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## **Marchantiophyta Family *Radulaceae* in Batang Toru Forest, North Sumatra Indonesia**

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### **ABSTRACT**

#### **KEYWORDS:**

*Batang Toru West Block, Indonesia, Marchantiophyta, Radulaceae, North Sumatra*

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The diversity of liverworts in North Sumatra is currently limited, highlighting the need for further investigations. Therefore, this study aims to collect and determine data on the liverworts of the *Radulaceae* family in the Batang Toru forest of North Sumatra. This forest was selected because it has very high rainfall with suitable humidity for the growth of liverworts. The samples were collected using an exploratory survey method, namely by collecting all the liverworts of the *Radulaceae* family along the Batang Toru forest hiking trails. The results showed 17 species of which three are new records for Sumatran liverworts namely *Radula iwatsukii*, *Radula kinabaluensis* and *Radula obscura*. The *Radulaceae* family was found as epiphytes on tree trunks and leaves. Based on the number of specimen collections, the most commonly found species was *Radula javanica*. In addition, *Radulaceae* in the Batang Toru forest was spread at altitudes between 800 and 1100 m.a.s.l and can be included in the Lower Montane Forest category.

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## **1. INTRODUCTION**

Liverworts are a diverse group of plants that can be found in a wide range of habits including lowland and upper montane forests (Gradstein, 2021) with an estimated 5000 species (Heinrichs *et al.* 2005). They live in moist, shaded environmental conditions, and can grow submerged in water or terrestrial habit (Kuglerová *et al.* 2016). One type of liverwort that lives in the environmental conditions described above is the *Radulaceae* family (Zartman *et al.* 2015).

The *Radulaceae* family is spread almost all over the world in areas with humid, tropical, or warm climates (Gradstein *et al.* 2001). They grow as epiphytes on tree trunks, branches, or on leaves (Promma & Chantanaorrapint 2015). Members of this family are characterized by rhizoids that arise from their lobules and lack ventral leaves (Yamada 1979).

Information about the distribution of *Radulaceae* in Indonesia is still limited although previous studies have been conducted in several regions, specifically in North Sumatra, and the results have not been published. Collection and information about leafy liverworts of the *Radulaceae* family in the Batang Toru Forest Block West Block, have also been reported to date. Therefore, this study aims to examine the *Radulaceae* species in the Batang Toru Forest Area West Block North Sumatra, for an inventory of the species.

## **2. MATERIALS AND METHODS**

This study was conducted in the Batang Toru Forest Block, North Sumatra, Indonesia, which has an area of 133,841 hectares. This forest is divided into two regional blocks separated by the fracture of the Sumatran fault. The western block has an area of 78,891 hectares, while the eastern block has an area of 54,950 hectares. Furthermore, the location of Camp Mayang in the West

Block is a 12,000-hectare Flora and Fauna monitoring station located between 49°93'31" East Longitude and 18°63'20" South Latitude. The tropical climate has high rainfall ranging from 4,500 to 5,000 mm per year, while temperatures at night can drop to 14°C. The highest temperature during the day is 31°C, and humidity ranges from 33% - 95% (YEL & WALHI 2013)

The samples were collected using an exploratory survey method by exploring the study area as has been done by Hussain *et al.* (2019). All samples obtained were photographed and collected using a sharp knife or pry tool from various substrates such as soil, tree trunks, rocks, weathered wood, and leaves. The specimens were collected dry and wet by my self. The dry collection was carried out by placing the specimens obtained from the field into paper envelopes. Meanwhile, the wet collection was performed by inserting the specimens into a plastic clip filled with wet wipes and labeled with a collection number (POCS 2020). The study location is shown in (Figure 1) below.

The collected specimens were identified using identification keys and species descriptions from various available literature specifically (Gradstein, 2011);(Renner *et al.*, 2013);(Bakalin & Klimova 2020) and (Oliveira-Da-Silva *et al.* 2020) and other publications on Malesiana and Asian liverworts such as (So 2006); (Yamada 1979);(Yamada & Piippo 1989); (Majumdar *et al.* 2016); (Renner 2014a); (Söderström *et al.* 2016); (Promma & Chantanaorrapint 2015); and (Hedwigia & Oliveira 2020). Some of the important morphological characteristics include plant width, lateral leaf shape, base, sac, margin, apex, and trigon cell, as well as underleaves, and perianth. Identification was carried out at the Laboratory of Plant Taxonomy, Department of Biology, Universitas Sumatera Utara.

