
Frullania dasyueshanensis, a new species with terete perianth from Taiwan (Marchantiophyta: Frullaniaceae)

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Abstract: Schäfer-Verwimp, A. & Winter, G. (2020): *Frullania dasyueshanensis*, a new species with terete perianth from Taiwan (Marchantiophyta: Frullaniaceae). *Frahmia* 20:1-14.

Frullania dasyueshanensis sp. nov. is described from Dasyueshan National Forest Recreation area and other localities in Taiwan. The new species was collected in mountain rainforests between 2230 and 2650 meter.

It differs from all known *Frullania* species in Taiwan by its clavate-cylindrical terete perianth and can be clearly distinguished from the similar *Frullania bhutanensis* S.Hatt. in its overall smaller size, the large size of the lobules compared to the lobes and the rounded, not appendiculate dorsal base of leaf lobe; *Frullania sphaerantha* S.Hatt. from India is best distinguished from the new species by smaller lobules compared with the lobes and the widely pyriform perianth with short beak. *Frullania sinosphaerantha* S.Hatt. et P.J.Lin is considered to be synonymous with *Frullania bhutanensis*. A key for Asian *Frullania* species with terete perianths is provided.

KEY WORDS: Dasyueshan National Forest Recreation area, *Frullania* subg. *Trachycolea*, endemism, new synonym

1. Introduction

For its size at only 35,980 km², Taiwan is extraordinarily rich in bryophytes and one of the bryological hotspots in Southeast Asia. Redfearn et al. (1996) mentioned 907, Chiang et al. (2001) 900 taxa of mosses, and 531 taxa of liverworts and hornworts (Wang et al. 2011) are known to occur, with additions published, e.g., by Akiyama & Shevock (2019), Bednarek-Ochyra & Koponen (2019), Bell et al. (2017), He et al. (2009), Higuchi (2011; 2016; 2017), Higuchi & Lin (2005; 2006), Higuchi et al. (2010; 2012), Lin et al. (2010), Schäfer-Verwimp et al. (2019), Yang (2014; 2016; 2019), Yang & Lin (2011; 2012a;b; 2013a;b;c;d; 2014a;b;c; 2016), Yang et al. (2013), Yao & Yang (2015), and Yao et al. (2015).

The genus *Frullania* is represented in Taiwan with 53 taxa (Wang et al. 2011). Subsequently, *Frullania junghuhniana* var. *tenella* (Sande Lac.) Grolle & S.Hatt. has been added by Yang (2016,

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as *F. subtilis* Steph.), *F. formosae* Steph. was replaced by the new name *F. obtusangula* Hentschel & von Konrat, *F. arecae* (Spreng.) Gottsche has been synonymized under *F. obscura* (Sw.) Mont., *F. acutiloba* Mitt. was lowered to a variety of *F. monocera* (Hook. f. & Tayl.) Gottsche, Lindenb. & Nees, and *F. caduca* S.Hatt. has been removed from synonymy of *F. amamiensis* Kamim., thus resulting in an actual total of 54 taxa. The vast majority of the species have been described during the 19th century (e.g., by Gottsche, Lindenberg, Nees, Hook. f. & Taylor, Mitten, Hampe, Sprengel) and early 20th century by Stephani from Asia, a smaller part by S. Hattori in the second half of the last century, the last one being *F. sphaerolobulata* S.H.Lin (Lin & Chen 1997). Five species are endemic to Taiwan.

In 2016 and 2018 the authors visited various places in Taiwan among these Dasyueshan National Forest Recreation Area in 2016 (Schäfer-Verwimp & Winter 2017, Shevock et al. 2017). Dasyueshan NFRA is located in Taichung County, the center of Taiwan. The total area of this National Forest Recreation Area is 3963 hectares. Many patches of virgin forests and giant “divine trees” have been preserved (also called “Sacred trees”).

