NUR SAIDATUL ATIQAH BINTI MD SAHIMI MASTER OF SCIENCE 2025

SPECIES RICHNESS AND COMPOSITION OF LIVERWORT (MARCHANTIOPHYTA) IN THREE DIFFERENT FOREST TYPES IN TERENGGANU, PENINSULAR MALAYSIA

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NUR SAIDATUL ATIQAH BT MD SAHIMI

Thesis Submitted in Fulfilment of the Requirement for the Master of Science
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Dedicated this thesis to:

My all and my anchor throughout the storm & turbulence:

Ayah (Md Sahimi b. Idris), Mak (Sholiah binti Haji Abdullah),

Brothers (Wafiuddin, Yusri Sabhi, Syaqroni, Atiqullah) and sisters (Hidayah, Wahidah, Izyani),

Family & my husband (Amirrul Haiqal),

My supervisor, Prof Madya Dr Lee Gaik Ee,

My senior, Kak Elizabeth Pesiu & others.

I owe you guys, big time

Thanks a lot

May Allah bless

Abstract of thesis presented to the Senate of Universiti Malaysia Terengganu in fulfillment of the requirements for the Master of Science

SPECIES RICHNESS AND COMPOSITION OF LIVERWORT (MARCHANTIOPHYTA) IN THREE DIFFERENT FOREST TYPES IN TERENGGANU, PENINSULAR MALAYSIA

NUR SAIDATUL ATIQAH BINTI MD SAHIMI

APRIL 2025

Main Supervisor : Assoc. Prof. Lee Gaik Ee, Ph.D

School/Institute : Institute of Tropical Biodiversity & Sustainable Development (IBTPL)

A study on liverwort diversity (Marchantiophyta) across three different forest types in Terengganu, Peninsular Malaysia was conducted. This study aims to identify, describe, and illustrate all the liverwort species collected from one-hectare plot in lowland dipterocarp forest (Belukar Bukit Recreational Forest), mangrove forest (Pulau Telaga Tujuh) and heath forest (Jambu Bongkok Forest Reserve). It also aims to construct a taxonomic key and evaluate the species richness of liverwort that occur in each forest type. A total of 373 specimens consisting of 43 species from 14 genera, and five families were recorded in Belukar Bukit Recreational Forest, 121 specimens, 15 species from nine genera, three families in Pulau Telaga Tujuh, and 51 specimens, 17 species from nine genera and two families were recorded in Jambu Bongkok Forest Reserve. The Sorensen similarity index between the three different forest types shows a low similarity percentage.

Keywords: Liverwort, Diversity, Heath, Mangrove, Plot

Abstrak tesis yang dikemukakan kepada Senat Universiti Malaysia Terengganu sebagai memenuhi keperluan untuk Ijazah Sarjana Sains Penyelidikan

KEKAYAAN SPESIES DAN KOMPOSISI LUMUT HATI (MARCHANTIOPHYTA) DALAM TIGA JENIS HUTAN BERBEZA DI TERENGGANU, SEMENANJUNG MALAYSIA

NUR SAIDATUL ATIQAH BINTI MD SAHIMI

APRIL 2025

Penyelia : **Assoc. Prof. Lee Gaik Ee, Ph.D**

Pusat Pengajian/Institut : **Institut Biodiversiti Tropika dan Pembangunan Lestari (IBTPL)**

Kajian tentang kepelbagaian lumut hati (Marchantiophyta) dalam tiga jenis hutan berbeza di Terengganu, Semenanjung Malaysia telah dijalankan. Kajian ini bertujuan untuk mengenal pasti, menghuraikan, dan menggambarkan semua spesies lumut hati yang dikumpul dari plot seluas satu hektar di hutan dipterokarpa tanah pamah (Hutan Lipur Belukar Bukit), hutan bakau (Pulau Telaga Tujuh) dan hutan kerangas (Hutan Simpan Jambu Bongkok). Ia juga bertujuan bagi membina kekunci taksonomi dan menilai kekayaan spesies lumut hati dalam setiap jenis hutan. Sebanyak 373 spesimen, 43 spesies daripada 14 genera, dan lima famili direkodkan di Hutan Lipur Belukar Bukit, 121 spesimen, 15 spesies daripada sembilan genera, tiga famili di Pulau Telaga Tujuh, dan 51 spesimen, 17 spesies daripada sembilan genera, dua keluarga direkodkan di Hutan Simpan Jambu Bongkok. Nilai indeks persamaan Sorensen antara tiga jenis hutan menunjukkan peratusan persamaan yang rendah.

Kata kunci: Lumut Hati, Kepelbagaian, Kerangas, Bakau, Plot

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I am grateful and thanks to Allah S.W.T. in giving His bless permission that I finally able to finish my research regarding liverwort (Marchantiophyta) flora in three different forest types in Terengganu, Peninsular Malaysia.

Special thanks to my main supervisor, Assoc. Prof. Dr Lee Gaik Ee who has guided, helps and gave moral supports in ensuring this project runs perfectly well.

I also like to express my gratitude towards my family, colleagues and individuals who had either directly or indirectly being with me throughout an inspiring journey of my postgraduate life. All the enthusiasm and support you delivered do help in completing my study.

APPROVALS

I certify that an Examination Committee has met on 14th Oktober 2024 to conduct the final examination of Nur Saidatul Atiqah binti Md Sahimi, on her Master of Science thesis entitled **"Species richness and composition of Liverwort (Marchantiophyta) in three different forest types in Terengganu, Peninsular Malaysia"** in accordance with the regulations approved by the Senate of Universiti Malaysia Terengganu. The Committee recommends that the candidate be awarded the relevant degree. The members of the Examination Committee are as follows:

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This thesis has been accepted by the Senate of Universiti Malaysia Terengganu in fulfilment of the requirement for the degree of Master of Science.

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Date:

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UMT or other institutions.

NUR SAIDATUL ATIQAH BINTI MD SAHIMI

Date 10 APRIL 2025

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Malaysia is home to a diverse number of bryophytes due to the tropical climate which favors fast and healthy plant growth. Bryophytes are the simplest and most primitive land plants (without roots, flowers, and seeds). They are dispersed by spores instead of seeds. Bryophytes are the second largest group of land plants after angiosperms. Collectively, bryophytes are divided into three main groups which are mosses (Bryophyta), hornworts (Anthocerotophyta), and liverworts (Marchantiophyta). They may grow on different substrates such as soil, rock, rotten wood, bark of trees and as epiphylls on living leaves. They are most abundant in tropical rainforests. Some bryophyte species occur in moist environments while others are found only in drier environments (Lee & Gradstein 2021).

Liverworts include about 5000-6000 species worldwide (Gradstein 2011; Lee & Gradstein 2021), and some authors suggest more than 7000 species worldwide (von Konrat *et al*. 2010a; Söderström *et al*. 2016). Most tropical liverworts occur as epiphytes in the cloud forests and rainforests. According to Sillett & Antoine (2004) and Leon-Vargas *et al.* (2006), epiphytic bryophytes have specific distribution patterns and are not randomly distributed, which can be linked to each species' microclimatic preferences. The epiphytic liverworts of the tropical rainforest, together with mosses, form distinct groups based on their ecological preferences (Kurschner & Parolly 1998). They also play a significant role in ecological and environmental indicators (Söderström *et al*. 2016).

Malaysia has a very rich flora of liverworts, with nearly 800 taxa reported (Lee & Gradstein 2021). This accounts for approximately 15% of the world's liverwort species. According to Lee *et al*. (2018), although bryophyte abundance is widespread in tropical rainforests in Malaysia, many local botanists have often overlooked their diversity. Such as in Terengganu, although this state is rich in primary and secondary forests as well as recreational forests, comprehensive taxonomic work on liverworts is still lacking. Only a limited number of studies have focused on these plants. While the vascular flora of Malaysia has received substantial attention and systematic documentation as seen in projects like the Flora of Peninsular Malaysia and Tree Flora of Sabah and Sarawak, non-vascular plants including liverworts have been relatively understudied (Lee *et al*. 2018).

This study aims to will produce a more comprehensive, reliable, updated checklist of Liverwort species for future research or references, particularly for Terengganu. Furthermore, when necessary, suitable conservation actions can also be implemented with the provided data on biodiversity, particularly on liverworts in Terengganu and Peninsular Malaysia as a whole. Additionally, thus far, there is no record of liverwort studies conducted in the mangrove and heath forests of Peninsular Malaysia. Hence, the research aims to bridge this knowledge gap by documenting the presence of liverwort species in three different types of forests which include lowland dipterocarp, mangrove and heath forests in Terengganu. Therefore, this study represents another effort to expand the knowledge of liverwort species present in Terengganu.

1.2 Objectives

This study aims to: -

1. Identify, describe, and illustrate all the liverwort species collected from three different types of forests, i.e., lowland dipterocarp forest, mangrove forest, and heath forest in Terengganu, Malaysia.
2. To construct a taxonomic key to the liverwort species that occur in each forest type.
3. To evaluate the similarity of species richness and composition of liverwort that occur in each forest type.

CHAPTER 2

LITERATURE REVIEW

2.1 Global Overview and the Importance of Liverwort (Marchantiophyta) Flora

Liverwort (Marchantiophyta) is a fascinating group of plants that belong to the species Marchantiophyta. Liverworts are one of the bryophyte groups with mosses (Bryophyta) and hornworts (Anthocerotophyta). These small, non-vascular plants can be found in a variety of habitats across the world for millions of years. They are the earliest terrestrial plant distributed worldwide and the most surviving living flora group (Slack, 2011). Liverworts are unique in their morphology and life cycle. They can be found dispersing and growing on many substrates, preferably in moist or damp environments (Schofield, 2000; Lee *et al*. 2019).

Liverworts are found in a wide range of habitats, from moist and shaded forests. They are particularly abundant in damp, moist areas such as streams, and riverbanks, as well as on soil, rocks, and tree bark. They have a flat, leaf-like structure known as a thallus, often lobed or divided. Unlike flowering plants, liverworts lack true roots, stems, and leaves. Instead, they have rhizoids, which are thread-like structures that help anchor the plant to its substrate and absorb water and nutrients. This is primarily due to their unique adaptive toleration with the surroundings, which can equilibrate air humidity (Wood, 2007). Reproduction in liverworts can occur both asexually and sexually. The sperm cells in liverworts typically require a film of water for effective movement to reach the eggs, highlighting their dependence on moist environments.

Liverwort can play several of their ecological roles and provide a little direct economic importance towards the world's ecosystem and other organisms, where most of their greatest impact is indirectly noticed by us nowadays. For instance, they can slightly reduce the erosion that occurs along the stream banks, collect and retain water in tropical forests or even from the soil crusts in deserts and polar regions. Some species such *Riccia fluitans* may be used by humans directly in aquariums as their bodies are thin with slender branches that float on the surface of water that provide shelter or flood sources for some small invertebrates and fish that need refuge and feed om them respectively (Glime, 2007).

According to Hallingbäck and Hodgetts (2000), numerous arthropods (acarinae, collembola, and tardigrades) are dependent on liverworts as habitat or as a food source, and several liverworts such as *Frullania* and *Plagiochila* are used in nest construction by birds too. It is also said that liverworts contain phenolic compounds that inhibit the growth of pathogenic fungi and bacteria. Furthermore, species diversity has a high positive correlation with forest carpet density (Glime, 2013) and this statement is also supported by Vanderpoorten *et al*. (2010) who proposed that searching for a habitat with plenty of bryophyte covers, to look up for high species richness of other organisms.

According to Bentley and Carpenter (1984), the amount of nitrogen fixed by cyanobacteria on living leaves is related to the density of the epiphyllous liverworts growing on these leaves. Thick coatings of liverworts on trees and soil may absorb significant amounts of rainwater and serve a crucial part in the forest's water balance and nutrient cycles. According to Cheah (2017), a few liverworts can be a good indicator of where they live. Because liverworts lack the protective cuticle that blooming plants have, they are extremely sensitive to changes in the moist environment and are good indicators of tiny changes or disturbances in the ecosystem (Santos *et al*. 2014).

Liverworts have been studied for their potential applications in biomonitoring, as they show sensitivity to heavy metals and air pollutants. Liverworts provide a microhabitat for a diverse range of organisms, including

insects and microorganisms, thereby promoting biodiversity. In addition, liverworts are fascinating plants that may appear inconspicuous but have ecological and economic implications. Their unique morphology, life cycle, and ability to thrive in various habitats make them vital contributors to ecosystem functioning.

2.2 Previous Studies of Liverwort (Marchantiophyta) Flora in Southeast Asia

The first worldwide checklist of liverworts and hornworts was published by Söderström et al. (2016), who reported a total of 7486 species in 398 genera and 92 families. The largest liverwort families were represented by Lejeuneaceae with 1987 taxa respectively. However, over five years later, many new genera and species have been added to the checklist mostly from the family Lejeuneaceae (Zhu & Shu, 2018; Shi *et al*. 2015; Ye & Zhu, 2018; Wang *et al*. 2016; Zhu *et al*. 2019; Gradstein *et al*. 2018; Zhu *et al*. 2018c; Zhu *et al*. 2017; Zhu *et al*. 2018b).

There were several checklists on liverworts that have been reported from different countries and regions such as in Japan (Katagiri & Furuki 2018), Taiwan (Wang *et al*. 2011), and Southeast Asia including Malaysia (Lee *et al*. 2022), Philippines (Tan & Engel 1986), Vietnam (Shu *et al*. 2017), Java Island (Gradstein 2011), Thailand (Lai *et al*. 2008), Laos (Söderström *et al*. 2020), Cambodia (Ingerpuu *et al*. 2020) and Singapore (Zhu *et al*. 2018a) as shown in Table 1. According to the checklist, Malaysia has the highest number of liverworts which are 773 species followed by Japan, with 655 species (Katagiri & Furuki 2018), and the lowest number, Laos with 66 species (Söderström *et al*. 2020). These checklists of liverwort from other countries were references for botanists to refer to the naming of the species. The differences in the number of liverwort and hornwort species could be due to the unavailability of well-access localities, and the influence of political turmoil or urbanization which affects the inventory efforts of certain countries (Söderström *et al*. 2020).

Table 2.1. The number of recorded species of liverworts according to countries

Bil	Country	Number of species	References
1	Malaysia	773	Lee *et al*. 2022
2	Japan	655	Katagiri & Furuki (2018)
3	Taiwan	512	Wang *et al*. 2011
4	Philippines	504	Tan & Engel (1986)
5	Vietnam	430	Shu *et al*. 2017
6	Java Island	430	Gradstein (2011)
7	Thailand	379	Lai *et al*. 2008
8	Laos	66	Söderström *et al*. 2020
9	Cambodia	138	Ingerpuu *et al.* 2020
10	Singapore	117	Zhu *et al*. 2018a

2.3 Previous Study of Liverwort (Marchantiophyta) Flora in Malaysia

The first collections of liverworts were made in the early 19th century on Penang Island by Nathaniel Wallich, in which 12 liverwort species were reported (Lehman 1934; Lee & Graidstein 2021). While in the second half of the 20th century, the unusual thalloid genus *Mizutania* Furuki & Z.Iwats was found on Mt. Kinabalu and later found elsewhere in Borneo and Cameron Highlands (Furuki & Iwatsuki 1989). Additional new species were reported by Japanese bryologists that collected on Mt. Kinabalu as well as in Penang Island and Cameron Highlands, Peninsular Malaysia (e.g., Inoue 1967a, 1967b; Kitagawa 1969b, 1971; Kitagawa & Kodama 1974, 1975; Kodama 1976; Lee & Gradstein 2021).

Thallose liverworts has found in Gunung Benom, Pahang (Johnson. 1958, 1972). Meanwhile, Tixier (1971, 1974, 1980) reported liverworts from Fraser Hill, Kedah Peak (Gunung Jerai), and the Cameron Highlands. Chuah-Petiot (2011) has published the first checklist of liverworts for the whole of Malaysia (Lee *et al*. 2018). While Cheah & Yong (2016), reported the study on genus *Bazzania* with a report of 11 species new to Malaysia and a key to 26 species from Peninsular Malaysia. Pòcs and Lee (2016) have listed 747 species and 42 infraspecific taxa of liverworts that are known to occur in Malaysia. According to Cheah (2017), about 106 liverwort species have been added as new to Peninsular Malaysia.

Liverwort in Malaysia represents approximately 15% of the total liverworts listed in the world checklist (Lee *et al*. 2018). Chuah-Petiot (2011) reported 718 species and 40 infraspecific taxa in 122 genera and 38 families (Lee *et al*. 2018). Besides, the first checklist comprising Malaysian Lejeuneaceae was updated with a total of 284 taxa in 30 genera (Lee *et al*. 2013). Additionally, a series on new Malaysia liverwort records by Pócs *et al*. 2014 and Pócs and Lee (2016) added a total of 24 new records. While Cheah and Yong (2016) added five new records and Pócs *et al*. (2020) added nine taxa on the epiphyllous liverworts from Sabah.

There are almost 800 species and infraspecific taxa reported in Sabah while Terengganu and Perlis were virtually unexplored (Chuah-Petiot, 2011). While Sarawak and Pahang were the second highest with more than 200 species. This may be due to the presence of higher geographical ranges providing high air humidity levels which in turn increase the liverwort diversity (Cheah, 2017). Sabah is also well known for the presence of the highest mountain in Southeast Asia, which is Mount Kinabalu. The higher geographical ranges that contain high humidity in the mountains area were favorable conditions for liverworts such as in Pahang the presence of three montane forests, Cameron Highlands, Genting Highlands, and Fraser's Hill with well-accessible roads (Chuah-Petiot, 2011; Lee & Gradstein, 2013; Pócs *et al*. 2020). Meanwhile, the lower occurrence of liverworts in Perlis, Terengganu, and Kuala Lumpur was probably due to the lower collecting density in these areas.

According to the latest checklist, Malaysia has 773 species of liverwort which make it as highest number of other countries (Lee *et al*. 2022). The largest family in Malaysia was Lejeuneacea with 312 species in 30 genera and the largest genera were *Cololejeunea*, *Bazzania,* and *Frullania*. In addition, according to the recorded species of liverworts per state in Malaysia, the greatest number of liverwort species was from Sabah with 565 species, followed by Pahang and Sarawak with 334 and 263 species (Lee *et al*. 2022). While in Terengganu, there were 62 species of liverwort as shown in Table 2.2. Most of the distributions were from the recent papers by Pesiu *et al*. (2021) and Sarimi *et al*. (2021) where they reported 51 species of liverwort. The largest family was represented by Lejeuneacea which was 44

species from 12 genera and the largest genus was Cololejeunea (Spruce) Steph. with 15 species.

2.4 Liverwort (Marchantiophyta) flora of Terengganu

According to Lee *et al*. (2019), the bryophyte flora of Terengganu consists of 255 taxa of mosses, two species of liverworts, and none for hornwort. Moss collection in Terengganu has been actively explored in the past 10 years due to several scientific expeditions organized by the Forestry Department of Peninsular Malaysia. Among them, four had been carried out in Terengganu in which 143 taxa of mosses were reported from Mount Mandi Angin (Damanhuri *et al*. 2006), 68 from Bukit Bauk (Damanhuri *et al*. 2008) and 120 from Mount Gagau (Damanhuri *et al*. 2014). However, none was reported for liverworts and hornworts.

The first species of liverworts, *Radula retroflexa* Taylor was recorded in Terengganu by Yamada (1979) which was from Kuala Berang, and one species was listed by Inoue (1984), *Plagiochila arbuscula* (Brid. Ex Lehm & Lindenb.) Lindenb (Lee *et al*. 2019). Additional two species of liverworts have been reported in Terengganu (Pocs and Lee 2016; Lee *et al*. 2018, 2019; Pesiu *et al*. 2021). First epiphyllous liverworts were reported in Terengganu which consisted of 54 species from 18 genera and seven families, while 43 liverworts were newly reported from Terengganu (Pesiu *et al*. 2021). According to Atiqah *et al*. (2023), an additional 26 liverworts were reported in bryoflora of Terengganu, which was represented by the Lejeuneacea family, with 54 species from 17 genera., followed by Lepidoziaceae with eight species and Radulaceae with seven species.

2.5 The Preferences of Lowland Dipterocarp Forest, Heath Forest and Mangrove Forest

Lowland dipterocarp forests are usually found in lowland areas and foothills up to a height of 300 m above sea level and the soil contains alluvium, lateric and podzolic. This forest has the most fertile plant community where the trees grow densely, tall, and evergreen, and consist of various types (Whitmore 1984). Typically, the trunks of the trees in this type of forest are scaly and cracked, cylindrical, long, and straight so that they can reach about 45 m high and wavy.

Heath forests generally have less fertile, highly acidic, coarse-textured soil conditions and are very different in terms of flora, structure, and physiognomy compared to lowland dipterocarp forests (Whitmore 1984). Usually, the vegetation found in the heath forest is like trees with a small diameter, dwarf, only around 20-26m high and with straight trunks. The tree canopy is low even, dense, and closed without any layering. Almost all the vegetation exhibits microphyll and sclerophylls type leaves (thick like leather) and these characteristics are the adaptation of the plant to environmental conditions that lack nutrients such as nitrogen and phosphorus (Whitmore 1984).

Mangrove forests are the most productive ecosystems with their low vegetational diversity belies a remarkable richness of associated species and trophic interactions which are the relative contributions of different sources of primary productivity and the patterns and mechanisms of their exploitation by herbivores, detritivores, and deposit feeders remains quite limited (Sousa & Dangremond 2011). They are distributed in the inter-tidal region between sea and land in tropical and subtropical latitudes which may help stabilize shorelines and reduce the devastating impact of natural disasters such as tsunamis and hurricanes (Giri *et al*. 2008). They also provide a nursing ground and breeding for marine species and a source of food, medicine, fuel, and building materials for local communities (Giri *et al*. 2008).

CHAPTER 3

METHODOLOGY

3.1 Study sites

This study was carried out from three specific forest types in Terengganu, Peninsular Malaysia which were lowland dipterocarp forest (Belukar Bukit Recreational Forest), mangrove forest (Pulau Telaga Tujuh), and heath forest (Jambu Bongkok Forest Reserve) as shown as in Figure 3.1. Terengganu is one of the states on the East Coast of Peninsular Malaysia. Geographically, this state spans from approximately 102.25°E to 103.5°E longitude and 4.0°N to 5.5°N latitude. It shares borders with Kelantan state to the north and northwest, while its southern and western boundaries connect with Pahang state. To the east, Terengganu is positioned along the South China Sea, forming a direct coastline along its eastern side, running from north to south.

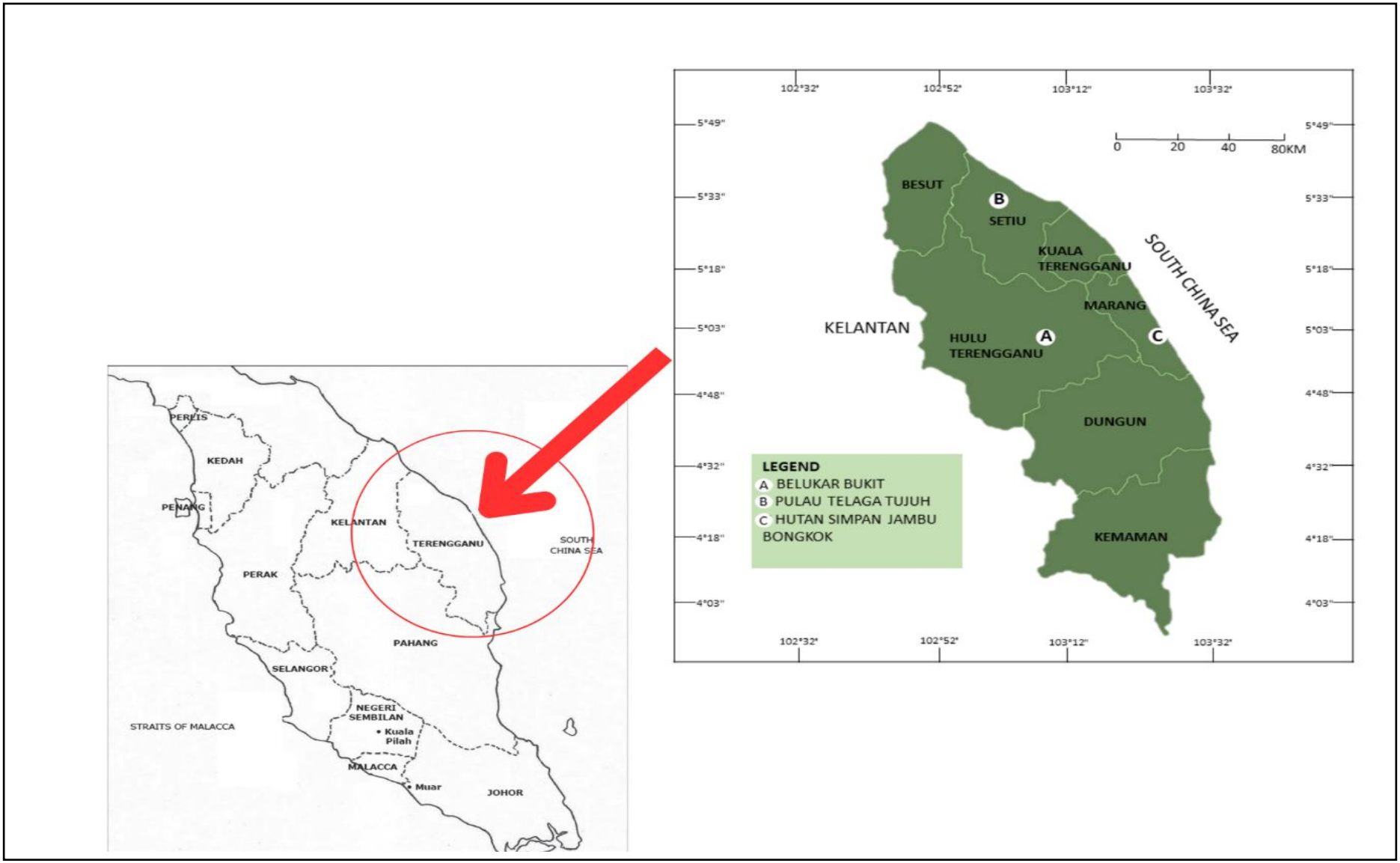

Figure 3.1 Map of Terengganu showing the localities of the study sites, A: Lowland dipterocarp forest (Belukar Bukit Recreational Forest), B: Mangrove Forest (Pulau Telaga Tujuh) and C: Heath Forest (Jambu Bongkok Forest Reserve).

3.1.1 Lowland Dipterocarp Forest, Belukar Bukit Recreational Forest

Belukar Bukit Recreational Forest (Figure 3.2) is located in Hulu Terengganu, Terengganu. It is categorized as a lowland dipterocarp forest and is known as a recreational area with waterfalls (Roslan *et al*. 2016). This forest is categorized by dense, tall, evergreen trees of various species (Whitmore 1984). According to Whitmore (1984), lowland dipterocarp forests are typically found in lowland areas and foothills at 300 meters above sea level. The soil in this forest is composed of alluvium, lateric and podzolic soil. In this forest, the tree trunks are typically scaly and cracked, cylindrical, long, and straight in shape, allowing them to reach a height of about 45 meters.

The presence of cauliflory and ramiflory are common phenomena features of the vegetation in this forest. Additionally, large woody climber's herbaceous plants, and epiphytic palms are frequently found on the forest floor, consisting of shade-loving such as *Iguanura* and *Pinanga* (Whitmore 1984). The primary tree family that dominates lowland dipterocarp is Dipterocarpaceae particularly the genera *Anisoptera* (Mersawa), *Shorea* (Balau), *Dipterocarpus* (Keruing), and *Parashorea* (Meranti). For this study, the elevation of the forest were 90 meters – 150 meters that has been studied and the temperatures were recorded at 26 ºC – 28 ºC. Lastly, the substrates that were chosen were on tree trunk, on small branches and on leaves (epiphylls). All the references have recorded while collecting the samples.

Figure 3.2 Belukar Bukit Recreational Forest

3.1.2 Mangrove Forest, Pulau Telaga Tujuh

Pulau Telaga Tujuh (Figure 3.3) is located within the lagoon of Setiu Wetland in Terengganu (Rohani *et al*. 2017). The major vegetation type in this area is mangrove (Rohani *et al*. 2017). Mangrove forests are characterized by their unique tangle of prop roots. According to Sousa & Dangremond (2011), mangrove forests are among the most productive ecosystems. Despite their low vegetational diversity, these ecosystems host a remarkable richness of associated species and trophic interactions.

Research on mangroves often focuses on understanding the contributions of different sources of primary productivity and the patterns and mechanisms by which herbivores, detritivores, and deposit feeders exploit these resources. Mangroves have a circumtropical distribution and are typically found in the intertidal regions between the sea and land within tropical and subtropical latitudes. They play a crucial role in stabilizing shorelines and reducing the devastating impact of natural disasters such as tsunamis and hurricanes (Giri *et al*. 2008). Additionally, they also provide nursing and

breeding for marine species and provide local communities with resources such as food, medicine, fuel and building materials (Giri *et al*. 2008).

The elevation that has been studied for this forest type were 10 meters - 35 meters only. As we know this forest was closed to the sea, so the elevation was not too high. While the temperatures that have been recorded were 29 ºC – 33 ºC and the substrates that were found were only on tree trunk and branches.

Figure 3.3. Pulau Telaga Tujuh

3.1.3 Heath Forest, Jambu Bongkok Forest Reserve

Jambu Bongkok Forest Reserve (Figure 3.4) is located in Marang, Terengganu. The presence of *Shorea materialis* holds significant ecological and botanical importance, particularly for heath forests (Jamilah *et al*. 2011). Heath forest is generally characterized by their lower fertility, high acidity, and reliance on specific soil conditions (Jamilah *et al*. 2011). The forest has small-diameter plants, dwarf trees and a low tree canopy without distinct layers. The elevation that has been studied were 10 meters - 15 meters, while the temperatures were 28 ºC – 32 ºC. The samples that have been found were on tree trunk and branches.

According to Whitmore (1984), heath forests differ significantly from lowland dipterocarp forests in terms of their flora, structure, and physiognomy. In heath forests, the vegetation is typical with small diameter and dwarf trees, only around 20-26 meters high and straight trunks. Most vegetation in heath forests is adapted to nutrient-poor environmental conditions, particularly low nitrogen and phosphorus levels (Whitmore 1984). Several plant species in heath forests include small climbing trees such as early rattan (*Flagellaria idica*), and *Hydinophytum formicarum* as well as species with leaves that grow obliquely and vertically such as *Agrostistachys longifolia*, *Gluta beccarii*, *Ploiarium alternifolium* (Whitmore 1984).

Myrtaceae is the main family found in heath forests, especially the genera *Tristania* and *Syzygium* apart from the family Dipterocarpaceae such as *Shorea albida* (Alan batu), *S. pachyphylla* (Kukup) and *S. scabrida* (Meranti tembalang) (Bruning 1973). In addition, the common tree species in heath forests include *Casuarina nobili*s (Ru), *Cotylelobium urckii* (Resak durian) and several shrubs such as *Antidesma puncticulatum* (Gunchar) and *Baccaurea bracteata* (Rambai).