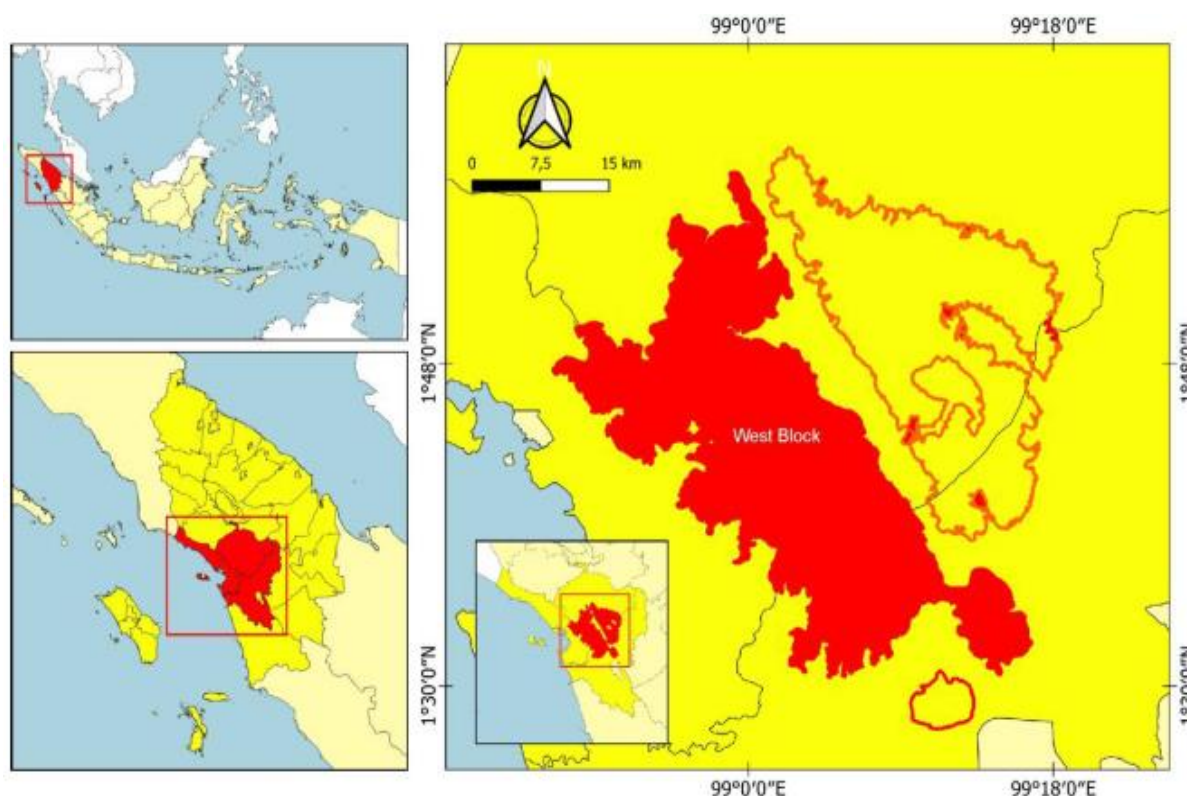


Figure1. Map of Study location in Batang Toru Forest (Damanik *et al.*, 2022)

### 3. RESULTS AND DISCUSSION

The results showed onegenus consisting of 17 species, including three new record types for Sumatra, namely *Radula iwatsukii*, *Radula kinabaluensis*, and *Radula obscura*. Based on the distribution of altitude, the *Radulaceae* family in the West Block Batang Toru Forest area is in the lower montane forest category between 800-1300m as illustrated Figure 2.

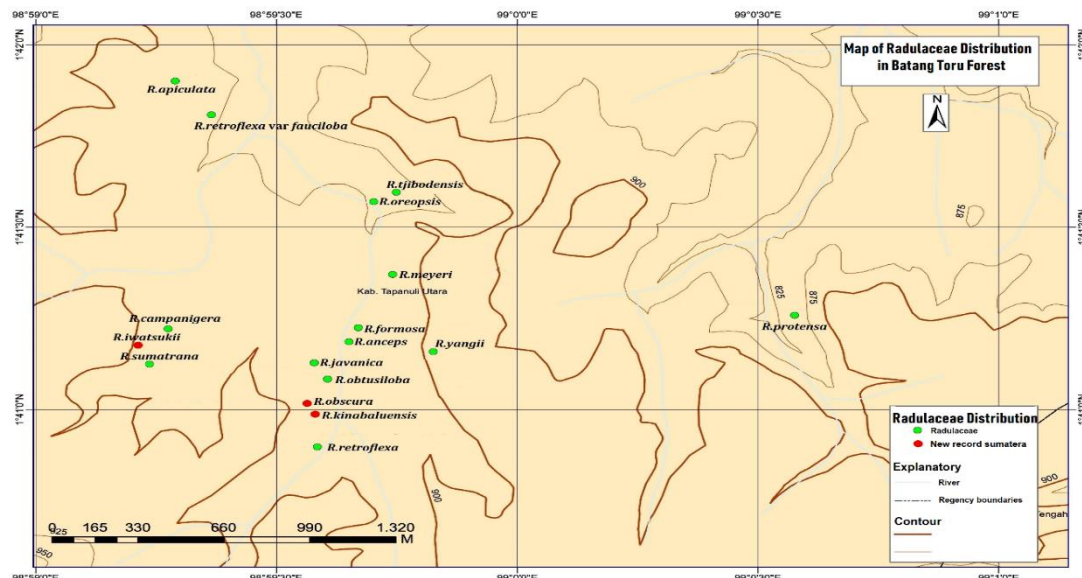


Figure 2. Distribution of *Radulaceae* families based on altitude in Batang Toru Forest

