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# Diversity and Distribution of Thalloid Liverworts in Mount Ungaran, Central Java, Indonesia

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## ABSTRACT

Thalloid liverworts are an important component of montane forest ecosystems, with significant roles in water retention, nutrient cycling, and as indicators of environmental quality. These groups belong to the polyphyletic group or have different ancestors, but they have similar forms and can survive in terrestrial ecosystems. The aims of the study are to update information on the identification, classification, and distribution of thallus liverworts on the slopes of Mount Ungaran and to reveal valuable insights into plant biodiversity, ecosystem dynamics, and their potential applications in various fields. We used the purposive sampling techniques, plots, and the identification of taxonomic literature. The results showed that the distribution of the thalloid liverworts were widely spread in three stations and we found 4 families with 6 species of complex thallus liverworts: *Marchantia polymorpha* L., *Marchantia emarginata* Reinw., Blume et al., *Marchantia treubii* Schiffn., *Wiesnerella denudata* (Mitt.) Steph., *Dumortiera hirsuta* (SW.) Nees., and *Cyathodium smaragdinum* Schiffn, which belong to the class Marchantiopsida. In addition, 3 families with 3 species of simple-thallus liverworts were found: Riccia treubiana Steph, which belongs to the class Marchantiopsida; *Metzgeria furcata* (L.) Dumort; and *Aneura maxima* Schiffn, which belongs to the class Jungermaniopsida.

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## INTRODUCTION

Bryophytes, which include mosses, liverworts, and hornworts, are non-vascular plants that play a significant role in global biodiversity, with approximately 20,000 species worldwide (Hao & Chu, 2021). Liverworts, belonging to the phylum Marchantiophyta, are a diverse group of non-vascular plants crucial to terrestrial ecosystems, divided into leafy and thalloid forms (Schuster, 1992). The number of species with approximately 6000 to 8000 species worldwide (He-Nygrén et al., 2006). Liverworts, exhibit a diverse array of habits based on their gametophytic characters. They are divided into three classes: the Marchantiopsida which possess complex thalloid gametophytes, Jungermanniopsida characterized by leafy or simple thalloid, and Haplomitriopsida characterized by leafy (Wheeler, 2000; Long, 2006; Moraga, 2022). Thalloid liverworts are found in the classes Marchantiopsida and Jungermanniopsida (Linde et al., 2023).

The liverworts are distributed in 398 genera and 92 families (Söderström et al., 2016), and including 850 species of thalloid liverworts (11%), 500 simple thalloid (6%) (Jungermanniopsida), and 350 complex thalloid (5%) (Marchantiopsida)

(Goffinet & Shaw, 2009). The number of liverworts in Indonesia has not been detected completely with validity, but there are several provinces that reveal this, including Java province (West Java, Central Java, and East Java) according to Söderström et al. (2024), at least more than 500 of liverwort species were recorded; Bali province according to Haerida (2017), 73 species identified consisting of 31 genera and 17 families; Sumatra province according to Susilo et al. (2022), 83 species identified consisting of 23 genera and 8 families; and Sulawesi province according to Ariyanti et al. (2009), 134 species identified.

Thalloid liverworts, which are characterized by their simple or complex thallus structure, play a significant role in the biodiversity of liverworts worldwide. Thalloid liverworts, characterized by a flattened, ribbon-like, or heart-shaped body (thallus) lacking a distinct stem and leaf structure, reproduce sexually through gametangia and asexually through fragmentation or gemmae production (Schuster, 1992). Thalloid liverworts are classified into two main categories: simple thalloid liverworts and complex thalloid liverworts (Brown et al., 2009) each with distinct features that contribute to their unique identities within the plant kingdom (Xiang et al., 2022) and that have intrigued researchers for years. The complex thalloid liverworts, belonging to the class Marchantiopsida, are considered the basal liverwort lineage and are associated with glomeromycete fungi, similar to most vascular plants (Bidartondo & Duckett, 2009). On the other hand, simple thalloid liverworts are part of the subclass Metzgeriidae and exhibit dichotomous branching patterns (Katagiri & Shinden, 2020).

The complex thalloid liverworts are recognized as one of the earliest land plant lineages, known for their specialized structures such as air pores, pegged rhizoids, and the absence of organellular RNA editing sites (Flores et al., 2017). These features are crucial in understanding the evolutionary history and ecological adaptations of these plants. In contrast, simple thalloid liverworts lack the intricate structures seen in the Marchantiopsida, has the same internal layer of 1 layer of cells, and is usually similar to leafy liverworts but different (Brown et al., 2009).

Thalloid liverworts are essential for ecosystems (Lang & Murphy, 2012), enhancing biodiversity (Fernandes et al., 2021), conservation, and plant breeding activities (Herman, 2020), influences nutrient cycling and soil health through interactions with fungi and other microorganisms such as forming mycorrhizal-like associations with fungi, thereby contributing to the absorption and cycling of nutrients in the soil. This symbiotic relationship plays an important role in ecosystem processes and nutrient dynamics (Pressel et al., 2021). Additionally, thalloid liverworts have potential medicinal uses due to their secondary metabolites, such as the antivirus marchantin A from *Marchantia polymorpha* (L.) (Ivković´ et al., 2021), and their chemical properties offer potential for chemotaxonomic applications (Wawrzyniak et al., 2021).

Thalloid liverworts, such as *M. polymorpha* are widely distributed across various regions, showcasing their adaptability to different habitats and climates. Their global presence underscores their diverse ecological roles, applications, and significant economic and ecological importance (Asakawa et al., 2000). Altitudinal distribution plays a crucial role in determining the habitat preferences and ecological niches of thalloid liverworts, with different elevations offering unique environmental conditions that influence their growth and survival (Wienskoski & Santos, 2022). This gives rise to a variety of species with a variety of morphological and anatomical characters and is often linked to adaptations to specific habitats and environmental conditions (B. Crandall-Stotler et al., 2009).

Research on the distribution of bryophyte diversity in the Mount Ungaran area has been carried out by Ergiana et al. (2013), Sulistyowati et al. (2014), and Utomo (2022) in different altitudes and resulted the numbers of species found. However, the research on thalloid liverworts in this area is currently limited. Given their vital presence, it is crucial to conduct in-depth studies on the diversity, distribution, and ecology of thalloid liverworts in Mount Ungaran, incorporating anatomical and morphology characteristics. This research of the study is to update information on the identification, classification, and distribution of thallus liverworts on the slopes of Mount Ungaran and to reveal valuable insights into plant biodiversity, ecosystem dynamics, and their potential applications in various fields.

## MATERIALS AND METHODS

### Research Location

Waterfall. The second station is Curug Lawe Sicepit. The last station is Medini Tea Garden (Fig.

1). These three stations are highland areas with an altitude of 700–1000 m asl. Morphological and anatomical observations were conducted at the Ecology and Biosystematics Laboratory Faculty of Science and Mathematics, Diponegoro University Indonesia.

Field work was carried out at three stations on the northern slopes of Mount Ungaran. The first station is the hot springs and Nglimut Gonoharjo

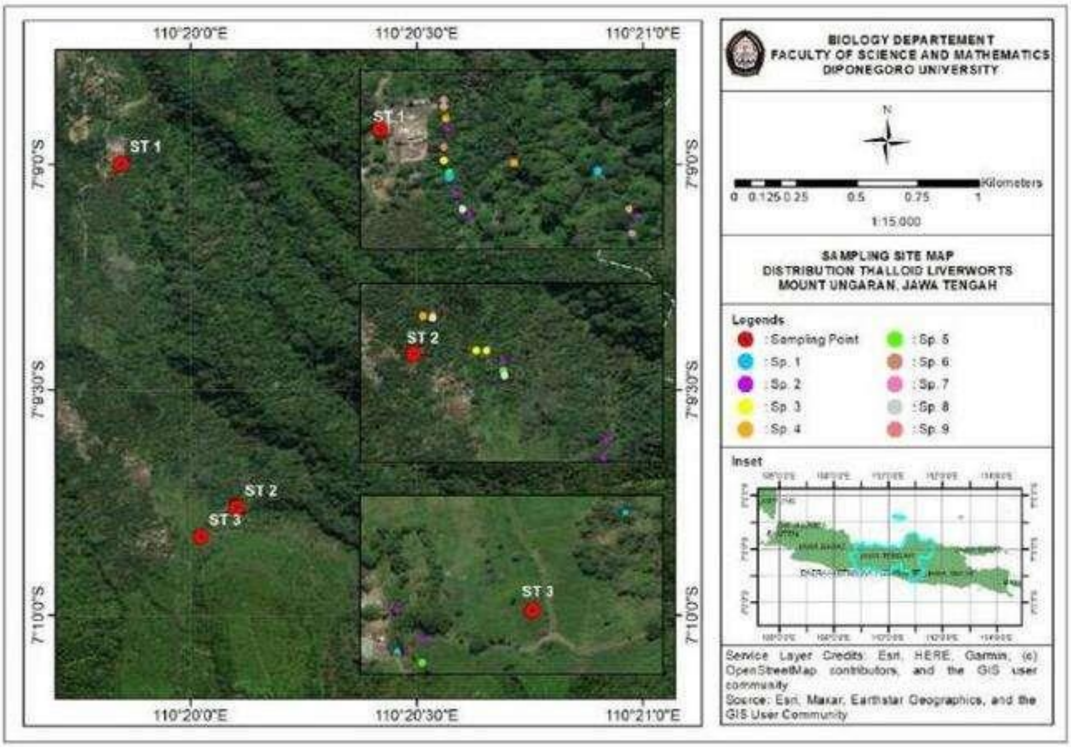


**Figure 1.** Sample plot map and distribution of thalloids liverworts on Mount Ungaran, Central Java

**Table 1**. Environmental Factor Data

| Parameters | Research Location | | |
|---|---|---|---|
| | Station 1 | Station 2 | Station 3 |
| Temperature (°C) | 22°C-25°C | 25°C-29°C | 25°C-31°C |
| Air Humidity (%) | 74%-95% | 65%-80% | 50%-60% |
| Soil pH | 7,5 | 7,6 | 7,9 |
| Soil Moisture Conditions | 2 | 1,1 | 1 |
| | Slightly Dry | Dry | Dry |
| Light Intensity (Cd) | 400-800 | 800-900 | 900-1000 |
| Elevation (MASL) | 730-800 | 820-900 | 910-1000 |

Note: [1]Nglimut Hot Springs, Kendal, Central Java [2]Curug Lawe Sicepit, Kendal, Central Java [3]Medini Tea Garden Tour, Kendal, Central Java

**Material and Tools**

Field research tools include a camera, GPS (Global Positioning System), lux meter, hygrometer, soil tester, altimeter, ruler, cutter, hand spray bottle, HVS envelope, cloth bag, observation table, and aluminum foil. Laboratory research tools include light microscope (Zeiss) and stereo microscope (Zeiss), optilab, refrigerators, petri dishes, glass slides, cover slips, dropper pipettes, label paper, and tweezers. The research material consists of the results of the exploration of thalloid liverworts in the Mount Ungaran area.