Figure 3.4 Jambu Bongkok Forest Reserve

3.2 Materials and Methods

The tools and equipment used to collect the liverwort samples include waterproof markers, a field notebook, 10× and 20× hand lenses, for closer examination, small and sturdy paper bags, for specimen storage, plastic bags for protection during rainy conditions, and sharp collecting knife for sample collection.

3.2.1 Fieldwork and plot-based inventory

In each study site, a plot of one hectare was established. Firstly, the temperatures and humidity were recorded, and the numbers of tree also were surveyed before the plot was established. A compass, and warning tape were used to mark the plot boundaries. A small knife was used to carefully remove the liverworts together with a substrate that was attached from the substrate layer such as on tree trunks and soil. The exception was made for large, fixed rocks and solid surfaces. Several paper bags were used to collect the samples, and different species were packed separately into different paper bags unless the samples were too small to be observed and distinguished among them in the field. All relevant data, including information about the type of substrate, elevation, and collection date, were recorded using a permanent marker pen. A global positioning system (GPS) device was also used to provide the exact location of each collected liverwort in the field.

3.2.2. Herbarium Specimen Preparation

After the sampling, all the liverwort samples were brought to Makmal Ekologi of Universiti Malaysia Terengganu for the drying process at room temperature (27ºC). To preserve the liverworts, the samples were stored in their original paper bag, and each paper bag was left on the table for several days/weeks until the samples were completely dry. Subsequently, these dried samples were transferred into their respective herbarium packets. Small samples of fertile plants were put in tiny paper envelopes within the standard-size envelope to avoid them from being lost. A label containing information about the location, genus and species name, substrate, and

collection date was glued to each herbarium packet. All specimens were kept in the Herbarium of Universiti Malaysia Terengganu (UMTP).

3.2.3. Identification, illustration, and description

Temporary slides of leaves and stem sections of liverworts were prepared for use during the identification process. Firstly, a liverwort was selected from the herbarium collection. The liverwort was then put into a petri dish filled with water for 3-4 minutes until it fully expanded and moistened. Next, the plant was transferred onto a glass slide and a few drops of water dripped onto the glass slide. Subsequently, some leaves were carefully selected and separated using forceps. The leaves were detached by gently pulling them towards the base to prevent them from breaking in half. The separated portion of the leaf was moistened with a few drops of water and covered with a glass cover slip. The temporary slides containing the leaves were then observed under the microscope with transmitted light.

All samples were identified up to the species level using taxonomic keys including illustrations from various books, journals, and monographs for example, Guide to the Genera of Liverworts and Hornworts of Malaysia (Lee & Gradstein 2021), Taxonomic Revision of Lejeuneacea subfamily Ptychanthoideae (Marchantiophyta) in China (Wang *et al*. 2016), Plagiochila (Hepaticae, Plagiochilaceae) in China (So 2001) and Epiphyllous Liverworts of China (Zhu & So 2001). Each specimen was observed on a temporary slide under a dissecting and compound microscope during the identification process. Important microscopic parts including leaf lobes, lobules, underleaves, leaf lobe cells (apical, median, and basal) oil bodies (if present), gynoecia, and androecia were also observed under the compound microscope.

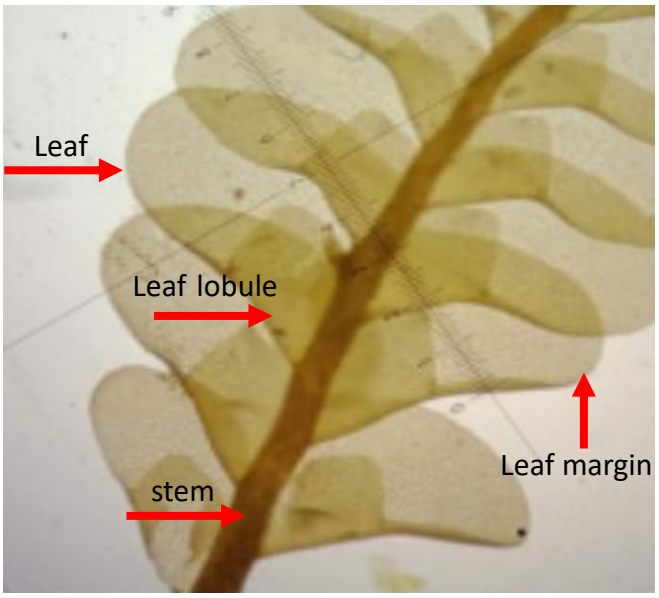

Figure 3.5. Example of liverwort structure used for identification (under microscope)

Illustrations were prepared using a Lucida drawing tube attached to an Olympus CX21 microscope. For each liverwort species studied, a description was prepared, with the diagnostic characteristics of the species, including their habits, gametophyte, and sporophyte characters (if present). Furthermore, the specific microhabitat for each liverwort in the area was documented, for example on roots, trunks, branches, twigs of small trees, rotten wood, rocks, and soil especially along the river's edge.

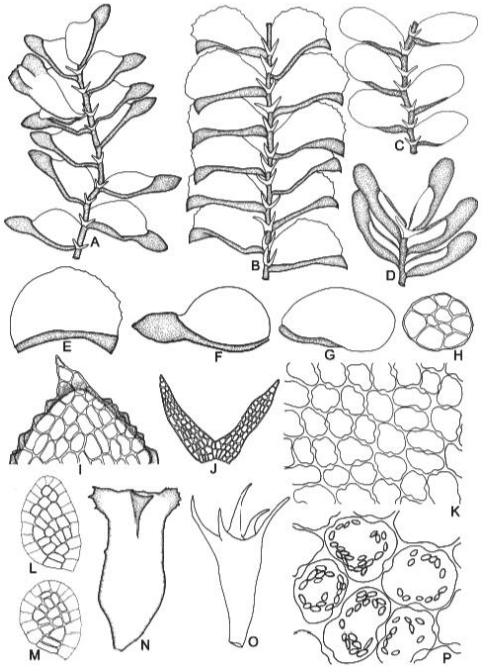

Figure 3.6. Example of liverwort for illustration (Source: Lee & Gradstein 2021)

3.3 Data analysis

Sorensen similarity coefficient used to evaluate the similarity of species is qualitatively according to the presence or absence of a species in these three different forest types (Brower *et al*. 1997).

$$\mathbf{S_S} = \frac{2a}{2a+b+c}$$

S_s = Sorensen similarity coefficient

a = number of species found in both areas

b = number of species found only in one area

c = number of species found only in area two

CHAPTER 4

RESULTS

4.1 Species Richness and Composition of Liverwort (Marchantiophyta) Flora

The total number of species in study sites is 69 species including in Belukar Bukit Recreational Forest are 61 species from four families and 17 genera, while in Pulau Telaga Tujuh are 26 species from three families and 10 genera. Unfortunately, Jambu Bongkok Forest Reserve has 24 species from two families and nine genera (Table 4.1). The largest family recorded in the study areas was Lejeuneacea with 53 species from the total number of species and followed by Radulaceae with a total of 10 species while Notoscyphaceae represented only by a single species and the remaining family Plagiochilaceae had five species (Figure 4.1)

Table 4.1 A summary of liverwort taxon according to study sites

study sites	Belukar Bukit Recreational Forest		Pulau Telaga Tujuh		Jambu Bongkok Forest Reserve	
Family	Genus	Species	Genus	Species	Genus	Species
Lejeuneacea	14	47	8	23	8	22
Notoscyphaceae	1	1	1	1	-	-
Plagiochilaceae	1	3	1	2	-	-
Radulaceae	1	10	-		1	2
Total	17	61	10	26	9	24

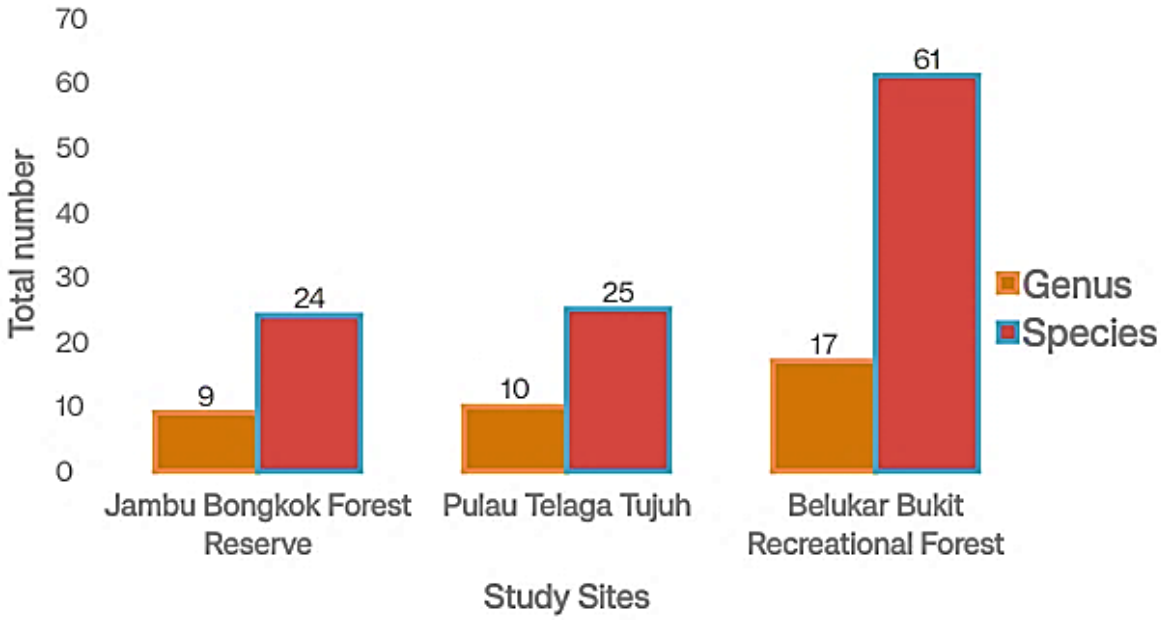

Figure 4.1. Total number of genera and species in study sites.

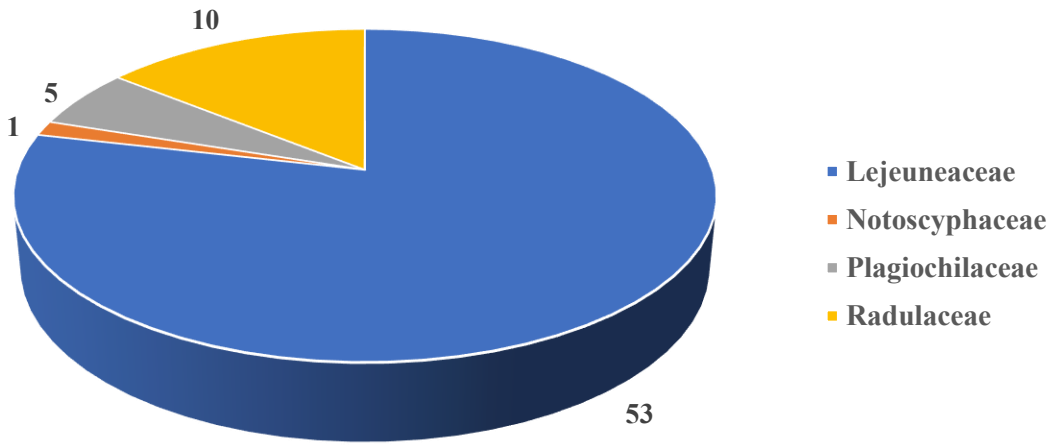

Figure 4.2. Total number of liverwort species according to families in study sites.

4.2 Key to the Genera and Species of Liverwort (Marchantiophyta) Flora

The classification of liverwort species recorded from Belukar Bukit Recreational Forest, Jambu Bongkok Forest Reserve, and Pulau Telaga Tujuh into genera, families, and higher order follows the World Checklist of Hornworts and Liverworts (Söderström *et al*. 2016) and Guide to the Genera of Liverworts and Hornworts of Malaysia (Lee & Gradstein 2021).

MARCHANTIOPHYTA

Jungermanniopsida Stotler & Crand-Stott.

Jungermanniales H.Klinggr

Notoscyphaceae

1. Notoscyphus Mitt

1. *Notoscyphus lutescen*

Plagiochilaceae Müll.Frib

2. *Chiastocaulon* Carl

2. Chiastocaulon dendroides

3. Plagiochila (Dumort.) Dumort.

3. Plagiochila bantamensis

4. Plagiochila kurzii

5. Plagiochila peculiaris

6. Plagiochila singularis

Porellales Schljakov

Lejeuneaceae Cavers

4. *Acrolejeunea* (Spruce) Steph.

7. Acrolejeunea arcuata

8. Acrolejeunea recurvata

9. Acrolejeunea sinensis

5. *Caudalejeunea* Schiffn.

10. Caudalejeunea cristiloba

11. Caudalejeunea reniloba

6. Ceratolejeunea (Spruce) J.B.Jack & Steph.

12. Ceratolejeunea aliena

13. Ceratolejeunea singapurensis

7. Cheilolejeunea (Spruce) Steph.

14. Cheilolejeunea decursiva

15. Cheilolejeunea intertexta

16. Cheilolejeunea orientalis

17. Cheilolejeunea trapezia

8. *Cololejeunea* (Spruce) Steph.

18. Cololejeunea aequabilis

19. Cololejeunea appressa

20. Cololejeunea ensifera

21. Cololejeunea equialbi

22. Cololejeunea falcata

23. Cololejeunea gottschei

24. Cololejeunea haskarliana

25. Cololejeunea inflata

26. Cololejeunea inflectens

27. Cololejeunea obliqua

28. Cololejeunea pluridentata

29. Cololejeunea schmidtii

30. Cololejeunea serrulata

9. *Colura* (Dumort.) Dumort.

31. Colura acroloba

32. Colura ari

33. Colura corynophora

34. Colura inuii

10. *Drepanolejeunea* (Spruce) Steph.

35. Drepanolejeunea longicornua

36. Drepanolejeunea spicata

37. Drepanolejeunea thwaitesiana

11. Lejeunea Lib.

38. Lejeunea micholitzii

39. Lejeunea sordida

40. Lejeunea tuberculosa

12. Lepidolejeunea R.M.Schust.

41. Lepidolejeunea bidentula

13. Leptolejeunea (Spruce) Steph.

42. Leptolejeunea amphiophthalma

43. Leptolejeunea borneensis

44. Leptolejeunea epiphylla

45. Leptolejeunea maculate

46. Leptolejeunea subacuta

47. Leptolejeunea tripuncta

48. Leptolejeunea vitrea

14. Lopholejeunea (Spruce) Steph.

49. Lopholejeunea applanata

50. Lopholejeunea ceylanica

51. Lopholejeunea eulopha

52. Lopholejeunea subfusca

15. Mastigolejeunea (Spruce) Schffn.

53. Mastigolejeunea auriculata

54. Mastigolejeunea repleta

55. Mastigolejeunea virens

16. Spruceanthus Verd.

56. Spruceanthus semirepandus

17. Thysananthus Lindend.

57. Thysananthus aculeatus

58. Thysananthus auriculatus

59. Thysananthus virens

Radulaceae Müll.Frib.

18. Radula Dumort.

60. Radula acuminata

61. Radula acuta

62. Radula assamica

63. Radula cavifolia

64. Radula gedena

65. Radula iwatsukii

66. Radula kojana

67. Radula nymanii

68. Radula tjibodensis

69. Radula vrieseana

4.2.1 Key to the Genera of Liverwort (Marchantiophyta) Flora

Order: Jungermanniales

1.	Leaves almost longitudinally inserted, flat. Underleaves present……	***Notoscyphus lutescens***
1.	Leaves asymmetrical, ventral margin arched. Underleaves absent or very small …….....	**2**
2.	Leaves opposite, leaf bases connected, ventral flagelliform branches present ……	***Chiastocaulon dendroides***
2.	Leaves not opposite, leaf bases free, ventral flagelliform lacking ……	***Plagiochila***

Order: Porellales

1.	Underleaves present, lobule attached to the lobe along keel, perianth shorter and broader, with a beak ……...	**2**
1.	Underleaves absent, lobule broadly attached to stem, perianth cylindrical, truncate, without beak…….	**Radula**
2.	Leaves highly specialized, distal part not forming an inflated sac ……...	***Colura***
2.	Leaves less specialized, distal part not forming an inflated sac ……	***3***
3.	Underleaves absent ……...	***Cololejeunea***
3.	Underleaves present …….....	***4***
4.	Underleaves undivided …….....	***5***
4.	Underleaves bifid …….....	***6***
5.	Leaves with a long vitta ……	***Thysananthus***
5.	Leaves without vitta……...	***7***
6.	Intermediate thickenings in leaves 1-3 per cell wall. Perianth 3-keeled …….	***Caudalejeunea***
6.	Intermediate thickenings in leaves 0-1 per cell wall. Perianth 3-10-keeled …….....	***Acrolejeunea***
7.	Leaf lobes with scattered ocelli …….	***Lepidolejeunea***
7.	Leaf lobes without ocelli ……...	***8***
8.	Plants with blackish pigmentation in cell walls. Gynoecial innovations absent …….	***Lopholejeunea***

8.	Plants without blackish pigmentation. Gynoecial innovations present ……...	***9***
9.	Plants usually more than 2 mm wide. Epidermis cells distinctly larger than inner cells ……	***Spruceanthus***
9.	Plants smaller, less than 2 mm wide. Epidermis cells distinctly larger than inner cells ……	***10***
10.	Leaf apex acute or rounded …….....	***Drepanolejeunea***
10.	Leaf apex mostly rounded …….	***11***
11.	Underleaf margins bordered by 6 large cells …….	***Leptolejeunea***
11.	Underleaf margins not bordered by 6 large cells …….	***12***
12.	Trigones radiate, walls of leaf cells yellowish brown…….	***Ceratolejeunea***
12.	Trigones do not radiate, walls of leaf cells colorless …….	***13***
13.	Perianth immersed, obovate …….....	***Mastigolejeunea***
13.	Perianth usually different …….....	***14***
14.	Plants opaque or dull, hyaline papilla distal to the largest lobule tooth ……...	***Cheilolejeunea***
14.	Plants usually not opaque, hyaline papilla proximal to the lobule tooth ……...	***Lejeunea***

4.2.2 Key to the Species of Liverwort (Marchantiophyta) Flora

Acrolejeunea (Spruce) Steph

1.	Branching predominantly *Frullania*-type, innovations present …….	***Acrolejeunea sinensis***
1.	Branching predominantly *Lejeunea*-type, innovations absent …….	***2***
2.	Leaves imbricate, clasping the stem when dry, widely spreading, and convex when moist ……	***Acrolejeunea arcuata***
2.	Leaves densely imbricate, clasping the stem when dry, widely spreading to squarrose when moist ……	***Acrolejeunea recurvata***

***Caudalejeunea* Schiffn.**

1. Leaf lobule narrowly triangular or ovate …… ***Caudalejeunea cristiloba***
1. Leaf lobule oblong, inflated, free lateral margin ……. ***Caudalejeunea reniloba***

Ceratolejeunea (Spruce) J.B.Jack & Steph

1. Leaf lobes with basal ocelli, underleaves undivided, orbicular …… ***Ceratolejeunea aliena***
1. Leaf lobes with basal ocelli, underleaves always distant …… ***Ceratolejeunea singapurensis***

Cheilolejeunea (Spruce) Steph.

1. Leaves lobe ovate……. ***2***
1. Leaf lobes suborbicular…… ***3***
2. Underleaves distant to imbricate ……. ***Cheilolejeunea decursiva***
2. Underleaves small, bilobed, subtransversely inserted on the stem ……..... ***Cheilolejeunea orientalis***
3. Lobe broadly ovate, margin entire, dorsal margin arched ……..... ***Cheilolejeunea trapezia***
3. Lobe oblong, margin entire, dorsal margin arched ……. ***Cheilolejeunea intertexta***

Cololejeunea (Spruce) Steph.

1. Irregularly branched with 5 cortical cells and 1 medullary cell ……. ***2***
1. Irregularly branched with 6 cortical cells and 1 medullary cell ……. ***3***
2. Lobe ovate, apex rounded, margin nearly entire, dorsal margin slightly arched …… ***C.ololejeunea appressa***
2. Lobe denticulate or obtuse rounded ……. ***4***
3. Intermediate thickening absent ……... ***5***
3. Intermediate thickening 1-3 per long wall ……. ***Cololejeunea gottschei***
4. Lobule small, ovate, inflated ……. ***Cololejeunea equialbi***
4. Lobule acute, sword-like …… ***Cololejeunea ensifera***
5. Perianth obovate …… ***6***

5.	Perianth triangular obconic …….....	***Cololejeunea pluridentata***
6.	Leaves broadly ovate …….	***7***
6.	Leaves loosely imbricate ……	***8***
7.	Leaf margin is spinose ……...	***Cololejeunea haskarliana***
7.	Hyaline marginal leaf lobes ……...	***Cololejeunea inflata***
8.	Trigones distinct …….....	***9***
8.	Trigones small ……	***10***
9.	Perianth has 4 keeled (2 ventral, 2 lateral) …….	***11***
9.	Perianth with elongated and wings …….	***Cololejeunea aequabilis***
10.	Lobe oblong ovate …….	***Cololejeunea schmidtii***
10.	Lobe narrowly ovate, falcate …….	***12***
11.	Perianth obovate and papillose …….	***Cololejeunea obliqua***
11.	Perianth emergent and obovate …….	***Cololejeunea serrulata***
12	Leaf lobules with strongly involute free margin ……	***Cololejeunea inflectens***
12	Falcate ovate leaf lobes with entire or slightly denticulate margins and rounded apices …….	***Cololejeunea falcata***

Colura (Dumort.) Dumort.

1.	Leaves imbricate…….....	***2.***
1.	Leaves contiguous ……...	***3.***
2.	Lobule inflated, smooth on surface …….....	***Colura acroloba***
2.	Lobule narrowly cylindrical ……	***Colura inuii***
3.	Underleaves distant, nearly transversely inserted to the stem, deeply bilobed …….	***Colura ari***
3.	Underleaves distant, nearly transeversely inserted to the stem……...	***Colura corynophora***

Drepanolejeunea (Spruce) Steph.

1.	Perianth with horn-like keel …….	***2***
1.	Perianth with 3-5 wings …….	***Drepanolejeunea thwaitesiana***
2.	Ovate leaf lobes.…….	***Drepanolejeunea longicornua***
2.	Falcate leaf lobes ……	***Drepanolejeunea spicata***

Lejeunea Lib

1.	Underleaves distant, transversely inserted ……	***Lejeunea tuberculosa***
1.	Underleaves reniform ……	***2***
2.	Has trigones and conspicuous intermediate thickenings …….	***Lejeunea micholitzii***
2.	Leaf lobules ovate, inflated along the keel …….	***Lejeunea sordida***

Lepidolejeunea R.M.Schust.

Lepidolejeunea bidentula

Leaf lobes wide spreading, falcate, numerous and scattered ocelli. Cells are small, wall thin, and cuticle smooth. Oil bodies are absent. Lobules are ovate and inflated. Underleaves bifid. Perianths inflated, 5 keeled, the keel swollen and smooth.

Leptolejeunea (Spruce) Steph.

1.	Underleaves distant, deeply bilobed …….....	***Leptolejeunea borneensis***
1.	Leaves imbricate to contiguous …….	***2***
2.	Truncate apex of leaf lobe …….	***leptolejeunea epiphylla***
2.	Lobe obliquely oblong-ovate ……	***3***
3.	Ocelli present ……	***4***
3.	Ocelli not present …….	***Leptolejeunea vitrea***
4.	One large basal ocellus …….	***5***
4.	Scattered ocelli in leaf lobes …….	***6***
5.	Obtuse to subacute leaf apices ……..	***Leptolejeunea subacuta***

5. Oblong leaf lobes, serrate margins of leaf lobes ……..... ***leptolejeunea maculata***
6. Ocelli in a row in the middle of the leaf …… ***Leptolejeunea tripuncta***
6. Scattered ocelli in the leaf lobes lobules and underleaves ……. ***Leptolejeunea amphiophthalma***

Lopholejeunea (Spruce) Steph.

1. Underleaves imbricate to contiguous, transversely oblong ……. ***Lopholejeunea eulopha***
1. Underleaves distant, contiguous to imbricate …… ***2***
2. Perianth obovate ……. ***Lopholejeunea subfusca***
2. Perianth emergent, obovate ……..... ***3***
3. Leaf lobule bordered by 7-10 subquadrate to rectangular by only 4 cells ……..... ***Lopholejeunea applanata***
3. Leaf lobule bordered by 7-10 subquadrate to rectangular by 35 cells ……..... ***Lopholejeunea ceylanica***

Mastigolejeunea (Spruce) Schffn.

1. Underleaves obliquely spreading, imbricate …… ***Mastigolejeunea virens***
1. Underleaves obliquely spreading to slightly squarrose, imbricate ……..... ***2***
2. Intermediate thickenings scarce ……. ***Mastigolejeunea auriculata***
2. Intermediate thickenings present …… ***Mastigolejeunea repleta***

Plagiochila (Dumort.) Dumort.

1.	Plants with branches predominantly lateral intercalary ……	***2***
1.	Plants with branches lateral intercalary ……	***3***
2.	Leaves closely imbricate, horizontally spreading ……	***Plagiochila bantamensis***
2.	Leaves contiguous to slightly imbricate ……	***Plagiochila kurzii***
3.	Gynoecia terminal on main shoot with 1-2 innovations ……	***Plagiochila peculiaris***
3.	Gynoecia terminal, bracts with dentate margins, keels unwinged ……	***Plagiochila singularis***

Spruceanthus Verd.

Spruceanthus semirepandus

Plant autoicous. Intercalary branches with 28 thick-walled epidermal cells, 1-2 rows thick walled subepidermal cells. Leaves imbricates, widely spreading when moist. Lobe cell walls thickened and had large trigones.

Thysananthus Lindenb.

1.	Stem without ventral epidermis cell ……	***Thysananthus viren***
1.	Stem with ventral epidermis cell ……	***2***
2.	Leaves imbricate, asymmetrically ovate …….	***Thysananthus convolutes***
2.	Leaves imbricate, asymmetrically oblong ……..…...	***Thysananthus aculeatus***

Radula Dumort.

1.	Leaf lobe apiculate-acute at apex ……	***Radula kojana***
1.	Leaf lobe rounded, rarely obtuse at apex ……	***2***
2.	Leaf lobe orbicular, strongly concave …….	***Radula cavifolia***
2.	Leaf lobe ovate, triangular-ovate or oblong-ovate……	***3***
3.	Gemmae perpendicular borne at ventral margin leaf ……	***Radula tjibodensis***
3.	Gemmae borne at margin of leaf lobe ……	***4***
4.	Leaf incubous, ovate to broadly ovate leaf lobes with rounded apices …….....	***5***
4.	Leaf lobe falcate …….	***6***
5.	Leaf cell irregular in size …….....	***Radula gedena***
5.	Leaf cell regular in size …….....	***7***
6	Leaf lobe falcate ovate, narrowly to broadly rounded apex …….....	***Radula acuminata***
6	Leaf lobe falcate with obtuse to rounded apices …….	***Radula assamica***
7	Leaf lobule inflated…….....	***Radula nymanii***
7	Leaf lobules subquadrate …….....	***8***
8	Have trigones …….	***Radula vrieseana***
8	No trigones …….	***9***
9	Cross section of stem 6 cells thick …….	***Radula iwatsukii***
9	Cross section of stem 10 cells thick …….	***Radula acuta***

4.3 Illustrations and Descriptions of Liverwort Species

1. ***Notoscyphus lutescens*** (Lehm. & Lindenb.) Mitt. (Figure 4.3)

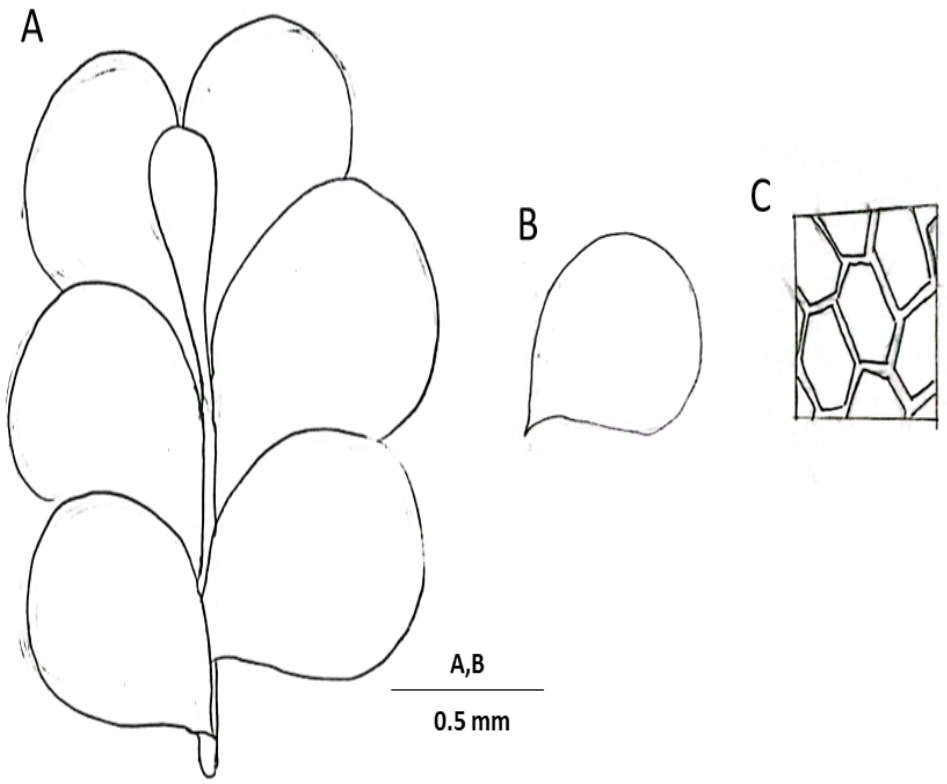

Figure 4.3. ***Notoscyphus lutescens*** (Lehm. & Lindenb.) Mitt. A: Part of plant. B: Leaf. C: Median leaf cell.

Plant dioicous with ventral-intercalary branched. Stems rigid, thick-walled. Leaves succubous, alternate, flat, and ovate, apex rounded, margins entire, insertion line not reaching dorsal midline of the stem. Cells with small trigones. Underleaves present, small, and bifid. Oil bodies not seen. Gametoecia on short ventral branches. Sporophyte not seen.

Collector and specimen number: Saidatul. 22019, 23030, 23134, 23177.

