



Faculty of Resource Science and Technology

**A Systematic Study of Selected Genus *Monophyllaea* (Family
Gesneriaceae) from Western Sarawak**

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A Systematic Study of Selected Genus *Monophyllaea* (Family Gesneriaceae)
from Western Sarawak

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



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ABSTRACT

Genus *Monophyllaea* is commonly known as the one-leaf plant that thrives in damp and shaded areas in limestone forest. *Monophyllaea* is one of the genus in the family Gesneriaceae that comprises 150–160 genera and about 3,200 species. *Monophyllaea* species are listed as a totally protected species under the Sarawak Wildlife Protection Ordinance 1998. *Monophyllaea* is sensitive towards disturbance of their surroundings and this genus can be used as a keystone species for disturbance indicators. In Sarawak, there are currently a total of 17 species of *Monophyllaea* species. There is a potential of more discovery of this species, especially in Sarawak. This study was conducted to produce a more detailed botanical descriptions based on the morphology of each species. The study also involved the analysis of occurrence, micromorphology, anatomical and palynology of *Monophyllaea* in western Sarawak. The locality and distribution of each taxon in western Sarawak including Bau, Padawan, Siburan and Serian limestone areas were recorded and mapped. A comprehensive study including the stem, leaf, and inflorescence (corolla, calyx, androecium, gynaecium and seeds) was done to produce more understandable characteristics that aid in species identification between each species and the varieties. Based on the micromorphology study, the result benefits in supporting the evidence in giving useful data to distinguish the differences between the taxa. The result of the epidermal surface and trichomes on the surface of the leaf gives essential information in comparison to the taxa level. Stomata in all *Monophyllaea* taxa are anisocytic and all taxa showed the presence of crystal epicuticular wax on both leaf surfaces. Pollen study in *Monophyllaea* also contributes important characteristics and distinct morphology between the taxa of *Monophyllaea* and the family Gesneriaceae. However, the result of the anatomy of stem cross-section revealed similar among the taxa and was not useful in determining the species. The midrib cross-section

showed little difference between the open and closed system of vascular bundles. The field key was constructed and introduced based on the founding species in western Sarawak. A new species, *Monophyllaea kazuea* was discovered and described during the study.

Keywords: Crystals, endemic, limestones, *Monophyllaea*, palynology

Kajian Sistematik Genus Monophyllaea Terpilih (Keluarga Gesneriaceae) dari Barat

Sarawak

ABSTRAK

Genus Monophyllaea umumnya dikenali sebagai tumbuhan satu daun yang tumbuh subur di kawasan lembap dan teduh di hutan batu kapur. Monophyllaea adalah salah satu genus dalam keluarga Gesneriaceae yang terdiri daripada 150–160 genera dan kira-kira 3,200 spesies. Spesies Monophyllaea disenaraikan sebagai spesies yang dilindungi sepenuhnya di bawah Ordinan Perlindungan Hidupan Liar Sarawak 1998. Monophyllaea adalah sensitif terhadap gangguan persekitaran mereka dan genus ini boleh digunakan sebagai spesies tunjang untuk indikator gangguan persekitaran. Di Sarawak, pada masa ini, terdapat sebanyak 17 spesies Monophyllaea. Terdapat lebih banyak penemuan untuk diterokai dalam genus Monophyllaea, terutamanya di Sarawak. Kajian ini dijalankan untuk menghasilkan huraian botani yang lebih terperinci berdasarkan morfologi setiap spesies. Kajian ini juga melibatkan analisis taburan, mikromorfologi, anatomi dan palinologi Monophyllaea di barat Sarawak. Lokaliti dan taburan setiap takson di barat Sarawak termasuk kawasan batu kapur di Bau, Padawan, Siburan dan Serian direkodkan dan dipetakan. Kajian menyeluruh termasuk batang, daun, dan perbungaan (korola, kelopak, androecium, gynaecium dan biji) telah dilakukan untuk menghasilkan ciri yang lebih mudah difahami yang membantu dalam identifikasi antara setiap spesies dan varieti. Berdasarkan kajian mikromorfologi, hasilnya memberi manfaat dalam menyokong bukti dalam memberikan data berguna untuk perbezaan antara taksa. Hasil daripada permukaan epidermis dan trikoma pada permukaan daun memberikan maklumat penting perbandingan dengan tahap taksa. Stomata dalam semua taksa Monophyllaea adalah anisocytic dan semua taksa menunjukkan kehadiran kristal epicuticular wax pada kedua-dua permukaan daun. Kajian debunga dalam

Monophyllaea juga menyumbang ciri penting dan morfologi yang berbeza antara taksa Monophyllaea dan keluarga Gesneriaceae. Walau bagaimanapun, hasil daripada anatomi keratan rentas batang mendedahkan yang serupa di kalangan taksa dan tidak berguna dalam menentukan spesies. Keratan rentas tulang daun menunjukkan sedikit perbezaan antara sistem terbuka dan tertutup berkas vaskular. Kekunci lapangan telah dibina dan diperkenalkan berdasarkan spesies pengasas di barat Sarawak. Spesies baru, Monophyllaea kazuea telah ditemui dan diterangkan semasa kajian.

Kata kunci: Batu kapur, endemik, kristal, Monophyllaea, palinologi

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LIST OF ABBREVIATIONS

aff.	akin to
c.	approximately
ca.	around or about
CGS	Centre for Graduate Studies
cm	centimeter
CPD	Critical Point Drying
°C	degree celcius
diam.	diameter
et al.	and others
FAA	Formalin-Acetic-Alcohol
FESEM	Field Emission Scanning Electron Microscope
holo	holotype
HUMS	Herbarium of Universiti Malaysia Sarawak
iso	isotype
km	kilometer
M	molarity
m	meter
mm	milimeter
µm	micrometer
NaOCl	sodium hypochlorite
NP	National Park
P	polar
E	equatorial

P/E ratio	ratio of the length of polar axis to the equatorial diameter
SAR	Herbarium of Sarawak Forestry Department
SEM	Scanning Electron Microscope
sp.	species (singular)
spp.	species (plural)
Syn	Synonym
UNIMAS	Universiti Malaysia Sarawak
var.	variety

CHAPTER 1

INTRODUCTION

1.1 Study Background

Borneo Island is the world's third-largest island and the largest in Asia (Figure 1.1). Politically, the island is divided among three countries: Brunei Darussalam, Indonesia (Kalimantan), and Malaysia (Sabah and Sarawak). The northern half of the island is in the northern hemisphere, while the southern half is in the southern hemisphere. Borneo Island is well known for its diverse animal and plant life. For example, it is estimated that Borneo comprises approximately 20% of the world's orchid species (*ca.* 30,000 species). One of many factors that contribute to the large number of animal and plant species is habitat diversity. For example, many endemic herbaceous plants in Borneo live in limestone habitats.

Sarawak's total area is nearly 124,450 km², with approximately 79% covered by various types of forests (including intact, degraded, mangrove, and peat swamp forests); the remaining 21% is agricultural land or plantations (Bryan et al., 2013; Gaveau et al., 2014). Sarawak is the largest and most diverse of Malaysia's 13 states in terms of flora and fauna. Sarawak's forest types include mixed dipterocarp forest (57%), peat swamp forest (13%), *kerangas* (3%), mangrove (1%), beach forest (less than 1%), riverine or alluvial forest (less than 1%), montane forest (less than 1%), limestone (less than 1%), and secondary forest from various succession periods (Tawan et al., 2008).



Figure 1.1: Map of Borneo (Source: <https://www.countryfacts.com/indonesia/>)

Monophyllaea is a genus of unusual herbaceous plants found in the understory of tropical rain forests, particularly in limestone areas of South-East Asia. According to Weber (2004), the species is known to range from the northern Malay Peninsula through Malesia to New Guinea. He continued by pointing out that Borneo has the most species, while New Guinea has only one. The plants are typically rain forest plants that grow on rocks and slopes in a constantly wet climate. The plants have only one leaf, which can grow to be more than 80 cm long and 50 cm wide (Okada, 1990). This leaf corresponds to one of the two cotyledons and does not stop growing during the whole perennial life of the plant. There are numerous many-flowered inflorescences from the base of this leaf.

Burt (1978) recognised more than 30 species, largely based on his collections and field experience in Sarawak, by providing a "preliminary" taxonomic revision of the genus and demonstrating a surprising morphological diversity as well as a remarkable range and

distribution pattern (Weber, 2004). According to Kiew and Sang (2013), Sarawak currently has 16 out of the 24 known species (Burt, 1978; Weber, 1998; Kiew, 2002) as it is the centre of diversity for *Monophyllaea* R. Brown.

1.2 Problem Statement

The botanical description of the genus *Monophyllaea* is still lacking, particularly in floral, pollination, and anatomical aspects. *Monophyllaea* species are still poorly known, and there have been few studies on them, particularly from Sarawak. When dried, specimens of the genus *Monophyllaea* become easily damaged and brittle. Flowers fade quickly during specimen collection and wilt after a few hours or a day. Pests and fungi commonly attack herbarium collections if proper protocols are not followed.

There were 17 *Monophyllaea* species found in Sarawak recently. The last taxonomy study of *Monophyllaea* was by Burt (1978). This study will contribute in more details and updates in taxonomy study of *Monophyllaea*. Kiew and Sang (2013) described two new species (*M. meriraiensis* Kiew & Sang and *M. grandifolia* Kiew & Sang) in the Tatau district. It is believed that there are more undescribed new species in Sarawak, as there are many limestone areas that need to be discovered. Moreover, *Monophyllaea* species are known to be very fragile and sensitive to changes in the surrounding environment. The *Monophyllaea* species are disturbed by the limestone quarry's rapid blooming. As a result, *Monophyllaea* can be used to detect limestone disturbance.

1.3 Objectives

Based on the problem statement, there are three main objectives of this study were:

- i. To revise the occurrence of selected *Monophyllaea* taxa in Western Sarawak.
- ii. To evaluate the morphological characteristics of *Monophyllaea* in Western Sarawak.
- iii. To examine the anatomy and palynology of the selected *Monophyllaea* in Western Sarawak.

CHAPTER 2

LITERATURE REVIEW

2.1 Limestone Ecology

Limestone, also known as karst, are sedimentary rock outcrops composed primarily of calcium carbonate (Li et al., 2021). It is distinguished by underground drainage systems and distinct landforms formed by solution erosion and consisting of cone-shaped or sheer-sided hills with caves and sinkholes (Gillieson, 2005; Simms, 2005). Calcium-secreting marine creatures (such as corals and brachiopods) produced the majority of the karsts millions of years ago, before tectonic movements raised them above sea level (Clements et al., 2006). Limestone is soluble in even slightly acidic waters, resulting in a plethora of karstic structures in limestone cliffs such as caves, cavities, pinnacle bedrock, solution slots, basal notches, stalactites/stalagmites, and overhangs (Tan, 2002). According to Göltenboth et al. (2006), water drainage is quick due to the typically porous substrate and thin soil. This may result in ongoing water stress for the vegetation (Göltenboth et al., 2006).

Sarawak's limestone forests cover approximately 520 km², or 0.4% of the total area (Rahman et al., 2010). Anderson (1965) and Anderson and Chai (1982) classified Sarawak's limestone hills into eight subtypes: alluvial soils at the base of limestone hills and ravines between hills; slopes of limestone hills; limestone cliffs; scree slopes on limestone hills at low elevation; summit of limestone hills at low elevation; submontane forest; and secondary vegetation.

The geology of Sarawak is divided into three provinces: west Sarawak, central Sarawak, and north Sarawak. The underlying geology of the area, as stated by Banda et al. (2004), has a significant influence on the distribution of the limestone formation; older formations are found in the south-western region, while younger formations are found in the central and northern regions of Sarawak. Gunung Selabor, located in the Serian region, is the oldest limestone formation, dating back to the Permian period (280 million years); the Jurassic (170 million years) limestone formations are found in the Bau and northern Serian areas (Banda et al., 2004). The Mulu and Subis limestones are Paleogene in age (50 million years).

The highest karst hills in Malaysia, Gunung Api and Gunung Benarat, which rise to 1700 m, are located in Sarawak's Gunung Mulu National Park (NP), whereas the most limestone hills can be found in the Kuching Division (Kiew, 2004). From Bau to Tebakang, Niah, and the Melinau massif in Mulu, there are numerous limestone hills. Limestone caves such as Mulu Caves and Niah Caves in the north and Wind Cave and Fairy Cave in west Sarawak are excellent geo-ecotourism destinations that are being developed with a focus on preserving the cave's natural beauty. Moreover, the Mulu and Niah caves in Sarawak are the most well-known limestone caves in Malaysia.

In comparison to the smaller caves in south-western Sarawak, where the limestone formations are more faulted and eroded, the northern limestone formation forms extensive caves (Banda et al., 2004). They also mentioned the Bukit Sarang Limestone in Bintulu and the Melinau and Subis Limestone Formations in the northern area, which occur as isolated hills in central and northern Sarawak. According to Kiew et al. (2007), the Bukit Sarang

limestone hills are enclosed by preserved freshwater swamp forest and covered in lowland limestone forest, with exposed summits covered in a layer of peat. The limestone in Bukit Sarang has at least five distinct microhabitats, such as the shaded base and fallen boulders; deeply shaded steep slopes and gullies; the cave mouth; the exposed summit; and the swampy area at the foot of the hill (Kiew et al., 2007).

The largest national park in Sarawak is Gunung Mulu, with an area of 544 km², where the Mulu Caves are located (Banda et al., 2004). With pinnacle and arête morphology, deep gullies, and cliffs, the upper surface of the limestone massifs landscape is stunning and incredibly rugged (Gillieson, 2005). As stated by Banda et al. (2004), the shale and limestone form the foundation of the Mulu Cave area. Regionally, semi-metamorphosed shale and a subordinate amount of sandstone compose the majority of the shale formation in the southeastern part of the area (Banda et al., 2004). Melinau Limestone is exposed in a variety of steep massifs, low mountains, and hills in a northeast-oriented outcrop that is 10 km broad and 35 km long, divided by the floodplains of the Medalam, Melinau, and Melinau Paku rivers (Waltham & Despain, 2012). There are three limestone mountains: Gunung Api, Gunung Benarat, and Gunung Buda (Sang et al., 2018). Based on the report of UNEP and WCMC (2000), there are numerous endemic calcareous species and various types of limestone forests, including scree forests, cliff vegetation, lowland montane forests, upper montane forests, and cave vegetation. Gesneriaceae species like *Monophyllaea beccarii* C.B. Clarke (synonym: *M. glauca* var. *beccarii* (C. B. Clarke) B.L. Burtt), *M. horsfieldii* R. Br., *Cytandra* spp., and the palm *Calamus neilsonii* J. Dransf. are examples of these species.

The limestones in Kuching Division have been divided into three major areas, which are the Bau, Padawan, and Serian limestone areas. Generally, the soil produced by the limestone forest ecosystem is rich in calcium carbonate. In west Sarawak, the limestone formation is located in the Bau-Serian area, which is also known as the Bau-Formation (Liechti et al., 1960). The left and right tributaries of the Sarawak River that run through the Bau Limestone Region contribute to supporting sufficient residual soil to sustain abundant vegetation (GlobinMed, 2022). There are several extensive limestone formations in Sarawak, the most well-known of which are Mulu and Bau. The rivers that flow through limestone are characterised by having a high calcium content and alkaline water (pH > 7).

Bau limestone is predominantly massive, often with weak, obscure bedding (Soon, 1992). Insignificant or very shallow soil can be found on limestone hill slopes (Adam & Mamat, 2005). Banda et al. (2004) stated the limestone in Bau may be divided into two varieties, the argillaceous and the fossiliferous. The argillaceous limestone is bedded and dark brown to dark grey, compared to the fossiliferous limestone, which is light grey (Banda et al., 2004). Soon (1992) mentioned that the Bau Limestone Formation begins with a basal conglomerate, settling on the Jagoi Granodiorite non-conformably. A series of sandstones that overlie Bau limestone, some of which are calcareous, is followed by the conglomerate (Soon, 1992). The forest is less dense and smaller in stature at the foot of limestone hills and in ravines lacking igneous rock than it is in ravines possessing igneous rock (Adam & Mamat, 2005). On the rock limestone cervices, calciphylous plants grow abundantly, including *Monophyllaea glauca* C. B. Clarke, *M. johannis-winkleri* Kraenzl., *Epithema involucratum* (Roxb.) B.L. Burtt, and *Pilea calcarea* Ridl. (Adam & Mamat, 2005). Fairy

Cave Nature Reserve and Wind Cave Nature Reserve are two protected caves located in Bau limestone.

According to Rahman et al. (2010), limestone areas are known to hold high levels of endemism and are also home to many species of flora and fauna that grow in nutrient-poor conditions. Although they occupy just around 1% of the total land area in Sarawak, it is by far one of the most vulnerable habitats in the region. As they separate from each other, the areas of limestone are likely to differ in biodiversity from one another (Karim et al., 2004). A study was done by Kiew (1981) on the distribution of endemic herbaceous species restricted to limestone. Kiew (1981) pointed out that the floras of the area, the Niah National Park, and the Gunung Api limestone belong to different phytogeographic areas (as yet one species has been described from Gunung Api (Kiew, 2001), but there are at least another seven undescribed species); for *Monophyllaea*, only one species, *M. merrilliana* Kraenzl., is found in all three areas and is a widespread species in Borneo, which is also recorded from other rock types; and for *Paraboea*, only one species, *P. clarkie* B. L. Burt, is found on both the Bau and Mulu limestones. Furthermore, based on *Monophyllaea* distribution, Burt (1978) identified two separate phyto-geographic areas in the Kuching Division: Bau against the Padawan-Serian limestone (Gunung Bra'ang, Gunung Selabor, Gunung Serapat, etc.). The distribution of other herbaceous endemic species indicates the phytogeographic distinction between the two areas (Kiew et al., 2004).

Kiew et al. (2004) stated that some groups of plants in several plant genera, such as *Chirita*, *Epithema*, *Monophyllaea*, and *Paraboea* in the Gesneriaceae, are endemic to limestone areas. None of them, however, can be regarded as being exclusively limestone-

dependent. For instance, *Chirita* and *Paraboea* in cultivation can thrive on a range of substrates as long as they are free-draining (Kiew et al., 2004). Lithophilous species, for example, *Epithema* and *Monophyllaea* species that grow on limestone, can also be found on a variety of other rock types, including granite and shale (Kiew et al., 2004). Rahman et al. (2010) also stated that the variety of microhabitats that the limestone hills provide within a restricted area affects the richness of the plant life.



Figure 2. 1: Quarrying activities happening in Niah limestone [Image taken by Yi Chang]

One of the major economic values of limestone is the karst landscape, which includes outsized lapies (karren), underground rivers, and caves with beautiful speleothem formations that become tourist attractions (Vermeulen & Whitten, 1999). Fairy Cave in Bau, for example, is a popular spot for climbing activities in limestone hills. Limestone caves are very important for local people as it is a natural places to revere ancestors or worship gods, making it a place of worship, a temple, and a burial cave. The presence of temples and visitors can endanger the plants that live in the cave (Vermeulen & Whitten, 1999). The most serious practices affecting biodiversity are agriculture, mining for mineral ores, and

quarrying for gravel, which are among the threats to limestone areas (Karim et al., 2004). The removal of the surrounding forest results in greater damage to the flora because the vegetation of the limestone hills becomes vulnerable to burning caused by agricultural practices in the nearby areas, even though quarrying for cement, road metal, and marble is frequently regarded as the most serious threat (Kiew, 1997). In Figure 2.1 shows the quarrying activities occurred in Niah limestone area. Adam and Mamat (2005) stated the activity of burning, and mining for gold and antimony deposits had happened for a century in the Bau limestone hills, causing serious disturbance to the limestone forest (Adam & Mamat, 2005). Even if the disturbed limestone forest is slowly recovered, the exposed limestone rock may remain bare for many years (Adam & Mamat, 2005). The impacts of limestone disturbance may cause the extinction of species from the area, distortion of the local fauna, and invasion of the area by non-native species (Vermeulen & Whitten, 1999). The network of hills in Sarawak with high biodiversity of limestone flora is required to be legally protected because there is no individual hill that conserves more than a fraction of the flora (Kiew et al., 2011).

2.2 Order Lamiales

The Order Lamiales is in the asteroid group of dicotyledonous flowering plants. As stated by Schäferhoff et al. (2010), Lamiales (eudicots/asterids) are one of the largest orders of flowering plants, with representatives found all over the world. It includes 26 families, 1,059 genera, and more than 23,800 species (Hai, 2015; Weber, 2020). The main families in the order are Lamiaceae, Verbenaceae, Plantaginaceae, Scropulariaceae, Orobanchaceae, Acanthaceae, Gesneriaceae, Bignoniaceae, Oleoaceae, Pedaliaceae, and the small

carnivorous families Lentibulariaceae and Byblidaceae (Berry, 2017). Schäferhoff et al. (2010) also mentioned that some of them are economically significant, such as Lamiaceae (pot-herbs like basil, mint, oregano, or sage), Oleaceae (olives), Pedaliaceae (sesame), Plantaginaceae (ornamentals, drugs like digitalis), Scrophulariaceae (ornamentals), and Verbenaceae (medicinal, timber).

The characteristics are easily recognized: the leaves are usually opposite, the glandular hair is frequently present, and the fruits are mostly capsular (Berry, 2017). Weber (2013) stated that some of the taxa of Lamiales display a special and otherwise unknown type of axillary inflorescence: cymes with flower pairs terminating the cyme units instead of single flowers. Based on Kadereit (2004), the flowers are sympetalous and mostly 5-merous, often demonstrating zygomorphic lip flowers with a showy corolla and with a single whorl of stamens and a bicarpellate ovary with the two carpels in median position (Endress, 1994). The anthers also often have a connective outgrowth into the anther locule, also known as the pollen sac placentoid (Hartl, 1964). The glandular hairs are often present on a head with only vertical cell walls, and pollen tubes lack callose (Prósperi & Cocucci, 1979; Cocucci, 1983).

2.3 Family Gesneriaceae

Gesneriaceae comprise 150–160 genera and about 3,200 species and are a clade of perennial herbs, shrubs, small trees or annuals, epiphytes, and climbers that exhibit an exceptional morphological diversity associated with the colonization of a variety of environments (Wiehler, 1983; Weber, 2004; Weber & Skog, 2007 onwards; Ittner & Nguyen, 2018). Weber (2004) stated that it is distributed mainly in the tropics and subtropics

of both the Old and the New World, with transgressions to the north (Europe, Asia, and China) and the south (south-east Australia, New Zealand, and south Chile). Gesneriaceae are particularly abundant, growing as epiphytes or on rock outcrops at mid-elevation in the mountain forest (Perret et al., 2013). Many of them have economic importance as horticultural ornamentals. The genera in the family Gesneriaceae include *Aeschynanthus*, *Tromsdorffia*, *Agalmyla*, *Lysionotus*, *Chirita*, *Didymorcarpus*, *Streptocarpus*, *Boea*, *Loxocarpus*, *Epithema*, *Stauranthera*, *Loxonia*, *Glossanthus*, *Loxotis*, *Monophyllaea*, *Platystemma*, *Rhabdothamnus*, *Fieldia*, *Rhynchotechum*, *Cyrtandra*, *Whitia* and more (Weber, 2004). Over the years, there have been more new genera added to this family, including *Whytockia*, *Billolivia*, *Somrania*, *Tribounia* and many more.

Leaves are usually opposite, herbaceous, or leathery. Many of the flowers are very showy and colourful, with a 5-lobed corolla with fused petals. Weber (2004) proposed five types of pollination syndromes in Gesneriaceae, such as deceptive nectar flowers, nectar flowers, pollen flowers, partially and fully deceptive pollen flowers, and perfume flowers. The fruit is a capsule with many tiny seeds. The fruits can be fleshy, with seed dissemination primarily reliant on animals like birds or ants, or they can be dry and dehiscent, with seeds dispersed by wind or raindrops (Kleinfeldt, 1978; Wiehler, 1983; Davidson, 1988; Smith, 2001).

Nishii et al. (2004) mentioned that in monocotyledonous and dicotyledonous plants, the leaves develop from the shoot apical meristem (SAM) and then differentiate into their mature form. However, there are several species in Gesneriaceae (certain South African sub-

genera of *Streptocarpus* and more than 30 species in *Monophyllaea*) that have the type produce one leaf throughout their life history and they do not retain SAM.

2.4 Subfamily Didymocarpoideae

Formerly, the subfamily Didymocarpoideae was known as subfamily Cyrtandroideae. The evidence showed in the morphological research of Weber (1975, 1976a,b,c, 1977a,b, 1978a,b, 1982) that the genera now included in the tribe Epithemateae might be sister to the rest of the subfamily. There are currently 71 genera and about 2500 species in the subfamily. The seedlings are generally anisocotylous. In the taxa with actinomorphic flowers, fertile stamens are 2, less often 4, very rarely 1, and rarely 5. It is nectary, if present, and either ring- or cup-shaped. It is occasionally lobed, rarely unilateral, and tongue-like, never consisting of separate glands, and sometimes lacking. The ovary always appears superior. The fruit is usually a dry, cylindrical (or less commonly, ovoid-globose) capsule, rarely indehiscent, which is a fleshy berry or sclerocarpous berry (Weber et al., 2020).

2.5 Tribe Epithemateae

Tribe Epithemateae C. B. Clarke relates to the "Epithematoid Gesneriaceae" in Weber (2004). There are more than 85 species in this small tribe, which consists of only seven genera. The distribution of the tribe Epithemateae is in tropical Asia, except for one species of *Rhynchoglossum* in Central and South America and one species of *Epithema* in Western and East Africa. The unusual morphological characteristics of Epithemateae, such as robust anisophylly in most taxa, monophyly and medullary vascular bundles in

Monophyllaeae, unilateral racemes in *Rhynchoglossum*, and a bilocular ovary in *Whytockia* and *Monophyllaea* (Weber et al., 2013), The characteristics of this tribe include placentae that are triangular in cross-section. The ovary and fruit $\pm$ globose; the fruit is capsular and never indehiscent. The capsule valves never twisted. The style clearly distinguishes itself from the ovary. Seeds are spirally striate to reticulate, always without ornamentation of testa cells. The plants are usually fleshy to succulent, with strongly asymmetrical leaves sometimes (Weber et al., 2020).

2.6 Subtribe Monophyllaeinae

Weber et al. (2013) formed the subtribe Monophyllaeinae A. Weber & Mich. Möller. Although the two included genera, *Monophyllaea* and *Whytockia* are quite different from one another, Weber (1976b) indicated a close relationship based on a comprehensive morphological examination. There are currently 6–8 recognized species in *Whytockia* and close to 40 in *Monophyllaea* (Weber et al., 2020). Mayer et al. (2003) discovered a sister relationship between the two genera.

2.7 History of *Monophyllaea*

In 1840, *Monophyllaea* was described by Robert Brown based on a plant collected by Horsfield in Sumatra. Another species, *M. hirtella* Miq. from Sumatra, was added 20 years later. Clarke updated the genus and increased the number of species to six in his monograph on the Cyrtandreae in 1883. Clarke only had access to nine specimens in all; *M. horsfieldii* alone was represented by multiple specimens, including two from Sumatra, one

from Java, and one from the Malay Peninsula. Later authors changed *M. pygmaea* C. B. Clarke, also from Java and described by Clarke, to *M. horsfieldii*, *M. glauca*, *M. beccarii*, and *M. lowii* C. B. Clarke (synonym: *M. glauca* var. *versipes* C. B. Clarke), Clarke's other three species, were all native to Borneo and are all classified as varieties of one here. The recognized range has since expanded from southern Thailand to the Philippines and New Guinea, as 10 other species have been identified since that time. A peculiar Borneo plant with flowers that are almost sessile up the stalk and along the midrib rather than in pedunculated inflorescences arising from the leaf base as in all known species of *Monophyllaea* at the time led Bayley Balfour and Wright Smith to propose the independent genus *Moultonia* in 1915. However, *Moultonia* has been reduced to *Monophyllaea* in this instance, as proposed by van Steenis (1961); other characteristics are not applied. It would be identifiable solely by the unusual arrangement of the flowers (Burt, 1978).

2.8 Genus *Monophyllaea* R. Br.

Monophyllaea is well known as a one-leaf plant, and most of them are endemic to limestone. Genus *Monophyllaea* are perennial monocarpic or annual herbs. The plants commonly have a single leaf (macro-cotyledon) and rarely have several leaves of the same shape as the macro-cotyledon. The lamina of a leaf is more or less symmetrical. The inflorescences arise from the axils of tiny bracts located at the base of the leaf or from the stem (hypocotyl) or the midrib (Weber et al., 2020). It bears a single large, oblong or sub-orbicular, ever-growing leaf (macro-cotyledon). The stem (hypocotyl) is fleshy, with medullary vascular bundles (Imaichi et al., 2000).

As stated by Imaichi et al. (2000), all members of the Malesian's *Monophyllaea* have unique monophyly, or phyllomorph (one-leaf type of growth form). 'Phyllomorph' means constructed as a leaf blade (lamina with a proximal petiole-like stalk (petiolode). 'Phyllomorph' is a term that was also proposed by Jong (1973, 1978) and Jong and Burt (1975) to describe such a unique growth form. Burt (1978) also stated that some *Monophyllaea* species produce several leaves and show a phyllomorphic structure. In tropical areas with persistent climate conditions throughout the year, prolonged monocarpic can be observed in numerous species of *Monophyllaea* (Weber, 2004).

Shortly after germination, these soft herbaceous plants reach the reproductive stage, and this stage continues for two to many years without interruption before the plants die (Weber, 2004). Death is often caused by external causes, such as destruction, desiccation, etc., whereas undisturbed plants seem almost immortal. In comparison, *Monophyllaea* species that grow in seasonal areas (*M. glabra* in the NW of the Malay Peninsula) are annually monocarpic: when the dry season starts, the plants die and only the seeds survive the unfavourable dry season (Weber, 2004). The study by Kohyama and Hotta (1986) estimated that it takes seedlings 4.6 years to reach sexual maturity, with observations made at three distinct times of the year and between two species, *M. hirtella* and *M. horsfieldii*, in different habitats.

Kiew (2009) mentioned that the primary flower visitor observed for *Monophyllaea* is butterflies, but observations on pollination are lacking. It appears that seed dispersal can only happen over a small distance, despite the lack of experimental data. Burt (1978) mentioned that rain-wash and soil that sticks to an animal's feet are the most likely dispersal

agents since cliff-dwelling species rely on draught to prevent an unstoppable migration towards the foot of the cliff. It is very rare to discover dry seed in many species, and in *M. glauca*, it appears likely that the calyx and capsule frequently fall together before the seed has been dispersed. However, *M. tenuis* still has dry capsule valves on its older infructescence; in this case, too, wind may be a factor in dispersal, with the drying, stiffening peduncles functioning as a censer mechanism (Burt, 1978). It is common to find seed that has already begun to germinate in the capsule when the environment is damp (or when it is raining).

Imaichi et al. (2001) stated that the inflorescences arise from the excrescent cotyledon at maturity. It has a huge macro-cotyledon, a long petiole below it, and many small inflorescences scattered along the petiolode and midrib. They also stated that the inflorescences of most *Monophyllaea* species are pedunculated and in a compact or loose cluster near the base of the macro-cotyledon.

Monophyllaea exhibit the most specialized anisocotily, the size inequality of the cotyledon, like several species of *Streptocarpus* (Burt, 1962; Burt, 1978; Imaichi et al., 2001). Anisocotyls mean that one cotyledon outgrows the other and that no vegetative shoots are formed throughout the life history. As stated by Tsukaya (1997), the large and single leaf is derived from one of two cotyledons. One of the cotyledons continues to grow, while the other does not. There are no new organs formed in the shoot after germination until the appearance of the inflorescence. Hence, these plants lack true leaves.

A study by Ayano et al. (2005) in which he examined the developmental morphology of *M. glabra*. They stated that the embryo in the seed consists of two cotyledons and a hypocotyl, with no shoot or root apical meristem. The endogenous root meristem is formed nearer the hypocotyl end. One of the cotyledons grows to form the macro-cotyledon through the basal meristem.

Monophyllaea is primarily a genus of limestone, and all of its species have chalk glands on their leaves, stems, and inside of the sepals (Puff, 1975; Weber, 1976). Weber (2004) mentioned that there are peltate glandular hairs that secrete calcium carbonate in *Monophyllaea*. The calcium salt crystals that are found in avian eggshells, fungi, plants, and animals are one of the types of crystals commonly recorded in various species (Cuéllar-Cruz et al., 2020). Most of these crystals act as sensors, security, support, or protection. The synthesis of these crystals is special in that it is regulated by proteins. Plants are commonly encrusted in the excretions of the numerous chalk glands, which makes them brittle when dry. Moreover, small corollas often vanish during specimen preparation unless they are preserved with extra caution.

Monophyllaea exhibits significant biological diversity concerning the microhabitats that exist on limestone. Nevertheless, Burt (1978) mentioned that the species *M. horsfieldii* and *M. merilliana* are at least two examples of those that are not completely dependent on limestone. Both species have the broadest ranges of their subgenus; Ridley found *M. horsfieldii* on granite in the Malay Peninsula, and *M. merilliana* was found on andesite in Sarawak as well as off limestone at least in Sabah. Based on Burt (1978), these two species are found farthest from the pure rock when they coexist with other species of the genus in

limestone areas. Thus, the leaves of these two species have less chalk encrustation than those of many other species, although it is still clearly visible on the inside of the sepals, particularly in *M. merilliana* (Burt, 1978).

Several microhabitats are typically present on a large limestone outcrop and occupied by different species. On relatively soft and protected cliff walls, *M. pendula* B. L. Burt is pendulous, whereas more exposed faces are more often seen with *M. fissilis* B. L. Burt, which is stiffer and sturdier (Burt, 1978). *M. merilliana* grows further out, but *M. cupiflora* B. L. Burt is frequently found towards the base of the cliffs, frequently close to the dripline. *M. glauca* is found outside or near the drip line, while *M. tenuis* B. L. Burt grows in sheltered overhangs (Burt, 1978).

Sarawak recorded 16 species of *Monophyllaea*, and it has a characteristic feature of limestone hills (Appendix 3). Kiew and Sang (2013) described two new species of *Monophyllaea* (*M. grandifolia* and *M. meriraiensis*) from Tatau District, Sarawak. Kiew and Sang (2013) also stated the highest number of *Monophyllaea* species that can be found on limestone hills in Sarawak, which were eight species in the Kuching Division and eight species in Gunung Mulu NP. On an isolated limestone hill in the Tatau District, the remaining species is found in Bukit Sarang. All the *Monophyllaea* species in Sarawak are listed as endangered species and protected under the Sarawak Wildlife Protection Ordinance 1998 (WPO, 1998).

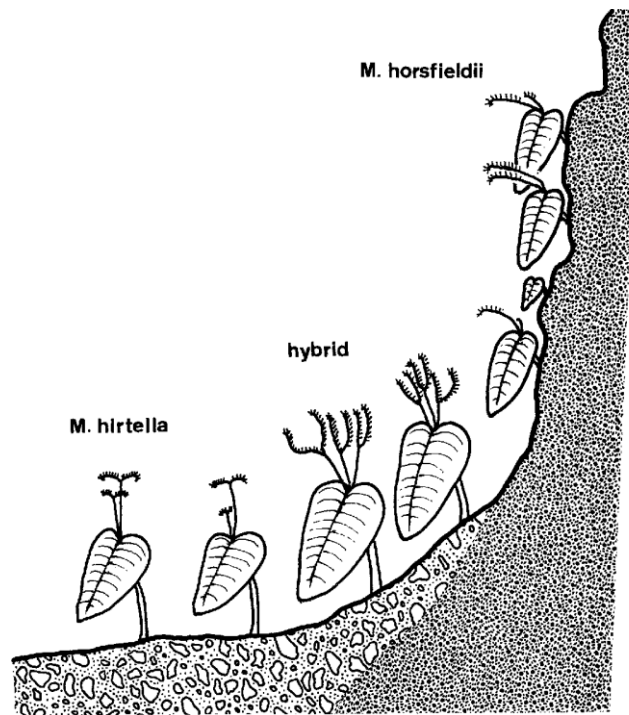


Figure 2.2: Diagram of habitat of *M. horsfieldii* grows on the vertical face of limestone cliffs, *M. hirtella* on the horizontal ground below, hybrid specimens are found in the transition zone (Okada, 1990)

A study had been conducted by Okada in 1990 in which the biometrical growth of two species, *M. horsfieldii* and *M. hirtella*, in their natural habitat in west Sumatra, was studied. On this occasion, a hybrid between the two species was found. Hybrids among parapatric species, *M. hirtella* and *M. horsfieldii*, seemed to have formed their habitat in boundary regions between both parental species and were able to reproduce viable seeds from mature offspring (Figure 2.2).

Kinoshita et al. (2020) mentioned that the studies of one-leaf plants have focused on the genera *Monophyllaea* and *Streptocarpus* in Gesneriaceae, which, based on their phylogenetic position, evolved independently. Furthermore, both genera belong to two

different tribes: Epithemateae and Trichosporeae (Jong & Burt, 1975; Burt, 1978; Smith, 1996; Smith et al., 1997; Möller et al., 2009; Weber et al., 2013).

2.9 Subdivision of Genus *Monophyllaea*

Early findings of the Burt (1978) study revealed that when the style base has dropped, the fruit of *M. horsfieldii* splits into four valves. In contrast, in *M. glauca* or *M. merrilliana*, the fruit wall was seen to be extremely thin, not splitting up into valves, and the style base was stretched over the ovary so that when it collapsed, the capsule was porose. It was initially assumed that these characteristics could divide the entire genus into two; however, it was later discovered that some species had very thin fruit walls where a valvular structure could hardly be seen and that there was also a significant variation in the behaviour of the style base. These characteristics were used in the grouping of the species in the following stage of research, but the concept of a formal subdivision of the genus was discarded.

Burt (1978) describes *M. horsfieldii* placentae and those of related species as having a broad attachment to the septum and a single, distinct median vascular strand. *M. merrilliana* and its allies have placentae that are thinly attached to the septum, resemble an anchor in the transverse section, and each has a vascular strand. This common pattern, however, has one notable exception. *M. leuserensis* is closely related to *M. horsfieldii* B. L. Burt, which has a broad-based attachment of the placenta to the septum, but each placenta has a vascular strand, like *M. glauca*. *M. leuserensis* has pedicels that are significantly longer than the calyx, making it a close ally of *M. horsfieldii* in every way. This proves that there

is variation in the vascular system but does not invalidate the distinction between the two groups.

Hence, there are two subgenera within the genus *Monophyllaea* as shown in Figure 2.3. The one comprising the type species, *M. horsfieldii*, automatically becomes subgenus *Monophyllaea*; for the second, the generic name *Moultonia* is maintained. Burt (1978) mentioned the subgenus *Moultonia* may one day be subdivided into sections, in which case the old generic idea based on *M. singularis* will reappear at the sectional level.

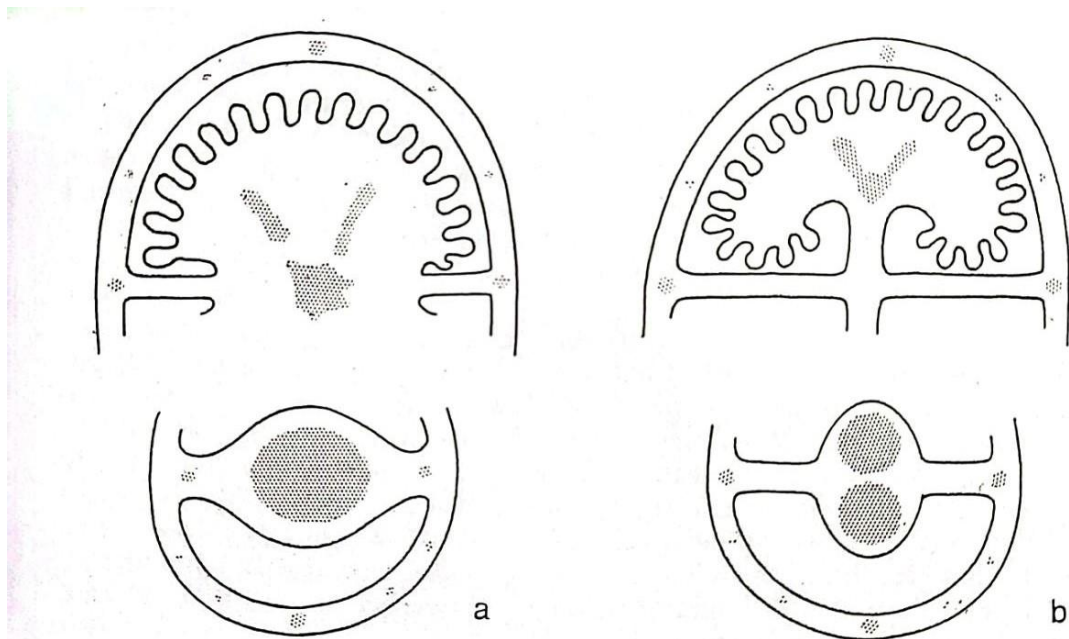


Figure 2.3: Diagrams of the two types of ovaries (sections of fertile and lower sterile region): a. subgenus *Monophyllaea*; b. subgenus *Moultonia* (Burt, 1978)

A. Subgenus *Monophyllaea*

Pedicels are distinctly longer than the calyx. Ovary bilocular, the placentae with a broad attachment to the septum which contains a single massive strand. Fruit-wall breaking up into

4 valves, usually after the fall of the style. Indumentum (if present) of uniseriate glandular or eglandular hairs.

Type species: *M. horsfieldii*

Subgenus *Monophyllaea*

1. *M. glabra* Ridl.
2. *M. hirticalyx* Franch. (including *M. patens*)
3. *M. longipes* Kraenzl.
4. *M. tenuis* B.L. Burtt
5. *M. selaborensis* B.L. Burtt
6. *M. sarangica* B.L. Burtt
7. *M. horsfieldii* R. Br.
 - var. *horsfieldii* (including *M. pygmaea*)
 - var. *hendersonii*
8. *M. caulescens* B.L. Burtt
9. *M. leuserensis* B.L. Burtt
10. *M. hirtella* Miq.
11. *M. pendula* B.L. Burtt
12. *M. elongata* B.L. Burtt
13. *M. glandulosa* B.L. Burtt
14. *M. andersonii* B.L. Burtt
15. *M. hottae* B.L. Burtt
16. *M. fissillis* B.L. Burtt
17. *M. cupiflora* B.L. Burtt
 - var. *cupiflora*
 - var. *aggregata*
18. *M. insignis* B.L. Burtt
 - var. *insignis*
 - var. *rubriflora*
19. *M. papuana* Lauterb. (including *M. finisterrae*)
20. *M. wildeana* B.L. Burtt
21. *M. grandifolia* Kiew & S. Julia

22. *M. meriraiensis* Kiew & S. Julia
23. *Monophyllaea kazuea* sp. nov. ined.

B. Subgenus ***Moultonia*** (Balf. fil. & W.W. Sm.) B. L. Burtt, **stat.nov.**

Syn.: *Moultonia* Balf. fil. & W. W. Sm. in Notes R. B. G. Edinb. 8: 349 (1915).

Pedicels equalling or shorter than the calyx. Ovary is bilocular, the placentae joined to the septum by a narrow bridge, each placenta with a main central strand. Fruit-wall not breaking up into valves, dehiscence porose by fall of style with a swollen base. Indumentum (if present) of uniseriate glandular or eglandular hairs, or in certain species of forked dendroid or stellate hairs.

Type species: *M. singularis*

Subgenus *Moultonia*

1. *M. glauca* C.B. Clarke
 - var. *glauca*
 - var. *hirta*
 - var. *beccarii*
 - var. *versipes* (including *M. lowii*)
 - var. *boraginea*
2. *M. eymae* B.L. Burtt
3. *M. brevipes* S. Moore
4. *M. tetrasepala* B.L. Burtt
5. *M. merrilliana* Kraenzl. (including *johannis-winkleri*)
6. *M. sp.* (aff. *M. merrilliana*)
7. *M. furcipila* Ohwi
8. *M. stellata* B.L. Burtt
9. *M. anthocrena* B.L. Burtt
10. *M. ramosa* B.L. Burtt
11. *M. singularis* (Balf. f. & W.W. Sm.) B.L. Burtt

var. *singularis*

var. *semiflorens*

12. *M. kostermansii* B.L. Burt

13. *M. burttiana* Kiew

Based on the study, there were four *Monophyllaea* species (*M. tenuis*, *M. selaborensis*, *M. glandulosa* and *M. kazuea*) under subgenus *Monophyllaea* while four species of *Monophyllaea* (*M. glauca*, *M. tetrasepala*, *M. merrilliana* and *M. singularis*) were under subgenus *Moultonia*.

2.10 Scanning Electron Microscope (SEM) and Field Emission Scanning Electron Microscope (FESEM)

According to Voutou and Stefanaki (2008), a scanning electron microscope (SEM) is a scientific instrument used to examine objects on a very fine scale using a beam of highly energetic electrons. SEM is used to study floral structures because it provides more details and depth of focus than a conventional light microscope (Troughton & Donaldson, 1972). The SEM's greater depth of focus enabled the creation of clear, realistic micrographs with a three-dimensional appearance (Bole & Parsons, 1973).

According to Troughton and Donaldson (1972), SEM was used to study some anatomical features of plants and the relationship of these structures to physiological processes. The leaf surface, stomata, inside the leaf, chloroplast, apical meristem, xylem, seed development, and flowers were all captured on camera. External features viewed best with SEM are more useful at the lower level (Stuessy, 1979). Several new SEM applications

have enhanced the potential of additional systematic characteristics. SEM fracture methods have enabled the simultaneous examination of internal and external structures.

Stuessy (1979) also mentioned that various other SEM technical innovations have been developed, such as critical-point drying, cell surface labelling, and uncoated specimens, some of which have been used for systematic work. SEM has been widely used as a tool in developing scientific theory and is a heavily used instrument in national lab research areas, the academic sector, and industry. This is because SEM produces greater resolution, compositional, and crystallographic information, as well as having higher magnification and a larger depth of field.

The field emission scanning electron microscope (FESEM) is ideal for the observation of material surface structures as small as 1nm (Mutalib et al., 2017). Organelles and nuclei of cells, synthetic polymers, and coatings are a few examples of artefacts studied with FESEM in practice, but it is also ideal for characterising the morphology and geometry of electro-spun nanofibers.

FESEM-EDX is known as Field Emission Scanning Electron Microscopy with Energy Dispersive X-Ray Spectroscopy. EDX analysis can be used to map out the lateral distribution of elements from the imaged area or to identify the chemical composition of specific areas (Nanakoudis, 2019). EDX elemental composition can be studied in areas as small as a few nanometers in diameter and can be quantified as weight percentage or atomic percentage. In general, it is an elemental analysis method related to electron microscopy that

involves the production of distinctive X-rays to indicate the presence of elements in the sample (Soonmin, 2022).

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Area and Distribution

The research areas were located in western Sarawak (Figure 3.1). The samples were collected based on previous collection records and in random limestone areas near Bau, Padawan, Siburan, and Serian. This research included field and laboratory work on eight species of the genus *Monophyllaea* in western Sarawak. The location, altitude, and GPS coordinates were all recorded for distribution analysis.

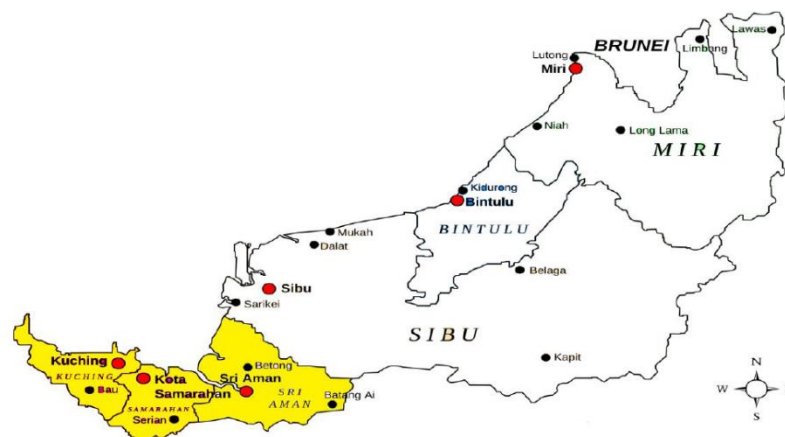


Figure 3.1: Map of Sarawak. The highlighted region is western Sarawak that has been proposed for this study

3.2 Research Materials and Specimen Verification

A few selected taxa of the genus *Monophyllaea* from western Sarawak were studied. The taxa include *M. glauca* (5 varieties), *M. singularis* (2 varieties), *M. tenuis*, *M. merrilliana* and *M. tetrasepala* B. L. Burtt. All the taxa are recorded from western Sarawak

except *M. merrilliana* in which this species has a much wider geographical range including the Philippines, Sarawak, Sabah and Kalimantan. At least three (3) samples per species were collected depending on the availability of the species. The study also examined herbarium specimens that were deposited at the Forest Department Sarawak Herbarium (SAR) (depending on the availability of specimens).

3.3 Herbarium Specimen Preparation

The fresh sample of *Monophyllaea* species was collected and preserved a herbarium specimens following the Standard herbarium methods (Bridson & Forman, 1992). The plant specimens collected were covered with newspapers and put inside the plastic bag. Then, 60% to 70% alcohol was added deliberately to preserve the samples until the newspapers were soaked thoroughly. The bags then were sealed tightly and left for one week. After one week, the specimens were taken out and placed in between new dry newspapers about A3 size. The newspapers then were stacked and arranged properly using the metal press. The metal straps were sealed tightly. The pressed specimens were then sent for drying in the oven for one week at 60 degree celcius. The specimen labels were prepared based on the field notes that have been taken after drying and pressing have been done. The specimens were mounted on a series of mounting sheets bearing the same collectors or herbarium numbers. 100% acid-free herbarium mounting paper was used for mounting herbarium specimens. The specimen label was glued on the bottom right-hand corner of the mounting paper. The dried specimen needs to be handled cautiously as *Monophyllaea* species are very brittle and can easily be damaged. After that, the specimens were glued and pressed until the glue hardened. The herbarium specimens also were sewed to hold the stem and leaves to prevent them from

falling apart. Completed mounted specimens were kept in a folder with the scientific name written at the bottom of the folder. The folder must be 100% acid-free paper. The specimens were indexed to record all the specimens with HUMS. The folder of the specimens was deposited into the cabinet according to the family, and the genus names were recorded accordingly.

3.4 Morphology Observation

Descriptions of the species were studied based on the morphological characteristics of the stem, leaf, inflorescence and seeds. The fresh sample was examined under a dissecting microscope. The parameters (length and width) were measured using a digital clipper, measuring tape and measuring software, in which images taken for the sample were observed under a dissecting microscope. The colour of every part was recorded. The herbarium specimens were examined and measurements of the relevant parts were taken accordingly. The parameter observed was stated in Table 3.1.

Table 3.1: Parameters for morphological characteristics of genus *Monophyllaea*

Structure	Parameters
Whole plant	Plant length
	Habit: pendulous
Stem	Length and width measurement
	Colour
	Surface: presence of hairs and chalk crust
Leaf	Length and width measurement
	Appearance: shape, apex, bases, margin, venation, surface
	Colour: Adaxial and abaxial
Inflorescence	Type of inflorescence
	Length (the whole inflorescence)
	Length of flower axis
Peduncle	Number of peduncles arising
	Length and width measurement
	Colour
	Surface: presence of hairs and chalk crust

Pedicels	Length measurement Surface: presence of hairs and chalk crust Colour
Sepals	Measurement: length and width Appearance: Shape, apex, bases, margin Colour
Flower	Corolla (upper lobes, median lobe and lateral lobes) - Measurement: length and width - Appearance: shape, apex, margin - Colour Androecium - Measurement: length (filament anterior and posterior) - Appearance: Presence of tooth, angle, trichomes Gynoecium (ovary, style) Measurement: length, diameter Appearance: colour, trichome
Capsule and seed	Capsule: Measurement, shape, colour, surface Seed: Measurement, shape, surface

3.5 Micromorphology

The micromorphology of leaves of the selected genus *Monophyllaea* was examined by using Scanning Electron Microscope (SEM) and Field Emission Scanning Electron Microscope (FESEM) following the modified Cutler (1978) standard method.

3.5.1 Preparation of Leaves for Scanning Electron Microscope (SEM) and Field Emission Scanning Electron Microscope (FESEM)

The leaf samples should be clean and free from diseases. Five mm² of the middle portion of the dry leaf lamina were cut. The cut leaf was cleaned with distilled water using a brush. The cut leaf was soaked in the 4% glutaraldehyde prepared in 0.1M phosphate buffer or FAA (formalin-acetic-alcohol) for 24 hours to fix the cell. After that, the cut leaf was immersed in a series of ethanol concentrations of 50% (15 minutes), 70% (15 minutes), 90%

(15 minutes, twice) and 100% (20 minutes, three times) as the preparation for critical point drying (CPD). CPD machine (Quorum K850) was used as shown in Figure 3.2.