*Sampling dan Identification Thalloid Liverworts*

The purposive sampling was used based on certain criteria. We sampled thalloid liverworts from the sites which have low light intensity and high moisture habitat or close to water, either on the ground or rocks (because liverworts are not found in places exposed to direct sunlight). The plots were selected based on the presence of thalloid liverworts. Each station contains 2-6 large plots by following the presence of thalloid liverworts along the road. The large plots were 100x100 cm in size and in each large plot we made a small plot with a size of 10x10 cm for sampling. For each large plot, abiotic data were measured including altitude, temperature, air humidity, light intensity and soil pH and soil moisture. Samples were collected from the patches and then placed in a microwaveable plastic box covered with wet paper wrapped in aluminum foil and stored in a refrigerator.

Morphological and anatomical observations of fresh materials were carried out, then identified directly in the laboratoryEcology and Biosystematics UNDIP, using the taxonomic literature, such as Guide to The Liverworts and Hornworts of Java (Gradstein, 2011), Mosses and Liverworts of Hongkong (Zhu & So, 1996), Guide to the genera of liverworts and hornworts of Malaysia (Lee & Gradstein, 2021), The gemma of *Marchantia pinnata* (Marchantiaceae, Marchantiophyta) (Zheng & Shimamura, 2019). Data on the distribution and identification of thalloid liverworts were analyzed descriptively.

## RESULTS AND DISCUSSION

The northern slopes of Mount Ungaran are a suitable place for liverworts to live. They live in humid environments, low to moderate temperatures, and slightly low light intensity. The three collection sites have different altitudes and climates, with liverworts being found in many locations near water and low light intensity according to the data in (Table 1). The collection stations based on altitude according to Steenis (2007) stations 1 and 2 are called tropical mainland forest zones, while location 3 is called the montana zone or low mountain forest. Based on these classifications, the liverworts found belonged to the Marchantiopsida and Jungermaniopsida classes (Table 2).

Species of Marchantiopsida class were grouped into five families, namely Marchantiaceae, Wiesnerellaceae, Dumortieraceae, Ricciaceae, and Cyathodiaceae. The Marchantiaceae family with 3 species namely *Marchantia polymorpha* L., *Marchantia emarginata* Reinw., Blume et Nees., *Marchantia treubii* Schiffn; family Wiesnerellaceae with 1 species namely *Wiesnerella denudata* (Mitt.) Steph; family Dumortieraceae with 1 namely *Dumortiera hirsuta* (SW.) Nees; family Ricciaceae with 1 species namely *Riccia treubiana* Steph; and family Cyathodiaceae with 1 species, *Cyathodium smaragdinum* Schiffn. Special characters of the Marchantiopsida according to Söderström et al. (2016) are include the largeand complex thallusthere are air pores, scales, lobes, larger rhizoids, gametangium in the form of anteridium and archegonium, and large spore capsules.

While the species from the Jungermaniopsida were grouped in two families, namely Metzgeriaceae and Aneuraceae with only one species in each family, namely *Metzgeria furcata* (L.) Dumort. and *Aneura maxima* Schiffn, respctively. Special characters of the Jungermaniopsida according to Crandall-Stotler et al. (2009) & Crandall-Stotler et al. (2005) include smaller thallus, thin, simple, without lobes, scales, thin rhizoids, the gametangium is not protected in a special place structure, and the spore capsule is small.

The thalloid liverworts are divided into two different group based on the shape and structure of the thallus, namely simple thalloid liverworts and complex thalloid liverworts. In this study, three species from the simple thalloid liverworts were found (Table 2), namely *Riccia treubiana* Steph from Marchantiopsida, *Metzgeria furcata* (L.) Dumort, and *Aneura maxima* Schiffn from Jungermaniopsida. Special characters of the simple thalloid liverworts according to Katagiri & Shinden, (2020) are simple thallus, has an unclear cell anatomy layer, has no special internal tissue to transport water, has no pores, simple means of reproduction or by using gemma and thallus fragments, many live epiphytes, moist, low light intensity, and less tolerant of extreme environmental conditions. According to Crandall-Stotler et al. (2008) in Goffinet & Shaw (2009) the family of the class marchantiopsus) the family of the marchantiopsida class that is included in the simple-thallus liverwort group is Ricciaceae, while from the Jungermaniopsida class according to Wikströma et al. (2009) namely Metzgeriaceae, Aneuraceae, Mizutaniaceae.

Six species of liverworts with complex callus were found from the class Marchantiopsida (Table

2), namely *Marchantia polymorpha* L., *Marchantia emarginata* Reinw., Blume et Nees., *Marchantia treubii* Schiffn, *Wiesnerella denudata* (Mitt.) Steph, *Dumortiera hirsuta* (SW.) Nees, *Cyathodium smaragdinum* Schiffn. Special characters according to Wikströma et al. (2009) anatomical cell layer

**Tabel 2.** Distribution and Species of Liverworts in the Mount Ungaran

| No. | Family | Species Nama | Thalloid Liverwort | | Research Location | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Station 1[1] | | Station 2[2] | | Station 3[3] | |
| | | | S[5] | C[6] | E[7] | T[8] | E | T | E | T |
| **Marchantiopsida** | | | | | | | | | | |
| **1.** | Marchantiaceae | *Marchantia polymorpha* L. | - | √ | - | √ | - | - | √ | √ |
| **2.** | | *Marchantia emarginata* Reinw., Blume et Nees. | - | √ | √ | √ | √ | - | √ | - |
| **3.** | | *Marchantia treubii* Schiffn | - | √ | - | √ | √ | √ | - | - |
| **4.** | Wiesnerellaceae | *Wiesnerella denudata* (Mitt.) Steph. | - | √ | - | √ | - | √ | - | - |
| **5.** | Dumortieraceae | *Dumortiera hirsuta* (SW.) Nees | - | √ | - | √ | - | √ | - | √ |
| **6.** | Cyathodiaceae | *Cyathodium smaragdinum* Schiffn | - | √ | - | √ | - | - | - | - |
| **7.** | Ricciaceae | *Riccia treubiana* Steph. | √ | - | - | √ | - | - | - | - |
| **Jungermaniopsida** | | | | | | | | | | |
| **8.** | Metzgeriaceae | *Metzgeria furcata* (L.) Dumort. | √ | - | √ | √ | √ | √ | - | - |
| **9.** | Aneuraceae | *Aneura maxima* Schiffn | √ | - | √ | √ | - | - | - | - |
| **Total** | 7 | 9 | 3 | 6 | 9 | | 5 | | 3 | |

arrangement has a thallus layer that differs between layers with chloroplasts and without chloroplasts, porous, ventral scales, rhizoid pegs (papilloid), reproductive organs in the form of antheridium and archegonium (Ruklani et al., 2015), and mostly live terrestrially and are tolerant of extreme conditions or variations in environmental conditions Morphological and Anatomical Description of Liverworts in Mount Ungaran Class Marchantiopsid

***Marchantia polymorpha* L.**

**Thallus** in the form of flat sheets resembling dichotomous branching ribbons overlapping which form a wide expanse (Fig. 2G); thallus length 2 - 10 cm; thallus width 0.5 - 2 cm; wavy white thallus edges; dry thallus black; anatomical arrangement of thallus composed of 4 different cell layers (characteristic of liverworts with complex thallus) colored white, green, purple, transparent black; black brown round oil bodies throughout the thallus constituent layers which are numerous (Fig. 2If). **Dorsal surface** of the thallus is shiny dark green (Fig. 2A), composed of a regular layer of epidermal cells with a diameter of ±25μm; there is a prominent-pores in the form of a small white dot (Fig. 2A), clear pores and air spaces with a diameter of ± 94μm; there is a gemma cup. (Fig. 2J); there is gemma cup, thin edge composed of one cell layer and serrated (Fig. 2F), appearing on the potential apical cell layer that produces disc-shaped gemma and the presence of oil body (Fig. 2N); there is midrib on the thallus surface (Fig. 2G(a)); the layer below the dorsal epidermis is an assimilation layer composed of chlorophyll cells (Fig. 2Id); the storage layer is a large-celled region of transparent white and transparent purple (Fig. 2Ie), ± 17μm in diameter (Fig. 2L). **Ventral surface** of the thallus is shiny light green (Fig. 2B), composed of the lower epidermal layer (Fig. 2Ih); there are purple oblanceolate, single-celled, rectangular scales of purple color arranged regularly, and rhizoids. (Fig. 2H), and papillose rhizoids (peg rhizoids) (Fig. 2B), transparent brown, 0.5 - 2 cm long, where peg rhizoids are covered by ventral scales (Fig. 2K, M), smooth rhizoids (Fig. 2Ii).

**Archegonium** located at the tip of the thallus (archegoniophore); 0.7 mm in diameter; many variations in green, yellow, brown colors; the number of lobes is 6-12 lobes, the ends of the lobes are emarginate; truncate (Fig. 2Cb); curved towards the stalk, papillose, chorus (Fig. 2C), the median dorsal rounded not prominent, the ventral lobes have involucre, pseudo-perianth, and blackish brown hairs (Fig. 2D). **Antheridium** undivided lobed, 6 - 8 intercalated, green margins, black median, papillose (Fig. 2E). Stalk of archegonia and antheridia threaded, hairy, blackish green. **Habitats** on rock cliffs or soil (Fig. 2G) were found at stations 1 and 3.

