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A checklist of *Frullania* (Frullaniaceae, Marchantiophyta) in Sulawesi based on herbarium specimens and literature

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Abstract

A study of the *Frullania* (Frullaniaceae, Marchantiophyta) of Sulawesi based on herbarium specimens stored in Herbarium Bogoriense (BO) and related literature, recognizes 20 species on the island belonging to the subgenus *Chonanthelia* (one species), subgenus *Diastaloba* Spruce (seven species), subgenus *Homotropantha* (four species), subgenus *Saccophora* (one species) and subgenus *Trachycolea* (seven species). *Frullania cordistipula* is new to Sulawesi.

Key words: Frullaniaceae, *Frullania cordistipula,* Indonesia, liverworts, new record

Introduction

Sulawesi, formerly named Celebes, is located between Borneo and New Guinea. This island is the fourth largest island of Indonesia and its flora and fauna are explained by Wallace's line (Ariyanti & Gradstein 2007). This distinctive biogeographical boundary between the areas west and east of Sulawesi is ascribed to the depth of the Makassar Strait between Borneo and Sulawesi. The strait has apparently hindered the dispersal of both animals and plants after the Sunda and Sahul shelves were revealed during the last glacial maximum (Moss & Wilson 1998).

Although the dispersal of many groups of animals and seed plants was affected by the deep ocean channel, its efficacy as a dispersal barrier for wind-dispersed organisms such as bryophytes is less known. Owing to their wind-dispersed spores, bryophyte species may be spread over long distances (Van Zanten & Gradstein 1988) and studies on mosses (Bryophyta) found that floristic divergences between western and eastern Malesia were much less noticeable compared to flowering plants (Tan 1984, 1998; Hyvönen 1989). However, Ariyanti & Gradstein (2007) found support for Wallace's line being a biogeographic border for liverworts (Marchantiophyta) based on the significantly greater number of eastern Malesian liverwort species in Sulawesi than western Malesian species. This result revealed that this major border between Asiatic and Australasian biogeographic regions could also be of importance to the distribution of wind-dispersed organisms, including liverworts. The study of Ariyanti & Gradstein (2007) indicated the importance of the island of Sulawesi for further phytogeographic studies.

Frullania Raddi (1818: 9) (Frullaniaceae, Marchantiophyta) is a large and taxonomically complex genus. More than 2000 taxa were described in this genus and 673 were accepted in a recent census (Söderström *et al.* 2016). However, many of the accepted taxa have not yet been studied critically and Gradstein (2021) suggested that only half of them may be good species. Moreover, the recent studies of *Frullania* argued for narrower species concepts and the possibility of many cryptic taxa (see Bombosch et al. 2010; Carter *et al*. 2017; Mamontov *et al*. 2020). Liverworts, including the genus *Frullania*, remain rather poorly known in Sulawesi (Gradstein *et al.* 2005, Ariyanti & Gradstein 2007, and Ariyanti *et al.* 2009).

In this paper, 20 species of *Frullania* are reported from Sulawesi, including one species, *F. cordistipula* (Reinwardt, Blume et Nees 1825: 220) Nees (1839: 119), new to Sulawesi. Compared to the island of Java, where 45 species of

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Frullania were reported (Söderström *et al.* 2010), the number of *Frullania* species recorded from Sulawesi is relatively low and more similar to that from the Lesser Sunda Islands (16 species; Nadhifah *et al.* 2021).

Methods

This study was based on herbarium specimens stored in Herbarium Bogoriense (BO) and related literature. A total of 24 herbarium specimens collected from Sulawesi were examined. The literature consulted for the distribution of *Frullania* included papers by Verdoorn (1930), Hattori (1975, 1976b, 1980a, 1980b, 1981a, 1981b), Hattori *et al*. (1977), Kamimura (1975), Grolle & Piippo (1984), Gradstein *et al.* (2005), Ariyanti & Gradstein (2007), Ariyanti *et al.* (2009), Söderström *et al.* (2010, 2016), Gradstein (2011, 2021), von Konrat *et al.* (2016), Haerida (2017), Sukkharak (2018), and Lee *et al.* (2022).

The word 'none' on the 'Specimen examined' indicates that there is no specimen available, and therefore the information concerning this species is based on literature. Kamimura (1975), Ariyanti & Gradstein (2007), Sukkharak (2018), and Gradstein (2021) are followed for categories of elevation: lowland (0-1200 m asl) and montane (1200-3000 m asl) in the general distribution for each species.

