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The first discovery on the sporophytes of a rheophytic moss: *Bryocrumia vivicolor* (Bryophyta, Hypnaceae)

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Abstract

Based on recent collections made in Yunnan Province, China, the sporophytes of *Bryocrumia vivicolor* were discovered for the first time for this species. With typical hypnoid peristome teeth, short operculum, and slightly collenchymatous exothecial cell walls, the capsule of *B. vivicolor* conforms to the basic definition of Hypnaceae, and this monospecific genus is deemed to belong in Hypnoideae according to current circumscription of the subfamily. Although the identity of *Bryocrumia* seems to be well-supported morphologically by the additional features such as the bluntly obtuse apex of perichaetial leaves and the deciduous annulus consisting of irregular-shaped cells in 1–2 rows, future molecular study could provide useful insights in understanding the distribution of this rarely collected yet geographically widespread species.

Key words: *Bryocrumia vivicolor*, sporophytes, perichaetial leaves, rheophyte, Yunnan

Introduction

Glossadelphus andersonii Bartram (1951: 81) was described based on a single collection (*Anderson 9237*, DUKE, FH) made from South Carolina, USA (Bartram 1951). Crum (1965) transferred it to *Taxiphyllum* M. Fleisch. (1923: 1434) and made a new combination, *Taxiphyllum andersonii* (E. B. Bartram) H. A. Crum (1965: 220), based on morphological and biogeographical evidence. In view of the smooth leaf cells as seen by Scanning Electronic Microscopy (SEM) and the rounded pseudoparaphyllia that this species has, Anderson (1980) established a new genus, *Bryocrumia* L. E. Anderson (1980: 65) in honor of Dr. Howard A. Crum (1922–2002). A second species, *Bryocrumia vivicolor* (Brotherus & Dixon) W. R. Buck (1987: 522), was added to the genus based on an Indian collection, basionym: *Taxithelium vivicolor* Brotherus & Dixon (1914: 86). Buck (1987) mentioned the possibility of synonymizing *B. andersonii* to this newly combined name pending examinations of more material. Two years later, *B. andersonii* was reported from Yunnan, China for the first time outside eastern North America (Redfearn *et al.* 1989). Later, Anderson *et al*. (1990) synonymized *B. andersonii* with *B. vivicolor* after confirming Redfearn's Chinese specimens. *Bryocrumia* became a monotypic genus again. No information on sporophytes has ever been reported for this taxon for over 100 years since its original publication.

During a recent bryological expedition to western Yunnan, both first and second authors discovered an interesting moss with a round leaf apex and faintly double costae. It further attracted our attetion as this moss seemed to be almost always found on rocks submerged in streams.

These specimens were determined to be *Bryocrumia vivicolor* after microscopic study in the laboratory. The species is characterized by 1) leaf apices mostly bluntly obtuse or sometimes rounded, 2) leaf bases contracted, 3) alar region slightly differentiated by a few rectangular cells, and 4) indistinct or occasionally fairly visible double costae. A combination of these striking features helped our identification work and several historical specimens in CAS and KUN with similar morphologies were comfirmed to be *B. vivicolor*. *Bryocrumia vivicolor* turned out to be much more widespread across Yunnan province than previously known, expanding from a single county (Redfearn *et al*. 1989; Jia *et al*. 2005) to nine additional counties, ranging from 960 to 2620 m in elevation.

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Among all specimens studied, five specimens from three different counties were found to have sporophytes, mostly with highly degraded capsules or with only setae present. Six capsules were found, but five of them were over-mature with either broken peristome teeth or without operculum, leaving us with a single intact capsule to study. In this paper, sporophytic features as well as perichaetial leaves of this interesting rheophytic moss are described and photographed.

Material and methods

Voucher specimens with capsules were deposited in CAS and KUN. Duplicate specimens with perichaetial leaves were distributed to H, MO, NY, and SZG. Other non-fertile specimens examined were deposited in herbaria listed in "Other specimens examined" below. Specimens were examined under microscopes and compared to the illustration (Anderson 1980) and voucher specimens cited in the literature (Jia *et al*. 2005). Microscopic images were created by the AxioCam ICc5 camera.