Habitat: on tree trunks, on branches

2. *Chiastocaulon dendroides* (Nees) Carl. (Figure 4.4)

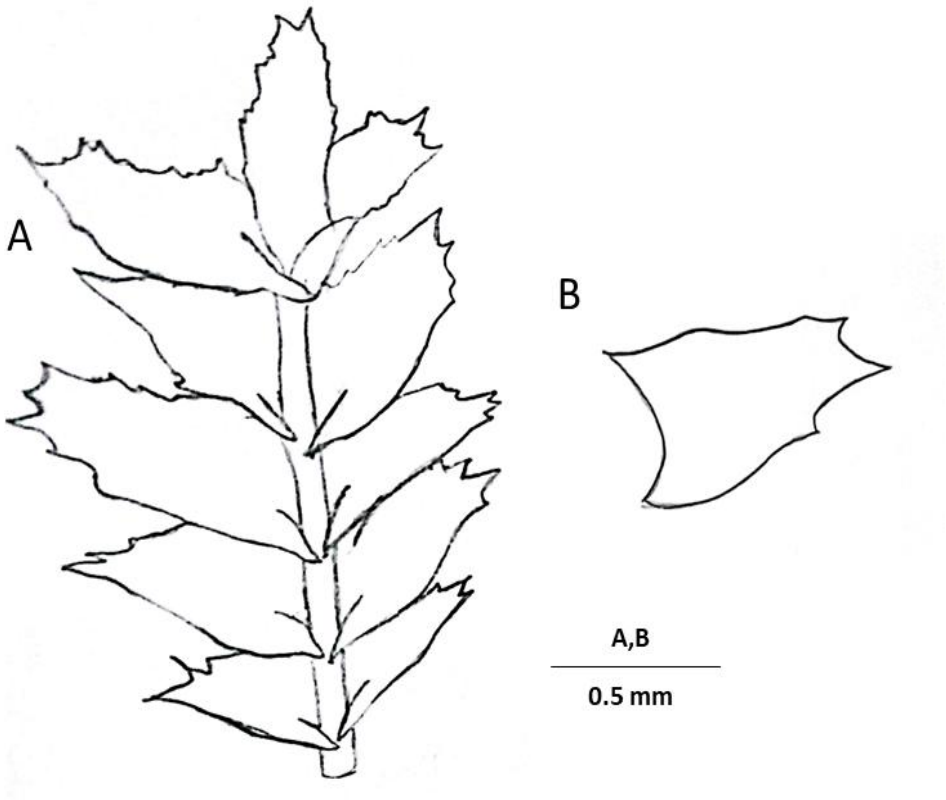

Figure 4.4. ***Chiastocaula dendroides*** (Nees) Carl. A: Part of plant. B: Leaf.

Plant dioicous with ventral-intercalary branched. Ventral branches fagelliform. Leaves alternate, orbicular, asymmetrical, margin entire. Leaf cells with small trigones, cuticle smooth. Ocelli and oil bodies not seen.

Collector and specimen number: Saidatul. 23201.

Habitat: on tree trunk

3. *Plagiochila bantamensis* (Reinw. *et al*.) Mont. (Figure 4.5.)

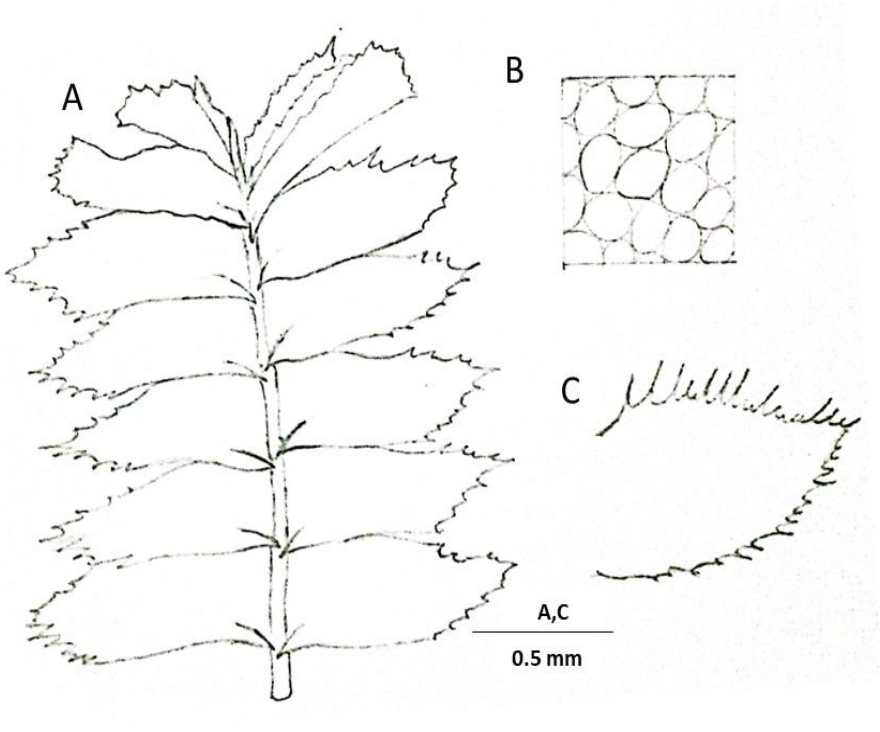

Figure 4.5. ***Plagiochila bantamensis*** (Reinw. *et al*.) Mont. A: Part of plant. B: Median leaf cell. C: Leaf.

Plants with branches predominantly lateral intercalary, cortex in 2-3 cell layers, thick wall. Leaves closely imbricate, horizontally spreading, oblong-ovate, dorsal margin straight, sparingly to densely toothed, recurved. Underleaves large, deeply bilobed with additional ciliate lobes. Oil bodies not seen. Androecia terminal, in a cluster of 2-5, bracts closely imbricate, margin entire, antheridia 1-2 per bract. Gynoecia terminal on the main shoot without innovation, bracts like stem leaves in shape, and marginal dentition. Sporophyte not seen.

Collector and specimen number: Saidatul. 23205, 23210.

Habitat: on tree trunks, on branches

4. *Plagiochila kurzii* Steph. (Figure 4.6)

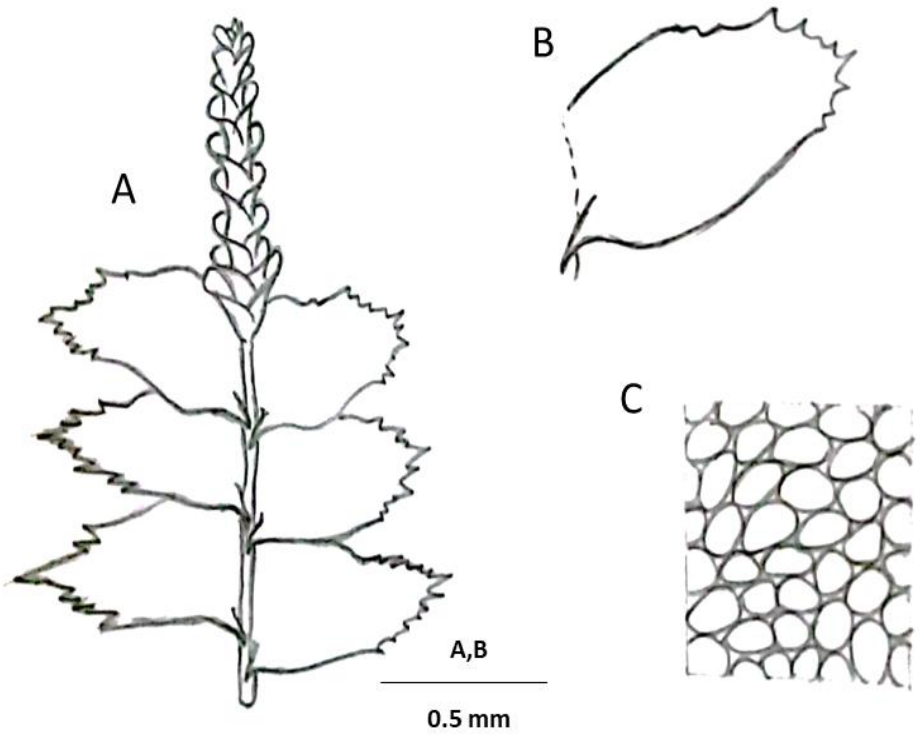

Figure 4.6. ***Plagiochila kurzii*** Steph. A: Part of the male plant. B: Leaf. C: Median leaf cell.

Plants with branches predominantly lateral intercalary, cortex in 2-3 cell layers, thick-walled. Leaves contiguous to slightly imbricate, horizontally spreading, teeth 7-9 per leaf, cuticle smooth. Oil bodies not seen. Androecia terminal and intercalary, long spicate, bracts in 12-15 pairs, loosely imbricate, base slightly inflated, margins almost entire antheridia 1 per bract. Gynoecia with 1-3 innovation. Sporophyte not seen.

Collector and specimen number: Saidatul. 22007, 22049, 23209.

Habitat: on tree trunk, on branches.

5. *Plagiochila peculiaris* Schiffn. (Figure 4.7)

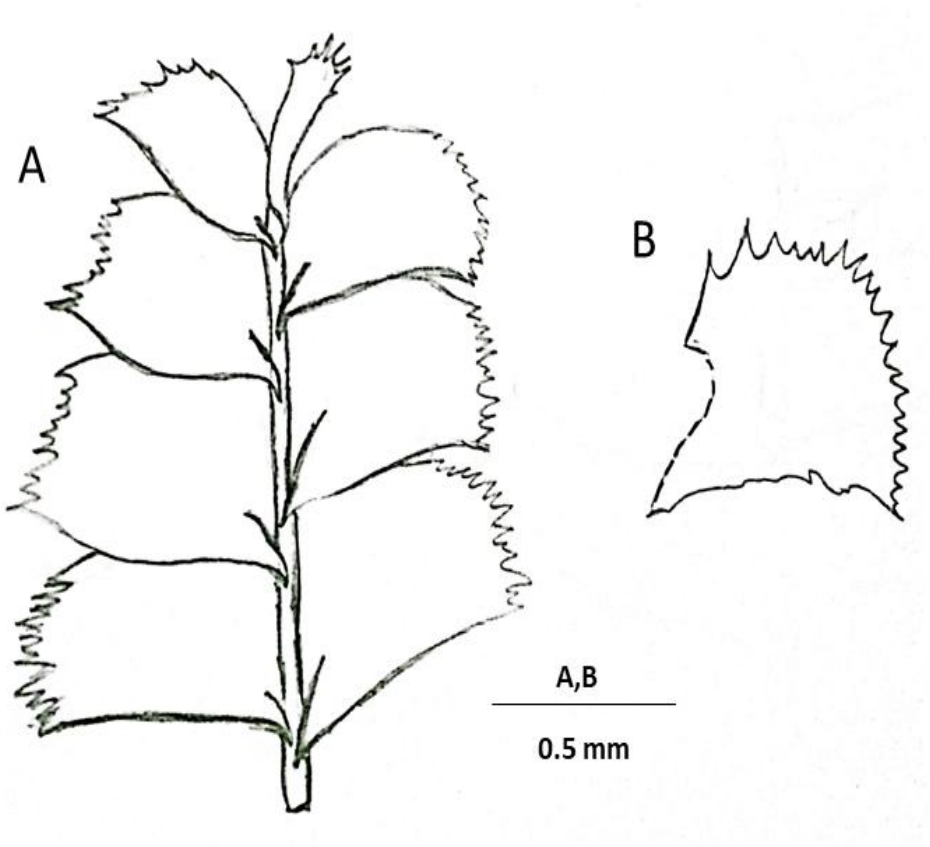

Figure 4.7. ***Plagiochila peculiaris*** Schiffn. A: Part of plant. B: Leaf.

The branches have lateral intercalary, stem with cortex 3 cell layer, thick-walled. Leaves closely imbricate, triangular, ovate, dorsal leaf margin slightly recurved, irregularly spinose dentate, ventral margin arched, walls with intermediate thickening, cuticle smooth. Oil bodies not seen. Androecia intercalary, bracts in 4-6 pairs, closely imbricate, margins slightly recurved and sparsely dentate, antheridia 1-2 per bract. Gynoecia terminal on the main shoot with 1-2 innovations. Sporophyte not seen.

Collector and specimen number: Saidatul. 22051.

Habitat: on tree trunks

6. *Plagiochila singularis* Schiffn. (Figure 4.8)

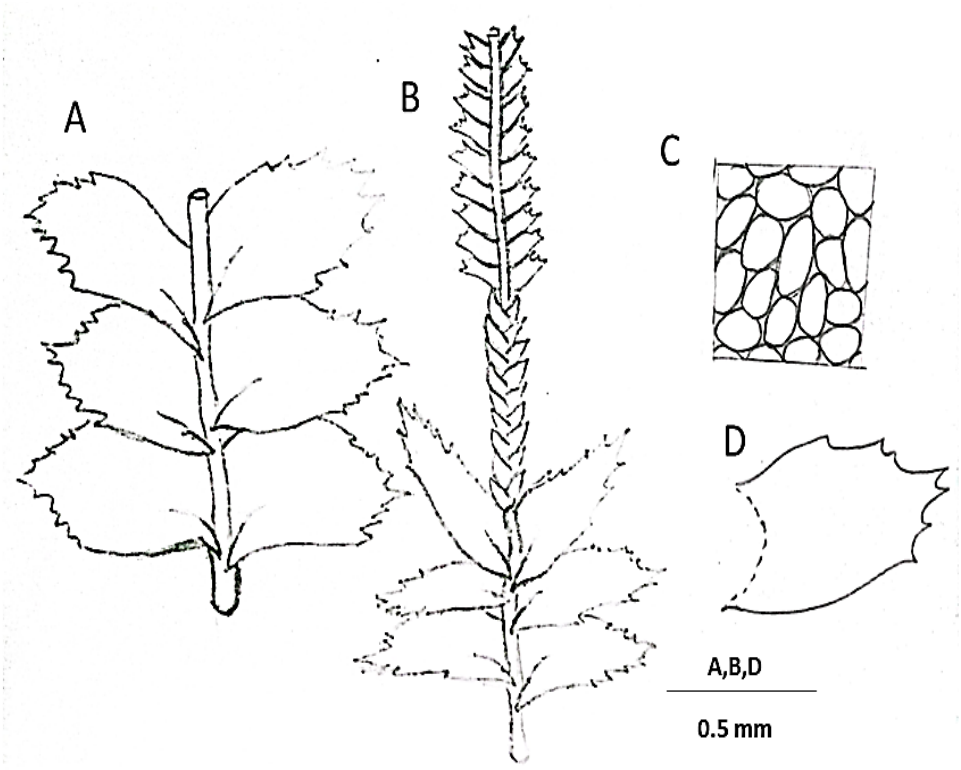

Figure 4.8. ***Plagiochila singularis*** Schiffn. A: Part of plant. B: Male plant. C: Median leaf cell. D: Leaf.

Plants with branches lateral intercalary, cortex in 2-3 cell layers, thick wall. Leaves remote to contiguous, obliquely spreading, oblong, dorsal and margin are parallel, dorsal margin entire, leaf base moderately decurrent, apex rounded, bilobed with 3-5 spinose teeth, ventral margin slightly arched, trigones small. Oil bodies not seen. Androecia with bracts in 10-12 pairs, inflated, margins irregularly dentate. Gynoecia terminal, bracts with dentate margins, perianth obovoid, slightly longer than wide, both keels unwinged. Sporophyte not seen.

Collector and specimen number: Saidatul. 22051, 22056.

Habitat: on tree trunk, on branches

7. *Acrolejeunea sinensis* (Jian Wang bis et al.) Jian Wang bis & Gradst. (Figure 4.9)

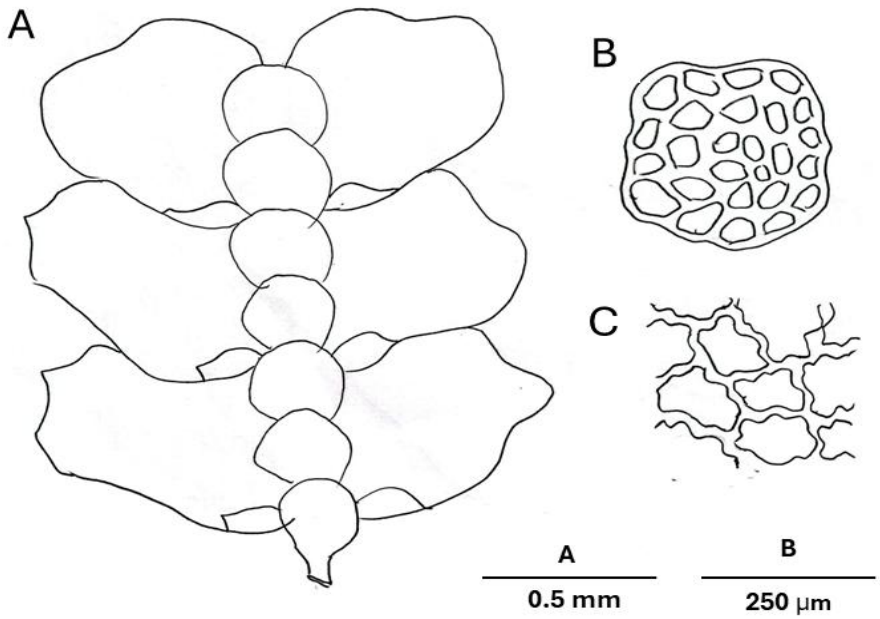

Figure 4.9. ***Acrolejeunea sinensis*** (Jian Wang bis et al.) Jian Wang bis & Gradst. A: Part of plant. B: Stem cell. C: Median leaf cell.

Plants with *Lejeunea*-type of branches. Leaves imbricate, clasping the stem when dry, widely spreading and convex when moist, not become squarrose, apex recurved. Lobe ovate oblong. Lobe cells are thin walled, sometimes slightly thickened, trigones cordate, intermediate thickenings present. Lobule oblong or ovate rectangular, free lateral margin not incurved. Ocelli and oil bodies are not present Androecia and gynoecia are not seen. Asexual reproductive organs not seen.

Collector and specimen number: Saidatul 19012, 19014, 19043.

Habitat: on tree trunk

8. ***Acrolejeunea arcuata*** (Nees) Grolle & Gradst. (Figure 4.10)

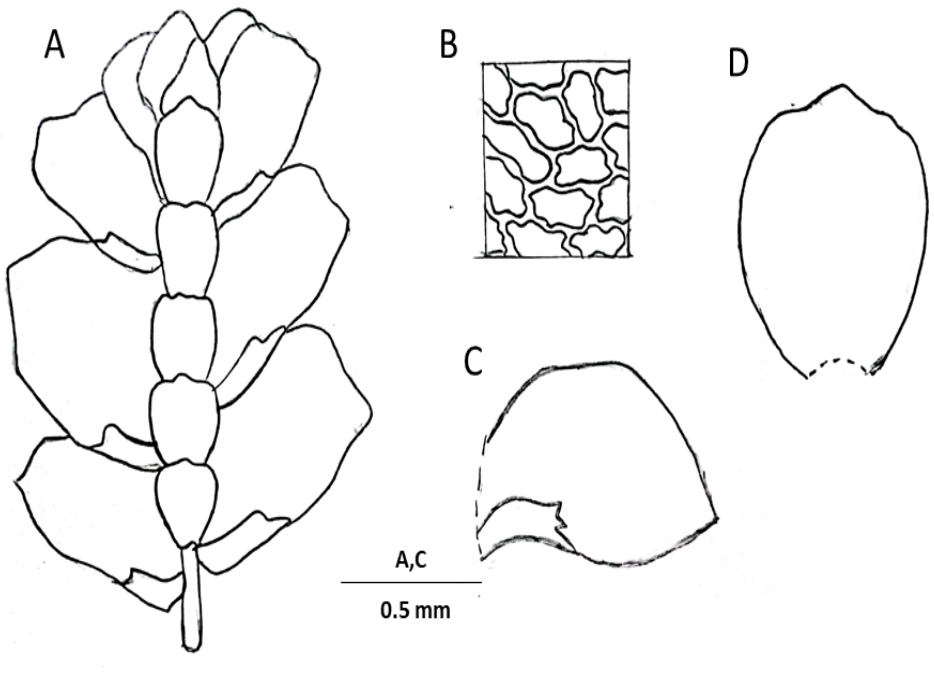

Figure 4.10. ***Acrolejeunea arcuata*** (Nees) Grolle & Gradst. A: Part of plant. B: Median leaf cell. C: Leaf. D: Underleaves.

Plant dioicous. Intercalary branches with 12-13 epidermal cells and medullary cells. Leaves imbricate, clasping the stem when dry, widely spreading, and convex when moist. Lobule is narrowly ovate, inflated, free lateral margin plane, apex truncate 1(-2) teeth, first tooth erect, curved outwardly or inwardly, second tooth occasionally present, very small, and hyaline papilla not seen. Underleaves imbricate to contiguous, oblong-elliptic, apex rounded, plane, margin entire, rounded at bases, and insertion line slightly arched. Lobe asymmetrically obovate-oblong, apex rounded, plane, margin entire, ventral margin incurved, keel arched. Lobe cell walls are thin to slightly thickened, trigones cordate, intermediate thickenings scarce, marginal cells subquadrate, median cells hexagonal, and basal cells elongate. Ocelli and oil bodies are not present. Androecia intercalary on short or long branches, bracts in 13-18 pairs, slightly smaller than leaves. Gynoecia without innovation, bracts, and bracteoles in 2-7 series, bract lobe oblong-ovate, apex obtuse, margin entire, bract lobule oblong, 4/5 as long as bract lobe. Perianth obovate, immersed, with 5-9 smooth keels.

Collector and specimen number: Saidatul 19018, 19017, 22024.

Habitat: on tree trunks, on branches

9. ***Acrolejeunea recurvata*** Gradst. (Figure 4.11)

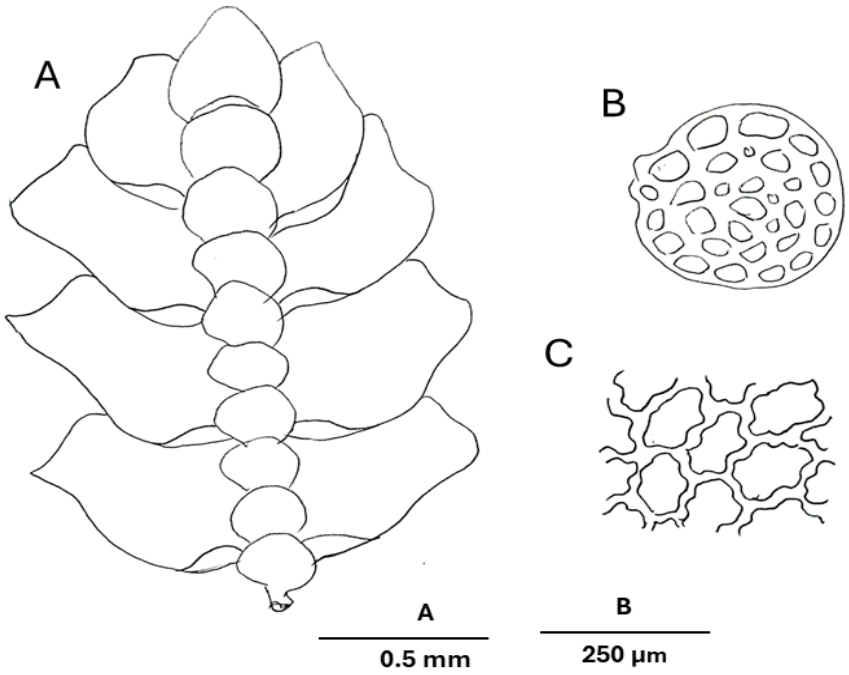

Figure 4.11. ***Acrolejeunea recurvata*** Gradst. A: Part of plant. B: Stem cell. C: Median leaf cell.

Plants with *Lejeunea*-type of branches. Leaves densely imbricate, clasping the stem when dry, widely spreading to squarrose when moist. Lobe asymmetrically ovate-orbicular, apex rounded, plane, margin entire, keel slightly arched. Lobe cell walls are thin to slightly thickened, trigones cordate, and intermediate thickenings scarce. Lobule ovate, inflated, free lateral margin. Underleaves imbricate, transversely oblong. Ocelli and oil bodies are not present. Androecia, gynoecia, and perianth not seen. Asexual reproductive organs are absent.

Collector and specimen number: Saidatul 19015, 19016

Habitat: on tree trunk

10. *Caudalejeunea cristiloba* (Steph.) Gradst. (Figure 4.12)

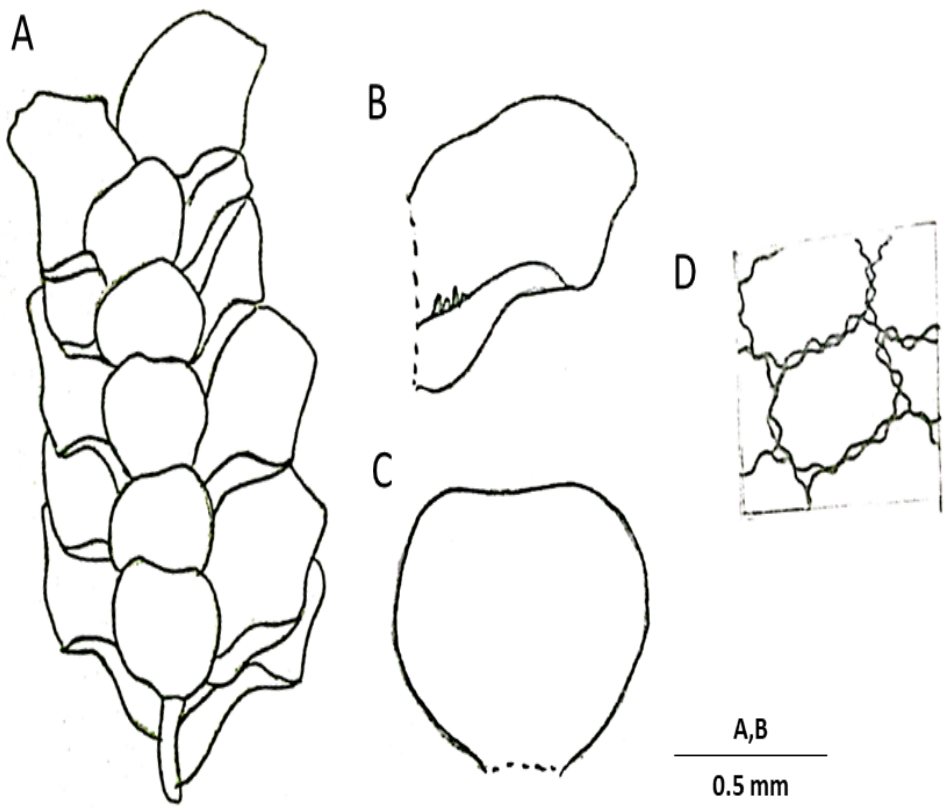

Figure 4.12. ***Caudalejeunea cristiloba*** (Steph.) Gradst. A: Part of plant. B Leaf. C: Underleaves. D: Median leaf cell.

Plants autoicous. Irregularly branched, rhizoids numerous. Leaves imbricate, obliquely spreading, ovate, margin entire. Cuticle smooth. Leaf lobule narrowly triangular or ovate. Underleaves imbricate, reniform, margin entire. Androecia on a long branch, bracts 4-6 pairs. Bract lobe closely imbricate, erect spreading, margin entire. Bracteoles densely imbricate, reniform. Gynoecia on a long branch without innovation, bract lobe ovate. Bract lobule small, free margin. Bracteole oblong, irregularly dentate, lateral margins entire. Perianth obovate.

Collector and specimen number: Saidatul 19006, 19007, 19019, 22008, 22011, 22013, 23025, 23054, 23065, 23079.

Habitat: on tree trunk

11. *Caudalejeunea reniloba* (Gottsche) Steph. (Figure 4.13)

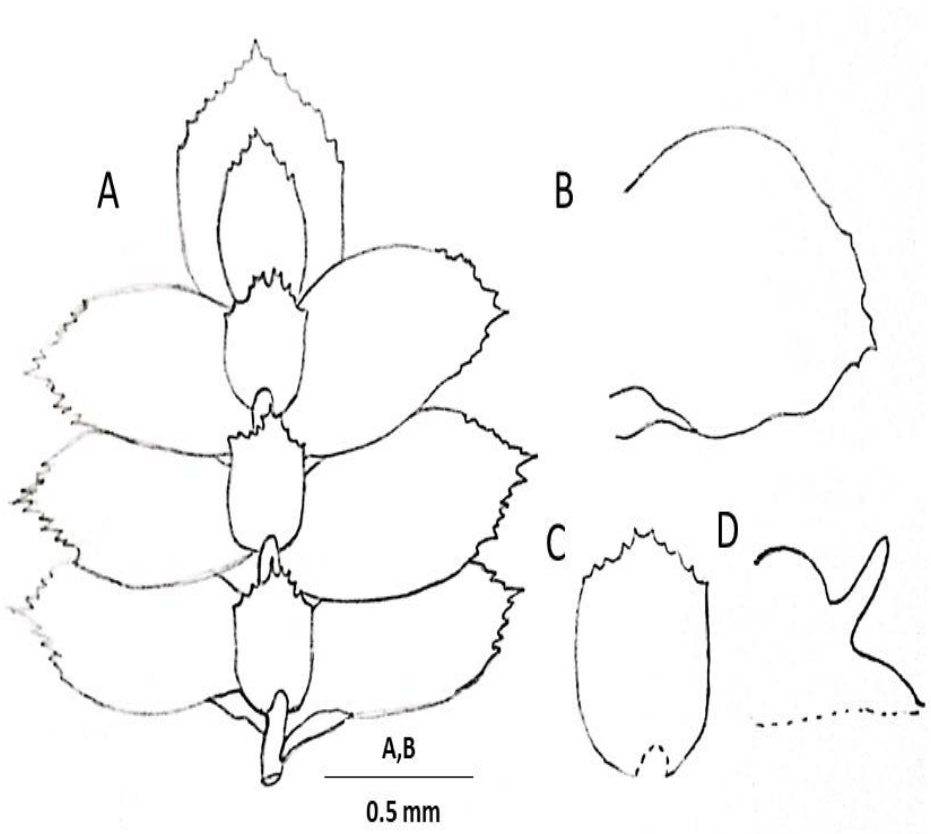

Figure 4.13. ***Caudalejeunea reniloba*** (Gottsche) Steph. A: Part of plant. B: Leaf. C: Underleaves. D: Part of leaf lobule

Plant autoicous. Intercalary branches with 11 epidermal cells and 30 medullary cells, epidermal cells larger than medullary cells. Leaves imbricate. Lobule oblong, inflated, free lateral margin, with 2-4 teeth, first tooth 2-4 cells long, 1-3 cells wide at the base. Underleaves imbricate and obovate. Lobe oblong-ovate, apex rounded-obtuse, entire to dentate, ventral margin entire, dorsal margin entire to dentate; lobe on circinate shoots asymmetrically oblong-ovate, apex rounded to rounded-obtuse. Lobe cell walls are thin, trigones large, cordate, intermediate thickenings frequent, marginal cells subquadrate, median cells hexagonal, basal cells elongate. Oil bodies and ocelli are not present. Androecia terminal on branches, bracts in 6-18 pairs, imbricate. Gynoecia on branches, without innovation. Perianth is obovate with 3-5 keels, dentate wings.

Collector and specimen number: Saidatul 23023, 23024, 23031, 23032, 23176, 23208, 23210.

Habitat: on branch, twig.

