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# ***Frullania pluricarinata* Gottsche (Frullaniaceae, Marchantiophyta): an overlooked liverwort species in the Brazilian bryophyte flora**

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## ABSTRACT

*Frullania pluricarinata* Gottsche is confirmed for the bryophyte flora of Brazil based on historical and recent collections. The species was first recorded in 1989 in Serra Negra, São Paulo, with specimens deposited in the Herbarium Senckenbergianum, Germany. In 2023, it was rediscovered in Brumadinho, Minas Gerais, significantly updating its distribution in Brazil. In addition, we address the typification of the species: although Yuzawa (1991) studied original material and informally treated the specimen in S as an “isotype,” no formal lectotypification had been proposed. In this study, we designate the S specimen as lectotype, thereby stabilizing the application of the name. With this addition, the number of *Frullania* Raddi species recognized in the country has increased to 39. We provide a detailed taxonomic description, highlighting diagnostic characters, comparisons within the subgenus *Chonanthelia* Spruce, and notes on its geographic distribution and ecology. These findings underscore the importance of integrating historical records with contemporary collections to enhance our understanding of biodiversity.

## KEY WORDS

Biodiversity,  
ecological assessment,  
*Frullania* subg.  
*Chonanthelia*,  
lectotypification,  
new record.

## RÉSUMÉ

*Frullania pluricarinata* Gottsche (*Frullaniaceae*, *Marchantiophyta*) : une espèce d'hépatique oubliée dans la flore bryophytique brésilienne.

*Frullania pluricarinata* Gottsche est confirmée pour la flore bryophytique du Brésil sur la base de collections historiques et récentes. L'espèce a été signalée pour la première fois en 1989 à Serra Negra, São Paulo, avec des spécimens déposés à l'Herbarium Senckenbergianum, en Allemagne. En 2023, elle a été redécouverte à Brumadinho, Minas Gerais, ce qui actualise de manière significative sa distribution au Brésil. Nous abordons également la question de la typification : bien que Yuzawa (1991) ait étudié du matériel original et traité de manière informelle le spécimen conservé à S comme un « isotype », aucune lectotypification formelle n'avait été proposée. Dans cette étude, nous désignons le spécimen de S comme lectotype, stabilisant ainsi l'application du nom. Avec cet ajout, le nombre d'espèces de *Frullania* Raddi reconnues dans le pays s'élève désormais à 39. Nous fournissons une description taxonomique détaillée, en mettant en évidence les caractères diagnostiques, les comparaisons au sein du sous-genre *Chonanthelia* Spruce, ainsi que des notes sur sa distribution géographique et son écologie. Ces résultats soulignent l'importance d'intégrer les données historiques aux collections contemporaines afin d'améliorer notre compréhension de la biodiversité.

## MOTS CLÉS

Biodiversité,  
évaluation écologique,  
*Frullania* subg.  
*Chonanthelia*,  
lectotypification,  
nouveau signalement.

## INTRODUCTION

Bryophytes include nearly 18 150 species in over 1200 genera worldwide, divided into three groups: liverworts (Marchantiophyta), hornworts (Anthocerotophyta), and mosses (Bryophyta) (Gradstein *et al.* 2001; Goffinet & Shaw 2009). Comprehensive phylogenomic time tree of bryophytes has revealed deep evolutionary relationships and uncovered gene incongruences in the last 500 million years of diversification (Bechteler *et al.* 2023). Liverworts are a phylum of small terrestrial plants, estimated to comprise about 5000 species in 391 genera (Goffinet & Shaw 2009), with 702 species recorded in Brazil (Flora e Funga do Brasil 2024). They occupy various habitats, from disturbed soils to tree trunks in natural or degraded landscapes, occurring on all continents, including Antarctica (Goffinet & Shaw 2009).