The CPD procedure was applied before the samples were observed under SEM because this procedure discarded liquid from the samples and avoided the effects of surface tension, which eventually caused the cell to shrink. First, the sample was placed in the container's hole, and the CPD holder was tightened. The Blue valve (cooling) was opened until the temperature reached below 10°C. The CPD chamber was filled by opening the green valve until it reached the upper line. The stirrer was turned on for 3 minutes. Then, the stirrer was turned off and the black valve was opened to medium out the liquid. The procedures were repeated three times to ensure the sample was completely dried. The chamber was filled by opening the green valve and the heater was turned on. The heater was turned off when the temperature reached 35°C above and the pressure reached 100 bar. The large red valve (bleed) and small black valve (fine bleed) were opened slowly to release the pressure. The sample was taken from the CPD holder when the pressure reached 0.



Figure 3.2: Critical point drying (CPD) machine

Then, it was fixed with a double-sided adhesive tape on labelled stubs. A sputter coater (JOEL model JEC-3000FC auto fine coater) was used to coat the specimen with platinum at about 30 nm of thickness. The specimen was examined, and SEM (JEOL model JSM 6290 LA) and FESEM (JEOL model SM-IT500HR) were used to capture the images with various magnifications to get better resolution. The observation was conducted at the Faculty of Resource Science and Technology laboratory. The parameter observed was stated in Table 3.2.

Table 3.2: Parameters of the structures of the leaf

Structure	Parameter
Epidermal cell	Shape and arrangement; anticlinal wall pattern and measurement of epidermal cell
Stomatal complex	Location abundancy and orientation; subsidiary cell and measurement of stomata
Trichome (if any)	Type of trichomes and measurement

3.6 Anatomical Analysis

The anatomy characteristics examination of mature sample parts was followed Cutler (1978) standard method.

3.6.1 Transverse Section of Stem

The specimens were obtained from freshly collected materials preserved in 60% alcohol. To preserve the stem or petiole-like, the stem was soaked in distilled water for 10 minutes before being cut to remove any excess alcohol. The stem was cut to 10-20 μm using a sliding microtome. The cut stem was transferred using a brush into a Petri dish that contains 70% sodium hypochlorite (NaOCl) for 3 minutes or more until it turned colourless. The stem

was transferred into a Petri dish containing 50% safranin (staining) for five minutes. The stem was washed with distilled water three times. Then, the stem was stained with Alcian blue (staining) for 2 minutes. The stem was washed with distilled water three times. A series of 50%, 60%, 70%, 80% and 90% ethanol were used to dehydrate the specimen in about three minutes respectively. The sections were differentiated in 70% alcohol with a drop of hydrochloric acid. The process was continued in three series of absolute ethanol for three minutes each. A clean slide was used to place the stem and a few drops of Canada balsam (glueing) were added to the slide. The slide was covered with a cover slip. The slide was dried using an oven or slide dryer for 3 days at 60°C. The anatomical characteristics of the petiole were studied after it had completely dried under a compound microscope. The parameter observed was stated in Table 3.3.

Table 3.3: Parameters for stem characteristics

Structure	Parameter
Stem	Shape and arrangement; diameter and size
Vascular bundles	Arrangement of vascular bundles; quantity of vascular bundles and pattern of vascular bundles

3.6.2 The Transverse Section of Midrib

The specimens were obtained from freshly collected materials preserved in 50% alcohol. To preserve the midrib, it was soaked with distilled water for 10 minutes before being cut to remove any excess alcohol. The midrib was cut to 10-20 µm using a sliding microtome. The cut midrib was transferred using a brush into a Petri dish that contains 70% sodium hypochlorite (NaOCl) for 3 minutes or more until it turned colourless. The midrib was transferred into a Petri dish containing 50% safranin (for staining) for five minutes. The midrib was washed with distilled water three times. Then, the midrib was stained with Alcian

blue (staining) for 2 minutes. The midrib was washed with distilled water three times. A series of 50%, 70% and 90% ethanol were used to dehydrate the specimen in about three minutes, respectively. The sections were differentiated in 70% alcohol with a drop of hydrochloric acid. The process was continued in three series of absolute ethanol for three minutes each. A clean slide was used to place the midrib and a few drops of Canada balsam (glueing) were added to the slide. The slide was covered with a cover slip. The slide was dried using an oven or slide dryer for 3 days at 60°C. The anatomical characteristics of the midrib were studied after it had completely dried under a compound microscope. The parameter observed was stated in Table 3.4.

Table 3.4: Parameters for midrib characteristics

Structure	Parameter
Midrib	Shape and arrangement
Vascular bundles	Arrangement of vascular bundles, quantity of vascular bundles and pattern of vascular bundles

3.7 Palynology

Palynology study of selected genus *Monophyllaea* were analysed using SEM and FESEM.

3.7.1 Pollen Preparation

Mature flowers of *Monophyllaea* species were used for palynological studies. The freshly collected flowers were soaked in 4% glutaraldehyde prepared in 0.1M phosphate buffer or FAA (formalin-acetic-alcohol) for 24 to 48 hours followed by standard procedure Cutler (1978).

3.7.2 Preparation of Pollen Using Scanning Electron Microscope (SEM) and Field Emission Scanning Electron Microscope (FESEM)

Pollen from *Monophyllaea* species was collected and examined using a scanning electron microscope (SEM) and a field emission scanning electron microscope (FESEM). The pollen was extracted from a fresh flower sample using a dissecting microscope. Then, using a brush, it was adhered to labelled stubs with double-sided adhesive tape. The pollen was then dried for 2 hours in a desiccator jar. The specimen was coated with platinum about 30 nm thick using a sputter Coater. SEM (JEOL model JSM 6290 LA) and FESEM were used to examine the specimens (JEOL model JSM-IT500HR). It was used to capture images at various magnifications to achieve higher resolution. The observation was carried out in the laboratory of the Faculty of Resource Science and Technology. The observed parameter is stated in Table 3.5.

Table 3.5: Pollen parameter characteristics

Structure	Parameters
Pollen	Shape; size Aperture Exine surface

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Distribution of *Monophyllaea* in Western Sarawak

Monophyllaea samples were gathered in western Sarawak. These sample collection sites included the districts of Bau, Padawan, Siburan, and Serian. There are numerous limestone hills in Bau-Serian districts where random sampling was conducted in a variety of locations. With a permit from the Sarawak Forestry Department, fresh samples were gathered, along with data and locations for each species.

Samples were gathered from Bau (*M. singularis* var. *singularis* and *M. glauca* var. *versipes*), Padawan (*M. glandulosa*), and Serian (*M. glauca* var. *hirta*) based on information provided by previous collectors. Other *Monophyllaea* species were found in a variety of limestone regions in Sarawak's west. While trekking through Bau, Sarawak, one new species was discovered in Gunung Stulang (*M. kazuea*).

However, two species, namely *M. tetrasepala* and *M. merrilliana*, were only examined based on herbarium specimens deposited in the Sarawak Herbarium (SAR). The map in Figure 4.1 depicts the distribution of all 14 *Monophyllaea* taxa discovered west of Sarawak.

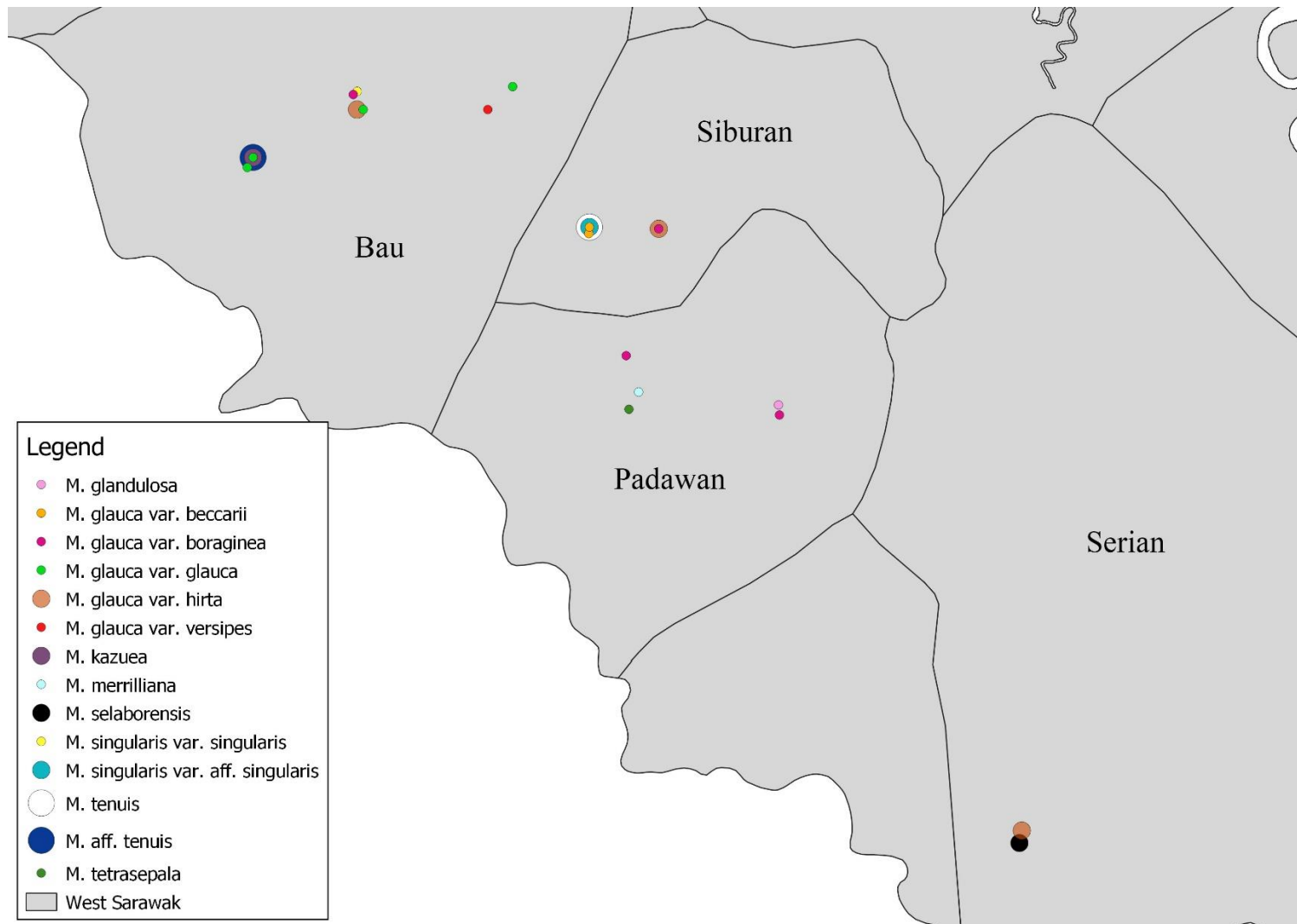


Figure 4.1: Map distribution of genus *Monophyllaea* in Western Sarawak

Most of the *Monophyllaea* species were found in the Bau district. *M. glauca* var. *boraginea*, *M. glauca* var. *glauca*, *M. glauca* var. *hirta*, and *M. singularis* var. *singularis* were collected scattered in the same area near the Fairy Cave in Bau. As recorded by the former collector, *M. tenuis* can also be found at Fairy Cave, but no samples were collected. *M. glauca* var. *versipes* was collected in Gunung Doya near Kampung Seromah, as stated by the previous collector. Three taxa (*M. glauca* var. *glauca*, *M. aff. tenuis* and *M. kazuea*) were found growing on the same limestone cliff at Gunung Stulang near Kampung Bogag, Bau.

In the Siburan district, there are three *Monophyllaea* taxa (*M. glauca* var. *beccarii*, *M. tenuis*, and *M. singularis* var. *aff. singularis*) found at Gunung Ma'asa, a limestone hill located near the Bengoh Resettlement Scheme. Two taxa, *M. glauca* var. *boraginea* and *M. glauca* var. *hirta*, were collected at the same area of a hill near Kampung Benuk, Siburan.

In Padawan district, two taxa (*M. glauca* var. *boraginea* and *M. glandulosa*) were collected in the same area but on different hills in Teng Bukap. Both *M. merrilliana* and *M. tetrasepala* were recorded and found in Padawan by previous collectors.

Both taxa (*M. glauca* var. *hirta* and *M. selaborensis*) were collected near the same area at Gua Silabur, Tebakang, and Serian. *M. selaborensis* was found growing on the wall inside the Silabur Cave, while *M. glauca* var. *hirta* can be found growing on the ground outside the cave. A list of *Monophyllaea* taxa and locality in west Sarawak, including the

previous collectors and later collectors, were tabulated in Table 4.1. There are a total of eight *Monophyllaea* species occurring in Western Sarawak. Six species of *Monophyllaea* were found and collected throughout this study. Two species, *M. merrilliana* and *M. tetrasepala* were unable to be collected as the location were too far. The number of *Monophyllaea* species increasing as new species were found in recent years.

As random sampling was used in this study, many limestones were visited during field work, and this was to gather a new record of these species. However, there were no *Monophyllaea* species was found in disturbed limestone area. This disturbed limestone area often caused by development on the area and quarrying of limestone materials.

Table 4.1: List of genus *Monophyllaea* recorded and collected in Western Sarawak

Taxa	Location	District	Latitude	Longitude
<i>M. glandulosa</i>	Teng Bukap	Padawan	1°12'33"N	110°21'52"E
<i>M. glauca</i> var. <i>beccarii</i>	Gunung Kebik	Siburan	1°18'31"N	110°15'16"E
	Gunung Ma'asa	Siburan	1°18'44.45"E	110°15'17.27"E
<i>M. glauca</i> var. <i>boraginea</i>	Hill near Kampung Benuk	Padawan	1°18'41"N	110°17'42"E
	Gunung Braang	Siburan	1°14'16"N	110°16'34"E
	Behind Fairy Cave	Bau	1°23'21.42"N	110°07'04.25"E
	Teng Bukap	Padawan	1°12'12"N	110°21'54"E
<i>M. glauca</i> var. <i>glauca</i>	Gunung Jagoi	Bau	1°20'49"N	110°3'23"E
	Fairy Cave	Bau	1°22'50"N	110°7'25"E
	Gunung Podam	Bau	1°21'158"N	110°3'577"E
	Gunung Stulang	Bau	1°21'10"N	110°3'35"E
<i>M. glauca</i> var. <i>hirta</i>	Entrance of Fairy Cave	Bau	1°22'50"N	110°7'12"E
	Hills near Kampung Benuk	Padawan	1°18'41"N	110°17'42"E
	Gua Silabur	Serian	0°57'44"N	110°30'20"E
<i>M. glauca</i> var. <i>versipes</i>	Gunung Doya	Bau	1°22'50"N	110°11'45"E
<i>M. kazuea</i>	Gunung Stulang	Bau	1°21'10"N	110°3'35"E
<i>M. merrilliana</i>	Gunung Regu	Padawan	1°13'00.03"N	110°17'00.00"E
<i>M. selaborensis</i>	Gua Silabur	Serian	0°57'18"N	110°30'15"E
<i>M. singularis</i> var. <i>singularis</i>	Buddha Temple, near Fairy Cave	Bau	1°23'27.80"N	110°07'12.23"E
<i>M. singularis</i> var. <i>aff. singularis</i>	Gunung Ma'asa	Siburan	1°18'44.45"E	110°15'17.27"E
<i>M. tenuis</i>	Gunung Ma'asa	Siburan	1°18'44.45"E	110°15'17.27"E
<i>M. aff. tenuis</i>	Gunung Stulang	Bau	1°21'10"N	110°3'35"E
<i>M. tetrasepala</i>	Gunung Manok	Padawan	1°12'23.97"N	110°16'39.75"E

4.2 Habitat of Genus *Monophyllaea*

Habitat of 12 taxa of genus *Monophyllaea* were recorded and tabulated in Table 4.2. Some of the genus *Monophyllaea* in western Sarawak were found grow on vertical hills, on foothill and on walls inside the cave at limestone area.

Table 4.2: List of elevation, habitat and estimated number of individuals of *Monophyllaea*

Taxa	Elevation	Habitat	No. of individual
<i>M. glandulosa</i>	13 m	Found grow on the vertical hills covered by sandy soil near the small river.	> 20
<i>M. glauca</i> var. <i>beccarii</i>	32 – 38 m	Found grow at shaded area on foothill of limestone.	> 20
<i>M. glauca</i> var. <i>boraginea</i>	22 – 90 m	Found grow at shaded area on foothill of limestone.	< 100
<i>M. glauca</i> var. <i>glauca</i>	42 – 80 m	Found grow at shaded area on foothill of limestone.	> 30
<i>M. glauca</i> var. <i>hirta</i>	35 – 80 m	Found grow at shaded area on foothill of limestone and on the ground near the opening of the cave	<100
<i>M. glauca</i> var. <i>versipes</i>	61 m	Found grow at shaded area on foothill of limestone.	> 10
<i>M. kazuea</i>	52 m	Found grow on the wall of vertical limestone at shaded area.	< 50
<i>M. selaborensis</i>	110 m	Found grow on wall of limestone rock inside Silabur cave	< 20
<i>M. singularis</i> var. <i>singularis</i>	20 m	Found grow overhangs on limestone wall at shaded area.	< 100
<i>M. singularis</i> var. <i>aff. singularis</i>	32 m	Found grow on 10 m sheltered vertical cliff along the dripline.	< 50
<i>M. tenuis</i>	32 m	Found grow on 10 m sheltered vertical cliff along the dripline.	< 50
<i>M. aff. tenuis</i>	52 m	Found grow on the wall of vertical limestone at shaded area.	< 50

Monophyllaea usually grows in areas with high humidity, slightly lower temperatures than normal, shaded areas, and some that are near small rivers or streams. They were found growing in the elevation range of 13 m to 110 m above sea level. *M. glauca* var. *versipes* has the fewest individual plants counted, as it was found to have no more than 10 individuals per

area. The three species with the largest number of individual plants among the twelve taxa of *Monophyllaea* were *M. glauca* var. *boraginea*, *M. glauca* var. *hirta*, and *M. singularis*. Figure 4.2 illustrates the range of altitude of *Monophyllaea* taxa in Western Sarawak.

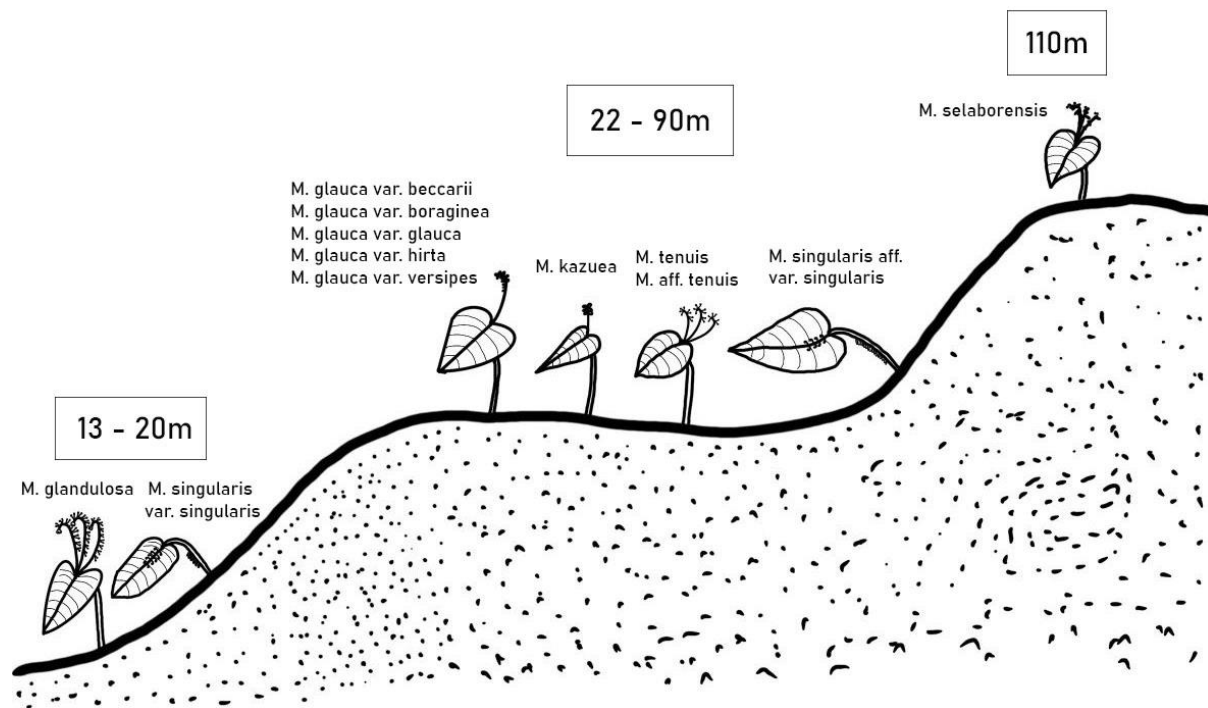


Figure 4.2: The range of altitude of *Monophyllaea* taxa in Western Sarawak

4.3 Morphology Study of *Monophyllaea* Taxa

Monophyllaea species are well known for its one leaf plant. The description of *Monophyllaea* species were taken during the field work and analysis of the sample.

4.3.1 Whole Plant

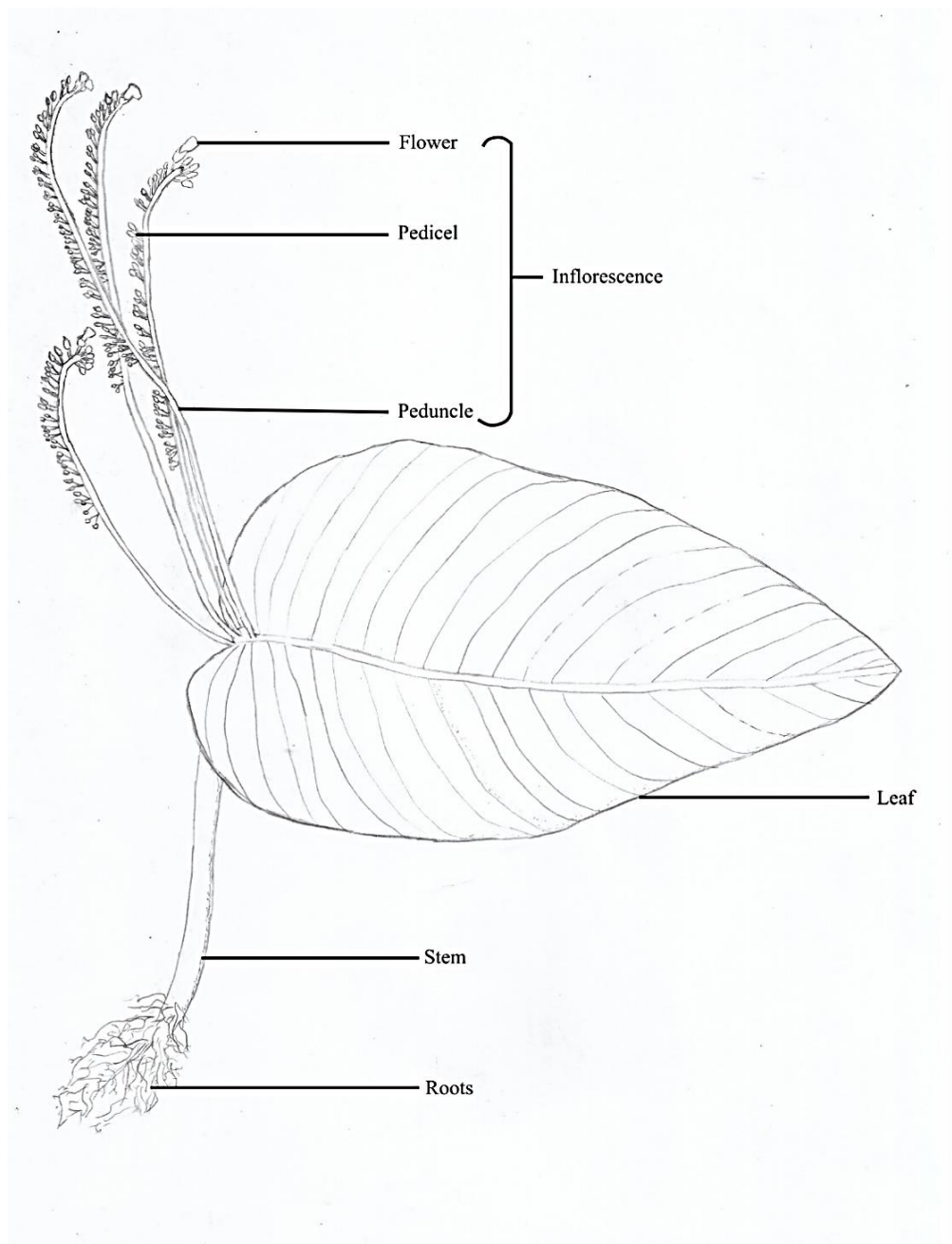


Figure 4.3: Plant habit of *Monophyllaea* [Illustration: Nur Athirah Nabihah]

Monophyllaea is a herbaceous plant that grows on damp limestone rocks in tropical rain forests. *Monophyllaea* reproductive individuals comprise one ovate-cordate leaf, a hypocotyl stem with delicate roots, and several to ten inflorescence stalks rising from the leaf (Kohyama & Hotta, 1986). The inflorescence usually grows at the base of the lamina or along the midrib. The general characteristics of the genus *Monophyllaea* are shown in Figure 4.3. Some

Monophyllaea species are erect (all varieties of *M. glauca*), and some are pendulous, especially the plants that grow on vertical cliffs.

4.3.2 Roots

Monophyllaea is a litophilous plant with numerous rootlets. The roots will spread on the ground and stick to rocks (Figure 4.3), dead wood, leaves, and soil. The roots spread well for the plant to have a good grip, especially growing on a vertical cliff and at the mouth of the cave. The roots comprise a primary root, a secondary root, a tertiary root, and some rootlets as shown in Figure 4.4.



Figure 4.4: The root habits of *Monophyllaea* species and the roots spread on the rocks

The colour of the roots varies from pale green to purplish brown. A pale green colour can be seen inside the roots with white dots when dissecting. The length of the root in all *Monophyllaea* recorded was in the range of 1.5 cm to 16.5 cm.

4.3.3 Stem

The stem is petiole-like, succulent, and cylindrical showed in Figure 4.5. A petiolode, which resembles a stem and petiole, and a single developing cotyledon (larger cotyledon) make up the whole aboveground vegetative body of a one-leaf plant (Ishikawa et al., 2017). Each phyllomorph is made up of a blade with the ability to continue growing and a petiolode (stalk), which combines the characteristics of both a leaf and a stem (Imaichi et al., 2001). According to the concept of "phyllomorphy", which is also applied to *Streptocarpus*, it similarly has unifoliate and rosulate structures (Jong, 1973; 1978; Jong & Burt, 1975; Burt, 1978). Imaichi et al. (2001) also mentioned that an intercalary meristem called the petiolode meristem, which is active at the base of the macrocotyledon, causes the petiolode below it to enlongate.

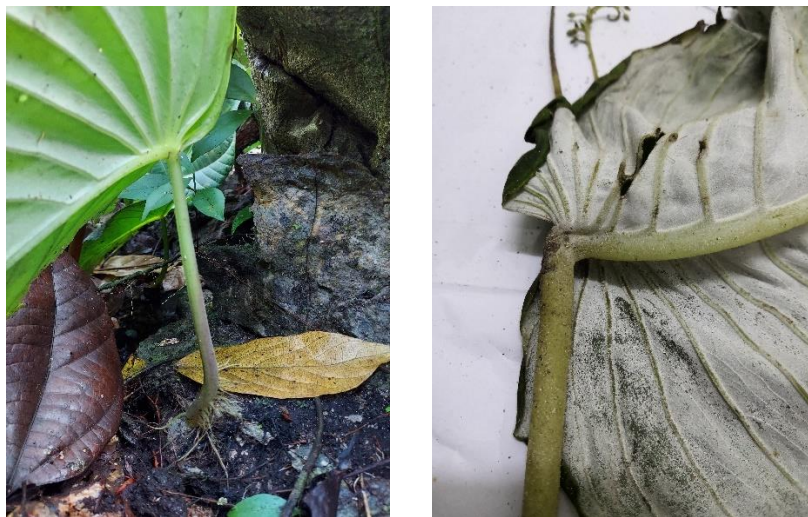


Figure 4.5: The stem of *Monophyllaea*

Table 4.3: The stem characteristics of *Monophyllaea*

Taxa	Length (cm)	Diameter (cm)	Colour	Stem encrusted	Indumentum
<i>M. glandulosa</i>	7 – 16	1.8 – 3	Pale green	Heavily encrusted	Sparsely long glandular
<i>M. glauca</i> var. <i>beccarii</i>	15.1 – 30.5	2.4 – 5.1	Greenish brown or reddish brown	Slightly encrusted	Glabrous
<i>M. glauca</i> var. <i>boraginea</i>	13 – 25	2.5 – 3.4	Reddish brown to greenish brown	Slightly encrusted	Glabrous
<i>M. glauca</i> var. <i>glauca</i>	13 – 21	1.4 – 1.5	Pale green	Slightly encrusted	Glabrous
<i>M. glauca</i> var. <i>hirta</i>	32 – 37	2.7 – 3.7	Pale green	Slightly encrusted	Glabrous
<i>M. glauca</i> var. <i>versipes</i>	13.5 – 17.0	1.6 – 2.9	Pale green	Heavily encrusted	Glabrous
<i>M. kazuea</i> .	9 – 11.5	1.5 – 1.7	Green	Heavily encrusted	Densely uniseriate tapering
<i>M. merrilliana</i>	5 – 30	N/A	Green	Slightly encrusted	N/A
<i>M. selaborensis</i>	13 – 15	1 – 1.5	Pale green	Heavily encrusted	Glabrous
<i>M. singularis</i> var. <i>singularis</i>	29 – 49	3.5 – 6	Pale green	Heavily encrusted	Glabrous sometimes densely tomentose
<i>M. singularis</i> aff. var. <i>singularis</i>	19 – 49	2.5 – 3.3	Pale green	Heavily encrusted	Glabrous
<i>M. tenuis</i>	9.5 – 14	1.5 – 1.7	Pale green	Slightly encrusted	Sparsely long pilose
<i>M. aff. tenuis</i>	7 – 9	1.5 – 2	Pale green	Heavily encrusted	Densely long pilose
<i>M. tetrasepala</i>	30	N/A	Reddish	N/A	N/A

*N/A- not available, the previous description was incompleated

The measurement and characteristics of the stem are tabulated in Table 4.3. Both *M. singularis* var. *singularis* and *M. singularis* var. *aff. singularis* have the longest stem as they can reach 49 cm, and *M. merrilliana* has the shortest stem with a length of 5 cm. *Monophyllaea singularis* var. *singularis* has the largest diameter of stem at 6 cm, while *M. selaborensis* has the smallest diameter of stem at 1 cm.

The colour of the stem varies from green to pale green to greenish brown to reddish brown. Some *Monophyllaea* species are heavily encrusted, showing a chalkier surface and a lot of small white flakes present on the stem. The species that are heavily encrusted also have a rough surface on the stem. The species that has slightly encrusted the stem surface showed less chalkiness, fewer small white flakes on the stem, and a smooth surface. Based on the observation of sample, there is a presence of white dots seen inside when dissecting the stem as shown in Figure 4.6.



Figure 4.6: The cross section of *Monophyllaea* stem

Monophyllaea selaborensis, *M. singularis* var. *aff. singularis* and five varieties of *M. glauca* have no indumentum on the stem. Some parts of the stem of *M. singularis* var. *singularis* are glabrous, sometimes densely covered with short white tomentose hairs. There is only one species that has sparsely glandular hairs on the stem, which is *M. glandulosa*. The glandular hairs are visible to the naked eye. *M. kazuea* has densely tapering hairs on the stem. *Monophyllaea tenuis* has sparsely long pilose hairs, while *M. aff. tenuis* has densely long pilose hairs.

Based on the observation of herbarium samples and descriptions recorded by Burtt (1978), *M. merrilliana* has various sizes of stem, green colour, and encrusted. *Monophyllaea tetrasepala* was found to have a reddish stem, and the inside of the stem also turned out to be red during the cut for pressing. Figure 4.7 shows the surface of the stems of *Monophyllaea* taxa in western Sarawak.

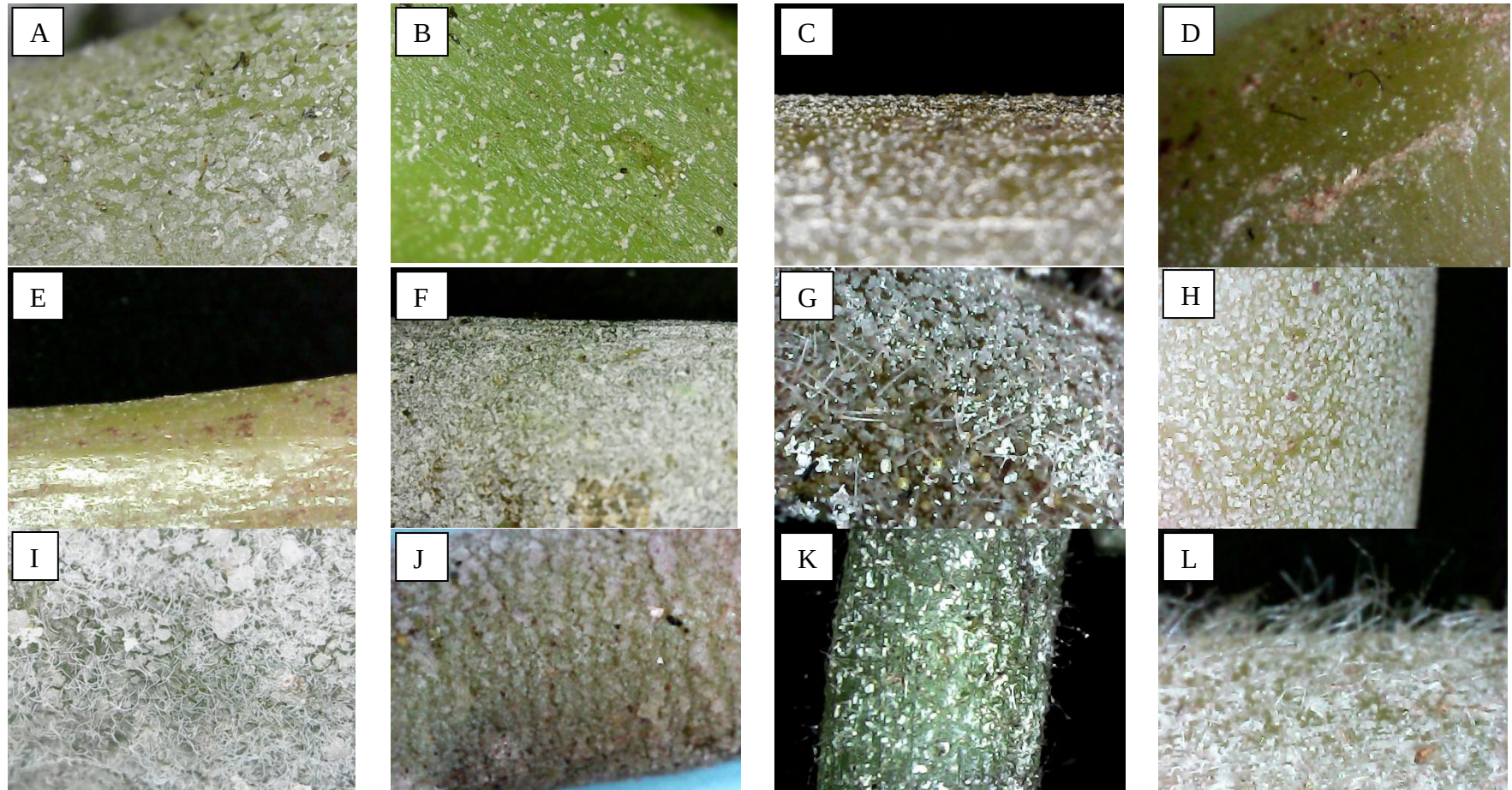


Figure 4.7: The surface of the stem showing the presence or absence of indumentum. **A.** *M. glandulosa*, **B.** *M. glauca* var. *beccarii*, **C.** *M. glauca* var. *boraginea*, **D.** *M. glauca* var. *glauca*, **E.** *M. glauca* var. *hirta*, **F.** *M. glauca* var. *versipes*, **G.** *M. kazuea*, **H.** *M. selaborensis*, **I.** *M. singularis* var. *singularis*, **J.** *M. singularis* var. *aff. singularis*, **K.** *M. tenuis*, **L.** *M. aff. tenuis*

4.3.4 Leaf Morphology Characteristics

Monophyllaea is well known for having only one leaf. However, some *Monophyllaea* species were found in the field, including *Monophyllaea selaborensis*, having three to four leaves growing on the leaf base at the top of the primary leaf, and *Monophyllaea tenuis* and *M. singularis* var. *aff. singularis*, which have two leaves on one plant as shown in Figure 4.8. The new leaf often emerged from the middle to the lower part of the stem.



Figure 4.8: *M. tenuis* has two leaves on the same plant

The colour of the leaf varies from dark green to pale green. The adaxial leaves found were mainly green to dark green, while all *Monophyllaea* species collected were pale green on the abaxial leaf. The measurements of the leaf size (length x width) and characteristics of the leaf were recorded in Table 4.4.

Table 4.4: The measurement of leaf size and characteristics of leaf

Taxa	Leaf size (cm)	Leaf shape	Leaf base	Leaf apex	Leaf margin	Thickness of leaf
<i>M. glandulosa</i>	17.0 -37.0 x 12.5 - 27.5	Ovate - oblong	Cordate	Acute	Entire	Thick
<i>M. glauca</i> var. <i>beccarii</i>	21.5 – 39.2 x 23 – 35.0	Broadly ovate	Deeply cordate	Acute	Entire	Thick
<i>M. glauca</i> var. <i>boraginea</i>	30.0 – 37.0 x 21.5 - 33	Broadly ovate	Deeply cordate	Acute	Entire	Thick
<i>M. glauca</i> var. <i>glauca</i>	30.0 – 31.0 x 26.0 - 27.2	Broadly ovate	Deeply cordate	Acute	Entire	Thick
<i>M. glauca</i> var. <i>hirta</i>	30.0 – 40.0 x 21.5 - 27.5	Broadly ovate	Deeply cordate	Acute	Entire	Thick
<i>M. glauca</i> var. <i>versipes</i>	15.0 – 24.0 x 19.5 - 22.5	Broadly ovate	Deeply cordate	Acute	Entire	Thick
<i>M. kazuea</i>	20.0 – 28.0 x 11.2 – 12.5	Lanceolate - oblong	Cordate	Acute	Entire	Thin
<i>M. merrilliana</i>	12.0 – 45.0 x 10.0 – 40.0	Broadly ovate/ oblong	Cordate	Acute	Entire	Thick
<i>M. selaborensis</i>	35.0 x 27.5	Ovate - oblong	Deeply cordate	Acute	Entire	Thick
<i>M. singularis</i> var. <i>singularis</i>	32.6 – 49.0 x 18.0 – 25.0	Oblong/ ovate - oblong	Cordate	Acute	Entire	Thick
<i>M. singularis</i> var. <i>aff. singularis</i>	33.0 – 50.0 x 12.4 – 25.0	Oblong/ ovate - oblong	Cordate	Acute	Entire	Thick
<i>M. tenuis</i>	16.0 – 25.0 x 11.0 – 14.0	Ovate	Deeply cordate	Acute	Entire	Thin
<i>M. aff. tenuis</i>	20.0 – 32.0 x 15.0 - 25.5	Ovate	Deeply cordate	Acute	Entire	Thin
<i>M. tetrasepala</i>	35.0 x 35.0	Broadly ovate	Cordate	Acute	Entire	Thick

The longest length of the leaf can be found in *M. singularis* var. *aff. singularis* at 50 cm, while the shortest leaf is *M. merrilliana* at 12 cm. *Monophyllaea merrilliana* has the biggest leaf width at 40 cm and the smallest leaf width at 10 cm.

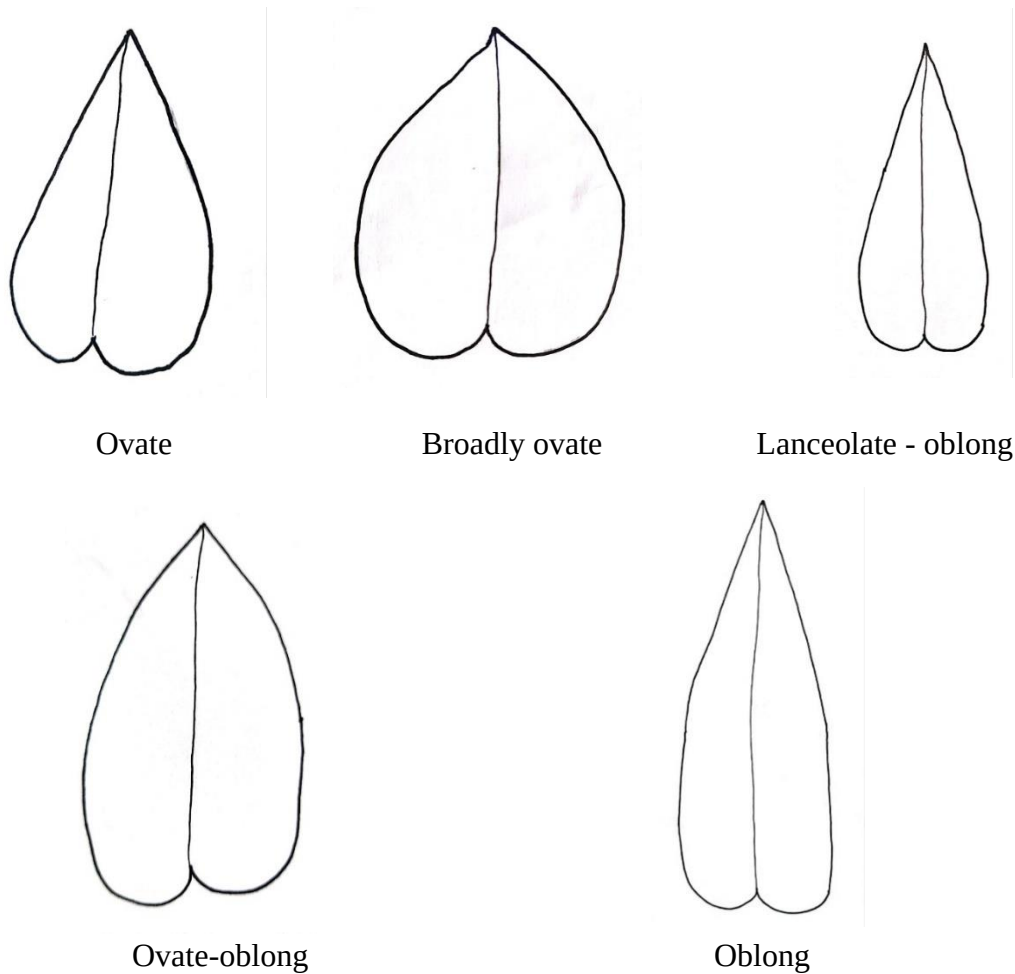


Figure 4.9: The different leaf shapes of *Monophyllaea* species

Monophyllaea have mainly five types of leaf shapes (Figure 4.9). Five varieties of *Monophyllaea glauca* and *M. tetrasepala* has a broadly ovate leaf shape. *Monophyllaea tenuis* and *M. aff. tenuis* has ovate leaf shapes. *Monophyllaea singularis* var. *singularis* and *M. singularis* var. *aff. singularis* have both ovate-oblong and oblong leaf types. *Monophyllaea kazuea* has a lanceolate-oblong leaf shape. *M. merrilliana* on the other hand has either a broadly ovate or oblong leaf shape.

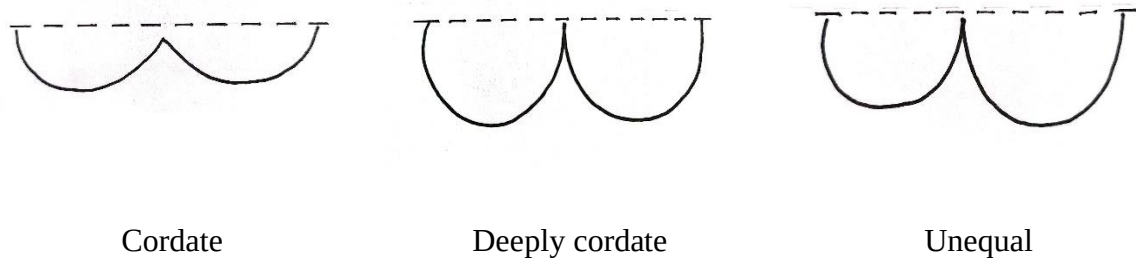


Figure 4.10: The types of leaf base of *Monophyllaea*

The leaf bases of *Monophyllaea* are usually cordate or deeply cordate (Figure 4.10). One species, *M. kazuea*, sometimes has an unequal base (Figure 4.10). The leaf apex or tip of the leaf on all flowering *Monophyllaea* plants is damaged in nature and rotten away. This may also be caused by the insects and snails consuming the leaf, as there were several encounters during the field trip. However, the young leaf shows *Monophyllaea* species have an acute apex. Most *Monophyllaea* have an entire leaf margin (five varieties of *M. glauca*, *M. glandulosa*, *M. selaborensis*, *M. singularis* var. *singularis* and *M. singularis* var. *aff. singularis*) and some are ciliate in some species (*M. kazuea*, *M. tenuis*, *M. aff. tenuis*).

The leaf thickness of *Monophyllaea* also varies. All five varieties of *M. glauca*, *M. glandulosa*, *M. merrilliana*, *M. selaborensis*, *M. singularis* var. *singularis*, *M. singularis* var. *aff. singularis* and *M. tetrasepala* have thick and succulent leaves. However, *M. kazuea*, *M. tenuis*, and *M. aff. tenuis* can be differentiated by the thin leaf. The indumentum and encrustation on the surface of the adaxial leaf were tabulated in Table 4.5.

Table 4.5: The characteristics of adaxial leaf surface of *Monophyllaea*

Taxa	Presence of indumentum	Colour of indumentum	Surface of leaf
<i>M. glandulosa</i>	Sparsely glandular	White	Slightly encrusted
<i>M. glauca</i> var. <i>beccarii</i>	Scattered soft bulbous-based	White	Glabrous
<i>M. glauca</i> var. <i>boraginea</i>	Scattered harsh scabrid with bulbous-based	White	Glabrous
<i>M. glauca</i> var. <i>glauca</i>	Glabrous	N/A	Glabrous
<i>M. glauca</i> var. <i>hirta</i>	Scattered short stiff erect	Brown	Glabrous
<i>M. glauca</i> var. <i>versipes</i>	Densely with soft erect	White sometimes brown	Glabrous
<i>M. kazuea</i>	Densely uniseriate tapering	White	Slightly encrusted
<i>M. merrilliana</i>	Densely branched/ glabrous	Brown	Glabrous
<i>M. selaborensis</i>	Sparsely capitate-glandular	White	Slightly encrusted
<i>M. singularis</i> var. <i>singularis</i>	Sparsely capitate-glandular	White	Slightly encrusted
<i>M. singularis</i> var. <i>aff. singularis</i>	Sparsely capitate-glandular	White	Slightly encrusted
<i>M. tenuis</i>	Densely thinly pilose glandular	White	Slightly encrusted
<i>M. aff. tenuis</i>	Densely thinly pilose glandular	White	Slightly encrusted
<i>M. tetrasepala</i>	Glabrous	N/A	Glabrous

*N/A- not available, the previous description was incompleted

Indumentums are one of the essential characteristics in determining the species in the genus *Monophyllaea*. The varieties in *M. glauca* are differentiated usually with types of trichomes seen on the surface of the leaf and inflorescence as shown in Figure 4.11 below.

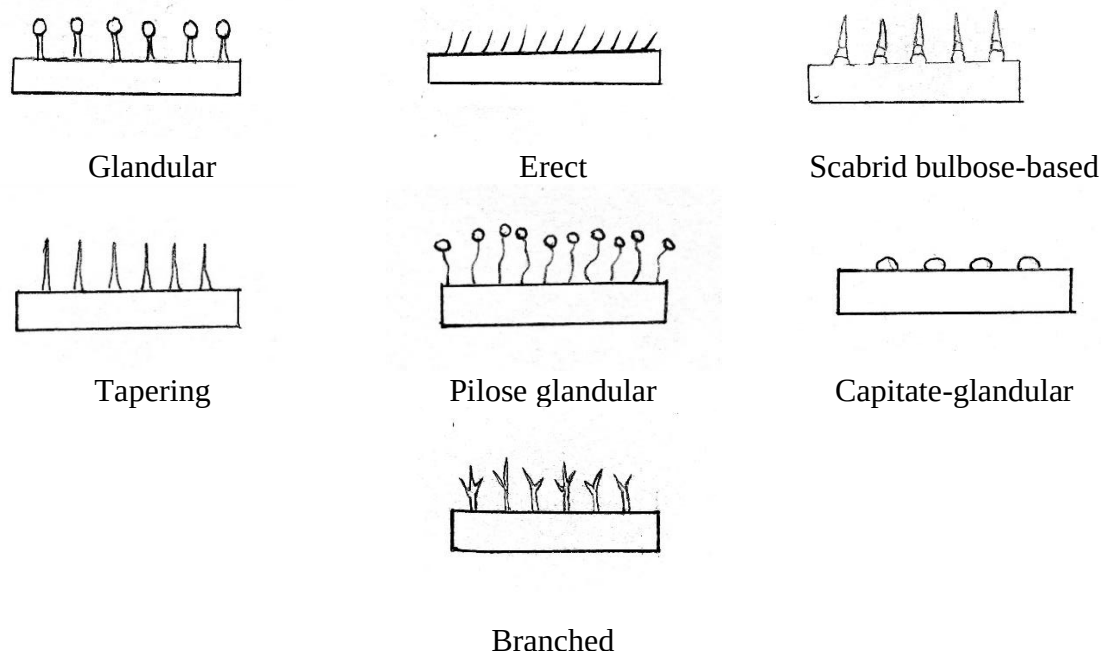


Figure 4.11: The types of indumentums on the leaf surface

M. glandulosa is easily recognized in the field for having glandular hairs on the leaf and other parts of the plant. *M. glauca* var. *glauca* are glabrous and no indumentum is present. *M. glauca* var. *hirta* has scattered brown stiff erect hairs while *M. glauca* var. *versipes* has white sometimes brown hairs soft erect hairs on the adaxial of the leaf. *M. glauca* var. *boraginea* has scattered harsh scabrid from persistent bulbous-based hairs compared to *M. glauca* var. *beccarii* which has scattered soft persistent bulbous-based hairs. *M. kazuea* has densely long tapering uniseriate hairs on the adaxial of the leaf. It is recorded that *M. merrilliana* has a branched type of indumentum sometimes glabrous on the adaxial of the leaf. *M. selaborensis*, *M. singularis* var. *singularis* and *M. singularis* var. *aff. singularis* have

sparsely capitate-glandular hairs on the adaxial surface of the leaf. Both *M. tenuis* and *M. aff. tenuis* has densely thinly pilose glandular hairs. However, it was recorded that *M. tetrasepala* is glabrous and no encrustation happened on the adaxial surface.

Crystal and chalky residues commonly appear on the leaf surface of *Monophyllaea*. Five varieties of *M. glauca*, *M. merrilliana* and *M. tetrasepala* are glossy and no encrustation is found on the adaxial of the leaf. Other *Monophyllaea* species collected have slightly encrusted on the adaxial of the leaf. The characteristics of indumentum and encrustation on the adaxial leaf of *Monophyllaea* can be seen in Figure 4.12.