12. ***Ceratolejeunea aliena*** Herzog. (Figure 4.14)

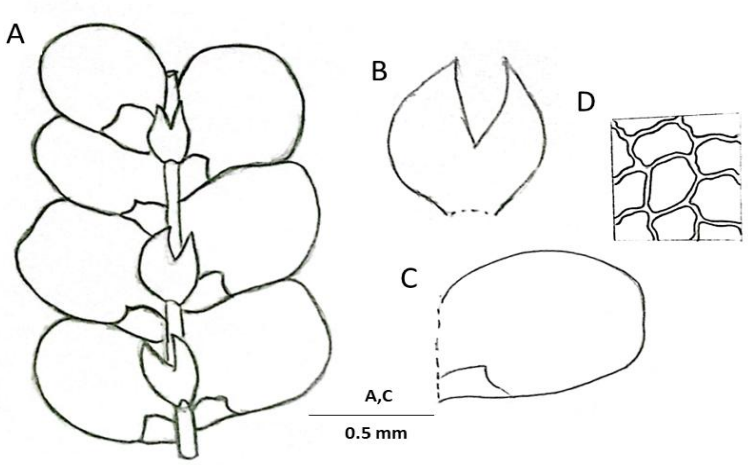

Figure 4.14. ***Ceratolejeunea aliena*** Herzog. A: Part of plant. B: Underleaves. C: Leaf. D: Median leaf cell.

Leaf lobes wide spreading, margin entire or oblong with rounded apices. Cells elongate and uniformly thick-walled, cuticle smooth. Underleaves undivided and orbicular. Lobules inflated, ovate. Oil bodies and ocelli were not seen. Gynoecia on long branches with pycnolejeuneoid innovations. Perianths 4 keeled. Sporophyte not seen.

Collector and specimen number: Saidatul 19015, 19016, 23183.

Habitat: on tree trunk

13. ***Ceratolejeunea singapurensis*** (Lindenb.) Schiffin. (Figure 4.15)

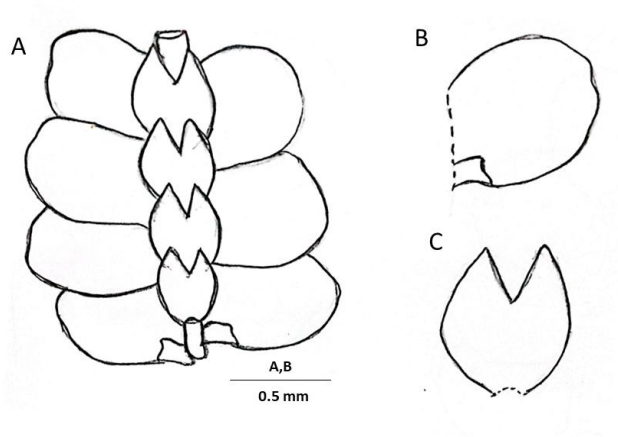

Figure 4.15. ***Ceratolejeunea singapurensis*** (Lindenb.) Schiffin. A: Part of plant. B: Leaf. C: Underleaves.

Leaf lobes wide spreading, margin entire or oblong with rounded apices. Cells elongate and uniformly thick-walled, cuticle smooth. Underleaves undivided and orbicular. Lobules inflated, ovate. Oil bodies granular, 1-6 basal ocelli. Gynoecia on long branches with pycnolejeuneoid innovations. Perianths 4 keeled. Sporophyte not seen.

Collector and specimen number: Saidatul 19041

Habitat: on tree trunk

14. *Cheilolejeunea decursiva* (Sande Lac.) R.M. Schust. (Figure 4.16)

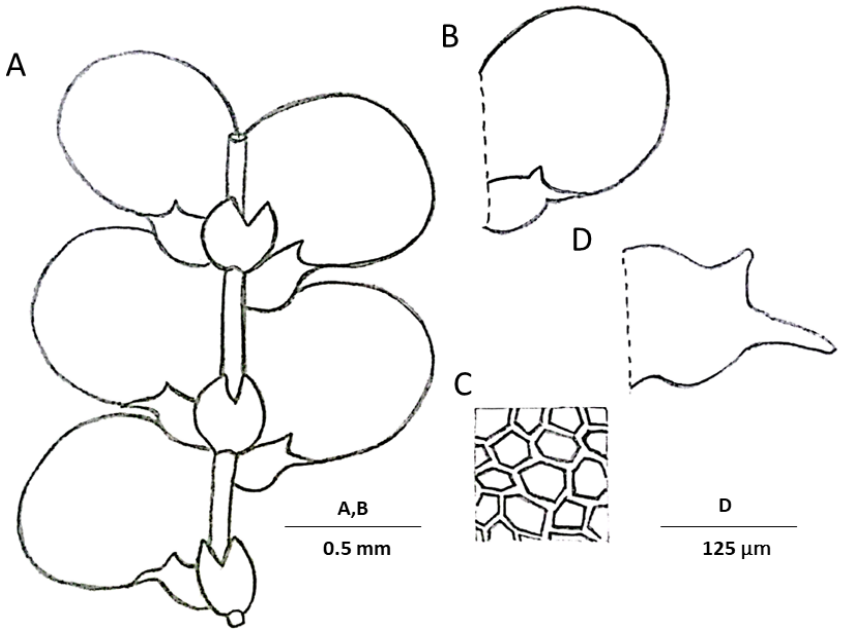

Figure 4.16. ***Cheilolejeunea decursiva*** (Sande Lac.) R.M. Schust. A: Part of plant. B: Leaf. C: Median leaf cells. D: Part of lobule.

Autoicous plant with intercalary branches with 11-16 medullary cells. Rhizoids are numerous, and fasciculate at the base of underleaves. Lobe obovate and falcate, margin entire, dorsal margin arched. Lobe cells thin-walled, intermediate thickenings absent, marginal cells subquadrate, median cells hexagonal, and basal cells like median ones. Cuticle smooth. Lobule large, rectangular, slightly inflated, free lateral margin slightly incurved, with 2 teeth. Underleaves imbricate. Androecia on branches, bracts in 2-7 pairs, densely imbricate, obliquely spreading, bracteoles 1-2, slightly smaller than underleaves, present only at the base of the androecium. Gynoecia on branches, with an innovation. Ocelli and oil bodies are not seen.

Collector and specimen number: Saidatul 19001, 19008, 19009, 19031, 23202, 23203.

Habitat: on tree trunk

15. *Cheilolejeunea orientalis* (Gottsche) Mizut. (Figure 4.17)

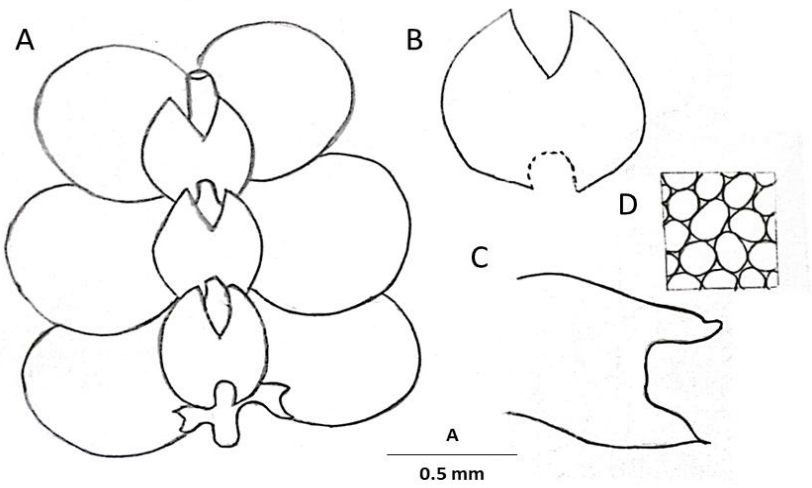

Figure 4.17. ***Cheilolejeunea orientalis*** (Gottsche) Mizut. A: Part of plant. B: Underleaves. C: Part of lobule. D: Median leaf cell.

Plant with intercalary branches with 11-16 medullary cells. Rhizoids are numerous, and fasciculate at the base of underleaves. Leaves usually imbricate, spreading from the stem. Lobe broadly ovate, margin entire, dorsal margin arched. Lobe cells are thin-walled, trigones usually large, intermediate thickenings usually absent, marginal cells subquadrate, median cells hexagonal, and basal cells like median ones. Cuticle smooth. Lobule large, rectangular, slightly inflated, free lateral margin slightly incurved, with 2 teeth. Underleaves are small, bilobed, sub transversely inserted on the stem. Androecia on branches, bracts in 2-7 pairs, densely imbricate, obliquely spreading, bracteoles 1-2, slightly smaller than underleaves, present only at the base of the androecium. Gynoecia on branches, with an innovation. Ocelli and oil bodies not seen.

Collector and specimen number: Saidatul 19021,19022, 19023, 19036.

Habitat: on tree trunk

16. ***Cheilolejeunea trapezia*** (Nees) Kachroo & R.M.Schust. (Figure 4.18)

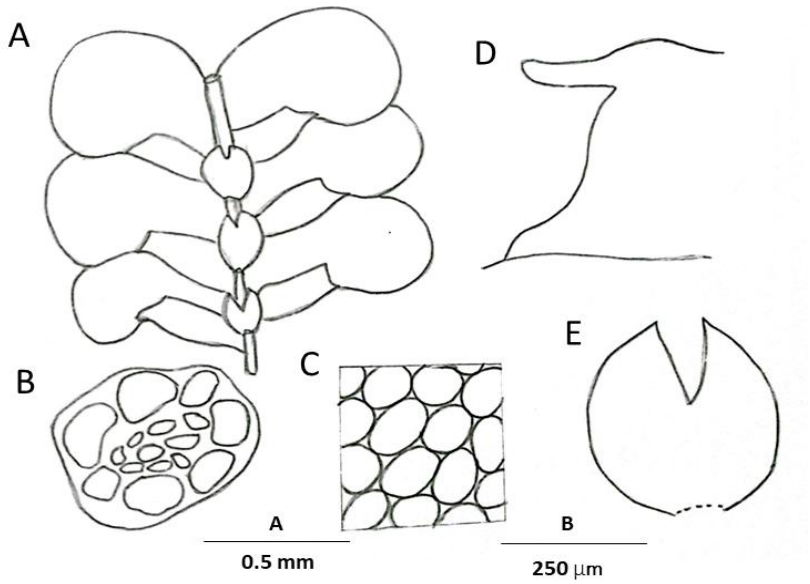

Figure 4.18. ***Cheilolejeunea trapezia*** (Nees) Kachroo & R.M.Schust. A: Part of plant. B: Cross section of stem cell. C: Median leaf cell. D: Part of lobule. E: Underleaves.

Plant with intercalary branches with 11-16 medullary cells. Rhizoids are numerous, and fasciculate at the base of underleaves. Leaves usually imbricate, spreading from the stem. Lobe broadly ovate, margin entire, dorsal margin arched. Lobe cells are thin-walled, trigones usually large, intermediate thickenings usually absent, marginal cells subquadrate, median cells hexagonal, and basal cells like median ones. Cuticle smooth. Lobule large, rectangular, slightly inflated, free lateral margin slightly incurved, with 2 teeth. Underleaves imbricate. Androecia on branches, bracts in 2-7 pairs, densely imbricate, obliquely spreading, bracteoles 1-2, slightly smaller than underleaves, present only at the base of the androecium. Gynoecia on branches, with an innovation. Perianth obovate, with 4 keels (2 ventral and 2 lateral). Smooth on the surface, beak short, 1-2 cells long. Ocelli and oil bodies are absent.

Collector and specimen number: Saidatul 23022, 23067, 23127, 23147.

Habitat: on tree trunk

17. *Cheilolejeunea intertexta* (Lindenb.) Steph. (Figure 4.19)

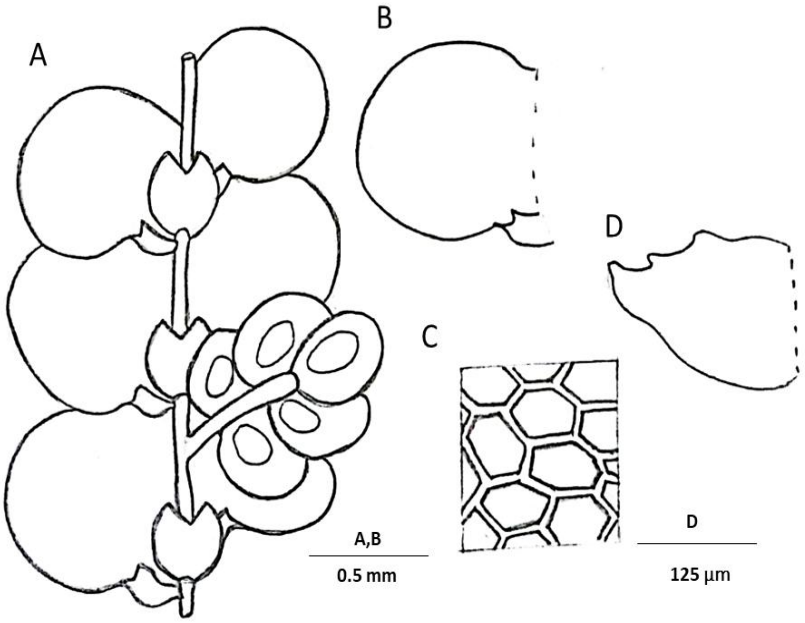

Figure 4.19. ***Cheilolejeunea intertexta*** (Lindenb.) Steph. A: Part of plant. B: Leaf. C: Median leaf cell. D: Part of lobule.

Plant with intercalary branches with 11-16 medullary cells. Rhizoids are numerous, and fasciculate at the base of underleaves. Leaves usually imbricate, spreading from the stem. Lobe oblong, margin entire, dorsal margin arched. Lobe cells are thin-walled, trigones are usually large, intermediate thickenings usually absent, marginal cells subquadrate, median cells hexagonal, and basal cells like median ones. Cuticle smooth. Lobule large, rectangular, slightly inflated, free lateral margin slightly incurved, with 2 teeth. Underleaves bilobed. Androecia on branches, bracts in 2-7 pairs, densely imbricate, obliquely spreading, bracteoles 1-2, slightly smaller than underleaves, present only at the base of the androecium. Gynoecia on branches, with an innovation. Ocelli and oil bodies not seen.

Collector and specimen number: Saidatul 19001, 19003, 19026, 19027, 23068, 23089, 23107, 23113, 23156.

Habitat: on tree trunk

18. ***Cololejeunea appressa*** (A.Evans) Benedix. (Figure 4.20)

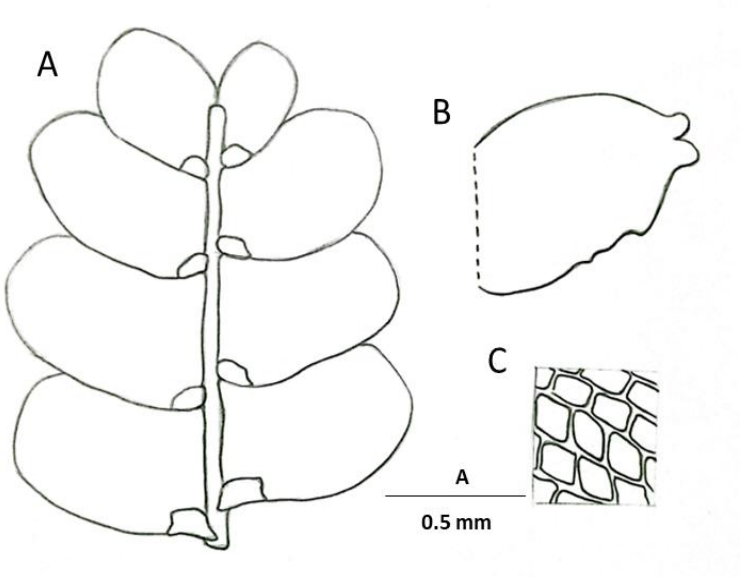

Figure 4.20. ***Cololejeunea appressa*** (A.Evans) Benedix. A: Part of plant. B: Part of the lobule. C: Median leaf cell.

Plant autoicous. Irregularly branched consisting of 5 cortical cells and 1 medullary cell. Rhizoids numerous, colourless, fasciculate. Leaves imbricate. Lobe ovate, apex rounded, margin nearly entire, dorsal margin slightly arched. Lobe cells are thin-walled, trigones small, intermediate thickening infrequent, apical marginal cells elongate, forming a vitta 1 row of 3-4 ocelli. Lobules ovate, inflated, smooth on ventral surface, free lateral margin slightly incurved oil bodies not seen. Androecia terminal, intercalary, on short or elongate branches, antheridia with 2 per bract. Gynoecia on short or elongate branches with innovation. Perianth obovate.

Collector and specimen number: Saidatul 23170, 23176.

Habitat: on tree trunk

19. *Cololejeunea gottschei* (Steph.) Pandé *et al*. (Figure 4.21)

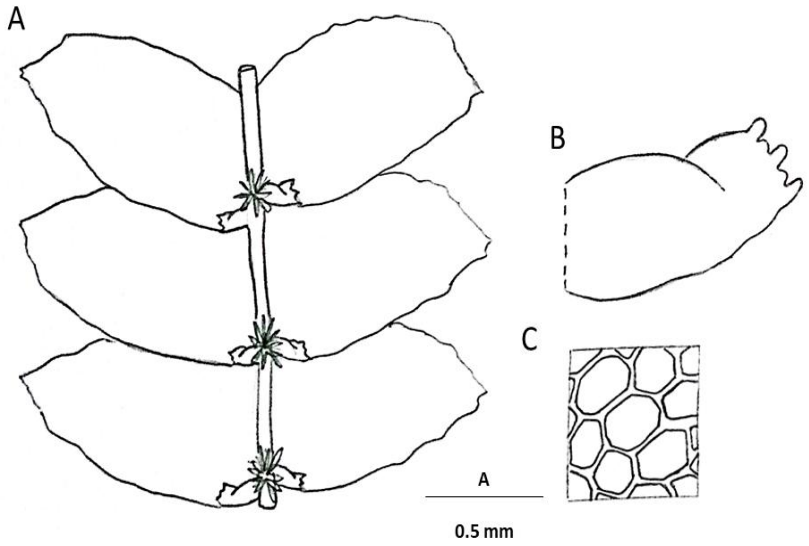

Figure 4.21. ***Cololejeunea gottschei*** (Steph.) Pandé *et al*. A: Part of plant. B: Part of the lobule. C: Median leaf cell.

Plants with irregularly branched stems consist of 6 cortical cells and 1 medullary cell. Rhizoids numerous, fasciculate. Leaves contiguous. Lobe ovate or oblong. Lobe cells thin wall trigones large, intermediate thickenings 1-3 per long wall, median cells hexagonal, basal cells hexagonal, and longer than median ones. Cuticle smooth. Oil bodies and ocelli are absent. Lobule oblong ovate, inflated. Androecia on branches, gynoecia terminal on long branches, with an athecal innovation, bract lobe oblong. Perianth obovate, 4 keeled. Spores irregularly oblong in shape. Gemmae on the ventral or dorsal surface of the leaf lobe. Perianths obovate, with 4 keels.

Collector and specimen number: Saidatul 19039

Habitat: on tree trunk

20. *Cololejeunea equialbi* Tixier. (Figure 4.22)

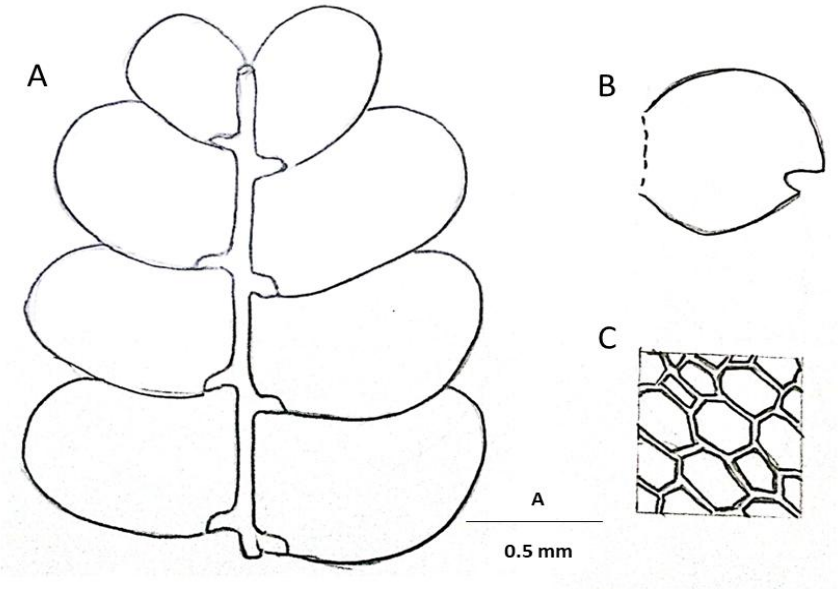

Figure 4.22. ***Cololejeunea equialbi*** Tixier. A: Part of plant. B: Part of lobule. C: Median leaf cell.

Plant with irregularly sparsely branched stems consisting of 5 cortical cells and 1 medullary cell. Rhizoids numerous, fasciculate. Leaves imbricate. Lobe denticulate or obtuse rounded. Lobe cells have thin walls, trigones, small, intermediate thickening absent, median cells hexagonal, basal cells slightly larger than median ones, and cuticle smooth. Ocelli and oil bodies are absent. Lobule small, ovate, inflated, ventral surface smooth, free lateral margin incurved. Androecia and gynoecia were not seen.

Collector and specimen numbers: Saidatul 22035, 22036, 22045, 22046, 22050, 22058.

Habitat: on tree trunk

21. *Cololejeunea ensifera* L.Söderstr. *et al*. (Figure 4.23)

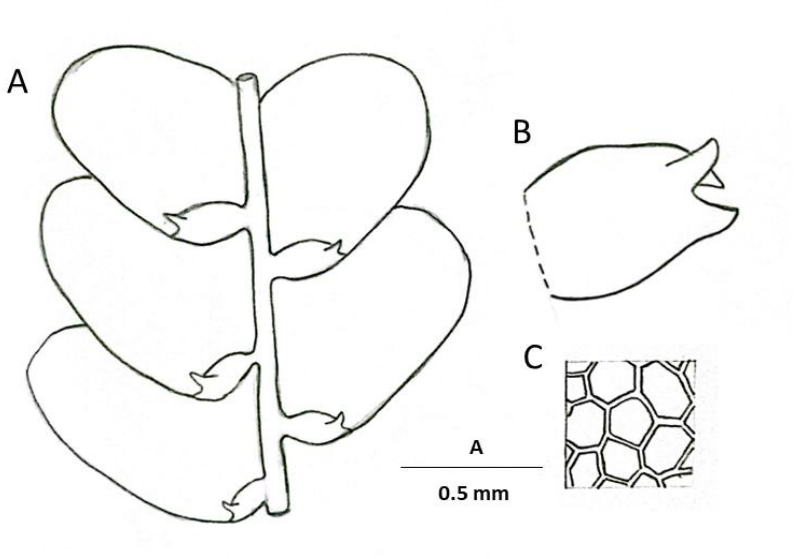

Figure 4.23. ***Cololejeunea ensifera*** L.Söderstr. *et al*. A: Part of plant. B: Part of lobule. C: Median leaf cell.

Plant with irregularly sparsely branched stems consisting of 5 cortical cells and 1 medullary cell. Rhizoids numerous, fasciculate. Leaves imbricate. Lobe denticulate or obtuse rounded. Lobe cells have thin walls, trigones, small, intermediate thickening absent, median cells hexagonal, basal cells slightly larger than median ones, and cuticle smooth. Ocelli and oil bodies are absent. Lobule acute, sword-like first lobule tooth crossing the triangular second tooth. The vitta are biseriate and pluricellular stylus. Androecia and gynoecia were not seen.

Collector and specimen number: Saidatul 23140, 23145.

Habitat: on tree trunk

22. *Cololejeunea pluridentata* P.C. Wu & J.X.Luo. (Figure 4.24)

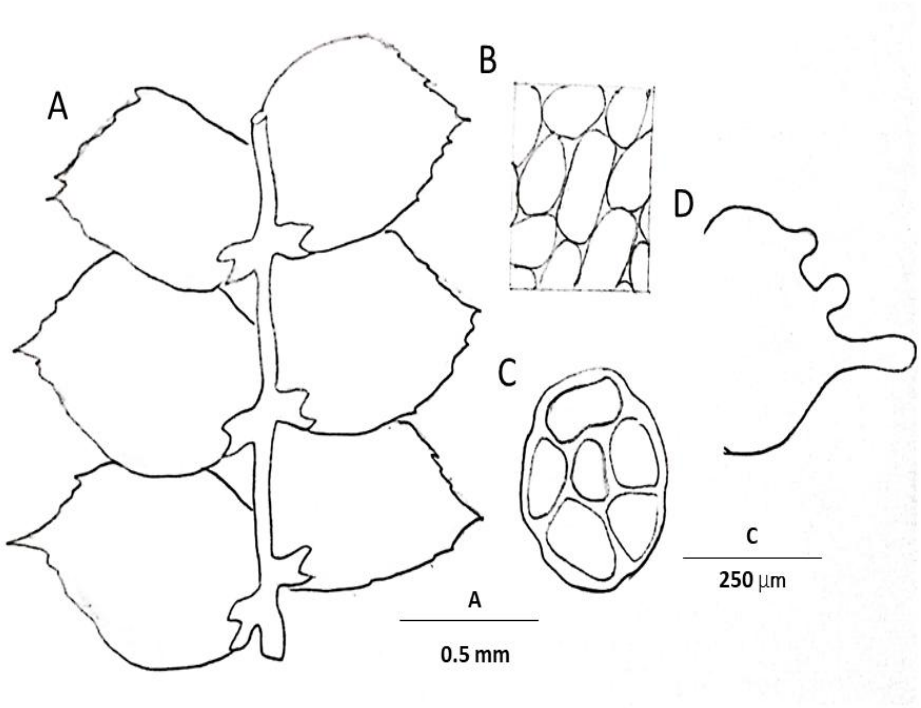

Figure 4.24. ***Cololejeunea pluridentata*** P.C. Wu & J.X.Luo. A: Part of plant. B: Median leaf cell. C: Cross section of stem cell. D: Part of lobule.

Plant autoicous. Irregularly branched. Rhizoids are numerous, colourless. Leaves imbricate. Lobe cells are thin-walled, trigones small, intermediate thickenings absent, median cells hexagonal, and basal cells larger than median cells. Oil bodies and ocelli are absent. Lobule ovate, inflated, smooth on the ventral surface. Androecia not seen. Gynoecia on long branches, with an athecal innovation, bract lobe ovate or obovate, bract lobule oblong. Perianth triangular obconic.

Collector and specimen number: Saidatul 19032, 23185.

Habitat: on tree trunk.

23. *Cololejeunea haskarliana* (Lehm. & Lindenb.) Schiffn. (Figure 4.25)

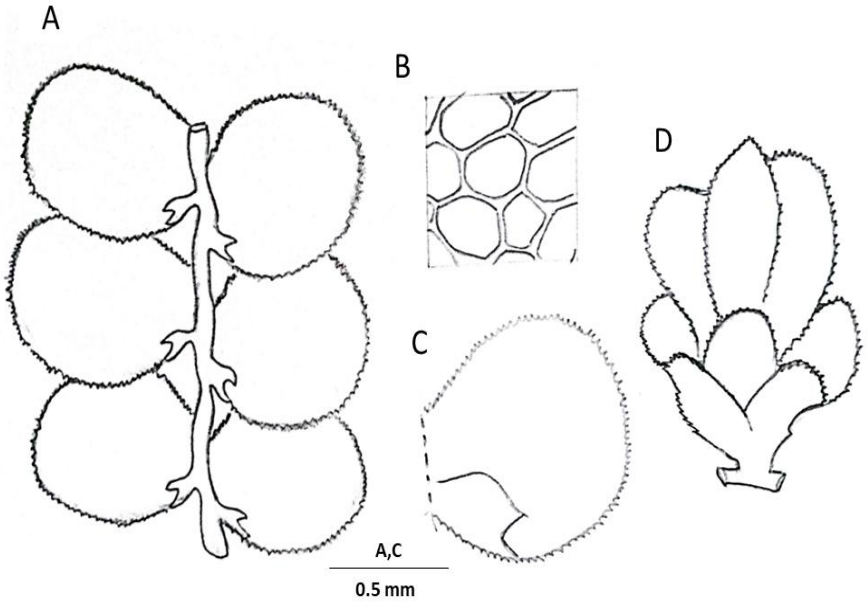

Figure 4.25. ***Cololejeunea haskarliana*** (Lehm. & Lindenb.) Schiffn. A: Part of plant. B: Median leaf cell. C: Leaf. D: Female bracts and perianth.

Plant with irregularly branched with stem section consisting of 5 cortical cells and 1 medullary cell. Rhizoids numerous. Leaves imbricate, and contiguous. Lobe ovate and asymmetric. Lobe cells thin walled, trigones absent or very small, intermediate thickening absent, median cells hexagonal, basal cells oblong. Ocelli and oil bodies are absent. Lobule ovate, inflated. Antheridia 2 per bract. Perianth obovate, inflated, 4 keeled (2 ventral, 2 lateral). The leaves are broadly ovate, while leaf margin is spinose.

Collector and specimen number: Saidatul 23174.

Habitat: on tree trunk

24. *Cololejeunea inflata* Steph. (Figure 4.26)

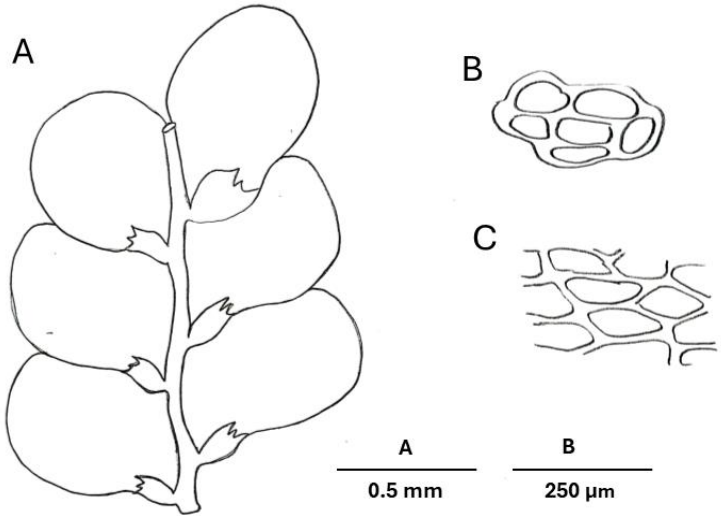

Figure 4.26. ***Cololejeunea inflata*** Steph. A: Part of plant. B: Cross section of stem. C: Median leaf cell.

Plant with leaves imbricate, widely spread, plane, ovate leaves, entire margin, rounded apices, rectangular, subquadrate hyaline in apical to hexagonal in median and basal cells without intermediate thickenings, trigones small. Lobule large, ovate, inflated. Perianth obconic.

Collector and specimen number: Saidatul 23208, 23211.