***Marchantia emarginata*** **Reinw., Blume et Nees**

**Thallus** shaped like a narrower ribbon with dichotomous branching and rosette overlapping to form a wide expanse (Fig. 3I); length 1 - 5 cm; thallus width 0.5 - 1 cm; wavy transparent brown thallus edge; no midrib; thick (Fig. 3A); dry thallus brown or black; anatomical arrangement of thallus

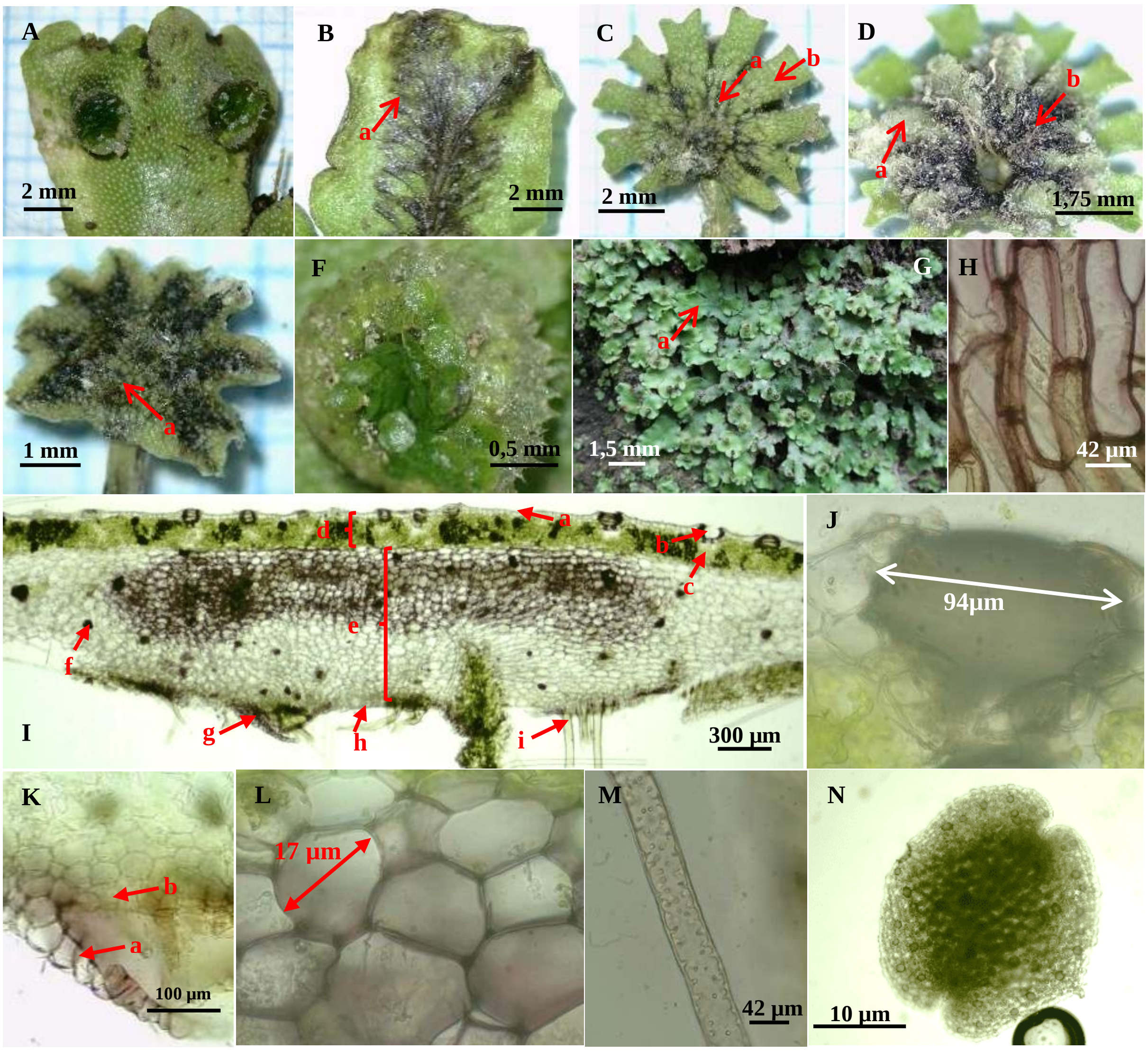


**Figure 2.** Morphology and Anatomy of *Marchantia polymorpha* L. (A) Dorsal TalusThallus, (B) Ventral TalusThallus; a) Ventral Scales, (C) Dorsal Archegonium; a) Receptacle; b) Lobe, (D) Ventral Archegonia; a) Involucre; (b) Pseudo-perianth, (E) Antheridia; a) Papillose Protrusion, (F) Gemma Cup, (G) Liverworts Habitus, (H) Ventral Scale Cells, (I) TalusThallus Cross Section; a) Epidermal Layer; b) Pore; c) Air Space; d) Assimilation layer; e) Storage region layer; f) Oil body; g) Ventral scales; h) Ventral epidermis; i) Smooth Rhizoid, (J) Diameter of Pores, (K) Place of Peg Rhizoid, (L) Diameter of Cells Composing Storage region, (M) Peg Rhizoid, (N) Gemma.

composed of 4 different layers of cells (characteristic of liverworts with complex thallus) colored white, green, purple, brown, transparent black (Fig. 3J); and round ash or black oil bodies throughout the thallus constituent layers with fewer than *M. polymorpha* (Fig. 3Je). **Dorsal surface** of thallus shiny dark green (Fig. 3A); composed of a neat layer of epidermal cells with a diameter of ± 3906µm; pore in the form of small white dots (Fig. 3A), ± 10µm in diameter (Fig. 3K), air spaces are clear; midrib pattern (Fig. 3A(a)); gemma cup present at the tip of the thallus with a thin edge composed of a single layer of serrated cells (Fig. 3C), containing a disc-shaped gemma with a thinner cell layer compared to *M. polymorpha* and the presence of an oil body (Fig. 3Q); beneath the epidermal layer there is an assimilation layer composed of chlorophyll cells (Fig. 3Jc), a large-celled storage region layer of white; purple; transparent brown (Fig. 3Jd), ± 14μm in diameter (Fig. 3M). **Ventral surface** of the thallus is shiny light green (Fig.3B); arranged in the lower epidermis layer there is a rhizoid peg covered with ventral scales (Fig. 3Jg); rhizoid papillose or peg (Fig. 3N), transparent brown in color, 0.2 - 2 cm long (Fig. 3Bb); there are obovate purple scales (Fig. 3Ba), single-celled, irregular rectangular in shape and purple in color (Fig. 3O).

**Archegonium** located at the tip of the thallus (archegoniophore); 0.5 cm in diameter; divided into 4, 6, 8, more than 10 lobes; green, yellow, orange, brown in color; median archegonia has a bulge on the dorsal part; the tip of the lobe does not divide; the lobe is rounded apically; papillose (Fig. 3R); ventral surface has receptacle, involucre, pseudo-perianth (Fig. 3D), with air pores and eggs (Fig. 3R); ventral surface with receptacle, involucre, pseudo- perianth (Fig. 3F). **Antheridium** are located at the end of the thallus (antheridiophore) which is different from the location of the archegonium; divide into 6 - 8 lobes, blunt lobe tips, green edges, black median, 0.2 - 0.7 cm in diameter (Fig. 3G), the ventral surface is like superimposed scales (Fig. 3H); anatomically the antheridium has spermatid cells associated with pores, the antheridium has wings (Fig. 3S). The second stalk of the gametangium is threaded, hairy, white-spotted, and blackish-green in color (Fig. 3E). **Epiphytic habitats** on rock cliffs or terrestrial soil (Fig. 3I) were found at stations 1, 2 and 3.

***Marchantia treubii* Schiffn**

**Thallus** shaped like a ribbon; dichotomous branching overlapping which forms a wide expanse; branching at the end of the thallus; medium-sized thallus when distinguished from M. polymopha and M. emarginata; 1 - 3 cm long; thallus width 1 - 1.5 cm; opaque; thin thallus; wavy light green thallus edges (Fig. 4A & B); dry thallus brown or black (Fig. 4H); anatomical arrangement of thallus composed of 4 layers of different cells (characteristic of liverworts with complex thallus) colored white, green, brown, transparent black (Fig. 4I); and a small number of round ash or black oil bodies. **Dorsal surface** of the thallus is dull light green (Fig. 4A); composed of wavy epidermal cell layers (Fig. 4I(a)), ± 7055μm in diameter; pores in the form of a small white dot (Fig. Ca), ± 11μm in diameter (Fig. 4K); reticulate pattern very clear purple- black (composed of 2-3 cells); gemma cup at the tip of the thallus, thin jagged edges (Fig. 4C), containing a disc-shaped gemma with a thinner cell layer compared to *M. polymorpha* and *M. emaginata* and the presence of oil body (Fig. 4P); under the epidermal layer there is an assimilation layer composed of chlorophyll cells (Fig. 4Id), a large- celled storage region cell layer is white and purple transparent, ± 69μm in diameter (Fig. 4Ic & M). **Ventral surface** of the thallus is shiny yellowish green; arranged in the epidermis layer there are single-celled, rectangular rounded scales with both ends irregularly blunt and purplish brown (Fig. 4N); and transparent white rhizoids, 0.2 - 2 cm long (Fig. 4B), there are rhizoid pegs (Fig. 4L) covered by ventral scales (Fig. 4J); rhizoids are smooth (Fig. 4Ig).

**Archegonium** is divided into 3 - 5 lobes; the candidate archegonium is spherical, 0.5 - 0.7 cm in diameter, light and dark green, pored, papillose (Fig. 4D(b)), ends of lobes branched (Fig. 4D(a)); the ventral lobe has a receptacle, purple-black scales, involucre, and pseudo-perianth (Fig. 4E); and anatomically the surface of the archegonium is rounded, with a pore on the dorsal side, eggs on the ventral side, and oviducts (Fig. 4Q). **Antheridium** is divided into 4-6 lobes; green margins; purple-black median; blunt lobe tips; papillose dorsally (Fig. 4F); and superimposed scale-like ventrally (Fig. 4G). The stalks of the archegonium and antheridium are both threaded, stiff and hairy. Habitats on rock cliffs or soil (Fig. 4H) were found at stations 1 and 2.

