 μ m diametro, binatum ab cellulis extimis corticalibus leviter elongatis abscissa.

Holotype and type locality: *D. W. Keats*, 1 December 1994, – 30 m, SUVA-A 5522L (cystocarpic, Fig. 1), Fish Patch, Suva Reef, Fiji (18°09.2 S, 178°24. 0 E).

Paratypes: Iles des Pins, New Caledonia, 30 November 2005, *leg. C. E. Payri*, – 28 m PC 0062764 (carpogonial); Fish Patch, Suva Reef, Fiji, 1 December 1994, *leg. D. W. Keats*, – 30 m, SUVA-A 5521L (tetrasporic); Vangunu Island, Solomon Islands, 3 July 2004, *leg. C. E. Payri & J.-L. Menou*, – 25 m PC 0062765 (spermatangial).

Other material examined: Fish Patch, Suva Reef, Fiji, *leg. D. W. Keats*, – 30 m, 1 December 1994, SUVA-A 913L; Passe de la Fourmi, New Caledonia, 2001, *leg. C. E. Payri & J.-L. Menou*, – 20 m, NOU-IRD 460, 461 (cystocarpic); Touho, New Caledonia, 03 December 2004, *leg. C. E. Payri*, – 52 m, NOU-IRD 458; Passe Amoss, New Caledonia, 2004, *leg. C. E. Payri*, – 40 m, NOU-IRD 457; Uitoé, New Caledonia, 28 February 2005, *leg. J.-L. Menou*, –55 m, NOU-IRD 456 (tetrasporic); Iles des Pins, New Caledonia, 26 November 2005, *leg. C. E. Payri*, – 45 m, NOU-IRD 1508, Iles des Pins, New Caledonia, 01 December 2005, *leg. C. E. Payri*, – 50 m, NOU-IRD 1509; Vangunu Island, Solomon Islands, 3 July 2004, *leg. C. E. Payri*, – 8 m, NOU-IRD 463; Honiara, Guadalcanal, Solomon Islands, 09 July 2004, *leg. C. E. Payri*, – 25 m, NOU-IRD 466; Three Sisters Islands, Solomon Islands, 19 July 2004, *leg. C. E. Payri & J.-L. Menou*, – 25 m, NOU-IRD 455; Marau Lagoon, Guadalcanal, Solomon Islands, 22 July 2004, *leg. C. E. Payri & J.-L. Menou*, – 20 m, NOU-IRD 464; Tuvana island, Santo, Vanuatu, 31 August 2006, *leg. C. E. Payri, C. Geoffray & J.-L. Menou*, – 50 m, NOU-IRD 1507; Tanjung Belusun, Sumbawa Island, Indonesia, 2 November 2004, *leg. J. R. Indy*, Herbarium Marine Botany, Graduate School of Fisheries Sciences, Faculty of Fisheries, Hokkaido University, Japan, JRI 0574 (tetrasporic), JRI 11006 (spermatangial).

Etymology: The specific epithet refers to the convoluted, infolded appearance of living plants, and is



derived from the Latin word '*cerebriformis*', meaning 'having an irregular brain-like appearance'.

Habitat: Growing in colonies or as a single individual on coral substratum, at depths from 8 m down to 55 m.

Distribution: So far only reported in the South Pacific Ocean from the Melanesian region including the Solomon Islands, Vanuatu, New Caledonia and Fiji, and from Sumbawa Island in the Java Sea, Indonesia.

Description: Plants deep red, to 10 cm broad, compressed to aplanate, soft and lubricous, with distinctive mamillate lobes, convoluted and infolded (Figs 1–3), attached to the substratum by multiple, terete to compressed, perennial basal holdfasts 0.6–1.0 mm in diameter, with distinct concentric growth lines 700–800 μm apart. Holdfast initiation seems to occur in marginal regions of the thallus, where cortical cells become elongate, apically divided and filamentous holdfast initials, eventually being bundled-up as parallel, irregularly branched filaments 8–10 μm in diameter (Figs 4 and 7). Margins smooth to slightly undulate, lacking innovations. Plants are nitent and adhere well to herbarium paper on drying.

Cortex three to four layered, pseudoparenchymatous, the outermost cells densely pigmented, ovoid to subrectangular, 3–5 μm in diameter; inner cells subspherical, 7.5–8.0 μm in diameter. Innermost cortical cells hyaline, 12–25 μm in diameter, with peripheral chloroplasts (Fig. 5). Below the cortex lies a subtending region of large, four to five armed stellate cells (30) 35–50 (70) μm in diameter (Fig. 6). The medulla is lax, composed of cylindrical filaments (5) 10–20 (30) μm in diameter (Fig. 8). Medullary gland cells are scarce, to 5 μm in diameter and lateral on medullary filaments.

