

THE DIVERSITY OF MANGROVE SPECIES AND ITS
ASSOCIATES IN KUANTAN AND PEKAN, PAHANG

BY

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requirement for the degree of Master of Science
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ABSTRACT

Mangrove ecosystems are home to numerous plant species, each with unique adaptations to the challenging coastal environment. Accurate identification enables scientists, conservationists, and policy makers to precisely catalogue and categorize these species, facilitating targeted conservation efforts and the preservation of rare or endangered mangrove plants. Our objectives can be restated as follows 1) to identify and record the diversity of true mangrove plant species and its associates in Kuantan and Pekan. 2) To produce distinct anatomical features for selected true mangrove species and its associates to be easily recognized and identified. 3) to determine the conservation status and population trend of true mangrove species and its associates in Kuantan and Pekan. The sampling was conducted using a random sampling method along the trails. For each plant species, three samples were taken in total. The samples were pressed, dried, and mounted on an herbarium sheet to be prepared into an herbarium voucher. The observation and recording of vegetative and reproductive, and anatomical structures were conducted for the purpose of species identification. The identification process was carried out by comparing with KEP herbarium specimens plus referring to specific keys of Mangrove and its associates provided by Giesen *et al.* (2006) and other previous studies. Based on this study, a total of 70 species from 39 families, which encompasses both true and associate mangroves, were collected and documented, enriching our understanding of the mangrove biodiversity in the studied area. This study has identified the characters and type of roots, stems, and fruits as important morphological structures for species identification between true mangrove and its associates' species. Meanwhile, the anatomical characteristics of their leaves for selected species used in this study showed a lot of similarities between the true mangrove species and associate' species. This is because the associates' species had undergone adaptation to survive in the habitat. However, an advances microscopic analysis such as Scanning Electron Microscope (SEM) can done in further study to get a strong supporting character between true mangrove species and associates' species. In conclusion, the mangrove areas in Pekan and Kuantan exhibit a substantial diversity of species. Furthermore, the study highlights the importance of considering both morphological and anatomical characteristics for the identification of mangroves and associated species. Hence, the findings derived from this study have significant potential for shaping and guide future conservation strategies specifically tailored to the preservation and sustainable management of mangrove forests located in the Pekan and Kuantan.

ملخص البحث

تعتبر نظم غابات المانغروف موطنًا لأنواع نباتية عديدة، لكل منها تكيفات فريدة لمواجهة البيئة الساحلية الصعبة. إن تحديد الأنواع بدقة يمكن العلماء والمحافظين وصانعي السياسات من تسجيل وتصنيف هذه الأنواع بشكل دقيق، مما يسهل الجهود المستهدفة لحفظها والحفاظ على النباتات النادرة أو المهددة بالانقراض في غابات المانغروف. يمكن إعادة صياغة أهدافنا كما يلي:

(1) التعرف على وتسجيل تنوع الأنواع النباتية المانغروف الحقيقية وشركائها في منطقتي كوانتان وبيكان. (2) إنتاج ميزات تشريحية مميزة لأنواع مختارة من المانغروف الحقيقي وشركائه لتسهيل التعرف عليها وتحديدها. (3) تحديد حالة الحفظ والاتجاه السكاني لأنواع المانغروف الحقيقي وشركائه في منطقتي كوانتان وبيكان. تم إجراء أخذ العينات باستخدام طريقة العينة العشوائية على طول المسارات. تم جمع ثلاث عينات لكل نوع نباتي، حيث تم ضغطها وتجفيفها وتثبيتها على ورقة هيرباريوم لإعدادها كعينة هيرباريوم. تم إجراء الملاحظات وتسجيل الهياكل الخضرية والتكاثرية والتشريحية بغرض تحديد الأنواع. تم تنفيذ عملية التعرف بمقارنة العينات مع عينات هيرباريوم KEP بالإضافة إلى الرجوع إلى مفاتيح محددة للمانغروف وشركائه كما قدمها Giesen وآخرون (2006) ودراسات سابقة أخرى. بناءً على هذه الدراسة، تم جمع وتوثيق ما مجموعه 70 نوعًا ينتمون إلى 39 عائلة، تشمل كلاً من المانغروف الحقيقي وشركائه، مما يؤثر فيهما لتنوع المانغروف في المنطقة المدروسة. حددت هذه الدراسة خصائص وأنواع الجذور والسيقان والثمار كهم الهياكل المورفولوجية للتعرف على الأنواع بين المانغروف الحقيقي وشركائه. وفي الوقت نفسه، أظهرت الخصائص التشريحية لأوراق الأنواع المختارة في هذه الدراسة تشابهاً كبيراً بين المانغروف الحقيقي وشركائه، بسبب تكيف الأنواع الشريكة للبقاء في هذا الموطن. ومع ذلك، يمكن إجراء تحليل مجهري متقدم مثل استخدام المجهر الإلكتروني الماسح (SEM) في دراسات مستقبلية للحصول على أدلة قوية لدعم التمييز بين أنواع المانغروف الحقيقي وشركائه. في الختام، تُظهر مناطق المانغروف في بيكان وكوانتان تنوعاً كبيراً في الأنواع. كما تسلط الدراسة الضوء على أهمية النظر في كل من الخصائص المورفولوجية والتشريحية للتعرف على أنواع المانغروف والشركاء المرتبطين بها. وبالتالي، فإن النتائج المستخلصة من هذه الدراسة لديها إمكانات كبيرة لتوجيه وتشكيل استراتيجيات الحفظ المستقبلية المصممة خصيصاً للحفاظ على الإدارة المستدامة لغابات المانغروف في منطقتي بيكان وكوانتان.