Habitat: on tree trunk

25. *Cololejeunea aequabills* (Sande Lac.) Schiffn (Figure 4.27)

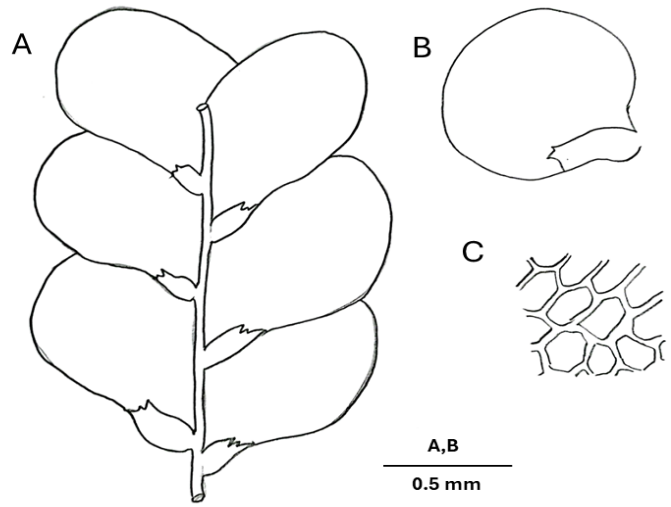

Figure 4.27. ***Cololejeunea aequabills*** (Sande Lac.) Schiffn. A: Part of plant. B: Leaf C: Median leaf cell.

Leaves distant to contiguous or slightly imbricate, asymmetrically ovate with rounded apices. Leaf lobes inflated, with the first tooth bicellular and the second tooth unicellular and obtuse. The hyaline papilla is entirely at the base of the first tooth and perianth with elongated wings.

Collector and specimen number: Saidatul 23116, 23203.

Habitat: on tree trunk

26. *Cololejeunea schmidtii* Steph. (Figure 4.28)

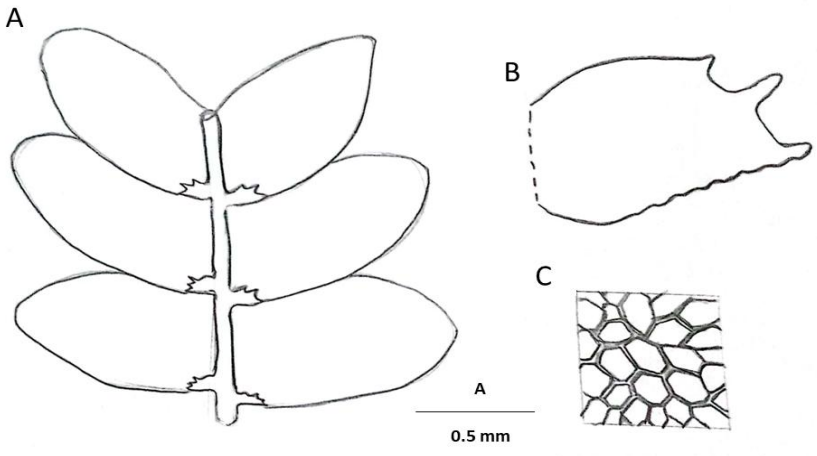

Figure 4.28. ***Cololejeunea schmidtii*** Steph. A: Part of plant. B: Part of lobule. C: Median leaf cell.

Plant autoicous. Irregularly branched. Rhizoids numerous, fasciculate. Leaves loosely imbricate. Lobe ovate or oblong-ovate, asymmetric. Lobe cells are thin-walled, trigones very small, intermediate thickenings absent, median cells hexagonal, basal cells larger than median cells. Ocelli and oil bodies not seen. Lobule ovate, inflated, ventral surface smooth. Gynoecia on branches with an athecal innovation. Perianth obovate, 4 keeled (2 ventral, 2 lateral). Sporophyte not seen.

Collector and specimen number: Saidatul 19013, 19011, 22046, 22052, 22053.

Habitat: on tree trunk.

27. *Cololejeunea obliqua* (Nees & Mont.) Schffn. (Figure 4.29)

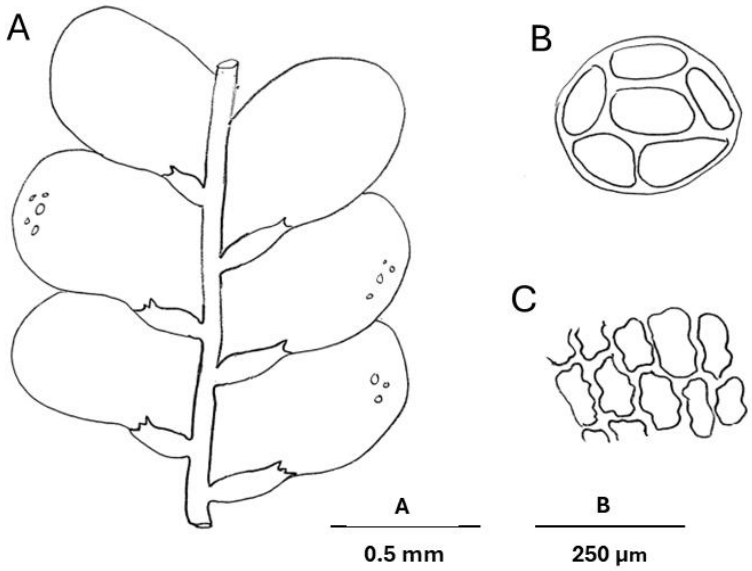

Figure 4.29. ***Cololejeunea obliqua*** (Nees & Mont.) Schffn. A: Part of plant. B: Cross section of stem. C: Median leaf cell.

Plant with leaves imbricate, widely spread, plane, ovate leaves, entire margin, rounded apices, rectangular, subquadrate hyaline in apical to hexagonal in median and basal cells without intermediate thickenings, trigones small. Lobule large, ovate, inflated. Perianth obconic. The obovate and papillose perianth with 4 short keels, crenulate margins of leaf lobes.

Collector and specimen number: Saidatul 23026, 23094.

Habitat: on tree trunk.

28. *Cololejeunea serrulata* Schiffn. (Figure 4.30)

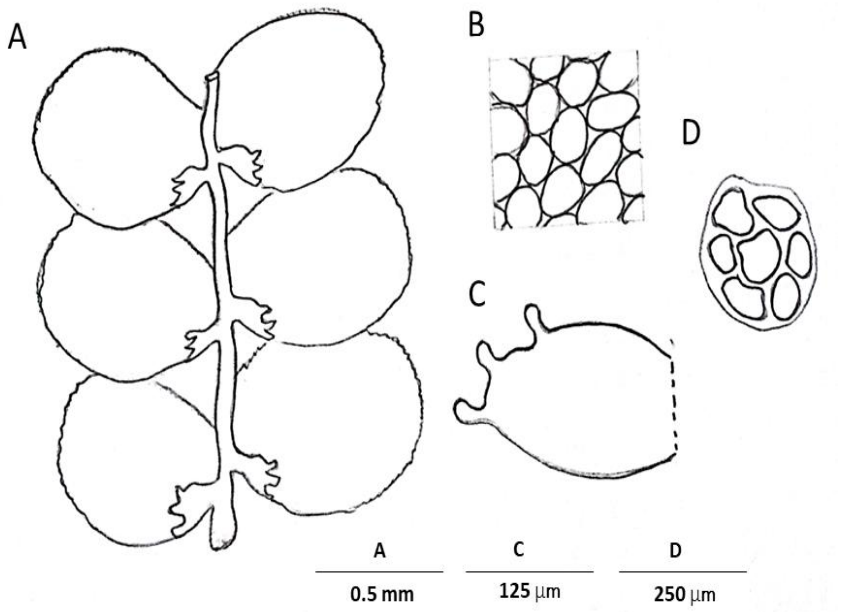

Figure 4.30. ***Cololejeunea serrulata*** Schiffn. A: Part of plant. B: Median leaf cell. C: Part of lobule. D: Cross section of stem cell.

Plant autoicous. Irregularly branched. Stem consisting of 6 cortical cells and 1 medullary cell. Rhizoids numerous, fasciculate. Leaves imbricate. Lobe ovate margin irregularly serrulate. Lobe cells thin walled, trigones indistinct or small intermediate thickenings absent. Median cells hexagonal, basal cells larger than median cells, cuticle smooth. Oil bodies and ocelli not seen. Lobule oblong-ovate, inflated. Androecia on long branches, smaller than leaves, antheridia with 2 per bract. Gynoecia on short or long branches, with an athecal innovation, bract lobe oblong. Perianth emergent, obovate, 4 keeled (2 ventral, 2 lateral). Surface smooth, beak short.

Collector and specimen number: Saidatul 23033, 23034, 23109, 23110.

Habitat: on tree trunk.

29. *Cololejeunea inflectens* (Mitt.) Benedix (Figure 4.31)

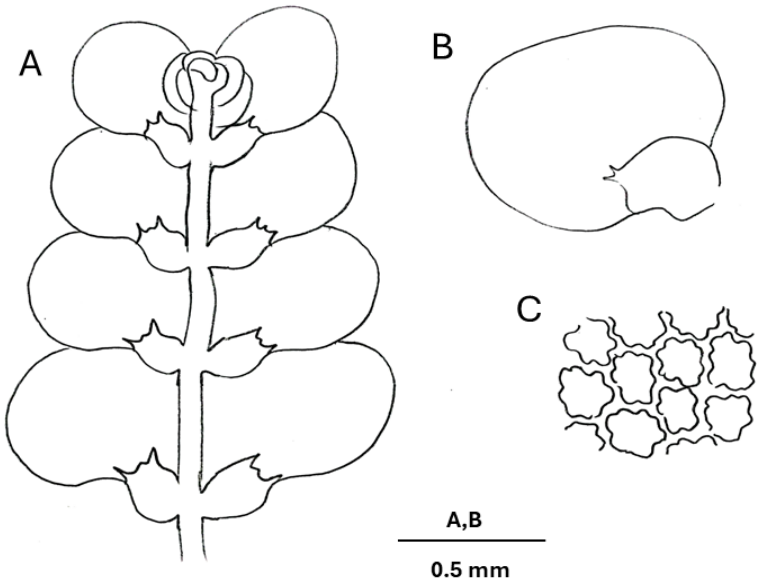

Figure 4.31. ***Cololejeunea inflectens*** (Mitt.) Benedix. A: Part of plant. B: Leaf. C: Median leaf cell.

Plant with leaves imbricate, widely spread, plane, ovate leaves, inflated leaf lobules with strongly involute free margin rounded apices, rectangular, subquadrate hyaline in apical to hexagonal in median and basal cells without intermediate thickenings, trigones small. Lobule large, ovate, inflated. Perianth obconic.

Collector and specimen number: Saidatul 23114, 23153.

Habitat: on tree trunk

30. *Cololejeunea falcata* (Horik.) Benedix (Figure 4.32)

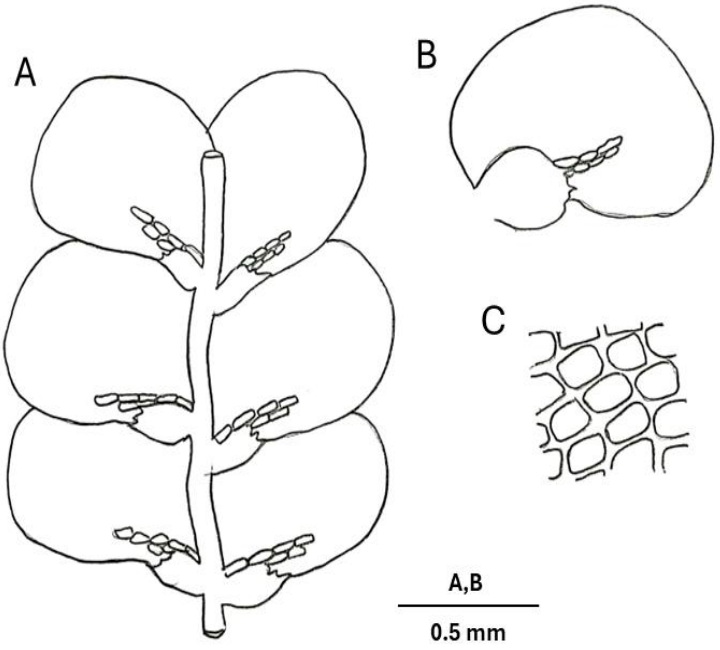

Figure 4.32. ***Cololejeunea falcata*** (Horik.) Benedix. A: Part of plant. B: Leaf. C: Median leaf cell.

Plant with irregularly sparsely branched falcate-ovate leaf lobes with entire or slightly denticulate margins and rounded apices. The leaf lobe vitta is made up of either single or double to triple lines, 5 or 6 cells long. Rhizoids numerous, fasciculate. Leaves imbricate. Lobe denticulate or obtuse rounded. Lobe cells have thin walls, trigones, small, intermediate thickening absent, median cells hexagonal, basal cells slightly larger than median ones, and cuticle smooth. Ocelli and oil bodies are absent. Lobule small, ovate, inflated, ventral surface smooth, free lateral margin incurved. Androecia and gynoecia were not seen.

Collector and specimen number: Saidatul 22037, 22048, 22050.

Habitat: on tree trunk

31. *Colura acroloba* (Prantl) Jovet-Ast. (Figure 4.33)

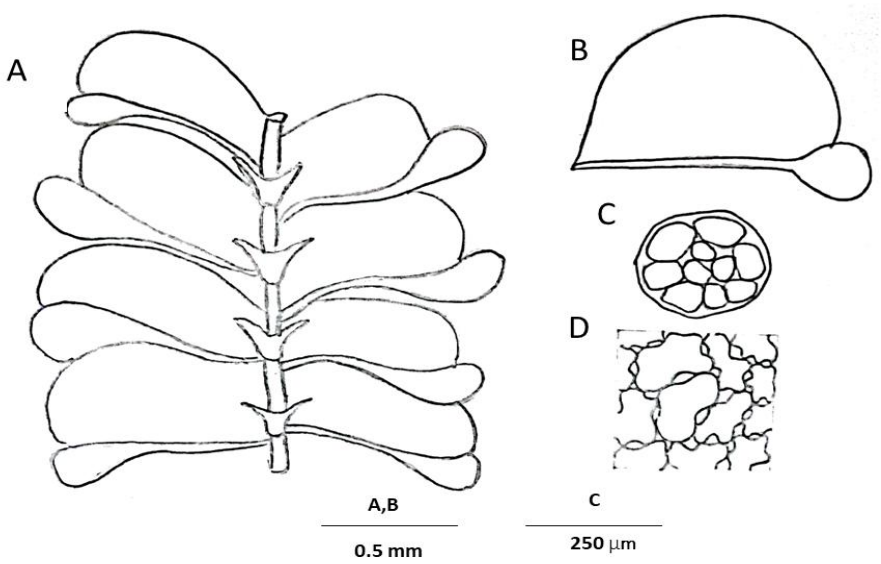

Figure 4.33. ***Colura acroloba*** (Prantl) Jovet-Ast. A: Part of plant. B: Leaf. C: Cross section of stem cell. D: Median leaf cell.

Plant autoicous. Irregularly branched with stem consisting of 7 cortical cells and medullary cells. Rhizoids numerous, fasciculate. Leaves imbricate. Lobe cells thin walled, trigones large, intermediate thickenings frequent, median cells isodiametric or hexagonal, basal cells larger than median ones. Cuticle smooth. Oil bodies and ocelli not seen. Lobule inflated, smooth on surface. Underleaves distant, nearly transversely inserted to the stem. Androecia terminal on long or short lateral branches. Bracteoles like underleaves, but slightly smaller. Gynoecia on long branches, with an athecal innovation, bract lobe oblong. Perianth obovate, with 3 wing-shaped keels, smooth on surface, beak very short.

Collector and specimen number: Saidatul 23186, 23138.

Habitat: on tree trunk.

32. *Colura inuii* Horik. (Figure 4.34)

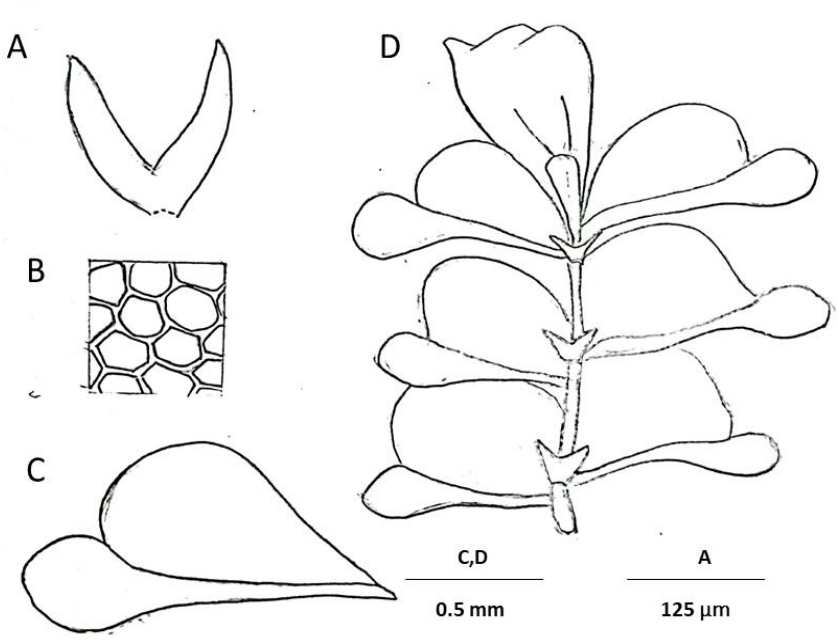

Figure 4.34. ***Colura inuii*** Horik. A: Underleaves. B: Median leaf cell. C: Leaf. D: Part of plant with perianth.

Plant with irregularly branched stem transverse section consisting of 7 cortical cells and 3 medullary cells. Rhizoids numerous, fasciculate. Leaves imbricate to contiguous. Lobe cells thin walled, trigones large, intermediate thickenings, median cells isodiametric, and basal cells larger than median cells. Cuticle smooth. Oil bodies not seen. Lobule narrowly cylindrical, smooth on surface.

Collector and specimen number: Saidatul 23105, 23121, 23122, 23134, 23136, 23137, 23141, 23172.

Habitat: on tree trunk.

33. *Colura ari* (Steph.) Steph. (Figure 4.35)

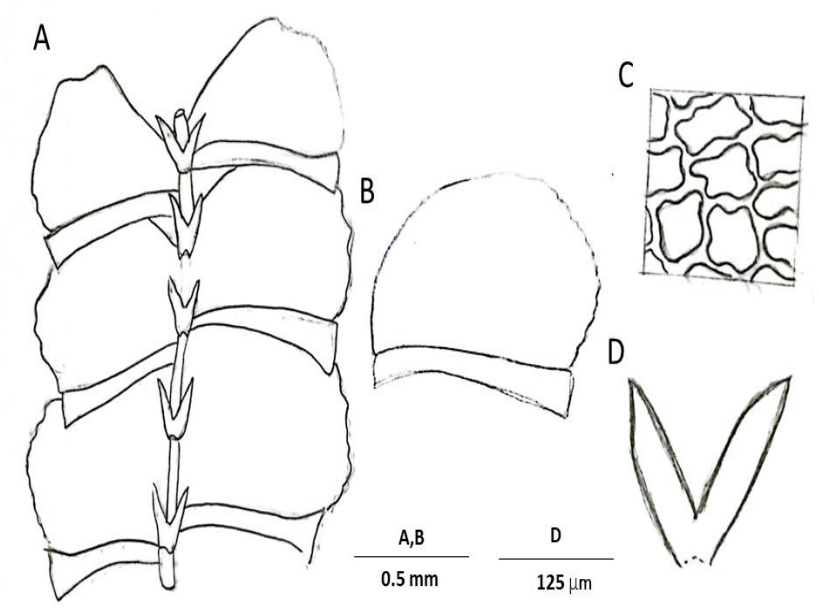

Figure 4.35. ***Colura ari*** (Steph.) Steph. A: Part of plant. B: Leaf. C: Median leaf cell. D: Underleaves.

The plant is irregularly branched, with a stem consisting of 7 cortical cells and 3 medullary cells and has a small sac parallel to the stem. Serrate dorsal margin of leaf lobe, narrow leaf lobule. Rhizoids numerous, fasciculate. Leaves imbricate. Lobe cells are thin-walled, trigones large, intermediate thickenings, marginal cells quadrate, median cells isodiametric, and basal cells larger than median cells. The cuticle is smooth. Oil bodies and ocelli were not seen. The lobule is narrowly tubular. Underleaves distant, nearly transversely inserted to the stem, deeply bilobed. Androecia on very short lateral branches. Terminal intercalary, bracts in 3-6 pairs, antheridia 2 per bracts, bracteoles like underleaves, but smaller.

Collector and specimen number: Saidatul 23020, 23028, 23029, 23066, 23081, 23118, 23119, 23170.

Habitat: on tree trunk.

34. *Colura corynophora* (Nees *et al*.) Trevis. (Figure 4.36)

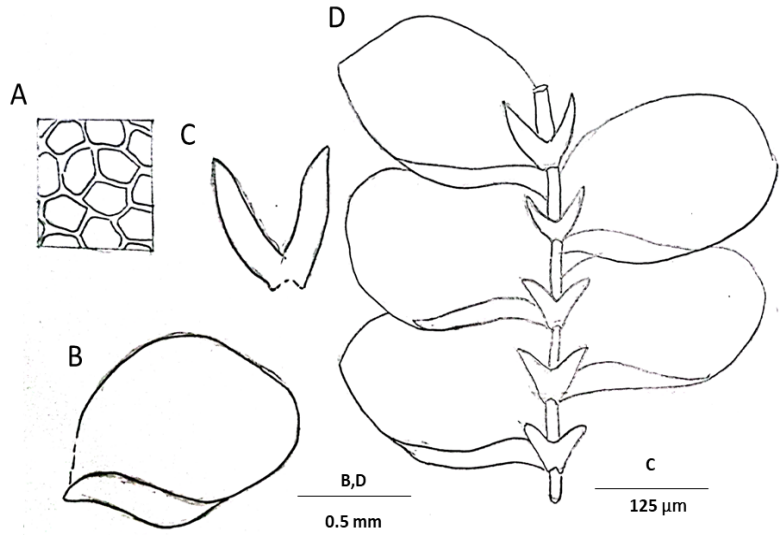

Figure 4.36. ***Colura corynophora*** (Nees *et al*.) Trevis. A: Median leaf cell. B: Leaf. C: Underleaves. D: Part of plant.

Plant with irregularly branched. Rhizoids numerous, fasciculate. Leaves contiguous to distant. Lobe cells are thin-walled, trigones large, intermediate thickenings very distinct, marginal cells subquadrate, median cells isodiametric to hexagonal, and basal cells larger than median cells. Cuticle smooth. Oil bodies and ocelli were not seen. The lobule is narrowly cylindrical. Underleaves distant, nearly transversely inserted to the stem. Androecia not seen. Gynoecia terminal on long branches, with an athecal innovation.

Collector and specimen number: Saidatul 23028, 23029, 23086, 23087, 23088, 23089, 23105, 23122. Habitat: on tree trunk.

35. *Drepanolejeunea thwaitesiana* (Mitt.) Steph. (Figure 4.37)

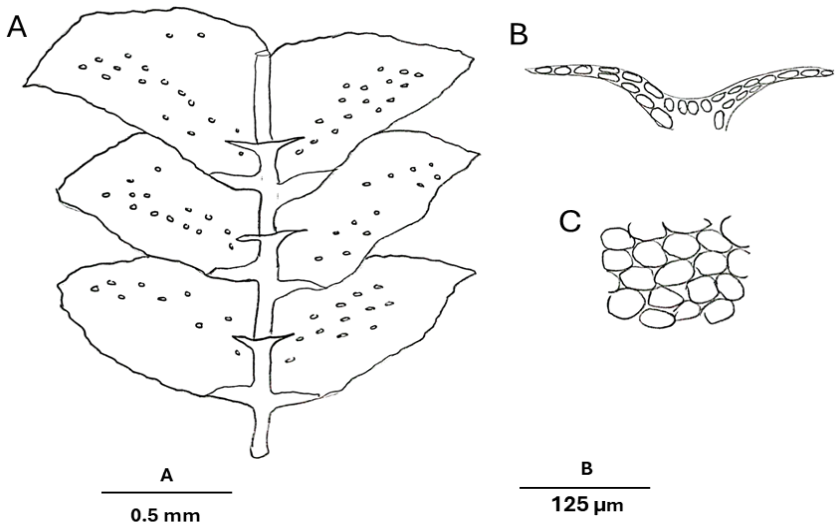

Figure 4.37. ***Drepanolejeunea*** *thwaitesiana* (Mitt.) Steph. A: Part of plants. B: Underleaves. C: Median leaf cell.

Plants with numerous ocelli scattered in all parts of the plants except male bracts & perianth the dentate dorsal margin of leaf lobes, and the obovate to obtriangular perianth with 3-5 wings.

Collector and specimen number: Saidatul 23154, 23169, 23171.

Habitat: on tree trunk.

36. *Drepanolejeunea longicornua* (Herzog) Mizut. (Figure 4.38)

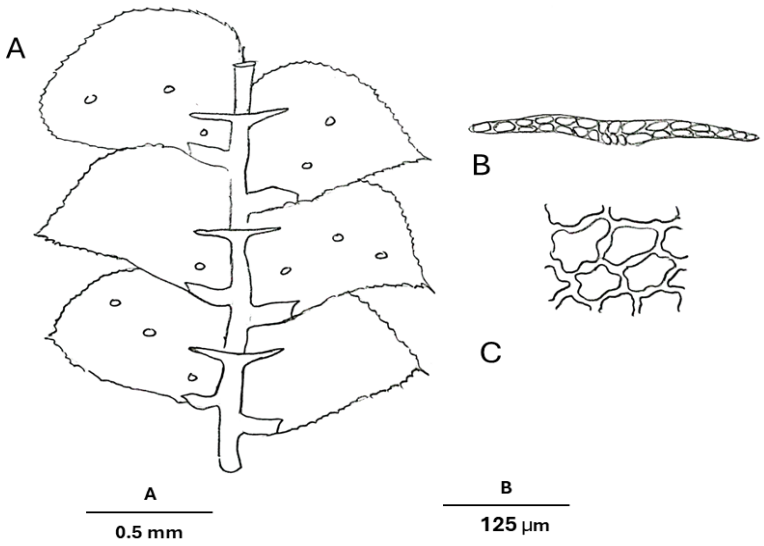

Figure 4.38. ***Drepanolejeunea longicornua*** (Herzog) Mizut. A: Part of plants. B: Underleaves. C: Median leaf cell.

Plant with obliquely ovate leaf lobes with 2-10 scattered ocelli and without basal ocellus and the perianth with 3-5 district wing.

Collector and specimen number: Saidatul 23169, 23171, 23172.

Habitat: on tree trunk.

37. *Drepanolejeunea spicata* (Steph.) Grolle & R.L. Zhu (Figure 4.39)

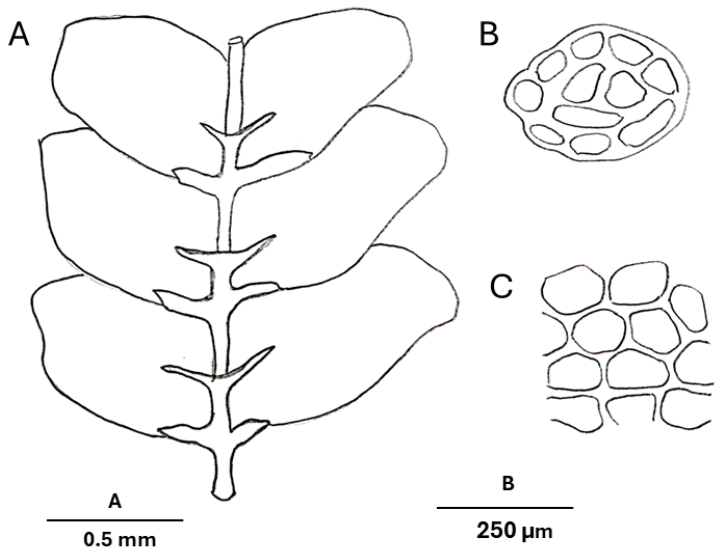

Figure 4.39. ***Drepanolejeunea spicata*** (Steph.) Grolle & R.L. Zhu A: Part of plants. B: cross section of stem cell. C: Median leaf cell.

Plant with 5 long, tubular a horn-like keels of the perianth, falcate leaf lobes, 2 mailiate basal ocelli on the leaf lobes, and the horizontally spreading underleaf lobes, each 6-10 cell long.

Collector and specimen number: Saidatul 23154, 23169, 23171.

Habitat: on tree trunk.

38. ***Lejeunea tuberculosa*** Steph. (Figure 4.40)

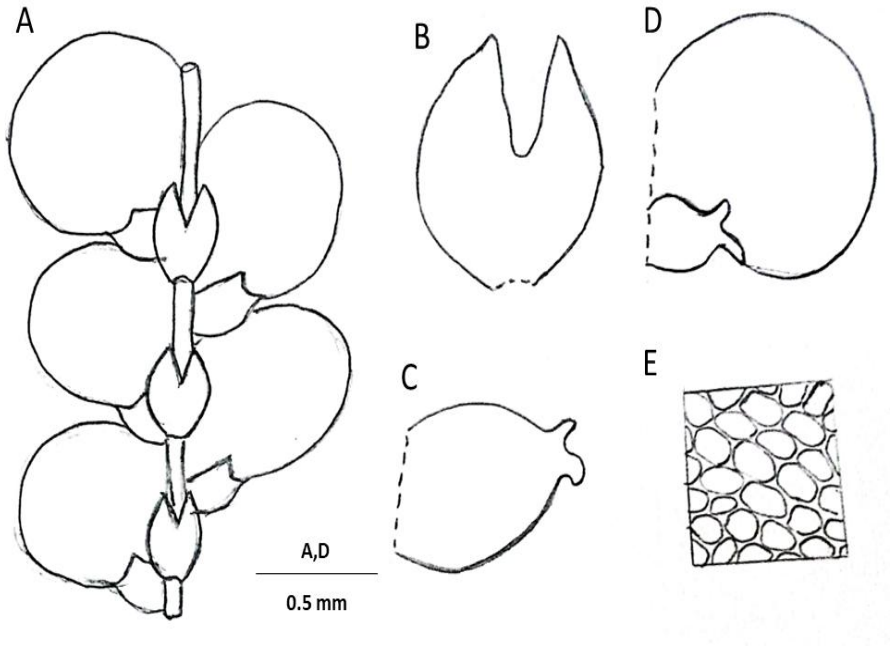

Figure 4.40. ***Lejeunea tuberculosa*** Steph. A: Part of plant. B: Underleaves, C: Part of lobule. D: Leaf. E: Median leaf cell.

Plant with irregularly branched. Rhizoids numerous, fasciculate. Leaves imbricate. Lobe ovate. Lobe cells are thin-walled and thickened, trigons are usually large, intermediate thickenings are usually frequent, median cells are hexagonal, and basal cells are like median cells. Oil bodies not seen. Lobule small, ovate, inflated, free lateral margin slightly incurved. Underleaves distant, transversely inserted. Androecia on short lateral branches, terminal, bracts in 2-3 pairs, densely imbricate, obliquely spreading, bracteole 0-1, present only at the base of the androecium. Gynoecia terminal on short branches, with an athecal innovation, bract lobe obovate, and perianth obovate.

Collecter and specimen number: Saidatul 19004, 19042.

Habitat: on tree trunk.