Carpogonial branches are three-celled, outwardly directed, located on inner cortical cells (Figs 9 and 10). The supporting cell is subspherical and about 20 μm in diameter, while the first two cells of the carpogonial branch are ovoid, 10–15 μm in diameter. The carpogonium itself is typically small and triangular-angular, 8–10 μm wide, bearing from its outward corner a relatively stout, recurved trichogyne 8–10 μm in diameter and 50–60 μm long, protruding from the outer cortex. Deeply staining subsidiary cells 10–15 μm in diameter are usually linked to the supporting cell. Auxiliary cells are subspherical, 15–20 μm in diameter, intercalary in separate cortical

filaments from those bearing carpogonial branches, and the two systems are linked together by connecting filaments. The auxiliary cell system (Fig. 11) consists of two to five spherical subsidiary cells connected to the auxiliary cell. Post-fertilization stages were not seen in our material, but the carpogonium is reported to fuse with either the cells of the carpogonial filament or the supporting cell in other species of the genus, forming a cellular mass from which is issued a connecting filament to the auxiliary cell (Codomier 1972). Mature cystocarps (Figs 12 and 13) are protuberant, 1.0–1.2 mm in diameter, scattered on the blade surfaces and lack distinct ostioles. Gonimoblast initials are outwardly directed, with gonimoblasts forming a compact mass 900–1050 μm in diameter composed mostly of carposporangia 15–23 μm in diameter (Fig. 14); carposporophytes are accommodated by modifications of the inner and outer cortex and no ampullar involucre is present.

Spermatangia are spherical, 1.5–2.0 μm in diameter, cut off in pairs from slightly elongate outermost cortical cells (Fig. 15) and occur in dense patches on the thallus surface; nemathecia are absent. Tetrasporangia are 10–20 μm in diameter, cruciately divided, scattered in the outer cortex, displacing normal outer cortical cells and lacking any involucre (Fig. 16). Tetrasporophytes are isomorphic with gametophytes.

No other reproductive structures were seen in male plants, suggesting that the species might be dioecious.

DISCUSSION

Sebdenia cerebriformis is superficially comparable to a number of other flattened members of the genus, but is distinct in its unique combination of characteristics (Table 1). The most obvious unique features are the convoluted, infolded appearance of the thallus surface, and the multiple, perennial marginal holdfasts, so far not reported in any other species, which all have smooth surfaces with a single, inconspicuous or stiped basal holdfast. It is closest in external habit to *Sebdenia dawsonii* (I. A. Abbott) G. I. Hansen from Baja California, but that species differs by its single holdfast, compact medulla and absence of surface infoldings.

The multiple, peg-like holdfasts of *S. cerebriformis* are perennial since they show regular concentric growth

Fig. 1–8. *Sebdenia cerebriformis*: vegetative morphology. 1. Habit of Holotype (SUVA-A 5522L), showing convoluted surface and multiple marginal holdfasts (arrowheads). 2. Detail of marginal holdfast, showing growth rings (arrowhead). 3. Habit of pressed specimen from Iles des Pins, New Caledonia (PC 0062764). 4. Transverse section of perennial holdfast, showing parallel bundles of multicellular filaments (f) and seasonal growth rings (arrowheads) (SUVA-A 5522L). 5. Transverse section of thallus (PC 0062764) showing small diameter cortical cells (c), ovoid subcortical cells (sc), stellate cells (st) and medullary filaments (m). 6. Detail of a pair of subtending stellate cells, showing 5 elongate arms (PC 0062764). 7. Basal region of cortex, showing elongate filamentous initials of holdfast (arrowheads) (SUVA-A 5522L). 8. Detail of medullary filaments (SUVA-A 5521L).

