



## The new synonymy of *Horikawaea* with *Cryptogonium* and a proposal of *Pseudocryptogonium*, *gen. nov.* (Musci, Pterobryaceae)

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### Abstract

Male organs and mature sporophytes of a calciphilous moss previously known as *Horikawaea dubia* are newly reported and described in detail based on a single specimen collected in Guangxi Province, southern China. Sporophytic features, such as the immersed and cylindrical capsule on a very short seta (ca. 1.2 mm long) and reduced peristome with 16 smooth and almost linear exostome teeth, as well as the gametophytic resemblance to *Cryptogonium phyllogonioides* in having complanate foliation, highly differentiated alar region of the stem and branch leaves, and more or less cucullate leaf apices, suggest a new synonymy of *Horikawaea* in *Cryptogonium*. Two new combinations, namely, *C. dubia* (Tixier) H.Akiyama & B.C.Tan **comb. nov.** and *C. nitida* (Nog.) H.Akiyama & B.C.Tan **comb. nov.** are made. Additionally, *Pseudocryptogonium* H.Akiyama & B.C.Tan **gen. nov.** is proposed to accommodate *Horikawaea tjibodensis* (syn. *H. redfearnii*).

**Key words:** Bryopsida, China, mosses, Malesia, taxonomy

### Introduction

In the course of examining bryophyte collections from limestone areas in the southern part of China (Guangxi Province) in 1997, two specimens of *Horikawaea dubia* (Tixier) S.H.Lin were found. One of them bore male gametangia and mature sporophytes, both of which were unknown for the species. They are newly described here as follows.

### Description

*Sexual organs and sporophytes of Horikawaea dubia* (Figures 1–16)

Dioicous? (at least, perichaetia and perigonia produced on different ascending stems). Perigonia lateral on ascending stems, bud-like; antheridia ca. 10 in number, long-pedicellate, 70–80 µm long, paraphyses filamentous, ca. 20 in number, to 0.7 mm long, longer than the length of antheridia. Perigonial leaves ovoid, shortly acuminate, concave, ecostate, ca. 1 mm long, yellowish green above, reddish brown at base; median laminal cells linear-rhomboid, smooth, ± thick-walled; basal laminal cells rectangular, thick-walled and pitted. Perichaetia lateral on ascending stems; archegonia 7–20 in number; paraphyses filamentous, fewer than archegonia in number. Perichaetial leaves oblong-ovate, ca. 1 mm long, incurved, ecostate, yellowish green above, reddish brown at base, becoming much longer after fertilization and reaching 7 mm long; upper and median laminal cells linear-rhomboid, smooth, ± thick-walled; basal laminal cells much differentiated, rectangular, thick-walled and pitted. Calyptrae cucullate, densely papillose, naked.

Seta short, ca. 1.2 mm long, yellow, smooth. Capsules deeply immersed among perichaetical leaves, cylindrical, to 3 mm long, not constricted below the mouth, weakly plicate at base when dry; columella absent; exothecial cells hexagonal, smooth; stomata absent; opercula conic or shortly rostrate, falling with calyptrae; annuli not seen. Peristome single, pale yellow, with weakly developed properistome; exostome teeth linear, 16, slightly inserted below the rim, sometimes adnate to each other and becoming paired, to 280 µm tall, smooth on both surfaces, sometimes perforate proximally, dorsal trabeculae thin, low and distant, ventral trabeculae thick and broad; closed when wet, open and recurved when dry. Spores spherical, light brown and thin-walled, greenish inside, minutely papillose, 25–30 µm in diameter, about half in a single spore sac highly shrunken.

Specimens examined:—CHINA. Guangxi: Baise City, Nabao county, between Nabao (23.4058°N, 105.8406°E) and Ping Meng (22.9333°N, 105.8333°E), Mt. Qui-Kan-Shan, 1060–1160 m elev., limestone area, on tree trunk in a well preserved, moist secondary forest, 1997 Oct. 19, *H. Akiyama China-1335* (HYO!), with sporophytes; *ibid.*, in the vicinity of Nabao, Mt. Longli, 1000–1200 m elev., on limestone boulder and shrub branches, 1997 Oct. 22, *H. Akiyama China-1386* (HYO!).