The genus *Frullania* Raddi (1818) belongs to Frullaniaceae and, in Brazil, has 39 species, with eight species endemic (Lima *et al.* 2025). They are nearly cosmopolitan plants, with species that are mainly epiphytic and inhabit diverse habitats, especially tropical ones (Hentschel *et al.* 2009). In Brazil, they are distributed in eight subgenera: *Caulisequa* Gerh. Winter & Schäf.-Verw., *Chonanthelia* Spruce, *Diastaloba* Spruce, *Frullania* Spruce, *Homotropantha* Spruce, *Meteoropsis* Spruce, *Saccophora* Verd. and *Trachycolea* Spruce (Lima *et al.* 2025).

In the most recent update to the infrageneric circumscription of *Frullania* Raddi, subg. *Trachycolea* Spruce now includes all species previously placed in subg. *Frullania* Spruce, while subg. *Thyopsiella* Spruce is currently treated as a synonym of subg. *Frullania* Spruce (Lima *et al.* 2020).

*Frullania pluricarinata* Gottsche belongs to the subgenus *Chonanthelia* Spruce, characterized by a consistently smooth perianth; 8-10 well-defined keels in a transverse section (some additional smaller keels are often present), the leaf-lobule being usually differentiated to a saccate portion and a laminal portion, and the keel of the lobule short and subparallel to the stem (Spruce 1884; Yuzawa 1991).

On January 25, 2019, in the municipality of Brumadinho, Minas Gerais, the rupture of the B1 dam at the Córrego do Feijão Mine released 9.7 million m<sup>3</sup> of mining tailings into the Ferro-Carvão stream basin (Robertson *et al.* 2019). This disaster caused severe environmental damage, affecting multiple levels of biological organization – from genes to entire ecosystems, and resulting in the destruction of 133.27 hectares of native Atlantic Forest vegetation and 70.65 hectares of permanent preservation areas (APPs) (Ampló 2019; Polignano & Lemos 2020). In response, the Biodiversity Monitoring Program was established to assess and monitor the potential effects of this event across spatial, temporal, and biological organizational levels (Ampló 2019).

In 2023, during fieldwork conducted in a semideciduous forest area in Brumadinho, Minas Gerais, we recorded the occurrence of *Frullania pluricarinata* Gottsche. This finding represents a new record for Brazil, extending the species' known geographical range and altitudinal distribution. Previously documented only from historical collections in São Paulo, the species is now confirmed in Minas Gerais, specifically in semi-deciduous forests adjacent to areas impacted by the 2019 Brumadinho dam rupture. This discovery underscores the importance of biodiversity monitoring and highlights the value of integrating historical herbarium data with contemporary fieldwork with contemporary fieldwork to improve our understanding of species distributions and their ecological significance.

## MATERIAL AND METHODS

The present study analyzed specimens collected by the “Program for the Diagnosis of Environmental Damage to Biota” project in Brumadinho municipality of Minas Gerais state, Brazil (20°8'34"S, 44°12'0"W) at 836.6 m a.s.l.

We collected epiphytic bryophyte samples (approx. 10 cm<sup>2</sup>) from the trunks of living trees in 2023. These samples were taken from both the base of the trees and the canopy (up to 15 m), with the assistance of climbers using ropes and stirrups. The material was collected with knives and placed in paper bags for transport and later identification. In the laboratory, all bags were kept open to allow the samples to air-dry. The specimens were examined under a dissecting microscope using needles and tweezers, and further observed with a stereomicroscope and light microscope to document characteristics of the gametophyte, perianth, and spores. Photomicrographs were taken using a Zeiss Axio Lab A1 microscope and an AxioCam ERc 5s camera at the Plant Systematics Laboratory of Universidade Federal de Minas Gerais (UFMG) to capture relevant features.