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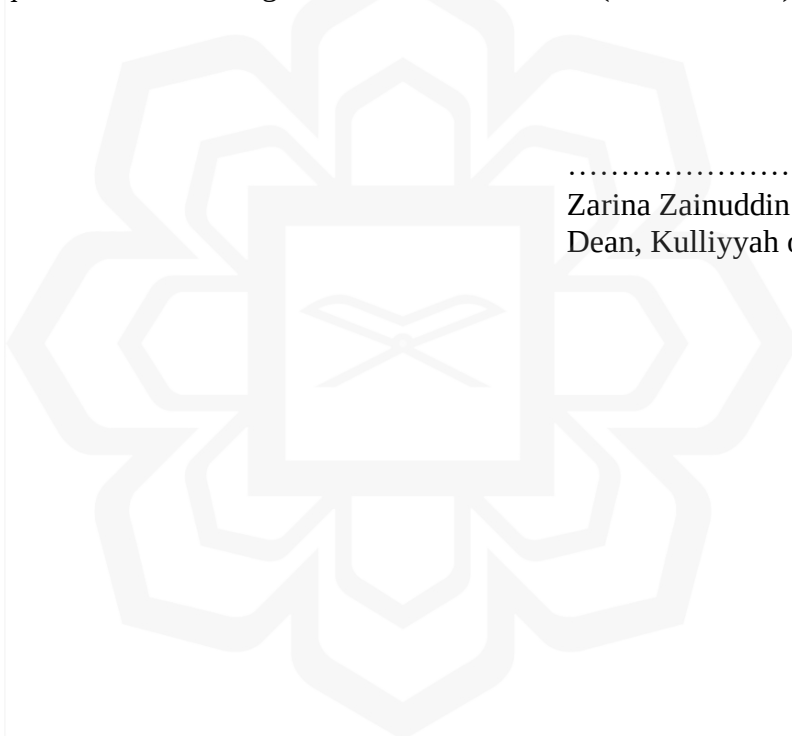
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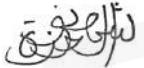
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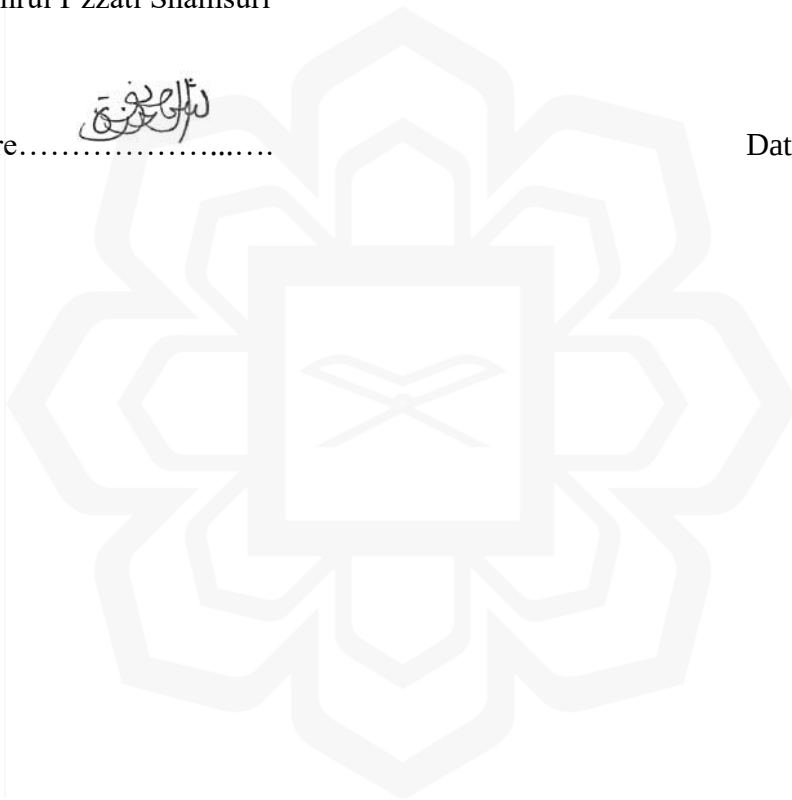
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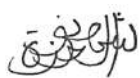
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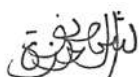
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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Mangroves are referred to woody plants that grow near the land-sea interface (Kathiresan *et al.*, 2001) and salt-tolerance evergreen forests found in tropical and subtropical latitudes (Sandilyan *et al.*, 2012). In 2000, the estimated total area of the world was 137,760 km² in 118 nations and territories, based on the first comprehensive assessment of all mangrove forests in the world. Asia (42%) has the highest number of mangroves, followed by Africa (20%), North and Central America (15%), Oceania (12%) and South America (11%) (Giri *et al.*, 2011).

Mangrove is very important and plays a crucial role in many aspects. Mangrove forests are critical to our socioeconomic growth, as they are incredibly valuable coastal resources. The protection of the coast from solar UV-B radiation, green-house effects, and the wrath of cyclones, floods, sea level rise, wave action, and coastal erosion accounts for a large part of the ecological value. In addition, it is also playing an important role in the global carbon cycle and generates a lot of litter in the form of fallen leaves, branches, and other debris. Mangrove ecosystems also play a role in intricate food webs and energy fluxes (Kathiresan, 2012).

Mangrove plant families constitute a rich and diverse mosaic of species that have undergone remarkable evolutionary adaptations to not only survive but flourish in the demanding and ever-changing intertidal regions of coastal ecosystems. Within mangrove ecosystems, a diverse array of plant species coexists, with *Avicennia*, *Rhizophora*, *Lumnitzera*, *Kandelia*, and *Sonneratia* being notable representatives. Mangrove species, uniquely adapted to coastal environments, exhibit several distinct characteristics that enable their survival in challenging conditions. These plants are renowned for their complex root systems, such as stilt roots or pneumatophores, which provide stability in soft, waterlogged soils and facilitate oxygen uptake in low-oxygen environments (Srikanth *et al.*, 2016). Mangroves are also well adapted to high salinity

levels; they either expel excess salt through specialised glands or limit its uptake from the soil. (Liang *et al.*, 2008) Their leaves are often thick and waxy to minimise water loss, and some species have viviparous seeds that germinate while still attached to the parent plant, ensuring seedling survival in unpredictable tidal waters. This combination of adaptations not only allows mangroves to endure harsh coastal conditions but it also makes them crucial for stabilising shorelines, providing habitats for diverse marine and bird species, and acting as natural filters for coastal waters (Liang *et al.*, 2008; Naskar *et al.*, 2015).