“Dasyueshan National Forest Recreation Area has abundant natural resources and provides habitat to a wide variety of wild plants and animals. Rising in elevation from 1,800 to 2,996 meters, plant cover ranges from warm temperate, temperate, to frigid forest. In warm temperate forests, broadleaf species like oaks (*Castanopsis-Cyclobalanopsis*) and Lauraceae-Machilus predominate, with the occasional *Pseudotsuga wilsoniana* Hayata and pine mixed in. The temperate forest zone is mixed broadleaf-coniferous forest, with oaks and Lauraceae-Machilus species and other broad leaves, and *Chamaecyparis obtusa* (Sieb. et Zucc.), Formosan red cypress, and *Tsuga formosana* Hayata being the dominant species. Small trees and shrubs like holly, *Viburnum*, *Symplocos* and Yushan cane, *Miscanthus transmorrisonensis* Hayata, ferns and mosses provide cover lower down. In the frigid forest zone, *Abies kawakamii* (Hayata) Ito is king, followed by small numbers of *Tsuga formosana* Hayata and *Juniperus formosana* Hayata. Yushan azaleas and Yushan cane form beautiful alpine grasslands.” [quoted from Dasyueshan National Forest Recreation Area (flyer), Dongshih Forestry District Office, Forestry Bureau, Council of Agriculture, Taichung city]

2. Description of the new species

Frullania dasyueshanensis Schäf.-Verw. & G.Winter bis, sp. nov.

Frullania, subgen. *Trachycolea* (Lima et al. 2020, subgen. *Trachycolea* reinstated)

Diagnosis: The new species is characterized by the following combination of characters: (1) plants of small to medium size, (2) large lobules in comparison to leaf lobes (compared with closely related *Frullania bhutanensis* and *F. sphaerantha*), (3) the rounded, not auriculate dorsal base of lobes, (4) central leaf cells mostly longer than wide, with flexuose, dark red brown walls and strong irregular, whitish, often spherical thickenings (5) obovate-obcuneate, 1/4-1/3 bilobed and nearly flat underleaves, (6) bilobed hemiphyll, (7) dioicous, and (8) clavate-cylindrical eplicate perianths

Etymology: It is named after the location where this species was found 2016 for the first time. Dasyueshan (大雪山) means “Big Snow Mountain” and is a National Forest Recreation area situated in Hopin township of Taichung City [County], the center of Taiwan.

Type: TAIWAN, Taichung County, Hopin Township, Dasyueshan National Forest Recreation Area, 2270 m; 24°15.2' N, 121°00.4' E: surroundings of the Visitor Center, on bark of road side tree, half exposed to sunlight, leg. A. Schäfer-Verwimp DY-106, 8. Oct 2016. Herb. Schäfer-Verwimp Nr. 37395, National Taiwan Museum (TAIM). Holotype: TAIM, isotypes: FR, TAIE, JE, CAS.



Figure 1 – *Frullania dasyueshanensis* © Foto: Kang-Yu Fan, 8 Oct 2016, from holotype

Plants dark green when fresh, dark brown in the herbarium, forming dense mats on bark. Stems 2-3 cm long, 150-220 μm in diameter, slightly dorsiventrally flattened (Figure 2G), in cross section ca 7 cells high and 9-10 cells wide, these firm-walled with often angular lumina, marginal cells in cross section slightly smaller than central ones with lack of clear cortication, $8 \times 10 - 16 \times 28 \mu\text{m}$; deep brown, with leaves ca 1-1.3(-1.8) mm wide, irregularly pinnately to bipinnately branched, branches obliquely spreading, ca 2-4(-5) mm long, often branched again (Figure 2A).

Lobes of stem leaves imbricate, widely spreading, dorsally extending ca 1-1.5x stem width beyond the farther edge of stem, slightly concave to almost flat, shortly oblong-ovate with rounded to widely obtuse apex and \pm semicircular appendage at dorsal base, 0.65 – 0.8(-1.0) mm long and 0.8 – 1.0(-1.3) mm wide.