Species are assigned to subgenera following Hentschel *et al.* (2015), von Konrat *et al.* (2016) and Gradstein (2021), except for subgenus *Trachycolea* which follows Gradstein (2021).

Results

The examination of specimens of *Frullania* deposited in BO and literature resulted in 20 species for Sulawesi. i.e. *Frullania riojaneirensis* (Raddi 1884: 23) Ångstrom (1876: 77-92) of subg. *Chonanthelia* Spruce (1884: 8); seven species of subg. *Diastaloba* Spruce (1884: 55) i.e. *F. apiculata* (Reinwardt, Blume & Nees 1825: 222) Nees (1845: 452), *F. cordistipula* (Reinwardt, Blume & Nees 1825: 220) Nees (1839: 38), *F. hasskarliana* Lindenberg (1845: 453), *F. neosheana* Hattori (1979: 350), *F. serrata* Gottsche (1845: 453), *F. sinuata* Sande Lacoste (1854: 424), and *F. ternatensis* Gottsche (1846: 465); four species of subgenus *Homotropantha* Spruce (1884: 35) i.e. *F. integristipula* (Nees 1831: 86) Nees (1845: 431), *F. intermedia* (Reinwardt, Blume & Nees 1825: 218) Nees (1845: 434), *F. nodulosa* (Reinwardt, Blume & Nees 1824: 217) Nees (1845: 433) and *F. sarawakensis* Hattori (1976: 496); one species of subgenus Saccophora Verdoorn (1928b: 121) i.e. *F. gaudichaudii* (Nees & Montagne 1836: 64) Nees & Montagne (1845: 435); and seven species of subgenus *Trachycolea* Spruce (1884: 31) i.e. *F. ericoides* (Nees 1833: 390 pp.) Montagne (1939: 51), *F. eymae* Hattori (1975: 284), *F. monocera* (Hooker *f.* & Taylor 1845: 89) Gottsche, Lindenberg & Nees (1845: 418), *F. nepalensis* (Sprengel 1827: 324) Lehmann & Lindenberg (1845: 422), *F. orientalis* Sande Lacoste (1855: 94), *F. ornithocephala* (Reinwardt, Blume & Nees 1825: 216) Nees (1845: 425), and *F. reflexistipula* Sande Lacoste (1845: 422). *Frullania* subgenera *Diastaloba* and *Trachycolea* are the most represented subgenera with seven species for each.

Frullania subgenus *Chonanthelia* Spruce, Trans. & Proc. Bot. Soc. Edinburgh 15: 8. 1884

1. ***Frullania riojaneirensis*** (Raddi) Ångstr., in Ångström, Trans. & Proc. Bot. Soc. Edinburgh 15: 23. 1884

Ariyanti & Gradstein (2007) provided this species as *F. galeata* (Reinwardt, Blume & Nees 1825: 215) Dumortier (1835: 13) whereas Hattori & Streimann (1985) treated this species as a synonym of *F. riojaneirensis*

Specimen examined: none.

Distribution in Indonesia: Bali (Hagewald & van Zanten 1986, Haerida 2017), Java (Söderström *et al.* 2010, Gradstein 2011), Kalimantan (Menzel 1988), LSI (Nadhifah *et al.* 2021), Sulawesi (Ariyanti & Gradstein 2007), Sumatra (Verdoorn 1930).

General distribution: Pantropical; lowland and lower montane (Sukkharak 2018).

Frullania* subgenus *Diastaloba Spruce, Trans. & Proc. Bot. Soc. Edinburgh 15: 55. 1884 (*s.l.*)

The name ***Diastaloba* s.l.** is used due to the unresolved taxonomy of this group (cf. Hentschel et al. 2009, Winter & Schäfer-Verwimp 2020).

2. ***F. apiculata*** (Reinw., Blume et Nees) Nees, in Gottsche, Lindenberg & Nees, Syn. Hepat.: 452. 1845. Sp. Hepat. 4: 542. 1911

Specimen examined: none.

Distribution in Indonesia: Java (Kamimura 1975, Söderström *et al.* 2010 & Gradstein 2011), Kalimantan (Menzel 1988), LSI (Nadhifah *et al.* 2021), Moluccas (Akiyama 2009, Verdoorn 1930), Papua (as West Irian) (Grolle & Piippo 1984, Verdoorn 1930), Sulawesi (Ariyanti & Gradstein 2007), Sumatra (Verdoorn 1930).