Mangrove forest area in Pahang is around 9,000 ha with nine total mangrove forest that had been gazette as Forest Reserve (Omar *et al.*, 2016; Forestry Department of Pahang, 2022). *Rhizophora apiculata*, *Rhizophora mucronata* and *Sonneratia alba* are the most common species that can be found in Pahang mangrove forest (Rozainah *et al.*, 2006; Shahbudin *et al.*, 2009; Zuhairi *et al.*, 2019). Kuantan and Pekan, two cities along Pahang's coastline in Malaysia, are home to a diverse assemblage of mangrove plant species that have evolved ingenious adaptations to thrive in the region's challenging and dynamic intertidal zones (Figure 1.1).

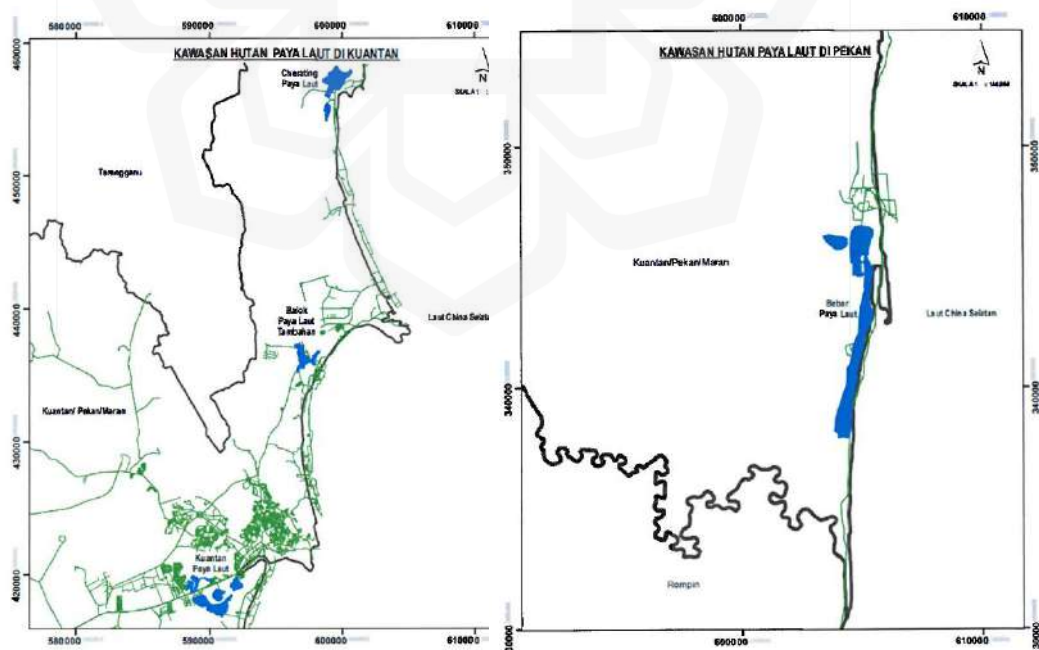


Figure 1: Kuantan and Pekan Mangrove Forest Area (Forestry Department of Pahang)

Mangrove forests, despite their vital ecological and socioeconomic significance, face a multitude of threats that put in danger their existence. One of the most pressing concerns is habitat loss and degradation due to urban development, aquaculture expansion, agriculture, and infrastructure projects, leading to the clearing of mangrove areas (Shahbudin *et al.*, 2009; Zuhairi *et al.*, 2019). Industrial and agricultural runoff further deteriorates the quality of the water, damaging both mangroves and the surrounding marine life. Climate change-related factors, such as increased sea level and increased storm intensity, intensify coastal erosion and inundation, posing a direct risk to mangrove ecosystems. Additionally, unsustainable fishing practices can exacerbate their vulnerability. These cumulative threats underscore the urgent need for conservation efforts and sustainable management practices to protect the critical services and biodiversity offered by mangrove forests.

Conservation through the study of mangrove plant diversity and identification is a multifaceted approach that forms the basis for the preservation of effective mangrove ecosystem preservation. By meticulously cataloguing and analysing the diverse array of mangrove species in a given region, researchers gain invaluable insights into the intricate web of life within these coastal forests. This knowledge not only aids in the identification of rare and endangered plant species but also unveils the critical roles that mangroves play in supporting various organisms, from fish nurseries to bird habitats. With a deep understanding of the diversity and ecological importance of these plants, conservationists can formulate targeted strategies to protect and restoring mangrove habitats, ensuring the long-term health and resilience of these ecosystems in the face of numerous threats. Thus, the objective of this study is to comprehensively document and analyse the diversity and morphological variation of mangrove species and their associated flora in Kuantan and Pekan.

1.2 PROBLEM STATEMENT

Plant taxonomy, the science of classifying and naming plants, is closely intertwined with plant morphology (the study of external plant structures) and plant anatomy (the study of internal plant structures) (Taia., 2005; Gupta *et al.*, 2012; Haider, 2018). Taxonomists utilize observable morphological traits, such as leaf shapes, flower

structures, and fruit types, to categorize and identify plant species (Haider, 2018). These morphological characteristics provide critical data for establishing evolutionary relationships and classifying plants into hierarchical categories. Meanwhile, plant morphology relies on taxonomic principles for naming and grouping plants based on shared characteristics. Plant anatomy complements both by delving into the internal organization of plant tissues, helping to explain the functional aspects of external morphological features and aiding in the resolution of taxonomic uncertainties. Together, these disciplines work in concert to unravel the complexities of plant life, from their external appearances to their inner workings, contributing to our comprehensive understanding of the diverse world of plants.

Identification of mangrove plants through the study of their morphological and anatomical structures is of paramount importance for a variety of reasons. This method provides a foundation for understanding the diversity of mangrove species within a given region. Mangrove ecosystems are home to numerous plant species, each with unique adaptations to the challenging coastal environment. Accurate identification enables scientists, conservationists, and policy makers to precisely catalogue and categorize these species, facilitating targeted conservation efforts and the preservation of rare or endangered mangrove plants.