#### *Differences of sporophytes between Horikawaea and Cryptogonium*

Sporophytic features of *Cryptogonium* (Müll.Hal.) Hampe have been described in detail by Noguchi (1961) and Lin (1984a) based on *C. phyllogonioides* (Sull.) Isov. In addition, the senior author (HA) has observed sporophytes on the specimens of *C. phyllogonioides* from Seram Island of Indonesia (see "specimens examined" below). Characteristic features of the sporophytes are distinctly pilose calyptrae; capsules constricted just below the mouth; and exostome teeth inserted below the rim. However, other important features such as peristome morphologies (e.g., number and shape of smooth and linear exostome teeth, the wide trabeculae on the inner side of the tooth surfaces, and presence of a weak properistome), the immersed position of the capsule amongst the perichaetial leaves, and the absence of stomata are quite similar between *C. phyllogonioides* and *Horikawaea dubia* (see description above), as well as their shared gametophytic features such as the cucullate leaf acumen, strong differentiation of alar regions, complanate foliation, single costa often reaching to the middle of leaf length, *Bryum*-type of dormant branch primordia with filamentous pseudoparaphyllia, and septate short gemmae in leaf axils (Lin 1984a, Isoviita 1986, Akiyama 1990).

When establishing a new genus *Pursellia* S.H.Lin (treated here as a synonym of *Cryptogonium*), Lin (1984a, table 10) pointed out some morphological differences from those of *Horikawaea*. At that time, however, no sporophyte was known for *Horikawaea*.

The present discovery of sporophytes from *Horikawaea dubia* and their resemblance to those of species of *Cryptogonium*, as well as their gametophytic similarities, strongly suggest that these two genera are congeneric. Recent molecular analyses (for example, Cox et al. 2010) are supportive of the cladistic proximity of these two genera.

The sporophyte of *Horikawaea tjibodensis* [syn., *H. redfearnii* B.C. Tan & P.-J. Lin], a species included in the genus recently by Ji & Enroth (2006) is, however, quite different from that of *Horikawaea phyllogonioides* and *Horikawaea dubia*. According to Tan & Lin (1995) and our confirmation, sporophytes of *H. tjibodensis* show the following features: young calyptrae bearing papillae on the surfaces; setae 4–5 mm long, weakly papillate; capsules (ovoid-oblong, erect, 1–1.5 mm long) highly exserted beyond the perichaetial leaves; opercula conic to rostrate; stomata present at neck (after Jia 2011); peristome highly reduced; exostome teeth about 8 in number, deeply inserted below the rim, outer surface weakly striate; spores round to tetrahedral, 24–44 µm in diameter, granulose and chlorophyllose. In addition, there are leaf morphological differences seen between *H. tjibodensis* and other congeners as shown in the keys below. We therefore propose a new genus, *Pseudocryptogonium*, in the Pterobryaceae to accommodate *H. tjibodensis*.

## Taxonomy

***Cryptogonium*** (Müll.Hal.) Hampe, *Fragm. Phyt. Austr.* 11: 49 (1881) [Pterobryaceae].

Basionym: *Phyllogonium* Brid. sect. *Cryptogonium* Müll.Hal., *J. Mus. Godeffroy* 3(6): 69 (1874).

*Pursellia* S.H.Lin, *J. Hattori Bot. Lab.* 55: 299 (1984). “Type species:—*Phyllogonium cylindricum* Lindb.” For more details, see Isoviita (1986).