Description of the sporophyte

Bryocrumia vivicolor (Brotherus & Dixon) W. R. Buck (Figs. 1, 2)

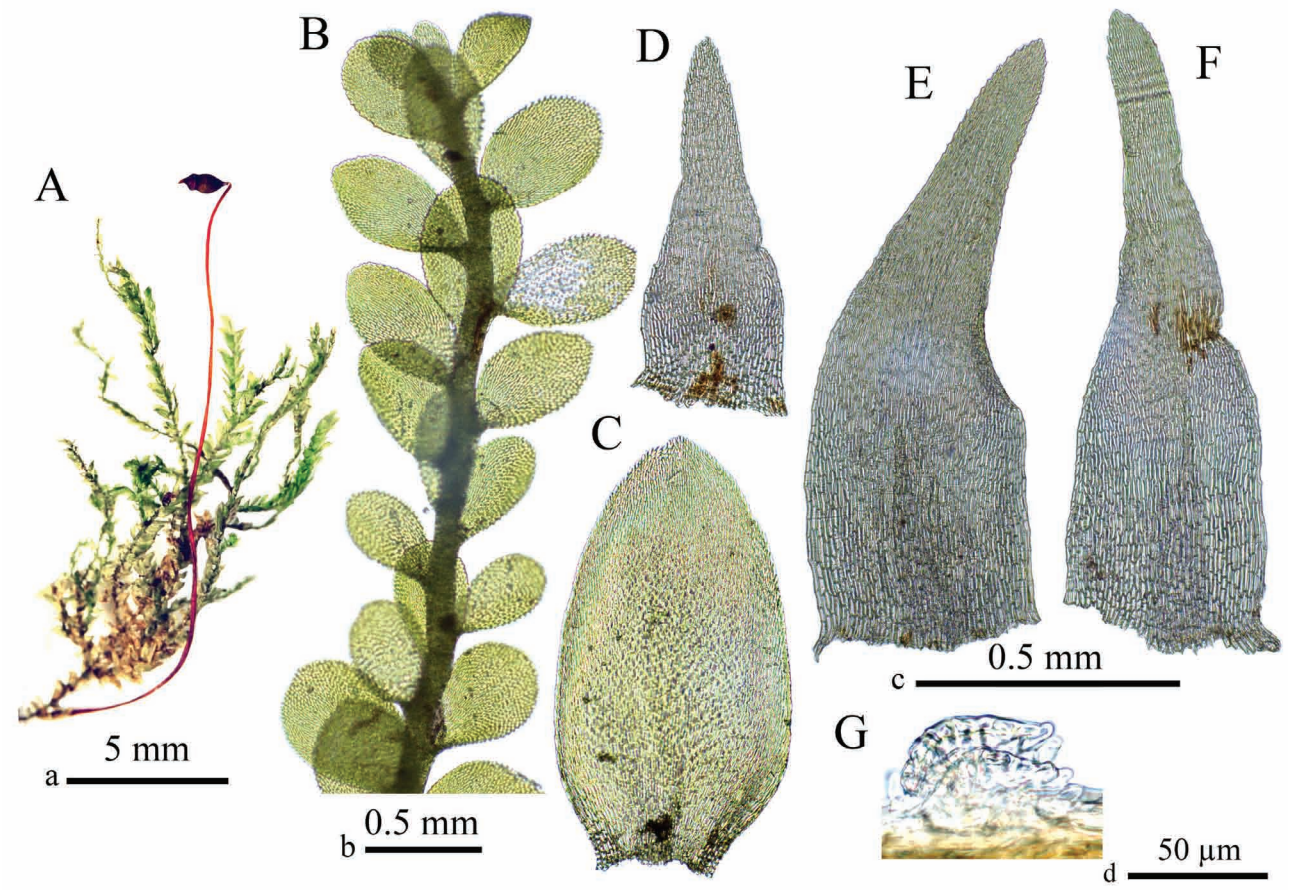

FIGURE 1. Plants and perichaetial leaves of *Bryocrumia vivicolor*: A. Plants with capsule. B. Young leaves on branch. C. Mature leaf. D. Outer perichaetial leaf. E. Middle perichaetial leaf. F. Inner perichaetial leaf. A–C from *Ma 15-7067*; D–F from *Shevock 47812*; G from *Redfearn 971*. Scale bars: a for A, b for B, c for C–F, d for G.

Perichaetial leaves different in size, ecostate. Inner perichaetial leaves 1.0–1.3 mm long, with a broadly ovate sheathing base, 0.36–0.43 mm wide and gradually narrowed in the middle, ending with a bluntly acute apex, 0.10–0.12 mm wide, strongly twisted when dry. Outer perichaetial leaves 0.70–0.76 mm long, with an indistinct sheathing base, 0.34–0.38 mm wide. Setae (8.4–) 10.7–12.4 (–17.0) mm long, reddish, smooth, slightly twisted when dry, a central strand present.

Capsules horizontal to pendulous at maturity, symmetric, ovoid, short-necked, 0.7–1.2 × 0.5–0.6 mm. Operculum conical, short-rostrate, 0.5–0.7 mm long. Annulus not persistent, falling off at maturity, consisting of 1–2 rows of cells. Exothecial cells subquadrate or 5–6 sided polygons, 14.1–18.3 × 8.1–12.0 µm, thin-walled, slightly collenchymatous. Stomata present only at the neck, short-pored, guard cells about 12.6 × 6.2 µm. Exostome teeth in 16 pairs, fused at base, linear-lanceolate, 142–150 µm long, *ca.* 25 µm wide at base, curved inwardly when dry, yellowish tangerine in the lower 2/3 portion, densely cross-striolate, light-colored above, sparsely papillose at the outer surface. Endostome segments large, nearly as long as exostome teeth, light brown to yellowish, keeled, minutely papillose at the outer surface, basal membrane well-developed, 50–60 µm high. Cilia mostly 2, sometimes 1 or 3 in groups, shorter than segments, *ca.* 35 µm long, light yellow, fragile. Spores spherical or slightly elliptic, 16–20 µm in diameter, minutely papillose. Calyptra not seen.