Furthermore, studying the morphological and anatomical characteristics of mangrove plants is essential to comprehend their ecological roles and functions within the ecosystem. Different species may exhibit variations in leaf shape, root structure, and reproductive mechanisms, which directly influence their interactions with other organisms and their ability to withstand environmental stressors such as saltwater flooding or strong winds (Hogart, 2015; Ahmad *et al.*, 2018; Naskar *et al.*, 2021; Aluri, 2022). This knowledge aids in unraveling the intricate web of ecological relationships within mangrove ecosystems, shedding light on how these plants provide habitat, stabilize shorelines, and contribute to nutrient cycling. In essence, the identification of mangrove plants through their morphological and anatomical traits not only enhances our understanding of these vital coastal habitats but also underpins informed conservation and management practices, ensuring the long-term sustainability of mangrove ecosystems.

Besides that, nowadays, the area of mangrove forests in Pahang is decreasing due to coastal development or global change (Shahbudin *et al.*, 2009; Zuhairi *et al.* 2019). Mangrove species indeed play a pivotal role in safeguarding our coastal areas from the destructive forces of erosion and floods. Therefore, an updated checklist documenting the biodiversity and distribution of mangrove species is not only a scientific endeavour but also a call to action. Such comprehensive studies shed light on the unique and fragile nature of these ecosystems, serving as a powerful tool for raising awareness and galvanizing conservation efforts. Besides, the information collected through this project will serve as a valuable resource for policymakers, conservationists, and local communities, enabling informed decision-making and the development of strategies to protect and sustainably manage the Kuantan and Pekan mangrove ecosystems. By improving our understanding of the diversity and morphology of mangrove species and their associates, this project contributes to the larger effort of preserving these critical coastal habitats for future generations.

1.3 RESEARCH OBJECTIVE

- a) To identify and record the diversity of true mangrove plant species and its associates in Kuantan and Pekan.
- b) To produce distinct anatomical features for selected true mangrove species and its associates to be easily recognized and identified.
- c) To determine the conservation status and population trend of true mangrove species and its associates in Kuantan and Pekan.

1.4 HYPOTHESIS

The number of plant species will differ significantly among the sampling sites, as variations in habitat types, microclimates, and ecological conditions at each site will influence the composition and richness. Besides, morphological and anatomical structural variations of mangrove plants and their associates can be utilized for species identification. Furthermore, plant diversity data can help monitor changes in vegetation composition and structure over time, providing early warning signs of ecosystem degradation or habitat loss.



CHAPTER 2

LITERATURE REVIEW

2.1 MANGROVE ECOSYSTEM

The mangrove forest stands as a fundamental element within the coastal ecosystems found across tropical and subtropical regions worldwide. It has been previously labelled as both the "Coastal Woodland" and the "Intertidal Forest," reflecting its unique ecological character (Aksornkoae, 1995). Besides, mangroves are distinguishable from tropical rainforests due to their composition of salt-tolerant plants that have evolved to thrive in the harsh conditions of high salinity and tidal zones (Minobe *et al.*, 2010; Shah *et al.*, 2015). This unique ecosystem endures daily fluctuations in temperature, exposure to saltwater, and varying degrees of oxygen deficiency.

Situated in the transitional zone between tropical and subtropical coastlines, mangrove ecosystems are invaluable resources that extend a wide range of significant benefits to both human societies and wildlife. Mangrove ecosystems provide substantial benefits to human communities. They are an essential resource for many coastal populations, offering materials for building, sources of food, and livelihoods through fishing and tourism. Furthermore, they provide a rich habitat for a diverse range of wildlife, including many fish species, birds, and invertebrates. These areas also serve as breeding grounds, nurseries, and feeding grounds for a multitude of marine organisms (Badola *et al.*, 2003; Datta *et al.*, 2012; Hutchison *et al.*, 2014; Hamzah *et al.*, 2020)

Joshi and Ghose (2014) have defined mangroves as a diverse assembly of taxonomically distinct woody shrubs and trees that thrive within the intertidal zone of tropical and subtropical coastlines. Mangrove vegetation, as commonly observed, primarily consists of dicotyledonous woody shrubs or trees, and these species predominantly thrive within the tropical regions of the world. These resilient plants frequently establish dense forests that exert dominance over intertidal muddy shores,

often forming patches characterized by almost exclusive species composition (Hogarth, 2007).

Mangrove are referred to the trees in the intertidal zone, between land and sea, in the tropics or sub-tropics. Mangroves' aerial roots help to stabilize the environment and provide a substratum for a variety of plant and animal species. The mangrove trees and canopy above the sea provide vital habitat for a variety of species. Birds, insects, mammals, and reptiles are among them. Epibionts such as tunicates, sponges, algae, and bivalves have overtaken the mangrove roots below the water's surface (Nagelkerken *et al.*, 2008).

In mangroves, the soft substratum provides habitat for a variety of infaunal and epifaunal species, while the space between roots provides shelter and food for motile fauna including prawns, crabs, and fish. Detritus is created from mangrove litter, which helps to support the mangrove food web. The mangrove food chain is additionally supported by plankton, epiphytic algae, and microphytobenthos. Mangroves provide a perfect home for a number of animal species during part or all of their life cycles. Mangroves, as a result, may serve as nursery habitats for (commercially important) crab, prawn, and fish species, as well as supporting offshore fish populations and fisheries (Nagelkerken *et al.*, 2008).

2.2 MANGROVE PLANT SPECIES

Generally, mangrove species can be categorized as true mangrove and mangrove associates. True mangroves are referred to as 'exclusive' species, as they are only found in the mangrove ecosystem. Meanwhile, mangrove associated are referred to as 'non-exclusive' species because they are found in both terrestrial and aquatic habitats of mangrove ecosystem (Wang *et al.*, 2011).