39. *Lejeunea micholitzii* Mizut (Figure 4.41)

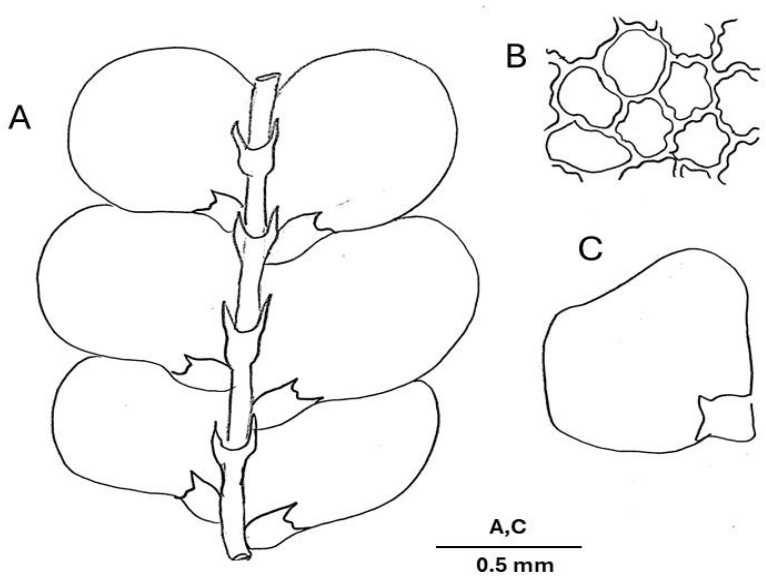

Figure 4.41. ***Lejeunea micholitzii*** Mizut A: Part of plant. B: Median leaf cell. C: Part of lobule.

Plant with reniform, deeply bifid underleaves with acute lobes, the well develop trigones and conspicuous, intermediate thickenings and the obovate perianths.

Collector and specimen number: Saidatul 19015, 19016.

Habitat: on tree trunk.

40. *Lejeunea sordida* (Nees) Nees. (Figure 4.42)

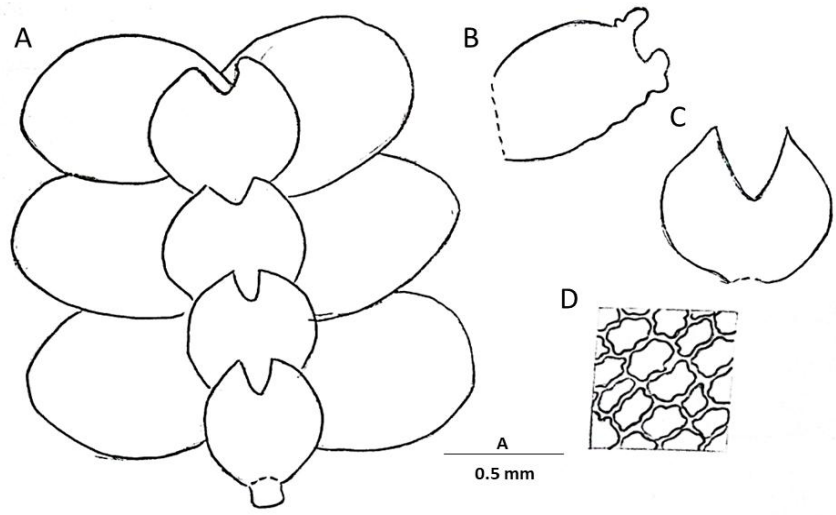

Figure 4.42. ***Lejeunea sordida*** (Nees) Nees. A: Part of plant. B: Part of lobule. C: Underleaves. D: Median leaf cell.

Plants are dioicous, irregularly, and loosely pinnate, with branches erect spreading. Stems with 11-12 medullary cells, and 7 epidermal cells. Leaves imbricate to contiguous. Leaf lobe orbicular, leaf apex broadly rounded, always flat, leaf margin entire. Leaf cells are rather uniform, usually quadrate to pentagonal, sometimes rounded, and irregularly quadrate to rectangular towards the leaf margin. Cuticle rough. Oil bodies not seen. Leaf lobules are rarely reduced, ovate, or inflated along the keel. Underleaves contiguous to sub imbricate, reniform. Androecia with bracts occasionally along the main shoot. Male bracts in 3-5 pairs entire without wing, apex obtuse, keels inflated. Male bracteole 1, smaller than underleaf, margin entire. Antheridia 2 per bract. Gynoecia on short branches, female bracts loosely arranged to somewhat crowded, with one innovation. Sporophyte not seen.

Collector and specimen number: Saidatul 19004.

Habitat: on tree trunk.

41. ***Lepidolejeunea bidentula*** R.M.Schust. (Figure 43)

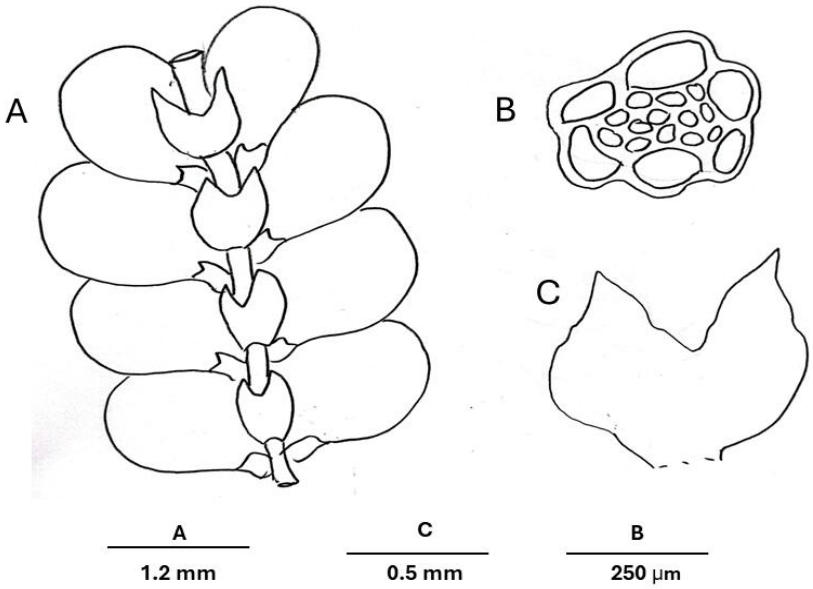

Figure 4.43. ***Lepidolejeunea bidentula*** R.M.Schust. A: Part of plant. B: Cross section of stem cell. C: Underleaves.

Leaf lobes wide spreading, often falcate, with numerous and scattered ocelli, apex rounded to acute apiculate, margin entire to crenulate. Cells are small, wall thin, and cuticle smooth. Oil bodies are absent. Lobules are ovate and inflated. Underleaves bifid. Perianths inflated, 5 keeled, the keel swollen and smooth.

Collector and specimen number: Saidatul 19004, 19042.

Habitat: on tree trunk.

42. *Leptolejeunea borneensis* Herzog. (Figure 4.44)

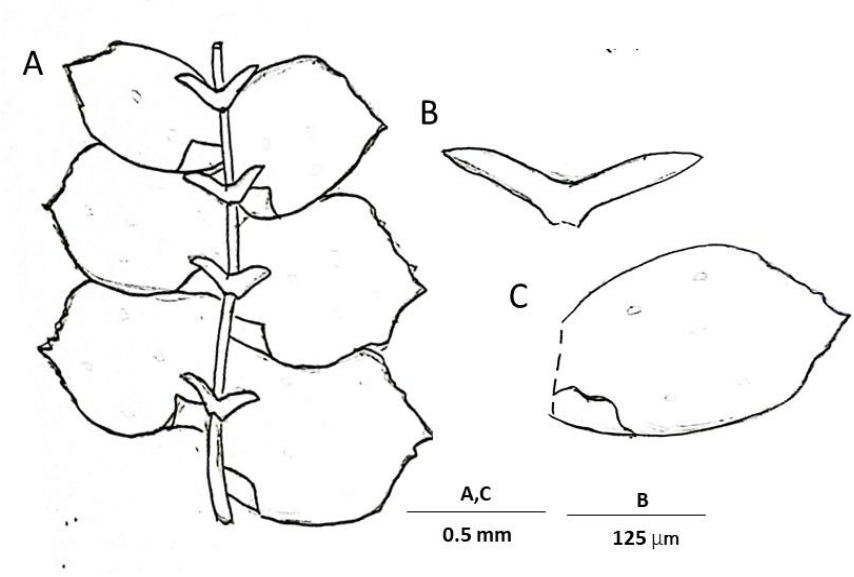

Figure 4.44**. *Leptolejeunea borneensis*** Herzog. A: Part of plant. B: Underleaves. C: Leaf.

Plant with irregularly branched. Stems consist of 7 cortical cells and 3 medullary cells. Rhizoids numerous and fasciculate. Leaves imbricate or contiguous, spreading widely. Lobe obliquely oblong-ovate. Lobe cells are thin-walled, trigones and intermediate thickenings small, median cells hexagonal, and basal cells like median ones but slightly larger. Cuticle smooth. Ocelli and oil bodies not seen. Lobule ovate, inflated, free lateral margin bordered by 4 rectangular cells, apex truncated, with 2 teeth, tooth obtuse, composed of one oblong cell, second tooth obsolete, hyaline papilla at the proximal side of the first tooth, keel straight and smooth. Underleaves distant, deeply bilobed, lobes linear.

Collector and specimen number: Saidatul 23026, 23059, 23073, 23078, 23094.

Habitat: on tree trunk.

43. *Leptolejeunea epiphylla* (Mitt.) Steph. (Figure 4.45)

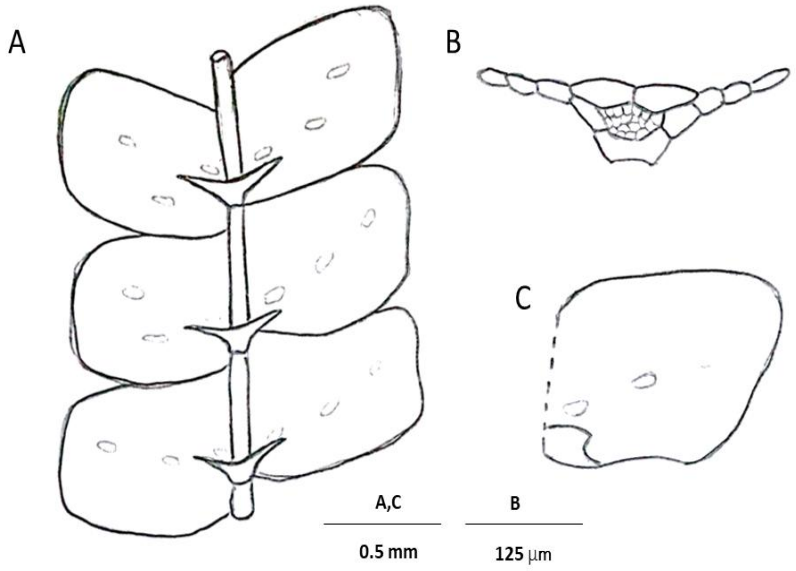

Figure 4.45. ***Leptolejeunea epiphylla*** (Mitt.) Steph. A: Part of plant. B: Underleaves. C; Leaf.

Plant with irregularly branched. Stems consist of 7 cortical cells and 3 medullary cells. Rhizoids numerous and fasciculate. Leaves imbricate or contiguous, spreading widely. Lobe obliquely oblong-ovate. Lobe cells are thin-walled, trigones and intermediate thickenings small, median cells hexagonal, and basal cells like median ones but slightly larger. Cuticle smooth. Ocelli and oil bodies not seen. Lobule ovate, inflated, free lateral margin bordered by 4 rectangular cells, apex truncated, with 2 teeth, tooth obtuse, composed of one oblong cell, second tooth obsolete, hyaline papilla at the proximal side of first tooth, keel straight and smooth. Underleaves distant, deeply bilobed, lobes linear.

Collector and specimen number: Saidatul 23095, 23121, 23160, 23167, 23178, 23211.

Habitat: on tree trunk, soil.

4.44. ***Leptolejeunea vitrea*** (Nees) Schiffn. (Figure 4.46)

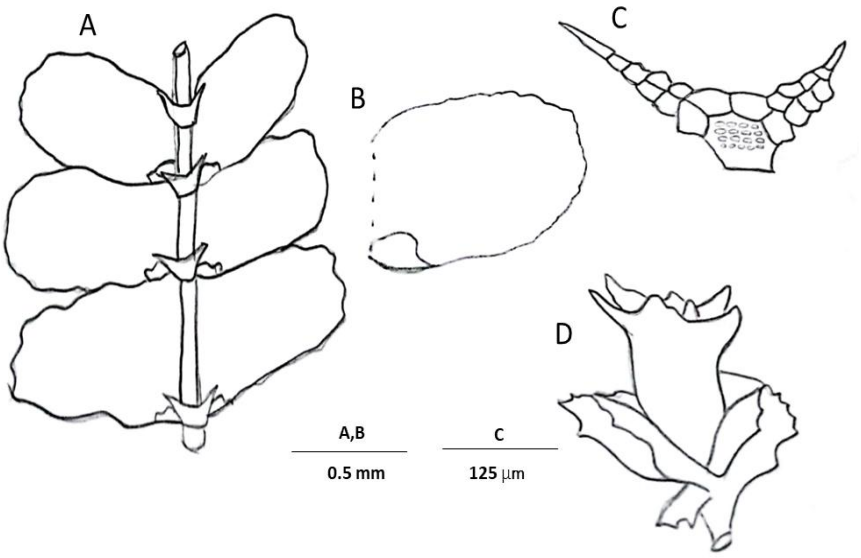

Figure 4.46. ***Leptolejeunea vitrea*** (Nees) Schiffn. A: Part of plant. B: Leaf. C: Underleaves. D: Female bracts and perianth.

Plant with irregularly branched. Stems consist of 7 cortical cells and 3 medullary cells. Rhizoids numerous and fasciculate. Leaves imbricate or contiguous, spreading widely. Lobe oblong, serrulate margins. Lobe cells are thin walled, with trigones and intermediate thickenings 2-4 per cell, median cells hexagonal, and basal cells like median ones but slightly larger. Cuticle smooth. Ocelli and oil bodies not seen. Lobule ovate, inflated, free lateral margin bordered by 4 rectangular cells, apex truncated, with 2 teeth, tooth obtuse, composed of one oblong cell, second tooth obsolete, hyaline papilla at the proximal side of the first tooth, keel straight and smooth. Underleaves distant, deeply bilobed, lobes linear.

Collector and specimen number: Saidatul 23016, 23019, 23039, 23047, 23061.

Habitat: on tree trunk.

4.45. *Leptolejeunea subacuta* A.Evans (Figure 4.47)

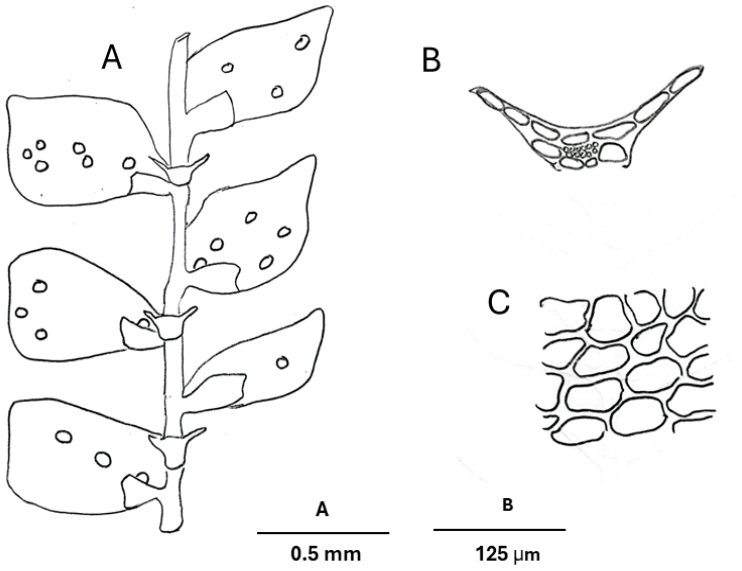

Figure 4.47. ***Leptolejeunea subacuta*** A.Evans. A: Part of plant. B: Underleaves. C: Median leaf cell.

Plant with irregularly branched. Stems consist of 7 cortical cells and 3 medullary cells. Rhizoids numerous and fasciculate. Obtuse to subacute leaf apices, one large basal ocellus. The lobe is obliquely oblong-ovate. Lobe cells are thin-walled, trigones and intermediate thickenings small, median cells hexagonal, and basal cells like median ones but slightly larger. Cuticle smooth. Ocelli and oil bodies not seen. Lobule ovate, inflated, free lateral margin bordered by 4 rectangular cells, apex truncated, with 2 teeth, tooth obtuse, composed of one oblong cell, second tooth obsolete, hyaline papilla at the proximal side of the first tooth, keel straight and smooth. Underleaves distant, deeply bilobed, lobes linear.

Collector and specimen number: Saidatul 23160, 23167, 23178, 23211.

Habitat: on tree trunk.

46. ***Leptolejeunea maculata*** (Mitt.) Schffn. (Figure 4.48)

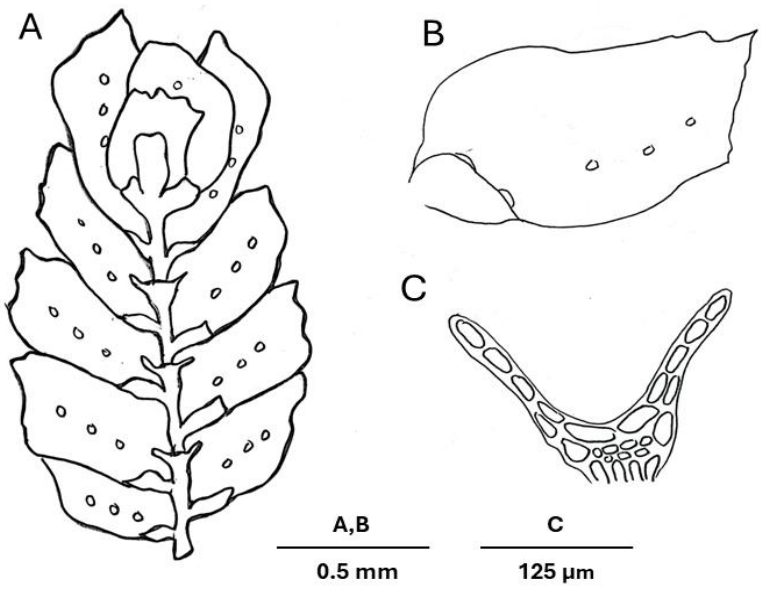

Figure 4.48. ***Leptolejeunea maculata*** (Mitt.) Schffn. A: Part of plant. B: Leaf. C: Underleaves.

Plant with oblong leaf lobes, serrate margins of leaf lobes, large trigones, distinct intermediate thickenings (2-4 per cell), and 1-5 scattered ocelli in the leaf lobes.

Collector and specimen number: Saidatul 23095, 23121, 23178, 23211.

Habitat: on tree trunk, soil.

47. *Leptolejeunea tripuncta* (Mitt.) Steph. (Figure 4.49)

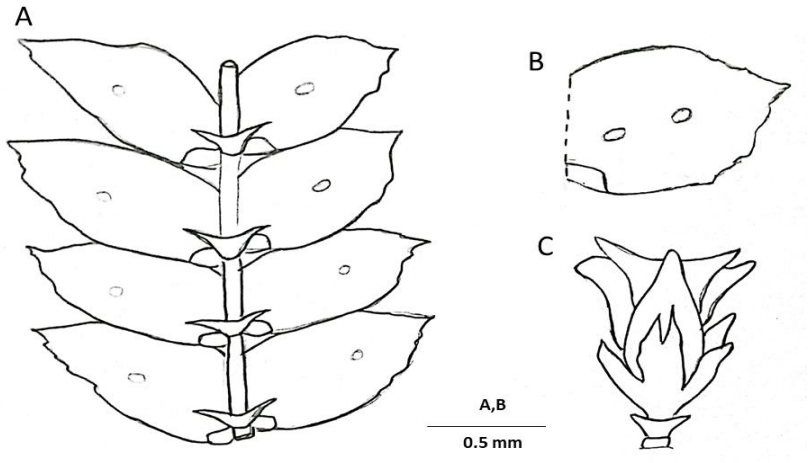

Figure 4.49. ***Leptolejeunea tripuncta*** (Mitt.) Steph. A: Part of plant. B: Leaf. C; Female bracts and perianth.

Plant with irregularly branched. Stems consist of 7 cortical cells and 3 medullary cells. Rhizoids numerous and fasciculate. Leaves imbricate or contiguous, spreading widely. Lobe obliquely oblong-ovate, 2-3 teeth on dorsal and ventral lobe margin. Lobe cells are thin-walled, trigones and intermediate thickenings small, median cells hexagonal, and basal cells like median ones but slightly larger. Cuticle smooth. Ocelli and oil bodies not seen. Lobule ovate, inflated, free lateral margin bordered by 4 rectangular cells, apex truncated, with 2 teeth, tooth obtuse, composed of one oblong cell, second tooth obsolete, hyaline papilla at the proximal side of the first tooth, keel straight and smooth. Underleaves distant, deeply bilobed, lobes linear.

Collector and specimen number: Saidatul 23026, 23052, 23158.

Habitat: on tree trunk.

48. ***Leptolejeunea amphiophthalma*** Zwickel (Figure 4.50)

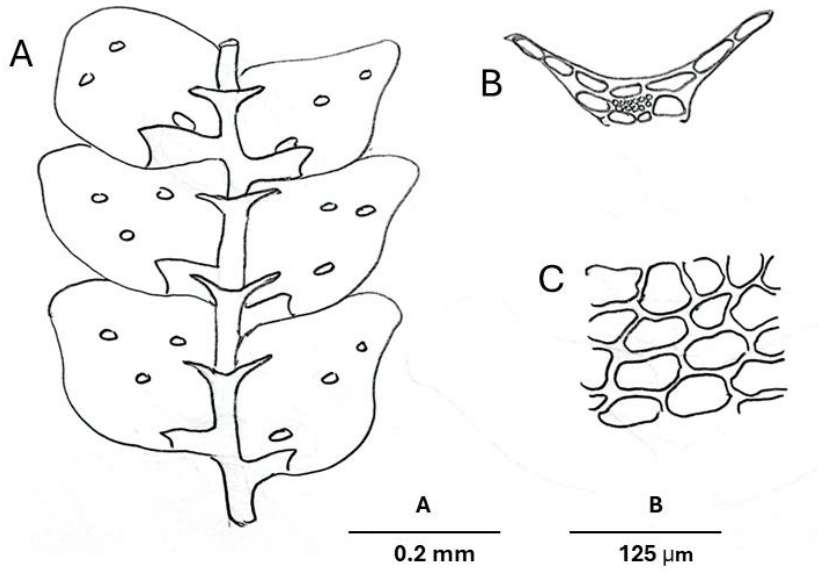

Figure 4.50. ***Leptolejeunea amphiophthalma*** Zwickel. A: Part of plant. B: Underleaves. C: Median leaf cell.

Plant with irregularly branched. Stems consist of 7 cortical cells and 3 medullary cells. Rhizoids numerous and fasciculate. Leaves imbricate or contiguous, spreading widely. The lobe is obliquely oblong-ovate. Lobe cells are thin-walled, trigones and intermediate thickenings small, median cells hexagonal, and basal cells like median ones but slightly larger. Cuticle smooth. Ocelli and oil bodies not seen. Lobule ovate, inflated, free lateral margin bordered by 4 rectangular cells, apex truncated, with 2 teeth, tooth obtuse, composed of one oblong cell, second tooth obsolete, hyaline papilla at the proximal side of the first tooth, keel straight and smooth. Underleaves distant, deeply bilobed, lobes linear.

Collector and specimen number: Saidatul 19032.

Habitat: on tree trunk.

49. *Lopholejeunea eulopha* (Taylor) Schffn. (Figure 4.51)

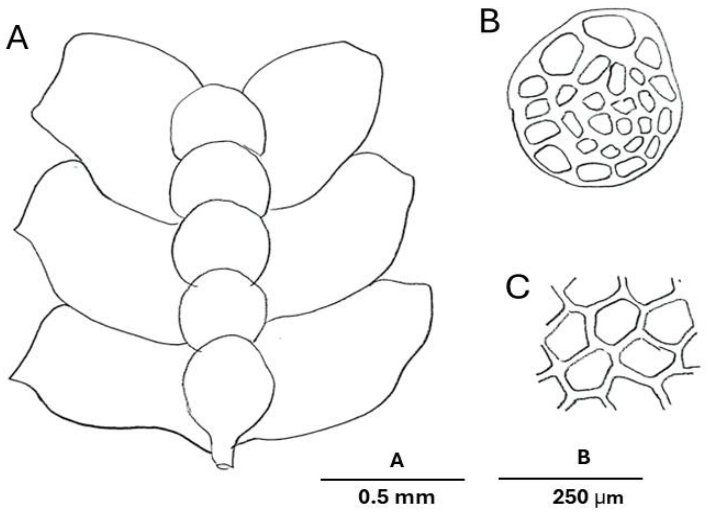

Figure 4.51. ***Lopholejeunea eulopha*** (Taylor) Schffn. A: Part of plant. B: Cross section of stem cell. C: Median leaf cell.

Plant dioicous with branches *Lejeunea*-type. Leaves imbricate, lobe ovate to oblong-ovate, falcate, apex rounded, acute, plane, margin entire. Lobe cell walls are thin, trigones are small, and intermediate thickening is frequent. Oil bodies not seen. Lobule ovate, inflated, free lateral margin. Underleaves imbricate to contiguous, transversely oblong. Perianth obovate.

Collector and specimen number: Saidatul 22036, 22037, 22055, 22058, 22070.

Habitat: on tree trunk.

50. *Lopholejeunea subfusca* (Nees) Schiffn. (Figure 4.52)

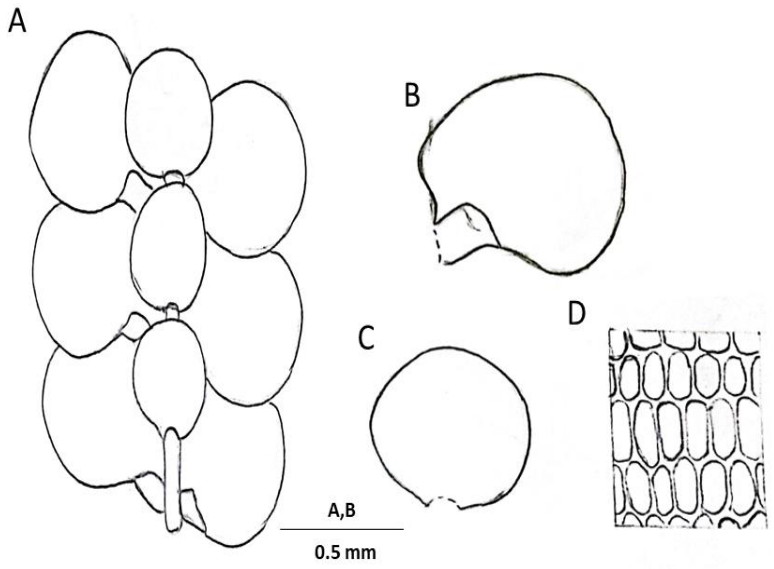

Figure 4.52. ***Lopholejeunea subfusca*** (Nees) Schiffn. A: Part of the plant. B: Leaf. C: Underleaves. D: Median leaf cell.

Plant autoicous. Intercalary branches with 9-10 epidermal cells and 8-10 medullary cells, epidermal cells larger than medullary cells, all cells with thin or slightly thickened walls. Leaves imbricate. Lobe cell walls are thin or slightly thickened, trigones small or large, simple triangular, intermediate thickening, marginal cells subquadrate, median cells isodiametric, basal cells hexagonal. Rhizoids are numerous, fasciculate, and brown, at the base of underleaves. Cuticle smooth. Ocelli and oil bodies not seen. Lobule ovate, inflated, free lateral margin incurved, unicellular tooth, keel slightly arched. Underleaves distant, contiguous to imbricate. Andoecia with bracts in 2-13 pair. Gynoecia without innovation. Perianth is obovate and immersed.

Collector and specimen number: Saidatul 19019, 19020, 19038, 19044, 22207, 23076.

Habitat: on tree trunk.

51. *Lopholejeunea applanata* (Reinw. *et al*.) Schiffn. (Figure 4.53)

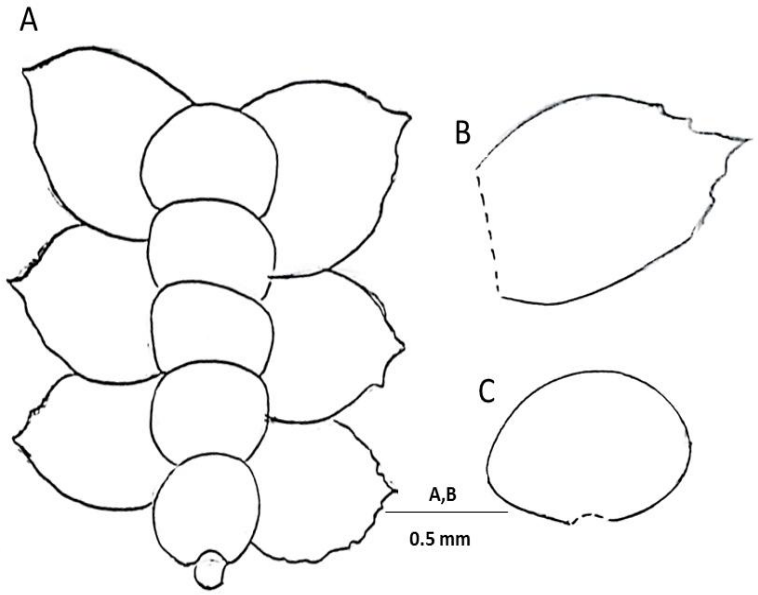

Figure 4.53. ***Lopholejeunea applanata*** (Reinw. *et al*.) Schiffn. A: Part of plant. B: Leaf. C; Underleaves.

Plant autoicous. Intercalary branches with 11-13 epidermal cells and 12-14 medullary cells, epidermal cells slightly larger than medullary cells, all cells with slightly thickened walls. Leaves imbricate, lobe ovate, falcate, dorsal margin slightly arched. Lobe cell walls thickened, trigones small, simple triangular, intermediate thickening, marginal cells subquadrate, median cell isodiametric, basal cells hexagonal. Lobule oblong-ovate, inflated, free lateral margin plane, keel slightly arched. Underleaves distant to contiguous. Ocelli and oil bodies not seen. Androecia with bracts in 2-6 pair. Gynoecia on branches, without innovation, bracts in 1 series. Perianth emergent, obovate, forming continuous wings at the lateral keels. Leaf apices are acute or obtuse, the dorsal margin of the leaf lobe recurved near the base leaf margin entire. Female bract lobule entire at the margin, female bracteole entire, distantly dentate, perianth emergent.

Collector and specimen number: Saidatul 22060.

Habitat: on tree trunk.