*Horikawaea* Nog., *J. Sci. Hiroshima Univ. B* (2), Bot. 3: 46 (1937), **syn. nov.**

Familial affinity of *Cryptogonium* has been variously proposed by different authors, for example, in the Neckeraceae, Phyllogoniaceae, or Pterobryaceae. Judging from morphological features, such as septate, short filamentous gemmae abundantly produced from dormant branch buds in leaf axils, and filamentous pseudoparaphyllia produced on dormant branch buds, as well as the presence of a reduced properistome, smooth exostome teeth, and well-developed alar regions of the stem and branch leaves, its placement in the Pterobryaceae is preferred (Akiyama 1990 and others). In addition, molecular analyses support this familial treatment [Goffinet et al. (2009), Cox et al. (2010; fig. 1-B), Wang et al. (2010; fig. 1)].

All members of *Cryptogonium* listed below share the following morphological features: (1) more or less shiny plants with complanate foliation; (2) somewhat cucullate apices of leaves in lateral position on stems and branches; (3) colored, well differentiated alar cells of leaves with quadrate, markedly pitted cells; (4) dormant branch buds of AI-type (Akiyama 1990) with a number of short, septate gemmae emerging directly from the surface of buds; and (5) filamentous pseudoparaphyllia (often branched and 1–2 cells wide at base).

### 1. *Cryptogonium nitidum* (Nog.) H.Akiyama & B.C.Tan, *comb. nov.* (Figs. 17–19)

Basionym: *Horikawaea nitida* Nog., *J. Sci. Hiroshima Univ. B* (2), Bot. 3: 47 (1937). “Type:—FORMOSA (TAIWAN).

Taipei: Sinten–Urai, Aug. 12, 1932, *Noguchi 5850* (holotype HIRO!, isotypes BM, NICH!).”

Other specimens examined:—TAIWAN. Taipei Hsien: San-hsia, 300 m elev., Jan. 28, 1986, *T. Y. Ching 12940* (HIRO!); *ibid.*, Nov. 3, 1987, *T. Y. Ching 23892* (HIRO!).

Distribution. Endemic to Taiwan.

Note. *Horikawaea nitida* is the type species of the genus *Horikawaea* Nog. We follow Lin (1984a) who treated *Cryptogonium nitidum* ( $\equiv$ *Horikawaea nitida*) and *C. dubium* ( $\equiv$ *H. dubia*) as two different species and *C. nitidum* as a Taiwanese endemic. For more details, see notes under *C. dubium*. Although the sporophyte of *H. nitida* is still not known, we can assume that it will be similar to that observed in *H. dubia* because of the strong similarity of their gametophytes and to the extent that the two have been accepted as synonyms by several researchers [Pócs (1969), Tan & Lin (1995), Ji & Enroth (2006)].