General distribution: Paleotropical; lowland and montane (Sukkharak 2018, Gradstein 2021).

3. ***F. cordistipula*** (Reinw., Blume et Nees) Nees in Montagne, C. Florula boliviensis. Cryptogames de La Bolivia. In A. C. V. D. Orbigny, Voyage dans l'Amérique Méridionale (Vol. 7, Issue 2, p. 119 pp, pl. 1–3). 1839

Specimens examined: Sulawesi, Kam Rante Mario, Batoebollong, 3300 m, *PJ Eyma 941*; Kam Boven Tinabang, Rante Mario, *PJ Eyma 770* ; Kam Rante Mario, Kombola, *PJ Eyma 909*.

Distribution in Indonesia: Java (Verdoorn 1930, Kamimura 1975, Söderström *et al.* 2010, Gradstein 2011), Sulawesi.

General distribution: Pantropical; lowland (Kamimura 1975).

4. ***F. hasskarliana*** Lindenb. in Gottsche, Lindenberg, & Nees von Esenbeck, In Synopsis Hepaticarum. 1844

Specimen examined: none.

Distribution in Indonesia: Java (Söderström *et al.* 2010, Gradstein (2011), Moluccas (Akiyama 2009), Sulawesi, Sumatra (Verdoorn 1930).

General distribution: Tropical Asia; montane (Ariyanti & Gradstein 2007).

5. ***F. neosheana*** S.Hatt. in Hattori, S. Journal of the Hattori Botanical Laboratory, 45, 323–363. 1979

Specimen examined: Sulawesi, Sorowako, Nuha, Luwu Timur, *FI Windadri 3168*.

Distribution in Indonesia: Borneo (Haerida *et al.* 2003), Sulawesi.

General distribution: Tropical Asia; lowland (Ariyanti & Gradstein 2007).

6. ***F. serrata*** Gottsche in Gottsche, Lindenberg & Nees von Esenbeck, In Syn. Hep. 1844

Specimens examined: Sulawesi, Minahasa, Poso Bivak, *FKM Steup s.n.*; Masimbollong, *PJ Eyma 973*; Tinabang, W. Zyole vd. Rante Marion 3000 m, Enrekang *PJ Eyma 797* .

Distribution in Indonesia: Java (Kamimura 1975, Söderström *et al.* 2010), Papua (as West Irian) (Grolle & Piippo 1984), Sulawesi, Sumatra (Kamimura 1975, Singh *et al.* 2008),

General distribution: Pantropical; lowland and montane (Ariyanti & Gradstein 2007).

7. ***F. sinuata*** Sande Lac. in Sande Lac. Ned. Kruidk. Arch. 3: 424, 1855

Specimen examined: none.

Distribution in Indonesia: Java (Söderström *et al.* (2010), Papua (as West Irian) (Grolle & Piippo 1984), Sulawesi (Ariyanti & Gradstein (2007), Sumatra (Verdoorn 1930).

General distribution: Asia; montane (Ariyanti & Gradstein 2007).

8. ***F. ternatensis*** **Gottsche in Gottsche, Lindenberg & Nees von Esenbeck** in Gottsche, Lindenberg, & Nees von Esenbeck. Syn. Hep. 1844

Specimens examined: Sulawesi, Todjamboe 1000 m. alt., *G. Kjellberg 1811 a*; Minahasa, Poso, 1800 m, Kamp. Poena *FKM Steup s.n.*; Gn. Lumut, *PJ Eyma 3656*; Tinabang, W. Zyole vd. Rante Marion 3000 m, *PJ Eyma 802*; Tadjamboe, ad arborum 800 m, *G. Kjellberg 32* .

Distribution in Indonesia: Bali (Haerida 2017), Java (Kamimura 1975, Söderström *et al.* 2010 & Gradstein 2011), Moluccas (Kamimura 1975), Papua (as West Irian) (Grolle & Piippo 1984), Sulawesi, Sumatra (Kamimura 1975).

General distribution: Asia; lowland and montane (Ariyanti & Gradstein 2002).

Frullania **subgenus** ***Homotropantha*** **Spruce**, Hep. Annz. et Andin.: 35. 1885

9. ***F. integristipula*** **(Nees) Nees** in Gottsche, Lindenberg & Nees von Esenbeck. In Syn. Hep. 1844

Specimen examined: none.