52. *Lopholejeunea ceylanica* Steph. (Figure 4.54)

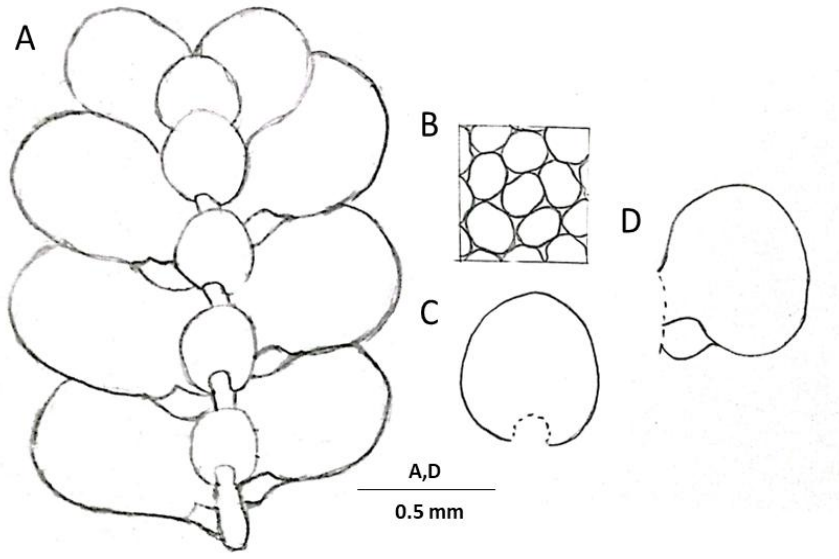

Figure 4.54. ***Lopholejeunea ceylanica*** Steph. A: Part of plant. B: Median leaf cell. C: Underleaves. D: Leaf.

Plant autoicous. Intercalary branches with 11-13 epidermal cells and 12-14 medullary cells, epidermal cells slightly larger than medullary cells, all cells with slightly thickened walls. Leaves imbricate, lobe ovate, falcate, dorsal margin slightly arched. Lobe cell walls thickened, trigones small, simple triangular, intermediate thickening, marginal cells subquadrate, median cell isodiametric, basal cells hexagonal. Lobule oblong-ovate, inflated, free lateral margin plane, keel slightly arched. Underleaves distant to contiguous. Ocelli and oil bodies not seen. Androecia with bracts in 2-6 pair. Gynoecia on branches, without innovation, bracts in 1 series. Perianth emergent, obovate, forming continuous wings at the lateral keels.

Collector and specimen number: Saidatul 22036, 22037, 22055, 22058, 22065, 22066, 22070.

Habitat: on tree trunk.

53. *Mastigolejeunea virens* (Angstr.) Steph. (Figure 4.55)

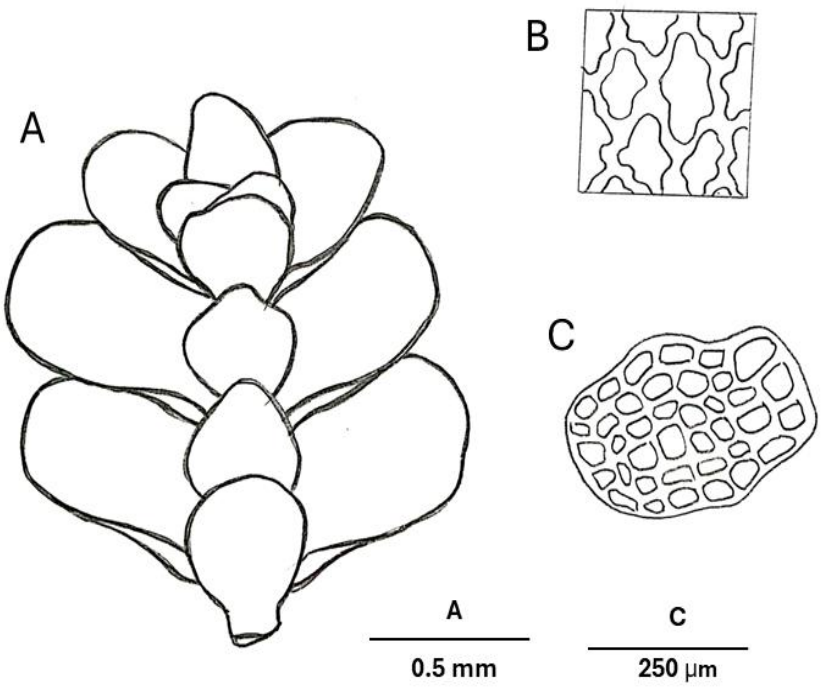

Figure 4.55. ***Mastigolejeunea virens*** (Angstr.) Steph. A: Part of the plant. B: Median leaf cell. C: Cross section of stem cell.

Plants autoicous with branches of *Lejeunea*-type. Leaves densely imbricate, lobe ovate, apex obtuse to rounded, margin entire, dorsal margin arched, ventral margin incurved. Lobe cell walls are thin, trigones large cordate, and intermediate thickenings scarce. Lobule ovate or oblong, apex obliquely truncate, with 1 tooth. Underleaves obliquely spreading to slightly squarrose, imbricate, apex rounded, entire. Oil bodies not seen. Androecia and gynoecia were not present.

Collector and specimen number: Saidatul 19019, 19038, 22207.

Habitat: on tree trunk.

54. ***Mastigolejeunea auriculata*** (Wilson & Hook.) Steph. (Figure 4.56)

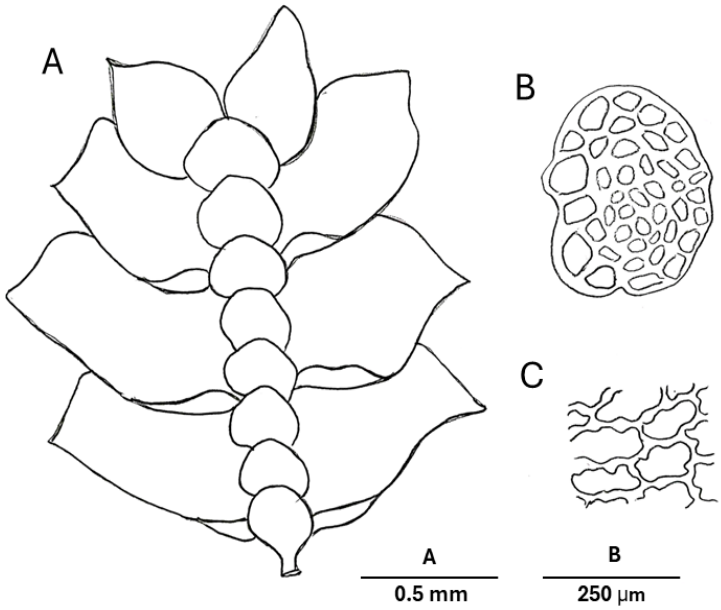

Figure 4.56. ***Mastigolejeunea auriculata*** (Wilson & Hook.) Steph. A: Part of the plant. B: Cross section of stem cell. C: Median leaf cell.

Plant autoicous with branches of *Lejeunea*-type. Leaves densely imbricate, entire, dorsal margin arched, ventral margin incurved. Lobe cell walls this, trigones large, cordate, intermediate thickenings scarce. Oil bodies absent. Lobule ovate, apex obliquely truncate. Underleaves obliquely spreading, imbricate. Androecia and gynoecia not present.

Collector and specimen number: Saidatul 19019, 19038, 22207.

Habitat: on tree trunk.

55. *Mastigolejeunea repleta* (Taylor) A. Evans (Figure 4.57)

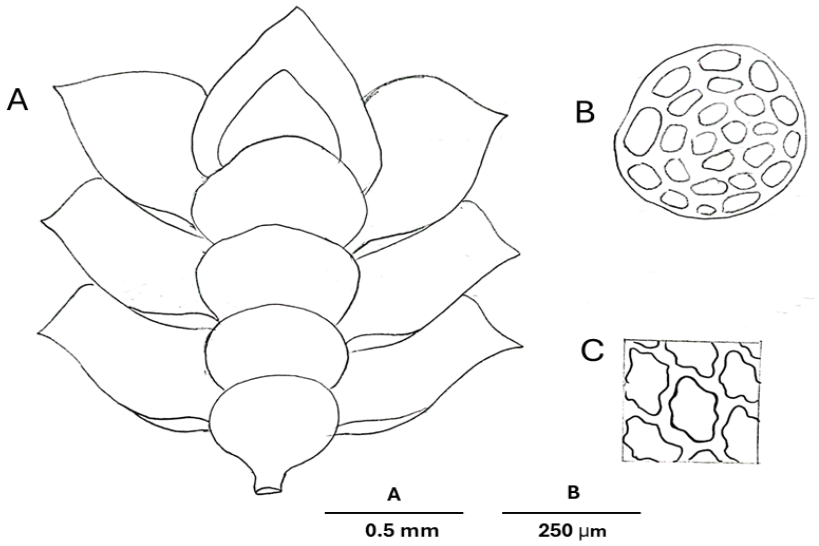

Figure 4.57. ***Mastigolejeunea repleta*** (Taylor) A. Evans. A: Part of the plant. B: Cross section of stem cell. C: Median leaf cell.

Plants autoicous with branches of *Lejeunea*-type. Leaves densely imbricate, lobe oblong, apex acute, margin entire, dorsal margin arched, ventral incurved. Lobe cell walls are thin or slightly thickened, trigones large, intermediate thickening present. Lobule ovate, apex obliquely truncate. Underleaves obliquely spreading, imbricate. Oil bodies not seen. Androecia and gynoecia were not present.

Collector and specimen number: Saidatul 19019, 19038, 22207.

Habitat: on tree trunk.

55. *Spruceanthus semirepandus* (Nees) Verd. (Figure 4.58)

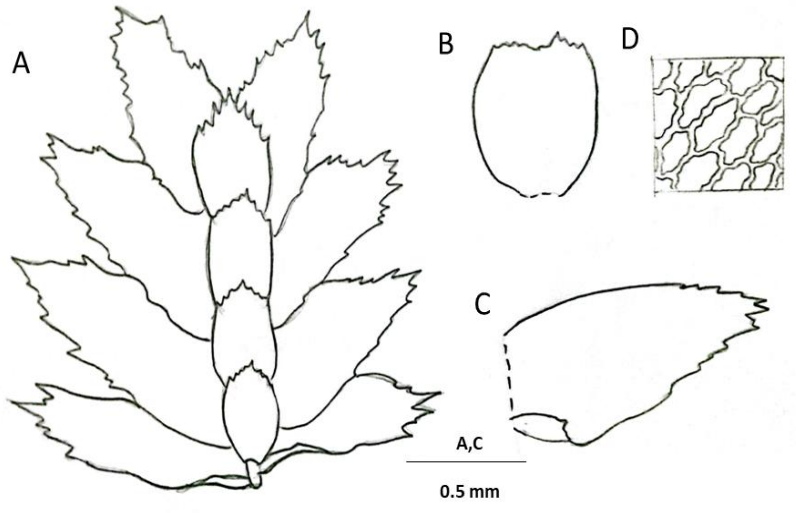

Figure 4.58. ***Spruceanthus semirepandus*** (Nees) Verd. A: Part of plant. B; Underleaves. C: Leaf. D Median leaf cell.

Plant autoicous. Intercalary branches with 28 thick-walled epidermal cells, 1-2 rows of thick-walled subepidermal cells, and 60 medullary cells. Leaves imbricate, widely spreading when moist, lobe obliquely ovate, ventral margin incurved, dorsal margin slightly arched. Lobe cell walls thickened, trigones large, intermediate thickenings frequent, marginal cells subquadrate, median cells hexagonal, basal cells elongated. Lobule ovate, inflated, free lateral margin incurved with 1-3 unicellular teeth. Underleaves imbricate, appressed to the stem apex rounded to truncate, bases asymmetrically. Oil bodies and ocelli were not seen. Androecia on branches with bracts in 5-8 pairs. Gynoecia with 2 innovations. Perianth obovate, with 5-10 smooth keels. Asexual reproductive organs are absent.

Collector and specimen number: Saidatul 19015, 19016.

Habitat: on tree trunk.

56. *Thysananthus virens* Ångstr. (Figure 4.59)

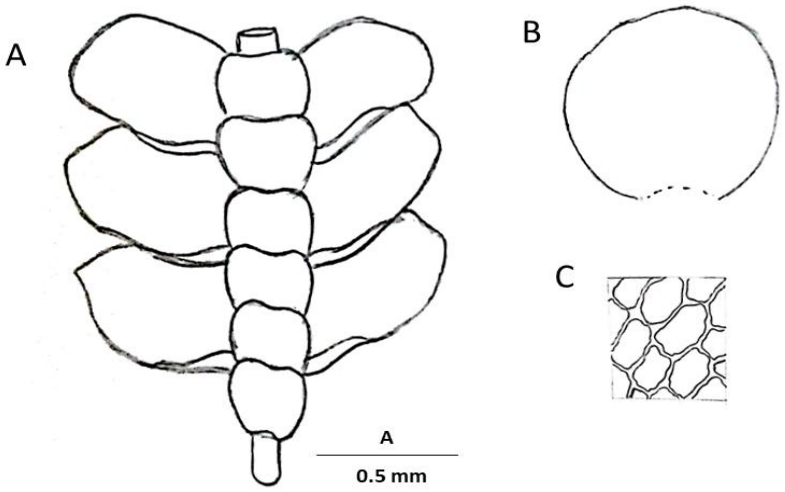

Figure 4.59. ***Thysananthus viren*** Ångstr. A: Part of plant. B: Underleaves. C: Median leaf cell.

Plant with small microphyllous branches. Stem without ventral epidermis cell, thick-walled. Leaf lobes wide-spreading, margin entire. Cells with trigones cordate. Underleaves undivided, apex rounded to emarginate and toothed. Oil bodies not seen. Gynoecia not seen.

Collector and specimen number: Saidatul 23145, 23148, 23150, 23151, 23157.

Habitat: on tree trunk.

57. *Thysananthus convolutes* Lindenb. (Figure 4.60)

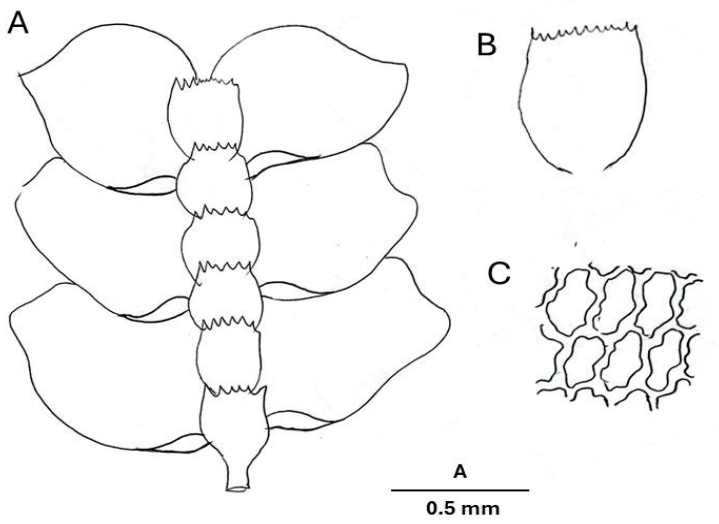

Figure 4.60. ***Thysananthus convolutes*** Lindenb. A: Part of plant. B: Underleaves. C: Median leaf cell.

Plant with small microphyllous branches. Stem without ventral epidermis cell, thick-walled. Leaf lobes wide-spreading, margin entire. Cells with trigones cordate. Underleaves undivided, apex rounded to emarginate and toothed. Oil bodies not seen. Gynoecia not seen.

Collector and specimen number: Saidatul 23145, 23148, 23152, 23155, 23158.

Habitat: on tree trunk.

59. *Thysananthus aculeatus* Herzog (Figure 4.61)

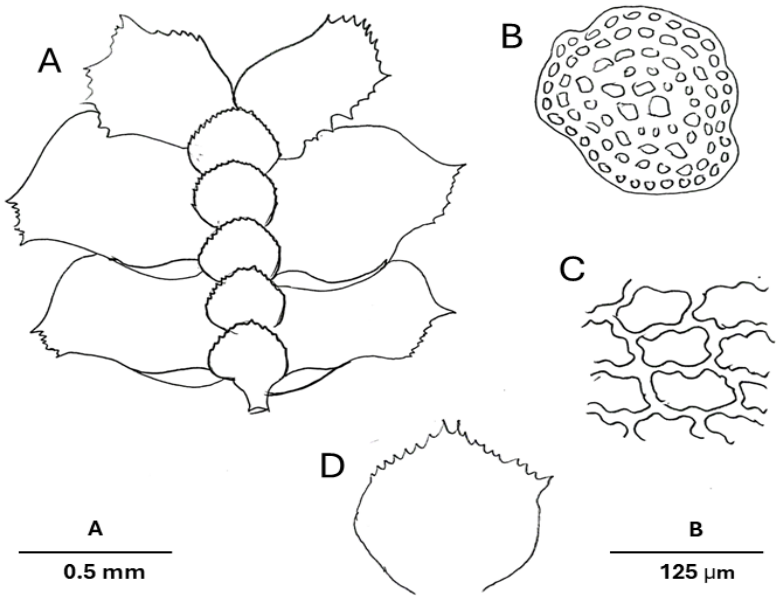

Figure 4.61. ***Thysananthus aculeatus*** Herzog. A: Part of plant. B: Underleaves. C: Median leaf cell.

Plant with small microphyllous branches. Stem without ventral epidermis cell, thick-walled. Leaf lobes wide-spreading, margin entire. Cells with trigones cordate. Underleaves undivided, apex rounded to emarginate and toothed. Oil bodies not seen. Gynoecia not seen.

Collector and specimen number: Saidatul 23145, 23148, 23152, 23155, 23158.

Habitat: on tree trunk.

60. *Radula kojana* Steph. (Figure 4.62)

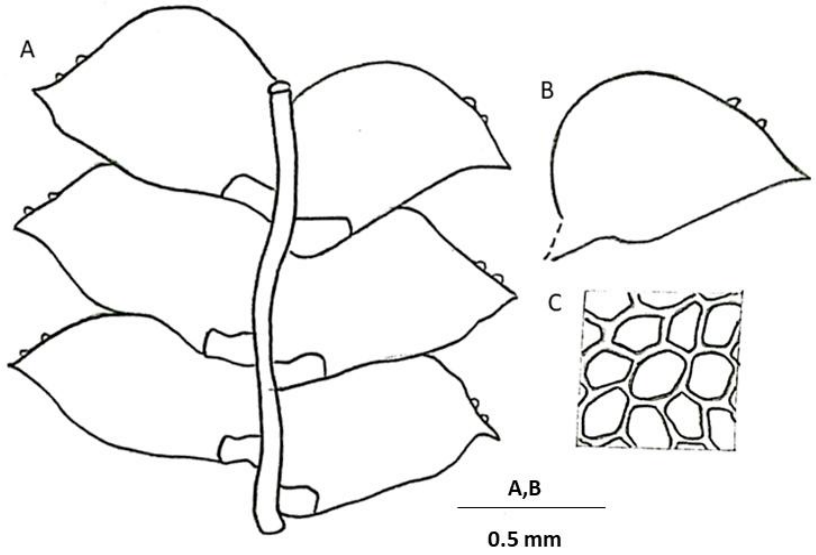

Figure 4.62. ***Radula kojana*** Steph. A: Part of plant. B: Leaf. C: Median leaf cell.

Plant dioicous. Leaves with irregular pinnate branching, branches obliquely spreading, cross section of stem 7-9 cells thick, cortical, and medullary cells not differentiated. Leaf lobes moderately to loosely imbricate, widely spreading, concave, ovate, or rarely narrowly falcate ovate. Discoid gemmae often occurring on the margins of leaf lobes. Leaf lobule subquadrate. Oil bodies not seen. Androecia terminal on short branches, with 3-5 pairs of bracts. Gynoecia terminal on stems with innovation, bracts in 1-2 pairs.

Collector and specimen number: Saidatul 19015, 23039, 23077, 23098.

Habitat: on tree trunk.

61. ***Radula cavifolia*** Hampe ex Gottsche, Lindenb. & Nees. (Figure 4.63)

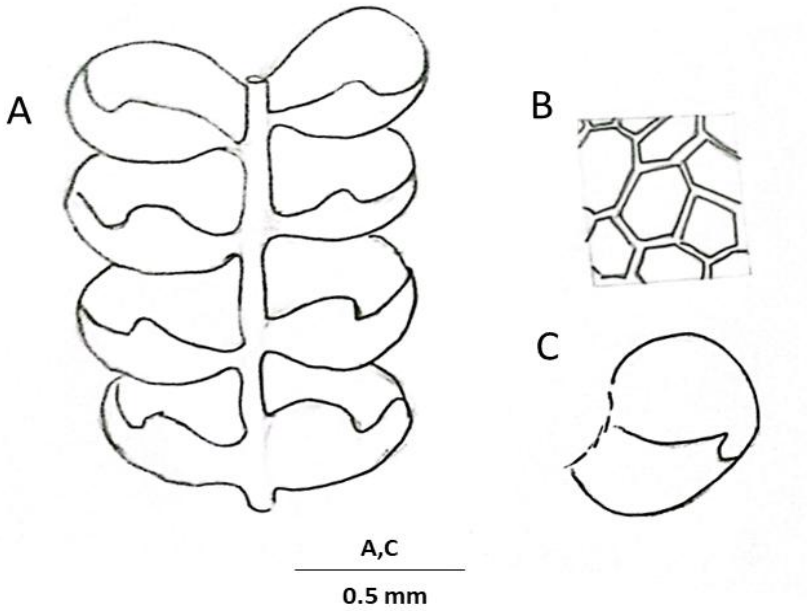

Figure 4.63. ***Radula cavifolia*** Hampe ex Gottsche, Lindenb. & Nees. A: Part of plant. B: Median leaf cell. C: Leaf.

Plant dioicous with pinnate branched. Leaves incubous, with a long insertion, lobe apex rounded, acute, margin entire, lobule broadly attached to the dorsal lobe stem, oblong, inflated, ovate and concave leaf lobes, inflated, large leaf lobule, strongly arched leaf keel. Cells are thin walled with small trigones, and cuticle smooth. Oil bodies not seen. Underleaves are lacking.

Collector and specimen number: Saidatul 19010, 19025, 22016, 23040, 23044.

Habitat: on tree trunk.

62. *Radula tjibodensis* K.I.Goebel. (Figure 4.64)

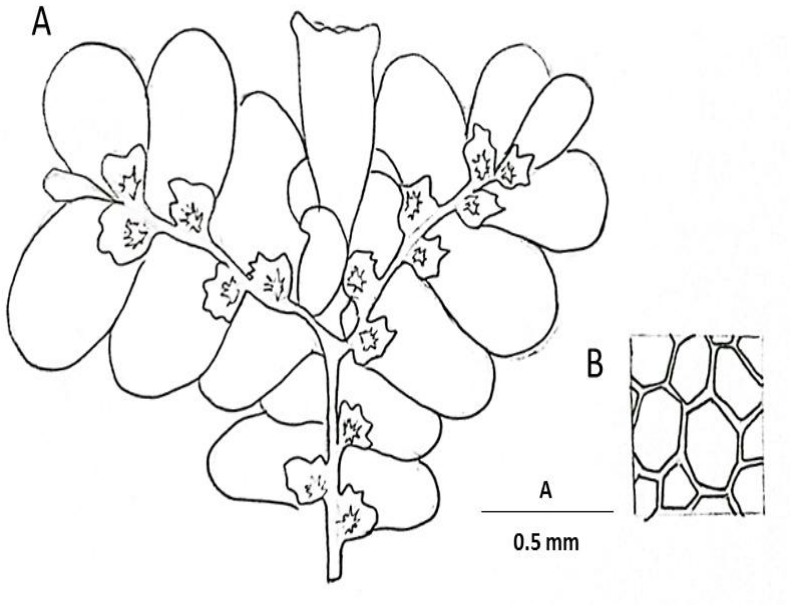

Figure 4.64. ***Radula tjibodensis*** K.I.Goebel. A: Part of plant with perianth. B: Median leaf cell.

Plant dioicous with pinnate branched. Leaves incubous, with a long insertion, lobe apex rounded, acute, margin entire, lobule broadly attached to the dorsal lobe stem, quadrate to oblong, inflated. Cells are thin-walled or with small trigones, cuticle smooth. Narrowly ovate or falcate ovate to oblong leaf lobe with narrowly rounded to obtuse apices. The subquadrate leaf lobule with a narrowly obtuse to bluntly protruding apex. Numerous discoid gemmae occur perpendicularly on the apical margins of leaf lobes. Oil bodies not seen.

Collector and specimen number: Saidatul 19015, 19016, 23015, 23018, 23023.

Habitat: on tree trunk.

63. *Radula gedena* Gottsche ex Steph. (Figure 4.65)

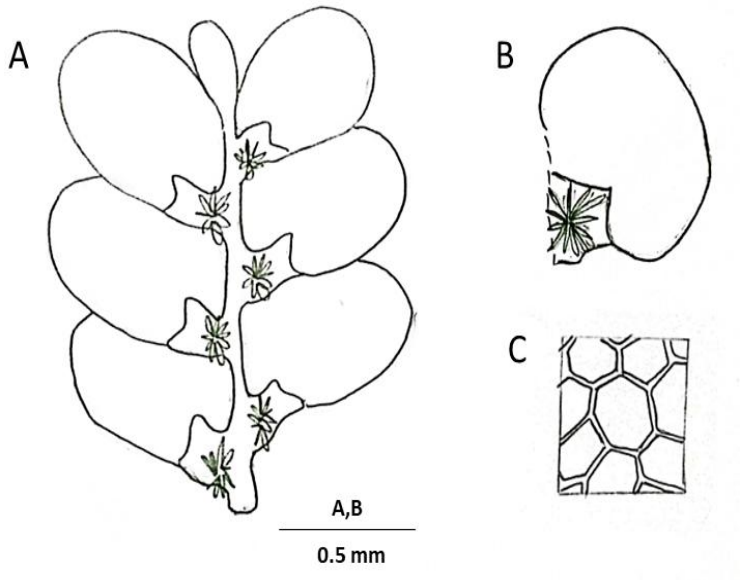

Figure 4.65. ***Radula gedena*** Gottsche ex Steph. A: Part of plant. B: Leaf. C: Median leaf cell.

Plant dioicous with pinnate branched. Leaves incubous, with a long insertion, ovate to broadly ovate leaf lobes with rounded apices. Lobe apex rounded, acute, margin entire, lobule broadly attached to the dorsal lobe stem, quadrate to oblong, inflated. Cells are thin-walled or with small trigones, cuticle smooth. The very irregularly shaped and sized leaf lobe cells, numerous discoid gemmae occurring on the dorsal margins of the leaf lobes and parallel with the surface of them. Oil bodies not seen.

Collector and specimen number: Saidatul 19015, 19016, 22021, 23009.

Habitat: on tree trunk.

64. *Radula acuminata* Steph. (Figure 4.66)

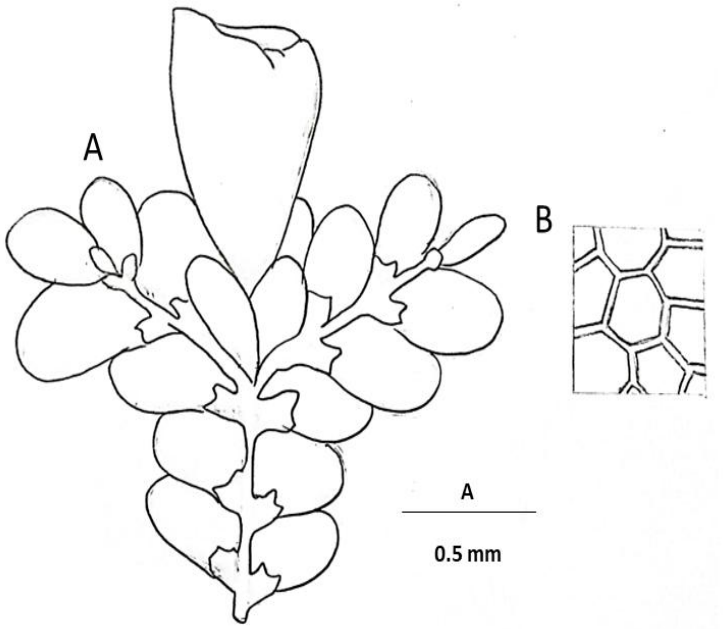

Figure 4.66. ***Radula acuminata*** Steph. A: Part of plant with perianth. B: Median leaf cell.

Plant dioicous with pinnate branched. Leaves incubous, with a long insertion. Leaf lobe falcate ovate, narrowly to broadly rounded apex. Cells are thin-walled or with small trigones, cuticle smooth. Leaf lobule subquadrate or obliquely quadrate with a blunt tip, free margin slightly incurved or not incurved. Numerous discoid gemmae occur perpendicularly on the ventral surface of the leaf lobes. Cross section of stem, 4-5 cells thick. Oil bodies not seen. Underleaves are lacking.

Collector and specimen number: Saidatul 23015, 23118, 23120, 23126.

Habitat: on tree trunk.

65. *Radula assamica* Steph. (Figure 4.67)

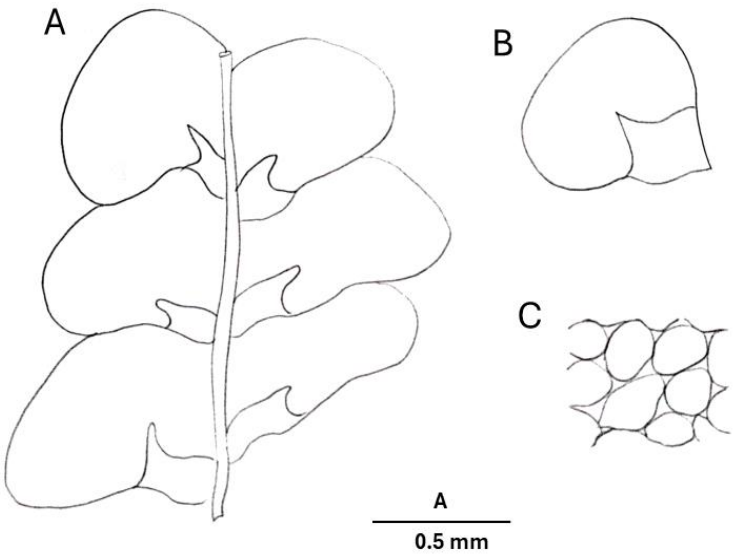

Figure 4.67. ***Radula assamica*** Steph. A: Part of the plant. B: Leaf. C: Median leaf cell.

Plant dioicous with falcate leaves with obtuse to rounded apices, the discoid gemmae developed at the ventral margin of leaf lobes and the triangular-leaf lobules. Cells are thin walled with small trigones, and cuticle smooth. Oil bodies not seen. Underleaves are lacking.

Collector and specimen number: Saidatul 23057, 23066, 23090, 23099.

Habitat: on tree trunk.

66. *Radula nymannii* Steph. (Figure 4.68)

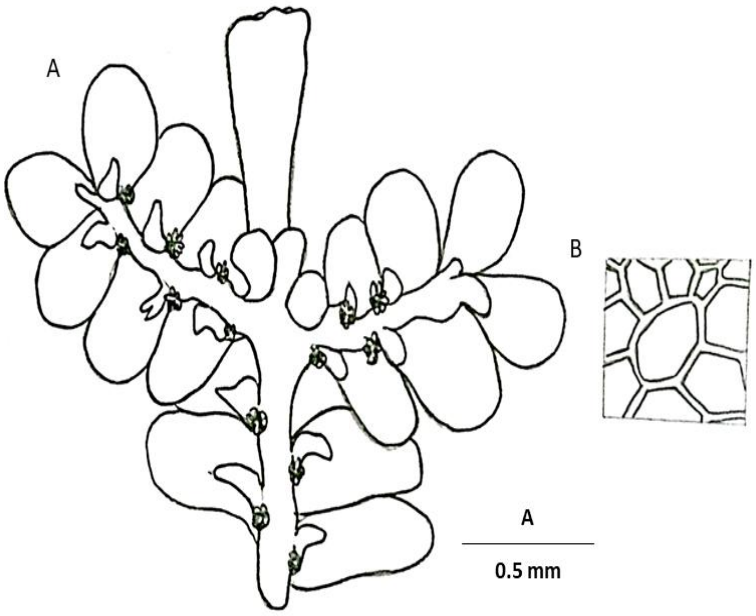

Figure 4.68. ***Radula nymannii*** Steph. A: Part of plant with perianth. B: Median leaf cell.