Marginal lobe cells subquadrate to short rectangular, tangential walls not flexuose and without intermediate thickenings in marginal cell row, 10-12 x 10-14 μm , median cells irregular in outline, mostly longer than wide, with flexuose, dark red brown walls and strong irregular, whitish, often spherical thickenings, 14-18 x 18-26 μm , few basal cells with thickenings only at upper end, the

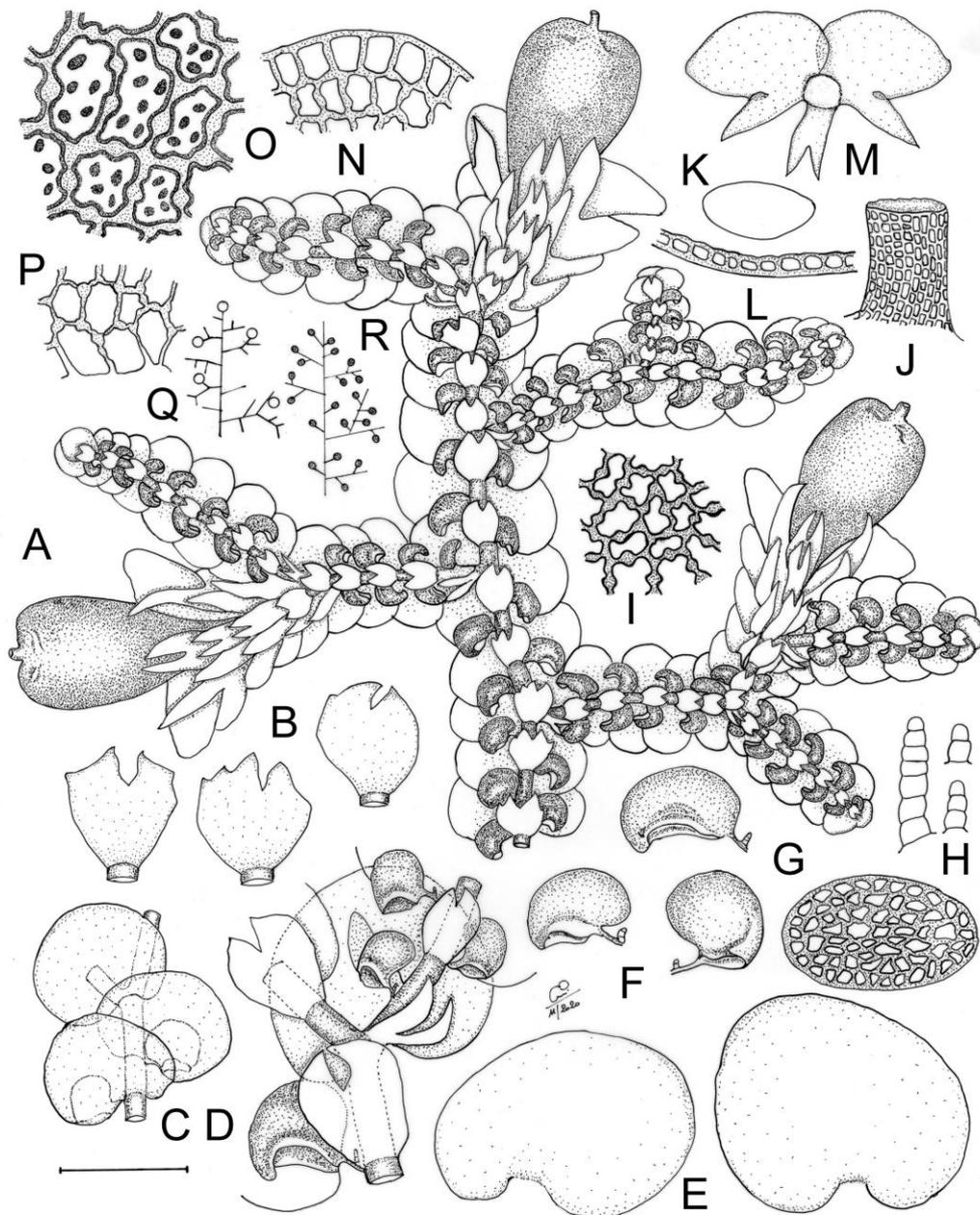


Figure 2 – *Frullania dasyueshanensis*. **A** upper part of female plant, ventral view. **B** three underleaves of main axis. **C** part of plant, dorsal view. **D** part of main axis with base of branch, ventral view. **E** two leaf lobes. **F** three lobules. **G** cross section of stem. **H** three styli. **I** central cells of perianth. **J** perianth beak. **K** cross section of perianth. **L** cells of perianth in cross section. **M** female bracts and bracteole. **N** marginal leaf cells. **O** central leaf cells with oil bodies. **P** basal leaf cells. **Q** cladograph of female plant, circle = perianth (upper part drawn in fig A). **R** cladograph of male plant, eclipse = androecium. Scale for: A, C, K = 1 mm; B, F = 380 μ m; D = 600 μ m; E = 450 μ m; G = 140 μ m; H, I, P = 100 μ m; J = 135 μ m; L = 85 μ m; M = 720 μ m; N = 70 μ m, O = 30 μ m. All figures from holotype DY-106