***Wiesnerella denudata* (Mitt) Steph**.

**Thallus** small; widened towards the tip of the thallus; dichotomously branched, some forming like a baffle, conical, and widening back at the branching; thick, strong, 2 - 5 cm long (Fig. 7A); 0.5 - 1 cm wide; thallus tip curved inward (Fig. 7D); thallus edge brown or black wavy; dry thallus light brown; composed of 4 different layers of cells (Fig. 5J) (characteristic of liverworts with complex thallus), cell arrangement 0.5 - 1 cm. 7D); wavy brown or black thallus edges; light brown dry thallus; composed of 4 different layers of cells (Fig. green/yellow/maroon/brown in color, easily detached (Fig. 5B); there is no median pattern and reticulate; and after the epidermal layer there is an assimilation layer composed of oval round light green chlorophyll cells, not tight like the sponge layer in leaf anatomy (Fig. 5L)

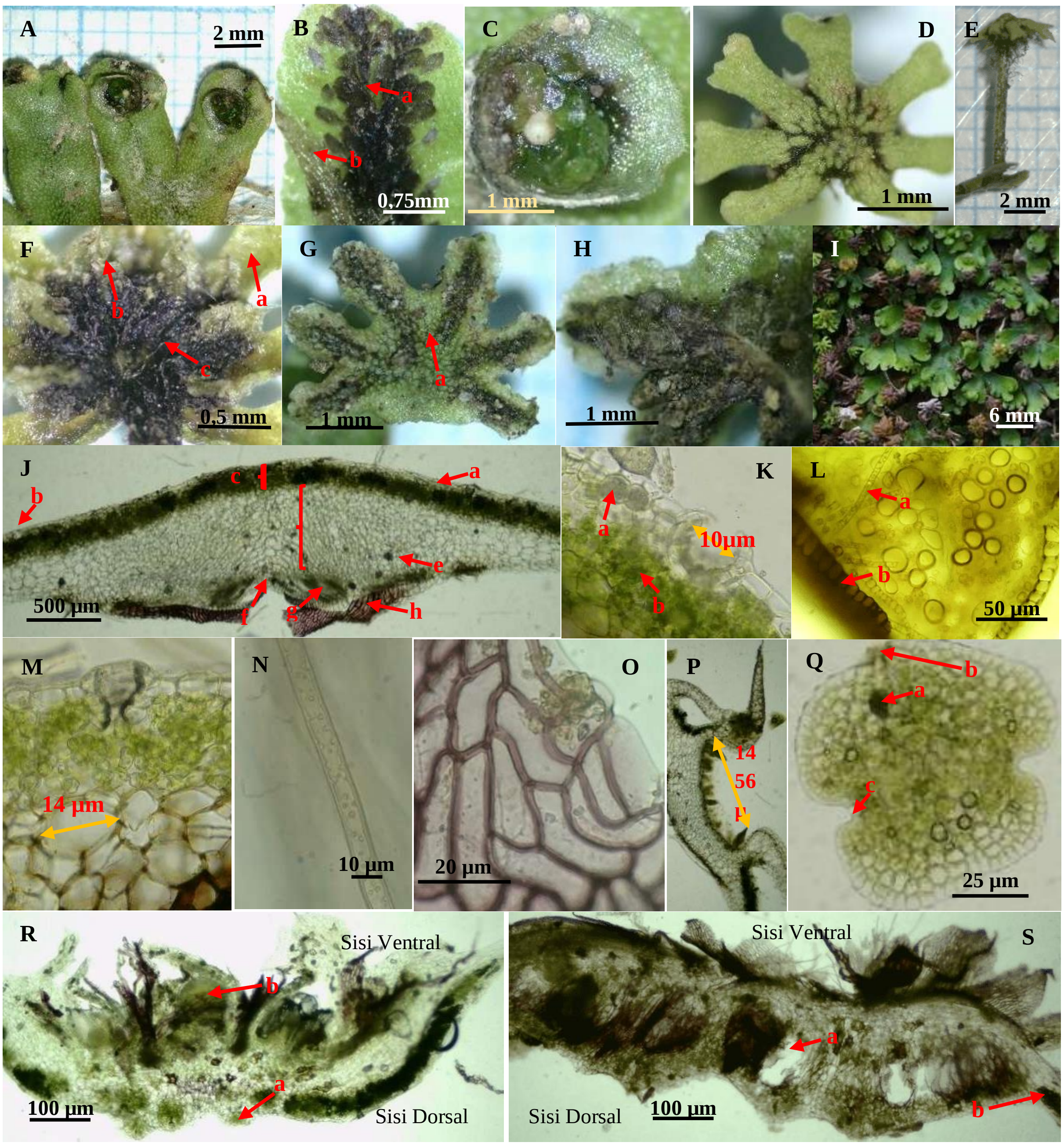


**Figure 3**. Morphology and Anatomy of *Marchantia emarginata* Reinw., Blume et Nees. (A) Dorsal Thallus, (B) Ventral Thallus; a) Ventral Scales; b) Rhizoid, (C) Gemma Cup; a) Gemma; b) Edge, (D) Dorsal Archegonium, a) Lobes (E) Long Archegonium, (F) Ventral Archegonium: a) Receptacle; b) Involucre; c) Pseudo-perianth, (G) Dorsal Antheridium; a) Papillose protrusion, (H) Ventral Antheridium, (I) Habitus, (J) Thallus Cross Section; a) Dorsal Epidermis; b) Air pores; c) Assimilation Region; d) Storage Region; e) Oil Body; f) Ventral Epidermis; g) Peg Rhizoid Site; h) Ventral Scales, (K) Dorsal Cross Section of Thallus; a) Oil Body; b) Chlorophyll, (L) Peg Rhizoid Site; a) Peg Rhizoid; b) Ventral Scale, (M) Storage Region Diameter, (N) Peg Rhizoid, (O) Ventral Scale Longitudinal Cross Section, (P) Gemma Cup Cross Section, (Q) Gemma; a) Oil body; b) Stalk mark; c) 2 notches, (R) Archegonium; a) Pores; b) Egg, (S) Antheridium; a) Spermatozoid; b) Wing.

5J) (characteristic of liverworts with complex thallus), the cell arrangement gets thinner from the center to the edges, green, brown, and purple; and the oil body is located throughout the layers of light brown or blackish grey (Fig. 5J(i) & L). **Dorsal surface** of light-older green thallus slightly shiny (Fig. 5A), composed of dorsal epidermal cell layer composed of 1 layer of neat cells, 8196 µm in diameter (Fig. 5Ja); thallus tip curved, branched to form a baffle (Fig. 5Aa); faint white small dot pore, conical upwards close

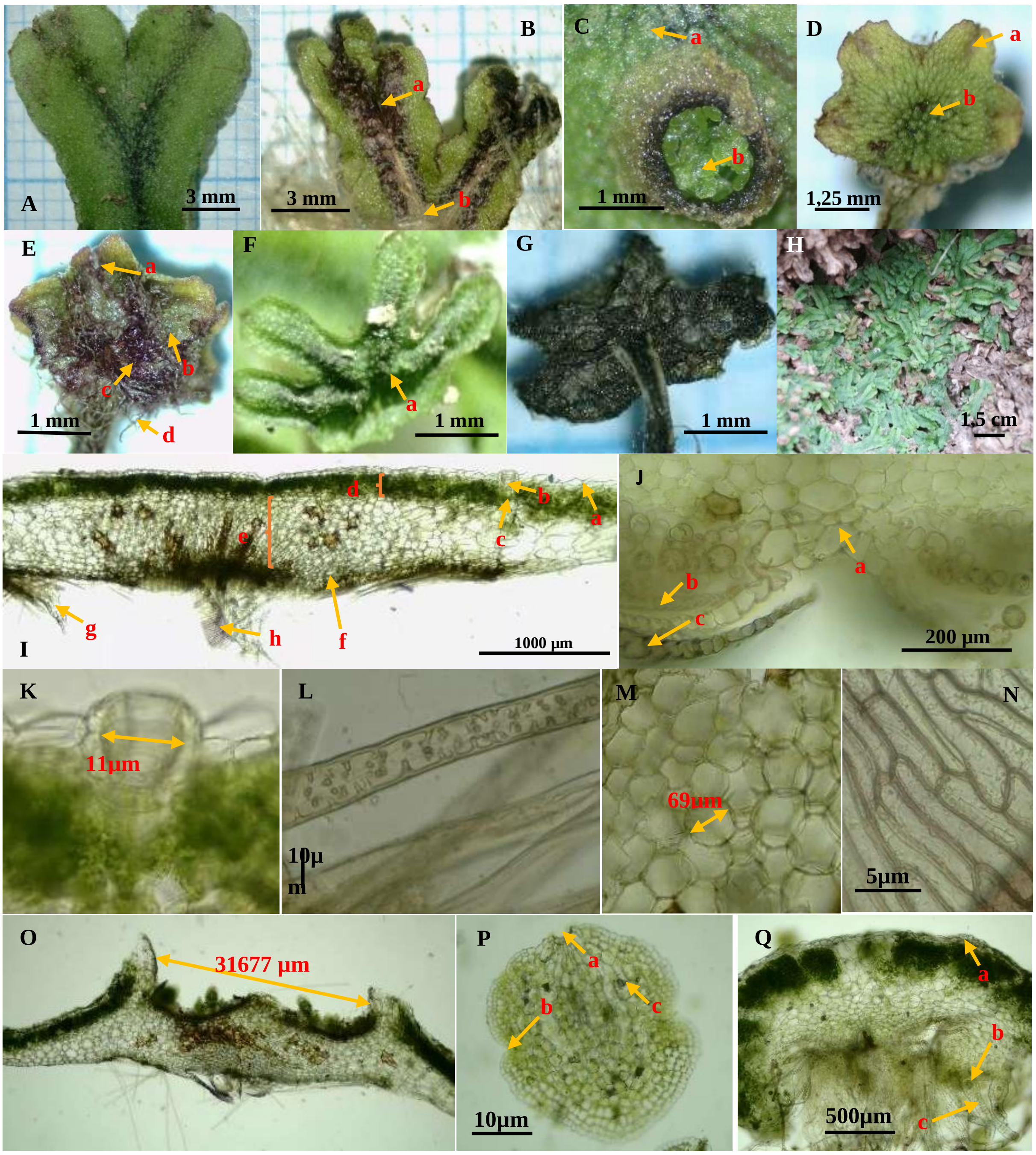


**Figure 4:** Morphology and Anatomy of *Marchantia treubii* Schiffn. (A) Dorsal Thallus, (B) Ventral Thallus; a) Ventral Scales; b) Rhizoid, (C) Gemma Cup; a) Pores; b) Gemma, (D) Dorsal Archegonia; a) Lobe; b) Pore, (E) Ventral Archegonia; a) Receptacle; b) Involucre; c) Pseudo- perianth; d) Papillose hairs, (F) Dorsal Antheridium; a) Papillose Bulge, (G) Ventral Antheridium, (H) Habitus, (I) Cross Section of Thallus; a) Dorsal Epidermis; b) Pores; c) Air Space; d) Assimilation Region; e) Storage Region; f) Ventral Epidermis; g) Smooth Rhizoid; h) Ventral Scales, (J) Peg Rhizoid Site: a) Ventral Epidermis; b) Peg Rhizoid; c) Ventral Scales, (K) Pores, a) Chlorophyll, (L) Peg Rhizoid, (M) Storage Region, (N) Ventral Scales, (O) Cross Section of Gemma Cup, (P) Gemma Disc; a) Stalk marks; b) 2 notches; c) Oil body, (Q) Cross section of Archegonium; a) Pore; b) Egg; c) Egg duct.

together in 1 cross section (Fig. 5Jb), ±11 µm in diameter, and large air chamber ±46 µm in diameter (Fig. 5K); there are no gemma cups but small smooth spheres of antheridium that are the storage region cell layer is larger transparent brown and transparent white, ±20 µm in diameter (Fig. 5N). **Ventral surface** of the thallus is shiny dark purple (Fig. 5C), composed of ventral epidermal cells arranged neatly (Fig. 5J(f)); there are reniform scales on the median thallus, purple-black (Fig. 5Ca), composed of 1 layer of purple cells, shaped like trapezoids of different sizes (Fig. 5O); single rhizoid with a length of 1-2 cm (Fig. 5D), there is a place of rhizoid peg covered by ventral scales (Fig. 5J(g)), smooth rhizoids parallel to the epidermis (Fig. 5J(h)); crescent-shaped thallus tip facing light green (Fig. 5E).