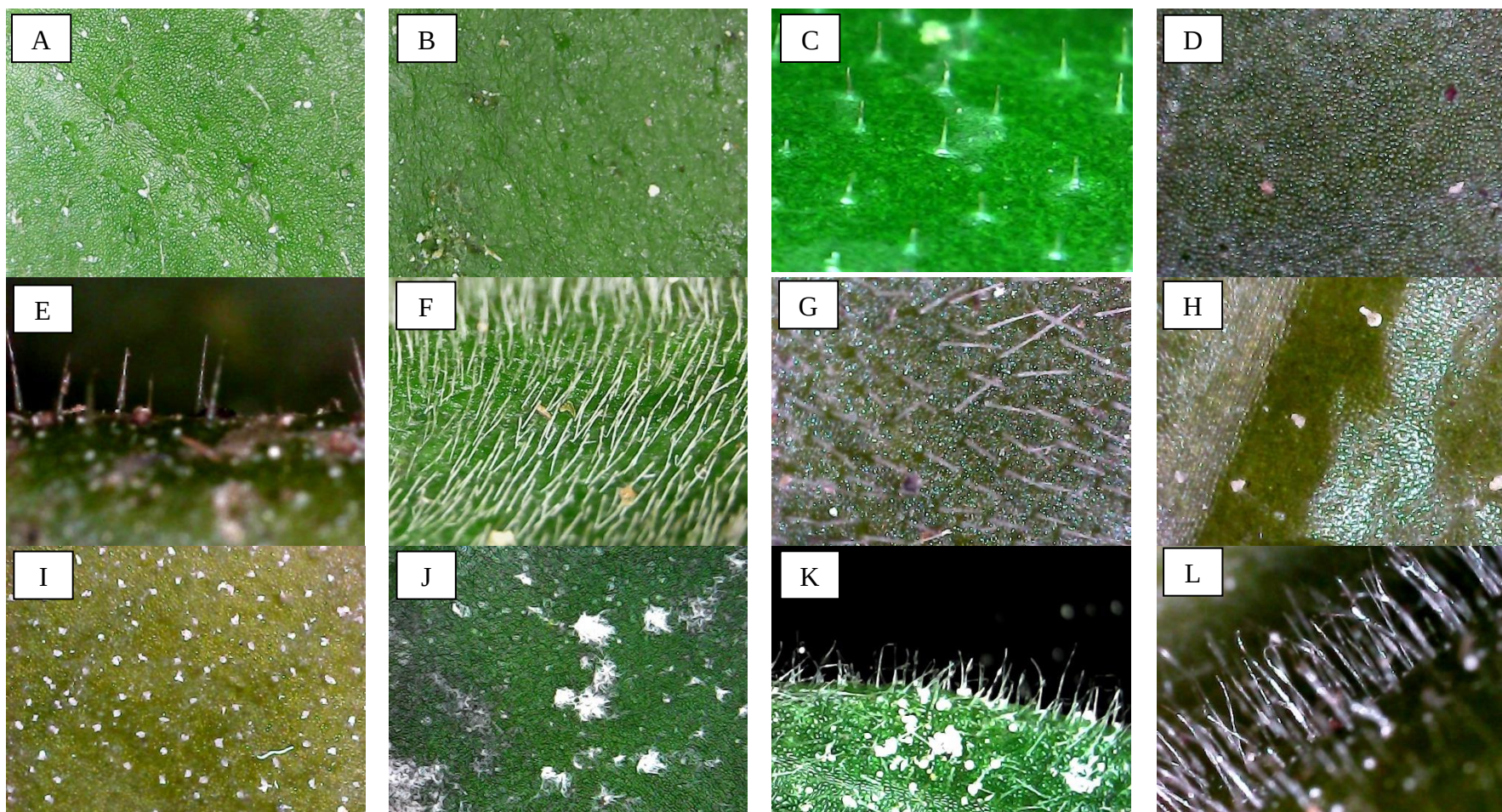


Figure 4.12: The indumentum and encrustation on adaxial surface of leaf. **A.** *M. glandulosa*, **B.** *M. glauca* var. *beccarii*, **C.** *M. glauca* var. *boraginea*, **D.** *M. glauca* var. *glauca*, **E.** *M. glauca* var. *hirta*, **F.** *M. glauca* var. *versipes*, **G.** *M. kazuea*, **H.** *M. selaborensis*, **I.** *M. singularis* var. *singularis*, **J.** *M. singularis* var. *aff. singularis*, **K.** *M. tenuis*, **L.** *M. aff. tenuis*

Table 4.6: The characteristics of leaf on the abaxial surface

Taxa	Presence of indumentum	Colour of indumentum	Surface of leaf
<i>M. glandulosa</i>	Sparsely glandular	White	Heavily encrusted
<i>M. glauca</i> var. <i>beccarii</i>	Scattered soft bulbous-based	White	Slightly encrusted
<i>M. glauca</i> var. <i>boraginea</i>	Scattered harsh scabrid bulbous-based	White	Slightly encrusted
<i>M. glauca</i> var. <i>glauca</i>	Glabrous	N/A	Slightly encrusted
<i>M. glauca</i> var. <i>hirta</i>	Densely stiff erect	Brown sometimes white	Slightly encrusted
<i>M. glauca</i> var. <i>versipes</i>	Densely soft erect	White sometimes brown	Slightly encrusted
<i>M. kazuea</i>	Densely uniseriate tapering	White	Heavily encrusted
<i>M. merrilliana</i>	Sparsely branched/ glabrous	Brown	Heavily/ slightly encrusted
<i>M. selaborensis</i>	Glabrous	N/A	Heavily encrusted
<i>M. singularis</i> var. <i>singularis</i>	Glabrous	N/A	Heavily encrusted
<i>M. singularis</i> var. <i>aff. singularis</i>	Glabrous	N/A	Heavily encrusted
<i>M. tenuis</i>	Densely thinly pilose glandular	White	Heavily encrusted
<i>M. aff. tenuis</i>	Densely thinly pilose glandular	White	Heavily encrusted
<i>M. tetrasepala</i>	Glabrous	N/A	Slightly encrusted

*N/A- not available/cannot determine the colour, the previous description was incompleated

Table 4.6 shows the characteristics of the indumentum and encrustation on the abaxial surface of the leaf. *M. glandulosa* has sparsely white glandular hairs and is heavily encrusted with crystal and white chalky flakes. *M. glauca* var. *beccarii* has scattered white soft bulbous-based hairs, while *M. glauca* var. *boraginea* has scattered white harsh scabrid bulbous-based hairs. *M. glauca* var. *glauca* and *M. tetrasepala* are glabrous, and there is no presence of indumentum. *M. glauca* var. *hirta* has densely brown, sometimes white, stiff erect hairs compared to *M. glauca* var. *versipes*, which has densely white, sometimes brown, soft erect hairs. Based on the observations, all five varieties of *M. glauca* have a slightly encrusted abaxial surface.

M. kazuea has densely white, tapering, uniseriate hairs. For *M. merrilliana*, it has glabrous or sparsely branched brown hairs encrusted on the abaxial surface. The indumentum on *M. selaborensis*, *M. singularis* var. *singularis*, and *M. singularis* var. *aff. singularis* cannot be seen with the naked eye. This may be affected by the heavily encrusted crystal and white chalky flakes covering the surface of the abaxial leaf. Both *M. tenuis* and *M. aff. tenuis* has densely white, thinly pilose glandular hairs that are heavily encrusted on the abaxial surface of the leaf. Detail images of the indumentum and encrustation can be observed in Figure 4.13.

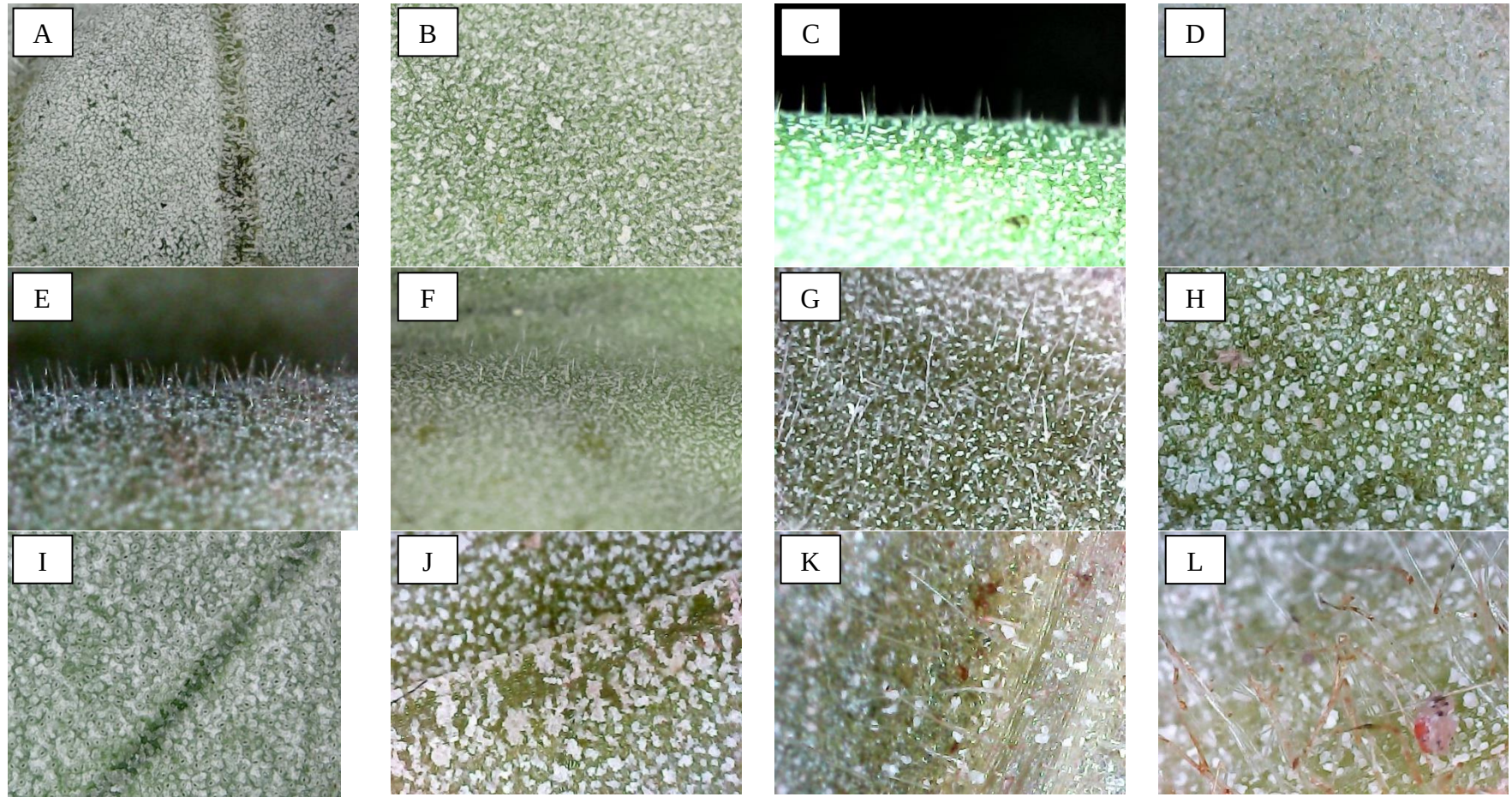


Figure 4.13: The indumentum and encrustation on abaxial surface of leaf. **A.** *M. glandulosa*, **B.** *M. glauca* var. *beccarii*, **C.** *M. glauca* var. *boraginea*, **D.** *M. glauca* var. *glauca*, **E.** *M. glauca* var. *hirta*, **F.** *M. glauca* var. *versipes*, **G.** *M. kazuea*, **H.** *M. selaborensis*, **I.** *M. singularis* var. *singularis*, **J.** *M. singularis* var. *aff. singularis*, **K.** *M. tenuis*, **L.** *M. aff. tenuis*

4.3.5 Inflorescence

The characteristics of inflorescence were recorded during the fieldwork and analysis of herbarium samples.

4.3.5.1 Type of Inflorescence

The inflorescence of *Monophyllaea* species consists of peduncle, pedicel and flower. It is pedicellate and ebracteate. *Monophyllaea* shows determinate inflorescence and perfect flower. Most *Monophyllaea* species have pedunculate inflorescences that cluster compactly or loosely at the base of the macro-cotyledon (Imaichi et al., 2001).

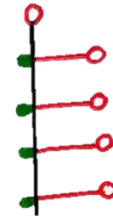
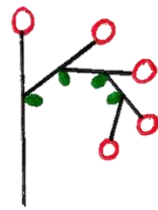
In *M. singularis* var. *singularis* and *M. singularis* var. *aff. singularis*, the inflorescence emerges from the stem and is scattered along both the petiole and the midrib of the blade. *M. glauca* are more or less contemporaneous as no dead inflorescences are found on the flowering plant. However, the flowering can seemingly continue for a long time as the fruits fall quickly and new flowers have always been produced. As for *M. selaborensis*, *M. tenuis* and *M. aff. tenuis*, the old-withered peduncles are often still visible while the fresh crop is flowering, so the inflorescences are not entirely contemporaneous. There are four inflorescence arrangements based on Burt (1978): Firstly, in a cluster at the base of the midrib (*M. glauca*, *M. horsfieldii*, etc.). Secondly, some are at the base of the midrib, and others, usually smaller, are scattered along it (some forms of *M. merrilliana*, *M. tetrasepala*). Thirdly, the inflorescence is on the stem below the lamina (*M. pendula* and *M. elongata*). Finally, the flowers are borne singly, or 2–3 on a very short common stalk, in a continuous zone up one side of the stem and/or along the midrib (*M. singularis*).

Table 4.7: Type and measurement of inflorescence

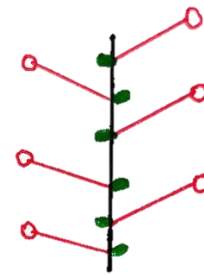
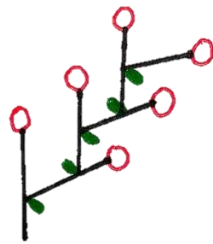
Taxa	Type of inflorescence	Length of inflorescence (cm)	Flowering type	Length of flowering axis (cm)
<i>M. glandulosa</i>	Simple helicoid cyme	11.0 – 34.3	Two paired	5.4 – 17.2
<i>M. glauca</i> var. <i>beccarii</i>	Simple helicoid cyme	5.0 – 25.1	Multiple	2.0 – 5.0
<i>M. glauca</i> var. <i>boraginea</i>	Simple helicoid cyme	13.1 – 25.2	Multiple	3.1 – 6.5
<i>M. glauca</i> var. <i>glauca</i>	Simple helicoid cyme	10.0 – 16.0	Multiple	2.0 – 5.0
<i>M. glauca</i> var. <i>hirta</i>	Simple helicoid cyme	12.5 – 18.0	Multiple	2.0 – 5.0
<i>M. glauca</i> var. <i>versipes</i>	Simple helicoid cyme	9.0 – 15.4	Multiple	1.4 – 3.0
<i>M. kazuea</i>	Simple cyme	8.0 – 20.0	Multiple	2.5 – 3.0
<i>M. merrilliana</i>	Simple dichasium	30.0	Multiple	N/A
<i>M. selaborensis</i>	Simple scorpoid cyme	14.0 – 15.0	Two paired	3.0 – 10.0
<i>M. singularis</i> var. <i>singularis</i>	Solitary	16.0 – 27.2	Multiple lines	16.0 – 27.2
<i>M. singularis</i> var. <i>aff. singularis</i>	Solitary	8.0 – 10.0	Two lines	8.0 – 10.0
<i>M. tenuis</i>	Simple helicoid cyme	6.3 – 10.3	Two paired	3.0 – 6.0
<i>M. aff. tenuis</i>	Simple helicoid cyme	15.0 – 20.0	Two paired	1.5 – 5.0
<i>M. tetrasepala</i>	Simple dichasium	3.0 – 30.0	Multiple	N/A

*N/A- not available, the previous description was incompleted

There are three types of inflorescences in *Monophyllaea*, cyme, dichasium and solitary. Most of the inflorescence found in *Monophyllaea* have simple helicoid cymes. As shown in Figure 4.14, the helicoid cyme is a uniparous cyme in which the lateral branches grow one after the other on the same side, resembling a helix. As for *M. selaborensis*, the term "scorpoid cyme" is applied as it refers to a uniparous cyme in which the successive lateral branches grow in a zigzag pattern on opposite sides. Only *M. kazuea* shows a simple cyme inflorescence type.



(A) Helicoid cyme



(B) Scorpid cyme

Figure 4.14: Cyme inflorescence. **A.** helicoid cyme of *M. aff. tenuis*, **B.** scorpid cyme of *M. selaborensis*

Both *M. merrilliana* and *M. tetrasepala* found branching in the flowering region, which takes on different forms. The first dichotomy of the flowering zone is represented by these two species as the first two flowers standing between the branches (Burt, 1978). In

these two species, the first dichotomy persists, but seldom more than the first; next, the cymes develop unilaterally and singly. Yet, *M. merrilliana* and *M. tetrasepala* have simple dichasium inflorescence, as shown in Figure 4.15.

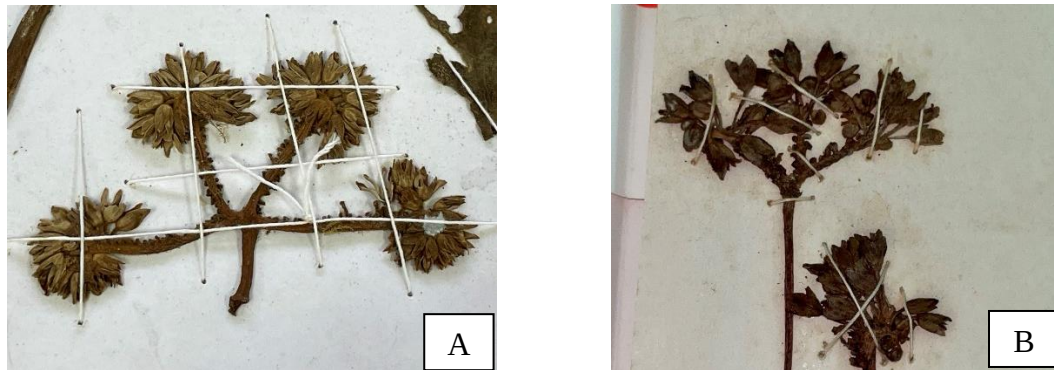


Figure 4.15: Dichasium inflorescence. **A.** *M. merrilliana*, **B.** *M. tetrasepala*

Solitary inflorescence was recorded in two *Monophyllaea* species which were *M. singularis* var. *singularis* and *M. singularis* var. *aff. singularis*. The solitary inflorescence was applied to both species as the flowers were borne singly and separately from one another even though the buds rose in groups together with the flower. *M. glandulosa* has the longest inflorescence at 34.3 cm long, while *M. tetrasepala* has the shortest inflorescence at 3 cm long.

The types of flowering axis are also different between the species. All varieties of *M. glauca*, and, *M. kazuea*, *M. merrilliana* and *M. tetrasepala* produce multiple flower buds at the flowering axis. Meanwhile, *M. glandulosa*, *M. selaborensis*, *M. tenuis* and *M. aff. tenuis*, they have produced two-paired flower buds, each along the flowering axis. *Monophyllaea singularis* var. *singularis* produced 2 –3 lines of inflorescence compared to *M. singularis* var. *aff. singularis*, which produced a double line of inflorescence along the flowering axis.

Based on the observations, the longest flowering axis was found in *M. singularis* var. *singularis* at 27.2 cm long, and the shortest flowering axis was found in *M. glauca* var. *versipes* at 1.4 cm long. The types of inflorescences of *Monophyllaea* species in western Sarawak are shown in Figure 4.16.

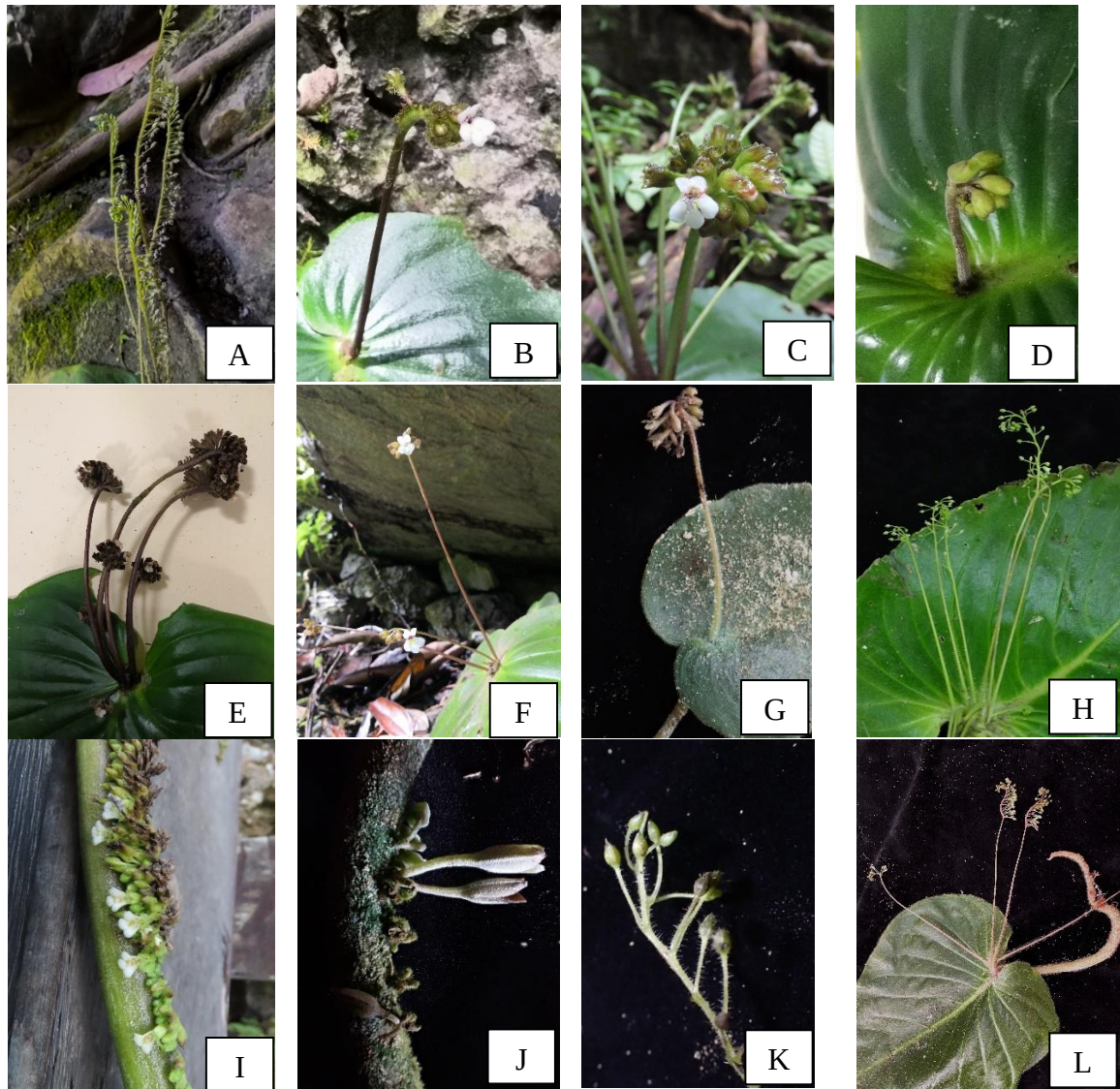


Figure 4.16: The inflorescence of *Monophyllaea* species. **A.** *M. glandulosa*, **B.** *M. glauca* var. *beccarii*, **C.** *M. glauca* var. *boraginea*, **D.** *M. glauca* var. *glauca*, **E.** *M. glauca* var. *hirta*, **F.** *M. glauca* var. *versipes*, **G.** *M. kazuea*, **H.** *M. selaborensis*, **I.** *M. singularis* var. *singularis*, **J.** *M. singularis* var. *aff. singularis*, **K.** *M. tenuis*, **L.** *M. aff. tenuis*

4.3.5.2 Peduncle

The peduncle in *Monophyllaea* is succulent and cylindrical. The peduncle usually arises from the base of the lamina or just below the base of the leaf or scattered along the midrib, with sometimes 3 – 4 with a short common peduncle. The peduncles are usually simple or branched. The peduncle is bearing the pedicels and flowers.

All *Monophyllaea* species were collected pedunculate except for two species which are *M. singularis* var. *singularis* and *M. singularis* var. *aff. singularis*. The most numerous peduncles arise from the base of the lamina in *M. glauca*, as it can bear up to 20 peduncles on one plant. *M. selaborensis*, *M. tenuis* and *M. aff. tenuis* are not contemporaneous as they had several dead and dry inflorescence stalks. Based on the observation and samples collected during the field, the varieties of *M. glauca* comprise 1–16 peduncles, and *M. selaborensis* consists of eight flowering peduncles and seven dead peduncles.

Table 4.8: The characteristics and measurement of peduncle

Taxa	Length (cm)	Diameter (cm)	Colour	Encrusted surface	Indumentum
<i>M. glandulosa</i>	11.0– 34.3	1.3 – 2.9	Pale green	Slightly encrusted	Densely white glandular hairs
<i>M. glauca</i> var. <i>beccarii</i>	5.0– 25.1	2.0 – 3.0	Pale green or greenish brown or reddish brown	Glabrous	Glabrous
<i>M. glauca</i> var. <i>boraginea</i>	13.1 – 25.2	2.4 – 3.7	Reddish brown or greenish brown	Slightly encrusted	Glabrous
<i>M. glauca</i> var. <i>glauca</i>	10.0 – 16.0	2.7– 3.0	Pale green or greenish brown	Glabrous	Glabrous
<i>M. glauca</i> var. <i>hirta</i>	12.5 – 1.8	2.5 – 4.1	Pale green	Glabrous	Glabrous
<i>M. glauca</i> var. <i>versipes</i>	9.0 – 15.4	1.5 – 2.0	Reddish brown to pale green	Slightly encrusted	Glabrous
<i>M. kazuea</i>	8.0 – 20.0	1.9 – 2.4	Reddish brown	Slightly encrusted	Densely white uniseriate tapering hairs
<i>M. merrilliana</i>	30.0	N/A	Dark purple or greenish purple	N/A	Glabrous or brown thinly pilose hairs
<i>M. selaborensis</i>	14.0 – 15.0	1.2 – 1.4	Pale green	Slightly encrusted	Densely white, thinly pilose hairs
<i>M. tenuis</i>	6.3 – 10.3	1.6	Pale green	Slightly encrusted	Densely white, thinly pilose hairs
<i>M. aff. tenuis</i>	6.5 – 7.8	1.7 – 2.0	Reddish brown to greenish-red	Glabrous	Sparsely white, thinly pilose hairs and glabrous reach the upper part
<i>M. tetrasepala</i>	3.0 – 30.0	N/A	Dark red or red	N/A	Glabrous

*N/A- not available, the previous description was incompleted

The length of the peduncle was measured in Table 4.8, and it found that the shortest peduncle found was *M. glauca* var. *beccarii*, 5.0 cm long, and *M. glandulosa* had the longest peduncle, up to 34.3 cm. *M. selaborensis* had the smallest width of the peduncle, with a 1.2 cm diameter, while *M. glauca* var. *boraginea* had the widest width of the peduncle, with a 3.7 cm diameter.

The colour of the peduncle varies among the *Monophyllaea* species, which include pale green to reddish brown to dark purple to greenish-red to dark red. Based on the observations, some of the *Monophyllaea* species were slightly encrusted with chalky and white residues.

All varieties of *M. glauca* showed glabrous and no indumentum. *M. glandulosa* had densely glandular hairs on the surface of the peduncle. Only *M. kazuea* had uniseriate tapering hairs on the peduncle. *M. merrilliana*, *M. selaborensis*, *M. tenuis* and *M. aff. tenuis* had thinly white pilose hairs on the peduncle surface. However, for *M. aff. tenuis*, the thinly pilose hairs are only present at the lower part of the peduncle and no indumentum on the upper part of the peduncle. Figure 4.17 shows the peduncle surfaces of *Monophyllaea*.

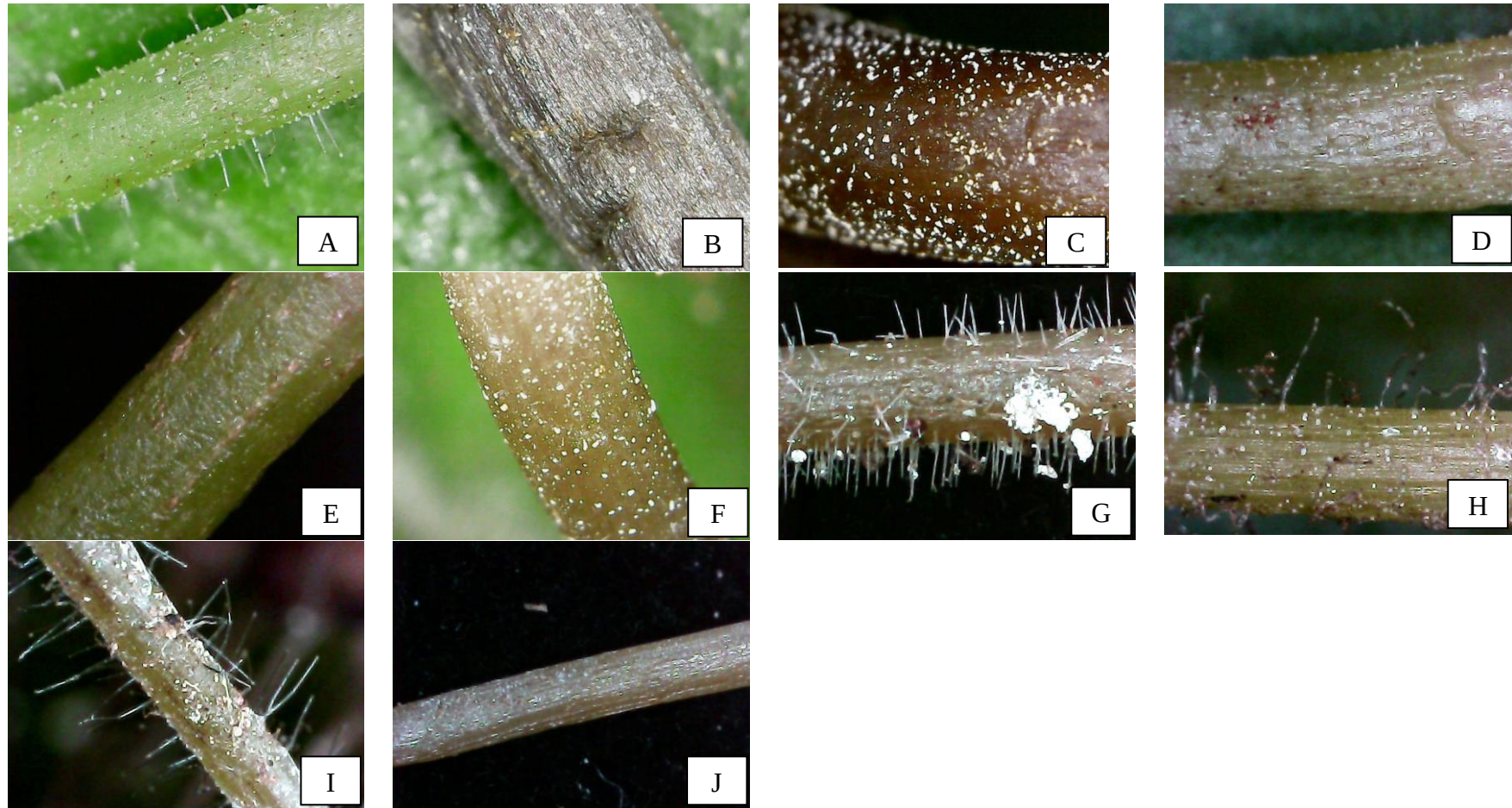


Figure 4.17: Surface of peduncle. **A.** *M. glandulosa*, **B.** *M. glauca* var. *beccarii*, **C.** *M. glauca* var. *boraginea*, **D.** *M. glauca* var. *glauca*, **E.** *M. glauca* var. *hirta*, **F.** *M. glauca* var. *versipes*, **G.** *M. kazuea*, **H.** *M. selaborensis*, **I.** *M. tenuis*, **J.** *M. aff. tenuis*

4.3.5.3 Pedicels

A pedicel is a small stalk which holds a single flower in an inflorescence. The pedicel usually grows on the peduncle except for *M. singularis* var. *singularis* and *M. singularis* var. *aff. singularis* where the pedicels directly grow on the adaxial of the stem.

The pedicel is one of the characteristics to determine the subgenus of a species in *Monophyllaea*. In the subgenus *Monophyllaea*, the pedicel is much longer than the calyx (Burt, 1978). In subgenus *Moultonia*, the pedicel is equal to or shorter than the calyx. However, the other characteristics, such as placental and fruit characters, need to be considered in classifying the subgenus.

Table 4.9: The characteristics and measurements of pedicel

Taxa	Length of pedicels (mm)	Colour	Surface encrustation	Indumentum
<i>M. glandulosa</i>	7.0 – 9.0	Pale green	Slightly encrusted	Densely white glandular hairs
<i>M. glauca</i> var. <i>beccarii</i>	2.8 – 5.0	Pale green	Glabrous	Densely white or brown thinly pilose hairs
<i>M. glauca</i> var. <i>boraginea</i>	3.0 – 4.7	Pale green	Glabrous	Densely or a few short white stiff hairs
<i>M. glauca</i> var. <i>glauca</i>	2.7 – 4.4	Reddish brown or pale green	Glabrous	Glabrous
<i>M. glauca</i> var. <i>hirta</i>	3.2 – 5.0	Reddish brown or pale green	Glabrous	Densely brown or white stiff hairs or short dendroid branching
<i>M. glauca</i> var. <i>versipes</i>	3.0 – 5.0	Reddish brown or pale green	Glabrous	Scattered short white stiff hairs
<i>M. kazuea</i>	4.0 – 6.0	Greenish brown or reddish brown	Slightly encrusted	Densely white uniseriate tapering hairs
<i>M. merrilliana</i>	4.0	Pale green	N/A	Densely brown branched hairs
<i>M. selaborensis</i>	5.5 – 6.2	Pale green	Slightly encrusted	Glabrous
<i>M. singularis</i> var. <i>singularis</i>	4.0 – 7.0	Pale green	Heavily encrusted	Glabrous or densely white thinly tomentose hairs
<i>M. singularis</i> var. <i>aff. singularis</i>	6.6 – 8.6	Pale green	Heavily encrusted	Glabrous
<i>M. tenuis</i>	6.6 – 9.5	Pale green	Slightly encrusted	Densely white thinly pilose glandular hairs
<i>M. aff. tenuis</i>	6.5 – 9.8	Pale green	Slightly encrusted	Glabrous
<i>M. tetrasepala</i>	5.0 – 6.0	Red	N/A	Short, somewhat crisped hairs

*N/A- not available, the previous description was incompleated

The pedicel was measured as tabulated in Table 4.9. The longest length of pedicels found in *M. aff. tenuis* with 9.8 mm long, while the shortest pedicels are found in *M. glauca* var. *glauca* with 2.7 mm long. The colours varied from pale green to greenish brown to reddish brown to red.

All varieties of *M. glauca* have no encrustation on the surface of the pedicel. *M. glandulosa*, *M. kazuea*, *M. selaborensis*, *M. tenuis* and *M. aff. tenuis* were found to have slight encrustation with white residues on the pedicel surface. Meanwhile, both *M. singularis* var. *singularis* and *M. singularis* var. *aff. singularis* were heavily encrusted with chalky and white residues that appeared on the pedicel surface.

Based on the observation, most of *Monophyllaea* species collected have indumentum on the pedicel surface except for four species which are *M. glauca* var. *glauca*, *M. selaborensis*, *M. singularis* var. *aff. singularis* and *M. aff. tenuis*. The pedicel in *M. glandulosa* was densely covered with glandular hairs. *M. glauca* var. *beccarii* consist of densely white or brown thinly pilose glandular hairs. As for *M. glauca* var. *boraginea*, it was either covered with a few short, stiff hairs or densely hairy. It was often for *M. glauca* var. *hirta* was covered with densely brown stiff hairs or short dendroid branching. *M. singularis* var. *singularis* usually has a glabrous surface of the pedicel. However, the species collected during the field showed that the pedicel is densely covered with white tomentose hairs. Based on the previous collection, *M. tetrasepala* had short, somewhat crisped hairs. Figure 4.18 shows the surface of pedicels of 12 *Monophyllaea* taxa.

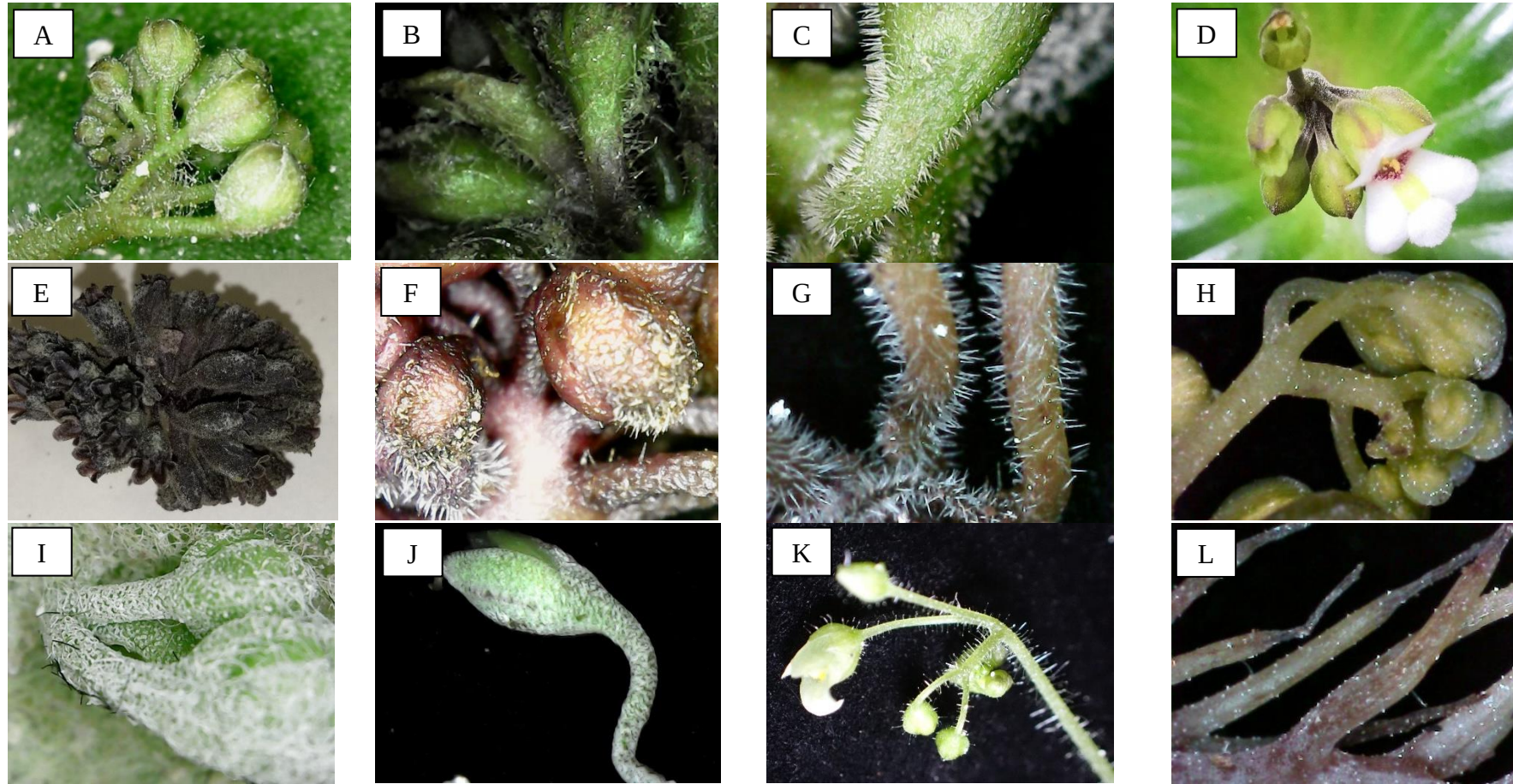


Figure 4.18: Pedicels of *Monophyllaea*. **A.** *M. glandulosa*, **B.** *M. glauca* var. *beccarii*, **C.** *M. glauca* var. *boraginea*, **D.** *M. glauca* var. *glauca*, **E.** *M. glauca* var. *hirta*, **F.** *M. glauca* var. *versipes*, **G.** *M. kazuea*, **H.** *M. selaborensis*, **I.** *M. singularis* var. *singularis*, **J.** *M. singularis* var. *aff. singularis*, **K.** *M. tenuis*, **L.** *M. aff. tenuis*

4.3.5.4 Flower Morphology

Monophyllaea is a complete flower and has the perigynous type of flower. *Monophyllaea* consists of small flowers, usually borne individually or by two to three flowers and are produced on a short peduncle that is crowded zone side of a stem and/or along the midrib of a leaf. Based on the observations on *Monophyllaea* species collection in western Sarawak, these species produced one to three flowers at one time.

As illustrated in Figure 4.19 and Figure 4.20, the *Monophyllaea* flower consists of a calyx, corolla, androecium, gynoecium and capsule.

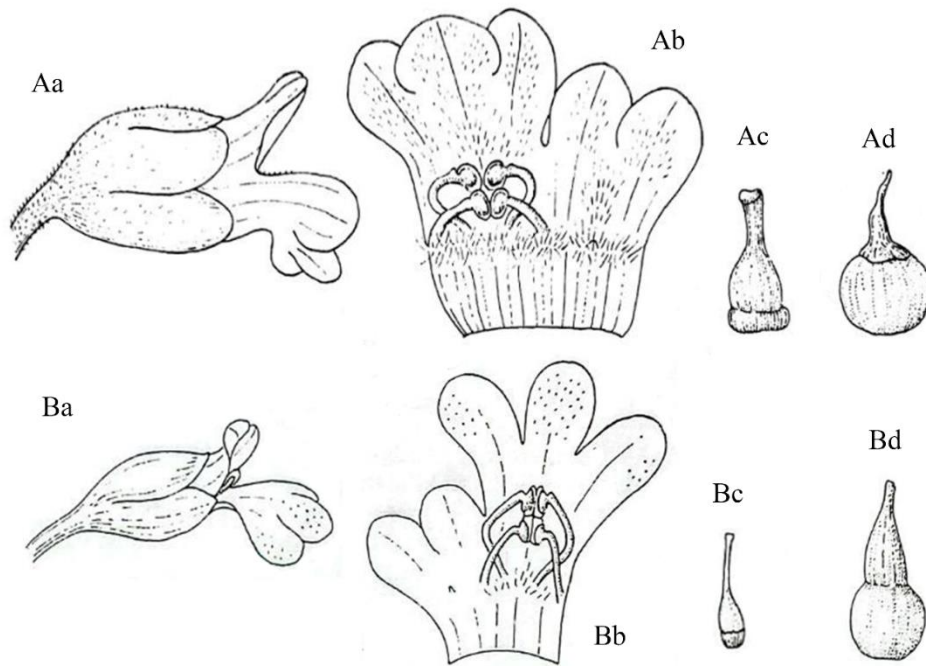


Figure 4.19: The flower structure of *Monophyllaea*. **A.** *M. glauca* var. *hirta*; **B.** *M. singularis* var. *singularis*; a. side view of calyx and flower; b. corolla, dissected; c. gynoecium; d. capsule. All x4 [Illustration adopted from Smith]

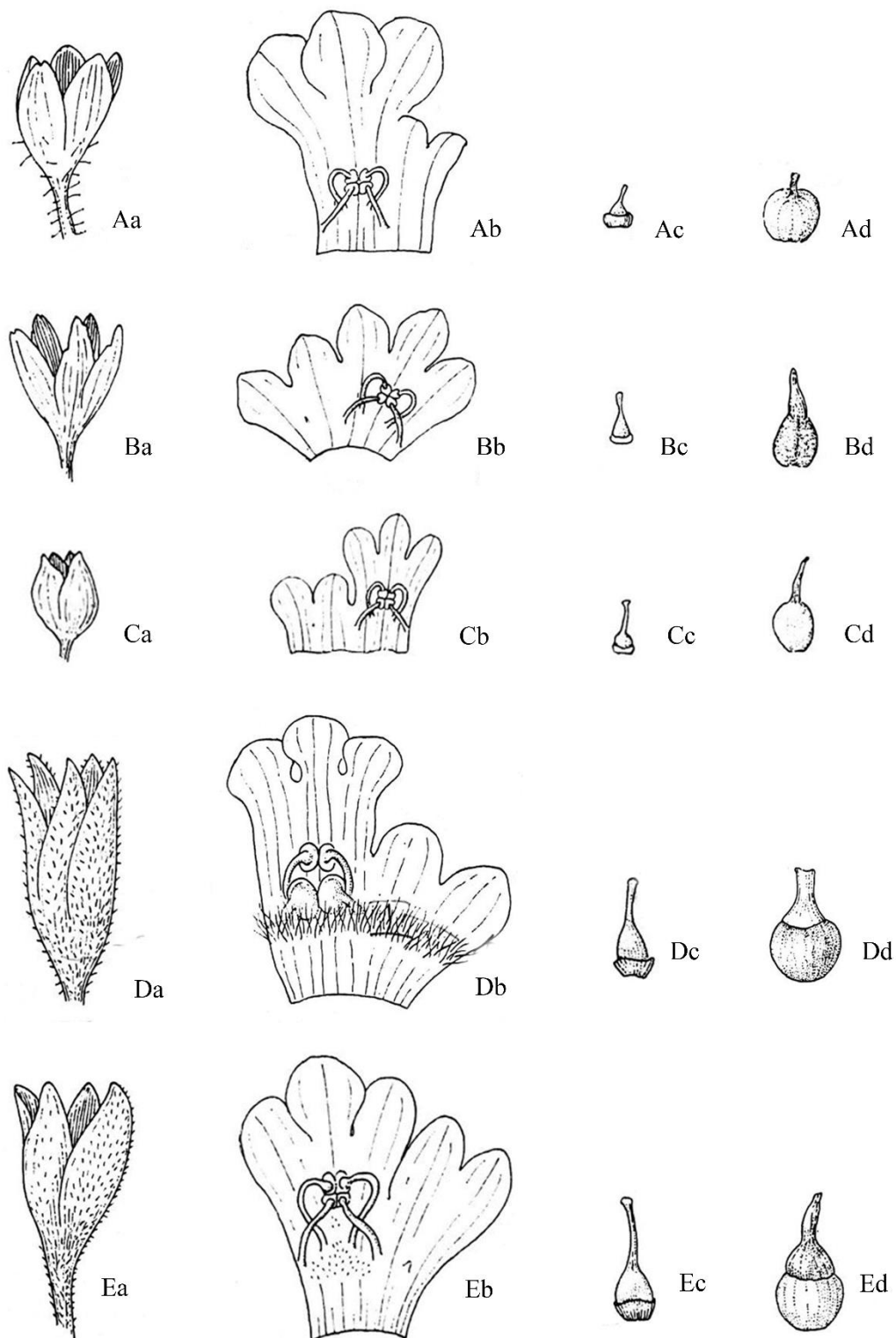


Figure 4.20: The flower structure of *Monophyllaea*. **A.** *M. glandulosa* (Burt 8113); **B.** *M. selaborensis* (Burt 8206); **C.** *M. tenuis* (Burt 8145); **D.** *M. merrilliana* (Burt 8244); **E.** *M. tetrasepala* (Burt 8119); a. calyx; b. corolla, dissected; c. gynoecium; d. capsule. All x4 [Illustration adopted from Smith]

4.3.5.5 Calyx/sepal

The calyx in *Monophyllaea* were 4 – 5 partite. The segments were imbricated in descending order, with an uppermost calyx outside. The uppermost calyx was broader than the rest of the calyx and usually slightly carinate. One of the anterior laterals is completely inside and is narrower than the others. Inside calyxes were all concave, streaked with longitudinal secretory canals and had an inside chalk gland patch in the centre (Burt, 1978).

There are two types of sepals in *Monophyllaea* species which are dorsal (posterior) and ventral (anterior) calyx. Each species has only one dorsal calyx and three or four ventral calyxes. The dorsal calyx always overlaps the other ventral calyx and is usually the largest calyx among all, as illustrated in Figure 4.21.

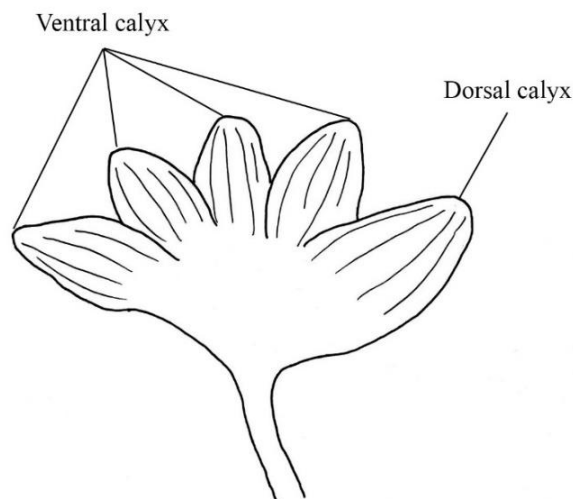


Figure 4.21: The difference between dorsal and ventral calyx

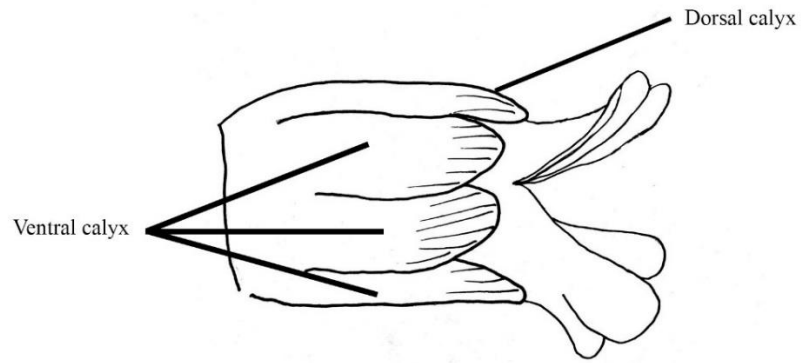


Figure 4.22: The side view of calyxes and corolla

As shown in Figure 4.22, the dorsal calyx is placed between the upper lobes of the corolla, while the other ventral calyxes are located on the lower lobes of the corolla.

Table 4.10: The characteristics of the calyx

Taxa	Total calyx	Colour	Encrustation	Indumentum
<i>M. glandulosa</i>	4 – 5	Pale green	Slightly encrusted	Densely white glandular hairs
<i>M. glauca</i> var. <i>beccarii</i>	5	Pale green	Glabrous	Densely brown, thinly pilose hairs
<i>M. glauca</i> var. <i>boraginea</i>	5	Greenish purple	Glabrous	Densely or a few short white stiff hairs
<i>M. glauca</i> var. <i>glauca</i>	5	Pale green	Glabrous	Glabrous
<i>M. glauca</i> var. <i>hirta</i>	5	Pale green or brown	Glabrous	Densely white or brown stiff hairs or short dendroid branching hairs
<i>M. glauca</i> var. <i>versipes</i>	5	Pale green or greenish purple	Glabrous	Scattered white erect hairs
<i>M. kazuea</i>	5	Greenish brown	Slightly encrusted	Densely white uniseriate tapering hairs
<i>M. merrilliana</i>	5	Pale green	N/A	Brown branched hairs
<i>M. selaborensis</i>	5	Pale green	Glabrous	Glabrous
<i>M. singularis</i> var. <i>singularis</i>	4 – 5	Pale green	Heavily encrusted	Glabrous or densely white thinly tomentose hairs
<i>M. singularis</i> var. <i>aff. singularis</i>	4	Pale green	Heavily encrusted	Glabrous
<i>M. tenuis</i>	4	Pale green	Slightly encrusted	Sparsely white, thinly pilose glandular hairs
<i>M. aff. tenuis</i>	4 – 5	Pale green	Glabrous	Glabrous
<i>M. tetrasepala</i>	4 – 5	Red	N/A	Short hairy

*N/A- not available, the previous description was incomplected

The characteristics of the calyx of *Monophyllaea* were tabulated in Table 4.10. The total calyx in *Monophyllaea* is usually 4–5. There were two species found to have four calyxes which are *M. singularis* var. *aff. singularis* and *M. tenuis*. The colours of the calyx in *Monophyllaea* were pale green, greenish purple, brown, greenish-brown or red.

All varieties of *M. glauca*, and, *M. selaborensis*, and *M. aff. tenuis* variants had glabrous surfaces. The calyx surface is slightly encrusted, as seen in *M. glandulosa*, *M. kazuea*, and *M. tenuis*. *M. singularis* var. *singularis* and *M. singularis* var. *aff. singularis* are the two taxa with considerable encrustation on the calyx.

M. glauca var. *glauca*, *M. selaborensis* and *M. aff. tenuis* were the species that had no indumentum and were glabrous found on the surface of the calyx. Only *M. glandulosa* consists of densely white glandular hairs. *M. glauca* var. *hirta* often has densely white or brown stiff hairs or short dendroid branching hairs on the surface of the calyx. The sample taken of *M. singularis* var. *singularis* was observed to have glabrous or sometimes densely with thinly tomentose white hairs. Based on past collections, *M. merrilliana* had brown branched hairs, and *M. tetrasepala* had a short-hairy surface of the calyx. The characteristics of each *Monophyllaea* species are provided in Figure 4.23.

Table 4.11: The measurements and apex of calyx

Taxa	Length (mm)		Width (mm)		Apex
	Dorsal	Ventral	Dorsal	Ventral	
<i>M. glandulosa</i>	2.7 – 3.6	2.4 – 3.5	1.7 – 1.8	1.5 – 1.6	Acute
<i>M. glauca</i> var. <i>beccarii</i>	5.9 – 6.1	5.3 – 5.6	2.3 – 2.6	1.6 – 1.7	Obtuse
<i>M. glauca</i> var. <i>boraginea</i>	4.9 – 6.6	4.0 – 6.5	1.9 – 2.8 –	1.7 – 1.9	Obtuse
<i>M. glauca</i> var. <i>glauca</i>	5.1	4.7 – 4.8	3.0	2.1 – 2.2	Obtuse
<i>M. glauca</i> var. <i>hirta</i>	7.1	5.7	2.7	2.1	Obtuse
<i>M. glauca</i> var. <i>versipes</i>	6.0	5.0	3.0	2.0	Obtuse
<i>M. kazuea</i>	5.6	3.1 – 4.6	2.7	1.8 – 2.9	Acute
<i>M. merrilliana</i>	4.5 – 5.0	4.5 – 5.0	3.5	1.8 – 2.5	Acute
<i>M. selaborensis</i>	3.2 – 3.5	2.4 – 2.9	1.5 – 1.7	1.3 – 1.5	Slightly erose
<i>M. singularis</i> var. <i>singularis</i>	5.9	4.3	2.7	1.6	Acute
<i>M. singularis</i> var. <i>aff. singularis</i>	5.6	3.5 – 4.5	1.3 – 3.0	2.0	Acute
<i>M. tenuis</i>	2.4	2.2	1.5	0.90	Slightly erose
<i>M. aff. tenuis</i>	3.2 – 3.3	2.5 – 3.0	1.5 – 1.6	1.4 – 1.5	Slightly erose
<i>M. tetrasepala</i>	7.0	N/A	6.0	N/A	Acute

*N/A- not available, the previous description was incompleted

The measurement of the dorsal calyx and lateral calyxes was tabulated in Table 4.11. The longest dorsal calyx was found in *M. glauca* var. *hirta* at 7.1 mm long, and the shortest dorsal calyx was found in *M. tenuis* at 2.4 mm long. *Monophyllaea tetrasepala* has the widest dorsal calyx at 6.0 mm wide, while the smallest width of dorsal calyx belongs to *M. singularis* var. *aff. singularis* at 1.3 mm wide. *Monophyllaea glauca* var. *boraginea* had the longest ventral calyx with a length of 6.5 mm, and the smallest ventral calyx was found in *M. tenuis*, 2.2 mm long. As for the width of the ventral calyx, *M. kazuea* was the widest at 2.9 mm, while *M. tenuis* was the smallest at 0.9 mm. All varieties of *M. glauca* have the obtuse and blunt apex of the calyx. *Monophyllaea glandulosa*, *M. kazuea*, *M. merrilliana*, *M. singularis* var. *singularis*, *M. singularis* var. *aff. singularis* and *M. tetrasepala* have acute apex with oblong-shaped calyx. *Monophyllaea selaborensis*, *M. tenuis* and *M. aff. tenuis* has a slightly erose and blunt apex.