Identification was carried out by comparing the samples with the original descriptions and available specialized literature (Clark & Svihla 1950; Yuzawa 1991; Gradstein 2021). The classification system followed Crandall-Stotler *et al.* (2009) and Bechteler *et al.* (2023) for liverworts. The specimens were deposited in the BHCb herbarium (BHCb216113, BHCb221003 and BHCb221007). An additional literature review and searches in biodiversity databases (e.g., species-Link and GBIF) were performed to assess the geographical distribution of *Frullania pluricarinata* (Fig. 1).

## TAXONOMY

Family FRULLANIACEAE Lorch  
Genus *Frullania* Raddi

*Frullania pluricarinata* Gottsche  
(Fig. 2)

*Annales des Sciences Naturelles, Botanique*, sér. 5, 1: 168 (Gottsche 1864).

TYPE MATERIAL. — **Colombia** • Bogotá prope la, Peña; 2700 m alt.; *unknown collector* (lectotype S-B237892, **designated here**).

SPECIMENS EXAMINED. — **Brasil** • São Paulo, Serra Negra; 22°35'S, 46°42'W; 1050 m alt.; 10.V.1989; *A. Schäfer-Verwimp* & *I. Verwimp s.n.* FR [FR0278192] • Minas Gerais, Brumadinho, from the living bark of *Lonchocarpus cultratus* (Vell.) A. M. G. Azevedo & H. C. Lima; 20°06'03.3"S, 44°12'16.7"W; 1162.4 m alt.; 25.IV.2023; *L. F. Mejia-Toro 2554* [BHCb216113] • Brumadinho, from the living bark of *Machaerium scleroxylon* Tul.; 20°07'10.3"S, 44°13'48.0"W; 817 m alt.; 12.VII.2023; *L. F. Mejia-Toro 3665* [BHCb221003] • Brumadinho, from the living bark of *Machaerium scleroxylon* Tul., 20°07'10.3"S, 44°13'48.0"W; 817 m alt.; 12.VII.2023; *L. F. Mejia-Toro 3669* [BHCb221007].

DISTRIBUTION AND ECOLOGY. — *Frullania pluricarinata* Gottsche has confirmed occurrences in Argentina, Chile, Colombia, Ecuador, Guatemala, Peru, Mexico, and the United States of America (Gradstein & Cuvertino 2015; Gradstein 2021; GBIF 2024; Dauphin *et al.* 2025). This study expands the known distribution of the species to include Brazil. The species is typically found on tree trunks in dry woodlands, open areas, urban parks, and along roads, and occasionally on rocks. It often thrives in urban environments, exhibits xerotolerance, and occurs at elevations ranging from 400 to 3350 m (Gradstein & Cuvertino 2015; Gradstein 2021).

## DESCRIPTION

Monoicous. Plants small, 0.7-1.6 mm wide, yellowish to dark-brown species with stems, loosely 1-2 pinnately branched. Hemiphylls divided, associated with a lobule. Leaf lobes imbricate, ovate-orbicular, 0.29-0.38 mm long, 0.25-0.37 mm wide, concave, dorsal base rounded, margin entire; basal cells isodiametric, 18-5 µm in diam., median cells isodiametric, 16-21 µm diam., cell walls with trigones and sometimes with one intermediate thickening. Lobules erect, (sub)parallel to the stem, helmet-shaped, 0.1-0.19 mm long, 0.1-0.17 mm wide, ½-⅓ of leaf length, without beak, laminate lobules rare. Styli subulate, 3-5(6) cells long, 1-2 cells wide at the base. Underleaves distant, longer than wide, ovate-oblong, 0.13-0.17 mm long, 0.13-0.22 mm wide, about as wide as the stem, bifid to 1/5-1/4 of underleaf length, margins entire, plane, apex obtuse, base cuneate, plane, insertion line almost straight. Androecia on very short branches, globose, 0.4-0.76 mm long, 0.38-0.5 mm wide, of 4-5 pairs of bracts. Gynoecia on short branches, bracts ovate, *c.* 0.7 mm long, *c.* 1.0 mm wide, margins entire, apex acute, lobules long-ovate, *c.* ½ lobe length, apex acute; bracteoles connate up to half of their length, ¼ bifid, ovate, *c.* 0.58 mm long, *c.* 0.27 mm wide, margins entire, apex obtuse. Perianths oblong, *c.* 1.2 mm long, *c.* 0.7 mm wide, surface smooth, 8-10-keeled, keels sinuous, rostrum very short, 0.38-0.55 mm long, 0.3-0.59 mm wide. Vegetative reproduction not observed.