**Archegonium** located at the tip of the thallus (archegoniophore) is brown, 5-lobed star shape, papillose, downy, has a stalk of 0.5 - 2 cm, smooth, purple-black (Fig. 5F), the ventral part has a white receptacle, and brown oval spores (Fig. 5G). **Antheridium** located at the tip of the thallus (antheridiophore) produced in the potential apical thallus is round very short-stemmed, has a spermatid partition, and is porous (Fig. 5P). Terrestrial habitats on the ground (Fig. 5I) were found at stations 1 and 2.

### ***Dumortiera hirsuta*** **(SW) Nees**

**Thallus** of *Dumortiera hirsuta* large and thick; dichotomous branching, non-rosette growth path, number of branches 2-4 branches from tip to base (Fig. 6A), growing on top of each other forming a bed (Fig. 6E); length 5 - 10 cm; thallus width 1 - 2 cm; thallus tips branched; stiff and crunchy texture; no fronds; semi-transparent, thallus tips curved inward; light green margins. 6E); length 5 - 10 cm; thallus width 1 - 2 cm; thallus tip branched; stiff and crunchy texture; no midrib; semi-transparent, thallus tip curved inward; flat light green edges, many white hairs; dry thallus remains green or light brown; composed of 3 layers of different cell

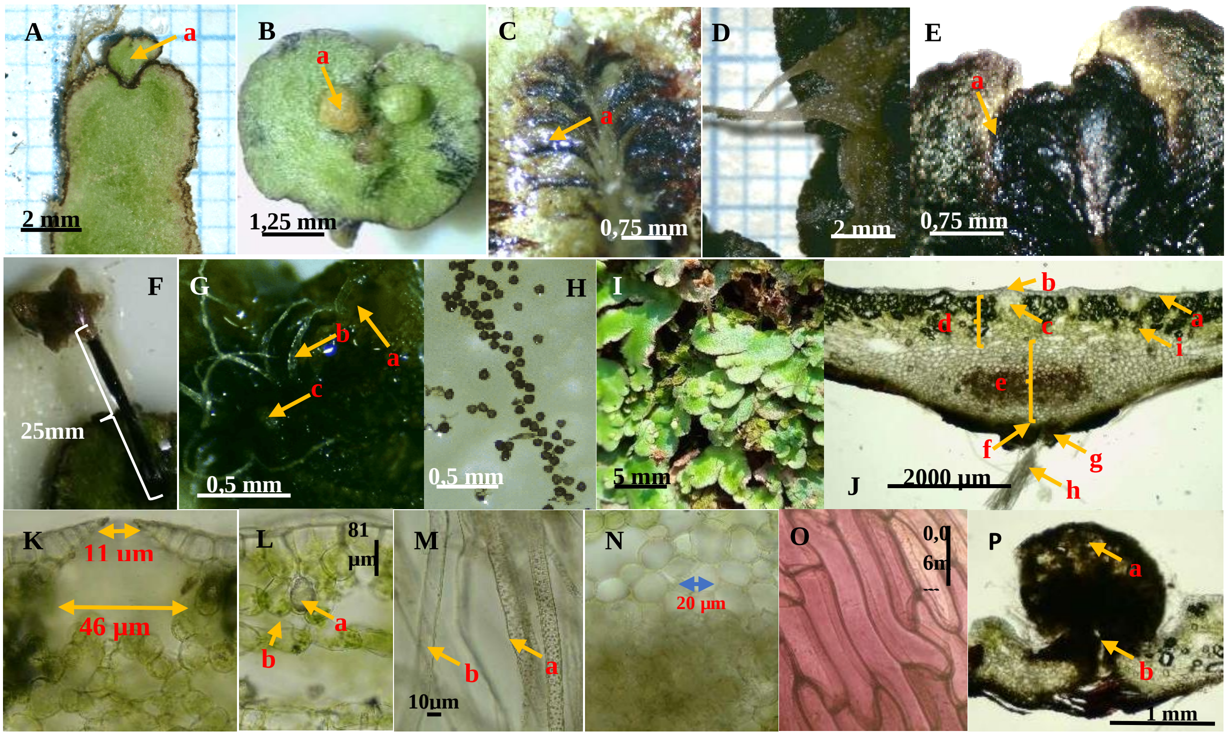


**Figure 5:** Morphology of *Wiesnerella denudata* (A) Dorsal thallus; a) Thallus branches from the ventral part, (B) Antheridium bulb, (C) Ventral thallus; a) Ventral scales, (D) Rhizoid, (E), Ventral tip, (F) Dorsal archegonium, (G) Ventral archegonium; a) Receptacle; b) Rhizoid; c) Archegonia protrusion, (H) Sporangium, (I) habitus, (J) Thallus cross section; a) Dorsal epidermis; b) Pores; c) Air space; d) Assimilation region; e) Storage region; f) Ventral epidermis; g) Rhizoid peg; h) Smooth rhizoid; i) Oil body, (K) Diameter of pore and air space, (L) Epidermis and assimilation region; a) Oil body cell; b) Chlorophyll, (M) Rhizoid; a) Rhizoid peg; b) Smooth rhizoid, (N) Storage region cell arrangement, (O) Longitudinal ventral scales, (P) Antheridium; a) Spermatid; b) Channel where the receptacle or stalk is attached.

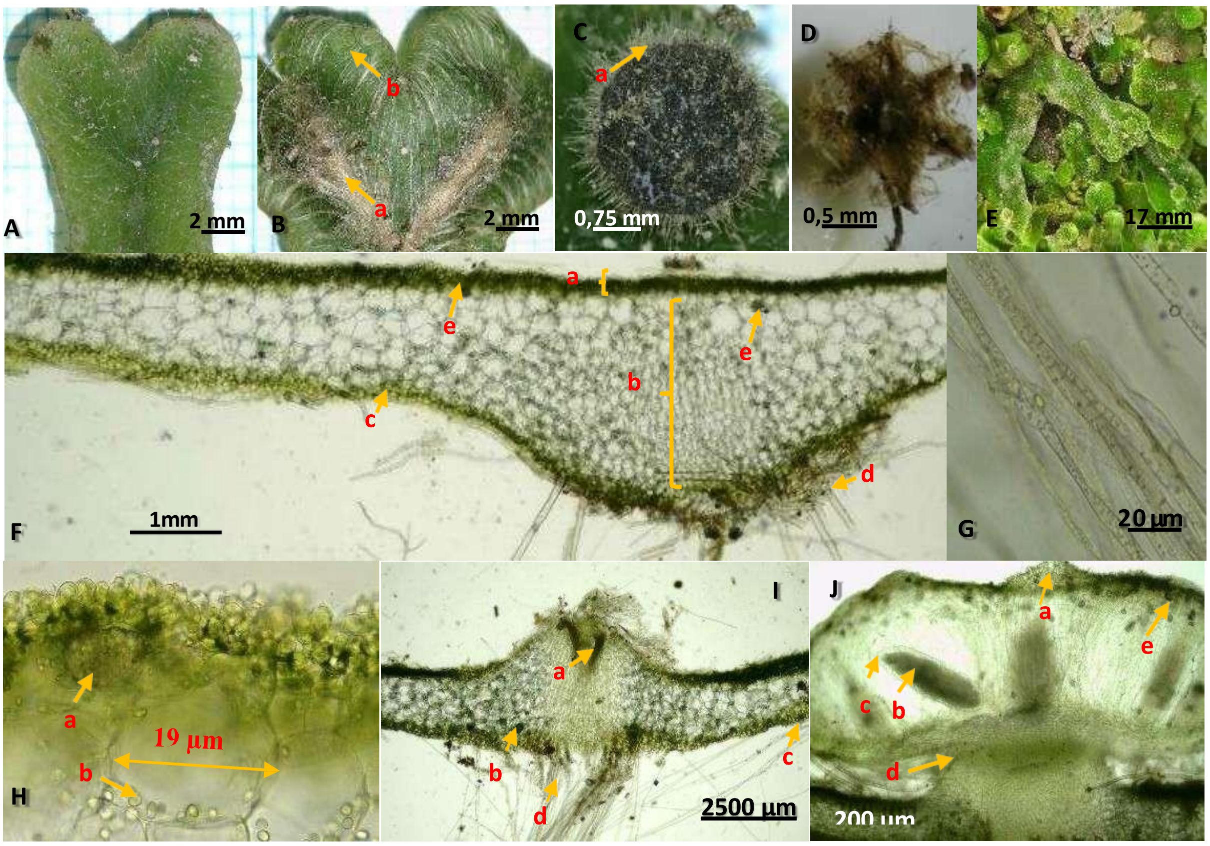


**Figure 6.** Anatomical Structure of *Dumortiera hirsuta* (A) Cross section of thallus; a) Dorsal epidermis as well as photosynthetic assimilation region; b) Storage region; c) Ventral epidermis; d) Rhizoid, (B) Cross section of thallus edge; a) Down, (C) Cross section of epidermis and storage region; a) Oil body cells in the epidermal layer; b) chlorophyll, (D) Cross section of storage region; a) Oil body cells, (E) Rhizoid stakes, (F) Cross section of thallus tip; a) Antheridium development process; b) Oil body cells; c) Fine hairs, (I) Cross section of antheridium (male receptacle); a) Small protrusions (papillose); b) Spermatid; c) Sterile protective cell; d) Oil body cell; e) Stalk of the antheridium, (G) Wingless antheridium; a) Oil body cell; b) Coarse hairs, (H) Length of the stalk of the antheridium, (I) Longitudinal section of thallus; a) Chlorophyll

layers (characteristic of liverworts with complex thallus), has a thick median to the edge getting thinner, the constituent cells are transparent white and transparent green on the edges; and grey or brown oil bodies spread on each layer (Fig. 6Fe).