Key Identification of the *Radulaceae* family in the Batang Toru Forest area

1. a. Branching with amentulose in each leaf axil.....2  
 b. Branching without amentulose in each leaf axil.....4
2. a. Amentulose is equivalent in length to the lobules.....4. *R. formosa*  
 b. Amentulose is longer than the lobules.....3
3. a. Leaves attachment is flat.....5. *R. iwatsukii*\*  
 b. Leaves attachment is flat to curved.....17. *R. yangii*
4. a. The base of the dorsal leaf is flat.....12. *R. protensa*  
 b. The base of the dorsal leaf is curved.....5
5. a. Lobules with obtuse apex, trigon clearly defined.....6. *R. javanica*  
 b. Lobules with subacute apex, trigone not clearly defined.....6
6. a. Trunk branches irregular.....12  
 b. Trunk branches regular.....7
7. a. The bases of the lobules are flat.....1. *R. anceps*  
 b. The bases of the lobules are curved.....8
8. a. Lobules ovoid in shape, flat margins.....3. *R. campanigera*  
 b. Lobules are rhombus-shaped, edges curved.....9
9. a. The lobe ends are tapered.....2. *R. apiculata*  
 b. The lobe ends are flat.....10
10. a. Lobule length 1/2 of the lobe, rectangular .....8. *R. meyeri*  
 b. Lobule length 1/3 of the lobe, round in shape.....11
11. a. Lobules attachments tapered, blunt ends.....13. *R. retroflexa*  
 b. Lobules attachments curved, rounded ends.....13
12. a. Lobules are rectangular.....11. *R. oreopsis*  
 b. Lobules are round resembling a crescent moon.....14. *R. retroflexa var fauciloba*
13. a. Cell shape is square to round, the cell wall is thin..... *R. kinabaluensis*\*  
 b. Cell shape is round, the cell wall is thick.....14
14. a. Cell surface is smooth, trigons are tight.....10. *R. obtusiloba*  
 b. Cell surface is rough, trigons are sparse.....15
15. a. Cell wall is thick, trigon not clear.....9. *R. obscura*\*  
 b. Cell wall is thin, trigon clear.....16
16. a. The edges of the leaves have gemma, smooth cell surface.....16. *R. tjibodensis*  
 b. The edge of the leaf has no gemma, the cell surface is rough.....15. *R. Sumaterana*

\* *New record for Sumatera*

## Description of the Radulaceae family in the Batang Toru Forest area

**3.1. *Radula anceps* Sande. Lac (Figure 3)**

Nederl. Kuidk. Arch. 3 :419 (1854)- *Radula acuta* Mitt. In Seeman, Fl. Vitiensis: 410 (1871)

The specimens were brownish-yellow in color with a width of 1.3-3 mm and radula-type branching. The leaves are closely arranged together, oval in shape, 0.68-0.9 mm long, and 0.41-0.5 mm wide. They also have a flat attachment, dorsal base, ventral base, and scalloped edges. The teeth range from short to long and pointed, measuring 2-5 cells long with a tapered tip. The cells are elongated and round with thin walls, smooth surface, as well as tight trigons. The lobules are rectangular in shape, and measure 1/3 of the lobes' length. They also have a flat base, attachments, edges, as well as pointed to a blunt tip.

**Specimen examined:** Sumatra: North Sumatra: Batang Toru forest, epixylous, June 13<sup>th</sup>, 2019 alt. 895 m asl. RD 314

**Distribution:** Indonesia (Sumatra, Java), Borneo, Philippines, Japan, Papua New Guinea, New Caledonia, Caroline (Yamada 1979).

**Habitat and Ecology:** Epiphyllous at an altitude of 895 m asl, humidity at 82% and temperature at 24,1°C.

**3.2. *Radula apiculata* Sande. Lac (Figure 4)**

Hedwigia 23: 150 (1884) - *Radula paucidens* Steph. Ex Castle, Rev. Bryol. Lichenol. 30:39 (1961)

The specimens have a brownish-yellow color with a width of 1-1.7 mm. The branches are not of radula type, while the leaves are closely arranged together, oval in shape, 0.5-0.68 mm long and 0.41-0.5 mm wide. They have a curved attachment, a tapered tip with a flat dorsal base. Both the dorsal and ventral edges are flattened and dentate, while the tip has one tooth rounded and pointed, 5 cells long. The cells are round to elongated with thin walls, and a smooth surface. Moreover, the trigon is quite tight, the lobule is quadrangular measuring one-fourth of the length of the lobe, with a curve base, flat attachment, obtuse dorsal edge, ventral edge covering the shaft, and a blunt tip.

**Specimen examined:** North Sumatra (Batang Toru forest) epiphyllous, June 25<sup>th</sup>, 2019 alt. 905 m asl. RD 2296.

**Distribution:** Indonesia (Sumatra), Thailand, Philippines, Borneo, Taiwan, Papua New Guinea, Samoa, Tahiti, Caroline (Yamada 1979).

**Habitat and Ecology:** Epiphytes on the leaves and stems are found at an altitude of 893 m asl, humidity at 85%, and a temperature of 26.1°C.

**3.3. *Radula campanigera* mont. (Figure 5)**

Piippo, S. 1990. Annotated catalogue of Chinese Hepaticae and Anthocerotae. J. Hattori Bot. Lab. 68: 1-192.

Lee, G. E., S. R. Gradstein, E. Pesiu & N. Norhazrina Binti Nik Mohamed Kamil. 2022. An updated checklist of liverworts and hornworts of Malaysia. PhytoKeys 199: 29-111.

The specimens are characterized by a yellowish-green color and a width of 1.5-2 mm. Their branching pattern is irregular, while the leaves arrangement are close together with oval-shaped leaves measuring 0.75-0.98 mm long and 0.61-0.75 mm wide. They also have a flat attachment, dorsal base, curved ventral base, as well as a flat edge and rounded ends. The cells are rounded in shape with a thick cell wall, smooth cell surface, and a clear trigon with a bulging shape. Additionally, the lobules are ovate, measuring 1/3 of the lobes' length, with a flat base, attachment, edge, and rounded tip.

**Specimens examined:** North Sumatra (Batang Toru forest) epiphyllous, June 17<sup>th</sup> until 24<sup>th</sup>, 2019 alt. 752-1006 m asl, RD 277, 289, 296, 874, 1207, 1219, 1367, 1987, 2003, 2118, 2164

**Distribution:** Malay Peninsula, Indonesia (Sumatra, Java, Kalimantan, Sulawesi), Taiwan, Thailand (Renner 2005); (Lukitasari 2018)

**Habitat and Ecology:** Epiphytes on tree trunks at an altitude of 752-1006 m asl, humidity at 72-85%, and temperature at 25.1-29.2°C.