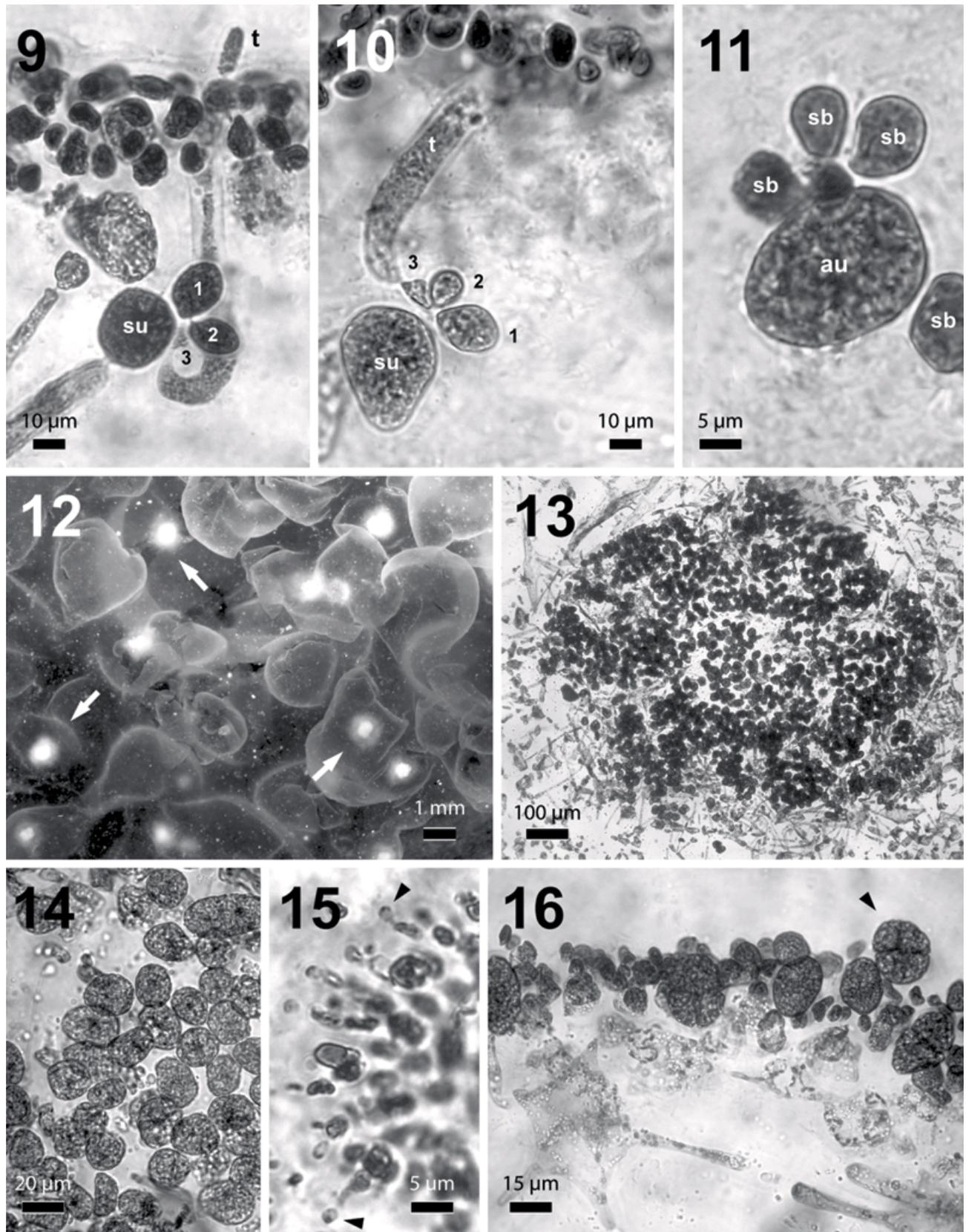


Fig. 9–16. *Sebdenia cerebriformis*: *reproductive morphology*. 9,10. Detail of three-celled carpogonial branches with protruding, outwardly directed trichogyne (t) and supporting cell (su) (PC 0062764). 11. Detail of auxiliary cell (au) remote from carpogonial branch, with four subsidiary cells (sb) (PC 0062764). 12. Closeup surface view of scattered cystocarps on female plant (SUVA-A 5522L), showing globose carposporophytes (arrows). 13. Transverse section of cystocarp, showing compact mass of carposporangia (SUVA-A 5522L). 14. Detail of carposporangia (SUVA-A 5522L). 15. Transverse section of cortex of male plant, showing terminal spermatangia (arrowheads) (PC 0062765). 16. Transverse section of tetrasporophyte, showing cruciate tetrasporangia (arrowhead) scattered in cortex (SUVA-A 5521L).

marks in longitudinal sections, and are analogous to the holdfast structure of the Halymeniaceae in the genera *Codiophyllum* Gray, *Cryptonemia* J. Agardh and *Thamnoclonium* Kützing, which are also composed of densely packed longitudinal filaments with periodic meristematic activity (Scott *et al.* 1982, 1984). The typically ruffled appearance of *S. cerebriformis*, quite marked in freshly collected plants, seems to be a variable character, sometimes almost absent from some specimens especially when young or not well developed, while always prominent in broad blades. Distal areas of the thallus usually show more infoldings than proximal regions. The numerous, prominent, four to five long-armed stellate subtending cells in *S. cerebriformis* are a further characteristic feature of the species, not encountered in many other algae.

N'Yeurt *et al.* (1996) previously reported *S. cerebriformis* from Fiji under the misapplied name *Sebdenia yamadae*. *Sebdenia cerebriformis* is pictured from an undisclosed location, but not elaborated on, on the back cover (third photo from the top) of the South Pacific algae field guide by Littler and Littler (2003), and has also been recently reported from Sumbawa Island in the Java Sea, Indonesia (J. R. Indy, pers. comm., 2007). The Indonesian plants are in most respects similar to the South Pacific material, except for a markedly lesser predominance of stellate subtending cells. To date the species has not been reported east of the Fiji Islands, suggesting that it has a southwestern Pacific distribution, with a probable center of origin in the Indonesian region. Moreover, this species has a broad distribution range from typical tropical areas to a more cool-temperate region in the south of New Caledonia, especially from Ile des Pins. So far, *Sebdenia cerebriformis* is the only representative of the genus in Indonesia, Solomon Islands and Vanuatu, while in New Caledonia and Fiji it occurs with the fastigiatly branched *Sebdenia flabellata* (J. Agardh) P. G. Parkinson (N'Yeurt 2001; Payri 2006).

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