According to Tomlison (2016), true mangrove can be identified as plant species that 1) occur only in mangrove forests and are not found in terrestrial communities; 2) play a major role in the structure of the mangrove community, sometimes forming pure stands; 3) have morphological specialisations to the mangrove environment; 4) have some mechanism for salt exclusion. All species of the genera *Avicennia*, *Lumnitzera*,

Bruguiera, *Ceriops*, *Kandelia*, *Rhizophora*, and *Sonneratia*, as well as *Nypa fruticans* and *Laguncularia racemosa*, are regarded "real mangroves" and make up the majority of mangrove forests around the world. Other species, such as *Acrostichum aureum*, *Aegiceras corniculatum*, and *Osbornia octodonta*, are also called "genuine mangroves," but they are just small components of mangrove forests (cited in Quadros *et al.*, 2017). However, no consensus among experts has been achieved in favor of this classification for some fringe species located mostly on the landward transitional zones of mangroves, and significant dispute has ensued (Wang *et al.*, 2011).

The Malaysian mangrove zonation species-specific belts is based on soil and flooding patterns in three zones, notably *Avicennia* - *Sonneratia*, *Bruguiera* - *Rhizophora*, and the back mangrove zones (Figure 2.1). The *Avicennia* - *Sonneratia* species endure the soft soils disturbed by daily tidal flooding on the seaward border, burying massive root systems just beneath the mud. Roots are sent downward for anchorage and upward for absorption in these underwater structures, which have numerous air spaces for breathing. *Sonneratia* fruits are encased in protruding lobes to aid in regeneration, allowing them to float atop the water currents (Jusoff, 2013).

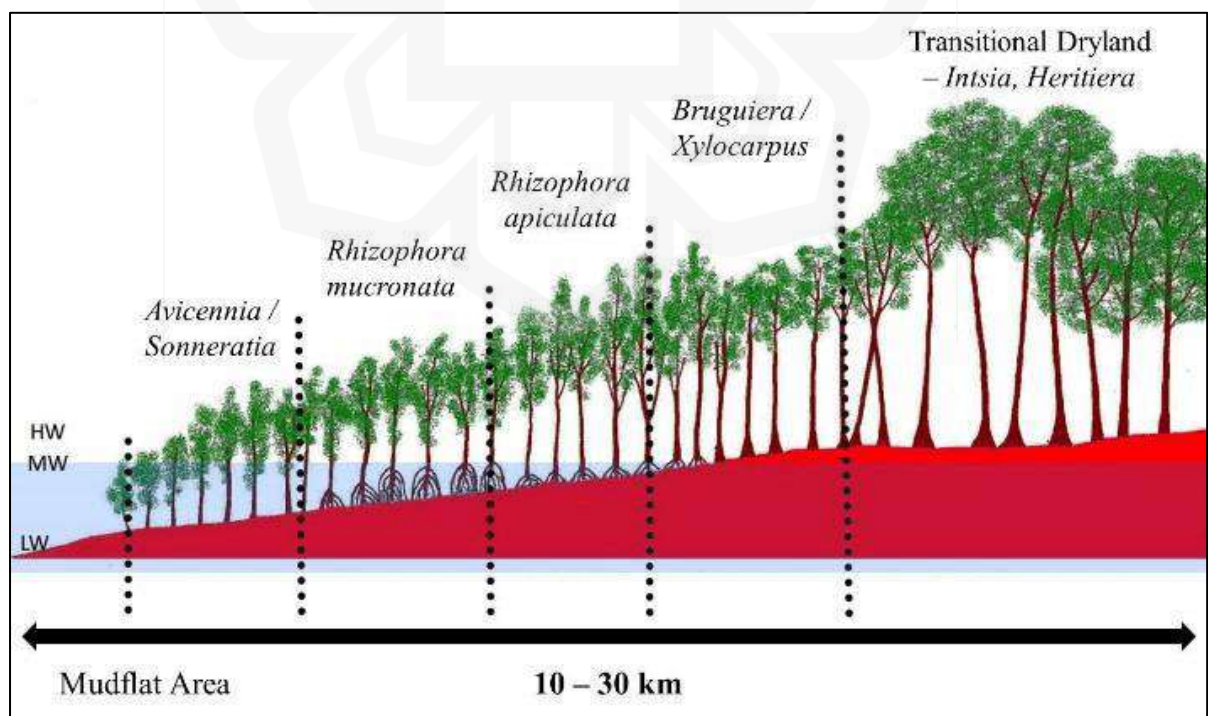


Figure 2: Typical mangrove forest zonation in Peninsular Malaysia

According to Jusoff (2013) also, the *Bruguiera* - *Rhizophora* zone, that located on slightly higher ground, is only flooded during high tide on more compressed soils. These are the most valued mangrove trees in terms of timber. The zone's height uniformity and expansive network of aerial root system distinguish it. *Rhizophora* seedlings hang like slender cigars, each one ready to drop into the silty soil and grow itself. Clay content, on the other hand, increases in the compact soils of the back mangrove zone. Crabs and lobsters construct mounds that raise the ground level another meter or two, revealing a rich understory of enormous fern clusters. Beyond the tidal reach, two varieties of swamp palm, *Nypa fruticans* and *Oncosperma horrida*, forest thrive in brackish waterways, with the dominating nipa palm growing in contiguous thickets on riverbanks.

2.3 MORPHOLOGICAL STRUCTURE OF MANGROVE SPECIES

The mangrove forest is mainly dominated by short trees. However, some species can reach 50 to 60 meters in height. Mangroves usually only reach a few kilometers inland from the shore or river mouths. In contrast to other forest types, mangrove forests lack shade-tolerant understory vegetation. There are just too many roots, water, and dirt at ground level for other plants to develop (Ahmad *et al.*, 2018).