### 3.4. *Radula formosa* Meissn. (Figure 6)

In Gott. *et al.*, Synop. Hepat: 258 (1845).- *Jungermania formosa* Meissn. Sprengel in Linnaeus Syst. Veg. 4(2): 325 (1827).-*Radula pycnolejeunoides* Schifn., Nova Acta Acad Caes. Leop. Carol 60 (2): 247 (1893).-*Radula novae guineae* Steph., Spec, Hepat 4: 233 (1910).

The specimens have a brownish-yellow color, and a 1.2-4 mm width. They exhibit regular branching with small shoots in each leaf axil, and the length of small shoots is equivalent to that of the lobules. The leaf arrangement is close together, and the leaves are oval-shaped, measuring 0.53-0.9 mm long and 0.4-0.6 mm wide. Furthermore, they have rounded attachments, a flat tip with a curved dorsal base and flat ventral base, a flat edge, and rounded leaf tips. The cells are rounded in shape, have thin to thick walls, a smooth surface, as well as a dense trigon that is triangular in shape. The lobules are oblong, measuring 1/2 the length of the leaf, with a flat base, attachment, edge, and tip.

**Specimens examined:** North Sumatra (Batang Toru forest) epiphyllous, June 17<sup>th</sup> until 24<sup>th</sup>, 2019 alt. 863-931 m asl, RD 186, 1225, 1664, 1674, 1746, 1775, 1882, 1990, 2015, 2134, 2169, 2184.

**Distribution:** Indonesia (Sumatra, Java), Borneo, Thailand, Malaya, Ceylon, Papua New Guinea, New Caledonia, Fiji, Tahiti, Japan, Philippines (Yamada 1979)

**Habitat and Ecology:** Epiphytes on weathered wood and leaves at an altitude of 863-931 m asl, humidity at 87-90% and temperature at 24.1-25.9°C.

### 3.5. *Radula iwatsukii* Yamada (Figure 7)

Yamada, kohsaku, and Sinikka Piippo. "Bryophyte Flora of the Huon Peninsula, Papua New Guinea. XXXII. Radula (*Radulaceae*, *Hepaticae*)." *Annales Botanici Fennici*, vol. 26, no. 4, 1989, pp. 349-87. *JSTOR*.

The specimens are brownish-yellow in color and have a width of 1.2-2 mm. They exhibit an amentulose branching pattern with small shoots in each leaf axil, and the length of small shoots is larger than that of leaf size. The leaf arrangement can be sparse or close together, and the leaves are ovoid in shape, measuring 1-1.6 mm long and 0.4-0.8 mm wide. They have rounded adherents, a curved dorsal base, a rounded ventral base, a flat edge and rounded tips. Furthermore, the cells are rounded in shape with thin to thick walls, a smooth surface, as well as a clear and bulging trigon. The lobules are oblong, measuring 1/2 length of the leaf with flat and bubbly, flat attachment, edge flat, and tip flat.

**Specimen examined:** North Sumatra (Batang Toru forest) epiphyllous, June 16<sup>th</sup>, 2019 alt. 891 m asl, RD 793

**Distribution:** Indonesia (New record for Sumatra), Borneo, Solomon Islands (Yamada 1979)

**Habitat and Ecology:** Epiphytes on leaves at an altitude of 908 m asl, humidity at 81%, and temperature at 20.5°C.

### 3.6. *Radula Javanica* Gott. (Figure 8)

In Gott. *et al.*, Synop. Hepat: 257.1845. Yamada. J. Hatt. Bot. Lab. 45: 235. 1979. Yamada & Piippo. Ann. Bot. Fennici 26: 360. 1989.

The specimens range from green to yellowish in color with a width of 1.3-2.5 mm, and an irregular branching pattern. The leaf arrangement is close together with ovate-shaped leaves,

measuring 1.2-1.3 mm long and 0.8-0.9 mm wide. They also have curved attachments with a dorsal and ventral base, flat edge, and rounded ends. The cells are rectangular to elongated in shape, with thin cell walls, a smooth surface, and a fairly clear trigon. Additionally, the lobules are rhombus-shaped, and measure 1/3 - 1/2 the leaf length, with curved base, attachments, edges, and an almost pointed tip.

**Specimens examined:** North Sumatra (Batang Toru forest) epiphyllous, June 17<sup>th</sup> until 25<sup>th</sup>, 2019 alt. 857-931 m asl, RD 737, 1041, 1043, 1055, 1095, 1099, 1158, 1206, 1270, 1558, 1607, 1720, 1751, 1791, 1805, 1904, 1998, 2040, 2091, 2291.

**Distribution:** South America, Central America, Sri Lanka, India, Japan, Philippines, Malay Peninsula, Indonesia (Sumatra, Java, Kalimantan, Papua), Papua New Guinea, Thailand (Yamada 1979)

**Habitat and Ecology:** Epiphytes on tree trunks, weathered wood and leaves at an altitude of 861-931 m asl, humidity at 78-86% and temperature at 25.8-30.1°C.