largest basal cells ca 24 x 45 μm . Oil bodies in central cells (3-)4-6 per cell, mostly ovoid to ellipsoidal or \pm fusiform, finely segmented, ca 2-3.5 x 3-5 μm (Figure 2O), ocelli absent.

Leaf lobules \pm polymorphic, subsymmetric-cucullate to helmet-shaped and \pm asymmetric, inflated from apex to sometimes well developed subtruncate to obtusely rounded beak, \pm as wide as long of often wider than long, up to 400(-450) μm wide and 350 μm long (“high”), but often smaller, especially at branches, beak often acute and incurved (Figure 2A, F; 4).

Stylus minute, filiform, consisting of 3-4, rarely up to 7 uniseriate cells, 45-50(-90) μm long (Figure 2H).

Hemiphyll bilobed, 1st branch-leaf lobe narrowly ovate and lobulus (Figure 2D).

Stem underleaves slightly remote or rarely contiguous, obovate-obcuneate, nearly flat, 350-600 μm long and 300-550 μm wide, 1/4-1/3 bilobed, sinus (sub-)acute to narrowly obtuse, lobes \pm triangular, acute, occasionally with 1-2 lateral acute or obtuse teeth (Figure 2A, B, D; 4); rhizoid-initial area sometimes developed, at middle, rhizoides fasciculate. Branch underleaves similar but mostly smaller.

Dioicous. Androecia (Figure 6) mostly terminal on short lateral branches (rarely intercalary), ca 0.61-0.73 mm wide and 0.55-0.61 mm long, bract lobules with a few spreading teeth, one basal bracteole. Gynoecia terminal on stem or branches, innovating below; bracts ca 3 pairs, grading to subfloral leaves, innermost bract lobe oblong, wide spreading, longer than stem leaves, free margin without any dentation, 0.8-1.1 mm long, 0.58-0.7 mm wide, with obtuse apex, the lobule ca 0/3-0.4-connate, lanceolate, ca 700-900 μm long and 250-320 μm wide, the margins smooth to slightly flexuose; innermost bracteole (Figure 5) long rectangular-lanceolate, 750-850 μm long, 270-280 μm wide, ca 1/3-1/2 bifid, sinus acute to narrowly rounded-obtuse, lobes narrowly triangular, acute (Figure 2M).

Perianth terete, more than half exserted, entirely smooth or sometimes truncate-rugose, usually retuse at tip, clavate-cylindrical, ca 2 mm long, upper part 0.7-1.0 mm wide, beak 120-170 μm long (Figure 2A, J; 3); with one archegonia each perianth.

Male plants slightly smaller than female plants.



Figure 3 – Perianth of *Frullania dasyueshanensis*



Figure 4 – Branch of *Frullania dasyueshanensis* with underleaves and lobuli from holotype

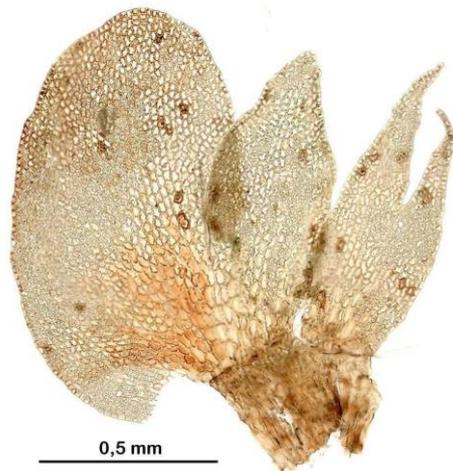


Figure 5 – Innermost bract and bracteole of *Frullania dasyueshanensis* from holotype