Plant dioicous with pinnate branched. Leaves incubous, with a long insertion, lobe apex rounded, acute, margin entire, lobule broadly attached to the dorsal lobe stem, quadrate to oblong, inflated. Cells are thin-walled or with small trigones, cuticle smooth. Falcate ovate leaf lobe with narrowly rounded apex. The hook-like leaf lobule with apices narrowly elongates and then abruptly turns outward, numerous discoid gemmae occurring on ventral margins of leaf lobes and parallel to the surface of leaf lobes. Oil bodies not seen.

Collector and specimen number: Saidatul 23057, 23066, 23090, 23099.

Habitat: on tree trunk.

67. *Radula vrieseana* Sande Lac. (Figure 4.69)

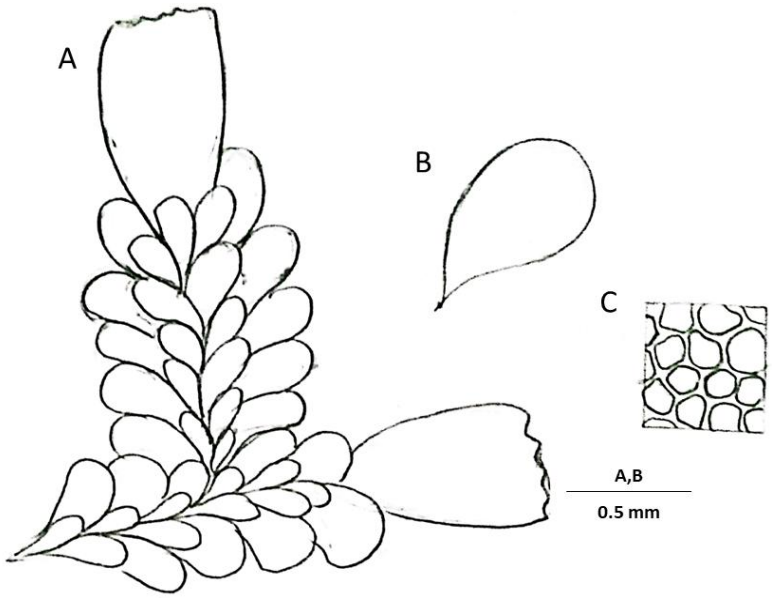

Figure 4.69. ***Radula vrieseana*** Sande Lac. A: Part of plant with perianth. B: Leaf. C: Median leaf cell.

Plant dioicous. Leaves with irregular pinnate branching, branches dense, obliquely spreading, with cross section of stem 12-14 cells thick, cortical cells smaller than medullary cells, with large trigones. Leaf lobe moderately to loosely imbricate, obliquely, or widely spreading, concave with strongly incurved ventral margin, oblong. Oil bodies not seen. Androecia terminal on branches, with 10-20 pairs of bracts, gynoecia terminal on stems and branches with 2 innovations.

Collector and specimen number: Saidatul 23011, 23025, 23027.

Habitat: on tree trunk.

68. *Radula iwatsukii* K.Yamada. (Figure 4.70)

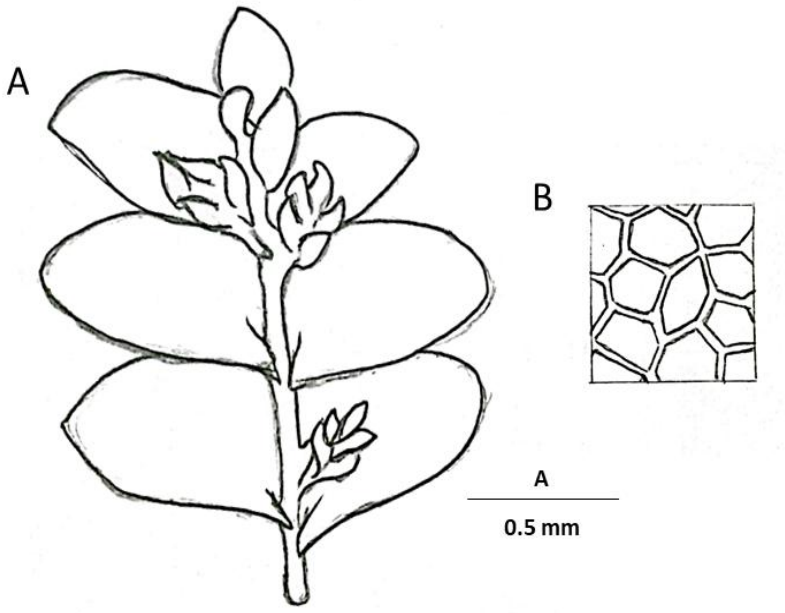

Figure 4.70. ***Radula iwatsukii*** K.Yamada. A; Part of plant. B: Median leaf cell.

Plant dioicous. Leaves with dense and irregularly pinnate branching, branches obliquely spreading, cross section of stem 6 cells thick, cortical cells equal to medullary cells. Leaf lobes moderately imbricate, fragile, concave with incurved apex, ventral margin usually incurved toward apex. Leaf lobules rectangular. Oil bodies not seen. Androecia terminal on branches and stems, with 5-8 pairs of bracts.

Collector and specimen number: Saidatul 19017, 19026, 23011, 230119.

Habitat: on tree trunk.

69. *Radula acuta* Mitt. (Figure 4.71)

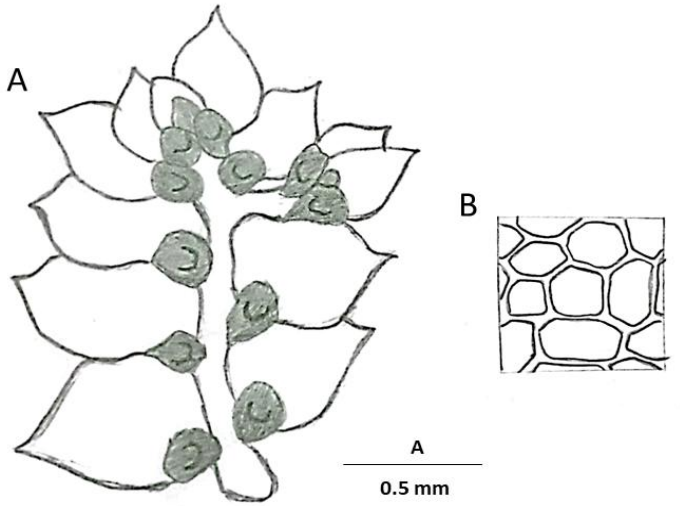

Figure 4.71. ***Radula acuta*** Mitt. A: Part of the plant. B: Median leaf cell.

Plant dioicous. Leaves with irregular and densely pinnate branching, branches obliquely spreading. Cross section of stem 10 cells thick, cortical, and medullary cells not differentiated. Leaf lobes are loosely imbricated, slightly concave, and ovate. Leaf lobule subquadrate. Oil bodies not seen. Underleaves are lacking.

Collector and specimen number: Saidatul 22010, 22013, 23015, 23021.

Habitat: on tree trunk.

4.4 Substrates Preferences

Overall, more than half of the liverworts found in Belukar Bukit Recreational Forest are growing on leaves (epiphylls) with a total of 36 species (Figure 4.72) from three total genera, and *Cololejeunea* contributes the greatest number of epiphylls (10 species). This is followed by the genus *Radula* with nine species, *Leptolejeunea* and *Colura* with four species each, *Lopholejeunea*, *Cheilolejeunea*, *Caudalajeunea* with two species each, *Lejeunea* and *Ceratolejeunea* with one species each.

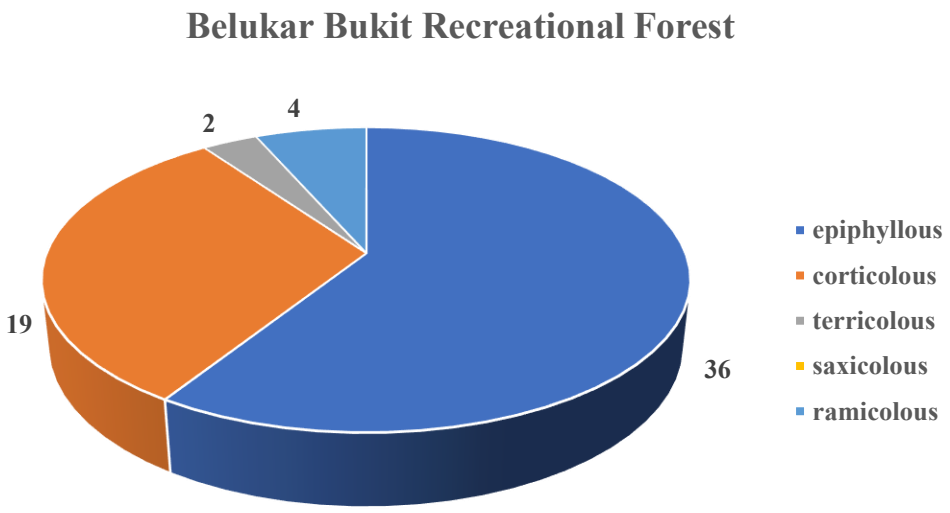

Figure 4.72 Substrates preferences of liverworts in Belukar Bukit Recreational Forest

Meanwhile, in Pulau Telaga Tujuh liverworts were found on tree trunks (Corticolous) with a total of 19 species (Figure 4.73) from three total genera, and *Cololejeunea* contributes the greatest number of epiphylls (10 species). This is followed by the genus *Radula* with nine species, *Leptolejeunea* and *Colura* with four species each, *Lopholejeunea*, *Cheilolejeunea*, *Caudalajeunea* with two species each, *Lejeunea* and *Ceratolejeunea* with one species each.

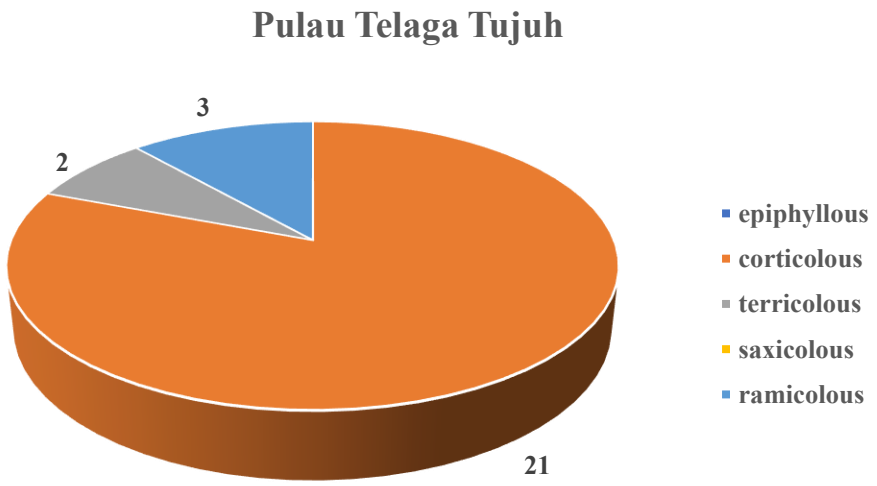

Figure 4.73 Substrates preferences of liverworts in Pulau Telaga Tujuh

Meanwhile, in Jambu Bongkok Forest Reserve all the species of liverworts were found on tree trunks (Corticolous) with a total of 24 species (Figure 4.74) from nine genera.

4.5. Species Similarity Index among the Forest Types.

Then, the overlapping of genera that found in all forest was recorded in figure 4.74. The result shows the similarity of genera between Belukar Bukit Recreational Forest, Pulau Telaga Tujuh and Jambu Bongkok Forest Reserve were *Caudalejeunea*, *Cheilolejeunea, Cololejeunea*, *Lejeunea* and *Lopholejeunea*. While the other genera were only found in certain forests (Figure 4.74). Then, the similarity of the species richness of liverwort are calculated using the Sorensen Index based on Table 4.2. This Sorensen Similarity Coefficient (S) is used to compare the level of similarity of species qualitatively according to the presence or absence of species in study sites. The comparison of Sorensen Index in Table 4.3 shows that in Belukar Bukit Recreational Forest with Jambu Bongkok Forest Reserve has higher index than in Pulau Telaga Tujuh with Belukar Bukit Recreational Forest or in Jambu Bongkok Forest Reserve with Pulau Telaga Tujuh. It may be cause of the humidity of the study sites.

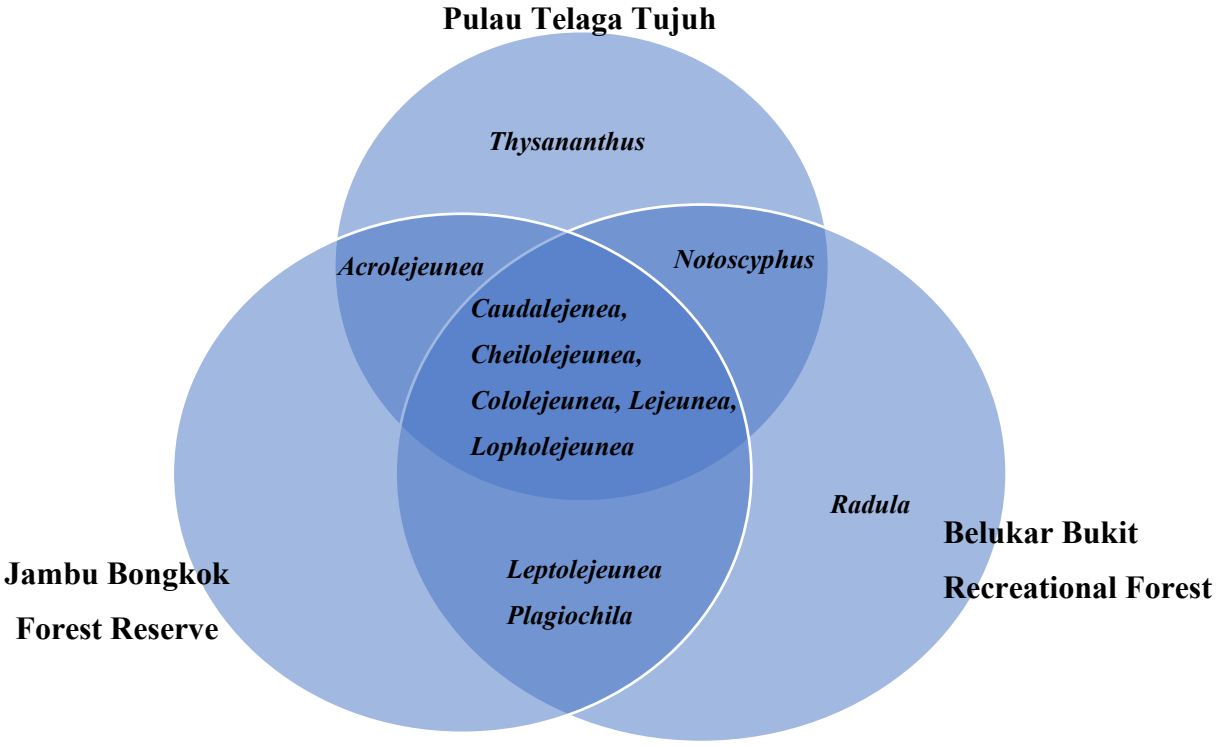

Figure 4.74. The overlapping of genera between the study sites

Table 4.2 Total number of liverwort species according to each study site

Species	Belukar Bukit Recreational Forest	Pulau Telaga Tujuh	Jambu Bongkok Forest Reserve
Acrolejeunea arcuata	-	/	/
Acrolejeunea recurvata	-	/	/
Acrolejeunea sinensis	-	/	/
Caudalajeunea cristiloba	/	/	/
Caudalejeunea reniloba	/	-	-
Ceratolejeunea aliena	/	-	/
Ceratolejeunea singapurensis	/	-	/
Cheilolejeunea decursiva	/	/	/
Cheilolejeunea intertexta	/	/	/
Cheilolejeunea orientalis	-	-	/
Cheilolejeunea trapezia	/	-	-
Chiastocaula dendroides	/	-	-
Cololejeunea aequabilis	/	-	-
Cololejeunea appressa	/	/	-
Cololejeunea ensifera	/	/	/
Cololejeunea equialbi	/	/	/
Cololejeunea falcata	/	/	/
Cololejeunea gottschei	/	-	/
Cololejeunea haskarliana	/	-	-
Cololejeunea inflata	/	/	-
Cololejeunea inflectens	/	/	-
Cololejeunea obliqua	/	/	-
Cololejeunea pluridentata	/	/	-
Cololejeunea schmidtii	/	/	/
Cololejeunea serrulata	/	-	-
Colura acroloba	/	-	-
Colura ari	/	-	-
Colura corynophora	/	-	-
Colura inuii	/	-	-
Drepanolejeunea longicornua	/	-	-
Drepanolejeunea spicata	/	-	-
Drepanolejeunea thwaitesiana	/	-	-
Lejeunea micholitzii	/	-	-
Lejeunea sordida	/	-	/
Lejeunea tuberculasa	/	/	/
Lepidolejeunea bidentula	/	-	-
Leptolejeunea amphiophthalma	/	-	/
Leptolejeunea borneensis	/	-	-

Leptolejeunea epiphylla	/	-	/
Leptolejeunea maculata	/	-	/
Leptolejeunea subacuta	/	-	/
Leptolejeunea tripuncta	/	-	-
Leptolejeunea vitrea	/	-	-
Lopholejeunea applanata	-	/	-
Lopholejeunea ceylanica	/	/	/
Lopholejeunea eulopha	/	/	/
Lopholejeunea subfusca	/	/	/
Mastigolejeunea auriculata	/	-	-
Mastigolejeunea repleta	/	-	-
Mastigolejeunea virens	/	-	-
Notoscyphus lutescens	/	/	-
Plagiochila bantamensis	/	-	-
Plagiochila kurzii	/	/	-
Plagiochila peculiaris	/	/	-
Plagiochila singularis	/	-	-
Radula acuminata	/	-	-
Radula acuta	/	-	-
Radula assamica	/	-	-
Radula cavifolia	/	-	-
Radula gedena	/	-	-
Radula iwatsukii	/	-	-
Radula kojana	/	-	-
Radula nymannii	/	-	-
Radula tjibodensis	/	-	-
Radula vrieseana	/	-	/
Spruceanthus semirepandus	/	-	-
Thysananthus aculeatus	-	/	-
Thysananthus auriculatus	-	/	-
Thysananthus virens	-	/	-
Total	**61**	**26**	**24**

Table 4.3. Percentage of Sorensen Similarity Coefficient (S) between Belukar Bukit Recreational Forest, Jambu Bongkok Forest Reserve, and Pulau Telaga Tujuh.

Study sites	Belukar Bukit Recreatioanl Forest	Jambu Bongkok Forest Reserve	Pulau Telaga Tujuh
Pulau Telaga Tujuh	37.93	56.25	-
Jambu Bongkok Forest Reserve	32.79	-	56.25
Belukar Bukit Recreational Forest	-	32.79	37.93

CHAPTER 5

DISCUSSION

5.1 Liverwort (Marchantiophyta) Flora according to the forest types

According to Atiqah *et al*. (2023), 63% of the 298 bryophyte species were recorded in Terengganu and 26 liverworts are new additions to the bryoflora of Terengganu. From this study, a total of 373 specimens, 43 species from 14 genera, four families were recorded in Belukar Bukit Recreational Forest, 121 specimens, 15 species from nine genera, three families in Pulau Telaga Tujuh and 51 specimens, 17 species from nine genera, two families were recorded in Jambu Bongkok Forest Reserve. The number of species shows that the diversity of liverwort is higher in Belukar Bukit Recreational Forest. The number of genera and families is also higher for the Belukar Bukit Recreational Forest. This may be due to the differences in humidity, topography, and the flora of the three forest types. As we know, the rainforest in Malaysia has high species diversity (Lee *et al*. 2022). Almost half the bryophyte species have occurred from the lowlands to the summit (Atiqah *et al*. 2023). This study also increased the number of liverworts for the state of Terengganu that was recorded by Lee *et al*. (2022), which were 62 species from the previous study.

Among the four families found in three plots of the study area, the largest family recorded for three plots is Lejeuneaceae, which is 27 species in Belukar Bukit Recreational Forest, while 12 species in Pulau Telaga Tujuh and 16 species in Jambu Bongkok Forest Reserve. The most prominent liverwort in Terengganu was represented by Lejeuneaceae (Atiqah *et al*. 2023). According to Lee *et al*. (2013), Lejeuneaceae is the largest family recorded in Malaysia. Lee *et al*. 2013 recorded that

Cololejeunea is the largest genus of Lejeuneaceae in Malaysia, followed by *Lejeunea*, *Drepanolejeunea*, *Cheilolejeunea,* and *Colura*. Pesiu *et al*. 2021 reported the first epiphyllous liverworts in Terengganu, which consist of 54 species from 18 genera and seven families of epiphyllous bryophytes. Most of the species have an Indo-Pacific distribution (Pesiu *et al*. 2021). The Lejeuneaceae family often has the most epiphyllous liverworts (Zhu & So, 2001). According to research by Pesiu *et al*. (2021), epiphyllous species that notably ruled the Mount Tebu Forest Reserve are the family of Lejeuneaceae. Lejeuneaceae are the prominent members of the epiphyllous bryophyte flora and are known for generating extensive covering on leaves in rainforests (Cornelissen & Gradstein, 1990; Gradstein *et al*. 2006; Pesiu *et al*. 2021).

Lejeuneacea may have adapted by developing protonemata spores that germinate quickly, a flattened habit with many rhizoids that help the gametophyte attach to the leaf, specialized lobules, or water sacs, that hold water to maintain moisture levels, and asexual reproduction (Glime & Pócs 2018). This is followed by the Radulaceae family recorded only in two plot study sites which consist of nine species in Belukar Bukit Recreational Forest and one species in Jambu Bongkok Forest Reserve. Next, the recorded number of Plagiochilaceae family in Belukar Bukit Recreational Forest has four species and two species in Pulau Telaga Tujuh while in Jambu Bongkok Forest Reserve there are none. In addition, the Notoscyphaceae family only has one species recorded in Belukar Bukit Recreational Forest and Pulau Telaga Tujuh.

5.2 The preferences of similarities Liverwort Species in Forest Types

The similarities of species between these three types of forests are different. It may be affected by the environmental implications and the habitat types. Belukar Bukit Recreational Forest is in a lowland dipterocarp forest, which has more humidity and lower temperatures than other forests. Pulau Telaga Tujuh is a mangrove forest that has different humidity, soil types, and water sources. At the same time, Jambu Bongkok Forest Reserve is a heath forest with a dry and sandy

soil surface, a lack of water sources, and more exposure to sunlight. Moreover, various microhabitats are found within different types of forests, indicating that those areas have a very complex and diverse topography for liverworts.

Liverwort flora is typical for lowland rainforest habitats with the dominance of the Lejeuneaceae family (Frahm, 2003). It is relatively rich compared to other families of similar latitude and altitude. As distributional aspect is concerned, most of the liverwort species that have been found have belonged to the Indo-Pacific group and others are Malesian-Pacific. According to Pócs (1996), the center of diversity for epiphyllous liverworts differs depending on the genera. For example, *Cololejeunea* species have the highest diversity in the Malesian archipelago, but *Ceratolejeunea* is more diverse in the Neotropics. Such as *Cheilolejeunea trifaria*, *Leptolejeunea maculata, Lopholejeunea eulopha*, *L. nigricans*, *L. subfusca*, and *Radula javanica* are pantropical distribution while *Cololejeunea lanciloba* and *Leptolejeunea subacuta* are paleotropical distribution. Moreover, *Acrolejeunea arcuata* and *Cololejeunea serrulata*, are in Southeast Asian distribution while the Malesian-Pacific species are *Cololejeunea gottschei*, *Lopholejeunea latilobula*, *Radula falcata* and *Radula tjibodensis*.

5.3 Habitat Preferences of Liverwort (Marchantiophyta) Flora

In the present study, liverwort habitats were examined and five major substrates as their microhabitat including the tree trunks (corticolous), tree branches (ramicolous), leaves (epiphyllous), soils (terricolous) and rocks (saxicolous). Most of the liverwort species have occurred on tree trunks, on soil surfaces, on rock surfaces, and as epiphylls which grow on leaf surfaces. From this study, only Belukar Bukit Recreational Forest has epiphylls. This may be due to the humidity and low temperature of the forest, which is caused by the lack of sunlight exposure. According to Zhu & so (2001), liverwort has its unique morphological adaptations.

In the present study, the liverwort species has occurred at five major substrates as their microsphere, including at tree trunk (corticolous), tree branches (ramicolous), on the soil surface (terricolous), on rock surface (saxicolous) and leaves surface (epiphyllous). Most of the liverwort species are widely found on leaves surface with a total of 36 of the total species recorded. From the study sites, only Belukar Bukit Recreational Forest has epiphylls. It may be due to the humidity and moisture of the environment that is favorable for epiphylls. However, the highest diversity of epiphylls in Peninsular Malaysia is in Pahang which has been well explored among other states. The number of liverworts found on the rest of the substrates is less than half the percentage of preference, as presented in Figure 5.1.

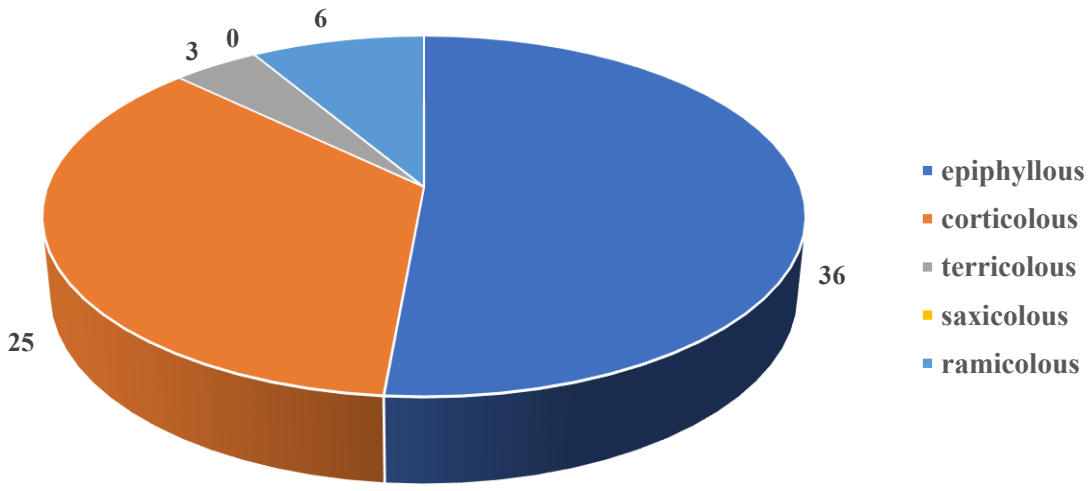

Figure 5.1 Summary of habitat preferences of liverworts in study sites

Tropical rainforests served high humidity and temperature therefore, they thrived well in the epiphyllous group of liverworts due to their unique morphological adaptations (Zhu & So, 2001). Most of epiphyllous specimens (especially *Cololejeunea*) were tightly appressed to the leaf surface. This is one of the best adaptation strategies for gaining moisture while preventing rapid water loss (Zhu & So, 2001). Therefore, a large percentage was represented by the leaves as the preferred substrate. Liverwort also lives on tree trunks as a second substrate preference. According to Lee *et al* (2016), liverwort species prefer tree trunks and branches as the

most preferred substrates, this substrate served the habitat mainly for *Lejeunea* species. The rough and cracked texture of the trunk surface makes a strong attachment, and the spore of liverwort will efficiently germinate. The absorption of water is also essential to liverworts surviving on tree trunks. Pócs (1996) reported that this corticolous group struggled with disturbances while still needing to survive in small niches.

The third substrate's preference is represented by soil. The liverwort specimens somehow grow within the soils instead of growing on the roots or rock surfaces. The ventral rhizoids help the liverwort grab the soil structures together and absorb the moisture. Other substrates like rocks (saxicolous) and twigs (ramicolous) are less preferred by liverwort. This may be due to exposure to rainfall, which easily wiped out a large portion of liverwort on the surface and affected the reproduction process (Glime *et al*. 1979; Suren, 1996). Therefore, they can favor various substrate preferences found in study areas on leaves, tree trunks, rocks, soil, or even on human-made materials such as poles, benches, pipelines, and trail ropes.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

In conclusion, the present study establishes the first comprehensive checklist regarding liverworts in three different types of forest with no addition new record for Terengganu and Malaysia as well. A total of 69 species were collected and placed under 18 genera in 4 families. Lejeuneacea signifies as the dominant family with reported in this study sites with 53 species, representing 53% of the total species. The liverworts are mostly found on the leaf surfaces of various textures as the preferred substrate, followed by tree trunks and branches or twig. The high number of liverwort species recorded in the present area indicates that the forest is still intact with constantly moist and high humidity, thus providing a favorable condition for liverworts. Furthermore, various microhabitats are found within different forest elevations. Therefore, these three types of forest are suggested as one of the promising forests that worth of future bryological studies including many other regions from Terengganu which are largely unexplored.

Moreover, the study and conservation of liverworts are crucial to understanding and preserving the delicate balance of our ecosystems. The unique species in these three different forests have the potential for future environmental monitoring research, especially in Malaysia. Also, this study could be a reason for local authorities to do conservation programs for preserving and protecting the species of liverwort in these three different forests in Terengganu, Malaysia. Thus, a whole view of liverwort information in these forests can be made known to the researchers and simultaneously assist the global biodiversity in the management area. This record also can become a new reference in updating or filling the gap in studies on liverwort species for the Terengganu state.

According to Chuah-Petiot (2011), the mosses of Malaysia are well collected and studied owing to the work of several local bryologists and their collaborators while liverworts and hornworts are generally under-collected and insufficiently studied in Malaysia. This indicates that there are very few studies being carried out and a lack of data collection for both groups, especially in the East Coast region such as Kelantan and Terengganu. Thus, this study may help future taxonomists, botanists, or researchers in getting the latest bryological information, particularly in Terengganu.

In Terengganu, there are only two studies on liverwort flora being conducted for its region by entirely until now. Thus, more initiatives in studying liverwort flora in Terengganu should be increased in an effort at the same level as done by the other states. By increasing the fieldwork exploration, more samples of liverworts particularly from these forest reserves were collected following available taxonomic keys. Thus, a more comprehensive and reliable updated checklist can be produced from this study for future research or references. Furthermore, suitable conservation actions can also be implemented in this place, when necessary, with the provided data on biodiversity particularly on liverworts.

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