### 3.7. *Radula kinabaluensis* Yamada. (Figure 9)

Misc. Bryol. Lichenol 6:97 (1973)

The specimens range from green to yellowish in color with a width of 1.5–2.3 mm and an irregular branching pattern. The leaf arrangement overlaps, with elongated round-shaped leaves measuring 0.8-0.95 mm long and 0.4-0.5 mm wide. Furthermore, they have a curved attachment, flat tip, curved dorsal base, ventral base, flat edge, and rounded tip. The cell shape is square to round with a thin cell wall, smooth surface, and a clearly bulging trigon. The lobules are small, rectangular in shape, 2/3 of leaf length, with a curved base, attachment, edge, and an almost blunt tip.

**Specimens examined:** North Sumatra (Batang Toru forest) epiphyllous, June 19<sup>th</sup> until 23<sup>th</sup>, 2019 alt. 802-891 m asl, RD 1588, 1600, 1638, 1878

**Distribution:** Indonesia (New record for Sumatra), Borneo (Yamada 1979); (Söderström *et al.*, 2016).

**Habitat and Ecology:** Epiphytes on tree trunks, weathered wood and leaves at an altitude of 802-891 m asl, humidity at 78-90% and temperature at 27.1-29.5°C.

### 3.8. *Radula meyeri* Steph. (Figure 10)

Hedwigia 27: 62. 1888. Yamada. J. Hatt. Bot. Lab. 45: 242. 1979.

The specimens are yellowish-green in color with a width of 1.2-1.5 mm and an irregular branching pattern. The leaves overlap and have an ovoid shape, measuring 0.5-0.7 mm long and 0.4-0.6 mm wide. Furthermore, they also have curved attachments, with a dorsal base, ventral base, flat edge, and rounded ends. The cell shape ranges from round to hexagon with a thick wall, smooth surface, and clear triangular trigon. The lobules are rectangular, and measure 1/2 the lobes' length, with a flat base, curved attachments, flat edges, and an almost pointed tip.

**Specimens examined:** North Sumatra (Batang Toru forest) epiphyllous, June 19<sup>th</sup> until 23<sup>th</sup>, 2019 alt. 802-891 m asl, RD 655, 1267, 1268, 1572, 1575, 1729, 1801, 1820, 1888, 1918, 1995, 2186, 2247.

**Distribution:** Africa, Indonesia (Sumatra), Thailand (Yamada 1979; Lai *et al.* 2008).

**Habitat and Ecology:** Epiphytes on tree trunks, weathered wood and leaves at an altitude of 857-931 m asl, humidity at 78-91% and temperature at 20.1-26.9°C.

### 3.9. *Radula obscura* Mitt. (Figure 11)

Jour. Proc. Linn. Soc. London 5 : 107 (1861)

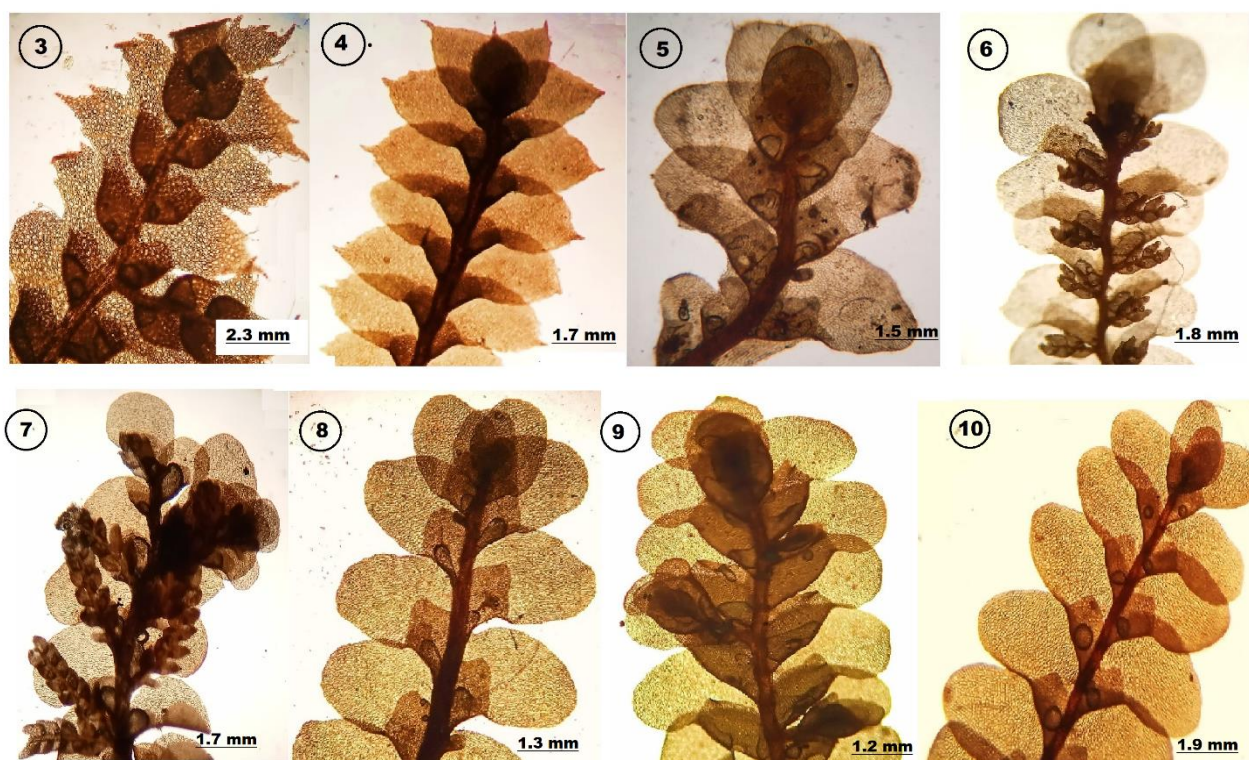
The specimens are yellowish-green in color with a width of 1.5-1.7 mm and an irregular branching pattern. The leaves are closely arranged together, have an elongated ovoid shape, and

measure 0.7-0.8 mm long and 0.5-0.6 mm wide. Furthermore, they have a flat attachment, curved dorsal base and ventral base, flat edge, and rounded tip. The cell shape ranges from round to elongated, with a thick cell wall, rough surface, and a sparse star-shaped trigon. The lobules are square in shape, and measure 1/3 the lobe length, with a blunt base, attachment, slightly curved edges, and a blunt tip.