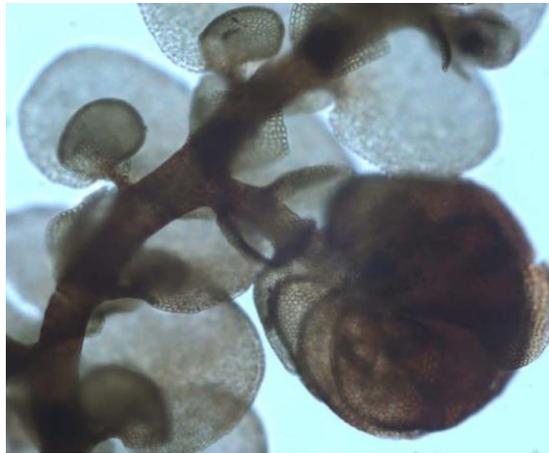


Figure 6 – Androecium of *Frullania dasyueshanensis* from holotype

Additional specimens examined:

TAIWAN, Taichung County, Hopin Township, Dasyueshan National Forest Recreation Area, surroundings of the Visitor Center, alt. 2270 m, 24°15.172'N, 121°0.418'E, 8 Oct 2016, epiphyte on broad-leaved tree, A. Schäfer-Verwimp & G. Winter DY-G17, DY-G24, DG-27, DY-G31 (all FR), epiphyte on *Acer kawakamii*, DY-G6 (FR).

TAIWAN, Taichung County, Hopin Township, Dasyueshan National Forest Recreation Area, near Snow Mountain Guest House, alt. 2220 m, 24°15.243'N, 121°0.4'E, 10 Oct 2016, epiphyte on broad-leaved tree, G. Winter DY-A14 (FR, mixed with *Frullania moniliata* (Reinw., Blume et Nees) Mont. and *Ptychanthus striatus* (Lehm. et Lindenb.) Nees).

TAIWAN, Taichung County, Hopin Township, Dasyueshan National Forest Recreation Area, Road from Siaoyueshan Visitor Venter to Tianehih Lake, alt. 2610-2630 m, 24°16.822'N, 121°1.555'E, 12 Oct 2016, epiphyte on solitary coniferous tree, G. Winter DY-C13 (FR, mixed with *Frullania moniliata* (Reinw., Blume et Nees) Mont. and *Frullania yuennanensis* Steph.).

TAIWAN, Nantou County, Rueilan River Major Wildlife Habitat, off of highway 14 between road markers 17-18 less than 0.5 km on LIXING ROAD at trail head of dirt road-trail, mixed hardwood forest with *Woodwardia* ferns on midslope, alt. 2250 m, 24°6.5'N, 121°11.8'E, epiphyte on hardwood tree, 15 Oct 2016, A. Schäfer-Verwimp 37508/A (TAIE, c. per., JE, c. per. + andr.), 37537 (TAIE, c. per., mixed with *Frullania davurica* Hampe).

TAIWAN, Nantou County, Taroko National Park; Mt. Bilu Trail along rocky steep slope off of highway 8 between km marker 111 and 111.5 next to tunnel, alt. 2600 m, 24°11.1'N, 121°18.6'E, epiphyte on bark of broadleaved tree, 16 Oct 2016, A. Schäfer-Verwimp 37589 (TAIE, JE, both c. per.).

TAIWAN, Chiayi County, Alishan National Forest Recreation Area, along Tashan trail up ridge between km marker 2.5 and 3.0, alt. 2520 m, 23°32' E, 120°49' E, secondary conifer forest of *Cryptomeria japonica* and *Chamaecyparis formosana*, in crown of fallen tree in partly filtered light, 20 Oct 2016, A. Schäfer-Verwimp 37831 (TAIE, JE, both c. per. + andr.); -, near km marker 3.0, alt. 2570 m, 23°32'04"N, 120°48'30"E, secondary conifer forest of *Cryptomeria japonica* and

Chamaecyparis formosana, on bark of hardwood tree rather exposed to sunlight, 20 Oct 2016, A. Schäfer-Verwimp 37857/B (TAIE, JE, both c. per.).