2.3.1 ROOT

Mangrove roots are the most notable adaptation (Figure 2.2), resulting in a wide range of shapes and sizes, including aerial roots, stilts, and pneumatophores, which can be knee-like or pencil-like (Srikanth *et al.*, 2016; Ahmad *et al.*, 2018). Mangrove species have gas-filled roots and can tolerate high tissue salt concentrations. Other than that, the environment factors such as soil compaction, waterlogging, wind force and storm had affected the depth of mangrove root in order to support the stability of the plant. For example, *Rhizophora* species have prop roots that descend from the trunk and branches, creating a stable support system. Meanwhile, *Xylocarpus* species develop buttress roots parallel to the wind direction, particularly on the leeward side can provide support from the falling. Besides, buttress roots also can function as conduits for long-

distance transport of water, nutrients, and metabolites (Srikanth *et al.*, 2016). Lenticels, or fine holes for breathing, are pierced into the surfaces of these roots. The plants breathe through these pneumatophores, which act as a snorkel (Srikanth *et al.*, 2016; Ahmad *et al.*, 2018).



Figure 3: The roots of mangrove plants. A) plank roots of *Xylocarpus granatum*. B) stilt roots of *Rhizophora apiculata*. C) pencil-like pneumatophores of *Avicennia alba*. D) knee-roots of *Bruguiera gymnorhiza*

2.3.2 STEM

Mangrove plant species exhibit distinctive stem morphological characteristics that are crucial for their adaptation to the demanding coastal environments they inhabit. One notable feature is the presence of lenticels (Figure 2.3 A), small pores or openings on the stem's surface, which facilitate gas exchange between the inner tissues and the external atmosphere. These lenticels are essential for ensuring oxygen supply to submerged roots in waterlogged soils (Shimamura *et al.*, 2010), a vital adaptation for mangrove plants. These plants typically possess flexible and often stilt-like prop roots (Figure 2.3 B) that emerge from the stem and extend both above and below the water's surface, providing stability and support in the loose, waterlogged soils they grow in

(Srikanth *et al.*, 2016). Furthermore, mangrove stems are often cylindrical and can range from thin and slender to stout and robust, depending on the species. This morphological diversity allows mangroves to adapt to varying tidal conditions and resist damage from strong currents and storms. Additionally, the bark of mangrove stems is often thick and resistant to saltwater, helping to protect the inner tissues from the detrimental effects of high salinity (Scholander, 1968; Parida *et al.*, 2010)



Figure 4: A) Lenticel on *Bruguiera sp.* stem. B) Stem with stilt-root of *Rhizophora apiculata*

2.3.3 LEAF

Mangrove plant species possess distinct leaf morphological traits that are highly adapted to their demanding coastal environments. One striking feature is their leaves' ability to excrete excess salt through specialized salt glands, which are often visible as small white spots on the leaf surface. Salt glands are present in all *Aegiceras*, *Avicennia*, and *Acanthus* species, while *Lumnitzera* (Figure 2.4) species have identical structures to the salt gland. This adaptation allows mangrove plants to thrive in saline environments while preventing salt buildup within their tissues. Additionally, mangrove leaves are often leathery and waxy, reducing water loss through transpiration and protecting against desiccation in the hot and windy coastal conditions. (Liang *et al.*, 2008; Ahmad *et al.*, 2018; Naskar *et al.*, 2021)



Figure 5: Thick leaves for water storage in *Lumnitzera littorea*.

2.3.4 FLOWER

The flowers of mangrove have different flowering period even within the same genus. For example, the flowering period for *Rhizophora apiculata* is between September – November, while for *Rhizophora mucronata* is between October – December (Nagarajan *et al.*, 2008). Besides, flower in *Rhizophora* also showed some characteristic of anemophily (Aluri, 2013). The pollinated time for mangrove flower also different based on the presence of abundant xylem and hydathodes. The presence of abundant xylem and hydathodes in *Ceriops decandra* was adapted for pollination in the day. Meanwhile species such *Ceriops tagal* and *Kandelia candel* (Figure 2.5 A) with absent of abundant xylem and lack hydathode were adapted for pollinated at night or early morning. Even though, understanding floral mechanics and genetic isolating mechanisms is crucial for studying successful dispersal and establishment. However, there is less information is available on floral biology, pollination, breeding systems, and propagule production success rates.



Figure 6: A) Flower of *Kandelia candel*. B) Flower of *Xylocarpus granatum*

2.3.5 SEED AND FRUIT

Additionally, mangrove fruit also have special characteristic that can help the plant for survival in extreme environment. Mangrove species exhibit unique seedling development and dispersal via vivipary. Vivipary is refers to the precocious and continuous growth of offspring while still attached to their mother. There are two types of vivipary: true and crypto-vivipary (Tomlison., 1986; Aluri., 2013; Yun *et al.*, 2022). True vivipary occurs when the embryo penetrates the fruit pericarp as hypocotyl and grows to a significant size before dispersal such as in Rhizophoraceae family (Figure 2.6 B). After mature, the propagule will free fall from the parent plant and planted on the same site during low tide and float to another site during high tide. Meanwhile, crypto-vivipary occurs when the embryo grows continuously but does not emerge from the fruit before dispersal such as in *Avicennia* (Figure 2.6 A) and *Aegiceras* (Aluri., 2013). Other than that, the salt concentration in viviparous propagules of some mangrove species is lower than in mother tree organs, but gradually increases during propagule maturation. Propagules may be trained to tolerate high salinity by absorbing it from their mother trees while still attached to them (Liang *et al.*, 2008). Early rooting, buoyancy during sea dispersal, nutrient transfer to hypocotyls, maintaining embryonic osmotic equilibrium, and establishment in coarse-grained environments, are other values of vivipary fruit (Aluri., 2013).