**Specimens examined:** North Sumatra (Batang Toru forest) epiphyllous, June 19<sup>th</sup>, 2019 alt.802-972 m asl, RD 1382, 1654

**Distribution:** Indonesia (New record for Sumatra), Borneo, Thailand, India, Ceylon, Nepal, Philippines, Taiwan, China (Yamada 1979); (Söderström *et al.* 2016; Shu *et al.* 2017).

**Habitat and Ecology:** Epiphytes on weathered wood at an altitude of 872-908 m asl, humidity at 78-87% and temperature at 21.2-29.1°C



**Figure 3.** *Radula anceps*, 4. *Radula apiculata*, 5. *Radula campanigera*, 6. *Radula formosa*, 7. *Radula iwatsukii*, 8. *Radula javanica*, 9. *Radula kinabaluensis*, 10. *Radula meyeri*. Habit of *Radula* (seen from the ventral side)

### 3.10. *Radula obtusiloba* Steph. (Figure 12)

Bull. Herb. Boiss. 5: 105 (1897). *Radula japonica* Gott. Var. Minor Amak., Jour. Hattori Bot Lab. 13:58 (1995).

The specimens range from yellow to brown in color with a width of 1.3-1.6 mm, and an irregular branching pattern. The leaves overlap, have an oval shape, and measure 0.7-0.9 mm long and 0.40-0.5 mm wide. Furthermore, they have a flat attachment to the stem, dorsal base, flat ventral base and edge, as well as a rounded tip. The cells are rectangular in shape, with thick walls, a smooth surface, and adjacent trigons which are triangular in shape. The lobules are small and rectangular, measure 1/3 the leaf length, with a flat base, attachment, edge, and blunt tip.

**Specimen examined:** North Sumatra (Batang Toru forest) epiphyllous, June 20<sup>th</sup>, 2019 alt. 802 m asl, RD 1587.

**Distribution:** Indonesia (Sumatra), Korea, Japan (Yamada, 1979); (Bakalin *et al.*, 2022)

**Habitat and Ecology:** Epiphytes on tree trunks at an altitude of 802 m asl, humidity at 80% and temperature at 29.3°C.

### 3.11. *Radula oreopsis* M.A.M.Renner. (Figure 13)

M.A.M. Renner 6270, V.C. Linis. E.A. Brown, 24 Maret 2012.

The specimens are yellowish-green in color and have a width of 1.6-2.1 mm with an irregular branching pattern. The leaves are arranged close together, ovoid in shape, as well as 0.8-1.2 mm long and 0.67-0.8 mm wide. Furthermore, they have a flat attachment, dorsal base, slightly curved, with a flat edge and rounded ends. The cell shape ranges from round to elongated, with thick cell walls, rough surface, as well as sparse and triangular trigon. The lobules are asymmetric rhombic, 1/3-1/2 of leaf length, with a tapered base, curved attachment, flat edge slightly curved, and a pointed tip.

**Specimens examined:** North Sumatra (Batang Toru forest) epiphyllous, June 12<sup>rd</sup> until 22<sup>rd</sup>, 2019 alt. 857-931 m asl, RD 266, 1046, 1054, 1815, 1873, 1996, 1997.

**Distribution :** Indonesia (Sumatra), Australia (Renner 2014b)

**Habitat and Ecology:** Epiphytes on tree trunks and rotting wood at an altitude of 863-1035 m asl, humidity at 82-87% and temperature at 28.1-29.6°C.

### 3.12. *Radula protensa* Lindenb. (Figure 14)

In Meissner, Bot. Zeit. 6: 462 (1848)

The specimens are yellow to brownish in color and have a width of 0.6-3 mm with an irregular branching pattern. The leaves are tightly arranged laterally, overlapping and folding at the tips. They have a flat attachment, are oval-elongated, 0.3-0.5 mm long, and 0.3-0.4 mm wide, with a flat dorsal base, edge, and rounded tip. The cells are hexagonal in shape with thick walls, a smooth surface, tight trigon, and a triangular shape. The lobules are ovate-shaped, measuring 1/8 the length of the leaf, with a flat base, curved flat edge, rounded tip, and curved attachment. However, generative organs are absent.

**Specimen examined:** North Sumatra (Batang Toru forest) epiphyllous, June 17<sup>th</sup>, 2019 alt. 1050 m asl, RD 1094

**Distribution:** Indonesia (Sumatra, Java), Borneo, India, Philippines, China, Taiwan, New Guinea (Williston 1912; Yamada 1979).

**Habitat and Ecology:** Epiphytes on leaves at an altitude of 1050 m asl, at 80% humidity and temperature at 25.4°C.

### 3.13. *Radula retroflexa* Tayl. (Figure 15)

London J. Bot. 5: 378. 1846. Yamada. J. Hatt. Bot. Lab. 45: 281. 1979. Yamada & Piippo. Ann. Bot. Fennici 26: 383. 1989.