### 2. *Cryptogonium dubium* (Tixier) H.Akiyama & B.C.Tan, *comb. nov.* (Figs. 1–16 & 26)

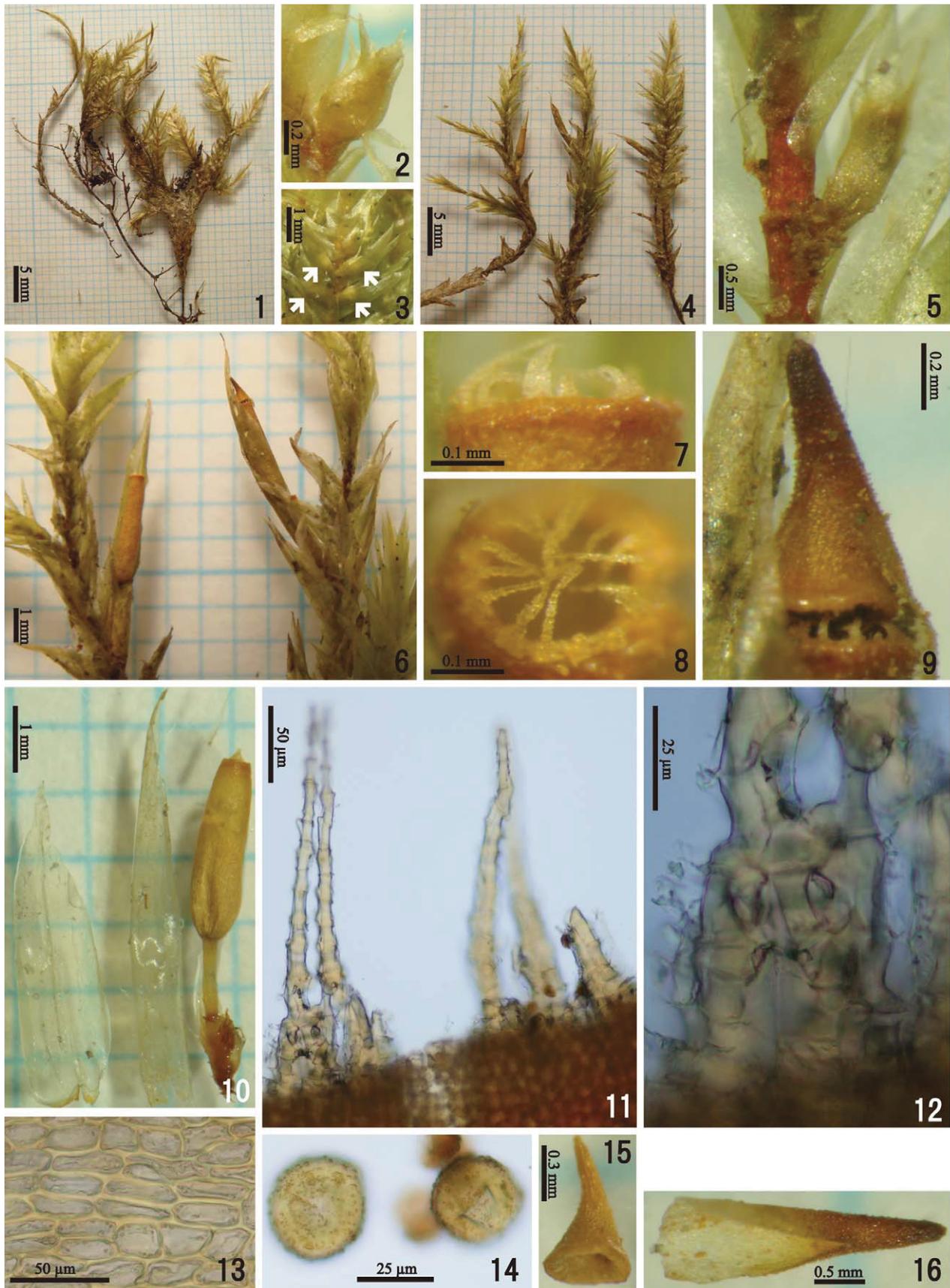
Basionym: *Pterobryopsis dubia* Tixier, *Bot. Közlem.* 54: 34 (1967).  $\equiv$  *Horikawaea dubia* (Tixier) S.H.Lin, *J. Hattori Bot.*

*Lab.* 55: 299 (1984). “Type:—VIETNAM. Ninh-Binh: reservatum Cuc-Phuong, Oct. 22, 1963, *T. Pócs 2634/d* (holotype PC, isotype EGR!).”