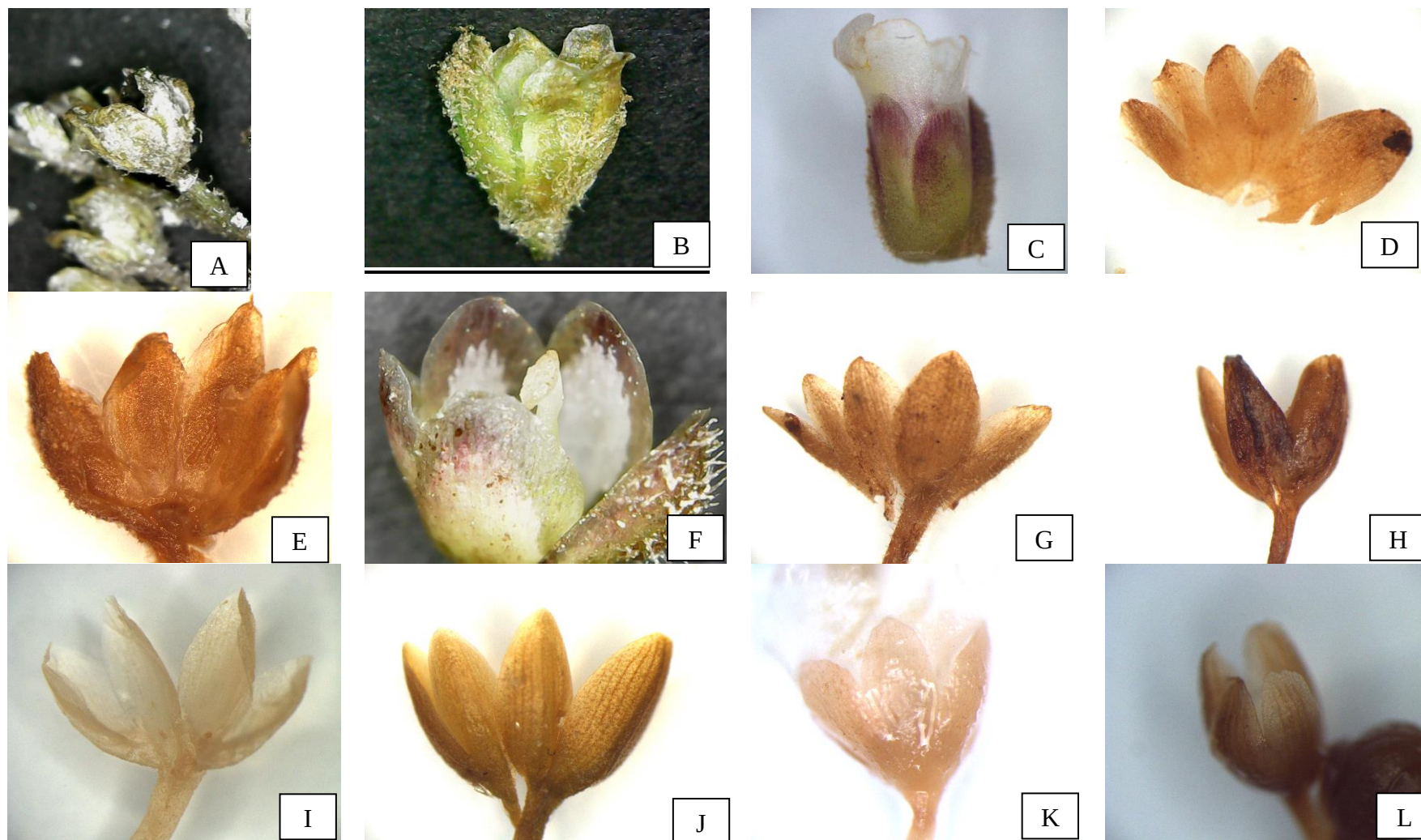


Figure 4.23: The calyces of *Monophyllaea* species. **A.** *M. glandulosa*, **B.** *M. glauca* var. *beccarii*, **C.** *M. glauca* var. *boraginea*, **D.** *M. glauca* var. *glauca*, **E.** *M. glauca* var. *hirta*, **F.** *M. glauca* var. *versipes*, **G.** *M. kazuea*, **H.** *M. selaborensis*, **I.** *M. singularis* var. *singularis*, **J.** *M. singularis* var. *aff. singularis*, **K.** *M. tenuis*, **L.** *M. aff. tenuis*

4.3.5.6 Corolla

The corolla of *Monophyllaea* was in the range of 5–15 mm long with roughly equal tubes and limbs. The tube was usually bearded inside with moniliform unicellular hairs below the filaments. The corolla has two-lobed upper lips and three lobed lower lips. The lobes were descending imbricate, often with short 2–3 celled uniseriate papillae.

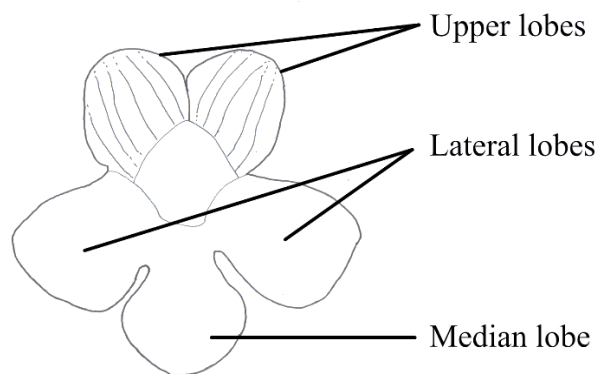


Figure 4.24: Flower parts of *Monophyllaea*

There are three parts for the flower of *Monophyllaea* species which include upper lobes, lateral lobes and median lobes (Figure 4.24). Each part of the lobes may vary in shape, which helps to determine the identification of the species.

Table 4.12: The characteristics of upper lobes

Taxa	Shape of upper lobes	Colour	Size (mm)
<i>M. glandulosa</i>	Oblique	Translucent white	1.0 x 3.0
<i>M. glauca</i> var. <i>beccarii</i>	Orbicular	Translucent white	2.5 – 3.0 x 1.9 – 2.0
<i>M. glauca</i> var. <i>boraginea</i>	Orbicular	Translucent white	1.8 – 3.2 x 1.5 – 3.1
<i>M. glauca</i> var. <i>glauca</i>	Orbicular	Translucent white	2.2 – 3.0 x 1.3 – 2.0
<i>M. glauca</i> var. <i>hirta</i>	Orbicular	Translucent white	2.7 – 3.0 x 2.2 – 3.0
<i>M. glauca</i> var. <i>versipes</i>	Orbicular	Translucent white	3.0 x 2.0
<i>M. kazuea</i>	Orbicular	White	3.2 – 3.3 x 2.4 – 2.6
<i>M. merrilliana</i>	Oblong	White	2.0 x 4.0
<i>M. selaborensis</i>	Revolute acute	Greenish white	1.6 – 2.1 x 1.6 – 2.1
<i>M. singularis</i> var. <i>singularis</i>	Orbicular	Translucent greenish white	3.0 x 2.0
<i>M. singularis</i> var. <i>aff. singularis</i>	Orbicular	Translucent greenish white	2.4 – 2.5 x 2.7
<i>M. tenuis</i>	Orbicular	Greenish white	0.5 x 1.5 – 1.8
<i>M. aff. tenuis</i>	Orbicular	Greenish white	2.1 x 2.2
<i>M. tetrasepala</i>	N/A	Pale greenish	3.0 x 3.0

*N/A- not available, the previous description was incompleted

Most of the *Monophyllaea* species consist of orbicular-shaped upper lobes of the corolla. The upper lobes of the corolla in *M. glandulosa* were oblique and reflexed. *Monophyllaea merrilliana* was recorded to have oblong-shaped upper lobes of the corolla. Only *M. selaborensis* had a revolute acute shape of upper lobes.

Monophyllaea glandulosa and all varieties of *M. glauca* consist of translucent white colour upper lobes. White colour upper lobes were found in *M. kazuea* and *M. merrilliana*. The greenish-white colour of the upper lobes was observed in *M. selaborensis*, *M. tenuis* and *M. aff. tenuis*. Two taxa, *M. singularis* var. *singularis* and *M. singularis* var. *aff. singularis* had the translucent greenish-white colour of upper lobes. *Monophyllaea tetrasepala* was recorded to have a pale greenish upper lobes colour.

The measurements and characteristics of the upper lobes were tabulated in Table 4.12. The smallest upper lobes of corolla were found in *M. tenuis* with a size of 0.5 x 1.5–1.8 mm, and the largest upper lobes were found in *M. kazuea* with a size of 3.2–3.3 x 2.4–2.6 mm.

Table 4.13: The characteristics and measurements of lateral lobes

Taxa	Shape of lateral lobes	Colour	Size (mm) Lateral
<i>M. glandulosa</i>	Orbicular-spatulate	White with a yellow patch at the centre of the palate	3.5 – 5
<i>M. glauca</i> var. <i>beccarii</i>	Orbicular	White with purple bar at centre of palate	2.7 – 3.9 x 2.5 – 2.8
<i>M. glauca</i> var. <i>boraginea</i>	Orbicular	White with a purple bar at the centre of the palate	2.8 – 3.9 x 2.1 – 3.0
<i>M. glauca</i> var. <i>glauca</i>	Orbicular	White with a purple bar at the centre of the palate	2.8 – 3 x 2
<i>M. glauca</i> var. <i>hirta</i>	Orbicular	White with a purple bar at the centre of the palate	3.1 x 2.0
<i>M. glauca</i> var. <i>versipes</i>	Orbicular	White with a purple bar at the centre of the palate	3.0 x 3.0
<i>M. kazuea</i>	Orbicular	White	4.2 – 4.3 x 3.0 – 3.4
<i>M. merrilliana</i>	Oblong	White	2.5 – 3 x 3 – 4
<i>M. selaborensis</i>	Revolute acute	Greenish white	1.5 – 1.9 x 0.9 – 1.5
<i>M. singularis</i> var. <i>singularis</i>	Oblong-obovate	White	3.0 x 2.5
<i>M. singularis</i> var. <i>aff. singularis</i>	Oblong-obovate	White	2.7 x 2.8
<i>M. tenuis</i>	Orbicular	Greenish white	1.5 x 1.5
<i>M. aff. tenuis</i>	Orbicular	Greenish white	1.9 x 1.8
<i>M. tetrasepala</i>	Oblong	Pink with an overlapping yellow patch at base	4.0 x 2.5

The characteristics and measurements are given in Table 4.13. The majority of the lateral lobes in *Monophyllaea* species were orbicular in form. Only *M. glandulosa* has lateral lobes that are orbicular-spatulate. *Monophyllaea merrilliana* and *M. tetrasepala* were found to have oblong lateral lobes. *Monophyllaea selaborensis* is the only species with revolute acute lateral lobes. Except for *M. tetrasepala*, which has pink lateral lobes with an overlapping yellow patch at the base, other corolla lateral lobes were white or greenish-white. *Monophyllaea glandulosa* was the only one that was white with a yellow patch in the centre of the palate. All *M. glauca* variants were white with a purple strip in the centre of the palate and occasionally overlapping yellow patches. *Monophyllaea kazuea* has the largest lateral lobes, measuring 4.2-4.3 x 3.0-3.4 mm, whereas *M. selaborensis* has the smallest, measuring 1.5-1.9 x 0.9-1.5 mm.

Table 4.14: The characteristics and measurement of median lobe

Taxa	Shape of median lobe	Colour	Size (mm) Median
<i>M. glandulosa</i>	Orbicular-spatulate	White with a yellow patch at the centre of the palate	3.0 x 4.0
<i>M. glauca</i> var. <i>beccarii</i>	Orbicular-spatulate	White with a yellow patch and overlapping purple bar at the centre of the palate	2.7 x 3.1
<i>M. glauca</i> var. <i>boraginea</i>	Orbicular-spatulate	White with a yellow patch and overlapping purple bar at the centre of the palate	3.0 – 3.3 x 2.7
<i>M. glauca</i> var. <i>glauca</i>	Orbicular-spatulate	White with a yellow patch and overlapping purple bar at the centre of the palate	2.6 x 2.2
<i>M. glauca</i> var. <i>hirta</i>	Orbicular-spatulate	White with a yellow patch and overlapping purple bar at the centre of the palate	2.8 x 2.1
<i>M. glauca</i> var. <i>versipes</i>	Orbicular-spatulate	White with a yellow patch and overlapping purple bar at the centre of the palate	3.0 x 3.0
<i>M. kazuea</i>	Orbicular	White with a yellow or green patch at the centre of the palate	4.5 x 3.0
<i>M. merrilliana</i>	Broadly spatulate	White with a yellow patch at the centre of the palate	2.5 – 3 x 3 – 4
<i>M. selaborensis</i>	Revolvate acute	Greenish white	1.5 – 1.9 x 1.2 – 1.6
<i>M. singularis</i> var. <i>singularis</i>	Orbicular-spatulate	White with a yellow patch at the centre of the palate	3.0 x 2.6
<i>M. singularis</i> var. <i>aff. singularis</i>	Orbicular-spatulate	White with a yellow patch at the centre of the palate	2.6 x 2.0
<i>M. tenuis</i>	Orbicular	Greenish white	1.5 x 1.9
<i>M. aff. tenuis</i>	Orbicular	Greenish white	1.9 – 2.1 x 1.6
<i>M. tetrasepala</i>	Spatulate	Pink with a yellow patch at base	4.0 x 3.0

Except for *M. kazuea*, *M. merrilliana*, *M. selaborensis*, *M. tenuis*, *M. aff. tenuis* and *M. tetrasepala*, the majority of *Monophyllaea* species have orbicular-spatulate median lobes. The median lobes of *M. kazuea*, *M. tenuis* and *M. aff. tenuis* have an orbicular shape, whereas *M. selaborensis* have a revolute acute shape. The median lobes of *M. merrilliana* and *M. tetrasepala* were found to be broadly spatulate and spatulate, respectively. *Monophyllaea singularis* var. *singularis* and *M. singularis* var. *aff. singularis* were both oblong-obovate in form.

The median lobes of some *Monophyllaea* species (*M. glandulosa*, *M. merrilliana*, *M. singularis* var. *singularis*, and *M. singularis* var. *aff. singularis*) were white, with a yellow patch in the centre of the palate. All *M. glauca* variants have white median lobes with a yellow patch and an overlapping purple strip in the centre of the palate. The median lobes of *M. selaborensis*, *M. tenuis* and *M. aff. tenuis* were both greenish-white median lobes. *Monophyllaea tetrasepala* was one of the species having pink middle lobes and a yellow patch at the base. According to the measurements in Table 4.14, *M. kazuea* has the biggest median lobe size of 4.5 x 3.0 mm, and *M. selaborensis* has the smallest median lobe size of 1.5-1.9 x 1.2-1.6 mm. Figure 4.25 shows the corolla of 12 *Monophyllaea* taxa.

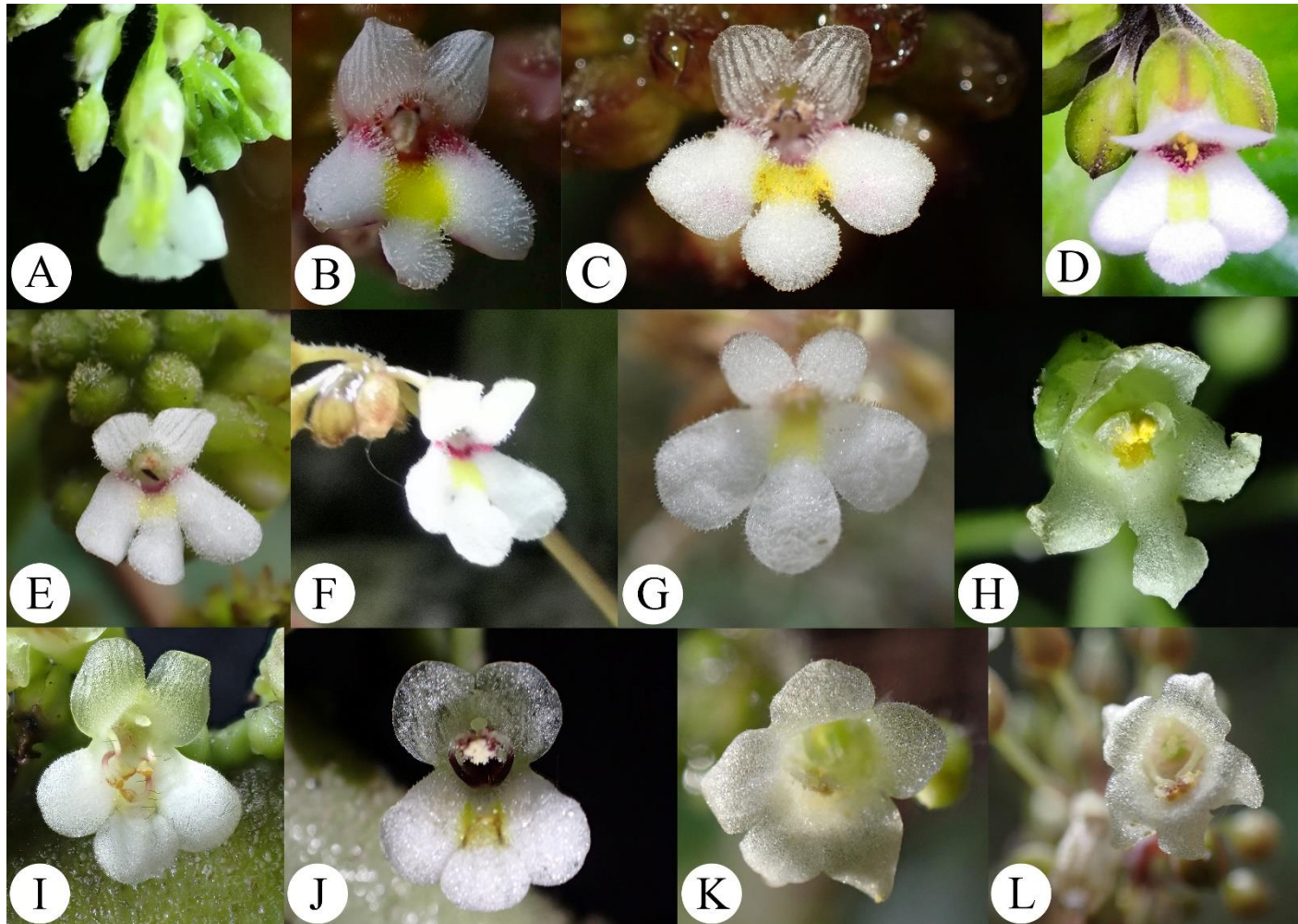


Figure 4.25: Corolla of 12 taxa of *Monophyllaea*. **A.** *M. glandulosa*, **B.** *M. glauca* var. *beccarii*, **C.** *M. glauca* var. *boraginea*, **D.** *M. glauca* var. *glauca*, **E.** *M. glauca* var. *hirta*, **F.** *M. glauca* var. *versipes*, **G.** *M. kazuea*, **H.** *M. selaborensis*, **I.** *M. singularis* var. *singularis*, **J.** *M. singularis* var. *aff. singularis*, **K.** *M. tenuis*, **L.** *M. aff. tenuis*

4.3.5.7 Stamen

The filament and anthers are found in the stamen. *Monophyllaea* has four fertile stamens and either present or absent small linear posterior staminodes. The filaments develop at the centre of the tube. As indicated in Figure 4.24, there are two pairs of filaments: posterior pairs and anterior pairs. Typically, the posterior pair is shorter and lower than the anterior pair. The anthers are pushed into contact by the highly arcuate or even curved anterior pairs, which typically have tiny teeth at the apex.

The anthers will eventually join two diverging thecae. The anthers are rarely didynamous or entirely free, instead cohering by their edges to create a downward-facing plate (Burt, 1978). Table 4.15 lists the filament properties as well as the anther measurements.

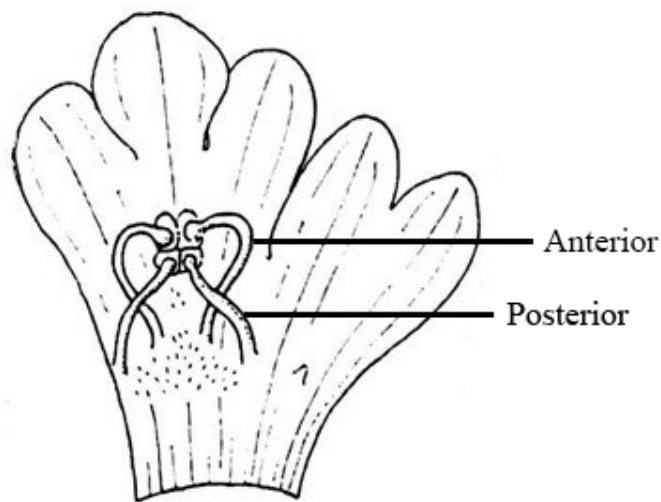


Figure 4.26: The anterior and posterior part of the filament

Table 4.15: The characteristics of filament and measurement of anther

Taxa	Filament	Anther diameter (mm)
<i>M. glandulosa</i>	Glabrous	1.00
<i>M. glauca</i> var. <i>beccarii</i>	Hairy	0.75
<i>M. glauca</i> var. <i>boraginea</i>	Hairy	0.75
<i>M. glauca</i> var. <i>glauca</i>	Hairy	0.75
<i>M. glauca</i> var. <i>hirta</i>	Hairy	0.75
<i>M. glauca</i> var. <i>versipes</i>	Hairy	0.75
<i>M. kazuea</i>	Glabrous	0.50
<i>M. merrilliana</i>	Hairy	0.75 – 1.25
<i>M. selaborensis</i>	Slightly hairy	0.75
<i>M. singularis</i> var. <i>singularis</i>	Hairy sometimes glabrous	0.50
<i>M. singularis</i> var. <i>aff. singularis</i>	Hairy	0.50 – 0.60
<i>M. tenuis</i>	Glabrous	0.75
<i>M. aff. tenuis</i>	Glabrous	0.70 – 0.73
<i>M. tetrasepala</i>	Glandular	1.25

Many *Monophyllaea* have hairy filaments, including *M. glauca* var. *beccarii*, *M. glauca* var. *boraginea*, *M. glauca* var. *glauca*, *M. glauca* var. *versipes*, *M. merrilliana*, and *M. singularis* var. *aff. singularis*. The filaments of *M. singularis* var. *singularis* had been studied; the filaments were hairy at times but glabrous at others. Three taxa have glabrous filaments: *M. glandulosa*, *M. tenuis*, and *M. aff. tenuis*, whereas, *M. selaborensis* filaments were slightly hairy. *Monophyllaea tetrasepala* is the only species known to contain glandular filaments. The smallest diameter of the anther was 0.50 mm which include three species (*M. kazuea*, *M. singularis* var. *singularis* and *M. singularis* var. *aff. singularis*). The largest diameter of anther was found in *M. merrilliana* and *M. tetrasepala* with 1.25 mm. The stamen of *Monophyllaea* taxa can be seen in Figure 4.27.

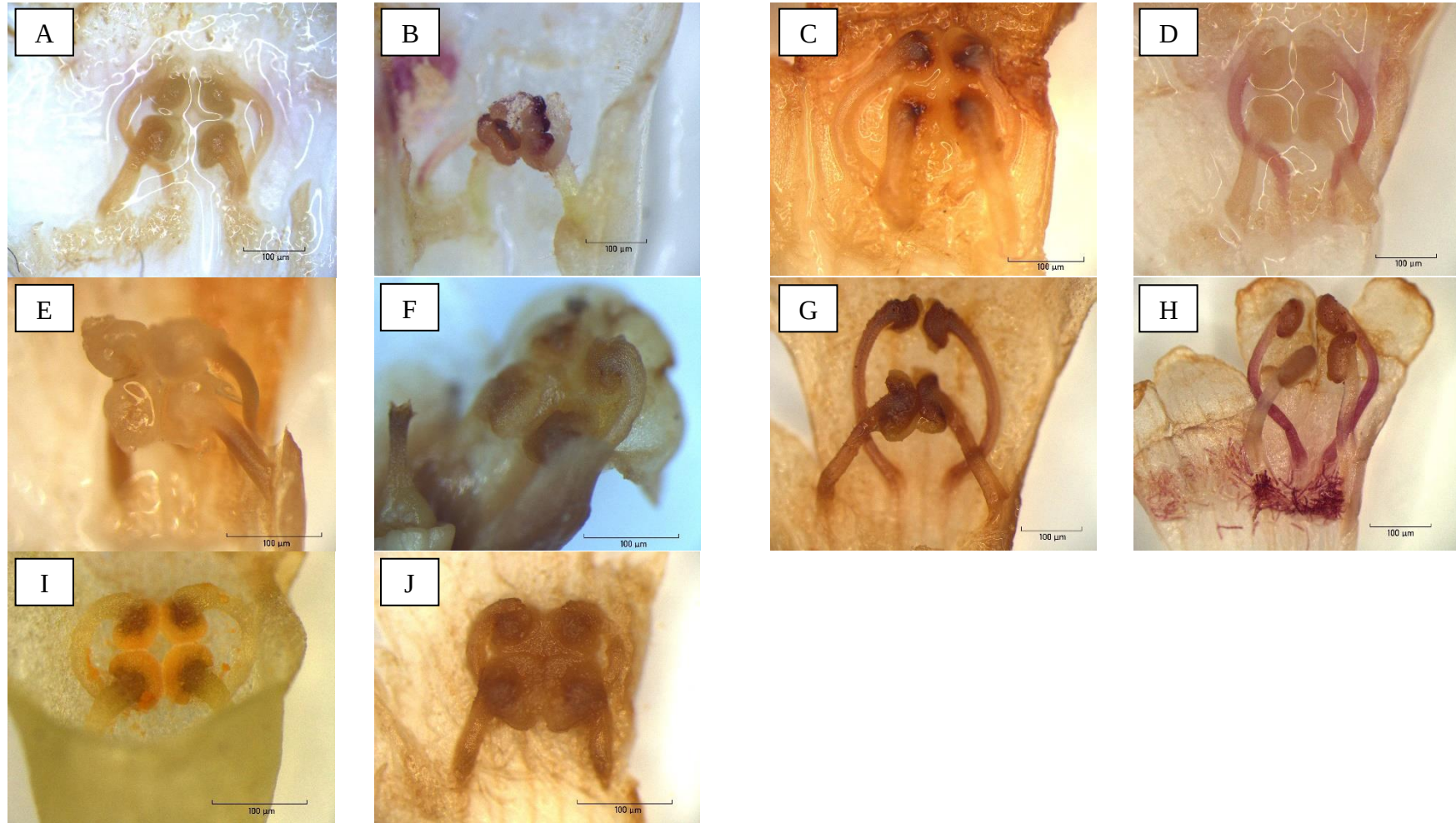


Figure 4.27: Stamen of *Monophyllaea* taxa. **A.** *M. glauca* var. *beccarii* (x32), **B.** *M. glauca* var. *boraginea* (x32), **C.** *M. glauca* var. *glauca* (x40), **D.** *M. glauca* var. *hirta* (x32), **E.** *M. kazuea* (x50), **F.** *M. selaborensis* (x50), **G.** *M. singularis* var. *singularis* (x32), **H.** *M. singularis* var. *aff. singularis* (x32), **I.** *M. tenuis*, **J.** *M. aff. tenuis* (x50) [x32 to x50 magnification]

4.3.5.8 Stigma and Style

The stigma were mostly capitate or slightly peltate or umbilical. The style is simple and straight.

Table 4.16: The characteristics and measurement of style

Taxa	Length (mm)	Indumentum
<i>M. glandulosa</i>	1.5	Glabrous
<i>M. glauca</i> var. <i>beccarii</i>	1.0	Glabrous
<i>M. glauca</i> var. <i>boraginea</i>	1.5 – 1.6	Glabrous
<i>M. glauca</i> var. <i>glauca</i>	2.6	Glabrous
<i>M. glauca</i> var. <i>hirta</i>	2.0	Glabrous
<i>M. glauca</i> var. <i>versipes</i>	2.5	Glabrous
<i>M. kazuea</i>	1.6 – 1.9	Glabrous
<i>M. merrilliana</i>	2.0 – 3.0	Sometimes with a few glandular hairs in the upper part
<i>M. selaborensis</i>	1.0	Glabrous
<i>M. singularis</i> var. <i>singularis</i>	2.7 – 2.8	Scattered short hairs only on the upper part, sometimes glabrous
<i>M. singularis</i> var. <i>aff. singularis</i>	3.5 – 3.7	Scattered short hairs only on the upper part
<i>M. tenuis</i>	0.6	Glabrous
<i>M. aff. tenuis</i>	0.8	Glabrous
<i>M. tetrasepala</i>	3.0	Scattered short hairs on the upper half

The shortest style of the ovary can be found in *M. tenuis*, with 0.6 mm long, and the longest style belongs to *M. singularis* var. *aff. singularis*, with 3.7 mm long (Table 4.16). Most of *Monophyllaea* had a glabrous surface style. However, *M. merrilliana* had the presence of sometimes a few glandular hairs in the upper part. *M. singularis* var. *singularis* consists of scattered short hairs only on the upper part, sometimes glabrous style. Scattered

short hairs only on the upper part can be found in *M. singularis* var. *aff. singularis*. As for *M. tetrasepala*, there was the presence of scattered short hairs on the upper half of the style.

4.3.5.9 Ovary

The ovary was binocular, with many ovules on the axile placentae. The ovary bears style and stigma at the top. Ovary of *Monophyllaea* is mostly globose or ovoid-shaped. The discs in *Monophyllaea* were cupular and thick. The disc also undulates or lobulates. Gesneriad Society stated that the individual placentae form (in cross-section) are quite thin, uniformly thick along their length (lamelliform), and curved back at the distal part in the Didymocarpoid Gesneriaceae (Didymocarpoideae). Figure 4.28 shows the longitudinal section of the carpel in *M. glauca*.



Figure 4.28: Longitudinal section of carpel

Table 4.17: The characteristics and measurements of ovary and disc

Taxa	Ovary size (mm)	Shape	Disc size (mm)
<i>M. glandulosa</i>	1.0	N/A	0.5
<i>M. glauca</i> var. <i>beccarii</i>	1.3 x 0.9	Globose	0.6
<i>M. glauca</i> var. <i>boraginea</i>	1.3 x 0.9	Globose	0.6
<i>M. glauca</i> var. <i>glauca</i>	1.3 x 1.0	Globose	0.9
<i>M. glauca</i> var. <i>hirta</i>	1.5 x 1.0	Globose	0.6 x 1.2
<i>M. glauca</i> var. <i>versipes</i>	1.5 x 1.0	Globose	0.6
<i>M. kazuea</i>	1.4 – 1.5 x 0.9 – 1.0	Ovoid	0.5 – 0.7 x 0.9 – 1.1
<i>M. merrilliana</i>	1.5	N/A	0.5 – 1.0
<i>M. selaborensis</i>	0.9 x 0.7	Globose	0.5 x 0.9
<i>M. singularis</i> var. <i>singularis</i>	1.5 – 1.6 x 1.1	Globose	0.6 – 0.7 x 1.4 – 1.5
<i>M. singularis</i> var. <i>aff. singularis</i>	1.3 – 1.4 x 0.9 – 1.0	Globose	0.6 – 0.7 x 1.3 – 1.4
<i>M. tenuis</i>	0.6 x 0.7	Subglobose	0.3 x 0.9
<i>M. aff. tenuis</i>	0.5 x 0.8	Subglobose	0.4 x 0.9
<i>M. tetrasepala</i>	1.0	N/A	0.5

* N/A- not available, the previous description was incompleated

Based on the measurement in Table 4.17, it was found that *M. singularis* var. *singularis* has the largest ovary with a size of 1.6 mm. The smallest ovary can be found in *M. aff. tenuis* with a size of 0.5 mm. The average size of the ovary of all *Monophyllaea* taxa is 1.2 mm.

Mostly, *Monophyllaea* consists of a globose shape of ovary, including *M. selaborensis*, *M. singularis* var. *singularis*, *M. singularis* var. *aff. singularis* and all varieties of *M. glauca*. *Monophyllaea tenuis* and *M. aff. tenuis* consists of a subglobose ovary shape. Only *M. kazuea* was found to consist of an ovoid shape of the ovary.

Monophyllaea glauca var. *glauca* has the longest disc with 0.87 mm. *Monophyllaea tenuis* has the shortest length of a disc, with 0.28 mm long. Figure 4.29 below shows the ovary of *Monophyllaea*.



Figure 4.29: The ovary of *Monophyllaea* taxa. **A.** *M. glauca* var. *beccarii* (x50), **B.** *M. glauca* var. *boraginea* (x25), **C.** *M. glauca* var. *glauca* (x32), **D.** *M. glauca* var. *hirta* (x32), **E.** *M. glauca* var. *versipes*, **F.** *M. kazuea* (x40), **G.** *M. selaborensis* (x50), **H.** *M. singularis* var. *singularis* (x32), **I.** *M. singularis* var. *aff. singularis* (x25), **J.** *M. tenuis* (x63), **K.** *M. aff. tenuis* (x63) [x25 to x63 magnification]

4.3.6 Capsule

The capsule is a dry fruit that opens when ripe and consists of multiple carpels that split along one seam per carpel to release seeds. The fruits in *Monophyllaea* are capsular and usually thin-walled. After the fall of persistent, often swollen style, sometimes the capsule breaks up into four valves or sometimes without valves. The expanded style base covered the top of the ovary. When the capsule falls, it effectively porose.

Table 4.18: The characteristics and measurements of capsule and style

Taxa	Size (mm)	Style	Style length(mm)
<i>M. glandulosa</i>	2.0	Persistent with thickened at base	1.5
<i>M. glauca</i> var. <i>beccarii</i>	3.1 x 2.3	Strongly thickened conical	2.4
<i>M. glauca</i> var. <i>boraginea</i>	2.5 x 1.9	Strongly thickened conical	2.9
<i>M. glauca</i> var. <i>glauca</i>	2.5 x 2.1	Shallowly dome-shaped persistent base	2.5
<i>M. glauca</i> var. <i>hirta</i>	2.8 x 2.6	Strongly thickened conical	2.8
<i>M. glauca</i> var. <i>versipes</i>	3.0 x 2.3	Strongly thickened conical	2.5
<i>M. kazuea</i>	2.5 – 2.8 x 1.7 – 2.2	Persistent style with swollen base	1.6 – 1.7
<i>M. merrilliana</i>	2.0 x 2.5	Persistent conical with swollen base	N/A
<i>M. selaborensis</i>	1.4 – 2.0 x 0.9	Persistent strongly thickened	0.9 – 2.0
<i>M. singularis</i> var. <i>singularis</i>	1.6 – 2.0 x 1.4 – 1.5	Persistent conical	1.0 – 3.0
<i>M. singularis</i> var. <i>aff. singularis</i>	2.1 x 2.2	Persistent conical	2.4
<i>M. tenuis</i>	1.6 x 1.5	Conical	1.1
<i>M. aff. tenuis</i>	1.6 – 2.3 x 1.3 – 1.5	Conical	0.9 – 1.6
<i>M. tetrasepala</i>	2.0	Broad minaret	N/A

* N/A- not available, the previous description was incomplected

Based on the measurement in Table 4.18, the largest capsule can be found in *M. glauca* var. *beccarii*, with a size of 3.1 x 2.3 mm. Meanwhile, *M. selaborensis* was found to have the smallest capsule among all *Monophyllaea* species, with 1.4–2.0 x 0.9 mm.

Most *Monophyllaea* have a conical capsule style (*M. glauca* var. *beccarii*, *M. glauca* var. *boraginea*, *M. glauca* var. *versipes*, *M. merrilliana*, *M. singularis* var. *aff. singularis*, *M. tenuis* and *M. aff. tenuis*). *M. glauca* var. *glauca* has a shallowly dome-shaped persistent style base. Persistent styles with enlarged or swollen bases are found in both *M. glandulosa* and *M. kazuea*. The capsule of *M. selaborensis* has a consistently thickened style. Only *M. tetrasepala* has a broad minaret style that is based on the capsule.

Monophyllaea singularis var. *singularis* had the longest style with 3.0 mm compared to both species of *M. selaborensis* and *M. aff. tenuis*, which had the shortest style with 0.9 mm. Figure 4.30 shows the ovary of *Monophyllaea* taxa collected in Western Sarawak.

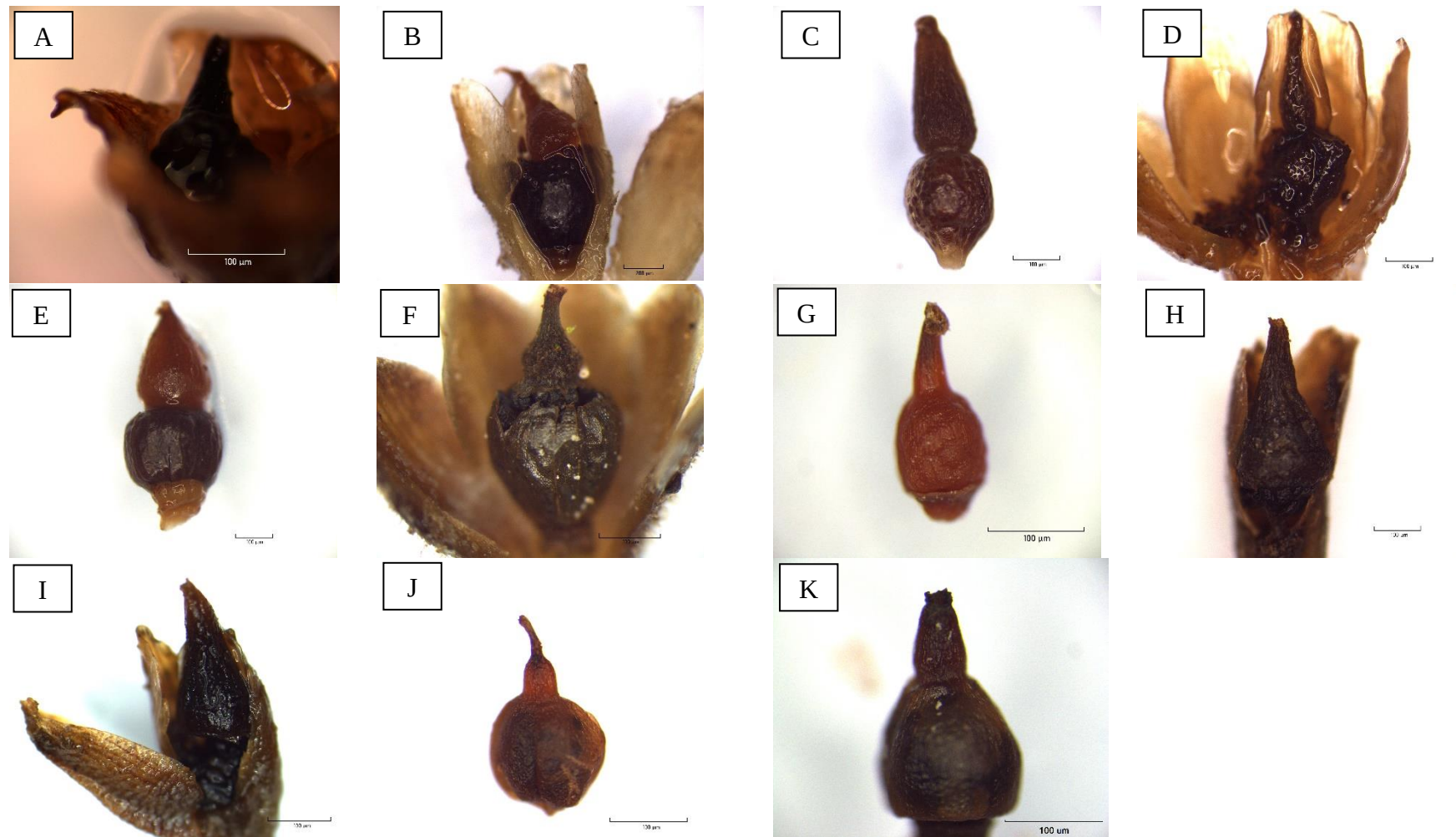


Figure 4.30: The capsule of *Monophyllaea* taxa. **A.** *M. glandulosa* (x50), **B.** *M. glauca* var. *beccarii* (x20), **C.** *M. glauca* var. *boraginea* (x25), **D.** *M. glauca* var. *glauca* (x25), **E.** *M. glauca* var. *hirta* (x20), **F.** *M. kazue* (x32), **G.** *M. selaborensis* (x50), **H.** *M. singularis* var. *singularis* (x25), **I.** *M. singularis* var. *aff. singularis* (x32), **J.** *M. tenuis* (x40), **K.** *M. aff. tenuis* (x50) [x20 to x50 magnification]

4.3.7 Seeds

This "macro-cotyledon" is one of the two original cotyledons that emerged from the seed in an enlarged form. With no shoot or root apical meristems, the embryonic structure of the seed is made up of two cotyledons and a hypocotyl. In comparison to other *Monophyllaea* species that have been studied, the endogenous root meristem forms closer to the hypocotyl end. Mostly the seeds were dark brown, sometimes light brown.

Table 4.19: The characteristics and measurements of seeds

Taxa	Length (mm)	Width (mm)	Shape	Ornamentation
<i>M. glandulosa</i>	0.228 – 0.254	0.165 – 0.183	Globose	Reticulate
<i>M. glauca</i> var. <i>beccarii</i>	0.400 – 0.435	0.194 – 0.223	Ellipsoid	Polygonal with straight or slightly curved raised ridges
<i>M. glauca</i> var. <i>boraginea</i>	0.371 – 0.454	0.153 – 0.180	Ellipsoid	Polygonal with straight or slightly curved raised ridges
<i>M. glauca</i> var. <i>glauca</i>	0.355 – 0.396	0.151 – 0.158	Ellipsoid	Polygonal with straight or slightly curved raised ridges
<i>M. glauca</i> var. <i>hirta</i>	0.377 – 0.426	0.177 – 0.196	Ellipsoid	Polygonal with straight or slightly curved raised ridges
<i>M. glauca</i> var. <i>versipes</i>	N/A	N/A	Ellipsoid	Polygonal with straight or slightly curved raised ridges
<i>M. kazuea</i>	0.320 – 0.407	0.188 – 0.208	Ellipsoid	Reticulate
<i>M. merrilliana</i>	N/A	N/A	N/A	N/A
<i>M. selaborensis</i>	0.360 – 0.393	0.250 – 0.328	Subglobose	Reticulate
<i>M. singularis</i> var. <i>singularis</i>	0.408 – 0.433	0.216 – 0.291	Subglobose	Polygonal with straight undulate raised ridges
<i>M. singularis</i> var. <i>aff. singularis</i>	0.294 – 0.326	0.196 – 0.207	Subglobose	Polygonal with straight undulate raised ridges
<i>M. tenuis</i>	0.246 – 0.284	0.166 – 0.205	Globose	Reticulate
<i>M. aff. tenuis</i>	0.285 – 0.322	0.196 – 0.221	Globose	Reticulate
<i>M. tetrasepala</i>	N/A	N/A	N/A	N/A

* N/A- not available, the previous description was incompleted

The seeds are tiny and come in a variety of forms. The characteristics and measurements of seeds were tabulated in Table 4.19. The majority of the seeds are smaller than 0.5 mm long. *M. glandulosa* has the smallest seed, measuring 0.228-0.254 mm, and *M. glauca* var. *beccarii* has the largest, measuring 0.400-0.435 mm.

All varieties of *M. glauca* and *M. kazuea* consist of ellipsoid shape seeds. The globose shape of seeds belongs to *M. glandulosa*, *M. tenuis* and *M. aff. tenuis*. While subglobose seed shapes can be found in *M. selaborensis*, *M. singularis* var. *singularis* and *M. singularis* var. *aff. singularis*

The seeds in all varieties of *M. glauca* had polygonal with straight or slightly curved raised ridges ornamentation. Reticulate seed ornamentation can be found in *M. glandulosa*, *M. kazuea*, *M. selaborensis*, *M. tenuis* and *M. aff. tenuis*. Seed ornamentation of polygonal with straight undulate raised ridges was found in *M. singularis* var. *singularis* and *M. singularis* var. *aff. singularis*. The seeds of *Monophyllaea* can be seen in Figure 4.31.

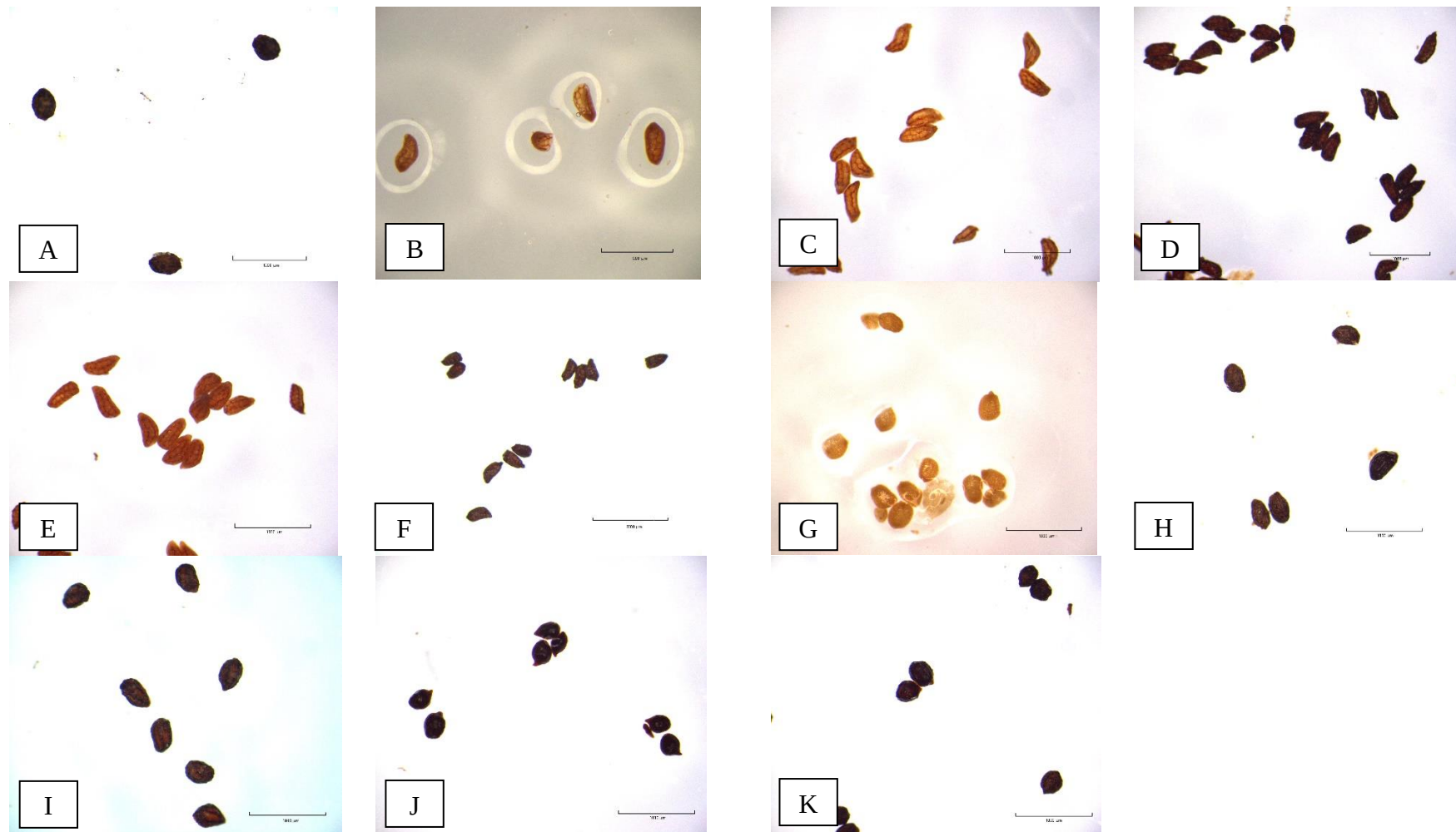


Figure 4.31: The seeds of *Monophyllaea* taxa. **A.** *M. glandulosa*, **B.** *M. glauca* var. *beccarii*, **C.** *M. glauca* var. *boraginea*, **D.** *M. glauca* var. *glauca*, **E.** *M. glauca* var. *hirta*, **F.** *M. kazuea*, **G.** *M. selaborensis*, **H.** *M. singularis* var. *singularis*, **I.** *M. singularis* var. *aff. singularis*, **J.** *M. tenuis*, **K.** *M. aff. tenuis* [All where photographed at x40 magnification]

4.3.8 General Discussion

Genus *Monophyllaea* was easily distinguished from its fertile inflorescences and determining several morphological characteristics of the genus. Some of the locality discovered consists of three different *Monophyllaea* species (*M. aff. tenuis*, *M. kazuea* and *M. glauca* var. *glauca*) growing near each other. So, the distinct characters can help in identifying the species.

The leaf in *Monophyllaea* is often found unifoliate but there are some species found having two leaves on one plant. Usually, the new leaf will emerge from the middle or lower part of the stem. As observed in *M. singularis* var. *singularis*, the roots grow out from the new leaf while still attached to the stem. From the field observation, *M. singularis* var. *singularis* and *M. singularis* var. *aff. singularis* have the longest stem as it grows on the wall of a limestone cliff and needs to bear the longest and biggest leaf. The best method to maintain the freshness of the plant is by sealing it in a ziplock bag for several days.

The trichomes present on the leaf surface are considered an important character, especially for the identification of varieties of *M. glauca*. The trichomes like glandular hairs, scabrid with bulbous-based hairs, erect and stiff hairs and thinly pilose glandular hairs are visible through the naked eye. As for capitate-glandular hairs, it is sometimes appear to be very short blunt hairs on the leaf surface and sometimes covered by many chalky residues which the trichomes are hardly to be seen. *M. glauca* var. *glauca* is often appears to have a glabrous leaf but sometimes there presence of a few scattered short sharp peripheral hairs on the leaf surface.

The inflorescence of *Monophyllaea* is divided into three main inflorescence types, cyme, dichasium and solitary. The cyme inflorescence types were divided into three which are simple, helicoid and scorpid cymes. *M. singularis* var. *singularis* and *M. singularis* var. *aff. singularis* also consists of the solitary flower together with clustered 2-3 buds scattered on the leaf midrib and adaxial of the stem. It had been recorded by Imaichi et al., 2001 that the flower and buds of *M. singularis* var. *singularis* were counted with some 365 along the 35 cm long flowering axis. The flowers also can be used as a key character for species identification as there are differences in shape, colour and markings that appear on the lobes. The gynoecium and androecium also have different morphology as shown in the anthers, stamen and ovary above. The seeds of each species have different shapes and surface ornamentation. Thus, further study needs to be done on seeds using FESEM for detailed observation.

4.4 Micromorphology Study

The observation of epidermal cells, stomata and epicuticular wax on leaf surfaces was studied in all 12 taxa of *Monophyllaea*.

4.4.1 Epidermal Cells

There are four types of epidermal cell shape observed on these 12 taxa on both adaxial surfaces and abaxial surfaces such as sinuous, straight, curved and undulated, as shown in Figure 4.32.