The specimens are yellowish-green in color, with a width of 1.3-1.6 mm, and exhibit an irregular branching pattern. The leaves are arranged closely together, resembling kidney shapes measuring 0.3-0.4 mm long and 0.3-0.6 mm wide. Furthermore, they have a tapered attachment, with a dorsal base that is fully curved, resembling a crescent moon, and a ventral base that is half curved. The edges are hairy, with long and pointed hairs, and rounded ends. The cell shape is isodiametric with thick walls, rough surface, a tight trigon, and a triangular shape. The lobules are oblong, measuring 1/2 the length of the leaf, with a tapering base, attachment, a flat and curved edge on the ventral side, and a blunt tip.

**Specimen examined:** North Sumatra (Batang Toru forest) epiphyllous, June 19<sup>th</sup>, 2019 alt. 893 m asl, RD 1468

**Distribution:** Indonesia (Sumatra, Java), Australia, Samoa, Papua New Guinea, New Caledonia, Marquesas, Philippines, Taiwan, Japan (Yamada 1979; So 2006)



**Habitat and Ecology:** Epiphytes on leaves at an altitude of 893 m asl at 82% humidity and temperature at 26.5°C.

### 3.14. *Radula retroflexa* var *fauciloba* (Steph.) Yamada (Figure 16)

*Radula fauciloba* Steph., Spec. Hepat.4:188 (1910).-*Radula weymouthiana* Steph., Spec. Hepat. 4: 190 (1910).-*Radula helmsiana* Steph., Spec. Hepat.4:123 (1910).-*Radula lunalatiloba* Horik, Jour. Hiroshima Univ. Scr. B, div. 2, 2: 226 (1934).

The specimens exhibit a green to yellowish color, with a width of 2-2.5 mm and a regular branching pattern. The leaves are arranged closely together, with ovoid shapes, measuring 1-1.1 mm long and 0.9-1 mm wide. They also have curved attachments, a dorsal base, a flat edge, and tips that range from rounded to blunt. Furthermore, the cell shape is elongated, with thin walls, a smooth surface, and a tight trigon. The lobules are crescent moon-shaped, measuring 1/3 of the length of the leaf, with curved bases, attachments, and edges, and a relatively blunt tip, with sinuous edges almost forming a sinus.

**Specimens examined:** North Sumatra (Batang Toru forest) epiphyllous, June 19<sup>th</sup> until 22<sup>rd</sup>, 2019 alt. 863-931 m asl, RD 1258, 1269, 1304, 1534, 1567, 1603, 1610, 1764, 1975, 1993.

**Distribution:** Japan, Taiwan, Philippines, Thailand, Malaysia, Indonesia (Sumatra, Java, Borneo), Hawaii, Tasmania, New Zealand (Yamada 1979; So 2006)

**Habitat and Ecology:** Epiphytes on tree trunks at an altitude of 863-931 m asl, humidity at 82-83% and temperature at 22.3-29.5°C.

### 3.15. *Radula Sumatrana* Steph. (Figure 17)

Spec. Hepat. 4: 204. 1910. Yamada. J. Hatt. Bot. Lab. 45: 250. 1979.

The specimens are yellowish-green in color and have a width of 2-2.6 mm with an irregular branching pattern. The leaf arrangement varies from sparse to dense at the tip stature. Furthermore, they have an ovoid shape, 1.15 - 1.3mm long and 0.82 - 0.9 mm wide, with a flat to slightly curved attachment, a curved dorsal base, a flat ventral base, a flat edge, and rounded tips. The cells are round in shape, with thick walls, a rough surface, and tight triangular trigones. The lobules are quadrangular, measuring 1/2 the length of the leaf, with a curved bases, attachments, flat edges, and blunt tips.

**Specimens examined:** North Sumatra (Batang Toru forest) epiphyllous, June 20<sup>th</sup> until 25<sup>th</sup>, 2019 alt. 802-911 m asl, RD 1605,1763, 2245

**Distribution:** Indonesia (Sumatra, Java, Kalimantan), India, Thailand, Malaysia (Yamada 1979; Lai et al, 2008; Singh et al, 2016)

**Habitat and Ecology:** Epiphytes on tree trunks and leaves at an altitude of 802-911 m asl, humidity at 82-85% and temperature at 26.2-26.1°C.

### 3.16. *Radula tjibodensis* Goebel. (Figure 18)

Nova Acta Acad. Caes. Leop. Carol. 60 (2): 249. 1893. Yamada. J. Hatt.Bot. Lab. 45: 294. 1979

The specimens exhibit yellowish-green color with a width of 1.2-1.5 mm and irregular branching. The leaves are closely arranged together, ovate-shaped, 0.63-0.8 mm long and 0.5-0.6 mm wide. They also have curved attachments, a dorsal base, a flat ventral base and edges. The tip are rounded and have gemma cups. Furthermore, the cells are hexagonal in shape with thick walls, a smooth surface, and tight and triangular trigones. The lobules are rectangular, measuring ¼ of the leaf length, with flat bases, attachments, edges, and tips forming a bulge.

**Specimens examined:** North Sumatra (Batang Toru forest) epiphyllous, June 13<sup>th</sup> until 24<sup>th</sup>, 2019 alt. 825-928 m asl, RD 321, 800, 1432, 1435, 2018

**Distribution:** India, Taiwan, Philippines, Thailand, Vietnam, Brunei, Singapore, Malaysia, Indonesia (Sumatra, Java, Kalimantan, Papua), Papua New Guinea, Samoa (Yamada, 1979; Gradstein, 1997; So, 2006; Lai *et al.*, 2008).

**Habitat and Ecology:** Epiphytes on tree trunks and leaves at an altitude of 825-928 m asl, humidity at 82-86% and temperature at 20.1-26.5°C.