**Dorsal surface** of the thallus is dark green-green; dull, covered with white hairs throughout the thallus surface (Fig. 6A), composed of fused epidermal and assimilate layers (Fig. 6Fa), oval round, chlorophyll epidermal cells with a diameter of ± 66 µm (Fig. 6H); no pore; no median pattern; no gemma cup; beneath the epidermis and assimilation layer there is a large-celled storage region 4-6x that of the epidermis, 19µm in diameter, transparent white, with chlorophyll in each cell (Fig. 6H). **Ventral surface** of the dull light green thallus is hairy throughout the surface (Fig. 6B), composed of the ventral epidermis layer, each cell is chlorophyll (Fig. 6Fc); rhizoids grow in the ventral median (Fig. 6Ba), transparent white, papillose, branched, 1 - 2 cm long, rhizoid pegs (Fig. 6G), and fine hairs resembling rhizoids (Fig. 6Ic).

**Archegonium** located at the end of the thallus (archegoniophore); star-shaped; located at the end of the main thallus; smooth-stemmed brown; 0.5 - 2 cm long; divided into 6 - 8 lobes; covered with hairs (Fig. 6D). **Antheridium** located at the tip of the main thallus (antheridiophore); hard; stiff and not hollow; round; green, brown, or black in color; 0.2 - 0.5 cm in diameter; short stalk 0.5 - 1 cm; papillose; covered with stiff and hard hairs on the edges; and not easily separated from the thallus (Fig. 6C); anatomically, the antheridium is not easily separated from the thallus. 6C); anatomically the antheridium is produced at the potential apical end (Fig. 6I); there is a small bulge. Terrestrial **habitats** on soil and epiphytes on new (Fig. 6E) were found at stations 1, 2, and 3.

### *Cyathodium smaragdinum* Schiffn

**Thallus** of *Cyathodium smaragdinum* small; growth furrow obcuneate (widening to the apex) (Fig. 8A); ±8 mm long; ±2.5-5 mm wide; very thin; superimposed on the same species (Fig. 8D); foul smelling when withered; transparent easily brittle; flat slightly wavy edges composed of 1 layer of cells (Fig. 8I(b)); dry thallus is green or disappears on the ground; composed of 3 layers of developed cells in the transverse section of the thallus (Fig. 8E) (characteristic of liverworts with complex thallus), 2 layers of cells are visible from the longitudinal section of the thallus (Fig. 8G), the median arrangement of the thallus (Fig. 8B), and the median arrangement of the thallus (Fig. 8G). 8G), median arrangement of the thallus to the edge with the same thickness (Fig. 8E), transparent white cell color in transverse section (Fig. 8F), and blackish green in longitudinal section (Fig. 8G); *oil bodies* in 1 cross section are few in number and spread in each constituent layer of the thallus (Fig. 8F(b)), colored white cell color. 8F(b)), black in color; and each cell contained oval round chlorophyll (Fig. 8F(a)).

**Dorsal surface of the thallus** is shiny light-dark green (Fig. 8A), composed of a dorsal epidermal layer with unequal cell size and wavy (Fig. 8Ea), epidermal cell height ±56 µm (Fig. 8F), diameter ±22 µm (Fig. 8H), chlorophyll. 8H), chlorophyll (Fig. 8F); small white slightly dark dots (Fig. 8Cb), pentagon shape (Fig. 8Ha) (characteristic of liverworts with complex thallus); no gemma cup; reticulate lines formed on the thallus surface to the edge (Fig. 8Ca), reticulate lines look like roads (Fig. 8Gb) associated with the edge of the thallus (Fig. 8I); sporophytes are located in the indentation of the tip of the thallus which is the potential apical tip (Fig. 8Ga); and under the epidermal layer there is a layer of assimilation and storage region fused (Fig. 8Eb), larger cells ±61 µm in diameter (Fig. 8F); hollow reticulate lines (Fig. 8Ee).

**Ventral surface of the thallus** is shiny light green (Fig. 8B) with a single smooth white rhizoid (Fig. 8Ba), the ventral epidermis of the same-sized cells is neatly arranged (Fig. 8Ec), the rhizoid is smooth (Fig. 8Ed). According to (Gradstein, 2011) **Archegonium** is located at the potential apical end and the **Antheridium** is embedded in the thallus. Terrestrial **habitats** on soil and epiphytes on rocks (Fig. 8D) were found at station 1 only.

### *Riccia treubiana* Steph

Small **thallus** of *Riccia treubiana*; dichotomous branching with 2, 4, up to 6 branches (Fig. 7A) and rosette (Fig. 7D); length ± 12mm; width ± 5mm; thin transparent thallus; rudimentary thallus edge; composed of several layers of cells that are difficult to distinguish (simple thallus liverwort) (Fig. 7E); the color of the constituent cells is green; chlorophyll organelles are visible in each oval round cell (Fig. 7G(a)); dry thallus is dull light green. The **dorsal surface of the thallus** is shiny light green (Fig. 7A); the dorsal epidermal layer is still distinguishable (Fig. 7E), the layer height is ± 27 µm (Fig. 7G); there is an indistinct pore, but anatomically the air pores and sporophyte pores (Fig. 7E) are clearly visible; just below the pores

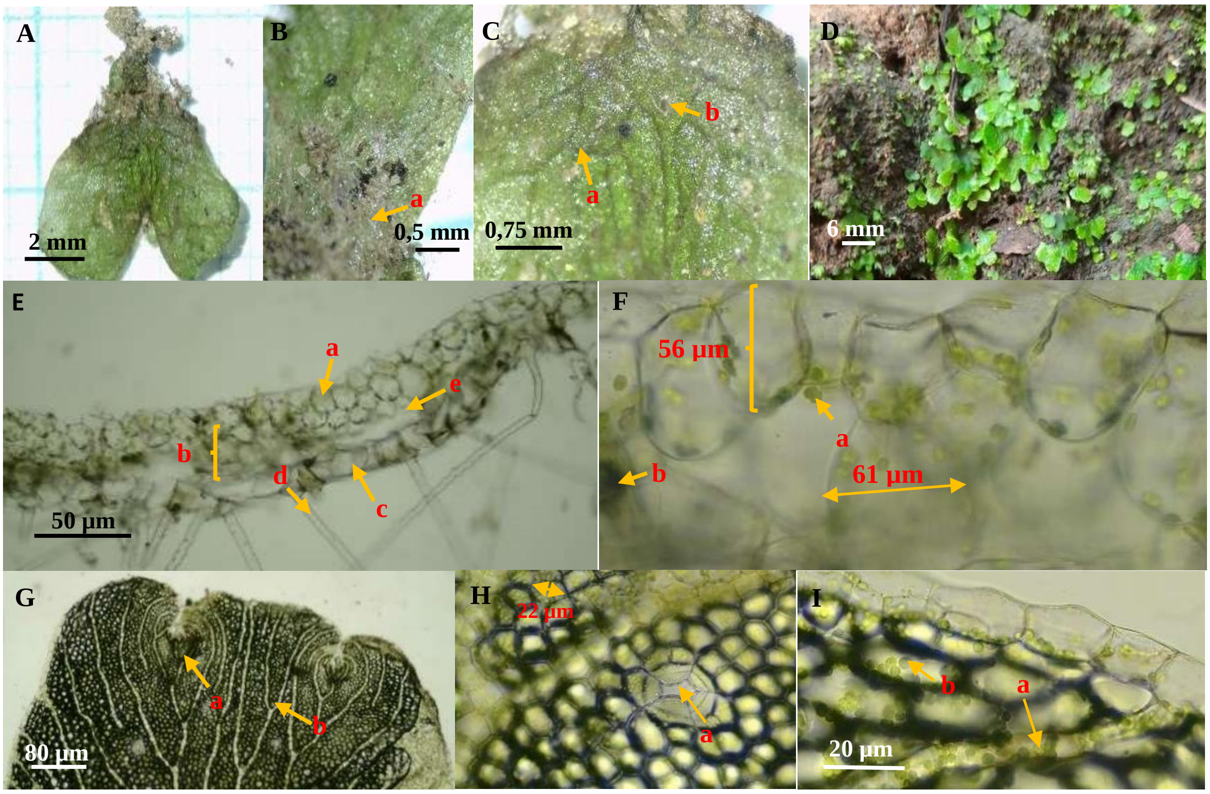


**Figure 7**. Morphology of *Cyathodium smaragdinum* (A) Dorsal thallus, (B) Ventral thallus; a) Rhizoid, (C) Dorsal surface of thallus; a) Reticulate lines; b) Pores, (D) Habitus of epiphytic liverwort on rock, (E) Cross section of thallus; a) Dorsal epidermis; b) Storage region; c) Ventral epidermis; d) Rhizoid; e) Reticulate lines, (F) Cross section of epidermis and storage area; a) Chlorophyll, (G) Longitudinal section of thallus; a) Apical end of sporophyte site; b) Lines on thallus, (H) Longitudinal section of thallus; a) Chlorophyll, (I) Longitudinal section of thallus edge; a) Reticulate lines; b) Chlorophyll.

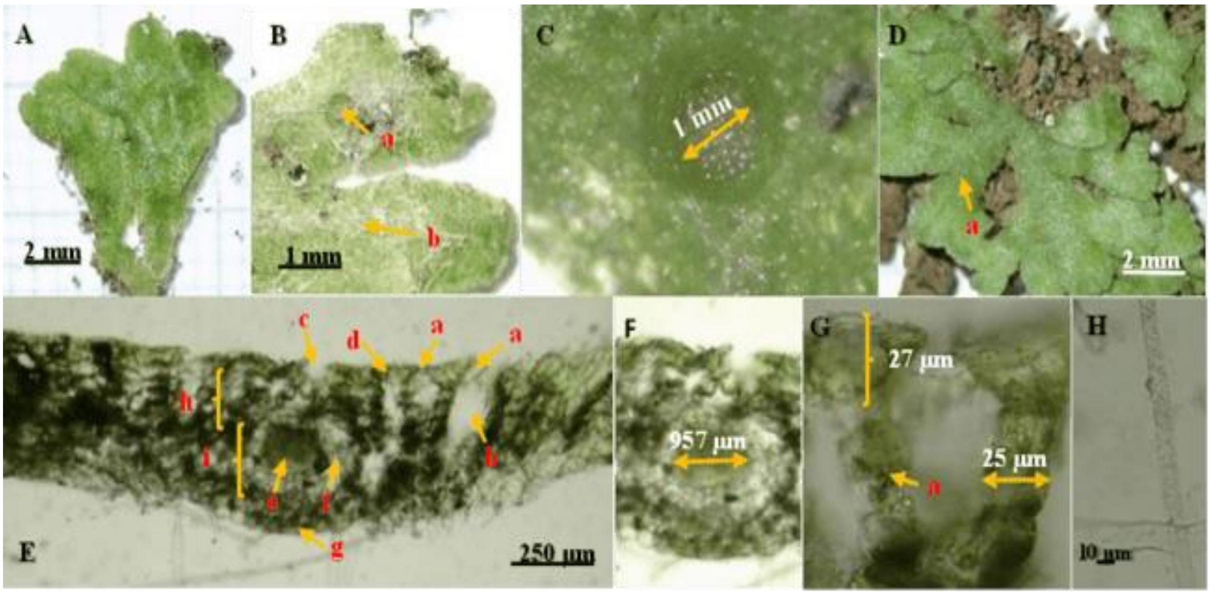


**Figure 8: Morphology and Anatomy of *Riccia treubiana*** (A) Dorsal thallus, (B) Ventral thallus; a) Sporophyte protrusion; b) Rhizoid, (C) Sporophyte Diameter, (D) Habitus; a) Median furrow, (E) Cross section of thallus; a) Air pore; b) Air chamber; c) Sporophyte pore; d) Dorsal epidermis; e) Sporophyte; f) Sporophyte protection cell; g) Ventral epidermis; h) Assimilation region, i) Storage region, (F) Diameter of sporophyte, (G) Thallus cross section of epidermis and assimilation region constituent cells; a) Chlorophyll, (H) Rhizoid peg.