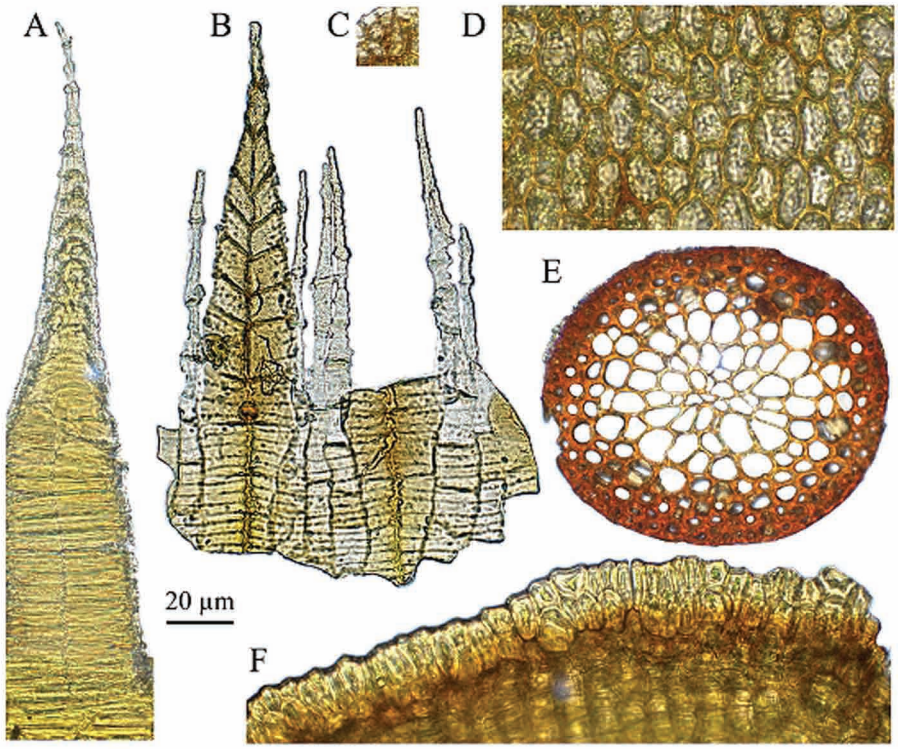

FIGURE 2. A. Exostome. B. Endostome. C. Stoma at capsule neck. D. Exothecial cells. E. Cross section of seta. F. Annuli attached on operculum. A–D & F from *Ma 15-7067*, E from *Shevock 47812*. Scale bar for A–F.

Habitat: on rocks, mostly along stream channels, seasonally (irregularly) submerged, alt. 800–2670 m.

Specimens examined with sporophytes (collected between May–October, 2015): CHINA. Yunnan: Dali Region, Yang-Bi County, *Ma & Shevock 15-6357* (CAS, KUN). Honghe Region, Jin-Ping County, *Ma 15-7067* (CAS, KUN); *Shevock 47812* (CAS, KUN). Lincang Region, Cang-Yuan County, *Ma & Shevock 15-6855* (CAS, KUN); *Shevock & Ma 47532* (CAS, H, KUN, MO, NY, SZG).

Other specimens examined (collected between July 1998 and September 2015): CHINA. Yunnan: Baoshan Region, Long-Yang District, *Shevock 27343* (CAS, E, KUN, MO); Teng-Chong County, *Long 32748* (CAS, E, KUN, MO), *Ma 15-6324* (CAS, KUN). Dali Region, Yang-Bi County, *Redfearn & Su 971* (CAS, DUKE, KUN, MO). Honghe Region, Lv-Chun Co., *Ma 15-6987*, *15-6997*, *15-7005* (all in CAS, KUN). Lincang Region, Geng-Ma County, *Ma & Shevock 15-6830* (CAS, KUN). Nujiang Region, Fu-Gong County, *Ma 13-5184* (CAS, KUN); Gong-Shan County, *Long 36207* (CAS, E, KUN, MO). Yuxi Region, Xin-Ping County, *Ma & Shevock 15-6760* (CAS, KUN, UC), *Ma & Shevock 15-6762* (CAS, KUN).

Discussion

Taxonomic notes

Bryophytes dwelling in rheophytic habitats rarely produce sporophytes, primarily due to demanding requirements

during the fertilization process in running water environment (Ochyra & Shevock 2012). With the newly discovered capsules of *B. vivicolor*, the identity of the genus *Bryocrumia* seems to be well-supported by the morphology of the sporophyte. Besides the characteristics of leaf morphology mentioned above for the species, the genus is further characterized by having all perichaetial leaves with blunt apices (Fig. 2: D–F), cilia in groups, mostly 2, occasionally 1 or 3 (Fig. 2: B), and annulus not persistent, consisting of 1–2 rows of irregular shaped cells. With well-developed peristome and cilia, inclined capsules, and scarcely differentiated alar cells, we suggest *Bryocrumia* be placed under the subfamily Hypnoideae according to the treatment in Moss Flora of China (Jia *et al*. 2005).

Vegetatively, *Taxiphyllum prostratum* (Dozy & Molkenboer 1844: 309) W. R. Buck (1987: 521) resembles *B. vivicolor* to a certain degree, although *T. prostratum* has not yet been reported from China. The former species can be separated from *B. vivicolor* in having acuminate perichaetial leaves and incurved capsules.