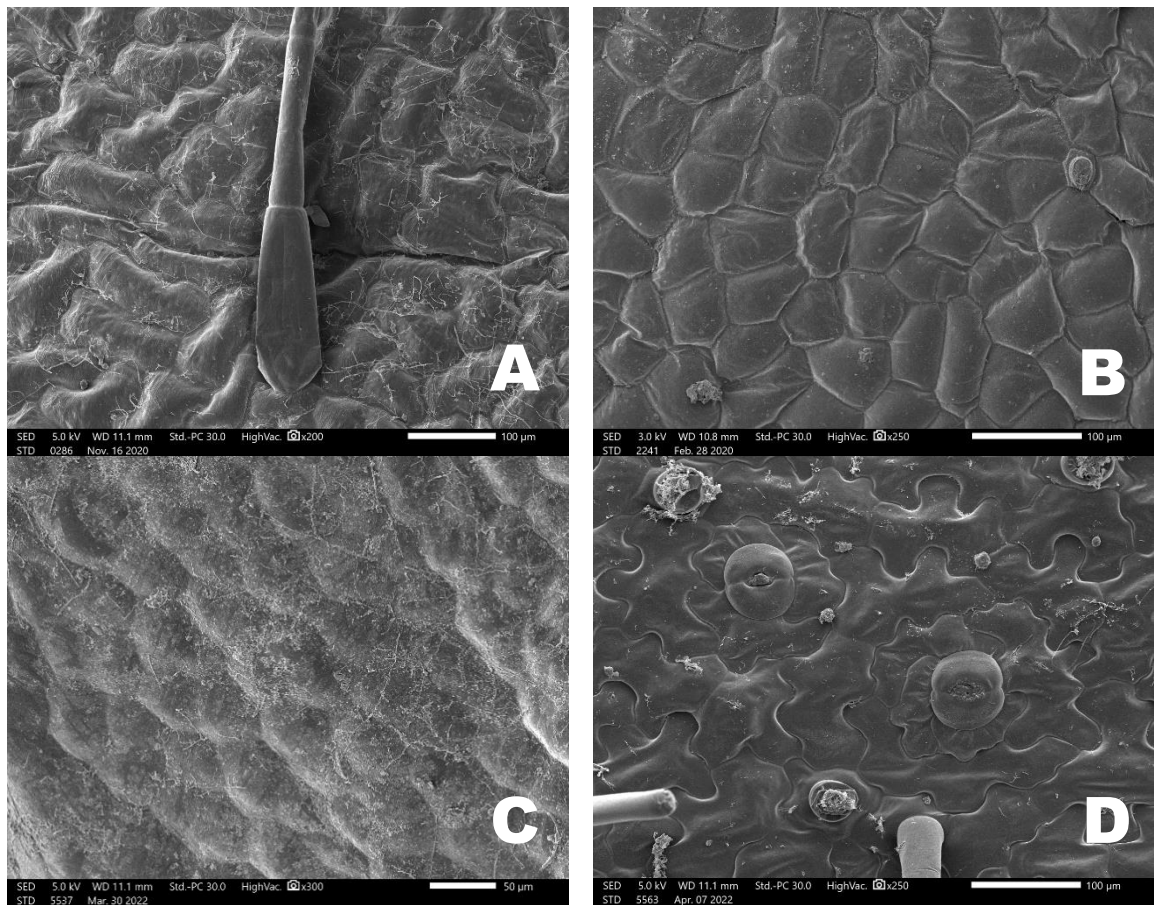


Figure 4.32: The anticlinal wall of *Monophyllaea* observed under FESEM. **A.** undulate, **B.** straight, **C.** curve, **D.** sinuous

Table 4.20: The characteristics and measurement of epidermal cells on upper and lower of leaf

Taxa		Epidermal cells		Average size (µm)
		Shape	Anticlinal wall	
<i>M. glandulosa</i>	Upper	Polygonal	Undulate	101.42 x 90.72
	Lower	Polygonal	Undulate	103.26 x 56.85
<i>M. glauca</i> var. <i>beccarii</i>	Upper	Polygonal	Straight	93.34 x 69.60
	Lower	Polygonal	Undulate	68.55 x 42.07
<i>M. glauca</i> var. <i>boraginea</i>	Upper	Polygonal	Straight	80.35 x 67.75
	Lower	Polygonal	Undulate	74.90 x 50.20
<i>M. glauca</i> var. <i>glauca</i>	Upper	Polygonal	Straight	86.96 x 65.45
	Lower	Polygonal	Undulate	95.95 x 69.13
<i>M. glauca</i> var. <i>hirta</i>	Upper	Polygonal	Straight	74.26 x 56.36
	Lower	Polygonal	Undulate	78.54 x 44.42
<i>M. glauca</i> var. <i>versipes</i>	Upper	Polygonal	Straight	72.74 x 51.83
	Lower	Polygonal	Undulate	46.66 x 27.07
<i>M. kazuea</i>	Upper	Polygonal	Straight	75.51 x 58.67
	Lower	Polygonal	Undulate	94.59 x 54.20
<i>M. selaborensis</i>	Upper	Isodiametric	Curve	107.58 x 81.10
	Lower	Isodiametric	Undulate	135.67 x 88.99
<i>M. singularis</i> var. <i>singularis</i>	Upper	Polygonal	Straight	85.56 x 58.21
	Lower	Polygonal	Straight	N/A
<i>M. singularis</i> var. <i>aff. singularis</i>	Upper	Polygonal	Straight	65.88 x 50.47
	Lower	Polygonal	Straight	69.08 x 41.36
<i>M. tenuis</i>	Upper	Random	Sinuuous	133.21 x 104.71
	Lower	Random	Sinuuous	144.22 x 114.82
<i>M. aff. tenuis</i>	Upper	Random	Sinuuous	102.14 x 86.43
	Lower	Random	Sinuuous	210.78 x 118.14

* N/A- not available, unable to observed

Table 4.20 shows the anticlinal wall and morphology of epidermal cells in all 12 *Monophyllaea* taxa collected. Epidermal cell shapes on both the upper and lower surfaces are polygonal, isodiametric, and random.

Monophyllaea tenuis had the biggest average size of epidermal cell on the adaxial surface, measuring $133.21 \times 104.71 \mu\text{m}$, and *M. singularis* var. *aff. singularis* had the smallest, measuring $65.88 \times 50.47 \mu\text{m}$.

Monophyllaea aff. tenuis had the biggest epidermal cell on the abaxial surface, with an average size of $210.78 \times 118.14 \mu\text{m}$, and *M. glauca* var. *versipes* had the smallest epidermal cell, with an average size of $46.66 \times 27.07 \mu\text{m}$. Figure 4.33 shows the adaxial surface of leaf from 12 *Monophyllaea* taxa.

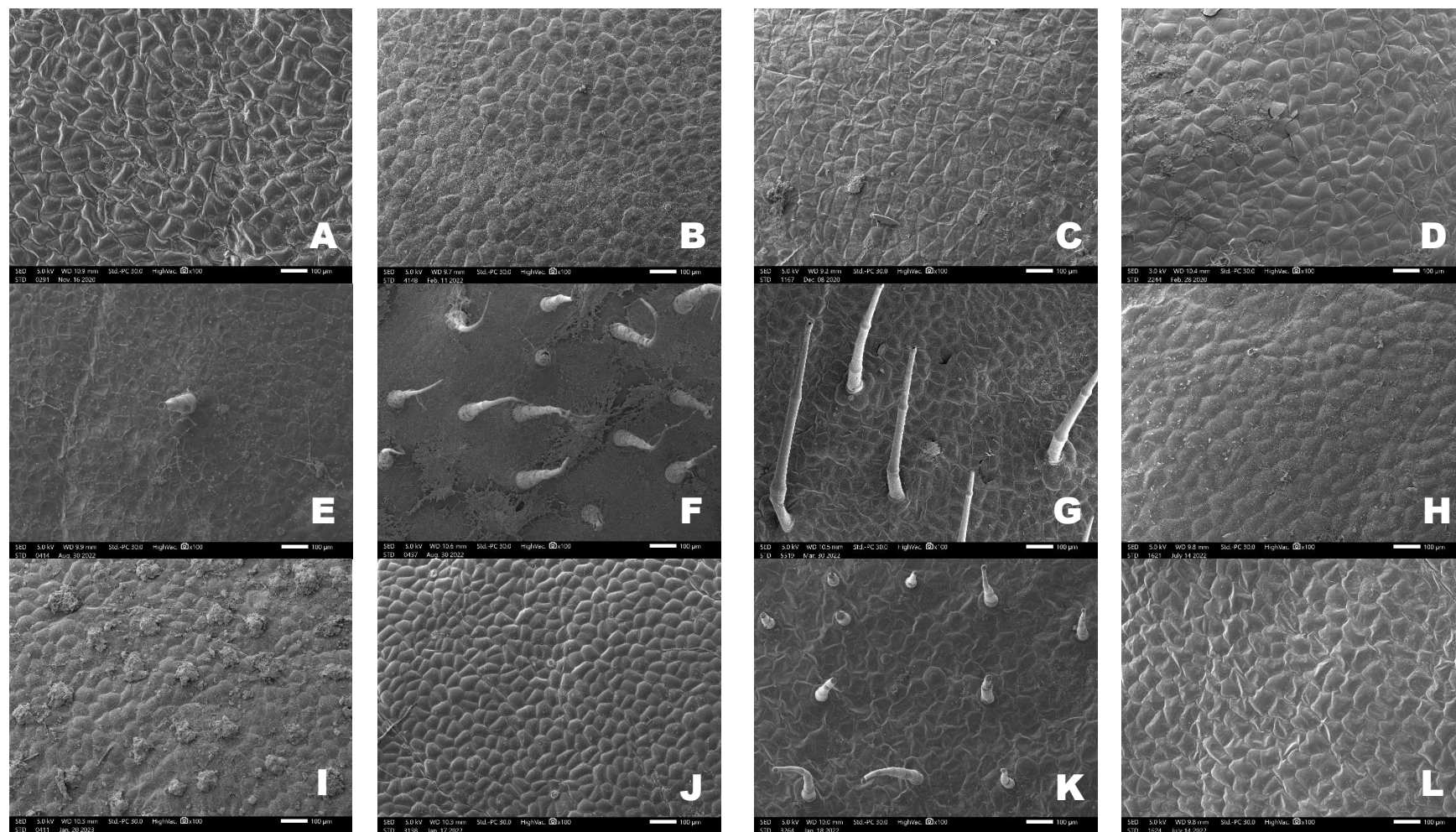


Figure 4.33: Adaxial surface of leaf. **A.** *M. glandulosa*, **B.** *M. glauca* var. *beccarii*, **C.** *M. glauca* var. *boraginea*, **D.** *M. glauca* var. *glauca*, **E.** *M. glauca* var. *hirta*, **F.** *M. glauca* var. *versipes*, **G.** *M. kazuea*, **H.** *M. selaborensis*, **I.** *M. singularis* var. *singularis*, **J.** *M. singularis* var. *aff. singularis*, **K.** *M. tenuis*, **L.** *M. aff. tenuis* [All were photographed at x100 magnification]

4.4.2 Stomata

Stomata are made of a pair of specialized epidermal cells referred to as guard cells. By adjusting the size of the stomatal pore, stomata control water loss as well as gas exchange between the plant and the environment (Melloto et al., 2008). Stomatal holes can be actively closed to block the microbial entrance and shield plants from pathogen infection and yield loss (Melloto et al., 2006). All 12 selected *Monophyllaea* taxa were observed under SEM and FESEM. All *Monophyllaea* species showed that stomata were present abundantly on the abaxial surface only, as shown in Figure 4.34. Stomata in the Gesneriaceae usually occur on the lower leaf surface (Sahasrabudhe & Stace, 1974; Wiehler, 1983). Wiehler (1983) asserts that the New World Gesneriaceae primarily have anisomesogenous stomata in which three subsidiary cells are present.

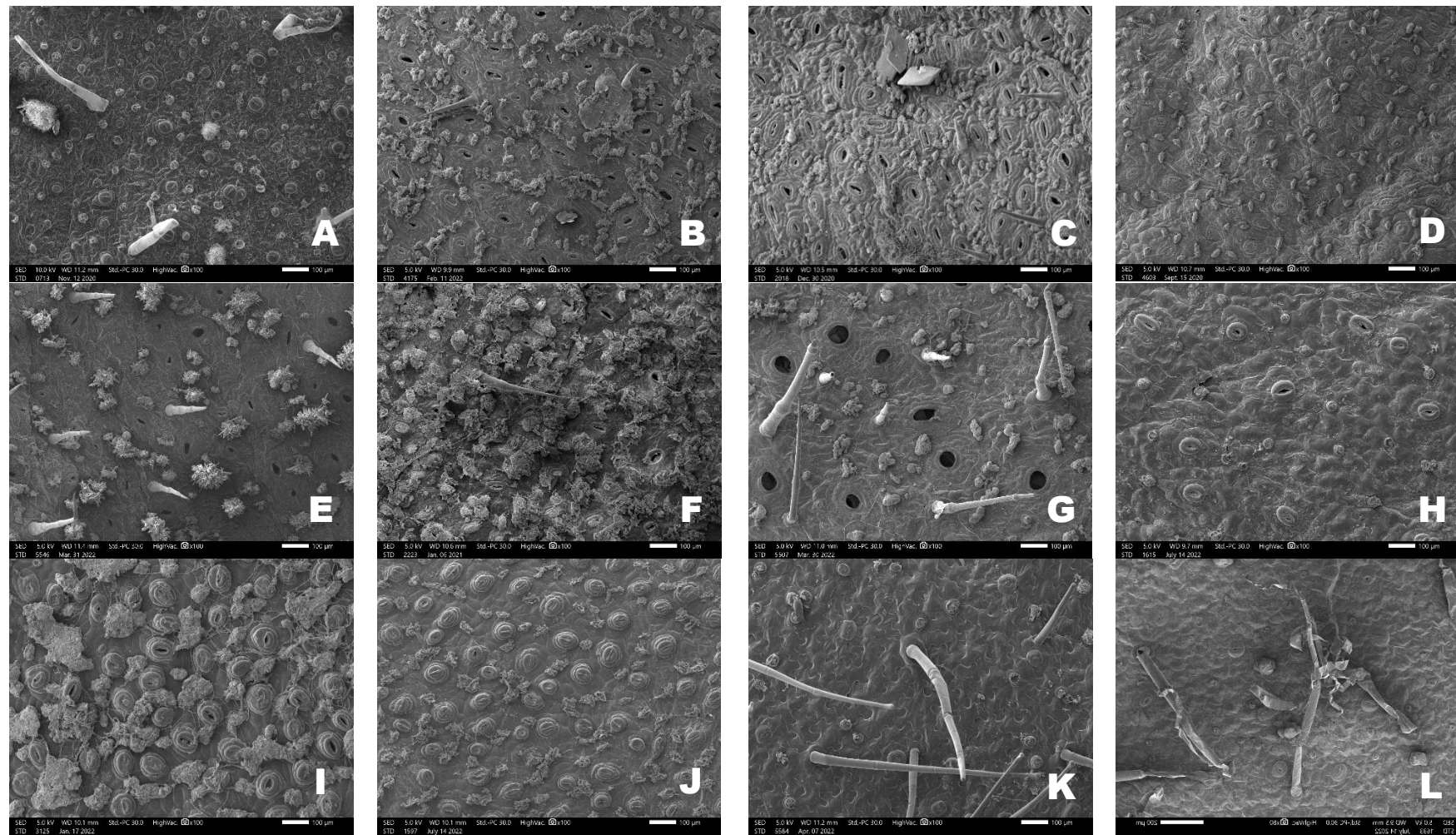


Figure 4.34: Abaxial surface of leaf. **A.** *M. glandulosa*, **B.** *M. glauca* var. *beccarii*, **C.** *M. glauca* var. *boraginea*, **D.** *M. glauca* var. *glauca*, **E.** *M. glauca* var. *hirta*, **F.** *M. glauca* var. *versipes*, **G.** *M. kazuea*, **H.** *M. selaborensis*, **I.** *M. singularis* var. *singularis*, **J.** *M. singularis* var. *aff. singularis*, **K.** *M. tenuis*, **L.** *M. aff. tenuis* [All were photographed at x100 magnification]

Table 4.21: The characteristics and measurement of stomata

Taxa	Type of stomata	Stomata appearance	Stomata range (μm)		Stomata average (μm)		Stomata density (mm^{-2})
			Length	Width	Length	Width	
<i>M. glandulosa</i>	Anisocytic	Raised	27.23 – 80.2	23 – 69.8	48.98	45.69	57.03
<i>M. glauca</i> var. <i>beccari</i>	Anisocytic	Level	40.3 – 52.6	38.9 – 41.3	46.93	40.15	44.81
<i>M. glauca</i> var. <i>boraginea</i>	Anisocytic	Level	44.37 – 72.9	31.5 – 53.1	61.56	39.74	32.59
<i>M. glauca</i> var. <i>glauca</i>	Anisocytic	Level	41.6 – 59.8	35.9 – 61.2	54.15	45.78	44.81
<i>M. glauca</i> var. <i>hirta</i>	Anisocytic	Level	42.82 – 59.2	31.04 – 51.9	51.95	38.21	97.76
<i>M. glauca</i> var. <i>versipes</i>	Anisocytic	Raised	32.8 – 82.2	31.4 – 79.9	60.87	43.93	101.84
<i>M. kazuea</i>	Anisocytic	Level	80.8 – 103.8	74 – 106.3	89.05	90.35	24.44
<i>M. selaborensis</i>	Anisocytic	Raised	70.1 – 99.2	71 – 83.8	91.85	79.33	32.59
<i>M. singularis</i> var. <i>singularis</i>	Anisocytic	Raised	27.64 – 75.4	34.20 – 57.6	51.36	43.41	81.47
<i>M. singularis</i> var. <i>aff. singularis</i>	Anisocytic	Raised	36.5 – 82.4	30.2 – 74.2	60.91	48.54	69.25
<i>M. tenuis</i>	Anisocytic	Raised	53.4 – 76.7	46.7 – 81.3	64.45	64.82	20.37
<i>M. aff. tenuis</i>	Anisocytic	Raised	54.6 – 108	49.9 – 84.1	84.21	72.34	20.37

Based on Figure 4.33, all *Monophyllaea* taxa consist of anisocytic stomata. Anisocytic stomatal complexes feature a guard cell pair and three subsidiary cells of unequal sizes, one of which is smaller than the other two (Gray et al., 2020).

The lower surface of *Monophyllaea* leaves has two types of stomata, which are level and raised. Several authors (Wiehler, 1983; Pereira-Dias & Santos, 2015; Papanatsiou et al., 2017; Gray et al., 2020) studied and discussed the functional significance of raised stomata, proposing that raised mounds and expanded stomatal chambers facilitate gas exchange and speed up transpiration, particularly in moist and humid tropical environments with little air movement. Furthermore, they contend that raising guard cells above the epidermal surface may help avoid stomatal chamber flooding in excessively humid situations.

Based on Table 4.21, the smallest stomata were found in *M. glauca* var. *beccari* with an average length of 46.93 μm and an average width of 40.15 μm . In comparison, the largest stomata were found in *M. selaborensis*, with an average length of 91.85 μm and an average width of 79.33 μm .

The stomata are scattered and random on both surfaces of the leaf (Figure 4.35). Both *M. tenuis* and *M. aff. tenuis* had the smallest stomata density, with 20.37 stomata per mm^{-2} . *M. glauca* var. *versipes* had the biggest stomata density, with 101.84 stomata per mm^{-2} .

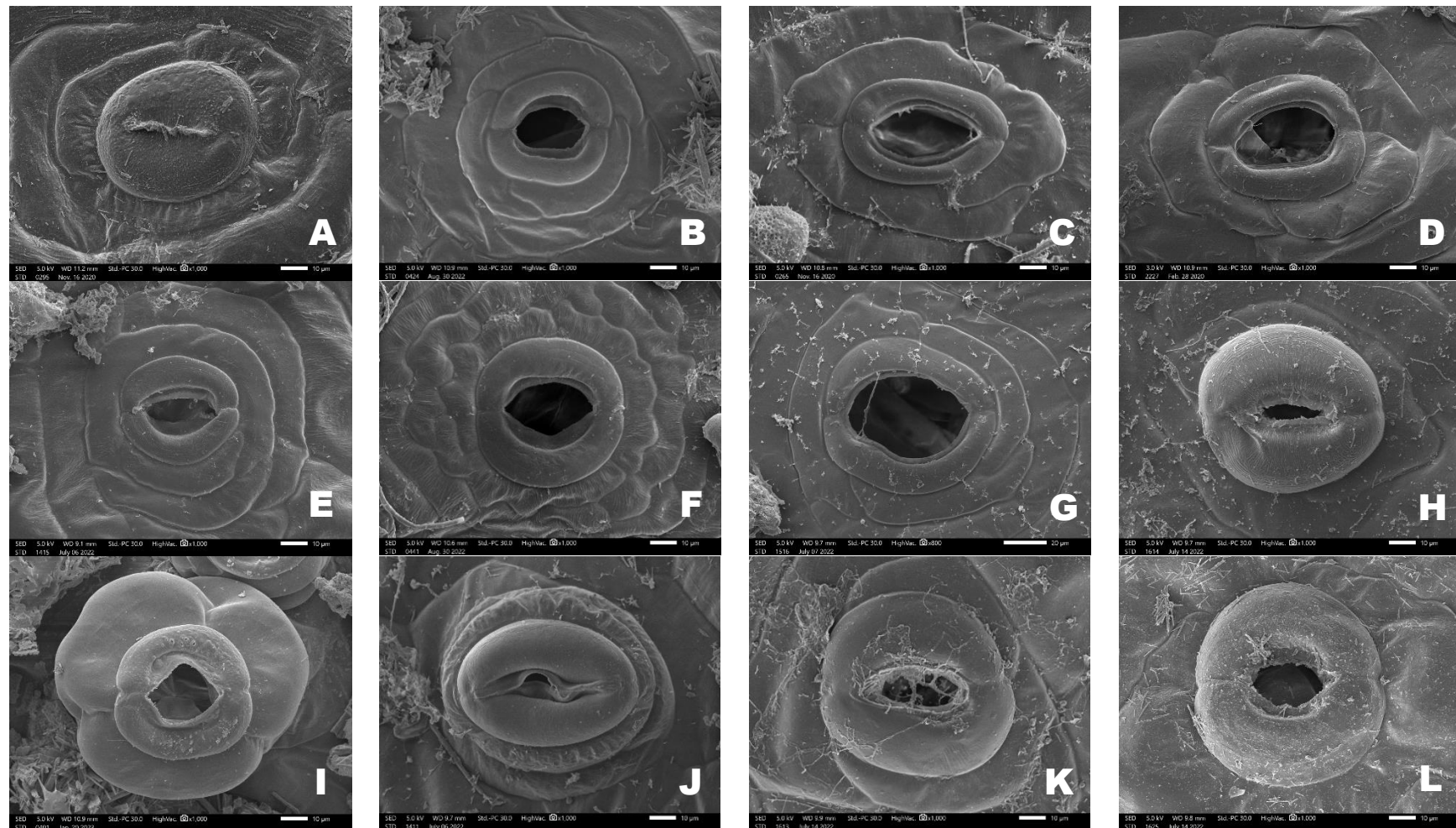


Figure 4.35: Anisocytic stomata of 12 *Monophyllaea* taxa. **A.** *M. glandulosa*, **B.** *M. glauca* var. *beccarii*, **C.** *M. glauca* var. *boraginea*, **D.** *M. glauca* var. *glauca*, **E.** *M. glauca* var. *hirta*, **F.** *M. glauca* var. *versipes*, **G.** *M. kazuea*, **H.** *M. selaborensis*, **I.** *M. singularis* var. *singularis*, **J.** *M. singularis* var. *aff. singularis*, **K.** *M. tenuis*, **L.** *M. aff. tenuis* [All were photographed at x1000 magnification except for *M. kazuea* at x800 magnification]

4.4.3 Trichomes

Trichomes are important as it is one of the main characteristics in identifying the varieties of *M. glauca* and some species in the genus *Monophyllaea*. Trichomes are specialised growths of epidermal cells with a variety of forms and functions. Trichomes can store or emit an immense variety of chemicals, from salts or nectars that draw insects to highly toxic secondary metabolites (Fanh, 2000; Wagner et al., 2004; Schilmiller et al., 2008). They also stated that trichomes can be divided into two types according to their secretory ability (glandular and non-glandular) and number of cells (unicellular and multicellular).

According to Simpson (2019), the trichomes are identified by the shape and morphology of the trichome. Trichomes with sharp ends are known as tapering trichomes. There are two types of glandular trichomes, capitate-glandular (Figure 4.37) and pilate-glandular trichomes (Figure 4.36). Capitate-glandular refers to a glandular cell that has a very short or no basal stalk with one or two head cells as compared to pilate-glandular, which has a glandular cell on top of an elongate basal stalk (Martínez-Natarén et al., 2018; Simpson, 2019). Glandular trichomes come in a variety of sizes, from simple ones to cell structures to complex ones with differentiated basal, stalk, and apical-secreting cells (Schilmiller et al., 2008). Most hairs in Gesneriaceae have a single terminal cell at their end, which is often bent into the form of a small hook (Weber, 1976; 1977).

Unicellular trichomes do not serve a secretory purpose; however, despite this, they protect plants from environmental threats such as herbivores, ultraviolet (UV) radiation,

pathogen invasion, and excessive transpiration and aid in seed distribution (Zhang et al., 2023).

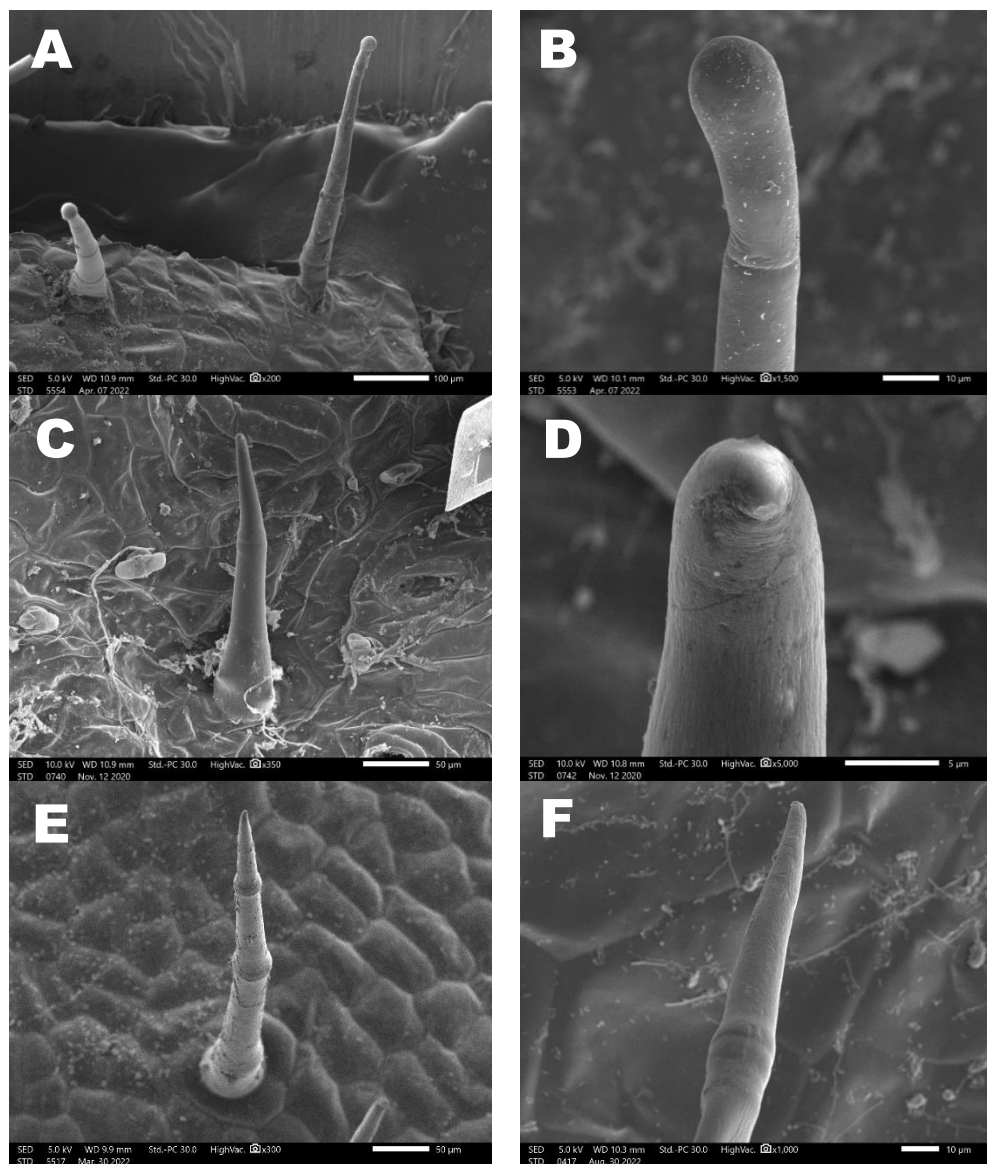


Figure 4.36: The unicellular trichomes of *Monophyllaea*. **A-B.** Pilate-glandular, **C-D.** Hooked uniseriate, **E-F.** Tapering uniseriate

Weber (2004) mentioned that there are peltate glandular hairs that secrete calcium carbonate in *Monophyllaea*. He also stated that a multicellular head is common in the glandular trichomes, and sometimes, the lumina are filled with cell wall material, and the terminal cells of glandular hairs are thickened (calcified or silicified). Schilmiller et al. (2008) stated that a significant amount of bioactive metabolites, including terpenoids, phenylpropanoids, flavonoids, alkaloids, and acyl sugars, can be produced, stored, and secreted by glandular trichomes.

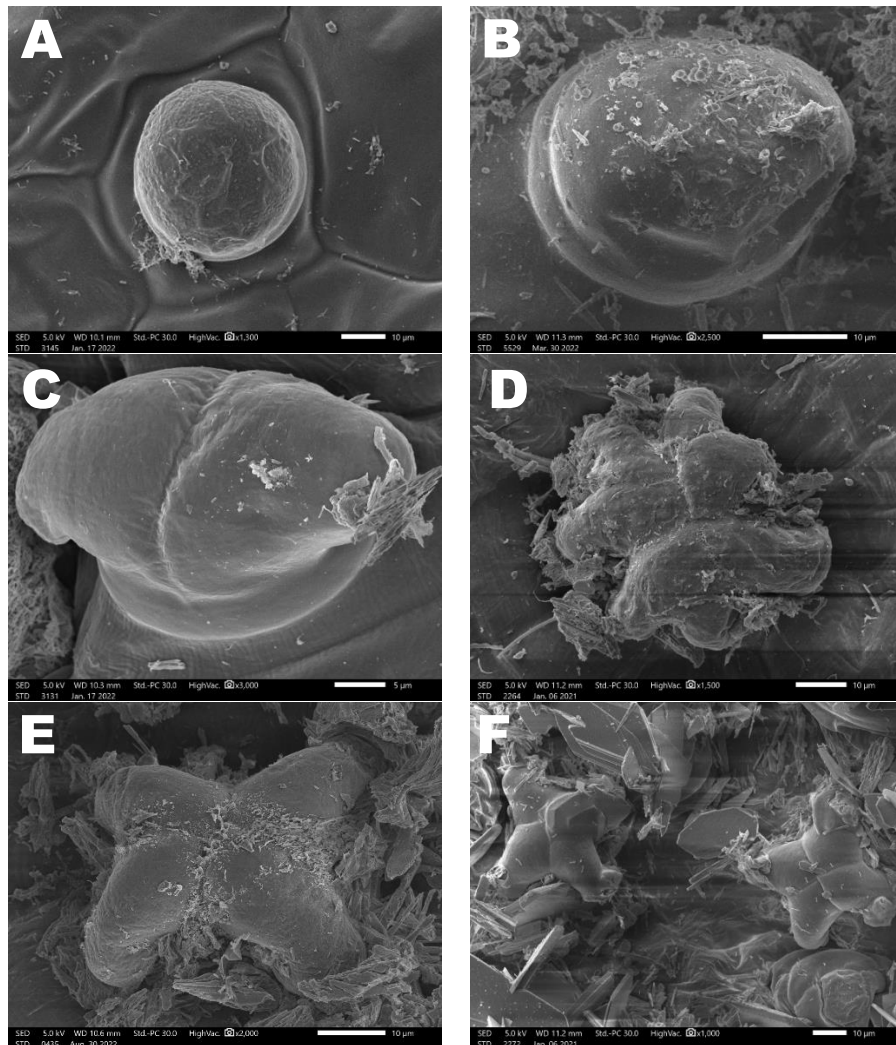


Figure 4.37: Capitulate-glandular trichomes on *Monophyllaea* leaf surface. **A-B.** One-celled capitulate-glandular trichomes, **C.** Two-celled capitulate-glandular trichome, **D.** Six-celled capitulate-glandular trichome, **E-F.** Four-celled capitulate-glandular trichome

Table 4.22: Type and measurement of trichomes

Taxa	Surface	Type of trichome	Segments/celled/arms	Length (µm)
<i>M. glandulosa</i>	Adaxial	Pilate-glandular	Segmented	838.53
	Abaxial	Pilate-glandular	Segmented	564.26
		Capitate-glandular	One-celled	N/A
<i>M. glauca</i> var. <i>beccarii</i>	Adaxial	Hooked uniseriate	Segmented	266.61
	Abaxial	Hooked uniseriate	Segmented	230.30
		Capitate-glandular	Two-celled	N/A
<i>M. glauca</i> var. <i>boraginea</i>	Adaxial	Hooked uniseriate	Segmented	222.33
	Abaxial	Hooked uniseriate	Segmented	168.33
		Capitate-glandular	One-celled	N/A
<i>M. glauca</i> var. <i>glauca</i>			Two-celled	N/A
	Adaxial	Glabrous	N/A	N/A
	Abaxial	Capitate-glandular	Two-celled	N/A
<i>M. glauca</i> var. <i>hirta</i>	Adaxial	Tapering uniseriate	Segmented	563.75
		Capitate-glandular	Two-celled	N/A
	Abaxial	Tapering uniseriate	Segmented	323.65
		Capitate-glandular	One-celled	N/A
			Two-celled	N/A

Table 4.22: Type and measurement of trichomes (continued)

<i>M. glauca</i> var. <i>versipes</i>	Adaxial	Tapering uniseriate	Segmented	490.82
	Abaxial	Tapering uniseriate	Segmented	347.04
		Capitate-glandular	Two-celled	N/A
<i>M. kazuea</i>	Adaxial	Tapering uniseriate	Segmented	751.81
	Abaxial	Tapering uniseriate	Segmented	463.87
		Capitate-glandular	One-celled	N/A
<i>M. selaborensis</i>			Two-celled	N/A
	Adaxial	Capitate-glandular	One-celled	N/A
	Abaxial	Capitate-glandular	One-celled	N/A
<i>M. singularis</i> var. <i>singularis</i>	Adaxial	Capitate-glandular	One-celled	N/A
			Four-celled	N/A
			Six-celled	N/A
<i>M. singularis</i> var. <i>aff. singularis</i>	Abaxial	Capitate-glandular	Four-celled	N/A
	Adaxial	Capitate-glandular	Two-celled	N/A
	Abaxial	Capitate-glandular	One-celled	N/A
			Two-celled	N/A

Table 4.22: Type and measurement of trichomes (continued)

<i>M. tenuis</i>	Adaxial	Pilate-glandular	Segmented	415.98
	Abaxial	Pilate-glandular	Segmented	863.72
		Capitate-glandular	One-celled	N/A
<i>M. aff. tenuis</i>	Adaxial	Pilate-glandular	Segmented	1394.48
		Capitate-glandular	One-celled	N/A
	Abaxial	Pilate-glandular	Segmented	935.80
		Capitate-glandular	One-celled	N/A

*N/A – not available/ no measurement

Based on Table 4.22, the uniseriate trichome has two types which are tapering and hooked trichomes. *M. kazuea* had the longest uniseriate trichome with 751.81 μm , and *M. glauca* var. *boraginea* had the shortest uniseriate trichome with 193.23 μm .

There are two types of glandular hairs present on the leaf surface of *Monophyllaea*, which are pilate-glandular and capitate-glandular. Pilate-glandular only can be observed in three species, *M. glandulosa*, *M. tenuis* and *M. aff. tenuis*. The longest pilate-glandular can be found in *M. aff. tenuis* with 1394.48 μm , and the shortest pilate-glandular is in *M. tenuis* with a length of 415.98 μm .

Capitate-glandular trichomes can be found on the leaf surface of all *Monophyllaea* taxa. The capitate-glandular trichomes can be single-celled or one-celled and multicell (two-celled, four-celled and six-celled). The size of capitate-glandular trichomes for one-celled is 28 – 35 x 28 – 35 μm , size of two-celled is 13 – 27 x 25 – 45 μm , the size of four-celled is 38 – 43 x 42 – 46 μm and size of six-celled 48 x 52 μm . Only one species, *M. singularis* var. *singularis* had four-celled and six-celled capitate-glandular present on both leaf surfaces.

4.4.4 Epicuticular Wax

Most *Monophyllaea* are endemic to limestone, and its species have chalk-glands on their leaves, stems, and inside of the sepal (Puff, 1975; Weber, 1976). The epicuticular wax often found covered both the upper and lower surfaces of the leaf in *Monophyllaea*. This study was conducted to have better understanding of importance epicuticular wax in *Monophyllaea*. *Monophyllaea* need to retain certain moisture level for survivability in which the epicuticular waxes helps in increasing resistance to waterloss through epidermis.

Alkanes, primary alcohols, aldehydes, secondary alcohols, ketones, esters, and other derived compounds are the main constituents of waxes, which cover the surface of leaves (Talik et al., 2018). These hydrophobic layers serve as a barrier for aerial plant organs and aid in the ability of different plant species to adapt to various environments (Shaheenuzzamn et al., 2019).

Minerals are typically retained inside tissues. However, biomineral particles have also been found on the surface of plant organs. Higher plants mineralize three primary types of compounds: calcium oxalate, calcium carbonate, and silica. If the calcium concentration in the soil is high, the accumulation of calcium in the shoots can often exceed the demand of the plant. To prevent calcium from causing harmful effects, it is precipitated in the form of calcium salts such as oxalate, phosphate, sulphate, carbonate, tartrate, citrate, and silicate (He et al., 2012). According to Chan et al. (2003) and White and Broadley (2003), high intracellular Ca can precipitate with phosphates which interfere with seed germination, disturb photosynthesis and slow down growth.

There are several types of calcium salts, including calcium oxalate, calcium phosphate, and calcium carbonate (Cuéllar-Cruz et al., 2020). Calcium oxalate (CaOx) is the most common salt that has been discovered in a wide variety of plant species (Bouropoulos et al., 2001; Franceschi & Nakata, 2005; Nakata 2012). The presence of calcium phosphate has not been thoroughly studied, particularly in plants. The observations were made recently by Cuéllar-Cruz et al. (2020) on plant trichomes, where silica is frequently substituted for calcium phosphates.

Crystals can appear in a variety of plant organs and take on numerous forms, such as druses, prismatic crystals, raphides, styloides, and crystal sands (Wu & Kuo-Huang, 1997). Cuéllar-Cruz et al. (2020) and Franceschi and Horner (1980) mentioned that one of the purposes of CaOx crystals in the raphides shape is to serve as a defence mechanism for plants against predators by cutting and injuring the throat and oesophagus of the predators when it chews on the plant leaves.

Based on Figure 4.38, there are various crystal forms in the genus *Monophyllaea*, such as prismatic, druses and raphides crystals. Block-like prismatic crystals that occur as one or more crystals per cell and large, elongated rectangular styloids that only appear as a single crystal in a cell are both examples of prismatic crystals. Raphides crystal is like bundles of needle-shaped crystal sands (also known as sand crystals) are masses of tiny angular crystals, and druses are multidimensional star-like, spherical, and bladed aggregate crystals (Haberlandt, 1914; Burchi et al., 2014).

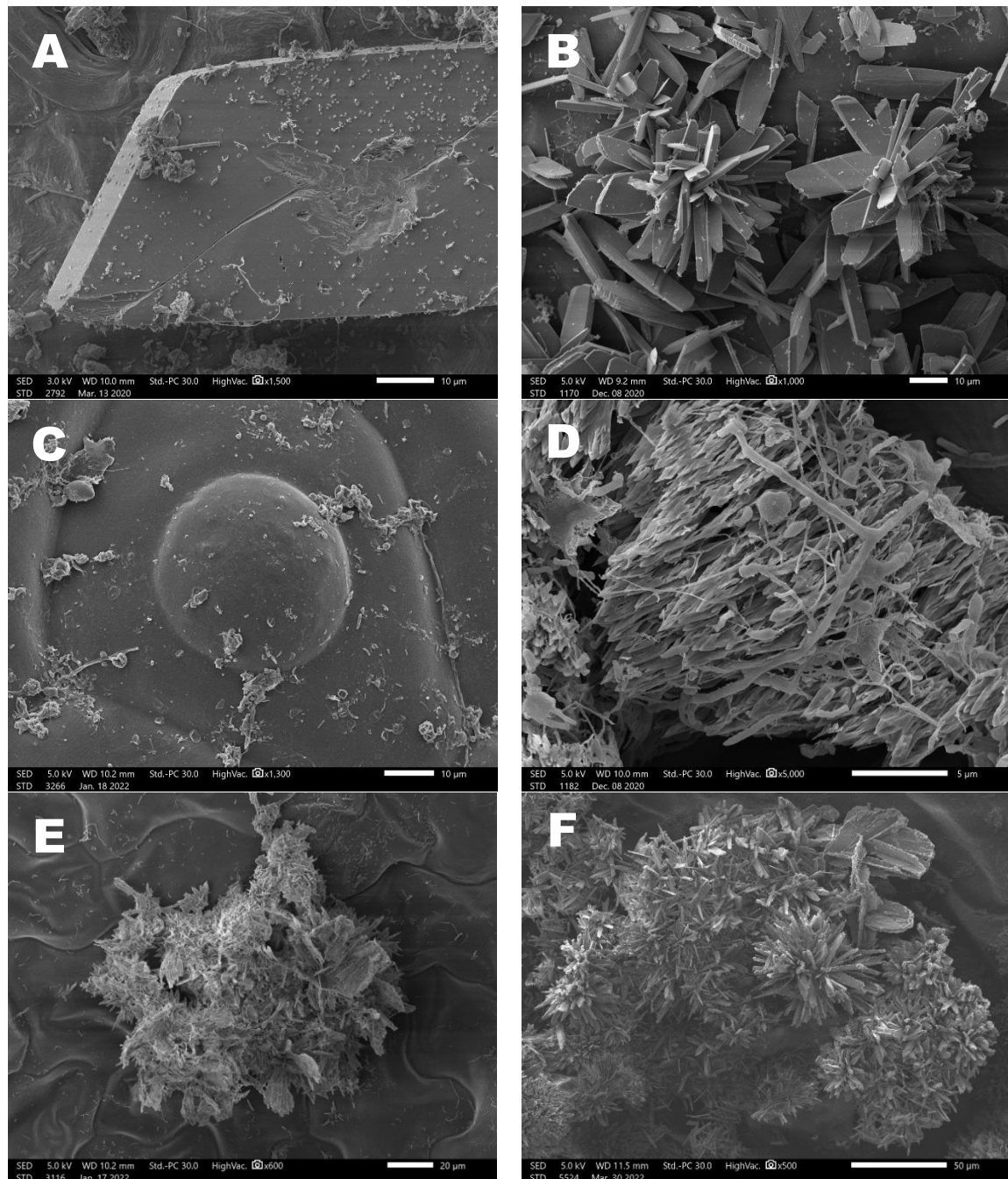


Figure 4.38: The crystal epicuticular wax on the surface of leaf. **A.** Prismatic crystal on lower surface of leaf *M. glauca* var. *glauca*, **B.** Cluster of prismatic crystal on adaxial surface of *M. glauca* var. *boraginea*, **C.** Sand crystal on upper surface of *M. tenuis*, **D.** Raphides crystal on lower surface of *M. glauca* var. *boraginea*, **E.** Druses crystal on abaxial surface of *M. tenuis*, **F.** Druses crystal on abaxial surface of *M. selaborensis*

In Figure 4.39 and Figure 4.41, the analysis using EDX method was applied to the sample of *M. glauca* var. *boraginea* and *M. singularis* var. *singularis* respectively. *M. glauca* observed to have the least white residue observed on the leaf while *M. singularis* leaf are covered with mostly white residue. The element found in crystal can be studied using EDX method. The leaf surface of *M. glauca* var. *boraginea* and *M. singularis* var. *singularis* were encrusted with CaOx crystal.

The result in Figure 4.40 and Figure 4.42 showed the crystal has the highest element found, including oxygen, calcium and phosphorus. There were numerous elements can be found on the crystal on leaf surface of *M. glauca* var. *boraginea* and *M. singularis* var. *singularis* as shows in Table 4.23 and Table 4.24. This may not be useful for delimitation of *Monophyllaea* species but using this EDX method on crystal found on the leaf can be helpful to understand the the elements found in the crystal and the variety of different crystal types produced by a single plant.

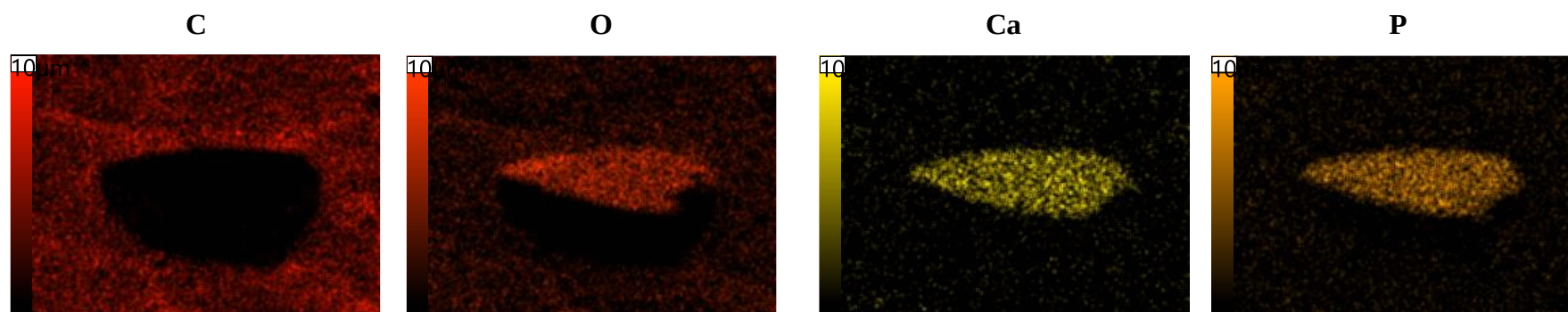
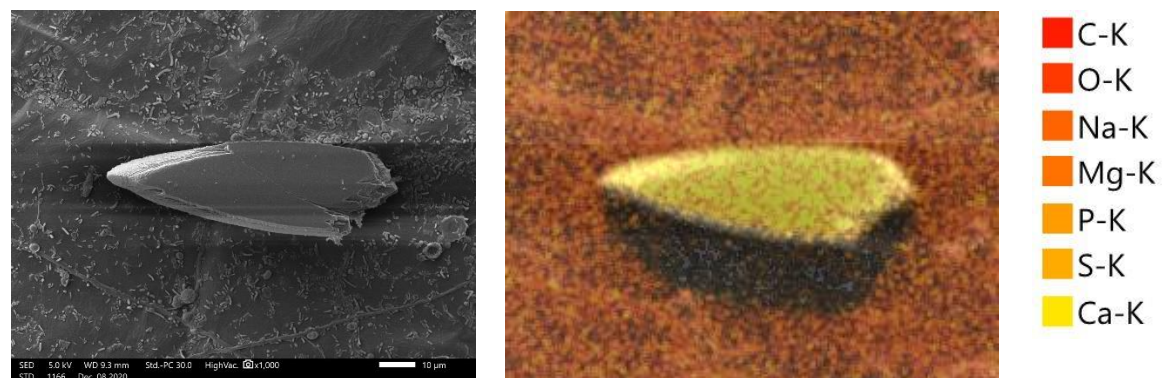


Figure 4.39: The EDX images of prismatic crystal found on leaf surface of *M. glauca* var. *boraginea*. C- carbon, O- oxygen, Ca- calcium, P- phosphorus

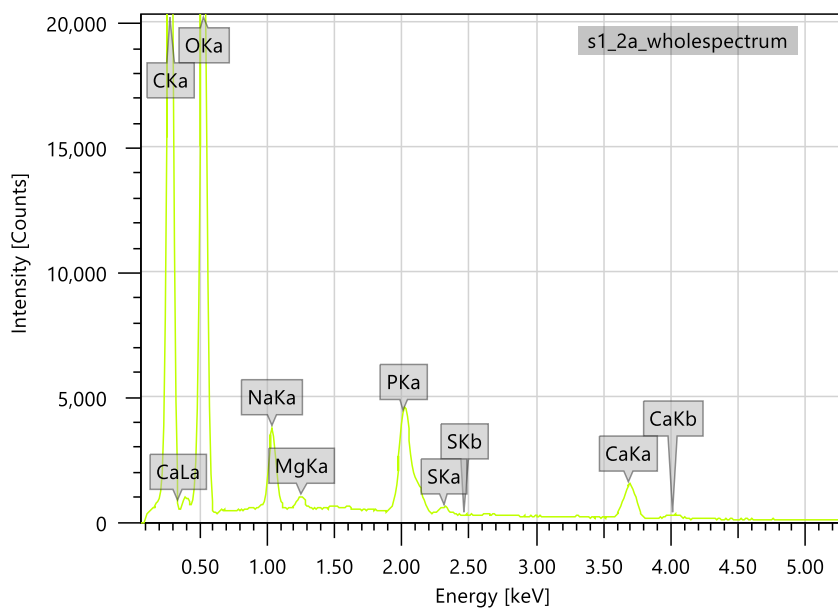


Figure 4.40: The element found on the prismatic crystal found on leaf surface of *M. glauca* var. *boraginea*

Table 4.23: The element found on the prismatic crystal found on leaf surface of *M. glauca* var. *boraginea*

Element	Line	Mass%	Atom%
C	K	42.48±0.04	52.77±0.05
O	K	43.47±0.08	40.54±0.08
Na	K	2.86±0.02	1.85±0.01
Mg	K	0.41±0.01	0.25±0.01
P	K	4.73±0.03	2.28±0.02
S	K	0.62±0.01	0.29±0.01
Ca	K	5.44±0.05	2.03±0.02
Total		100.00	100.00
s1_2a_wholespectrum		Fitting ratio 0.0109	

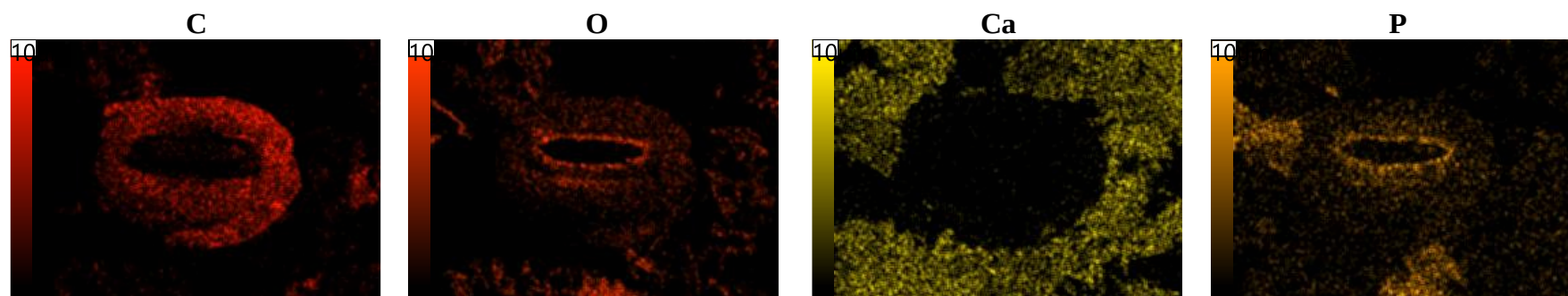


Figure 4.41: The EDX images of crystal found on leaf surface of *M. singularis* var. *singularis*. C- carbon, O- oxygen, Ca- calcium, P- phosphorus

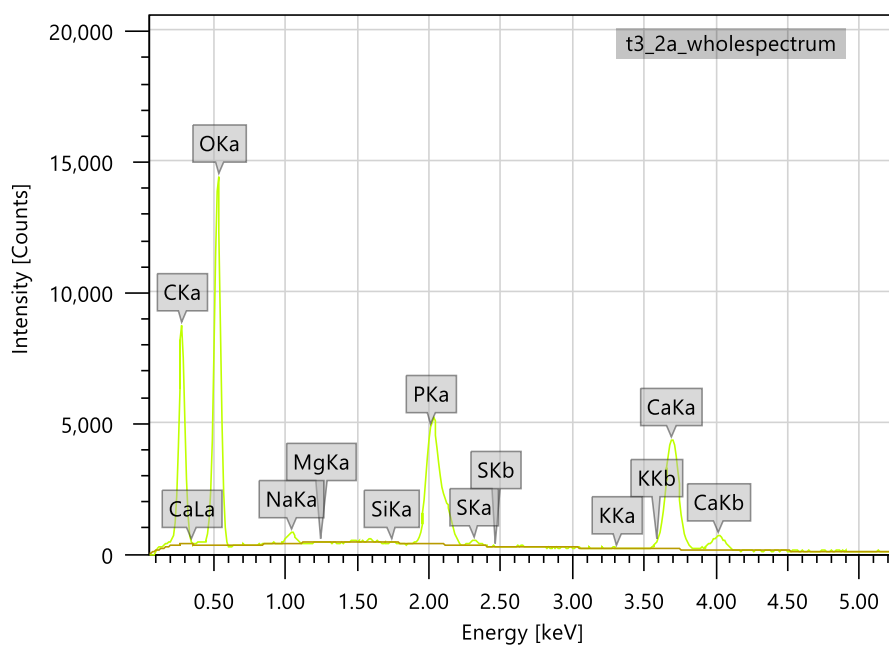


Figure 4.42: The element found on the crystal on leaf surface of *M. singularis* var. *singularis*

Table 4.24: The element found on the crystal on leaf surface of *M. singularis* var. *singularis*

Element	Line	Mass%	Atom%
C	K	26.76±0.04	39.21±0.06
O	K	41.13±0.11	45.25±0.12
Na	K	1.82±0.02	1.39±0.02
Mg	K	0.78±0.02	0.56±0.01
Si	K	0.06±0.01	0.04±0.01
P	K	4.01±0.04	2.28±0.02
S	K	0.89±0.02	0.49±0.01
K	K	0.19±0.02	0.09±0.01
Ca	K	24.36±0.13	10.70±0.06
Total		100.00	100.00
t3_3b_wholespectrum		Fitting ratio 0.0317	

4.4.5 General Discussion

The epidermal cells were observed only using SEM and FESEM methods. The leaf was soaked in FAA or 4% glutaraldehyde to maintain the cells inside the leaf. Soaking with ethanol will damage the cell as it will be dehydrated when observed under FESEM. Several other methods also been used during the experiment such as epidermal splitting by boiling in 5% nitric acid, nail polishing and scrapping off the surface of the leaf. However, these methods are proved not suitable to produce a better view of the epidermal surface. This is because the leaf of *Monophyllaea* is fragile and succulent.