Distribution in Indonesia: Java (Kamimura 1975, Söderström *et al.* 2010 & Gradstein 2011), Sulawesi (Ariyanti & Gradstein 2007), Sumatra (Kamimura 1975).

General distribution: Tropical Asia; lowland and montane (Ariyanti & Gradstein 2007).

10. ***F. intermedia*** **(Reinw., Blume et Nees) Nees** in Gottsche, Lindenberg & Nees von Esenbeck. In Syn. Hep. 3: 434. 1844

Specimen examined: none

Distribution in Indonesia: Java (Söderström *et al.* 2010 & Gradstein 2011), Papua (as West Irian) (Grolle & Piippo 1984), Sulawesi (Ariyanti & Gradstein (2007).

General distribution: Pantropical; lowland (Hattori *et al.* 1977).

11. ***F. nodulosa*** **(Reinw., Blume et Nees) Nees** in Gottsche, Lindenb. & Nees, Syn. Hepat. 3: 433. 1845

Specimen examined: Sulawesi, CA. Kakanauwe, Buton, SM. Lambusango BSH-15, *FI Windadri s.n.*; P. Wawoni, *Purwaningsih s.n.* ; Sulut, Minahasa, Likupang, on coconut trunk, *Wulijarni 378* .

Distribution in Indonesia: Borneo (Verdoon 1930), Java (Söderström *et al.* 2010 & Gradstein 2011), Moluccas (Verdoorn 1930, Akiyama 2009), Papua (as West Irian) (Grolle & Pippo 1984), Lesser Sunda Island (Sumba), Sulawesi, Sumatra (Verdoorn 1930).

General distribution: Pantropical; lowland (Gradstein 2021).

12. ***F. sarawakensis*** **S. Hatt.** in Hattori, S. Journ. Hatt. Bot. Lab. 40, 461–507. 1976a

Specimen examined: none.

Distribution in Indonesia: Sulawesi

General distribution: Western Malesia; lowland (Ariyanti & Gradstein 2007).

Frullania **subgenus** ***Saccophora*** **Verdoorn**, Ann. Bryol. 2: 121, 1928a

13. ***F. gaudichaudii*** **(Nees et Mont.) Nees et Mont.** in Gottsche, Lindenb. & Nees, Syn. Hepat. 3: 435, 1845

Specimen examined: none.

Distribution in Indonesia: Bali (Haerida 2017), Java (Söderström *et al.* 2010 & Gradstein 2011), Moluccas (Akiyama 2009), Papua (as West Irian) (Grolle & Piippo 1984), Sulawesi (Ariyanti & Gradstein 2007).

General distribution: Pantropical; lowland and montane (Ariyanti & Gradstein 2007).

***Frullania* subgenus *Trachycolea* Spruce,** Trans.& Proc. Bot. Soc. Edinburgh. 15: 31. 1884.

In the *World Checklist of Hornworts and Liverworts* (Söderström *et al.* 2016) this subgenus was called "subgenus *Frullania*". For the use of the correct name "subgenus *Trachycolea*" see Gradstein (2021, p. 351).

14. ***F. ericoides* (Nees) Mont**. in Ann. Sci. Nat., Bot., Ser. 2,12: 51. 1839

Specimen examined: none.

Distribution in Indonesia: Bali (Haerida 2017), Java (Söderström *et al.* 2010 & Gradstein 2011); Moluccas (Akiyama 2009), Sulawesi (Ariyanti & Gradstein 2007).

General distribution: Pantropical; lowland (Ariyanti & Gradstein 2007, Gradstein 2021).

15. ***F. eymae* S. Hatt.** in Hattori, S. Journ. Hatt Bot. Lab. 39, 277–313. 1975

Specimen examined: none.

Distribution in Indonesia: Sulawesi (Ariyanti *et al.* 2009), Papua (as West Irian) (Grolle & Piippo 1984, Hattori & Streimann 1985).

General distribution: Tropical Asia ; montane (Hattori & Streimann 1985).

16. ***F. monocera*** (Hook.*f.* et Taylor) Gottsche, Lindenb. et Nees, in Gottsche, Lindenberg & Nees von Esenbeck. In Syn. Hep. 1844

Specimen examined: none.