TAIWAN, Nantou County, Yushan National Park, Tataka park housing area, along small road just below highway 18 near km marker 107, alt. 2550 m, 23°28'45.46" N, 129°53'1.75" E, epiphyte on hardwood tree, 23 Oct 2018, G. Winter 23/3-1a (FR), A. Schäfer-Verwimp 39002/A (TAIE, JE, both c. per.).

TAIWAN, Chiayi County, Yushan National Park, along the 8.5 km trail from Paiyun Lodge to Tataka Saddle, alt. 2650 m, 23°28'30.82"N 120°54'12.45"E, epiphyte on *Abies kawakamii*, 26 Oct 2018, G. Winter 26/10 (FR)

DISTRIBUTION and ECOLOGY



Figure 7 – Distribution of *Frullania dasyueshanensis*

Frullania dasyueshanensis seems to be scattered but widely distributed in mountain forests of central Taiwan (Figure 7), usually growing as epiphyte on bark of broadleaved trees and conifers at altitudes between 2230 and 2650 m above sea level. The host trees may be young with a stem only several cm in diameter at rather open situations (at road sides), or it was found on bark of old growth trees under more shady conditions. Once it was found in the crown of a fallen broadleaved tree. It is often mixed with other *Frullania* species, among these *F. moniliata* (Reinw., Blume & Nees) Mont., *F. kagoshimensis* Steph., *F. inouei* S.Hatt., *F. hamatiloba* Steph., *F. davurica* Hampe, *F. muscicola* Steph., *F. sphaerolobulata* S.H.Lin and *F. yuennanensis* Steph. To further associated species belong *Fauriella tenuis* (Mitt.) Card., *Brachymenium nepalense* Hook. in Schwägr., *Claopodium prionophyllum* (Müll. Hal.) Broth., *Pterobryon arbuscula* Mitt., *Pilotrichopsis dentata* (Mitt.) Besch., *Chrysocladium retrorsum* (Mitt.) M.Fleisch., *Sinskea flammea* (Mitt.) W.R.Buck, *Acrolejeunea sandvicensis* (Gottsche) J.Wang bis & Gradst., *Pylaisiadelpha tenuirostris* (Sull.) W.R.Buck, *Macrocoma tenuis* subsp. *sullivantii* (Müll. Hal.) Vitt, *Drepanolejeunea ternatensis* (Gottsche) Schiffn., *Cololejeunea longifolia* (Mitt.) Benedix, *Daltonia marginata* Griff., *Uloa morrisonensis* Horik. & Noguchi, *Cheilolejeunea krakammae* (Lindenb.) R.M.Schust. and *Ptychanthus striatus* (Lehm. et Lindenb.) Nees.

3. COMPARISON with closely related species and SYNONYMY of *Frullania sinosphaerantha* with *F. bhutanensis*

Frullania dasyueshanensis is similar to *Frullania bhutanensis* S.Hatt., Hattori in Hara 1971: 232-234, from Bhutan with terete perianth. We checked the holotype NICH 287339 (Figure 8-11) and isotype L 60920. It differs from *Frullania dasyueshanensis* by the smaller size of the lobuli in relation to the leaf lobes, the large dorsal auricle of the lobe, the larger size of the lobe, the shortly incised apex of the underleaves, the shape of bract and bracteole, the shape of the hemiphyll consisting only of two appendages, one slightly incised, the other lanceolate. The differences are summarized in the following table:

	<i>Frullania bhutanensis</i>	<i>Frullania dasyueshanensis</i>
stem leaf lobes	1.2-1.3 mm long, 0.82-0.83 mm wide	0.65- 0.8(-1.0) mm long and 0.8-1.0(-1.3) mm wide
stem leaf lobules	0.33 mm long, 0.29 mm wide	0.35 mm long (“high”), 0.4(-0.45) mm wide
stem underleaves	0.7-1.0 mm long and wide	0.35-0.6 mm long, 0.3-0.55 mm wide
innermost bract lobes	2.3 mm long, 1.25 mm wide	0.8-1.1 mm long, 0.58-0.7 mm wide
innermost bract lobules	1.4 mm long, 0.65 mm wide	0.7-0.9 mm long, 0.25-0.32 mm wide
innermost bracteoles	1.8 mm long, 1.6 mm wide	0.75-0.85 mm long, 0.27-0.28 mm wide
Perianth		ca. 2 mm long, upper part 0.7 mm wide, beak 0.12-0.17 mm long