## AFFINITIES AND DIFFERENTIATION

Currently, the subgenus *Chonantheia* includes ten species for Brazil, three of which (*F. ecklonii*, *F. obscura* and *F. pluricarinata*) have perianths with 8-10 keels (Lima 2019). The table



FIG. 1. — Geographic distribution of *Frullania pluricarinata* Gottsche in the Americas. The map highlights occurrences in Brazil, particularly in Serra Negra (São Paulo) and Brumadinho (Minas Gerais). The inverted orientation emphasizes a southern perspective, aligning with the focus on regional biodiversity.

below (Table 1) highlights the main differences among these species reported in Brazil.

Diagnostic traits of *Frullania pluricarinata* include widely ovate stem leaves with rounded dorsal bases, cucullate lobules with a narrowly developed laminar portion, minute subulate styli (3-5 cells), oblong-obovate stem underleaves *c.* ¼-bifid, entire-margined bract lobes, bract leaf lobes highly connate with entire-margined bracteoles, and perianths with 8-10 keels (Clark & Svihla 1950; Yuzawa 1991; Lima 2019; Gradstein

2021). This combination of traits aligns closely with the descriptions of *F. pluricarinata* and allows its distinction from *F. ecklonii* and *F. obscura*, particularly by its obovate to oblong bracts and shorter keel, rounded leaf bases, bifid hemiphylls, 1-5-celled stylus, and undeveloped lobe beak (Yuzawa 1991; Lima 2019; Table 1).

Atwood (2017) highlights similarities between *F. pluricarinata* and *F. mexicana* but distinguishes them by bract apex shape (acuminate vs rounded) and bracteole shape (oblong



FIG. 2. — *Frullania pluricarinata* Gottsche: **A**, ventral side with perianth; **B**, habit; **C**, leaf; **D**, cells and trigones; **E**, styli; **F**, hemiphylls; **G**, bracteole; **H**, perianth. Specimens: A, G. Winter, Herbarium Senckenbergianum [FR0278192]; B-H, O. Gonçalves, Herbarium BHCB [BHCB216113]. Scale bars: A, 1 mm; B, 0.7 mm; C, E, G, H, 0.2 mm; D, 50  $\mu$ m; F, 10  $\mu$ m.

TABLE 1. — Comparison between the morphological characters of *Frullania* subg. *Chonantheia* Spruce present in Brazil and *Frullania pluricarinata* Gottsche (Clark & Svihla 1950; Yuzawa 1991; Lima 2019).