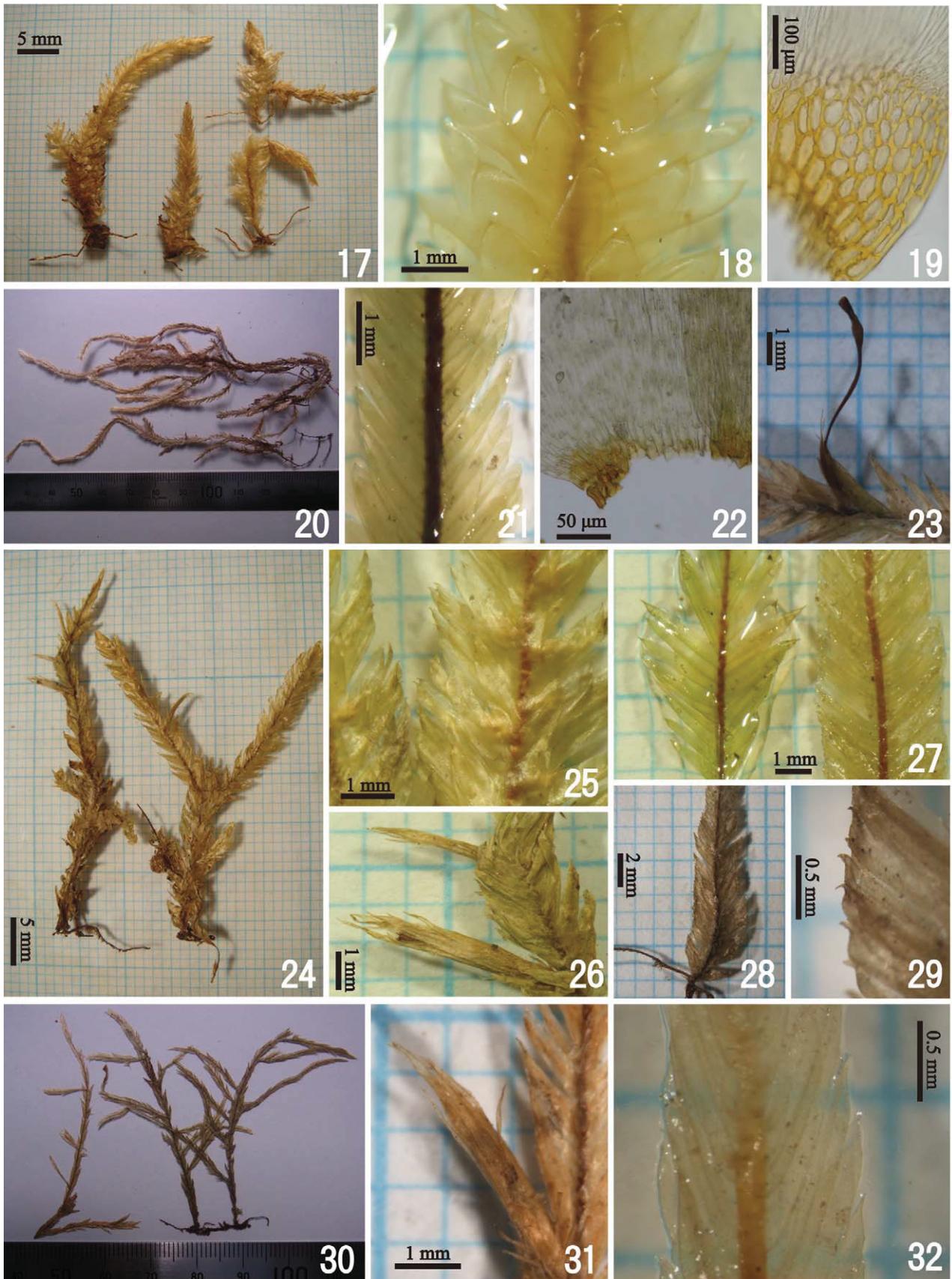
Other specimens examined:—As described above.

Distribution. E. India, North Vietnam, China (Guangdong, Guizhou, Hainan, Sichuan, Yunnan).

Note. Lin (1984a, table 9) compared the morphological features of *Cryptogonium dubium* and *C. nitidum* (as *Horikawaea nitida*) in detail and treated them as two distinct species. Luo (1989) and Jia (2011) followed the treatment. The main differences between the two species are: (1) more slender and shorter plants with pendent flagelliform branches; (2) small medullary cells of stems with incrassate walls; and (3) strongly complanate foliation in *C. dubium*. However, Pócs (1969), Tan & Lin (1995), Ji & Enroth (2006) regarded these morphological differences as just phenotypic plasticity caused by environmental factors and treated them as a single variable species. We tentatively treat them as different species here. As shown in the keys below, *C. dubium* and *C. nitidum* can be distinguished by their difference in leaf shape at the dorsal and ventral position of stems, especially when wet.