Figure 8 – Leaf and lobulus of *Frullania bhutanensis* (left), *Frullania dasyueshanensis* (right)

After careful examination of the holotype of *Frullania bhutanensis* and comparison with the original description of *F. sinosphaerantha* S.Hatt. & P.J.Lin, we came to the conclusion that the latter one is best treated as synonym of *Frullania bhutanensis*. Hattori & Lin (1985) already stated that *F. sinosphaerantha* “seems to be most closely related to *F. bhutanensis*”. As shown in figures 9-11, the differences given by Hattori & Lin (1985) to distinguish *F. bhutanensis* from *F. sinosphaerantha* by (1) “very shortly bifid underleaves”, (2) obtuse to subacute innermost female bract-lobe” and (3) “cell walls with less bulging trigones and intermediate thickenings of leaf lobes” do not justify to keep *F. sinosphaerantha* as a separate species.

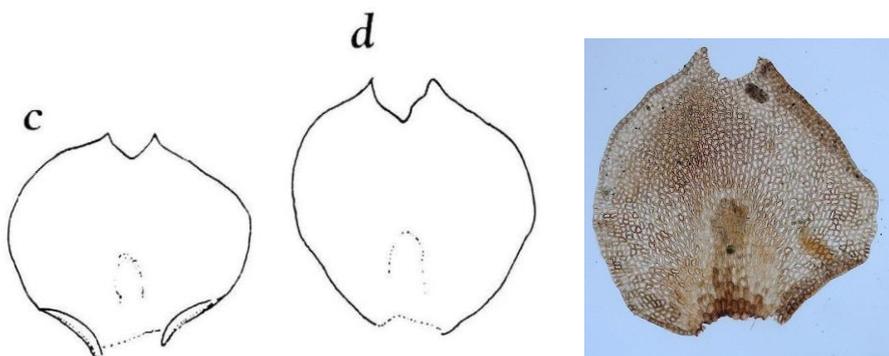


Figure 9 – Underleaves of *Frullania sinosphaerantha* (left, from Hattori & Lin, 1985: 145, fig. 4c,d) and from *Frullania bhutanensis* (right, holotype).

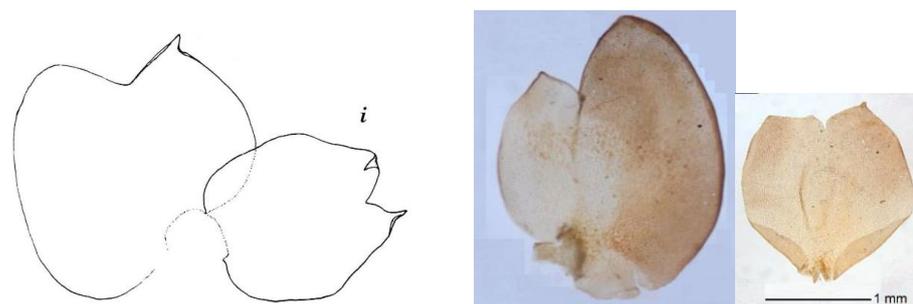


Figure 10 – Bract and bracteole of *Frullania sinosphaerantha* (left, from Hattori & Lin, 1985: 145, fig. 4i) and from *Frullania bhutanensis* (right, holotype).

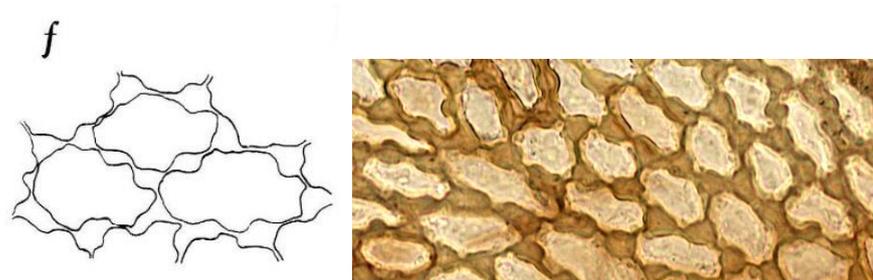


Figure 11 – Cell-walls of *Frullania sinosphaerantha* (left, from Hattori & Lin, 1985: 145, fig. 4f) and from *Frullania bhutanensis* (right, holotype)

Consequently, we consider *Frullania sinosphaerantha* to be conspecific with *Frullania bhutanensis*.