The method of using CPD is efficient to be used in drying the delicate samples of *Monophyllaea* leaf. However, the CPD may cause pressure on the surface of the leaf and some of the trichomes broke and fell off. Drying the leaf sample by putting it in a desiccator jar is also not recommended as the leaf with crumpled and completely dehydrated.

All *Monophyllaea* taxa observed using FESEM consist of glandular hairs. As mentioned above, glandular trichomes may secrete various chemical compounds and whether these chemical compounds attract the insect and animals or as protection from these threats. Further studies are needed to identify the chemical compound secreted by glandular trichomes.

4.5 Anatomy Study

Anatomy studies were conducted on all 12 *Monophyllaea* taxa including stem cross-section and midrib cross-section.

4.5.1 Stem Cross-Section

A cross-section of the stem was seen in 12 *Monophyllaea* taxa. The stems of all *Monophyllaea* taxa are cylindrical. The stem's cross-section is normally spherical, but it can also be oval. Figure 4.43 depicts a tight system of vascular bundles in all *Monophyllaea* taxa.

The Gesneriaceae stele is a hollow cylinder of continuous phloem and xylem, the latter part of which may contain fibres and/or libriform tracheids (Weber, 2004). The cylinder's middle has a pith of massive parenchymatic cells. The pith crystals contain starch grains and/or sclereid nests. Weber (2004) reports the presence of medullary bundles.

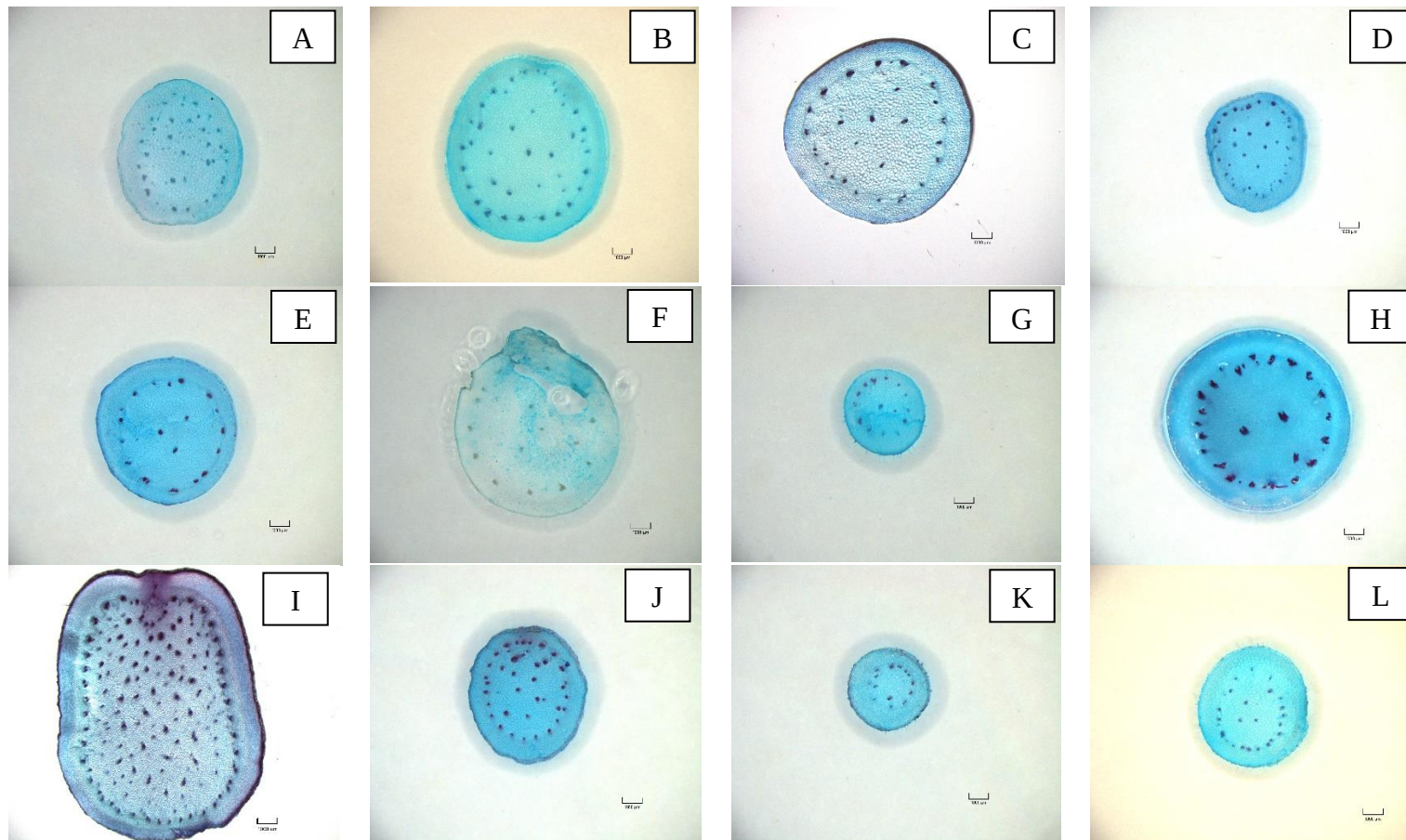


Figure 4.43: Stem cross-section of *Monophyllaea*. **A.** *M. glandulosa*, **B.** *M. glauca* var. *beccarii*, **C.** *M. glauca* var. *boraginea*, **D.** *M. glauca* var. *glauca*, **E.** *M. glauca* var. *hirta*, **F.** *M. glauca* var. *versipes*, **G.** *M. kazuea*, **H.** *M. selaborensis*, **I.** *M. singularis* var. *singularis*, **J.** *M. singularis* var. *aff. singularis*, **K.** *M. tenuis*, **L.** *M. aff. tenuis* [All magnification x10]

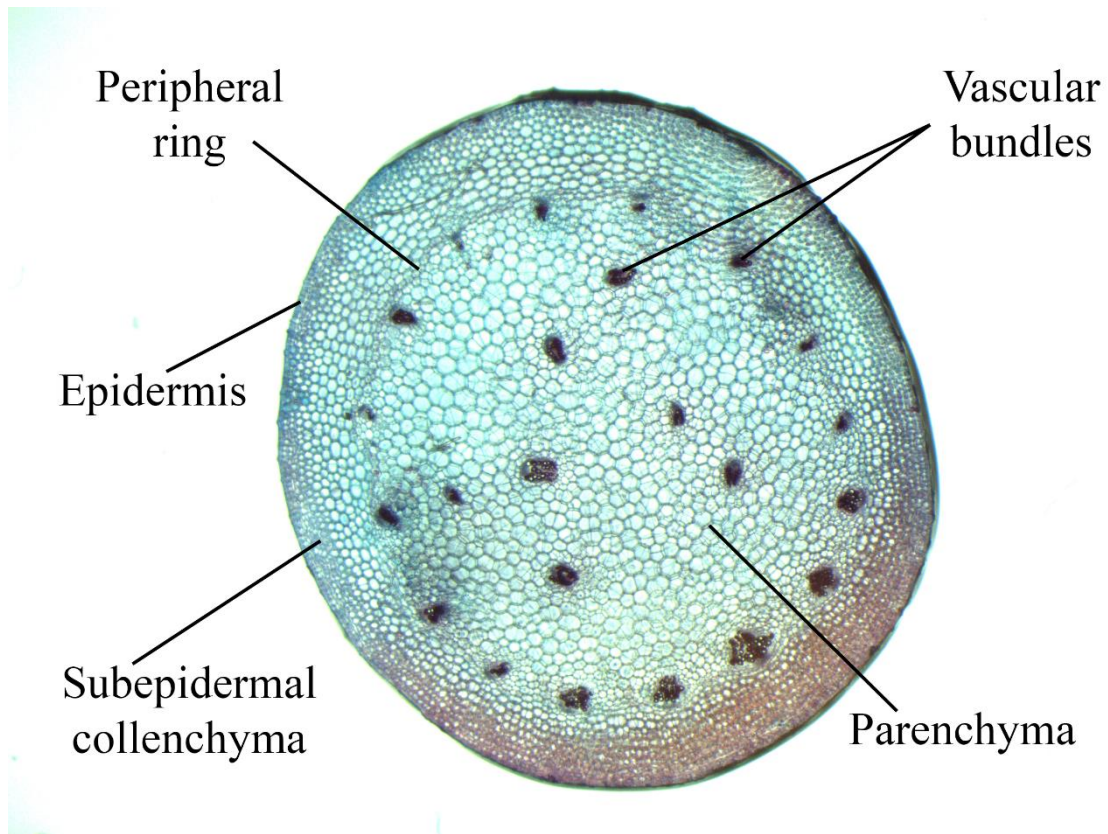


Figure 4.44: Stem cross-section of *M. glauca* var. *boraginea*

In stem cross-section, all *Monophyllaea* taxa studied are comparable and have the same strengthening tissues and vascular bundles. The stem cross-section of all *Monophyllaea* species, according to Figure 4.44, consists of an epidermal layer, a subepidermal collenchyma layer, a peripheral ring, vascular bundles, and parenchyma tissues.

The epidermal layer is made up of only one layer. *Monophyllaea* has 3-6 layers of subepidermal collenchyma, with only *M. singularis* var. *singularis* having 6-10 layers.

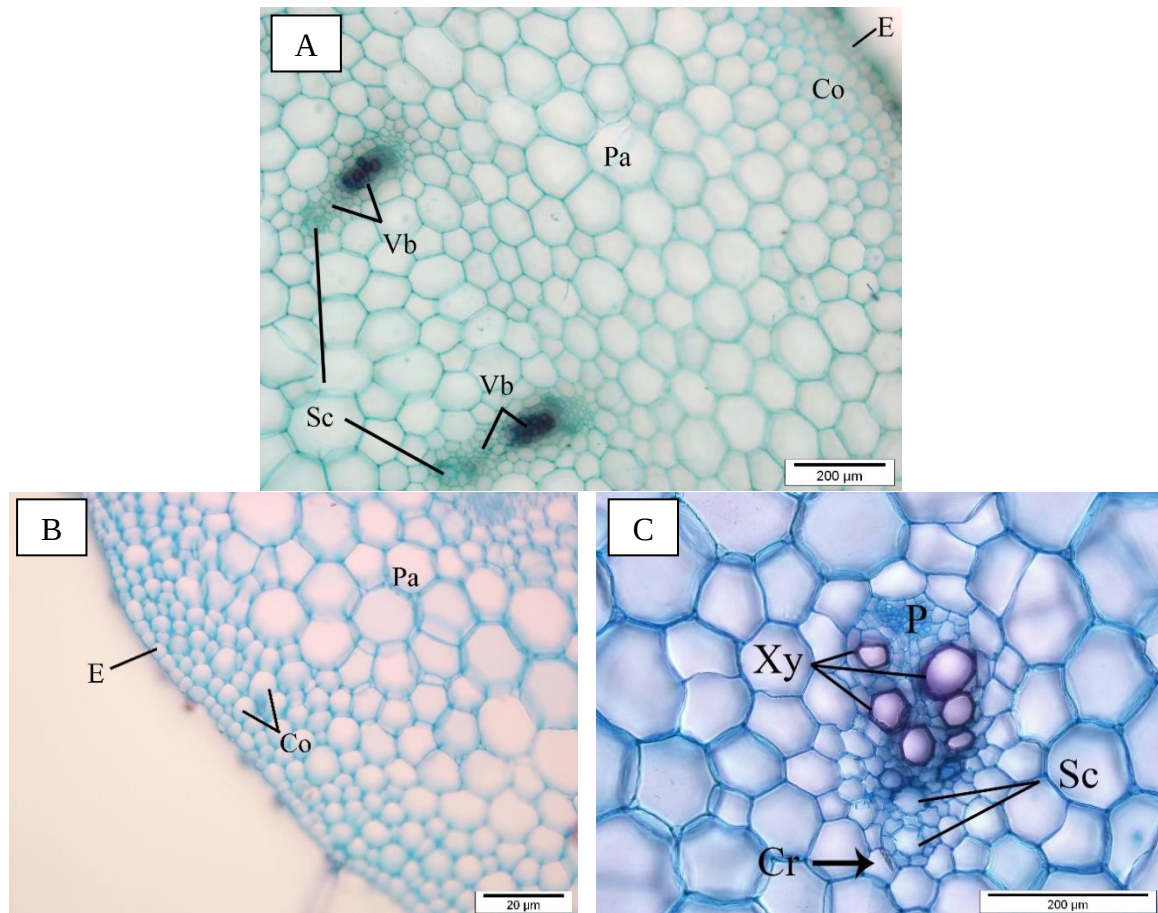


Figure 4.45: Strengthening tissues and vascular bundles in the stem. **A.** *M. glauca* var. *glauca*, **B.** *M. glandulosa*, **C.** *M. glauca* var. *beccarii*. The cross-section (A-C) shows epidermis (**E**) layer, subepidermal collenchyma (**Co**) layers, vascular bundles (**Vb**), phloem (**P**), xylem (**Xy**), secretory canal (**Sc**) and crystal (**Cr**)

Vascular bundles

The different sizes of vascular bundles were arranged in a peripheral ring with some vascular bundles scattered in the centre. Hadrocentric vascular bundles were found in *Monophyllaea* as the phloem tissues surrounded the xylem tissues (Figure 4.45C).

Table 4.25: Number and measurement of vascular bundles in stem cross-section

Taxa	Average size (mm)	Vascular bundles in peripheral ring	Vascular bundles in center	Average size of vascular bundles(mm)
<i>M. glandulosa</i>	7.464 x 5.599	18 – 24	14 – 15	0.255 x 0.204
<i>M. glauca</i> var. <i>beccarii</i>	9.033 x 7.926	24	16 – 17	0.457 x 0.339
<i>M. glauca</i> var. <i>boraginea</i>	8.263 x 8.250	16 – 25	5 – 16	0.472 x 0.332
<i>M. glauca</i> var. <i>glauca</i>	5.840 x 5.011	23 – 26	9 – 14	0.419 x 0.195
<i>M. glauca</i> var. <i>hirta</i>	9.471 x 9.401	16 – 40	4 – 32	0.705 x 0.552
<i>M. glauca</i> var. <i>versipes</i>	9.280 x 8.053	15	4	0.222 x 0.155
<i>M. kazuea</i>	4.012 x 6.267	13 – 17	2 – 7	0.244 x 0.213
<i>M. selaborensis</i>	8.758 x 8.636	21 – 22	4	0.327 x 0.260
<i>M. singularis</i> var. <i>singularis</i>	13.212 x 12.930	36 – 45	62 – 85	0.444 x 0.349
<i>M. singularis</i> var. <i>aff. singularis</i>	6.825 x 5.952	21 – 25	13 – 14	0.314 x 0.272
<i>M. tenuis</i>	3.883 x 3.832	11 – 12	2 – 3	0.370 x 0.261
<i>M. aff. tenuis</i>	5.841 x 5.266	15 – 19	4 – 6	0.287 x 0.217

According to Table 4.25, *M. singularis* var. *singularis* had the biggest stem size at 13.212 x 12.930 mm, and *M. tenuis* had the smallest stem size at 3.883 x 3.832 mm. *Monophyllaea singularis* var. *singularis* has the most vascular bundles in the peripheral ring and centre, with 36-45 and 62-85, respectively. While *M. tenuis* has the fewest vascular bundles in the peripheral ring, 11-12, and the most in the middle, 2-3, *M. glauca* var. *hirta* had the largest vascular bundle measured, measuring 0.705 x 0.552 mm, and *M. glauca* var. *versipes* had the smallest, measuring 0.222 x 0.155 mm.

Secretory canal

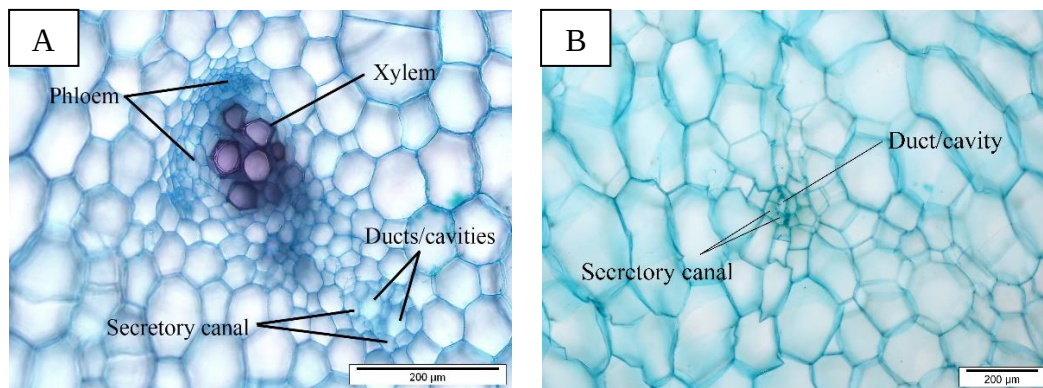


Figure 4.46: Secretory canal found near phloem and in the center (parenchyma). **A.** Secretory canal found near phloem in *M. glauca* var. *beccarii*, **B.** Secretory canal found in center of *M. glauca* var. *hirta*

The majority of the vascular bundles discovered in *Monophyllaea* are made up of adjacent secretory canals. Secretory channels are frequently found near phloem tissues (Figure 4.46A). A few secretory channels were also seen distributed throughout the parenchyma (Figure 4.46B). Near these secretory canals, crystal sands and raphides can also be found.

Internal secretory structures called ducts and cavities are made up of a lumen surrounded by a secretory epithelium that regulates secretion production, accumulation, and externalisation (Fahn, 1979; Prado & Demarco, 2018). Tetley (1925) and Williams (1954) proposed that because these ducts are so close to the phloem, they may aid in the transport of organic material to the sieve tubes.

These structures also produce and store compounds which carry out numerous purposes, such as protecting developing young and adult structures and organs, retaining water, and providing protection from fungi, insects, herbivores, and high levels of radiation, in addition to facilitating the colonisation and establishment of species in various ecosystems (Fahn, 1979; Souza et al., 2015; Machado et al., 2016; Bezerra et al., 2020).

Table 4.26: The measurement of duct/cavity and secretory canal in stem cross-section

Taxa	Average size of duct/cavity (µm)	Average size of secretory canal (µm)
<i>M. glandulosa</i>	77.310 x 43.210	63.950 x 80.940
<i>M. glauca</i> var. <i>beccarii</i>	42.085 x 37.688	76.263 x 70.342
<i>M. glauca</i> var. <i>boraginea</i>	32.258 x 36.988	89.111 x 97.416
<i>M. glauca</i> var. <i>glauca</i>	42.062 x 33.868	84.905 x 75.550
<i>M. glauca</i> var. <i>hirta</i>	62.949 x 33.111	102.335 x 122.192
<i>M. glauca</i> var. <i>versipes</i>	N/A	N/A
<i>M. kazuea</i>	43.239 x 33.756	78.969 x 64.120
<i>M. selaborensis</i>	N/A	N/A
<i>M. singularis</i> var. <i>singularis</i>	45.414 x 44.045	89.704 x 77.758
<i>M. singularis</i> var. <i>aff. singularis</i>	96.766 x 87.582	135.011 x 115.726
<i>M. tenuis</i>	N/A	N/A
<i>M. aff. tenuis</i>	90.530 x 61.902	120.942 x 129.234

*N/A – not available, stem section were damaged

Based on Table 4.26, *Monophyllaea glauca* var. *boraginea* has the smallest duct/cavity with an average size of 32.258 x 36.988 μm and *M. singularis* var. *aff. singularis* has the largest duct/cavity and secretory canal with average size of 96.766 x 87.582 μm and 135.011 x 115.726 μm , respectively. The smallest size of secretory canal was found in *M. glandulosa* with 63.950 x 80.940 μm .

4.5.2 Midrib Cross-section

Midrib cross-section was observed in 12 *Monophyllaea* taxa collected in western Sarawak (Figure 4.49). The anatomy of the midrib is relatively similar to the anatomy of the petiole. Based on Figure 4.47B, the midrib cross-section in all *Monophyllaea* taxa consists of an epidermal layer, subepidermal collenchyma layer, vascular bundles and parenchyma tissues.

The epidermis layer consists of only one layer on both the adaxial and abaxial. Most of the subepidermal collenchyma in the midrib of *Monophyllaea* consists of 3 – 4 layers on both adaxial and abaxial (Figure 4.47A).

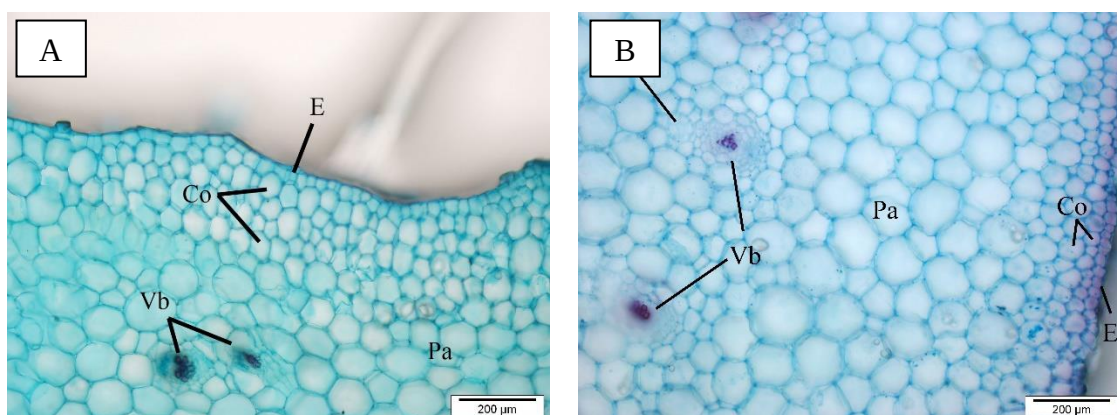


Figure 4.47: Midrib cross-section. **A.** Adaxial of midrib in *M. selaborensis*, **B.** Abaxial of midrib in *M. glauca* var. *glauca* [Scalebar 200 μm]

Vascular bundles

However, *Monophyllaea* taxa have open-system and closed-system of vascular bundles as shown in Figure 4.48.

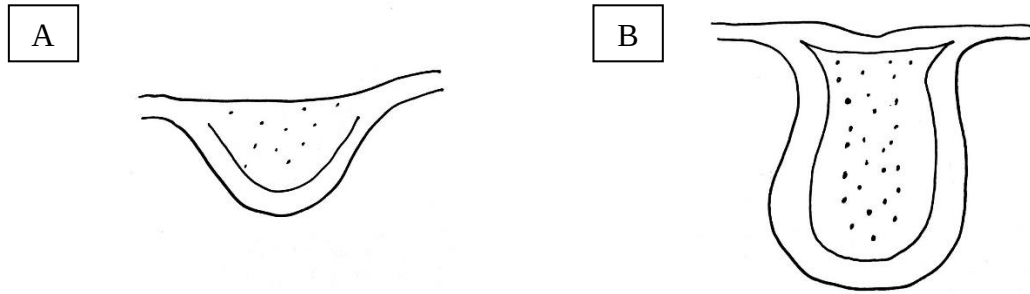


Figure 4.48: Open-system and closed-system of vascular bundle. **A.** Open-system of vascular bundle, **B.** Closed-system of vascular bundle

Most of *Monophyllaea* taxa collected consist of open-system vascular bundles. The vascular bundles at the abaxial were arranged in an arc shape (Figure 4.46A). The vascular bundles were scattered at the adaxial and the centre of the midrib.

Closed-system were found in two species, *M. singularis* var. *singularis* and *M. singularis* var. *aff. singularis*. The vascular bundles were arranged in an irregular ring in closed-system with scattered vascular bundles observed in the centre of the midrib (Figure 4.46B).

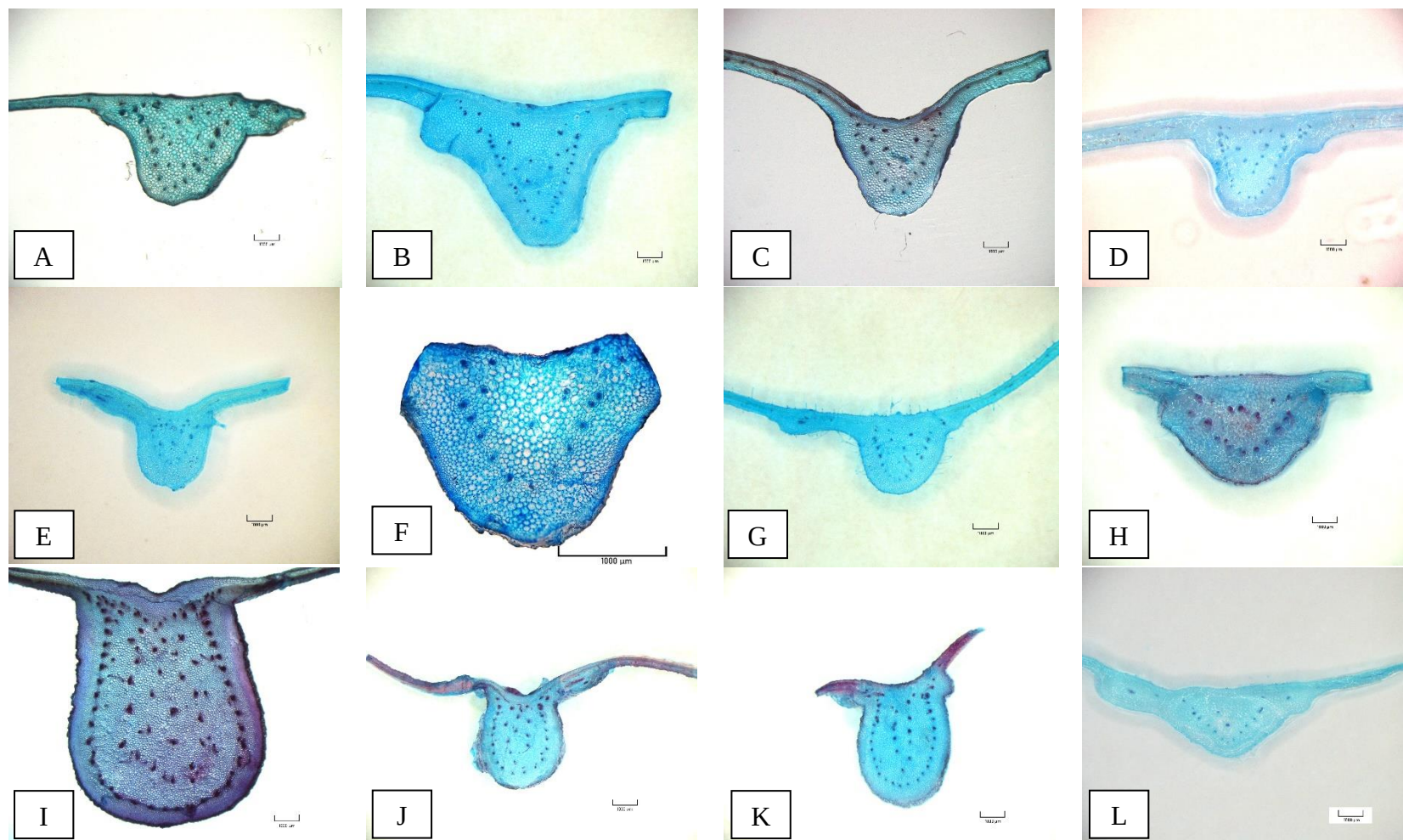


Figure 4.49: Midrib cross-section of 12 *Monophyllaea* taxa. **A.** *M. glandulosa*, **B.** *M. glauca* var. *beccarii*, **C.** *M. glauca* var. *boraginea*, **D.** *M. glauca* var. *glauca*, **E.** *M. glauca* var. *hirta*, **F.** *M. glauca* var. *versipes*, **G.** *M. kazuea*, **H.** *M. selaborensis*, **I.** *M. singularis* var. *singularis*, **J.** *M. singularis* var. *aff. singularis*, **K.** *M. tenuis*, **L.** *M. aff. tenuis* [All magnification x12.5 except *M. glauca* var. *versipes* x20]

Table 4.27: Number and measurement of vascular bundles in midrib cross-section

Taxa	Average size (mm)	Vascular bundles in peripheral ring	Vascular bundles in center	Average size of vascular bundles(mm)
<i>M. glandulosa</i>	3.262 x 4.018	16 – 19	15	0.234 x 0.287
<i>M. glauca</i> var. <i>beccarii</i>	5.296 x 5.970	30	14	0.209 x 0.204
<i>M. glauca</i> var. <i>boraginea</i>	3.803 x 4.625	16 – 17	8 – 12	0.246 x 0.292
<i>M. glauca</i> var. <i>glauca</i>	5.292 x 5.532	22	13 – 15	0.364 x 0.272
<i>M. glauca</i> var. <i>hirta</i>	3.126 x 3.248	12	9	0.220 x 0.202
<i>M. glauca</i> var. <i>versipes</i>	3.616 x 4.013	12	6	0.206 x 0.190
<i>M. kazuea</i>	3.199 x 3.734	15	7	0.274 x 0.200
<i>M. selaborensis</i>	3.069 x 5.208	12	5	0.194 x 0.166
<i>M. singularis</i> var. <i>singularis</i>	9.492 x 7.860	50	38	0.371 x 0.339
<i>M. singularis</i> var. <i>aff. singularis</i>	4.089 x 3.598	27 – 35	11 – 16	0.206 x 0.172
<i>M. tenuis</i>	4.754 x 3.643	30	16	0.196 x 0.174
<i>M. aff. tenuis</i>	2.124 x 4.311	13 – 15	2 – 3	0.262 x 0.267

As shown in Table 4.27, *M. singularis* var. *singularis* has the largest size of midrib with 9.492 x 7.860 mm while *M. aff. tenuis* has the smallest midrib with a size of 2.124 x 4.311 mm.

Three *Monophyllaea* taxa, *M. glauca* var. *hirta*, *M. glauca* var. *versipes* and *M. selaborensis* have the least vascular bundles arranged in arc line with 12 vascular bundles. *Monophyllaea singularis* var. *singularis* consist of the largest number of vascular bundles arranged in a ring with 50 vascular bundles. *Monophyllaea aff. tenuis* consists of 2 – 3 vascular bundles scattered in parenchyma compared to *M. singularis* var. *singularis* with 38 vascular bundles.

The largest average size of vascular bundles was found *M. singularis* var. *singularis* with a size of 0.371 x 0.339 mm and *M. selaborensis* has the smallest average size of vascular bundles with a measurement of 0.194 x 0.166 mm.

Secretory canal

The secretory canal is also present in the midrib cross-section. However, the secretory canals are only found near the phloem tissues as shown in Figure 4.50.

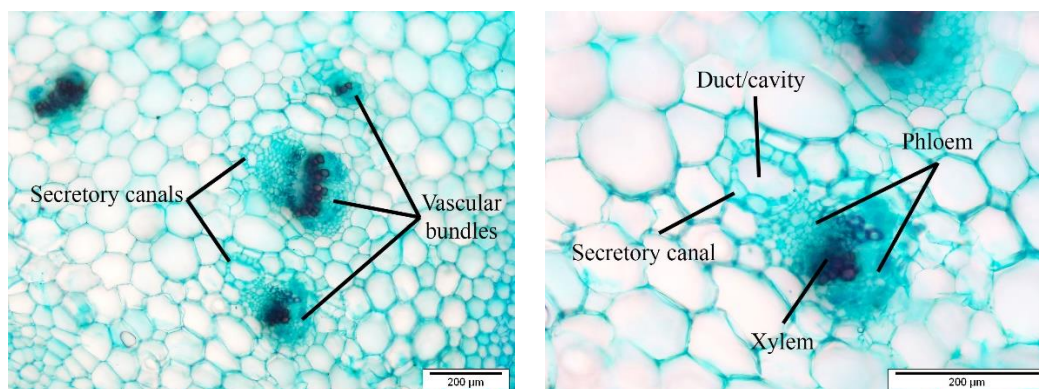


Figure 4.50: The secretory canal and vascular bundles in *M. kazuea*

Table 4.28: The measurement of duct/cavity and secretory canal in midrib cross-section

Taxa	Average size of duct/cavity (µm)	Average size of secretory canal (µm)
<i>M. glandulosa</i>	52.581 x 65.288	94.004 x 115.007
<i>M. glauca</i> var. <i>beccarii</i>	34.277 x 34.610	50.222 x 58.581
<i>M. glauca</i> var. <i>boraginea</i>	29.838 x 38.001	49.300 x 60.141
<i>M. glauca</i> var. <i>glauca</i>	53.438 x 32.576	101.468 x 72.160
<i>M. glauca</i> var. <i>hirta</i>	21.781 x 40.660	54.688 x 57.371
<i>M. glauca</i> var. <i>versipes</i>	N/A	N/A
<i>M. kazuea</i>	60.662 x 59.509	82.832 x 88.576
<i>M. selaborensis</i>	N/A	N/A
<i>M. singularis</i> var. <i>singularis</i>	N/A	N/A
<i>M. singularis</i> var. <i>aff. singularis</i>	45.500 x 45.329	72.406 x 76.189
<i>M. tenuis</i>	50.851 x 57.540	87.947 x 91.204
<i>M. aff. tenuis</i>	45.740 x 59.041	84.832 x 98.015

*N/A – not available, unable to observed

Table 4.28 shows the measurement of the duct/cavity in the secretory canal and the size of the secretory canal of *Monophyllaea*. *Monophyllaea glauca* var. *hirta* has the smallest average size of duct/cavity with 21.781 x 40.660 µm and *M. kazuea* has the largest average size of duct/cavity with 60.662 x 59.509 µm. The largest secretory canal was found in *M.*

glandulosa with a size of 94.004 x 115.007 µm and the smallest secretory canal was found in *M. glauca* var. *boraginea* with a size of 49.300 x 60.141 µm.

4.5.3 General Discussion

The anatomy of the stem is not useful to identify the species of *Monophyllaea* as the result showed similar characteristics. However, there are small characters in the midrib that can support species identification. The stem and midrib are best cut when it is freshly collected but the sample also can be soaked in 60% ethanol to maintain the turgidness cell. However, the stem and midrib became too soft to be cut after being soaked in ethanol for several weeks. During the cutting process using microtome and staining, the cut layer of stem and midrib needs to be handled extra cautiously as the thin layer is fragile and easily torn.

4.6 Palynology Study

Pollen studies were carried out on all 12 *Monophyllaea* taxa collected in western Sarawak (Appendix 4.1). Several factors have been evaluated, including pollen unit, polarity, aperture, shape, size, and exine surface ornamentation.

4.6.1 Pollen Unit and Polarity

Pollen units in Gesneriaceae are primarily monads and isopolar (Luegmayer, 1993). Because isopolar pollen has identical proximal and distal poles, the equatorial plane is symmetric (Halbritter et al., 2018). *Monophyllaea* pollen exhibited monads, isopolarity, and radial symmetry.

4.6.2 Pollen Aperture

According to Leugmayr (1993), the aperture of Gesneriaceae was generally tricolpate or tricolporate, with only a small fraction of the few species examined having a tetracolpate aperture. Figure 4.51 depicts three types of apertures observed in *Monophyllaea*: tricolpate, tetracolpate, and tricolporate.

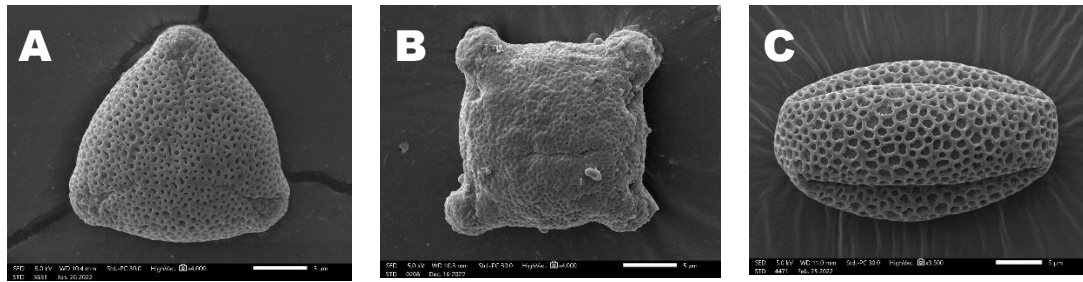


Figure 4.51: Aperture of pollen in *Monophyllaea*. **A.** Tricolpate, **B.** Tetracolpate, **C.** Tricolporate

According to Leugmayr (1993), the pollen of Gesneriaceae contained ectexinous glanular components that frequently covered the endexious colpus membrane and were rarely smooth. As shown in Figure 4.52, some *Monophyllaea* pollen contained ectexinous glanular components that frequently covered the endexious colpus membrane, and the majority of them had a rough surface of the endexious colpus membrane.

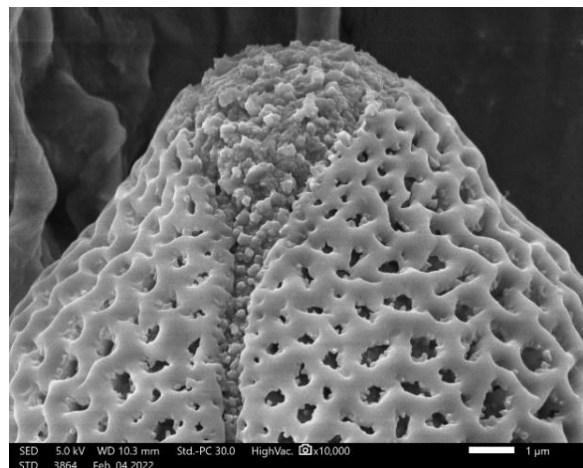


Figure 4.52: Ectexinous glanular elements covered the endexious colpus membrane in *Monophyllaea singularis* var. *aff. singularis*

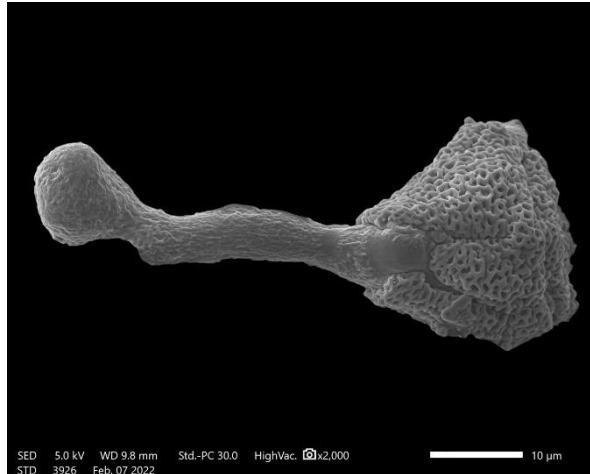


Figure 4.53: A pollen tube rises from pollen of *M. glauca* var. *beccarii*

Usually, the aperture serves as the primary location for germination (Halbritter et al., 2018). A single pollen tube often emerges during germination, as shown in Figure 4.53.

4.6.3 Pollen Shape, Outline and Size

Pollen shapes are determined by the 3-dimensional shape of a pollen grain concerning the P/E ratio (Halbritter et al., 2018). P/E ratio refers to the ratio of the equatorial diameter (E) to the length of the polar axis (P) between the two poles. There are four shapes of pollen in *Monophyllaea* (Figure 4.54), which are sub-spheroidal, triangular pyramid, quadrangular and prolate.

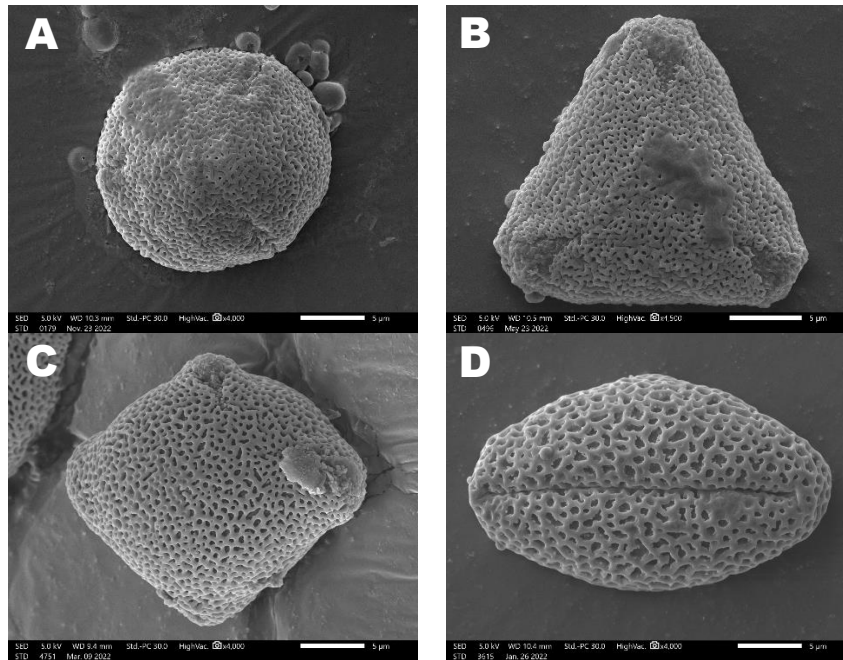


Figure 4.54: Shape of pollen. **A.** Subspheroidal, **B.** Triangular pyramid, **C.** Quadrangular, **D.** Prolate

Outline

The pollen of *Monophyllaea* varies in shape based on findings by Luegmayer (1993), which were semi-angular to angular in the polar view and sub-oblate to oblate in the equatorial view. There are different outline shapes of the polar view and equatorial view, as illustrated in Figure 4.55 and Figure 4.56. Based on the result, pollen in *Monophyllaea* also consists of non-angular shapes like circular and lobate outlines (polar view) and angular shapes like rhombic broad outline shapes (equatorial view).

Polar view

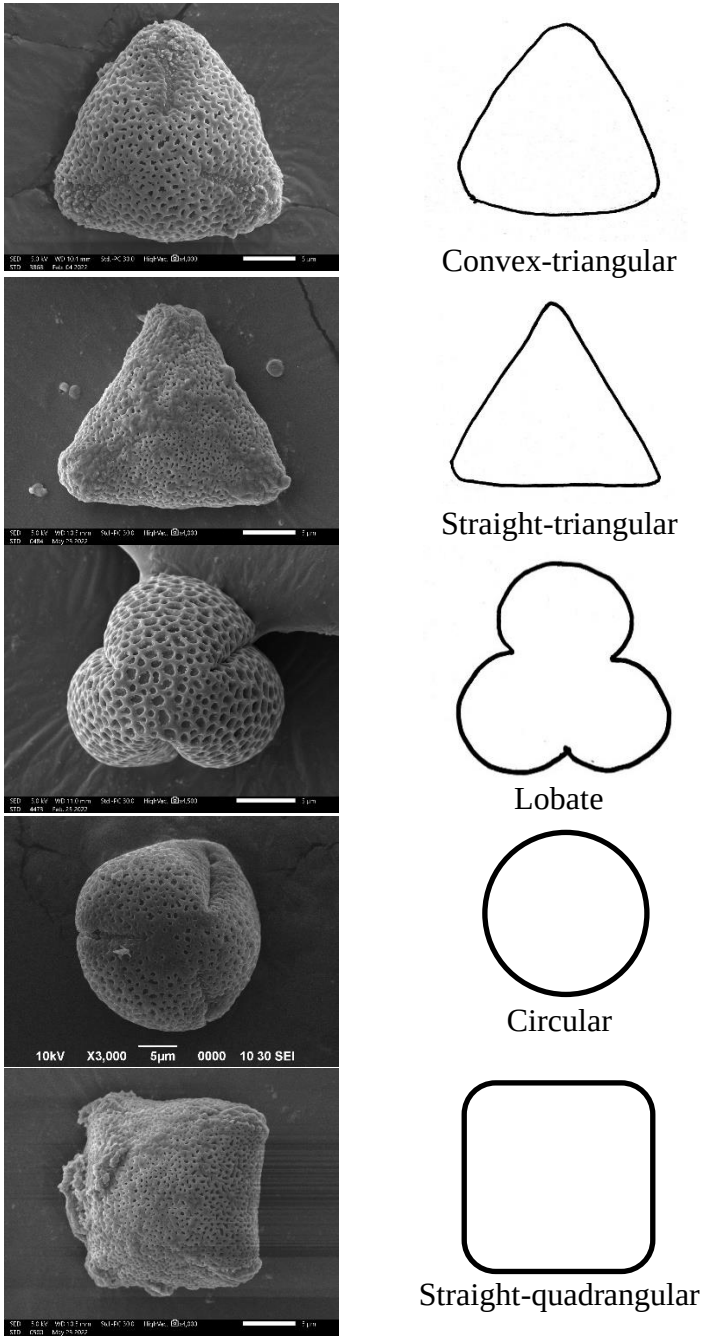


Figure 4.55: Various types of outline shapes in polar view

Equatorial view

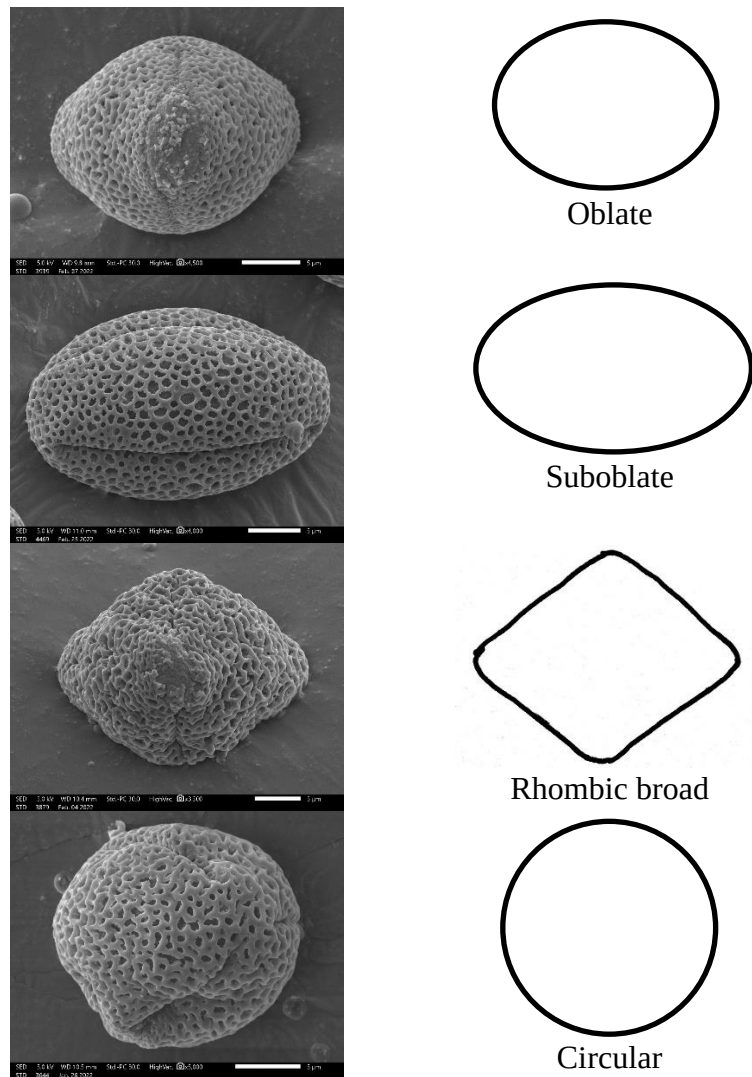


Figure 4.56: Various types of outline shapes in equatorial view

Table 4.29: The characteristics and measurement of pollen

Taxa	Shape	Aperture	Polar Outline	Polar (µm)	Equatorial outline	Equatorial (µm)	Ratio (P/E)
<i>M. glandulosa</i>	Spherical	Tricolpate	Circular	21.41 – 25.21	Circular	19.80 – 24.31	1.06
	Prolate	Tricolporate	Lobate	17.54 – 21.35	Suboblate	24.45 – 28.23	1.35
<i>M. glauca</i> var. <i>beccarii</i>	Triangular pyramid	Tricolpate	Convex-triangle	19.15 – 22.21	Oblate	19.39 – 23.82	0.92
	Quadrangular	Tetracolpate	Straight-quadrangular	17.35	Suboblate	18.91	0.92
<i>M. glauca</i> var. <i>boraginea</i>	Triangular pyramid	Tricolpate	Convex-triangle	22.20 – 28.48	Oblate	21.67 – 32.46	0.94
	Prolate	Tricolporate	Lobate	19.84 – 21.53	Suboblate	27.43 – 31.49	0.70
<i>M. glauca</i> var. <i>glauca</i>	Triangular pyramid	Tricolpate	Convex-triangle	18.28 – 22.64	Oblate	18.73 – 24.63	0.94
	Quadrangular	Tetracolpate	Straight-quadrangular	17.95	Suboblate	19.18	0.94
<i>M. glauca</i> var. <i>hirta</i>	Triangular pyramid	Tricolpate	Convex-triangle	20.37 – 24.33	Oblate	20.78 – 24.20	0.99
	Prolate	Tricolporate	Lobate	20.09 – 23.61	Suboblate	27.77 – 31.44	0.74
	Quadrangular	Tetracolpate	Straight-quadrangular	22.70	Suboblate	25.99	0.87
<i>M. glauca</i> var. <i>versipes</i>	Triangular pyramid	Tricolpate	Convex-triangle	17.64 – 26.07	Oblate	19.58 – 26.90	0.94

Table 4.29: The characteristics and measurement of pollen (continued)

<i>M. kazuea</i>	Triangular pyramid	Tricolpate	Straight-triangle	19.12 – 20.50	Suboblate	19.52 – 23.27	0.93
	Quadrangular	Tetracolpate	Straight-quadrangular	19.03 – 19.04	Suboblate	18.64 - 18.74	1.02
<i>M. selaborensis</i>	Prolate	Tricolporate	Lobate	17.57 – 18.92	Suboblate	29.25 – 31.11	0.60
<i>M. singularis</i> var. <i>singularis</i>	Triangular pyramid	Tricolpate	Convex-triangle	19.31 – 21.56	Oblate	20.14 – 24.62	0.95
<i>M. singularis</i> var. <i>aff. singularis</i>	Triangular pyramid	Tricolpate	Convex-triangle	20.27 – 21.33	Oblate	20.34 – 22.11	0.98
<i>M. tenuis</i>	Triangular pyramid	Tricolpate	Convex-triangle	18.64 – 25.10	Oblate	20.30 – 26.96	0.93
	Prolate	Tricolporate	Lobate	14.94 – 20.61	Suboblate	25.73 – 28.39	0.65
<i>M. aff. tenuis</i>	Triangular pyramid	Tricolpate	Convex-triangle	21.05 – 22.19	Oblate	20.60– 24.98	0.93
	Quadrangular	Tetracolpate	Straight-quadrangular	16.19 – 18.64	Suboblate	16.44 – 17.75	1.01

Pollen size

Table 4.29 shows the characteristics and measurement of pollen in 12 taxa of *Monophyllaea*. In tricolpate pollen, the smallest pollen is *M. glauca* var. *versipes* with 17.64 – 26.07 μm (polar view) and 19.58 – 26.90 μm (equatorial view) while the largest pollen is *M. glauca* var. *boraginea* with 22.20 – 28.48 μm (polar view) and 21.67 – 32.46 μm (equatorial view). Most of *Monophyllaea* have tricolpate pollen except for *M. selaborensis*.

Five *Monophyllaea* species were found to have tetracolpate pollen, including *M. glauca* var. *beccarii*, *M. glauca* var. *glauca*, *M. glauca* var. *hirta*, *M. kazuea* and *M. aff. tenuis*. The smallest tetracolpate pollen is *M. aff. tenuis* with 16.19 – 18.64 μm (polar view) and 16.44 – 17.75 μm (equatorial view) compared to the largest tetracolpate pollen *M. glauca* var. *hirta* with 22.70 μm (polar view) and 25.99 μm (equatorial view).

Tricolporate pollen was found mainly in *M. selaborensis*. However, there are some found in small quantities in *M. glandulosa*, *M. glauca* var. *boraginea*, *M. glauca* var. *hirta* and *M. tenuis*. The smallest tricolporate pollen was *M. tenuis* with 14.94 – 20.61 μm (polar view) and 25.73 – 28.39 μm (equatorial view), while *M. glauca* var. *hirta* has the largest tricolporate pollen with 20.09 – 23.61 μm (polar view) and 27.77 – 31.44 μm (equatorial view).

Table 4.30: Range of pollen size

Size	Measurement (µm)
Very small	<10
Small	10 – 25
Medium	25 - 50
Very large	>100

The size of pollen grain followed (Edertman, 1945; Halbritter et al., 2018), the categorisation of different pollen size classes based on the size expressed as the length of the longest axis as showed in Table 4.30. Based on Table 4.31, the pollen in *Monophyllaea* are small to medium size grains.