**FIGURES 1–16.** *Cryptogonium dubium* (H.Akiyama China-1335). 1; male plants. 2; close-up of a perigonium (stem leaves are removed). 3; stem with several perigonia arranged in rows. 4; female plants. 5; close-up of a perichaetium, with filamentous pseudoparaphyllia at base. 6; two sporophytes. 7 & 8; close-up of peristome teeth. 9; almost detached operculum. 10; two perichaetial leaves and a sporophyte inside. 11; peristome teeth. 12; close-up of basal part of peristome teeth, with poration. 13; exothecial cells. 14; spores. 15; operculum. 16; cucullate calyptra.



**FIGURES 17–32.** 17–19; *Cryptogonium nitidum* (holotype of *Horikawaea nitida*). 20–23; *Pseudocryptogonium tjibodensis* (holotype of *Horikawaea redfearnii*). 24–26; *C. phyllogonioides* (*H. Akiyama C-10140*). 27; *C. dubium* (left; *H. Akiyama China-1335*) and *C. phyllogonioides* (*H. Akiyama C-10140*). 28–29; *C. phyllogonioides* (holotype of *Neckera phyllogonioides*). 30–32; *C. phyllogonioides* (lectotype of *Phyllogonium cylindricum*).

**3. *Cryptogonium phyllogonioides*** (Sull.) Isov., J. Hattori Bot. Lab. 60: 452 (1986). (Figs. 24–32)

Basionym: *Neckera phyllogonioides* Sull., Proc. Arts Sci. 3: 181 (1855) ≡ *Orthorrhynchium phyllogonioides* (Sull.) E. Britton in A. Gepp, Philipp. J. Sci. 68: 232 (1939) ≡ *Horikawaea phyllogonioides* (Sull.) Nog., Bull. Bot. Soc. Univ. Saugar 13: 29 (1961) ≡ *Pursellia phyllogonioides* (Sull.) S.H.Lin., J. Hattori Bot. Lab. 55: 299 (1984). “Type:—PHILIPPINES. Luzon: *Wilkes U.S. Explor. Exped. s.n.* (holotype US!, isotype FH-herb. Fleisch!).”

*Phyllogonium cylindricum* Lindb., Öfvers. Kongl. Vet.-Akad. Förh. 21: 603 (1865) ≡ *Cryptogonium cylindricum* (Lindb.) Paris, Ind. Bryol.: 293 (1894), *nom. invalid*, based on superfluous combination under *Cryptogonium* Lindb. (Art. 34.1) ≡ *Orthorrhynchium cylindricum* (Lindb.) Broth., Natürl. Pflanzenf. I (3): 835 (1906). “Type:—TAHITI: insula O'tahiti, ubi inter alios muscos sparse crescens, Sept. 1852, S. B. Pontén s.n. (lectotype H!, isolectotype H).” For complete list of synonyms, see Lin (1984a).

Other specimens examined:—MALAYSIA. Sabah: Crocker Range National Park, *H. Akiyama Crocker-248* (BORN!, HYO!). INDONESIA. West Seram: *H. Akiyama C-10016, C-10135, C-10139* and *C-10140* (c. sp.) (all HYO!). Central Seram: *H. Akiyama C-9261, C-9368, and C-9488* (c. sp.) (all HYO!).

Distribution. Widely distributed in South India, Sri Lanka, SE Asia, Pacific Islands (New Hebrides, Samoa, Tahiti), and New Zealand (after Lin 1984a).

Note. This species has been fully treated by Noguchi (1961) and Lin (1984a).

***Pseudocryptogonium*** H. Akiyama & B.C. Tan, *gen. nov.*

Differing from *Cryptogonium* in having weakly conduplicate foliation, almost plane leaf lamina even at the apices, weak differentiation of leaf alar regions, longer setae 3–4 mm in length, and capsules well exerted beyond the perichaetial leaves.