Frullania bhutanensis S.Hatt., Hattori in Hara 1971: 232-234. - *Frullania sinosphaerantha* S.Hatt. et P.J.Lin, Hattori and Lin, *The Journal of the Hattori Botanical Laboratory* 59: 144-146 (1985), **syn. nov.**

Another species with terete perianths from Asia is ***Frullania sphaerantha*** (Hattori 1980) from India (Assam, Meghalaya). As the type specimen was not available for examination we had to use the original description for comparison. *Frullania sphaerantha* has a similar rounded but not auriculate dorsal leaf base and is best distinguished from *F. dasyueshanensis* by its larger plant size, leaf lobes as long as wide, lobules about 1/8-1/10 the size of the leaf lobe, and a widely pyriform perianth with short beak; *F. dasyueshanensis* has leaf lobes wider than long, the lobules about 1/4-1/5 the size of leaf lobe, and the perianth is clavate-cylindrical with a long beak. The distinguishing characters of *Frullania dasyueshanensis*, *F. bhutanensis* and *F. sphaerantha* are summarized in the following key.

Key to the three species with terete perianths mentioned in this paper

- 1 Large rounded subquadrate to ligulate appendage on dorsal base of leaf-lobes
[Bhutan, China (Yunnan)] *Frullania bhutanensis* (syn. *Frullania sinosphaerantha*)
- 1' dorsal base of leaf-lobes rounded, not auriculate 2
- 2 leaf-lobules about 1/8-1/10 the size of leaf-lobe, leaf-lobes ca 0,85 mm long and wide
(as long as wide), perianths ca 1,3-1,5 mm wide, 1.8-2(2.2) mm long, widely pyriform in
outline, with very short beak
[India (Assam, Meghalaya)] *Frullania sphaerantha*
- 2' leaf-lobules about 1/4-1/5 the size of leaf-lobe, leaf-lobes 0.65-1.0 mm long and 0,8-
1.3 mm wide (wider than long), perianths ca 0,7-1.0 mm wide, up to 2 mm long,
somewhat stipitate and longly exerted, clavate-cylindrical in outline, with long beak
[Taiwan] *Frullania dasyueshanensis*

4. Discussion

Frullania dasyueshanensis is the first and single species known from Taiwan with terete perianths. This prominent character alone allows to distinguish it from all other known congeners in Taiwan. Therefore, a comparison was made only with three other Asian species possessing this unique character, *Frullania bhutanensis*, *F. sphaerantha* and *F. sinosphaerantha*. As a first result, we recognized *F. sinosphaerantha* to be synonymous with *F. bhutanensis*. The two remaining species are easily distinguished from *F. dasyueshanensis* by the characters given in the key: in *Frullania bhutanensis*, the dorsal base of the leaf lobe is conspicuously auriculate, being only rounded but not auriculate in *F. dasyueshanensis*. And *Frullania sphaerantha* with a similar dorsal leaf base is best distinguished from the new species by its larger plant size, leaf lobes as long as wide, lobules about 1/8-1/10 the size of the leaf lobe, and a widely pyriform perianth with short beak, in *F. dasyueshanensis* the leaf lobes are wider than long, the lobules about 1/4-1/5 the size of leaf lobe, and the perianth clavate-cylindrical with long beak.

Numerous recently published additions to the bryophyte flora of Taiwan including several new species (see Introduction) raised the number of mosses to about 935 (based on Chiang et al. 2001) and that of liverworts and hornworts to about 570 taxa resulting in a total of 1505 taxa. Though

this extraordinary high number of bryophyte taxa, *Frullania dasyueshanensis* adds to growing evidence that the very rich bryophyte flora of Taiwan is still incompletely known.

5. Acknowledgements

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