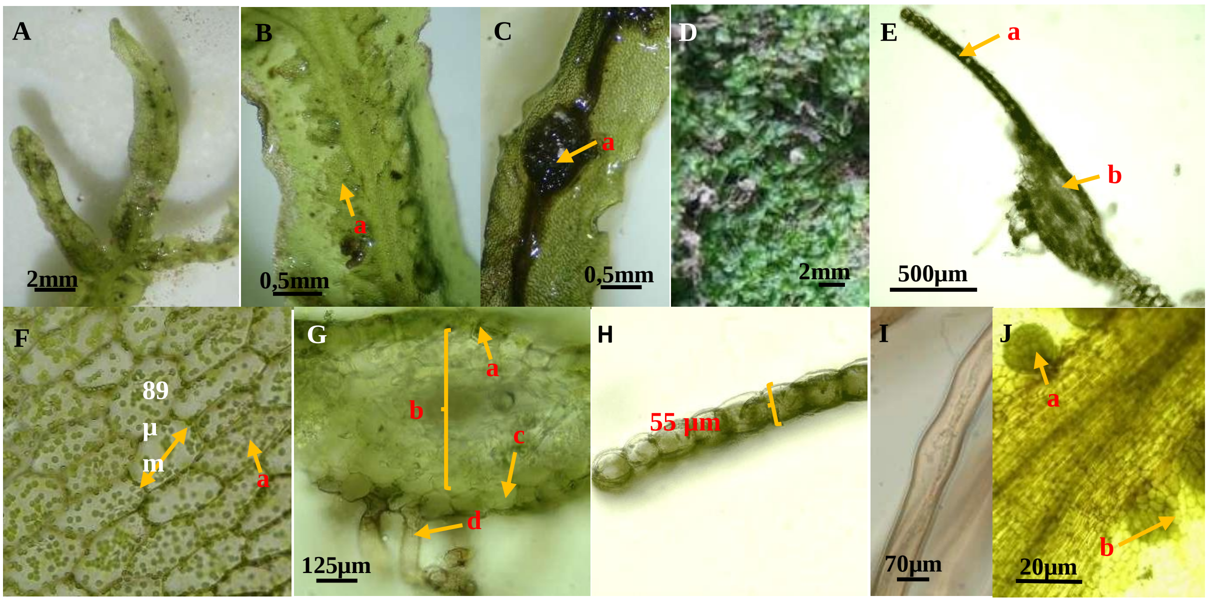


**Figure 9.** Morphology and Anatomy of *Metzgeria furcata* (L.) Dumort. (A) Dorsal Thallus, (B) Ventral Thallus; a) Lobule, (C) Dorsal Thallus; a) Gemma Cup, (D) Liverworts Habitus, (E) Thallus Cross Section; a) Thallus Margin; b) Thallus Median, (F) Thallus Longitudinal Cross Section; a) Chlorophyll, (G) Thallus Median Cross Section; a) Dorsal Epidermis; b) Storage Region; c) Ventral Epidermis; d) Smooth Rhizoid, (H) Thallus Margin Cross Section, (I) Smooth Rhizoid, (J) Thallus Ventral Longitudinal Cross Section; a) Archegonia (Sporophyte); b) Involucre.

there is a large and conspicuous air space (Fig. 7E(b)); no pores. 7E(b)); lacking gemma cup, midrib on median thallus (Fig. 7D(a)); assimilation layer and *storage region* layer are indistinguishable (Fig. 7E), one of the cells is ±25 µm in diameter (Fig. 7G), thallus slices of reticulate sporophyte protrusions in the center is the place of sporophyte production with a diameter of 1 mm (Fig. 7C) (characteristic of March class). 7C) (characteristic of the Marchantiopsida class), sporophytes ±957 µm in diameter (Fig. 7C); sporophytes are protected by sterile cells (Fig. 7F).

**Ventral surface of** light green **thallus** slightly shiny (Fig. 7B); single rough white rhizoid (Fig. 7B (b)) or papillose commonly referred to as peg rhizoids that are incompletely thickened on their walls (Fig. 7H), reticula-shaped sporophyte protrusions, 101 µm in diameter (Fig. 7B(a) & C); anatomically the ventral layer, the ventral epidermis (Fig. 7E (g)) is composed of round and neat cells, there is a rhizoid peg parallel to the epidermis (Fig. 7E). Terrestrial habitat on clay type soil (Fig. 7D) was found only at station 1.

***Metzgeria furcata*** **(L.) Dumort.**

**Thallus** small transparent; composed of 1 layer of cells (characteristic of liverworts with simple thallus); small; light or dark green shiny; 0.5 - 2 cm long; 2-3 mm wide (Fig. 9A); thallus not narrowed towards the tip of the thallus, fronded; thallus surface not notched; no reticulate pattern; creeping growth path; branching (Fig. 9A); and stacked not rosette (Fig. 9D). **Dorsal surface of** large gammae on shoots (Norden et al., 2015), has no pores, small hairs on the margins, and the dorsal surface is along the median thallus (Fig. 9C), the gammae are easily detached and can grow into new plants. The **ventral surface of** the midrib is composed of 4 - 8 rows of cells, curved and wavy (lobule), the same color as the thallus, like scales but facing sheets (Fig. 9B). **Rhizoid** along the midline of the thallus; single; transparent; very small (Fig. 9I), *involucre* in the center of the thallus (Fig. 9J(b)). 9J(b)). **Archegonium and antheridium** are located on the ventral surface of the thallus (Fig. 9J), and the sprout is not produced in the thallus. This species smells of leaves, and when picking it up, there is an itchy feeling on the hands.

**The arrangement of the thallus layer** in cross section is ±55 µm high (Fig. 9H) and longitudinal section is ±89 µm in diameter (Fig. 9F). Each cell contained light green oval- shaped chlorophyll (Fig. 9F(a)). The **midrib cell arrangement is** rudimentary, consisting of a dorsal epidermal layer that is fused with the cells that make up the edge, a second layer of *storage region*, and ventral epidermal layer parallel to the smooth rhizoid (Fig. 9G), straight (Fig. 9I), single, brownish in color, midrib is composed of 2 rows of wide cells and this median layer has cells arranged vertically (Fig. 19J). Terrestrial **habitats** on soil and epiphytes on rocks and pieces of wood (Fig. 9D) were found at stations 1.

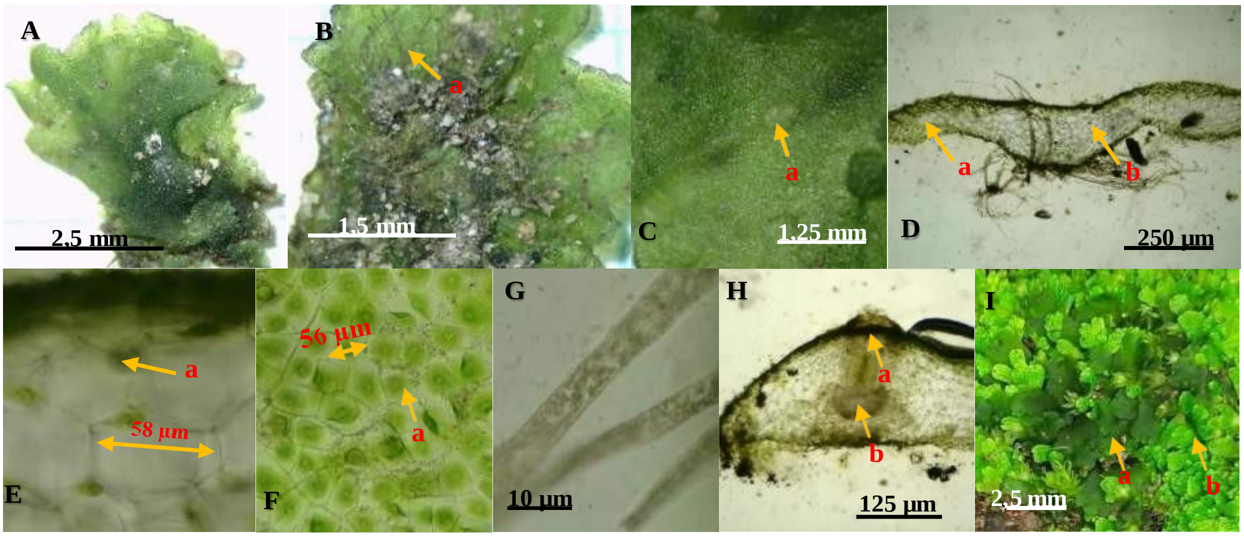


**Figure 10.** Morphology and Anatomy of *Aneura maxima* Schiffn. (A) Dorsal TalusThallus, (B) Ventral TalusThallus; a) Rhizoid, (C) Pores, (D) Cross section of TalusThallus; a) Edge wing; b) oil body, (E) Storage region; a) Chlorophyll, (F) Dorsal Longitudinal Section; a) Chlorophyll; (G) Rhizoid Peg; (H) Sporophyte Area; a) Pore; b) Sporophyte, (I) Liverworts Habitus; a) *Aneura maxima* Schiffn; b) *Cyathodium Smaragdinum*..

***Aneura maxima*** **Schiffn**

**Thallus of** ***Aneura maxima*** small, ±10 mm wide; slightly fleshy; transparent dark green in color (Fig. 10A); indistinctly porous (Fig. 10C(a)); not shiny; dichotomous branching; irregular thallus edge; small protruding spheres found; (gb. 10A); composed of 3 indistinguishable cell layers (characteristic of simple thallus liverworts) consisting of the uppermost chlorophyll- covered epidermis layer (Fig. 10E), ±37µm in height. 10E), ±37µm high, ±56 µm in diameter (Fig. 10F), porous (Fig. 10C); the second layer of cells is larger than the cells of the upper layer, ±58 µm in diameter, transparent white in color, oil bodies are present (Fig. 10D (b)) and there are 1 chlorophyll organelle per cell; the third layer can be called the lower epidermis, parallel to the appearance of the rhizoid peg (Fig. 10G).