Bryocrumia vivicolor with small, rather remotely arranged, more or less oblong-ovate leaves, and bluntly obtuse to rounded-obtuse leaf apices could be easily recognized with a hand-lens by moistening its leaves. The bluntly obtuse leaves had well-typified *B. vivicolor*, however, the species could still be misidentified as several other Hypnaceous species with similar rounded leaf apices, such as *Ectropothecium dealbatum* (Reinwardt & Hornschuch 1829: 729) A. Jaeger (1880: 264) and *Taxiphyllum arcuatum* (Bosch & Sande Lac. 1862: 56) S. He (1997: 37). The presence of obtuse pseudoparaphyllia (Fig. 1: G), together with the shape of leaf in *B. vivicolor* will be reliable characters in telling it apart from other species with similar leaf morphology.

FIGURE 3. Distribution of *Bryocrumia vivicolor* in Yunnan. Specimens with sporophytes were shown with pentagrams. 1, Gong-Shan Co. (*Long 36207*); 2, Fu-Gong Co. (*Ma 13-5184*); 3, Teng-Chong Co. (*Ma 15-6324*); 4, Long-Yang Dist. (*Shevock 27343*); 5, Teng-Chong Co. (*Long 32748*); 6, Geng-Ma Co. (*Ma & Shevock 15-6830*); *7, Cang*-Yuan Co. (*Ma & Shevock 15-6855*; *Shevock & Ma 47532*); 8, Yang-Bi Co. (*Redfearn & Su 971*); 9, Yang-Bi Co. (*Ma & Shevock 15-6357*); 10, Xin-Ping Co. (*Ma & Shevock 15-6760; 15-6762*); 11, Lv-Chun Co. (*Ma 15-6997; 15-7005*); 12, Lv-Chun Co. (*Ma 15-6987*); 13, Jin-Ping Co. (*Ma 15-7067; Shevock 47812*).

Ecology and distribution

Bryocrumia vivicolor could be under-collected in China. The potential misidentification of some specimens of *B. vivicolor* might have accounted for the rare documentation in specimen representation in herbaria. In South Carolina, *B. vivicolor* (as *Glossadelphus andersonii*) was first documented growing on "moist vertical rock" (Bartram 1951), and in North Carolina, it (as *Bryocrumia andersonii*) was noted as growing on "moist and wet rocks" (Anderson 1980). It is easy to associate *B. vivicolor* with damp environments; however, the limited habitat information resulting from a poor understanding of the habitat requirements of this species may explain its under-collection. Based on all 17 specimens examined in this study, only three were collected on rocks without any possibility of submersion, which indicates *B. vivicolor* has a high preference for rheophtic environments. We noticed that some broken setae with different lengths were still attached to the plants, which indicates that the capsules may have been eaten by certain aquatic larvae versus broken-off by water flow. Future surveys for this species should focus not only on wet rocks from seeps and springs, but also among rheophytic habitats as well.

Bryocrumia vivicolor is widely distributed across several continents from Asia (Brotherus 1925; Redfearn *et al*. 1989; Printarakul *et al*. 2013), Africa (O'Shea 2006), and North America (Anderson 1980). We believe as more specimens become available for study, it will exhibit a more explainable distributional pattern. Prior to this study, *B. vivicolor* was only known from a single location in Yunnan (Fig. 3: dot number 9). With our recent expeditions in Yunnan, nine more county records were added for the province. In fact, there was no biased sampling against any counties, although our recent collecting activities were primarily focused on rheophytic habitats along streams and near waterfalls. When all these collection sites were displayed on a map, an interesting pattern was shown (Fig. 3). All occurrences seem to be coincidently within the west boundary of the Tanaka Line, a biogeographic concept that separates two floristic sub-regions in Yunnan Province (Tanaka 1954). Vascular plants with a similar biogeographic pattern were considered as elements with an ancient origin that resulted from the movement of the Burma-Malaya Geoblock (Li 1994). However, the populations documented in North America and Africa make it more complicated to explain the dispersal of *B. vivicolor*. It will be interesting to determine if molecular data could be integrated to understand the biogeographic processes of *B. vivicolor*.

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