Figure 7: A) Crypto-viviparous fruit of *Avicennia officinalis*. B) Viviparous fruit of *Bruguiera parviflora*

2.4 DIVERSITY OF MANGROVE PLANT IN PAHANG

Mangrove plant families found in Pahang, Malaysia, encompass a diverse array of species that have uniquely adapted to the challenging and dynamic intertidal zones of the coastal environment. These families play a vital role in shaping the unique ecosystems along Pahang's coastline. The mangrove plant family found in Pahang includes Rhizophoraceae, Acanthaceae, Combretaceae, Pteridaceae, Rubiaceae and Lythraceae. (Rozainah *et al.*, 2006; Zuhairi *et al.*, 2019)

One of the most significant families is Rhizophoraceae, which includes iconic species such as *Rhizophora apiculata* and *Rhizophora mucronata*, commonly referred to as the tip-mangroves. These mangroves are characterized by their distinctive prop roots, which provide stability in the muddy substrate and aid in oxygen uptake (Hou, 1955; Tomlison *et al.*, 1979). Another prominent family is Avicenniaceae, represented by species like *Avicennia alba*, known as the white mangrove. These species have specialized salt-excreting glands and often develop pneumatophores, aerial roots that facilitate gas exchange in waterlogged soils (Tan *et al.*, 2013; Srikanth *et al.*, 2015). Sonneratiaceae is another important family, featuring species like *Sonneratia caseolaris*, also known as the crab-apple mangrove, with its impressive aerial roots and adaptability to brackish waters (Rahim *et al.*, 2018)

2.5 GEOGRAPHICAL DISTRIBUTION

2.5.1 DISTRIBUTION OF MANGROVE IN MALAYSIA

Mangrove forests span an area of around 577,500 ha in Malaysia with around 60 different species. Sabah having the most extensive coverage of mangroves, accounting for 59% (or 341,000 ha) of the country's total, Sarawak 132,000 ha (23%), and Peninsular Malaysia 104,200 ha (18%). In Peninsular Malaysia, mangrove forests can be found on sheltered beaches, estuaries, rivers, and certain near-shore islands. The mangroves of the Matang Mangrove Forest Reserve along Perak's coast are particularly noteworthy. (Jusoff, 2013). Malaysia's large mangrove forest cover is attributed to the humid tropical climate and geomorphological structure. Even though, mangroves are still abundant in South and Southeast Asia, but they are also among the most disturbed ecosystems, having been identified and destroyed as a result of human development and climate change (DasGupta *et al.*, 2013).

A study related biodiversity of mangrove forest at two area in Selangor state by Zhila *et al.* (2014) had recorded seven species from four families of true mangrove and one associates species. Other than that, there are five dominant species, which are *Avicennia alba*, *Bruguiera gymnorhiza*, *Nypa fruticans*, *Rhizophora mucronata* and *Sonneratia caseolaris*, were recorded at Tumpat, Kelantan mangrove forest (Satyanarayana *et al.*, 2010). There are 16 families for both true mangrove species and associates' species were recorded at Semporna Mangrove Forest. Rhizophoraceae family was recorded with the greatest number of species, which is six species in total (Wah *et al.*, 2011).

2.5.2 DISTRIBUTION IN PAHANG

Pahang is one of Peninsular Malaysia's largest states, with a mangrove forest area of around 9,000 ha. However, only about a third of the mangrove forest has been gazette as a Forest Reserve under the Department of Forestry's jurisdiction (Omar *et al.*, 2016). According to Forestry Department of Pahang States (2022), there are nine mangrove reserve forest that located in Kuantan, Rompin and Pekan. There are Pontian Reserve

Forest, Rompin Reserve Forest, Endau Reserve Forest, Balok Reserve Forest, Cherating Reserve Forest, Kuantan Reserve Forest, Bebar Reserve Forest, Sungai Soi Reserve Forest, and Peramu Reserve Forest.

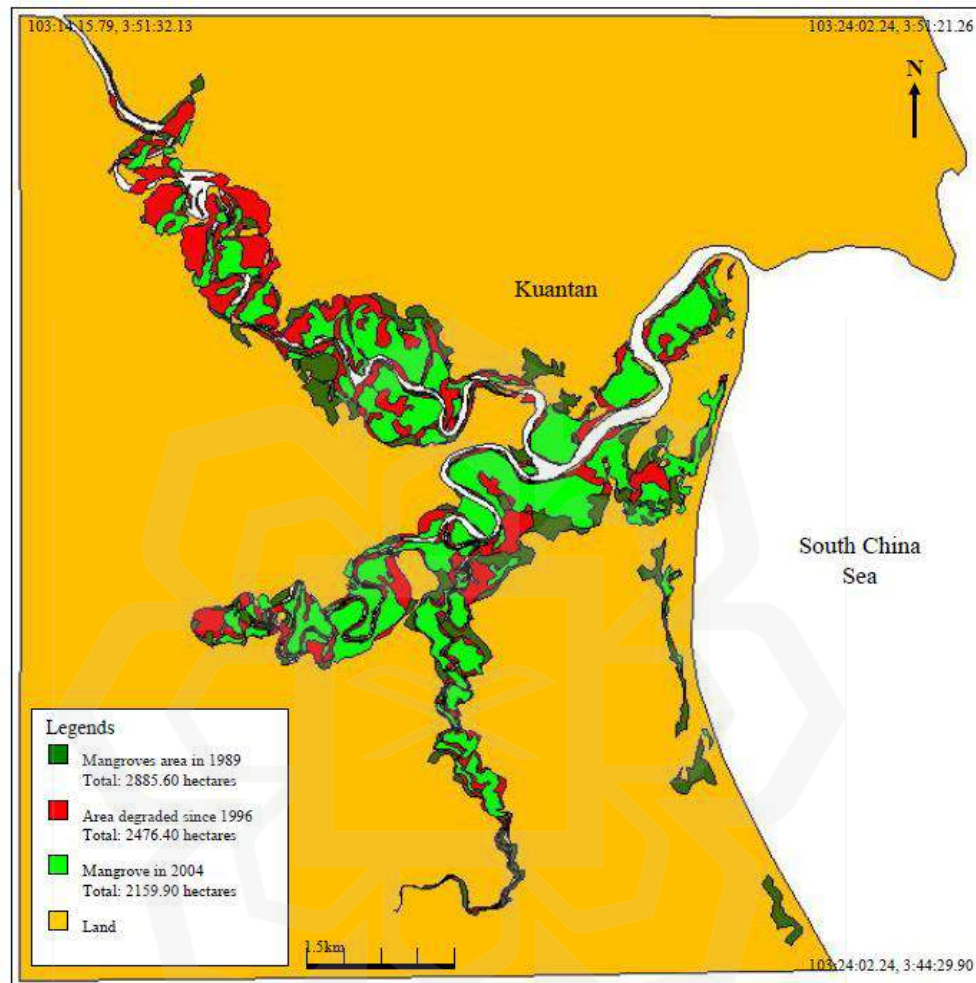


Figure 8: Mangrove distribution and degradation map in Kuantan, Pahang (Shahbudin *et al.*, 2009)