Distribution in Indonesia: Sulawesi (Ariyanti *et al.* 2009);

General distribution: Widely distributed in tropical and subtropical regions of Asia, occurring disjunctively northward to Japan, Australia and New Zealand (Hattori *et al.* 1977).

17. ***F. nepalensis* (Spreng.) Lehm et Lindenb.** in Gottsche, Lindenberg & Nees von Esenbeck. In Syn. Hep. 1844

Synonym: *Frullania sanguinea* Steph.

Specimen examined: Sulawesi, Palopo, *C. Schoorel s.n.*

Distribution in Indonesia: Java (Söderström *et al.* 2010 & Gradstein 2011), Papua (as West Irian) (Grolle & Piippo 1984), Sulawesi, Sumatra (Singh *et al.* 2008).

General distribution: Asia; montane (Ariyanti & Gradstein 2007).

18. ***F. orientalis*** Sande Lac. in Dozy, Accedunt Novae Hepaticarum Javanicarum Species. Jac. Hazenberg Corn. 1856

Specimens examined: Sulawesi, Pendakian Padaeha, Desa Sedoa, *Dewi 16* ; Res. Manado, Poso, Malino, growngroen, *PJ Eyma 3485* ; Z. Celebes, Kp Porema 1200 m, *G. Kjellberg 2683*; Kp Poerema *G Kjellberg 2681, 2645, 2643, 2633*.

Distribution in Indonesia: Java (Söderström *et al.* 2010 & Gradstein 2011), Moluccas (Akiyama 2009), Papua (as West Irian) (Grolle & Piippo 1984), Sulawesi.

General distribution: Tropical Asia; montane (Ariyanti & Gradstein 2007).

19. ***F. ornithocephala*** (Reinw., Blume et Nees) Nees, in Gottsche, Lindenberg, & Nees von Esenbeck, Syn. Hep. 1844

Specimen examined: Sulawesi, Boeloe Palaka 3695 m alt., *EC Abendanon s.n.*

Distribution in Indonesia: Java (Söderström *et al.* 2010 & Gradstein 2011), Bali (Haerida 2017), Sulawesi.

General distribution: Tropical Asia; montane (Ariyanti & Gradstein 2007).

20. ***F. reflexistipula* Sande Lac.** in Sande Lac., Ned. Kruidk. Arch. 3(4): 422. 1855

Specimen examined: none

Distribution in Indonesia: Moluccas (Akiyama 2009), Papua (Grolle & Piippo 1984), Sulawesi (Ariyanti & Gradstein 2007).

General distribution: Pantropical; lowland and montane (Ariyanti *et al.* 2009, Bardat *et al.* 2023).

General discussion

The newly recorded species *Frullania cordistipula* (Fig. 1) was collected by P. J. Eyma from Rante Mario, Latimojong mountains in 1937, and has not been found elsewhere in Sulawesi since then. This is likely because exploration efforts in Sulawesi have been limited. In general, based on the literature (i.e., Gradstein *et al.* 2005, Ariyanti & Gradstein 2007, and Ariyanti *et al.* 2009) and specimens stored in the BO herbarium, the species diversity of *Frullania* from Sulawesi is relatively low when compared to Java (see Introduction) and is probably significantly higher in reality. Hence, the data presented here suggest that additional collections and studies of the bryophyte diversity in Sulawesi are needed.

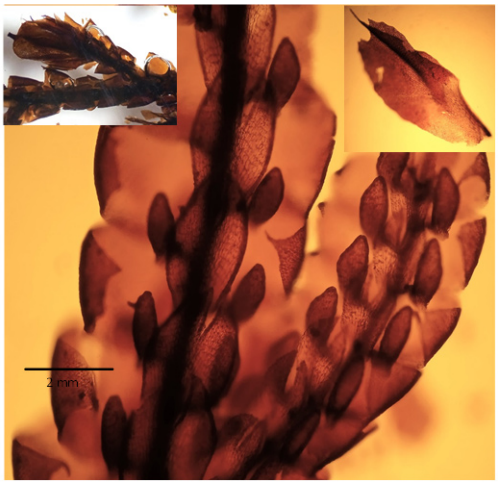

FIGURE 1. Shoot of *Frullania cordistipula.* Top left: shoot with perianth (30x); top right: female bract (100x). Specimen: *P.J. Eyma 770.* Photo: Ida Haerida.

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