Black or white **rhizoids** spread on the ventral thallus (Fig. 10B(a)). This species lives attached to rocks or terrestrial on the ground, if taken using a cutter it will release sticky mucus. *Aneura maxima* is composed of three cell layers in cross section (Fig. 10D), but only one cell layer in longitudinal section (Fig. 10G). The **pore on the dorsal surface** is connected to the sporophyte channel (Fig. 10 H(b)), the sporophyte is hemispherical, grey brown in color. A **distinctive feature of** this species can be seen in the cross section (Fig. 10D), where the edge of the thallus forms a wing, which is different from the cross section of *Aneura pinguis* (Buczkowska et al., 2006).

The distinguishing characteristics of each species are supporting aspects of diversity and kinship between species. The differences in these characters include the genus *Marchantia*, which has differences in the shape of the gametangia, the edge of the thallus, the reticular pattern, the ventral scales, and the shape of the pores (Alcaraz et al., 2018; Bowman et al., 2017; Heinrichs et al., 2005; Söderström et al., 2016). The shape of the thallus of the 9 species is almost the same but in *Dumortiera hirsuta* it is covered with hairs (Akiyamai et al., 2003; Forrest et al., 2011), *Cyathodium smaragdinum* many reticular patterns on the dorsal surface to the edge of the thallus and pores in the form of a pentagon (Rahmadani et al., 2023; Srivastava & Dixit, 1996), *Wiesnerella denudata* forms a small rounded antheridia at the tip of the colorful thallus and the tip of the thallus has additional reniform (Huang et al., 2012; Sharma & Bhagat, 2017). Whereas *Riccia treubiana* has sporophyte protrusions with 4 reticular patterns on the ventral surface (Gradstein, 2011), *Metzgeria furcata* is composed of 1 layer of cells, fronds, and lobules (Fuselier et al., 2009; Norden et al., 2015), *Aneura maxima* is slimy and the thallus is irregular (Bączkiewicz et al., 2016).

The distribution of thallus liverwort was found to be spread over 3 field locations in the northern slope of Mount Ungaran, namely the first location of Nglimut Waterfall and Hot Springs with 9 species from Sp. 1-9, the second location of Curug Lawe Sicepit with 5 species from sp. 2; sp. 3; sp. 4; sp. 5; and sp. 8, and the third location of Kebut Teh Medini with 3 species from sp. 1; sp. 2; and sp. 5 (Table 2). The difference in the number of thallus liverwort species in each location is influenced by different environmental factors at each altitude (Table 1). Therefore, thallus liverworts can grow in high humidity conditions to support their lives, the drier the liverworts are the rarer, although some liverworts have strong resistance to extreme weather (Bowman et al., 2017). At higher elevations, thallus tends to be thicker, more intensely colored, and has variations in length and width, habitat, gametangium shape and color, and number of oil bodies. In environments with high light intensity and low humidity, thallus is more susceptible to damage and has more oil bodies, but in suitable locations, liverworts grow well and fresh.

Analysis of species location data at each station (Figure 1) shows that the species are widely distributed. The distribution of data points shows a diverse distribution of species, including *Marchantia polymorpha* species found in two stations, namely stations 1 and 2, each of which has 2 points of moss presence; *Marchantia emarginata* found in three stations, namely at station 1 there are 4 points, station 2 has 3 points, and station 3 has 2 points of l species presence; *Marchantia treubii* was found in two stations, namely stations 1 and 2, there were 1 and 2 points of presence of moss species, respectively; *Wiesnerella denudata* was found in two stations, namely stations 1 and 2, there were 3 points of presence, respectively; *Dumortieraa hirsuta* was found in three stations, namely stations 1, 2, 3, there were 1, 1, 3 points of presence, respectively. *Cyathodium smaragdinum* was found in station 1 only with 2 presence points; *Riccia treubiana* was found in station 1 only with 2 presence points; *Metzgeria furcata* was found in two stations namely station 1 and 2 with 1 and 3 presence points respectively; and *Aneura maxima* was found in station 1 only with 1 presence point.

**Ecological adaptation of thallus liverworts**

Environmental factors also shape adaptations in the form of physical expressions in the morphology of thalloid liverworts. The prominent characters and variations in each species in different places include length, width, attached habitat, dorsal or ventral thallus color, thallus margin, thallus median, thallus texture, gametangium character, and the number of oil bodies in cross section. The species *M. polymorpha*, *M. emarginata*, *M. treubii*, *Wiesnerella denudata*, and *Dumortiera hirsuta* are liverworts that are resistant to extreme environmental conditions. The form of adaptation activity is the presence of an oil body as a defense for liverwort in tense conditions (Ludwiczuk & Asakawa, 2015). Whereas the species *Cyathodium smaragdinum*, *Riccia treubiana*, *Metzgeria furcata*, *Aneura maxima* have thin and transparent bodies that can only survive in slightly wet substrate conditions and are related to the characteristics of thallus liverworts that cannot tolerate environmental stress (Crandall-Stotler et al., 2005; Duckett et al., 2014). Another influencing factor is the place of growth or habitat. Six species of thalloid liverwort grow epiphytically on rocks and terrestrially on soil, except for the species *Dumortiera hirsuta*, *Cyathodium smaragdinum*, and *Riccia treubiana* which only live epiphytically on rocks (Table 2).

Ecological implications for thalloid liverworts result in variations in expression, so there are different characters in each of the same species in each different location. Based on observations at higher locations the thallus tends to be thicker, more intense in color, and has variations in length and width, habitat, shape and color of the gametangium, and the number of oil bodies is more due to the form of moss adaptation to unsuitable environmental conditions. Examples of some of the character variations seen in *Dumortiera hirsuta* at 3 stations include having thallus length loc. 1 1.5-2 cm, loc. 2 0.8-1 cm, loc. 3 1-1.5 cm; thallus width loc. 1 6-12 cm, loc. 2 3-7 cm, loc. 3 3-6 cm; habitat loc. 1 terrestrial on soil, loc. 2 terrestrial on soil, loc. 3 epiphytic on rock near water; dorsal thallus color loc. 1 light green, loc. 2 and loc. 3 dark green; thallus margin of loc. 1 light green and flat, loc. 2 green and slightly wavy, loc. 3 light brown and slightly wavy; oil body count loc. 1 < 10, loc. 2 < 15, loc. 3 < 20; and thallus texture loc. 1 dry, crispy and the white hairs on the thallus surface are very visible, loc. 2 slightly wet, crunchy and slightly visible hairs, loc. 3 is wet, very easily torn, and hairs are not visible. The difference seen in *Marchantia polymorpha* is that the thallus edge of loc. 1 dark green slightly wavy and loc. 3 dark brown very wavy; variations in *Marchantia emarginata* are in the color of the gametangium loc. 1 green, loc. 2 green yellow, brick red, and brown, loc. 3 green, yellow, brown, and black; variation on the margin of *Marchantia treubii* loc. 1 light green flat, loc. 2 slightly wavy yellow; and variation in ventral coloration of *Wiesnerella denudata* loc. 1 greenish purple and loc. 2 dark purple.

The distribution of thalloid liverworts in the Java region includes Ungaran, Central Java, the families Marchantiaceae, Aneuraceae, Dumortieraceae, and Cyathodiaceae (Utomo, 2022); Limbangan Central Java there are families of Aneuraceae and Wiesnerellaceae (Ergiana et al., 2013); Klaten Central Java there are families of Cyathodiaceae and Ricciaceae (Sujadmiko & Amalia, 2022); the slopes of Mount Prau in Central Java contained the families Cyathodiaceae, Marchantiaceae, Radulaceae and Ricciaceae (Lianah et al., 2021); the forest area of Mount Bromo in East Java contained the families Marchantiaceae, Dumortieraceae, and Metzgeriaceae (Putri et al., 2024); Batu and Mojokerta, East Java, where the families Marchantiaceae and Aneuraceae are found (Samti et al., 2016); and Tulungagung East Java there are families of Marchantiaceae, Dumortieraceae, Cyathodiaceae (Febriansah et al., 2019); Cibodas West Java there is a genus Cyanthodium (Rahmadani et al., 2023); Situ Gunung Sukabumi National Park, West Java, where the families Marchantiaceae and Dumortieraceae were found (Pasaribu et al., 2022); Bandung, West Java, where Ricciaceae and Marchantiaceae families were found (Putri et al., 2023); Mount Halimun Salak area of West Java contained the families Aneuraceae, Metzgeriaceae, Marchantiaceae, Dumortieraceae, and Dumortieraceae (Haerida & Gradstein, 2012).

In addition to Java, liverworts with callus are distributed in Bali, including the families Aneuraceae, Metzgeriaceae, Marchantiaceae, Ricciaceae, and Wiesnerellaceae (Haerida, 2017); the Taupe Forest area of West Sulawesi has the Aneuraceae and Marchantiaceae families (Eman et al., 2022); Pontianak Kalimantan has families of Aneuraceae and Marchantiaceae (Paryono et al., 2017); Aceh there are families of Marchantiaceae and Dumortieraceae (Raihan et al., 2018); etc.

## CONCLUSION

Exploration of thalloid liverworts in the Mount Ungaran area at 3 research sites, found 9 species of thallus liverworts consisting of 5 families with 7 species belonging to the Marchantiopsida class, namely *Marchantia polymorpha L.; Marchantia emarginata Reinw,* Blume et Nees.*; Marchantia treubii* Schiffn; *Wiesnerella denudata* (Mitt.) Steph.*; Dumortiera hirsuta (SW.) Nees; Riccia treubiana Steph.; Cyathodium smaragdinum* Schiffn., *and 2 families with 2 species belonging to the Jungermaniopsida class namely Metzgeria furcata* (L.) Dumort., and *Aneura maxima* Schiffn. The presence of liverworts is spread across the 3 research stations, with differences in the number of species at each station most likely influenced by variations in environmental conditions.

## SUGGESTIONS

Future research can be carried out by expanding the study area to other zones on Mount Ungaran to get a more complete picture of the diversity, kinship between species of thalloid liverworts throughout the mountain area, and adaptation of liverworts in the mountain environment, by adding molecular characters. In addition, research on the potential utilization of thalloid liverwort also needs to be improved, namely by testing the levels of secondary metabolite content so that it can be used for the development of new medicines.

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