### 3.17. *Radula yangii* Yamada, *nom. Nov* (Figure 19)

*Radula pinnulata* Yang, *Taiwania* 7:35-39 (1960), non Mitt. In. Seeman, *Flora Vitiensis*: 410 (1871)

The specimens are brownish-yellow in color and have a width of 1.1-2.1 mm. The branching pattern is amentulose, with shoots in each leaf axil. The length of the shoot can sometimes be as small as a lobe or large as the leaves. They have an elongated oval shape, 1-1.8 mm long and 0.8-1 mm wide, with a flat attachment, a curved dorsal base, a rounded ventral base, flat edges, and rounded tips. Moreover, the cell shape ranges from rectangular to elongated rectangle, with thin walls, a smooth surface, and tight trigons. The lobules are oblong, measuring 1/2 the length of the leaf, with flat bases, attachments, edges, and tips.

**Specimens examined:** North Sumatra (Batang Toru forest) epiphyllous, June 16<sup>th</sup> until 22<sup>nd</sup>, 2019 alt. 877-937 m asl, RD 784, 786, 788, 1820, 2017, 2075

**Distribution:** Indonesia (Sumatra), Borneo, Thailand, Taiwan, Malaysia, Ceylon (Yamada 1979; Promma & Chantanaorrapint 2015)

**Habitat and Ecology:** Epiphytes on tree trunks, weathered wood and leaves at an altitude of 877-937 m asl, humidity at 80-86% and temperature at 21.6-27.4°C.

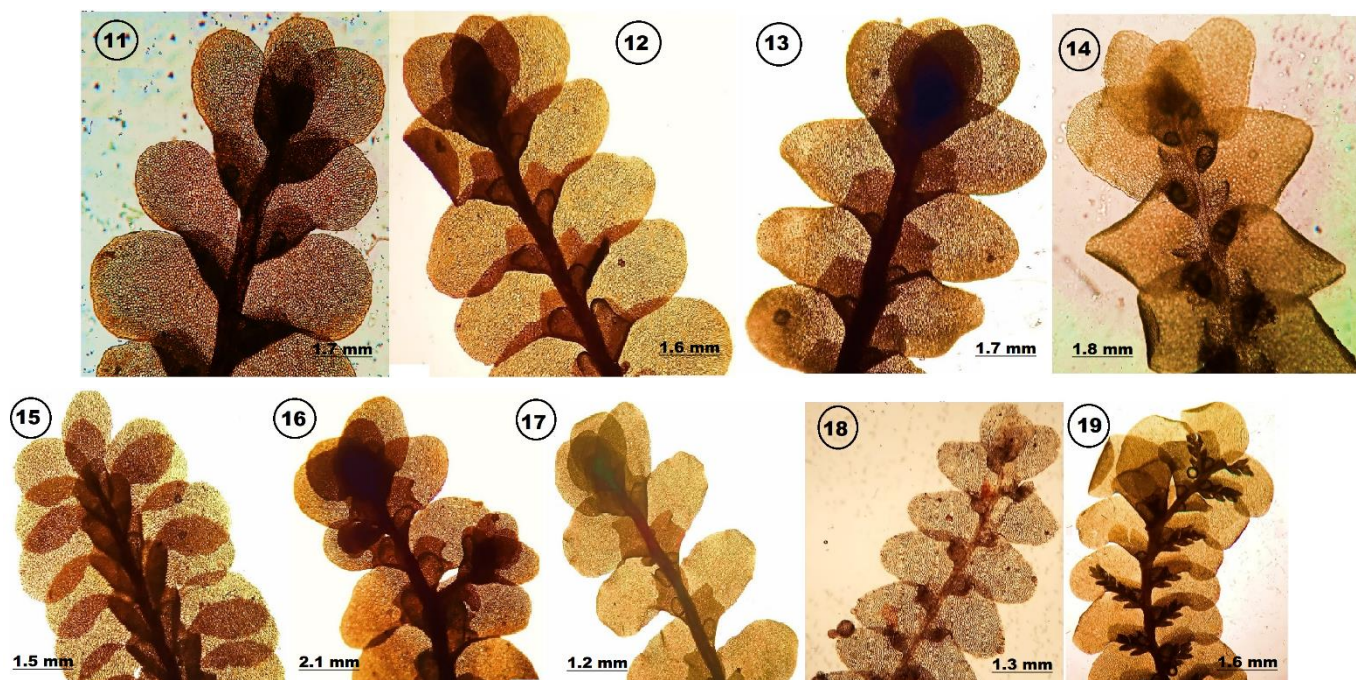


Figure 11. *Radula obscura*, 12. *Radula obtusiloba*, 13. *Radula oreopsis*, 14. *Radula protensa*, 15. *Radula retroflexa*, 16. *Radula retroflexa* var *fauciloba*, 17. *Radula sumatrana*, 18. *Radula tjibodensis*. 19. *Radula yangii*. Habit of *Radula* (seen from the ventral side)

## 4. CONCLUSIONS

This study, conducted in the Batang Toru Forest Area, West Block, North Sumatra, discovered 17 species of the Radulaceae family, of which three are new records for Sumatran

liverworts, namely *R. iwatsukii*, *R. kinabaluensis*, and *R. obscura*. They were found as epiphytes on tree trunks and leaves. Based on the number of specimen collections, the most commonly found species is *Radula javanica*. Additionally, Radulaceae in the Batang Toru forest are distributed at altitudes between 800 and 1100 meters above sea level, hence they are included in the Lower Montane Forest category.

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