	<i>F. cuen-</i> <i>censis</i> Taylor	<i>F. duse-</i> <i>nii</i> Steph.	<i>F. eck-</i> <i>lonii</i> (Spreng.) Gottsche, Lindenb. & Nees	<i>F. gib-</i> <i>bosa</i> Nees	<i>F. lind-</i> <i>manii</i> Steph.	<i>F. neuro-</i> <i>ta</i> Taylor	<i>F. obs-</i> <i>cura</i> (Sw.) Nees ex Mont.	<i>F. plat-</i> <i>ycalyx</i> Herzog	<i>F. plur-</i> <i>icarinata</i> Gottsche	<i>F. rio-</i> <i>janeir-</i> <i>ensis</i> (Raddi) Ångstr.
<b>Sexual system</b>	Dioicous	Monoicous	Monoicous	Monoicous	Dioicous	Monoicous	Monoicous	Monoicous	Monoicous	Monoicous
<b>Bracts</b>	Long-ovate, margin entire, apex acute	Ovate, margin entire, apex apiculate	Long-ovate, margin irregularly toothed, apex acuminate	Long-ovate, margin entire, apex apiculate	Oblong, margin entire, apex acute to apiculate	Ovate, margin entire, apex acute to apiculate	Ovate to lanceolate, margin entire, apex acute to acuminate	Ovate, margin entire, apex acute	Obovate to oblong, margin entire to slightly sinuous, apex acuminate	Ovate, margin entire to irregularly toothed, apex acute to short-pointed
<b>Bracteole</b>	Ovate, margin entire or toothed	Ovate, margin irregularly toothed	Margin entire to irregularly toothed	Ovate, margin entire	Ovate, margin entire to toothed	Ovate, margin entire or toothed	Ovate, margin entire	Oblong, margin entire	Oblong to ovate, margin entire	Ovate, margin entire or toothed
<b>Perianth keels</b>	4 keels	4 keels	8-10 keels	4 keels	6-7 keels	4 keels	8-10 keels	4 keels	8-10 keels	4 keels
<b>Styli</b>	Filiform, 3-5 cells long	Filiform, 3-5 cells long	Filiform, 1-3 cells long	Orbicular, 3-6 cells long	Filiform, 1-3 cells long	Filiform, 3-4 cells long	Filiform, 3-4 cells long	Filiform, 3-4 cells long	Subulate, 3-5(6) cells long	Filiform, 2-3 cells long
<b>Insertion of the leaf</b>	Subimbricated to imbricated	Imbricated	Imbricated	Imbricated	Distant to imbricated	Subimbricated to imbricated	Imbricated	Subimbricated to imbricated	Imbricated	Subimbricated to imbricated
<b>Base leaf</b>	Auriculated	Auriculated	Auriculated	Auriculated	Auriculated	Auriculated	Auriculated	Rounded	Rounded	Auriculated
<b>Leaf</b>	Ovate	Ovate to suborbicular	Ovate-orbicular	Ovate-orbicular	Orbicular	Ovate	Ovate to suborbicular	Suborbicular	Ovate	Orbicular
<b>Hemiphylls</b>	Entire, associated with a lobule	Entire, associated with a lobule	Entire, associated with a lobule	Entire, associated with a lobule	Entire, associated with a lobule	Entire, associated with a lobule	Entire, associated with a lobule	Divided, associated with a lobule	Divided, associated with a lobule	Entire, associated with a lobule
<b>Beak of lobule</b>	Short, not decurrent	Short, not decurrent	Short, decurrent along the distal margin	Short, not decurrent	Short, not decurrent	Short, decurrent along the distal margin	Developed, not decurrent	Short, not decurrent	Not developed	Long, not decurrent
<b>Laminar portion of the lobule</b>	Absent or present, when present triangular, 1/3 of the length of the saccate portion of the lobule	Absent	Present, triangular or triangular-rounded, greater than the length of the saccate portion of the lobule	Absent or present, when present triangular, 1/2 of the length of the saccate portion of the lobule	Present, oblong, 1/3 of the length of the saccate portion of the lobule	Present, generally triangular, sometimes triangular-rounded, greater than or equal to the length of the saccate portion of the lobule	Present, oblong, the same length as the saccate portion of the lobule	Present, rounded, 1/2 of the length of the saccate portion of the lobule	Present, narrowly triangular, with a short, sinuose keel	Present, oblong, the same length as the saccate portion of the lobule
<b>Laminar lobules</b>	Rare	Rare	Rare	Rare	Common	Rare	Rare	Common	Rare	Rare
<b>Under-leaves</b>	(1.5-) 2 × stem width, 1/5-1/4 bifid	2-3 × stem width, 1/4-1/6 bifid	2-4 × stem width, 1/6-1/8 bifid	3-4 × stem width, 1/4-1/6 bifid	(1.5-) 2 × stem width, 1/5-1/4 bifid	2-3 × stem width, 1/4-1/6 bifid	2-4 × stem width, 1/6-1/8 bifid	3-4 × stem width, 1/4-1/6 bifid	(1.5-) 2 × stem width, 1/5-1/4 bifid	2-3 × stem width, 1/4-1/6 bifid