Type species:—*Neckera tjibodensis* M.Fleisch., Musci Fl. Buitenzorg 3: 873 (1908)

The monotypic new genus is based on *Neckera tjibodensis*. It differs from *Cryptogonium* in having: (1) a weakly conduplicate foliation and a plane (not cucullate) leaf lamina and apices; (2) development of very short double costae (except for *C. phyllogonioides*); and (3) longer setae and capsules exerted beyond the perichaetial leaves. See Lin (1984a) for more details. Its differences from the superficially similar genus, *Neckera* Hedw., have been well elaborated by Ji & Enroth (2006).

**1. *Pseudocryptogonium tjibodensis*** (M.Fleisch.) H.Akiyama & B.C.Tan, *comb. nov.* (Figs. 20–23).

Basionym: *Neckera tjibodensis* M.Fleisch., Musci Fl. Buitenzorg 3: 873 (1908) ≡ *Horikawaea tjibodensis* (M.Fleisch.) M.C. Ji & Enroth, J. Bryol. 28: 167 (2006). “Type:—INDONESIA. Java: Tjibodas, *detex F.* (holotype FH-herb. Fleisch!, isotype L).”

*Horikawaea redfearnii* B.C.Tan & P.J.Lin, Trop. Bryol. 10: 59 (1995), *fide* Ji & Enroth (2006). “Type:—PHILIPPINES. Palawan: Aborlan Municipality, Barangay Aporawan, Sitio Daan, Mt. Tinikbasan (ca. 2000 ft), 27 Apr., 1992, B.C.Tan & W.S.Gruezo 92-739 (holotype FH!, isotypes BO!, BM!, CAHUP!, H!, IBSC!, L!, MO!, NY!, US!).”

Other specimens examined:—CHINA. Hainan Island: Changjiang Co., Bawanglin Forest Reserve, 1000-1100 m elev., *P.L.Readfearn 35918* (FH!); *ibid.*, Mt. Jiangfengling, *P.C.Chen et al. 431g* (IBSC!).

Distribution. Philippines (Palawan), Indonesia (Java), China (Hainan).

Note. In *Pseudocryptogonium tjibodensis*, the totally naked dormant buds are surrounded by single-celled wide, unbranched filamentous pseudoparaphyllia. Asexual reproductive organs were not found among the specimens examined. Molecular phylogenetic analyses including the new genus (as *Horikawaea redfearnii*) show a low bootstrap support in a clade with *Cryptogonium phyllogonioides*, but a close relationship with members of the family Pterobryaceae (Cox et al. 2010 fig.1-B, Wang et al. 2010, fig.1).

**Keys to the species of *Cryptogonium* and *Pseudocryptogonium***

1. Costa single, reaching middle of leaf length or short and double; pseudoparaphyllia filamentous, two-cell wide and branched at base ..... 2.

- . Costa absent or short and double, rarely single but not reaching 1/4 of leaf length; pseudoparaphyllia filamentous, single-cell wide at base and usually not branched..... 3.
- 2. Stem leaves at dorsal, lateral and ventral position deeply concave and cucullate at apices. Taiwan endemic. (Sporophyte unknown.)..... *Cryptogonium nitidum*
- . Stem leaves at dorsal and ventral position not concave (often weakly conduplicate), plane at apices. Widely distributed in limestone areas from E. India to South China. (Seta ca. 1.2 mm long. Capsules deeply immersed among perichaetial leaves)..... *Cryptogonium dubium*
- 3. Stem leaves at lateral position deeply conduplicate, cucullate at apices; alar cells markedly developed and decurrent; setae ca. 1.2 mm long; capsules deeply immersed among perichaetial leaves. Widely distributed in Southeast Asia, South Pacific Islands, and New Zealand..... *Cryptogonium phyllogonioides*
- . Stem leaves at lateral position weakly conduplicate, weakly cucullate to plane at apices; alar cells narrower and not decurrent; seta 3–4 mm long; capsules long exerted. So far known only by three locations (Java, Hainan, and Palawan Islands) ..... *Pseudocryptogonium tjibodensis*

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