Table 4.31: Small and medium size pollen in *Monophyllaea* taxa

Small size pollen grain	Medium size pollen grain
<i>M. glauca</i> var. <i>beccarii</i>	<i>M. glandulosa</i>
<i>M. glauca</i> var. <i>glauca</i>	<i>M. glauca</i> var. <i>boraginea</i>
<i>M. kazuea</i>	<i>M. glauca</i> var. <i>hirta</i>
<i>M. singularis</i> var. <i>singularis</i>	<i>M. glauca</i> var. <i>versipes</i>
<i>M. singularis</i> var. <i>aff. singularis</i>	<i>M. selaborensis</i>
<i>M. aff. tenuis</i>	<i>M. tenuis</i>

4.6.4 Exine Surface Ornamentation

Exine ornamentation gives substantial diagnostic characteristics as it is a variable feature in Gesneriaceae. According to Luegmayr (1993), the exine pattern is the character of the greatest ability and taxonomically significant trait.

Monophyllaea pollen has two forms of exine ornamentation: reticulate and microreticulate (Table 4.32). A reticulate exine pattern is a network-like pattern composed of muri and lumina, where the muri are equal to or narrower than the lumina's width. The reticulate exine pattern, as illustrated in Figure 4.57, has a lumina of 1 μm or higher in diameter, whereas the micro reticulate has a lumina of less than 1 μm in diameter (Punt et al., 2007; Halbritter et al., 2018). The lumina has somewhat circular to irregular shapes as well.

Table 4.32: The exine surface ornamentation in *Monophyllaea*

Reticulate	Microreticulate
<i>M. glandulosa</i>	<i>M. glauca</i> var. <i>beccarii</i>
<i>M. glauca</i> var. <i>glauca</i>	<i>M. glauca</i> var. <i>boraginea</i>
<i>M. glauca</i> var. <i>hirta</i>	<i>M. kazuea</i>
<i>M. glauca</i> var. <i>versipes</i>	<i>M. aff. tenuis</i>
<i>M. selaborensis</i>	
<i>M. singularis</i> var. <i>singularis</i>	
<i>M. singularis</i> var. <i>aff. singularis</i>	
<i>M. tenuis</i>	

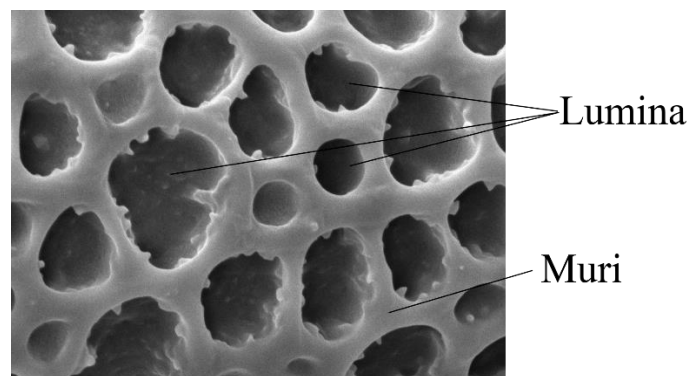


Figure 4.57: The lumina (holes) and muri (ridges) on pollen grain

Furthermore, Luegmayr (1993) discovered noticeable and prominent minute sinuses at the lateral surface of muri in *Monophyllaea*. Figure 4.58 shows noticeable minute sinuses on the lateral surface of the muri of *M. selaborensis* pollen. *Monophyllaea glandulosa*, *M. glauca* var. *beccarii*, *M. glauca* var. *boraginea*, *M. glauca* var. *hirta*, *M. singularis* var. *singularis*, *M. singularis* var. *aff. singularis*, *M. tenuis*, and *M. aff. tenuis* all have noticeable minute sinuses on the lateral surface of the muri.

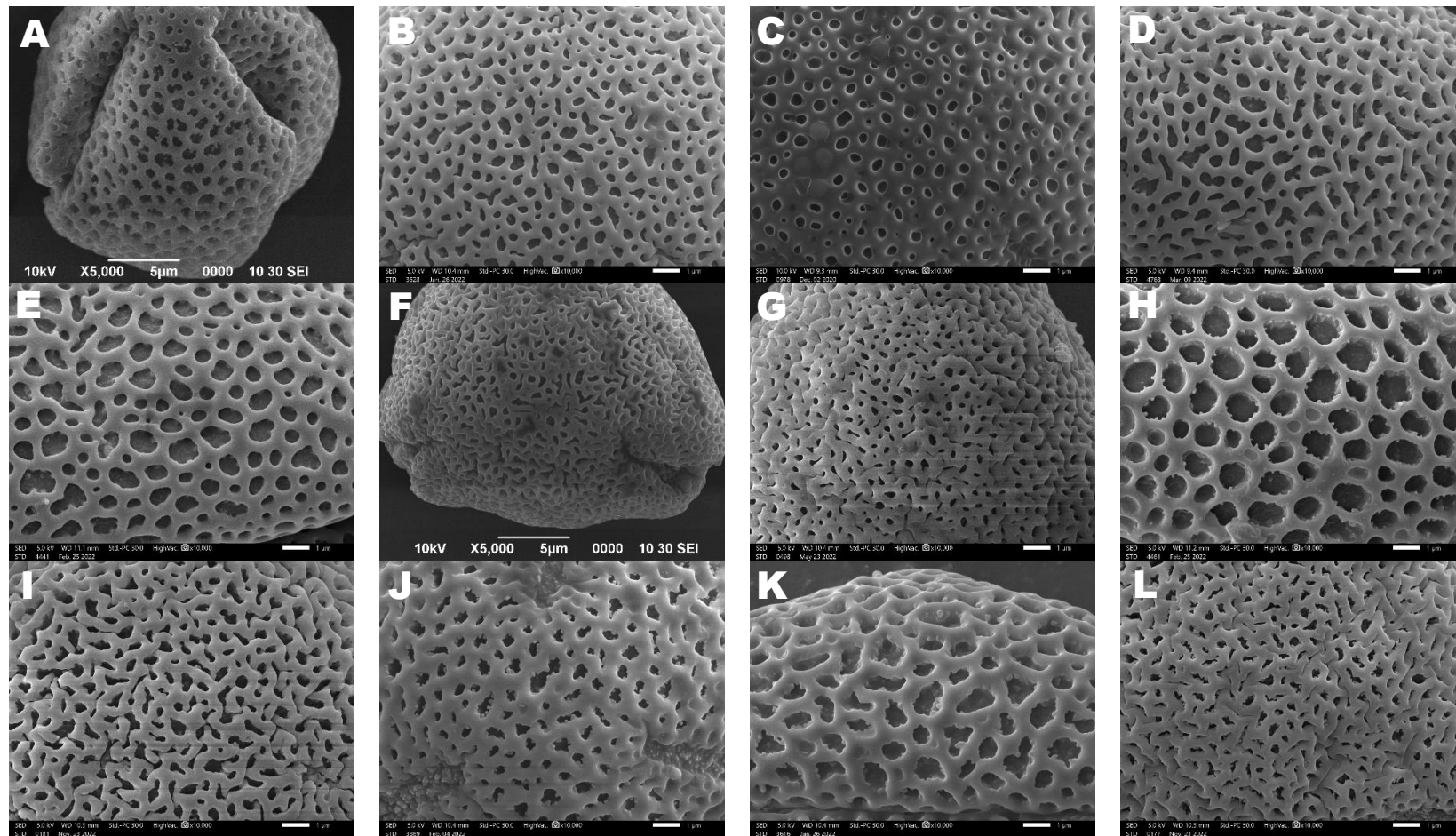


Figure 4.58: The exine surface ornamentation of *Monophyllaea*. **A.** *M. glandulosa*, **B.** *M. glauca* var. *beccarii*, **C.** *M. glauca* var. *boraginea*, **D.** *M. glauca* var. *glauca*, **E.** *M. glauca* var. *hirta*, **F.** *M. glauca* var. *versipes*, **G.** *M. kazuea*, **H.** *M. selaborensis*, **I.** *M. singularis* var. *singularis*, **J.** *M. singularis* var. *aff. singularis*, **K.** *M. tenuis*, **L.** *M. aff. tenuis* [All x10 000 magnification except for *M. glandulosa* and *M. glauca* var. *versipes* x5000 magnification]

4.6.5 General Discussion

Palynology study of the genus *Monophyllaea* showed strong characters in pollen morphology which is extremely useful in the identification of the species. *Monophyllaea* pollen were monads, isopolarity, and radial symmetry with three types of apertures observed which were tricolpate, tetracolpate, and tricolporate. The size of pollen in 14 taxa of *Monophyllaea* were small and medium sized. The polar view of *Monophyllaea* pollen showed angular to semi angular to non-angular shape. The equatorial view of *Monophyllaea* pollen exhibit mostly angular to non-angular shape. *M. glandulosa* had distinct shape which was circular shape in both polar and equatorial view among all 14 *Monophyllaea* taxa. *M. kazuea* also showed significant shape in polar view as it was straight-triangular. There were two types of exine ornamentation found in *Monophyllaea* which were reticulate and microreticulate.

The simple methods such as dropping distilled water on pollen and drying it in a desiccator jar produced great results on the observation of pollen using SEM or FESEM. Even the flowers of *Monophyllaea* easily fall off, the flowers can be soaked in FAA or 4% glutaraldehyde and then washed with distilled water to help remove excess chemical substances and this produces a better and clearer image of FESEM.

4.7 PAST: Analysis

Based on Euclidean principles, a numerical cluster analysis of important morphological characteristics has apparently separated the species under study into many clusters. The selected characteristics were based on the comparison of morphological characteristics including stem, leaf, peduncle, pedicel, calyx, corolla, filament, anther, ovary, style and seed. Figure 4.59 illustrates the relationship between the species studied using dendrogram of hierarchical clustering based on morphological characteristics.

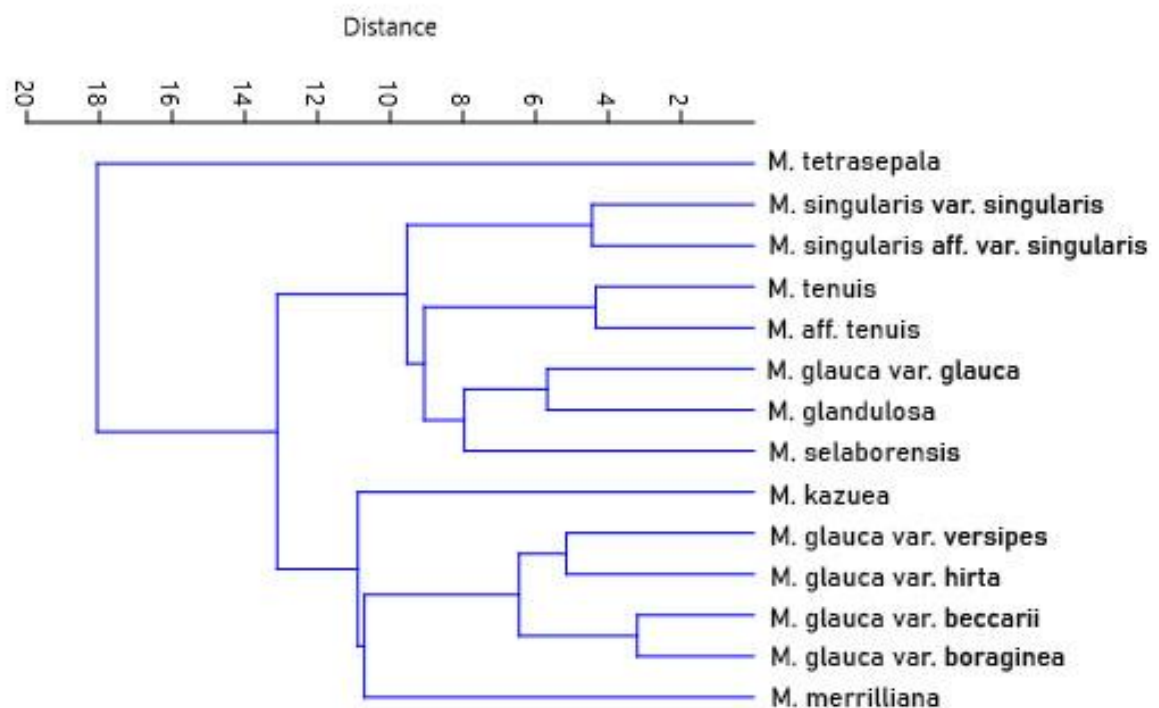


Figure 4.59: Dendrogram of relationship of morphological characteristics of 14 *Monophyllaea* taxa using Euclidean similarity and UPGMA algorithm.

The dendrogram divided the taxa into two cluster in which *M. tetrasepala* was positioned at a separate cluster. This shows *M. tetrasepala* is totally different compared to the other taxa based on the comparison of morphological characteristics. The second cluster consists of 13 taxa which divided into two sub-cluster. *M. singularis* var. *singularis* and *M. singularis* aff. var. *singularis* same as *M. tenuis* and *M. aff. tenuis* were grouped into the same cluster respectively as they have similarities in most of the characters. Based on the dendrogram, the result showed the analysis is important for taxa/species identification. However, further molecular studies need to be done to investigate the relationship between all the taxa intensively.

CHAPTER 5

SPECIES/ TAXONOMIC TREATMENT

A total of 12 *Monophyllaea* taxa were collected around western Sarawak. Three individual living specimens based on the availability during the field collection were described and measured. All of the samples collected were preserved in 70% ethanol and herbarium preparation. Two species, *M. merrilliana* and *M. tetrasepala* were studied based on the herbarium sample available in Sarawak Herbarium (SAR).

5.1.1 General Description of Genus *Monophyllaea* B. L. Burtt

Monophyllaea R. Br. in Bennet, Pl. Jav. Rar. 121 (1840); DC., Prodr. 9:274 (1845); Benth. in Benth. & Hook. f., Gen. Pl. 2:1017 (1876); C. B. Clarke in A. DC., Mon. Phan. 5(1): 181 (1883); K. Fritsch in Engl. & Prantl, Nat. Pflanzenfam. 4(3B):160 (1895), et Nachtr. 4 zu 2 – 4:328 (1915).

Syn: *Horsfieldia* Chiffot in Compt. Rend. Acad. Sc. Paris, 148:941 (1909) – non Willd.

Type: *H. javanica* Chiffot = *M. horsfieldii* R. Br.

Moultonia Balf. fil. & W. W. Sm. In Notes R. B. G. Edinb. 8:349 (March 1915) et in Sarawak Mus. Journ. 2:276 (Sept. 1915); Steenis in Blumea 11:133 (1961). Type: *M. singularis* Balf. fil. & W. W. Sm.

Type species: *M. horsfieldii* R. Br.

Descriptions: Herbs with fleshy stem, perennial monocarpic or annual herbs, Stem usually (hypocotylar) fleshy in origin, with medullary vascular bundles, usually bearing a single leaf (the macrocotyledon) ever-growing leaf, occasionally a few species caulescent with 3 – 4 petiolate leaves; whole plant provided with chalk glands; leaf lamina with basal meristem, lateral nerves close together near leaf base, becoming more widely spaced higher up and usually about 1 – 2 cm apart in middle of leaf, usually wide-spreading from midrib, more ascending near leaf margin. **Inflorescences** are often long-pedunculate, usually pedunculate arising at or just below the base of the leaf, occasionally also scattered along the midrib, with small subtending bracts at the base and sometimes 3 – 4 with a short common peduncle; peduncles simple or branched; flowering axis helicoid cyme, flowers in pairs, pedicellate, ebracteate; more rarely flower borne singly or 2 – 3 on a very short peduncle in crowded zone on one side of stem and/or along midrib of leaf. **Calyx** 4 – 5 partite; segments descending imbricate, the uppermost outside, somewhat broader than the rest and often slightly carinate, one of the anterior laterals wholly inside and narrower than the rest, all concave on the inside, streaked with longitudinal secretory canals, provided with a central patch of chalk glands on the inside. **Corolla** in the range 5 – 15 mm long, with tube and limb roughly equal; tube usually bearded inside below the filaments with moniliform unicellular hairs; upper lip 2-lobed; lower lip 3-lobed with a patch of erect cylindrical unicellular hairs on the palate; the lobes descending imbricate, often with short 2 – 3-celled uniseriate papillae. **Stamens** 4 fertile, with or without a short linear posterior staminode: filaments arising about the middle of the tube, the posterior pair often lower than the anterior and shorter than them, so that the anterior are strongly arcuate or even curved back to bring

anthers into contact, often with a small tooth at apex; anthers with 2 divergent thecae soon confluent, usually all four cohering by their edges to form a down-facing plate, more rarely didynamous or all free. **Disc** cupular, thick, undulate or lobulate. **Ovary** bilocular with numerous ovules on axile placentae; style persistent and simple, swelling after anthesis; stigma capitate, or slightly peltate, or umbilical. **Fruit** capsular, often thin-walled, sometimes breaking up into 4 valves after fall of persistent, often swollen, style, or sometimes without valves, the top of the ovary covered by the expanded style base and the fruit effectively porose when it falls. **Seeds** small, c. 0.5 mm, ellipsoid, dark brown, reticulate, occasionally the reticulate pattern with a spiral twist.

Distribution: South Thailand, Langkawi Islands, Malay Peninsula, Sumatra, Java, Borneo, Philippines (Luzon, Samar, Bohol and Mindanao), Celebes, Ceram, New Guinea.

5.1.2 General Key for Species Identification of the Genus *Monophyllaea* from Western Sarawak

Field key to Monophyllaea species of Western Sarawak (modified from Burtt, 1978)

- 1a. Flowers arising in continuous zone on adaxial side of petiolode* and/or on midrib.....2
- 1b. Flowers in pedunculate inflorescence from base of leaf or just below it on petiolode.....3
- 2a. Flowers arising in groups of 3 – 5 with very short stalk.....

M. singularis var. *singularis*

- 2b. Flowers arising in groups of 1 – 2 with very short stalk.....
- M. singularis* var. *aff. Singularis***
- 3a. Inflorescence spread scattered on the midrib and branched.....**4**
- 3b. Inflorescence arising clustered from the leaf base and not branched.....**5**
- 4a. Hairs branched ***M. merrilliana***
- 4b. Hairs simple ***M. tetrasepala***
- 5a. Pedicel shorter than or equal to calyx, eventually disarticulating just above base and leaving regular row of stubs; fruit wall not valvular**6**
- 5b. Pedicel longer than calyx, not usually disarticulating regularly; fruit wall valvular ..**7**
- 6a. Peduncle glabrous or shortly pilose; corolla bearded inside ***M. glauca***
- 6b. Peduncle hairy; corolla bearded heavily above ***M. kazuea***
- 7a. Upper corolla-lobes very oblique at base ***M. glandulosa***
- 7b. Upper corolla-lobes erect or slightly oblique at base **8**
- 8a. Corolla-lobes with recurved margins, appearing acute; glandular hairs coarse; calyx segment erose at tip ***M. selaborensis***
- 8b. Corolla-lobes flat, rounded; glandular hairs slender; calyx segment entire at tip**9**

- 9a. Peduncle covered with densely thinly pilose glandular hairs, pedicel covered densely with thinly pilose glandular hairs ***M. tenuis***
- 9b. Peduncle covered with sparsely thinly pilose glandular hairs below and glabrous as reach upper part; pedicel glabrous ***M. aff. tenuis***

Key to varieties (Burt, 1978):

- 1a. Leaf and inflorescence glabrous **var. *glauca***
- 1b. Leaf or inflorescence hairy **2**
- 2a. Leaf glabrous above, or slightly hairy on basal lobes, or with a very few scattered hairs on upper surface; pedicels and usually calyx with indumentum of stiff brown hairs.....
var. *hirta*
- 2b. Leaf with erect hairs all over upper surface **3**
- 3a. Pedicels and calyx with rather dense indumentum of brown hairs; young fruiting pedicels deflexed..... **var. *versipes***
- 3b. Pedicels and calyx glabrous or with short white hairs; young fruiting pedicels erect... **4**
- 4a. Hairs on leaf soft, from slender base; base of peduncle glabrous..... **var. *beccarii***
- 4b. Hairs on leaf harsh, from thick swollen persistent base; base of peduncle with scattered stiff spreading hairs..... **var. *boraginea***

5.1.3 Description of Genus *Monophyllaea*

1. *Monophyllaea glandulosa* B. L. Burt

Description: **Stem** 7.0 – 16.0 cm x 1.8 – 3.0 cm, sparsely long glandular hairs, rough surface, heavily encrusted, pale green. **Leaf** up to 17.0 – 37.0 cm x 12.5 – 27.5 cm, ovate-oblong, cordate at base, acute apex, entire, thick, upper surface sparsely white glandular hairs, slightly encrusted, green, underside with sparsely white glandular hairs and heavily encrusted, pale green, younger parts with few scattered hairs above. **Inflorescences** 2 – 5 arising from the leaf base, simple helicoid two-paired cyme, glandular-pilose throughout; slightly encrusted; **peduncle** 11.0 – 34.3 cm x 1.3 – 2.9 cm, densely white glandular hairs, slightly encrusted, pale green; flowering axis 5.4 – 17.2 cm, flower pairs c. 2 – 3 mm apart; **pedicels** 7 – 9 mm, densely white glandular hairs, slightly encrusted, pale green. **Calyx** 4 – 5 calyxes, dorsal calyx 2.7 – 3.6 x 1.7 – 1.8 mm, ventral calyx 2.4 – 3.5 x 1.5 – 1.6 mm, acute apex, densely white glandular hairs outside, slightly encrusted, pale green; tube 0.5 mm; segments 2.5 – 3.0 mm, striate (showing the lines of the secretory canals) when dry. **Corolla** c. 9 mm, white, mouth yellow, very oblique; tube 5 mm to lateral sinus, only 3 mm to dorsal sinus, slightly bearded inside the below the stamens; upper lobes 1 x 3 mm, very oblique at base, reflexed, translucent white, laterals 3.5 x 5 mm, median 3 x 4 mm, both laterals and median orbicular-spatulate, white with yellow patch at centre of palate, all ciliolate. **Stamens** posterior filaments arising 1.5 mm above base, 0.5 mm long, anterior

filaments nearly 3 mm above base, 1 mm long, glabrous; anthers 1 mm diam. **Disc** 0.5 mm.

Ovary 1 mm; style 1.5 mm, glabrous. **Capsule** 2 mm, persistent style 1.5 mm, thickened at base. **Seed** 0.228 – 0.254 x 0.165 – 0.183 mm, globose, reticulate.

Specimen examined: Borneo, Malaysia, Sarawak, Padawan, Teng Bukap, Gunung Jacket, 11 July 2019 and 28 October 2020, *Nur Athirah Nabihah, M. M., Meekiong, K., Nurul Khaleeda, R., NAN0007, NAN0008* (Herbarium of Universiti Malaysia Sarawak).

Ecology and habitat: Found it growing on the limestone vertical hills at 13 m elevation near the small river with sandy soil with less than 20 individuals.

Distribution: Sarawak

Notes: *M. glandulosa* is particularly distinctive among Sarawak species due to the very oblique corolla mouth, with the upper lobes being oblique at the base and reflexed.



Figure 4.60: Botanical picture of *M. glandulosa* B. L. Burtt. collected from limestone area in Teng Bukap, flower (image in circle)

2. *Monophyllaea glauca* var. *beccarii* B. L. Burtt

Description: **Stem** 15.1 – 30.5 cm x 2.4 – 5.1 cm diam, slightly encrusted, greenish brown or reddish brown; **Leaf** 21.5 – 39.2 cm x 23 – 35 cm, broadly ovate, deeply cordate at base, acute apex, entire margin, thick, upper surface with scattered white soft bulbous-based hairs, glabrous, green, lower surface scattered soft white scabrid with bulbous-based hairs, slightly

encrusted, pale green. **Inflorescence** arising at base of the lamina, 2 – 6, more or less contemporaneous, simple helicoid cyme; **peduncle** 5 – 25.1 cm x 2 – 3 cm diam, glabrous, slightly encrusted, light green or greenish brown or reddish brown, flowering axis 2 – 5 cm, clustered of multiple flowered bud; **pedicel** 2.8 – 5 mm, densely white or brown thinly pilose hairs, glabrous surface, pale green. **Calyx** 5 – 6 mm; tube 1.5 – 1.75 mm, segments 5 (rarely 4), 4 – 4.5 mm long, oblong, obtuse, blunt, no encrustation, densely with thinly brown pilose hairs, pale green, the dorsal one more or less carinate on the back and slightly larger, dorsal 5.9 – 6.1 x 2.3 – 2.6 mm, ventral 5.3 – 5.6 x 1.6 – 1.7 mm. **Corolla** 7.5 mm; tube broadly cylindric, c. 5 mm, bearded inside c. 1.5 cm above base; upper lobes 2.5 – 3 x 1.9 – 2 mm, orbicular, translucent white, erect; lower lip 5 mm, densely papillose, with central yellow patch with a purple bar below it, lateral lobes 2.7 – 3.9 x 2.5 – 2.8 mm, orbicular, median 2.7 x 3.1 mm, orbicular-spatulate. **Stamens** with posterior filaments arising 2.5 mm above base of tube, 2 mm, hairy at top; anterior arising 3 mm above base of tube, 3 mm, strongly arcuate, connective with distinct apical tooth, hairy; anthers 0.75 mm diam. **Disc** 0.6 mm. **Ovary** 1.3 x 0.9 mm, globose; style 1.0 mm, both glabrous. **Capsule** 3.1 x 2.3 mm, surmounted by strongly thickened conical style 2.4 mm long. **Seeds** 0.4 – 0.435 x 0.194 – 0.223 mm, ellipsoid, polygonal with straight or slightly curve raised ridges, dark brown.

Specimen examined: Borneo, Malaysia, Sarawak, Padawan, Gunung Kebik, 22 June 2019, *Nur Athirah Nabihah, M. M., Meekiong, K., Nurul Khaleeda, R., NAN0001, NAN0002, NAN0003* (Herbarium Universiti Malaysia Sarawak); Gunung Ma'asa, 13 January 2022, *Nur Athirah Nabihah, M. M., Meekiong, K., Nurul Khaleeda, R., Umie Naylisa, A., NAN0012* (HUMS).

Ecology and distribution: Found growing at elevation of 32 – 38 m at shaded area on foothill of limestone with less than 20 individuals.

Distribution: Sarawak.



Figure 4.61: Botanical picture of *M. glauca* var. *beccarii* B. L. Burt. collected from limestone area in Gunung Ma'asa, flower (image in circle)

3. *Monophyllaea glauca* var. *boraginea* B. L. Burtt

Type: Sarawak, Lobb (K).

Description: **Stem** 13 – 25 cm x 2.5 – 3.4 cm diam, erect, reddish brown to greenish brown, glabrous, slightly encrusted. **Leaf** 30 – 37 cm x 21.5 – 33 cm, broadly ovate, deeply cordate at base, acute apex, entire, upper surface with harsh white scabrid hairs arising from persistent bulbous-based, glabrous, green sometimes with silver marks or lining, lower surface with scattered harsh scabrid hairs with bulbous-based, slightly encrusted, pale green.

Inflorescence arising at the base of the lamina, 3 – 16; **peduncle** 13.1 – 25.2 x 2.4 – 3.7 cm, reddish brown to greenish brown, slightly encrusted; flowering part 3.1 – 6.5 cm, clustered with multiple flower bud; **pedicels** 3 – 4.7 mm, gaps between each pedicel 0.3 – 0.5 mm, densely or a few of short white stiff hairs, smooth surface, pale green. **Calyx** 3.58 – 6.30 mm x 1.52 – 1.94 mm, tube c. 1 – 1.75 mm; segments 5 (rarely 4), 4 – 4.5 mm, oblong, blunt, glabrous, densely or a few short white stiff hairs, the dorsal one more or less carinate on the back and slightly larger, dorsal 4.9 – 6.6 x 1.9 – 2.8 mm, ventral 4.0 – 6.5 x 1.7 – 1.9 mm. **Corolla** 7 – 8 mm; tube broadly cylindric, 4 – 4.5 mm, bearded inside c. 1.5 cm above base; upper lobes translucent white, erect, 1.8 – 3.2 x 1.5 – 3.1 mm, orbicular, lower lip 5 – 6 mm, densely papillose, central yellow patch with purple bar below it, lateral lobes 2.8 – 3.9 x 2.1 – 3.0 mm, orbicular, median 3.0 – 3.3 mm x 2.7 mm, orbicular-spatulate. **Stamens** with posterior filaments arising 2.5 mm above base of tube, red, 2 mm, hairy at top; anterior arising 3 mm above base of tube, white 1 mm, strongly arcuate, connective with distinct apical tooth, hairy; **anther** 0.52 – 0.63 mm diam. **Disc** 0.6 mm x 0.8 – 1.1 mm, yellow, glabrous. **Ovary** 1.3 x 0.9 mm, globose, pale green, style 1.5 – 1.6 mm. **Capsule** 2.5 x 1.9 mm, surmounted by strongly thickened conical; style 2.9 mm long. **Seed** 0.371 – 0.454 x

0.153 – 0.18 mm, ellipsoid, polygonal with straight or slightly curve raised ridges, dark brown.

Specimen examined: Borneo, Malaysia, Sarawak, Bau, near Bra'ang Range, Banjaran Gayu, 28 October 2020, *Nur Athirah Nabihah, M. M., Meekiong, K., Nabilah Huda, M. H., Umie Naylisa, A., NAN0009, NAN0010, NAN0011* (Herbarium of Universiti Malaysia Sarawak); Near Fairy Cave, 03 November 2020, *Nur Athirah Nabihah, M. M., Meekiong, K., Nabilah Huda, M. H., Umie Naylisa, A.*; Padawan, Teng Bukap, 03 December 2022, *Nur Athirah Nabihah, M. M., Meekiong, K., Nabilah Huda, M. H., Awang Ahmad Zahid, A. B., NAN0051, NAN0052, NAN0053* (HUMS).

Ecology and distribution: Found growing at elevation of 22 – 90 m at shaded area on foothill of limestone with more than 100 individuals.

Distribution: Sarawak.



Figure 4.62: Botanical picture of *M. glauca* var. *boraginea* B. L. Burtt. collected from limestone area in Teng Bukap, flower (image in circle)

4. *Monophyllaea glauca* var. *glauca* B. L. Burtt

Type: Sarawak, sine loc., *Lobb* (K).

Description: Stem 13 – 21 cm x 1.4 – 1.5 mm, glabrous, slightly encrusted, pale green. **Leaf** 30 – 31 cm x 26 – 27.2 cm, broadly ovate, deeply cordate at base, acute apex, entire,

subglabrous at both sides of leaf with a few scattered short sharp peripheral hairs merge into the marginal asperities, upper surface glabrous, green, lower surface slightly encrusted, pale green. **Inflorescence** arising at base of the lamina, 1 – 5, more or less contemporaneous, simple helicoid cyme; **peduncle** 10 – 16 cm x 2.7 – 3 cm, pale green or greenish brown, glabrous; flowering part 2 – 5 cm, clustered with multiple flower buds; **pedicels** 2.7 – 4.4 mm, gaps between each pedicel c. 0.3 – 0.5 mm, glabrous, reddish brown or pale green. **Calyx** 5.6 mm, glabrous, pale green; tube 1 – 1.75, segments 5 (rarely 4), 4 – 4.5 mm, oblong, blunt, glabrous, the dorsal one more or less carinate on the back and slightly larger, dorsal 5.1 x 3.0 mm, ventral 4.7 – 4.8 x 2.1 – 2.2 mm. **Corolla** 5.29 mm; tube broadly cylindric, 4.5 mm, bearded inside c.1.5 cm above base; upper lobes translucent white, erect, 2.2 – 3 x 1.3 – 2 mm, orbicular; lower lip 3 mm, densely papillose, with central yellow patch with a red bar below it, lateral lobes 2.8 – 3 x 2 mm, orbicular, median 2.6 x 2.2 mm, orbicular-spatulate. **Stamen** with posterior filaments arising 2.5 mm above base of tube, 2 mm, hairy at top; anterior arising 3 mm above base of tube, 3 mm, strongly arcuate, connective with distinct apical tooth, hairy; anthers 0.75 mm diameter. **Disc** 0.9 mm. **Ovary** 1.3 x 1.0 mm; style 2.6 mm; both glabrous. **Capsule** 2.5 – 2.1 mm, surmounted by strongly thickened with shallowly dome-shaped persistent style base; style 3 mm long. **Seed** 0.355 – 0.396 x 0.151 – 0.158 mm, ellipsoid, polygonal with straight or slightly curve raised ridges, dark brown.

Specimen examined: Borneo, Malaysia, Sarawak, Bau, Gunung Stulang, 15 February 2022, Nur Athirah Nabihah, M. M., Meekiong, K., Raffi, A, Nurul Khaleeda, R., Nurul Nabilah Huda, M. H., Umie Naylisa, A., NAN0017, NAN0018 (Herbarium of Universiti Malaysia Sarawak).

Ecology and distribution: Found growing at elevation of 42 – 80 m at shaded area on foothill of limestone with less than 30 individuals.

Distribution: Sarawak.



Figure 4.63: Botanical picture of *M. glauca* var. *glauca* B. L. Burt. collected from limestone area in Gunung Stulang, flower (image in circle)

5. *Monophyllaea glauca* var. *hirta* B. L. Burtt

Type: Sarawak, Lobb (K).

Description: **Stem** 32 – 37 cm x 2.7 – 3.7 cm, erect, pale green, glabrous, slightly encrusted. **Leaf** 30 – 40 x 21.5 – 27.5 cm, broadly ovate, deeply cordate at base, acute apex, entire, scattered short stiff erect hairs on upper surface, densely brown sometimes white short stiff hairs on lower surface, slightly encrusted. **Inflorescences** arising at base of the lamina, 1 – 6, simple helicoid cyme; **peduncle** 12.5 – 18 x 2.5 – 4.1 cm high, glabrous, pale green, flowering part 2 – 5 cm, clustered with multiple flower buds; **pedicels** 3.2 – 5 mm, gaps between each pedicel 0.3 – 0.5 mm, reddish brown or pale green, dense indumentum of brown or white short stiff hairs, sometimes with short dendroid branching. **Calyx** 4 – 5 mm, tube c. 1 – 1.75 mm; segments 5 (rarely 4), 4 – 4.5 mm, oblong, blunt, pale green or brown, densely white or brown stiff hairs or short dendroid branching hairs, the dorsal one more or less carinate on the back and slightly larger, dorsal 7.1 x 2.7 mm, ventral 5.7 x 2.1 mm. **Corolla** 6 mm x 4.81 mm; tube broadly cylindric, 4.5 mm, bearded inside, c. 1.5 cm above base; upper lobes translucent white, erect, 2.7 – 3 x 2.2 – 3 mm, orbicular, lower lips 4.81 – 5 mm, densely papillose, white with central yellow patch with purple bar below it, lateral lobes 3.1 x 2.0 mm, orbicular, median 2.8 x 2.1 mm, orbicular-spatulate. **Stamens** with posterior filaments arising 2.5 mm above base of tube, 2 mm, hairy at top; anterior arising 3 mm above base of tube, 3 mm, strongly arcuate, connective with distinct apical tooth, hairy; anthers 0.75 mm diam. **Disc** 0.6 x 1.2 mm, yellow. **Ovary** 1.5 x 1.0 mm, globose, green; style 2.0 mm, both glabrous. **Capsule** 2.8 x 2.6 mm, surmounted by strongly thickened conical style 2.8 mm long. **Seed** 0.377 – 0.426 mm, ellipsoid, polygonal with straight or slightly curve raised ridges, dark brown.

Specimen examined: Borneo, Malaysia, Sarawak, Serian, Tebakang, Gua Silabur, 25 February 2022, *Nur Athirah Nabihah, M. M., Meekiong, K., Nurul Khaleeda, R., Umie Naylisa, A., NAN0024* (Herbarium of Universiti Malaysia Sarawak).

Ecology and habitat: Found growing at elevation of 35 – 80 m at shaded area on foothill of limestone with more than 100 individuals.

Distribution: Sarawak.

Notes: In the inflorescence, brown simple hairs can occasionally be observed mixed with brown dendroid hairs.



Figure 4.64: Botanical picture of *M. glauca* var. *hirta* B. L. Burtt. collected from limestone area in Gua Silabur, flower (image in circle)

6. *Monophyllaea glauca* var. *versipes* B. L. Burtt

Synonym: *M. lowii* C. B. Cl. (as *lowei*) in DC. Mon. Phan. 5:183 (1883)?

Type: Borneo, *Low* (K).

Description: Stem 13.5 – 17 cm x 1.6 – 2.9 cm, heavily encrusted, pale green. **Leaf** 15 – 24 x 19.5 – 22.5 cm, broadly ovate, deeply cordate at base, acute apex, entire, upper surface densely with white and brown soft erect hairs, smooth surface, lower surface densely with white sometimes brown soft erect hair, slightly encrusted. **Inflorescences** arising at base of

the lamina, 2 – 3, simple helicoid cyme; **peduncle** 9 – 15.4 x 1.5 – 2 cm, reddish brown to pale green, glabrous, slightly encrusted; flowering part 1.4 – 3 cm, clustered with multiple flower buds; **pedicel** c. 3 – 5 mm, scattered with white stiff hairs, reddish brown or pale green, smooth surface, young fruiting pedicel deflexed for a short time then erect again. **Calyx** c. 5 – 6 mm, tube c. 1 – 1.75 mm; segments 5 (rarely 4), 4 – 4.5 mm, oblong, blunt, scattered with white erect hairs, pale green or greenish purple, the dorsal one more or less carinate on the back and slightly larger, dorsal 6 x 3 mm, ventral 5 x 2 mm. **Corolla** c. 7 cm; tube broadly cylindric, 4.5 mm, bearded inside c. 1.5 cm above base; upper lobes translucent white, erect, 3 x 2 mm, orbicular; lower lip 5 mm, densely papillose, white with central yellow patch with a purple bar below it, lateral lobes c. 3 x 3 mm, orbicular, median c. 3 x 3 mm, orbicular-spatulate. **Stamens** with posterior filaments arising 2.5 mm above base of tube, 2 mm, hairy at top; anterior arising 3 mm above base of tube, 3 mm, strongly arcuate, connective with distinct apical tooth, hairy; anthers 0.75 mm diam. **Disc** 0.75 mm. **Ovary** c. 1.5 mm, globose; style c. 2.5 mm, both glabrous. **Capsule** 3 x 2.5 mm, surmounted by strongly thickened conical style 2.5 mm long. **Seed** c. 0.3 – 0.4 mm, ellipsoid, polygonal with straight or slightly curve raised ridges, dark brown.

Specimen examined: Borneo, Malaysia, Sarawak, Bau, Gunung Doya, 22 June 2022, *Nur Athirah Nabihah, M. M., Meekiong, K., Nurul Khaleeda, R., NAN0004, NAN0005, NAN0006* (Herbarium of Universiti Malaysia Sarawak).

Ecology and habitat: Found growing at elevation of 61 m at shaded area on foothill of limestone with less than 10 individuals.

Distribution: Sarawak.

Notes: The leaf surface are dense with white or brown soft erect long hairs.

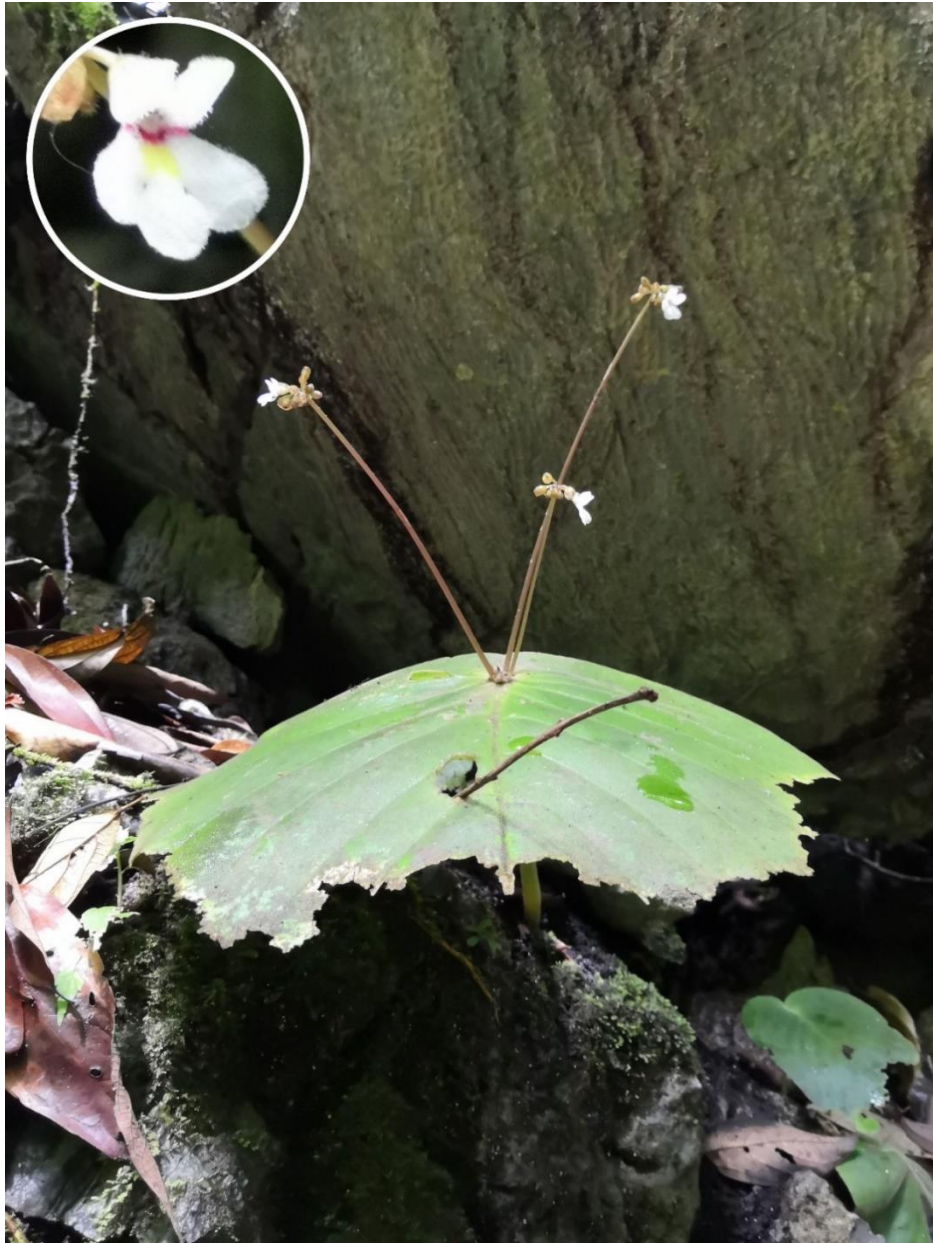


Figure 4.65: Botanical picture of *M. glauca* var. *versipes* B. L. Burt. collected from limestone area in Gunung Doya, flower (image in circle)

7. *Monophyllaea selaborensis* B. L. Burt

Description: **Stem** 13 – 15 x 1 – 1.5 cm, glabrous sometimes at first somewhat pilose with rather thick hairs, heavily encrusted, pale green; one or two secondary stems not infrequently arising among inflorescences on leaf base and themselves bearing a leaf and inflorescences. **Leaf** up to 35 cm x 27.5 cm, ovate – oblong, deeply cordate at base, entire, the most densely short white thinly pilose hairs near the base of the leaf near the inflorescence and none or rarely near the apex of leaf, slightly encrusted, green, hairy on the nerves below, the hairs becoming encrusted like the rest of the lower surface, pale green. **Inflorescences** arising from base of leaf, simple scorpioid two-paired cyme, in various stages on one plant but perhaps not produced in definite crops, the inflorescences not all contemporaneous, old withered peduncles often present when a fresh crop is flowering; **peduncle** 14 – 15 cm x 1.2 – 1.4 mm, thinly pilose with thick spreading hairs at lower peduncle and the presence of hairs getting lesser or none at the top of peduncle, slightly encrusted, pale green; flowering axis up to 3 – 10 cm; **pedicels** 5.5 – 6.2 x 2 mm, glabrous, slightly encrusted, pale green, two pedicels together arranged alternately along the flowering axis, usually a clustered of young pedicels at the tip of flowering axis with curled 360° inwards. **Calyx** tube 2.5 mm; segments 2.6 – 2.8 mm x 1.8 mm, blunt, slightly erose around the apex, the dorsal one carinate and tending to be notched at the tip, dorsal 3.2 – 3.5 x 1.5 – 1.7 mm, ventral 2.4 – 2.9 x 1.3 – 1.5 mm, pale green, glabrous. **Corolla** 4.65 – 6.5 mm long, greenish white; tube 2.5 – 2.6 x 2.5 mm, bearded all round inside below the filaments; upper lobes 1.6 – 2.1 mm x 1.6 – 2.1 mm, laterals 1.5 – 1.9 mm x 0.9 – 1.5 mm, median 1.5 – 1.9 mm x 1.2 – 1.6 mm, all spreading and with the margins somewhat revolute so that the lobes appear acute. **Stamens** posterior filaments arising 1.5 mm above the base of corolla tube, 1.5 mm long, anterior 2 mm above base, 2.25 mm long with an apical tooth, all thick and slightly hairy,

anther 0.75 mm diam. **Disc** 0.5 x 0.9 mm. **Ovary** 0.5 – 0.9 x 0.7 mm, globose; style 0.5 – 1 mm, both glabrous. **Fruit** 1.4 – 2 x 0.9 mm, persistent strongly thickened style 0.9 – 2 mm, little swollen at base, fruiting pedicels ascending. **Seed** 0.360 – 0.393 x 0.250 – 0.328 mm, subglobose, reticulate, light brown.

Specimen examined: Borneo, Malaysia, Sarawak, Serian, Tebakang, Gua Silabur, 24 February 2022, *Nur Athirah Nabihah, M. M., Meekiong, K., Nurul Khaleeda, R., Umie Naylisa, A., Awang Ahmad Zahid, A. B., NAN0025* (Herbarium of Universiti Malaysia Sarawak).

Ecology and habitat: Found growing on the wall of limestone rock inside the cave at 110 m elevation with less than 20 individuals.

Distribution: Sarawak.

Notes: Based on the previous description, the leaf at first was very thinly pilose above, then very soon glabrescent below except for the ciliate margin.



Figure 4.66: Botanical picture of *M. selaborensis* B. L. Burtt. collected from limestone area in Gua Silabur, flower (image in circle)

8. *Monophyllaea singularis* var. *singularis* (Balf. Fil. & W. W. Sm.) B. L. Burtt.

Synonym: *Moultonia singularis* Balf. fil & W. W. Sm. in Notes R. B. G. Edinburgh 8:349 (1915) et in Sarawak Museum Journal 2:278 (1915); Steenis in Blumea, 11: 533 (1961), excl. spec.

Description: **Stem** 29 – 49 x 3.5 – 6 cm, glabrous sometimes densely short pilose, heavily encrusted, pale green. **Leaf** at flowering stage 32.6 – 49 cm x 18 – 25 cm, oblong or ovate oblong, cordate at base, acute apex, entire, glabrous, slightly encrusted on upper surface, heavily encrusted on lower surface, nerve wide-spreading from midrib, ascending near

margin, c. 1.5 cm apart. **Flowers** in a double or triple ranked line up the stem and double on to the midrib of the leaf, or on stem or midrib only, arising in groups of 3 – 5 with very short common stalk, the younger still in very small bud when oldest opens; **pedicel** 4 – 7 mm, glabrous or densely with white thinly tomentose hairs, heavily encrusted, pale green. **Calyx** 4 – 5 partite glabrous, the parts exposed in bud thick and heavily encrusted, the covered parts submembranous, pale green; tube 0.5 mm; posterior/ dorsal 5.9 x 2.7, strongly keeled, 3 anterior/ ventral segments 4.3 x 1.6 mm. **Corolla** 9 mm, white with yellow mark on palate; tube 4.5 mm, bearded below insertion of filaments; posterior/upper lobes 3 x 2 mm, orbicular, more or less erect, translucent greenish white, laterals 3 x 2.5 mm, oblong-obovate, median 3 x 2.6 mm, orbicular-spatulate; palate papillose. **Stamens** anterior filaments arising 3.5 mm above, 3 mm long, very arcuate; posterior 3 mm above base, 1.5 mm long, all glabrous; anthers 0.5 mm diam. **Disc** 0.6 – 0.7 x 1.4 – 1.5 mm, cupular. **Ovary** 1.5 – 1.6 x 1.1 mm, globose, gradually narrowed to thick style 2.7 – 2.8 mm long tapering a little upwards, scattered short hairs only on upper part sometimes glabrous. **Capsule** 1.6 – 2 x 1.4 – 1.5 mm, truncate at top, surmounted by the thickened persistent conical style 1 – 3 mm wide at base. **Seed** 0.408 – 0.433 x 0.216 – 0.291 mm, subglobose, polygonal with straight undulate raised ridges, dark brown.

Specimen examined: Borneo, Malaysia, Sarawak, Bau, Krokong, Fairy Cave, 3 December 2020 and 16 November 2022, *Nur Athirah Nabihah, M. M., Meekiong, K., Awang Ahmad Zahid, A. B., Nabilah Huda, M. H., Umie Naylisa, A., NAN0037, NAN0038* (Herbarium of Universiti Malaysia Sarawak).

Ecology and habitat: Found growing on wall of limestone near mouth cave at shaded area of elevation 20 m with more than 100 individuals.

Distribution: Sarawak.

Notes: The flowers appearing first on the stem, later spreading to the midrib of the lamina. The inflorescence is in 2 – 3 ranked line up the stem observed compared to previous notes of double ranked line up the stem.

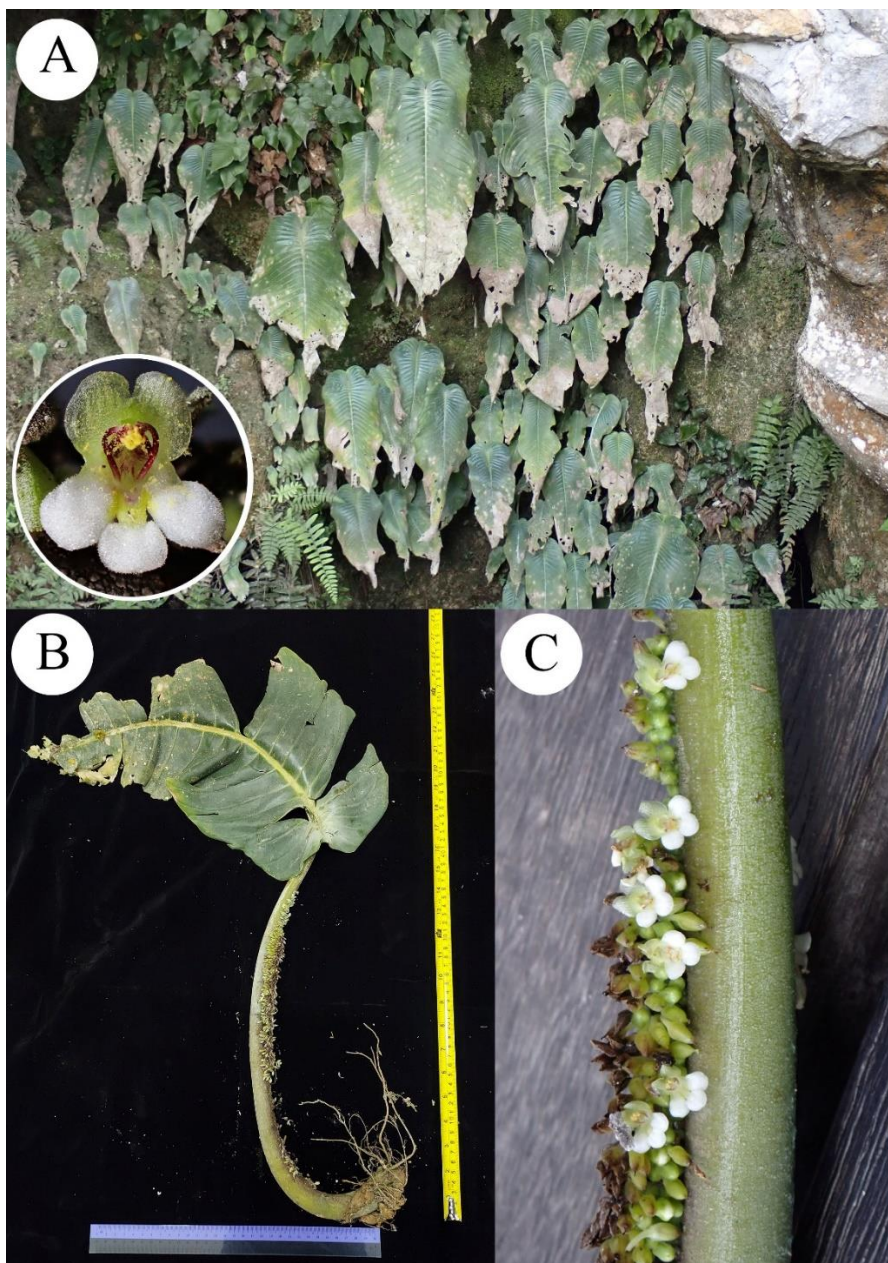


Figure 4.67: Botanical picture of *Monophyllaea singularis* var. *singularis* (Balf. Fil. & W. W. Sm.) B. L. Burtt. **A.** Plant grow on wall of vertical cliff at limestone area near Fairy Cave, flower (image in circle), **B.** Herbarium specimen collected, **C.** Inflorescence spread on stem

9. *Monophyllaea singularis* var. *aff. singularis*

Description: **Stem** 19 – 49 cm x 2.5 – 3.3 cm, glabrous, heavily encrusted, pale green. **Leaf** up to 33 – 50 cm x 12.4 – 25 cm, ovate – oblong or oblong, cordate at base, acute apex, entire, glabrous, upper surface slightly encrusted, green, heavily encrusted, rough on lower

surface, pale green, with arcuate lateral nerves; nerve wide-spreading from midrib, ascending near margin, c. 1.5 cm apart, new leaf often growing at lower stem or at middle stem on inflorescence. **Flowers** arising direct from upper two thirds of the stem in a single sometimes double lines up on the stem or both on the stem and on the midrib of the leaf, arising in groups of 1 – 2 with very short common stalk; **pedicels** 6.6 – 8.6 mm, glabrous, heavily encrusted, pale green. **Calyx** 4 partite glabrous and heavily encrusted, the parts exposed in bud thick and heavily encrusted, the covered parts submembranous; tube c. 0.5 mm, segments 5.8 – 8.5 x 3.6 – 4.3 mm, opening calyx c. 2 cm long, dorsal 5.6 x 1.3 – 3 mm, with posterior dorsal strongly keeled, elliptic shape, blunt apex, anterior ventral 3.5 – 4.5 x 2 mm, pale green. **Corolla** 9 mm, white with yellow mark on palate; tube c. 4.5 mm, dark purple sometimes reddish pink bearded with segmented long hairs below insertion of filaments; upper lobes 2.4 - 2.5 mm x 2.7 mm, slightly erect, orbicular, translucent greenish white, laterals 2.7 mm x 2.8 mm oblong – obovate, median 2.6 mm x 2.0 – 2.8 mm narrow orbicular – spatulate; palate papillose. **Stamens** anterior filaments arising 2.75 mm above, 4.4 – 4.6 mm long, arcuate, posterior 2.9 mm above base, 3.2 mm long, hairy; anthers 0.5 – 0.6 mm diam. **Disc** 0.6 – 0.7 x 1.3 – 1.4 mm, cupular. **Ovary** 1.3 – 1.4 x 0.9 – 1.0 mm, globose, glabrous; gradually narrowed to thick style 3.5–3.7 mm long tapering a little upwards, scattered short hairs only on upper part. **Capsule** 2.1 x 2.2 mm, truncate at top, surmounted by thickened persistent conical style 2.4 mm wide at base. **Seed** 0.294 – 0.326 x 0.196 – 0.207 mm, subglobose, polygonal with straight undulate raised ridges, dark brown.