vs obovate) and *F. mexicana* also has a highly connate internal bracteole with a lobe on one side and less on the other (Evans 1915). Additionally, *F. pluricarinata* is characterized by less-ramified, wider shoots (1.2-1.4 mm), appressed and

less imbricate dry leaves, wavy moist leaf margins, and partly squarrose innermost gynoecial bract lobes (Atwood 2017).

As noted by Atwood & Mamontov (2018), the synonymy of these taxa remains unresolved. Future phylogenetic studies

may confirm their conspecificity, in which case *F. mexicana* would take precedence as the older name.

## DISCUSSION

*Frullania pluricarinata* was described in 1864 by Gottsche based on material collected in Bogotá, Colombia. The original specimen is probably destroyed (Gradstein 2016), but an isotype in good condition is preserved in S herbarium (Yuzawa 1991). This specimen, which bears both gynoecia and androecia, is designated here as the lectotype. Yuzawa (1991) also illustrated a “type specimen” supposedly deposited in G, but this material could not be located and may represent either a lost specimen or a citation error.

Many bryophyte floristic inventories in Brazil are typically restricted to the understory of forests (Campelo & Pôrto 2007; Siqueira *et al.* 2011; Oliveira & Bastos 2014; Remor *et al.* 2021; Koga *et al.* 2022), whereas studies investigating the vertical zones of trees, including the canopy, are far less common (Chilanti & Bordin 2016; Oliveira & Oliveira 2016; Garcia *et al.* 2020; Souza *et al.* 2020; Reis *et al.* 2023). These limitations likely result from logistical constraints and the increased costs associated with sampling in the upper portions of the canopy (Glime 1988). The occurrence of this species is likely associated with niches in the upper zones of trees, which are often overlooked in conventional surveys. In our study, in fact, we found specimens at approximately 15 meters in height on trees within a semideciduous forest (i.e., a seasonal phytophysiognomy of the Brazilian Atlantic Forest) (Oliveira-Filho & Fontes 2000).

The wide distribution of *Frullania pluricarinata* across South and Central America suggests that its underrepresentation in collections reflects its preference for upper areas of trees, which are rarely sampled. The species appears to prefer periodically dry habitats and is commonly found in the canopy, on occasional rocks, in dry forests, urban parks, and on roadside trees. It is characterized as xerotolerant and occurs at altitudes ranging from 400 to 3 350 meters. (Schäfer-Verwimp *et al.* 2013; Gradstein & Cuvertino 2015; Gradstein 2021; CRIA 2024).

According to data retrieved from the GBIF network, *F. pluricarinata* was first collected in Serra Negra, São Paulo, in 1989 and identified in 2020 by Dr. Alfons Schäfer-Verwimp, with the specimen housed in the Senckenberg Herbarium (GBIF 2024; Senckenberg 2024). However, the species had not been documented in the published literature until now.

In summary, the case of *F. pluricarinata* illustrates how species restricted to less accessible microhabitats, such as the upper strata of trees, can remain underrepresented in floristic surveys despite having a wide geographic distribution. By integrating historical herbarium records with targeted field sampling in underexplored vertical zones, this study documents the first published record of the species for the region and provides key ecological and distributional data to inform its conservation assessment. Considering its apparent association with periodically dry habitats and its occurrence in both natural and anthropogenic environments, understanding its

ecological requirements becomes essential for preserving the forest structures that sustain its populations. This integrative approach reinforces the need for more comprehensive sampling strategies that include canopy habitats, thereby contributing to a more accurate understanding of bryophyte diversity and distribution.

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