Specimen examined: Borneo, Malaysia, Sarawak, Padawan, Gunung Ma'asa, 13 January 2022 and 3 December 2022, *Nur Athirah Nabihah, M. M., Meekiong, K., Awang Ahmad*

Zahid, A. B., Nurul Khaleeda, M. R., Nabilah Huda, M. H., Umie Naylisa, A., NAN0015, NAN0016, NAN0039, NAN0040, NAN0041 (Herbarium of Universiti Malaysia Sarawak).

Ecology and habitat: Found growing on the wall of vertical limestone at shaded area of elevation of 32 m with less than 50 individuals.

Distribution: Sarawak.

Notes: New leaf/plant often grow at lower stem or middle stem on the inflorescence before growing roots by itself.



Figure 4.68: Botanical pictures of *M. singularis* aff. *singularis*. **A.** Plant grow on wall of vertical cliff at limestone area in Gunung Ma'asa, flower (image in circle), **B.** Herbarium specimen collected, **C.** Inflorescence spread on midrib

10. *Monophyllaea tenuis* B. L. Burtt

Description: Stem 9.5 – 14 x 1.5 – 1.7 cm, sparsely long pilose hairs, slightly encrusted, pale green. **Leaf** often 16 – 25 x 11 – 14 cm, ovate, deeply cordate at base, acute apex, entire, rather thin, densely with white thinly pilose glandular hairs on upper and lower sides, ciliate

on margins, slightly encrusted upper, heavily encrusted below. **Inflorescences** not all contemporaneous, old withered peduncles often present when a fresh crop is flowering, simple helicoid two-paired cyme; **peduncles** 6.3 – 10.3 x 1.6 cm diam, densely with white thinly pilose hairs, slightly encrusted, pale green; flowering axis up to 3 – 6 cm with flower-pairs up to 1 cm apart; **pedicels** 6.6 – 9.5 mm, densely with white thinly pilose hairs or delicate glandular hairs, slightly encrusted, pale green. **Calyx** 4 calyx, divided almost to the base into segments 2 x 1 mm, sparsely with white thinly pilose or glabrous, slightly encrusted, dorsal 2.4 x 1.5 mm, ventral 2.2 x 0.9 mm. **Corolla** 3.2 – 4.8 mm, greenish-white; tube 3 mm long, nearly 3 mm wide at mouth, pilose inside between the filaments; upper lobes 0.5 x 1.5-1.8 mm, lateral 1.5 x 1.5 mm, median 1.5 x 1.9 mm, all orbicular, all at first ciliate, palate shortly hairy. **Stamens** posterior filaments arising 1.5 mm above base, 1 mm long, anterior 2 mm above base, 2 mm long, with occasional hair near base or all glabrous; anthers 0.75 mm diam. **Disc** 0.3 x 0.9 mm. **Ovary** 0.6 x 0.7 mm, subglobose; style 0.6 mm, both glabrous. **Fruit** 1.6 x 1.5 mm, surmounted by 1.1 mm conic style; fruiting pedicels ascending. **Seed** 0.246 – 0.284 x 0.166 – 0.205 mm, globose, reticulate, dark brown.

Specimen examined: Borneo, Malaysia, Sarawak, Padawan, Gunung Ma'asa, 13 January 2022 and 3 December 2022, *Nur Athirah Nabihah, M. M., Meekiong, K., Raffi, A., Nurul Khaleeda, R., Nurul Nabilah Huda, M. H., Umie Naylisa, A., NAN0026, NAN0027, NAN0028, NAN0048, NAN0049, NAN0050* (Herbarium of Universiti Malaysia Sarawak).

Ecology and habitat: Found grow on the wall of vertical limestone at shaded area on elevation of 32 m with less than 50 individuals.

Distribution: Sarawak.

Notes: The calyx in *M. tenuis* found were hairy with thinly pilose glandular hairs.

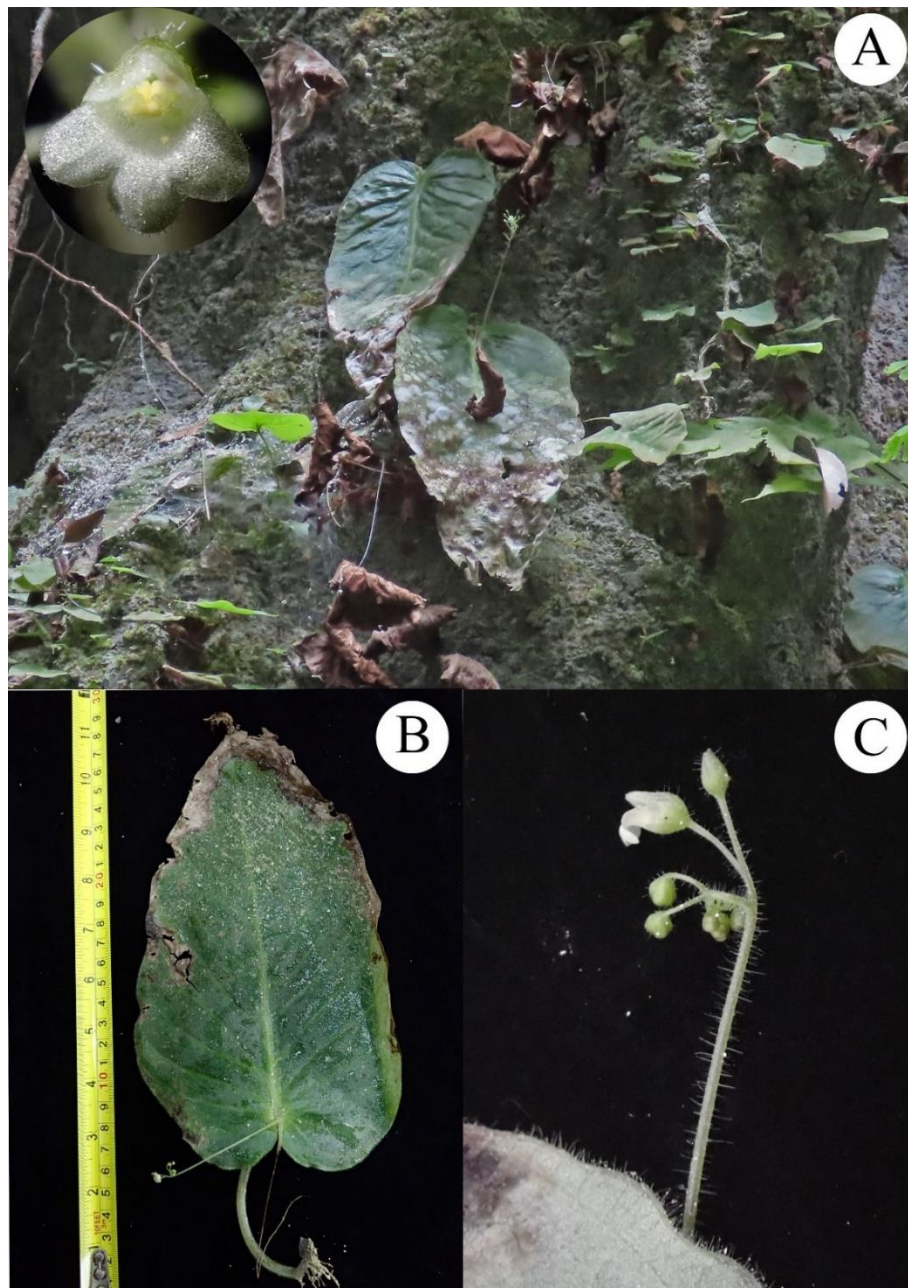


Figure 4.69: Botanical picture of *M. tenuis* B. L. Burtt. **A.** Plant grow on wall of vertical cliff at limestone area in Gunung Ma'asa, flower (image in circle), **B.** Herbarium specimen collected, **C.** Inflorescence

11. *Monophyllaea aff. tenuis*

Description: Stem 7 – 9 cm x 1.5 – 2 cm, densely with long pilose hairs, heavily encrusted, pale green or reddish green. **Leaf** often 20 – 32 cm x 15 – 25.5 cm, ovate, deeply cordate at base, rather thin, densely thinly pilose glandular hairs on upper and lower surface, ciliate on margins, slightly encrusted on upper surface, heavily encrusted below. **Inflorescences** not all contemporaneous, old withered peduncles often present when a fresh crop is flowering, simple helicoid two-paired cyme; **peduncles** 6.5 – 7.8 x 1.7 – 2 cm, densely thinly pilose at lower part and getting lesser at the middle, glabrous at upper peduncle, smooth surface, reddish brown to greenish red; flowering axis up to 1.5 – 6 cm with flower-pairs up to 1 cm apart; **pedicels** 6.5 – 9.8 mm x 1.7 – 2.0 mm, glabrous, greenish red. **Calyx** 4 – 5 (rarely 5), divided almost to the base into segments 2 x 1 mm, blunt, slightly erose on apex, the dorsal one carinate and tending to be notched at the tip, glabrous, dorsal 3.2 – 3.3 x 1.5 – 1.6 mm, ventral 2.5 – 3 x 1.4 – 1.5 mm. **Corolla** 5.2 – 5.4 mm x 4 mm, greenish white, tube 3 mm long, nearly 3 mm wide at mouth, pilose inside between the filaments; upper lobes 2.1 x 2.2 mm, lateral 1.9 x 1.8 mm, median 1.9 – 2.1 mm x 1.6 mm, all orbicular, all at first ciliolate, palate shortly hairy. **Stamens** posterior filaments arising 1.5 mm above base, 1 mm long, anterior 2 mm above base, 2 mm long, all glabrous or with an occasional hair near base; anthers 0.75 mm diam. **Disc** 0.4 x 0.9 mm. **Ovary** 0.5 x 0.9 mm, subglobose; style 0.8 mm, both glabrous. **Capsule** 1.6 – 2.3 x 1.3 – 1.5 mm, surmounted by 0.9 – 1.6 mm conic style; fruiting pedicels ascending. **Seed** 0.285 – 0.322 x 0.196 – 0.221 mm, globose, reticulate, dark brown.

Specimen examined: Borneo, Malaysia, Sarawak, Gunung Stulang, Bau. 15 February 2022 and 16 November 2022, *Nur Athirah Nabihah, M. M., Meekiong, K., Raffi, A., Nurul Khaleeda, R., Nurul Nabilah Huda, M. H., Umie Naylisa, A., NAN0019, NAN0020, NAN0021, NAN0026, NAN0027, NAN0028* (Herbarium of Universiti Malaysia Sarawak).

Ecology and habitat: Found growing on the wall of vertical limestone at shaded area on elevation of 52 m with less than 50 individuals.

Distribution: Sarawak.

Notes: Flower similar to *M. tenuis* except the pedicels and upper part of peduncles are glabrous and reddish in colour.



Figure 4.70: Botanical picture of *Monophyllaea aff. tenuis* collected from limestone area in Gunung Stulang, flower (image in circle)

12. *Monophyllaea tetrasepala* B. L. Burtt

Description: **Stem** 30 cm or more. **Leaf** up to 35 x 35 cm, broadly ovate, cordate at base, shining, glabrous except for asperities on and near margin; nerves 3 cm apart, ascending.

Inflorescences spread interruptedly up the midrib, the larger near the base up to 30 cm, forked below the first flowers and, more rarely, one of the laterals forked again, the smallest

higher up the midrib only 3 cm, glabrous; **pedicels** 5 – 6 mm with short somewhat crisped hairs. **Calyx** c. 7 mm, shortly hairy outside, tube 1 – 1.5 mm; segments 4 – 5, 6 mm, the dorsal one keeled on the back. **Corolla** 10 mm; tube 5 mm, densely bearded inside about 2.5 mm above base; upper lobes pale greenish 3 x 3 mm; lower lip pink except for yellow patch at base of middle lobe and overlapping onto laterals, papillose, laterals 4 x 2.5 mm oblong, median 4 x 3 mm spatulate. **Stamens** anterior filaments arising 4 mm above base, 3 mm long; posterior arising 3 mm above base, 2.5 mm long; all glandular towards top; anthers 1.25 mm diam. **Disc** 0.5 mm. **Ovary** 1 mm, glabrous; style 3 mm, with some scattered short hairs in upper half; stigma bifid. **Fruit** 2 mm, surmounted by broad minaret-shaped style-base.

Specimen examined: Borneo, Malaysia, Sarawak, Gunung Manok, Padawan. 13th v 1975, Burtt, B. L., B.8119 (holo. E, iso. SAR).

Ecology and habitat: Found growing on loose limestone slopes in forest gaps.

Distribution: Sarawak.

Notes: *M. tetrasepala* known to have large shining leaves and reddish inflorescences. The forking of the inflorescence and the way the later flowers appear spread up the midrib of the leaf accentuate the similarity to *M. merrilliana*. However, the closed fruiting calyx and absence of branching hairs indicate that there is also a close familiarity with *M. glauca*.

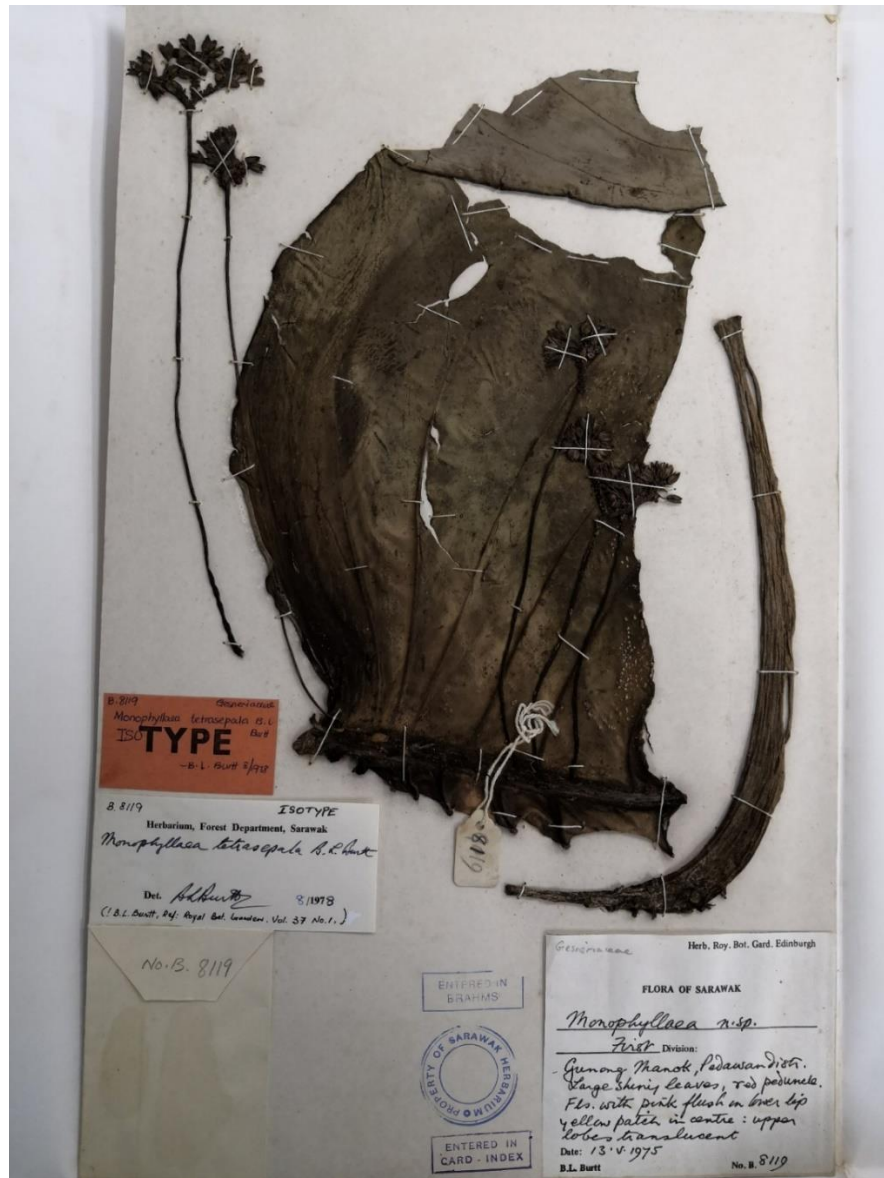


Figure 4.71: Botanical picture of *Monophyllaea tetrasepala* B. L. Burtt. (adopted from herbarium specimen, B. L. Burtt, B. 8119 (SAR))

13. *Monophyllaea merrilliana* Kraenzlin

Syn: *M. johannis-winkleri* Kraenzlin in Mitt. Ins. Bot. Hamburg, 7:91 (1927). Syntypes: [Kalimantan], West Borneo, Bukit Mehigit, Winkler 674; Bukit Raja, Winkler 930 (HBG).

Description: Very variable in size: **Stem** 5 – 30 cm, encrusted. **Leaf** 12 – 45 x 10 – 40 cm, usually broadly ovate occasionally oblong, base cordate; upper surface covered all over, or only near base, with brown branched hairs or glabrous, lower surface more or less encrusted. **Inflorescences** arising at base of the midrib, with or without additional ones scattered along it; primary peduncles up to 30 cm, branching below first flowers, more rarely twice branched, secondary ones sometimes only 1 cm, not branched; glabrous or thinly pilose; flowering axis and pedicels rather densely clad with brown branched hairs; **pedicels** c. 4 mm. **Calyx** 7 – 8 mm, with branched hairs on the outside; tube 2.5 – 3 mm; anterior and lateral lobes 4.5 – 5 x 1.75 – 2.5 mm, dorsal 4.5 – 5 x 3.5 mm, all acute. **Corolla** 12 – 13 mm, white with yellow patch in centre of palate; tube 6 – 7 mm, bearded inside below filaments; upper lobes 2 x 4 mm, laterals 2.5 – 3 x 3 – 4 mm oblong, median similar but broadly spatulate, papillose. **Stamens** with red filaments (? always): posterior arising 4 mm above base, 1.5 – 2 mm long, anterior 4.5 mm above base, 2 – 3 mm, arcuate, all verrucose-glandular near top and back of connective; anthers 0.75 – 1.25 mm diam. **Disc** 0.5 – 1 mm. **Ovary** 1.5 mm, glabrous; style 2 – 3 mm, sometimes with a few glandular hairs in upper part. **Fruit** 2 x 2.5 mm, thin-walled crowned by persistent conical style with swollen base; fruiting calyx open.

Specimen examined: Borneo, Malaysia, Sarawak, Gunung Regu, Padawan District, 6th v 1975, *Burtt, B. L., B.8087* (holo. E, iso. SAR).

Ecology and habitat: *M. merrilliana* known to have wide geographical range as it is less strongly calcicole than most other species of the genus. This specimen was found among wet limestone rocks.

Distribution: Borneo (Sarawak, Sabah and Kalimantan) and Philippines.

Notes: *M. merrilliana* seem to vary in shape according to the place they grow. Pendulous leaves tend to be oblong and erect stem to be ovate. The leaf showed in type specimen was oblong compared to most Bornean material was ovate. The inflorescence also differ as often the larger inflorescence were forked below the first flowers and the smaller ones were unbranched. Sometimes, smaller inflorescences develop intermittently along the midrib. Sometimes, the huge primary inflorescences are suppressed, and all are of secondary stature, beginning at the base of the midrib and then dispersed up it.



Figure 4.72: Botanical picture of *Monophyllaea merrilliana* B. L. Burtt. (adopted from herbarium specimen, B. L. Burtt, B. 8087 (SAR))

5.1.4 New Taxa/ New Taxon/ New Record/ New Discovery

***Monophyllaea kazuea* Nur Athirah Nabihah & Meekiong, sp. nov.**

Similar to *M. glauca*, but differentiated by the hairy peduncle and corolla bearded heavily above.

Type: MALAYSIA, Borneo, Sarawak, Kuching, Bau District, Gunung Stulang, sandy soil, vertical cliff, limestone habitat. 23 Nov. 2022. Nur Athirah Nabihah M.M. et al. NAN0033 (holo: SAR, iso: Herbarium of Universiti Malaysia Sarawak).

Distribution: Sarawak. Currently recorded only from a single limestone hill (type locality) in Bau District, Kuching, Sarawak.

Habitat: Sandy soil on a shaded vertical limestone cliff at an elevation of 52 m, 1°21'10" N, 110°3'35" E. The vertical cliff is estimated to be 10 m high.

Description: **Petiolode** 9-11.5 cm x 1.5-1.7 cm, densely hairy with long white uniseriate tapering hairs, heavily encrusted, green. **Leaf** up to 20-28 cm x 11.2-12.5 cm, lanceolate-oblong, sometimes ovate, cordate at base, sometimes unequal, attenuate at apex, densely hairy on both adaxial and abaxial surfaces with white sometimes light-brown long uniseriate tapering hairs, encrusted on abaxial surface, younger parts densely hairs with white uniseriate tapering hairs, lateral veins 1.2-1.5 cm apart, midrib sunken above, prominent below, tertiary veins reticulate. **Inflorescence** 1-2 arising from the leaf base, densely hairs with long white uniseriate tapering hairs, fruiting pedicels deflexed downward, flowering

pedicels erect upwards, reddish brown. **Peduncle** 8-20 cm x 1.9-2.4 mm; hairy, floriferous part 2.5-3 cm long, flower pairs ca. 0.9 mm apart; pedicel 4-6 mm long. **Calyx** 3.1-4.6 mm x 1.8-2.9 mm, dorsal calyx 5.6 mm x 2.7 mm, all acute, reddish brown, with light brown long-tapering hairs; tube c. 5 mm long ; segments 5, 5.6 mm long. **Corolla** 7.3-10.5 mm long, white, with green sometimes yellow mark at the centre of palate, tube 6.6 mm long, bearded heavily above the filament all around, densely papillose, upper lobes 3.2-3.3 mm x 2.4-2.6 mm, orbicular, erect 30°, lateral and median lobes connate for c. 2 mm in length, laterals 4.2-4.3 mm x 3.0-3.4 mm, orbicular, median 4.5 mm x 3.1 mm, obovate, all ciliolate, slightly curved. **Stamens:** posterior filaments arising 1.6 mm above base, more or less straight, 1.7-1.8 mm long with a hooked apical tooth, anterior filament c. 1.7 mm long, anther 0.5 mm. **Disc** 0.4-0.6 mm x 0.7-1.2 mm, yellow. **Ovary** ovoid, 0.9-1 mm diameter, glabrous, pale green; style 1.8 mm long, glabrous. **Capsule** c. 5-7 mm long, globose, truncate at tip, thin wall crowned by short persistent style with swollen base; fruiting calyx open, erect at 90°. **Seeds** 0.3-0.4 mm long, ellipsoid, mucronate, dark brown, ornamentation reticulate, irregularly raised with irregular cross-connexions.

Other materials examined: Sarawak, Kuching, Bau District, Gunung Stulang, sandy soil, vertical cliff, limestone habitat. 15 Feb. 2022, *Nur Athirah Nabihah M.M. et al.* NAN0024; NAN0025; 23 Nov. 2022. *Nur Athirah Nabihah M.M. et al.* NAN0034; NAN0035; NAN0036; NAN0037; NAN0038.

Etymology: The species epithet honors Mrs. Kazue Sakai, a dedicated woman who served as a coordinator for the Japan-Malaysia Association in Sarawak and contributed significantly to maintaining a positive relationship between Japan and Malaysia. She has also had a

significant impact on the environment in Sarawak, Malaysia, especially regarding the preservation and restoration of species.

Notes: Studies conducted around the hill and other nearby limestone hills revealed no other populations of *M. kazuea*. *Monophyllaea kazuea* occupies an extremely narrow niche and is deemed hyper-endemic to Mount Stulang. The populations were discovered on two vertical cliffs in the northeastern portion of Mount Stulang, comprising only two significant groups, each with 15–20 plants. Young plants also grow on the cliffs, and some have yet to bloom. Additionally, the absence of old peduncles on the plants indicates that *M. kazuea* is an annual species. There are now 17 known species of *Monophyllaea* in Sarawak. Given that a few other specimens are ambiguous and under study, there could be as many as 20 different species in total. Research on its interactions with other species in Western Sarawak is ongoing; more information will be provided in a subsequent paper. *Monophyllaea kazuea* was discovered coexisting with *M. tenuis* and *M. glauca*, two others known *Monophyllaea* species. *M. tenuis* was found growing alongside *M. kazuea*. On the same cliff, while *M. glauca* was found on the ground below the cliff. The shape of upper and lateral lobes of *M. kazuea* is similar to *M. glauca* except for median lobes. *M. glauca* has stiff or bulbose-based hairs and sometimes branched while *M. kazuea* has uniseriate long hairs. Cross-hybridization with *M. glauca* is considered unlikely due to the significant dissimilarities in their characteristics (Table 4.30).

Table 5.1: Comparison between *M. kazuea* and *M. glauca*

Character	<i>M. kazuea</i>	<i>M. glauca</i>
Habit	Pendulous	Erect
Petiolode length (cm)	9 – 11.5	15 – 60
Petiolode diameter (cm)	1.5 – 1.7	1.6 – 2.9
Petiolode hairs	Uniseriate tapering hairs	Glabrous
Petiolode surface	Heavily encrusted	Slightly encrusted
Leaf texture	Thin	Thick
Leaf width (cm)	11.2 – 12.5	19.5 – 22.5
Relative width of leaf to length	1:2	2:1 (3:1)
Leaf shape	Oblong-lanceolate	Broadly ovate, deeply cordate
Pedicel hairs	Uniseriate long hairs	Stiff/branched/bulbose-based hairs
Corolla shape (median lobe)	Obovate	Orbicular-spatulate
Corolla tube length (mm)	6.6	4.5
Flower colour	White with green/yellow mark on the palate	White with yellow mark and purple bar on the palate
Ovary length (mm)	1.0	1.5
Style length (mm)	1.8	2.5

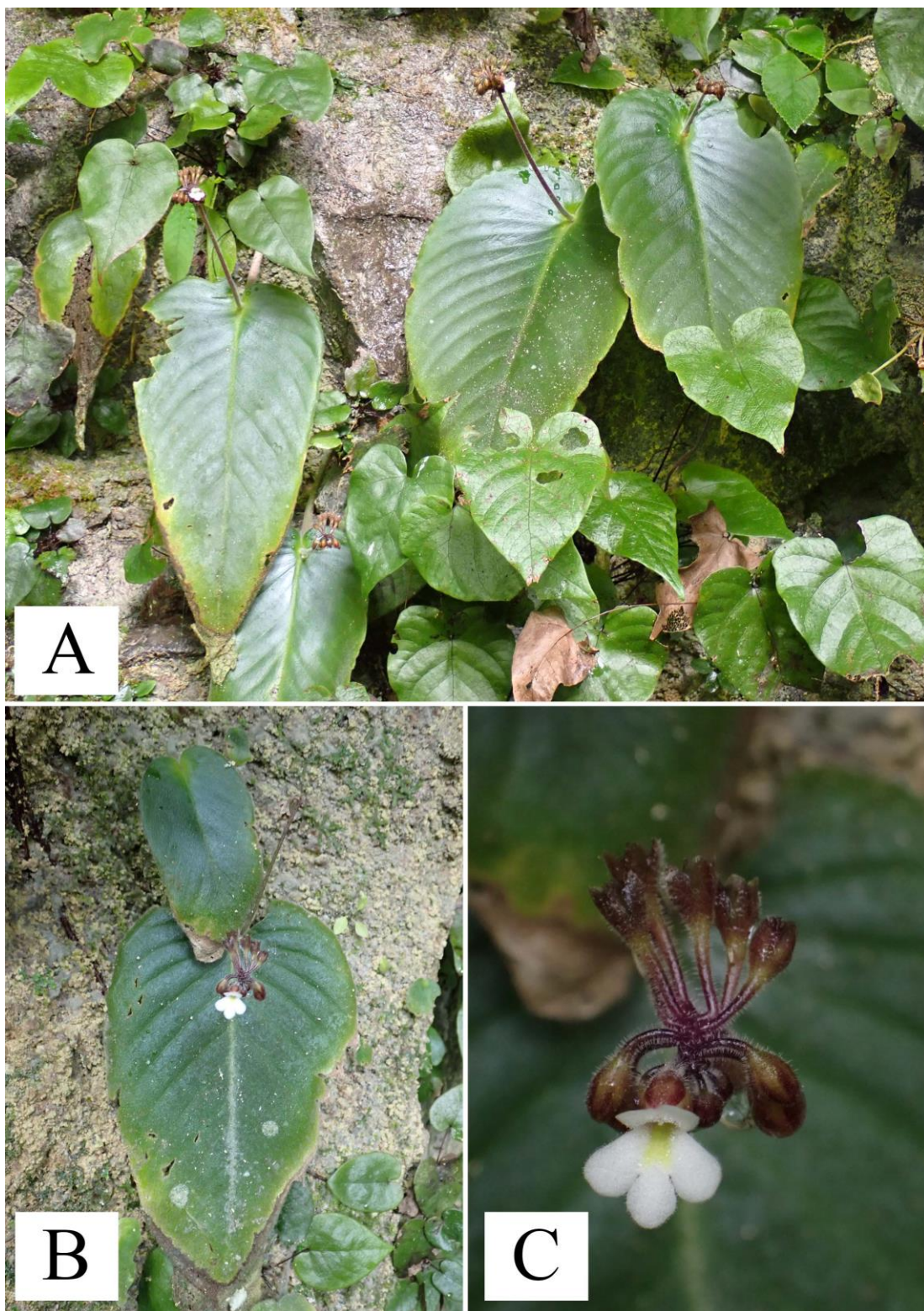


Figure 4.73: *Monophyllaea kazuea* Nur Athirah Nabihah & Meekiong sp. nov. **A.** Habit; **B.** Leaf with mature inflorescence and young leaf; **C.** Pedicels and flower

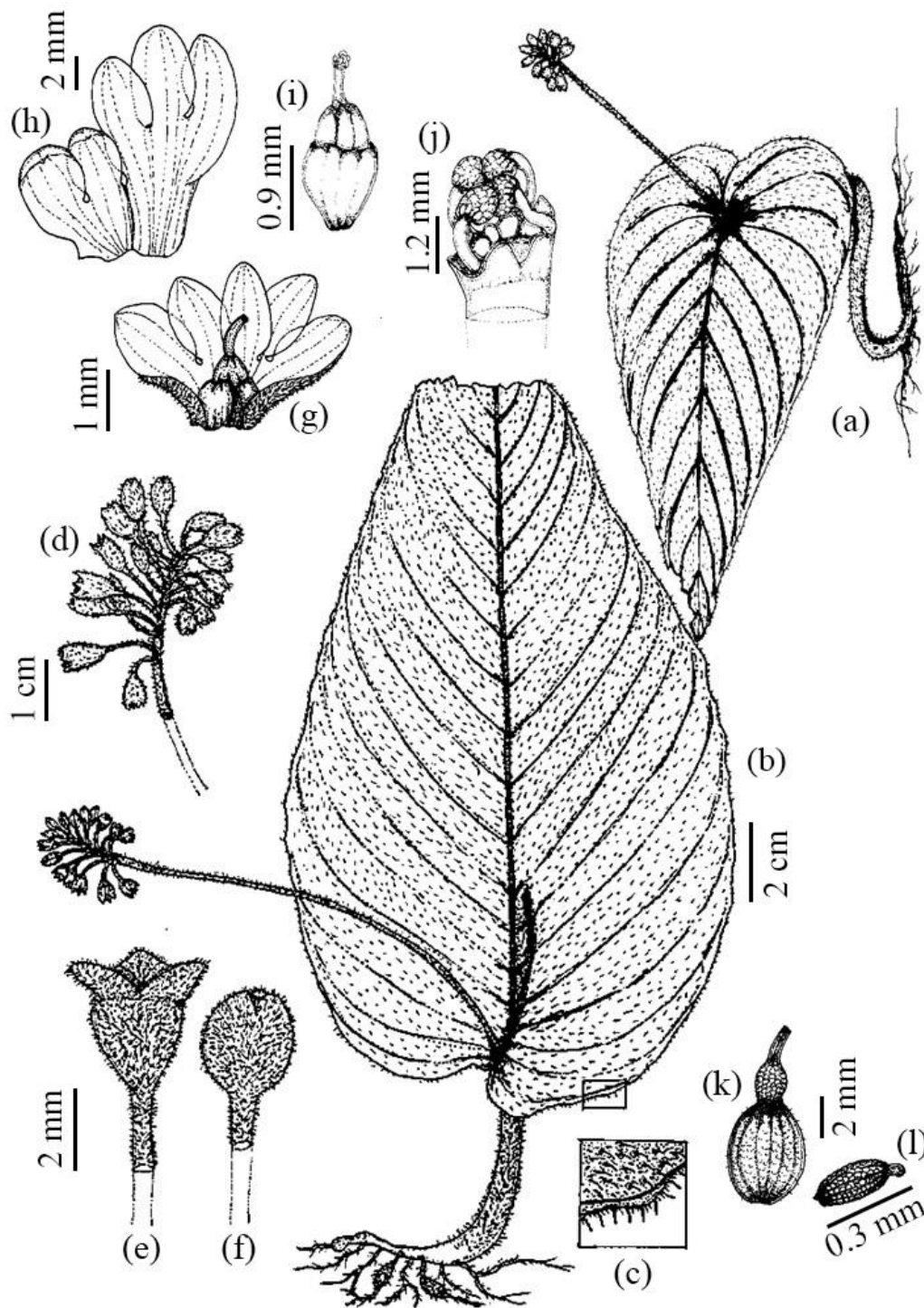


Figure 4.74: *Monophyllaea kazuea* Nur Athirah Nabihah & Meekiong **a.** habit; **b.** whole plant; **c.** uniseriate hairs; **d.** inflorescence; **e.** open pedicel; **f.** close pedicel; **g.** sepal and ovary; **h.** corolla; **i.** ovary; **j.** anther; **k.** capsule [Drawing by Meekiong K.]

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

There were a total of 12 *Monophyllaea* taxa found in western Sarawak which include limestone areas in Bau, Serian, Siburan and Padawan. The distribution map based on each taxa locality had been mapped. There was one new species discovered and described in Sarawak, *M. kazuea*. Thus, currently, there are a total of 17 species of *Monophyllaea* in Sarawak. Three *Monophyllaea* species were hyper-endemic species based on the analysis of the localities of *Monophyllaea* in western Sarawak, *M. glandulosa* in Teng Bukap, *M. selaborensis* in Gua Silabur and *M. kazuea* in Gunung Stulang. Throughout the observation done on the field, *Monophyllaea* thrives in a shady and high-humidity environment of limestone.

The morphology study on these 12 taxa of *Monophyllaea* was observed and recorded based on the scoring data. There were differences in the characteristics of each species, especially the leaf and inflorescence. As for differentiation between the varieties of *M. glauca*, the identification of each variety can be made based on the type of trichomes on the leaf and inflorescences. The flowers were very small and different in shape and colour of every species could help in the identification of species.

Moreover, the micromorphology includes the epidermal cell pattern, stomata and trichomes were analysed. The observation of epidermal cell pattern showed that there were

few distinct differences between each species of *Monophyllaea*. As for the result of stomata, it showed all 12 taxa of *Monophyllaea* have anisocytic stomata. There is the presence of different types of trichomes in the genus *Monophyllaea*. Glandular trichomes are found in all taxa in *Monophyllaea*. Epicuticular wax found was calcium oxalate or calcium phosphate crystal on the surface of the leaf.

The anatomy study of *Monophyllaea* was done on stem and midrib cross-section. Based on the examination of the sample showed similarity in stem-cross section in all 12 taxa of *Monophyllaea*. Midrib cross-section in *Monophyllaea* consists of open-system vascular bundles arranged in an arc at abaxial and close-system vascular bundles arranged in a ring. The anatomy result may not be useful for species identification for *Monophyllaea*.

Palynology study in *Monophyllaea* produced successful results. Each of the 12 *Monophyllaea* taxa consists of distinct characters which can aid in species identification of the species and among the family Gesneriaceae.

Among all characters examined, the type of trichomes, pollen, and inflorescence are the main characters that may aid in the identification of the species in *Monophyllaea* species. As for subgenus classification, the pedicels length and type of indumentum are the characters that can be focussed into during observation. Further investigation on the ovary and fruit formation is needed, as they might be helpful in species delimitation.

In conclusion, the objectives of this project were fully achieved. The key of *Monophyllaea* taxa was constructed and the key between the varieties of *M. glauca* was mentioned in this thesis.

6.2 Recommendations

Monophyllaea is a sensitive, unique one-leaf plant and a totally protected species. However, descriptions of species in *Monophyllaea* in other parts of Sarawak (central and north Sarawak) are not updated and need more revision. More deeper studies can be conducted in the future. A few recommendations are suggested below to provide more details for the classification of the genus *Monophyllaea*.

- Further morphological and ecological studies should be conducted in other parts of Sarawak (central and north Sarawak) including Western Sarawak.
- Molecular study is recommended to be done as there is still no study on that particular aspect.
- The phytochemical study should be conducted to analyse the chemical compound released by the glandular trichomes and secretory canal in *Monophyllaea*.
- In-depth study on seeds (size, surface, ornamentation) using FESEM.
- In-depth study on pollen using transmission electron microscope (TEM) to produce more details in the aperture of pollen.
- Further assessment on the conservation status of genus *Monophyllaea* in limestone area.

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APPENDICES

Appendix 1: Permit

Your Ref. : 2020073
Our Ref. : SFC.810-4/6/1(2021) - 025

Date : 6 May 2021



Miss Nur Athirah Nabihah Binti Mohamad Mahmud
Dr. Qammil Muzzammil Abdullah @ Meekiong Kalu
Miss Nurul Khaleeda
Miss Umie Naylisa Binti Mohamad Asmadi
Miss Nurul Nabilah Huda Binti Mohd Hisham
Miss Salasiah Binti Mohamad
Mr. Hidir Bin Marzuki
Mr. Sekudan Tedong
Faculty of Resource Science and Technology
Universiti Malaysia Sarawak
94300 Kota Samarahan, Sarawak

Dear Sir/Madam,

Permission to Conduct Research on Biological Resources/Collect Samples of Biological Resources for Research:- Systematic Studies of Genus *Monophyllaea* spp. (Family Gesneriaceae) in Western of Sarawak

Greetings from SFC!

The above subject matter refers.

2. With regards to your application for the above subject, I am pleased to inform that permission is hereby granted for you and your team members to conduct research and collect samples of biological resources within the area as per table below:

Species		Location	Quantity
Scientific Name	Type of Organism		
<i>Monophyllaea</i>	All parts of plant (whole plant)	4 Division in Western Sarawak (Kuching, Samarahan, Serian and Sri Aman) - Gunung Gading National Park	3 samples for each species

SARAWAK FORESTRY Corporation

Lot 218, KCLD, Jalan Tapang, Kota Sentosa, 93250 Kuching
Tel: (+6) 082 610088 Fax: (+6) 082 629744 www.sarawakforestry.com

		• Santubong National Park • Bako National Park • Kubah National Park • Batang Ai National Park • Fairy Cave Nature Reserves • Gunung Lesong National Park • Bungo Range National Park • Dered Krian National Park • Gunung Pueh National Park • Samunsam Wildlife Sanctuary	
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3. This permission is **valid for one (1) year**, effective from **6 May 2021 – 5 May 2022**. This permit shall be surrendered to the Controller of Wild Life, Sarawak or any officer duly authorized by him upon the expiry thereof.
4. The permission is granted on a 'personal-to-holder' basis and shall not be assigned. The holder must produce this letter/permit for inspection when called upon by any member of the issuing authority or any other enforcement agencies.
5. This is not a permit for the holder to conduct research on medicinal, pharmaceutical, therapeutic, nutritional or agricultural properties of the biological resources collected.
6. The permission may be summarily withdrawn in the event of non-compliance with the condition set therein.
7. The authority is at liberty to assign one or more local counterpart to accompany the holder and to participate in research and in the collection of the biological resources.
8. The issuing authority and/or the State Government of Sarawak shall not be liable for any injuries or loss of life caused or arising from activities related to the implementation of the research and the collection of the biological specimens.
9. The holder shall bear all the expenses incurred on the research conducted unless otherwise stated.

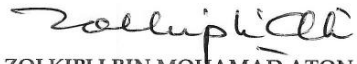
SARAWAK FORESTRY Corporation

Lot 218, KCLD, Jalan Tapang, Kota Sentosa, 93250 Kuching
 Tel: (+6) 082 610088 Fax: (+6) 082 629744 www.sarawakforestry.com

23. The authority (Controller of Wild Life) has the right to impose any condition to the permit as it deems fit from time to time.

Thank you.

I CARE



ZOLKIPLI BIN MOHAMAD ATON
Controller of Wild Life and
National Parks & Nature Reserves
SARAWAK

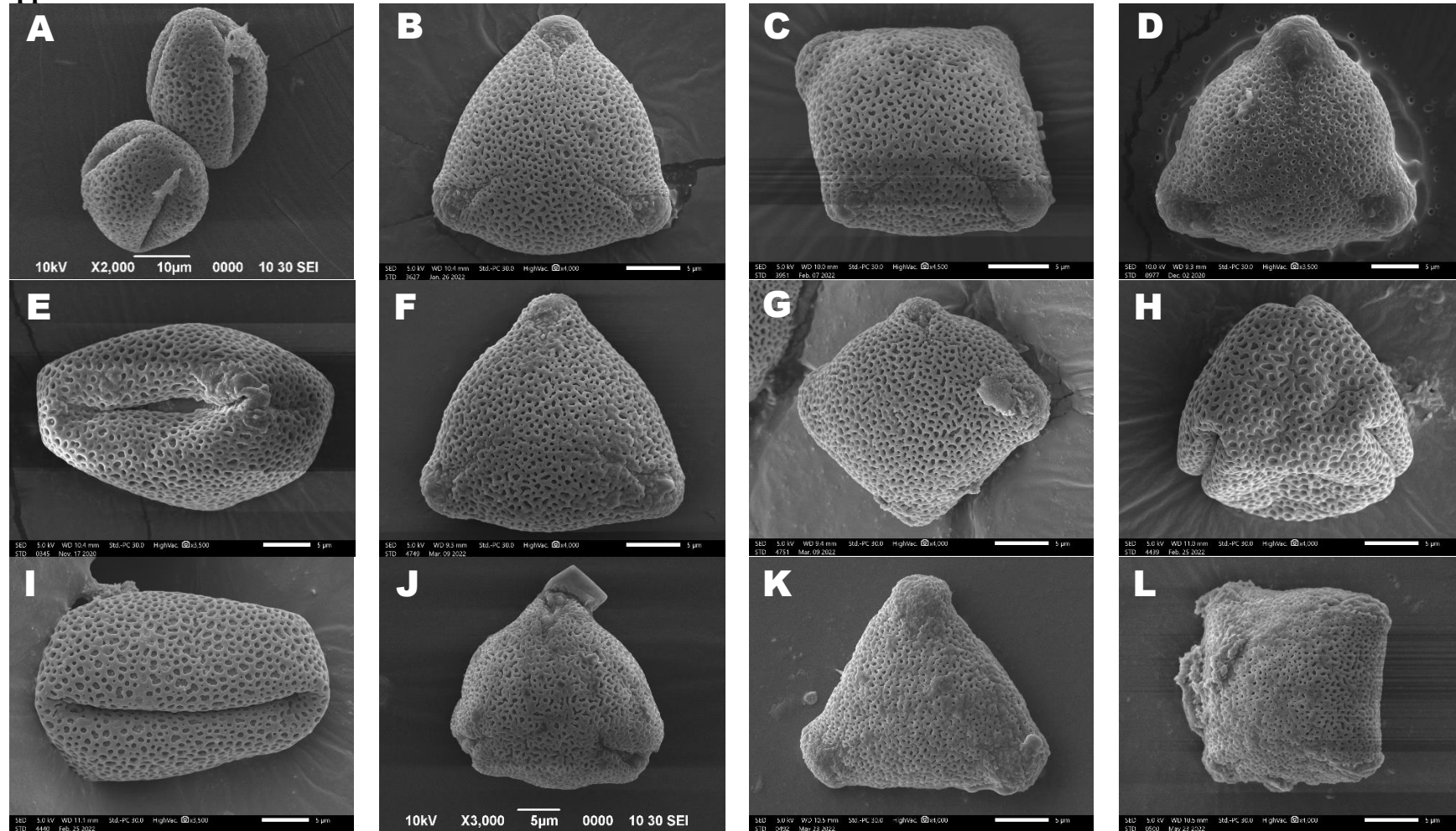
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"NEW FRONTIER IN BIODIVERSITY CONSERVATION"

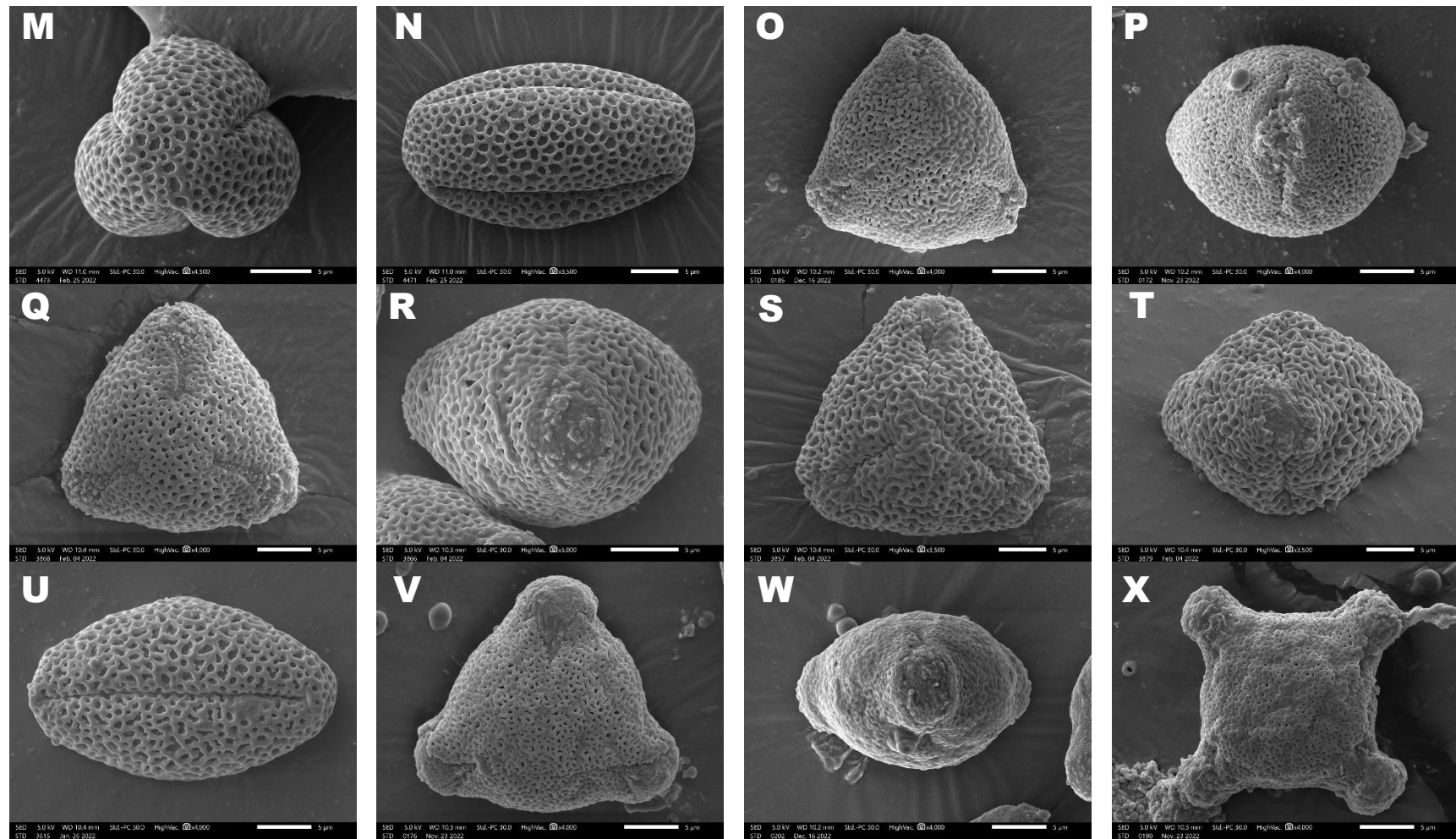
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Appendix 2: Pollen



Appendices 4.1: Pollen of *Monophyllaea*. **A.** *M. glandulosa*, tricolpate and tricolporate in equatorial view; **B-C.** *M. glauca* var. *beccarii* in polar view, **B.** Tricolpate, **C.** Tetracolpate; **D-E.** *M. glauca* var. *boraginea*, **D.** Tricolpate, polar view, **E.** Tricolporate, equatorial view; **F-G.** *M. glauca* var. *glauca* in polar view, **F.** Tricolpate, **G.** Tetracolpate; **H-I.** *M. glauca* var. *hirta*, **H.** Tricolpate, polar view, **I.** Tricolporate, equatorial view; **J.** *M. glauca* var. *versipes*, tricolpate, polar view; **K-L.** *M. kazuea* in polar view, **K.** Tricolpate, **L.** Tetracolpate



Appendices 4.1: Pollen of *Monophyllaea*. **M-N.** *M. selaborensis*, **M.** Polar view, **N.** Equatorial view; **O-P.** *M. singularis* var. *singularis*, **O.** Polar view, **P.** Equatorial view; **Q-R.** *M. singularis* var. *aff. singularis*, **Q.** Polar view, **R.** Equatorial view; **S-U.** *M. tenuis*, **S.** Polar view, **T.** Equatorial view, **U.** Tricolporate, equatorial view; **V-X.** *M. aff. tenuis*, **V.** Polar view, **W.** Equatorial view, **X.** Tetracolporate, polar view

Appendix 3: List of *Monophyllaea* in Sarawak

Kuching Division

1. *M. glauca* C. B. Clarke
 - var. *glauca*
 - var. *hirta*
 - var. *beccarii*
 - var. *versipes*
 - var. *boraginea*
2. *M. singularis* (Balf. f. & W. W. Sm.) B. L. Burtt
 - var. *singularis*
 - var. *semiflorens*
3. *M. tenuis* B. L. Burtt
4. *M. glandulosa* B. L. Burtt
5. *M. selaborensis* B. L. Burtt
6. *M. merrilliana* Kraenzl (including *johannis-winkleri*)
7. *M. tetrasepala*
8. *M. kazuea* Nur Athirah Nabihah & Meekiong

Mulu National Park

1. *M. andersonii* B. L. Burtt
2. *M. cupiflora* B. L. Burtt
 - var. *cupiflora*

var. *aggregate*

3. *M. fissilis* B. L. Burtt
4. *M. hottae* B. L. Burtt
5. *M. insignis* B. L. Burtt

var. *insignis*

var. *rubriflora*

6. *M. pendula* B. L. Burtt
7. *M. merrilliana* Kraenzl (including *johannis-winkleri*)

Bukit Sarang, Tatau District

1. *M. sarangica* B. L. Burtt
2. *M. grandifolia* Kiew & Sang
3. *M. meriraiensis* Kiew & Sang