According to Shahbudin *et al.* (2009), Kuantan, Pahang's capital, has a total of 2159.90 ha of mangroves, with 11 species dominated by *Sonneratia alba* and *Rhizophora mucronata*. However, since 1989, the overall area of Kuantan's mangroves has been degraded by more than 725.70 ha (Figure 2.7). Besides that, the total mangrove area in Pahang River Estuary, Pekan sub-district, also had been decreased in 2017 (1,535.40 ha) by almost half of its size since 1990 (2,206.20 ha) (Zuhairi *et al.*, 2019). At Balok, there are 14 species of true mangrove and 8 associates' species had been recorded in 2006. *Rhizophora apiculata* and *R. mucronata* were the common species

that can be found (Rozainah *et al.*, 2006). Meanwhile at Cherating, there are 15 species for both true mangrove and its associates' species were recorded in 2019. Some of the species that had been recorded are *R. apiculata*, *R. mucronata*, *Nypa fruticans* and *Pandanus tectorius*. (Zuhairi *et al.*, 2019).

2.6 IMPORTANCE OF MANGROVE FOREST

Mangrove forests are significant because they protect coastlines from erosive wave action and strong coastal winds, by creates a buffer zone (Shahbudin *et al.*, 2009; Jusoff, 2013), as well as serving as natural barriers against tsunamis and severe storms (Jusoff, 2013). They keep salt water out of rivers, and they use a natural filtration process to keep concentrations, recycle nutrients, and eliminate toxicants (Jusoff, 2013). It also offers construction materials, fuel, charcoal, pulp, tannin, and traditional medicine to the local villagers. Products from the mangroves, like as charcoal and construction materials, have significant commercial value, making them a good source of revenue for the locals (Shahbudin *et al.*, 2009).

Furthermore, the production of detritus along the mangrove region offers food for shrimp, fish, mollusks, birds, and other marine animals, resulting in a rise in the fishery stock (Tse *et al.*, 2008). In addition, other creatures find shelter and food in mangrove settings. Some, such as the Borneo proboscis monkey, are particularly important due to their endangered condition. Migratory birds from faraway lands, such as the Bar-tailed godwit, stop at Malaysia's mangrove wetlands to 'refuel.' Besides that, as part of the wild menagerie, monkeys and snakes also thrive in mangroves (Jusoff, 2013).

Apart from that, the enormous variety of flora and animals connected with the mangrove ecosystem gives opportunities for education, ecotourism, and natural resource scientific study (Ashton *et al.*, 2002). Coastal zone ecosystems, particularly mangrove forests, are extremely valuable from an economic standpoint and should be exploited to optimize economic benefits (Shahbudin *et al.*, 2009). Uncontrolled development will destabilize the mangrove ecosystem and disrupt the interactions of many natural processes (Shahbudin *et al.*, 2009; Polidoro *et al.*, 2010). The only option

for dealing with mangrove depletion and excessive exploitation for short-term profit appears to be sustainable use and management. Pollution, changes in water flow patterns, and natural loss due to high energy waves are all factors that have an impact on mangroves (Shahbudin *et al.*, 2009).

2.7 PLANT DIVERSITY STUDY

Studying plant biodiversity involves a multifaceted approach, combining various scientific methods and techniques to understand the vast array of plant species and their interactions within ecosystems (Naeem *et al.*, 2016). One fundamental aspect of this approach is field research, which includes the identification and cataloguing of plant species in their natural habitats (Haider, 2011). This is often supplemented by herbarium studies, where collected plant specimens are preserved and studied in detail. Researchers utilize tools like dichotomous keys for species identification and GPS technology for mapping species distribution (Botella *et al.*, 2018; Torkar, 2021). This method involves examining the morphological and anatomical structure of plants, including characteristics like leaf shape, flower structure, vascular bundle and stomata. Detailed observations and measurements of these features are crucial for identifying and classifying plant species, understanding their evolutionary relationships, and discerning adaptations to different environments.

2.8 MORPHOLOGICAL APPROACH

The morphological approach in plant identification is a basis of botanical science, offering a reliable and time-tested method for classifying and differentiating plant species. This approach relies on the careful examination and description of physical characteristics and structures of plants, encompassing a wide array of traits such as leaf shape, arrangement, and venation, flower structure, fruit type, and stem characteristics (Sattler *et al.*, 1997; Kaplan, 2001). Botanists and researchers use these distinctive morphological features to construct dichotomous keys, field guides, and taxonomic descriptions, facilitating the accurate identification of plants in various ecosystems and regions (Haider, 2018; Rouhan *et al.*, 2021). The importance of the morphological

approach extends beyond taxonomy; it plays a crucial role in ecological studies, conservation efforts, and agriculture. For instance, the identification of invasive or endangered plant species relies heavily on their morphological traits, aiding in the development of targeted management strategies (Pyšek *et al.*, 2013; Dudley *et al.*, 2019). Furthermore, farmers and horticulturists utilize morphological characteristics to select and cultivate specific plant varieties for agricultural purposes (Imahori, 2014; Malhotra *et al.*, 2022). Overall, the morphological approach remains an indispensable tool for understanding, classifying, and utilizing the incredible diversity of plant life on Earth.

2.9 PLANT ANATOMICAL APPROACH

The anatomical structure approach in plant identification is a specialized and invaluable method that delves deep into the internal tissues and cellular features of plants. Unlike the morphological approach, which focuses on external traits, the anatomical approach examines the microscopic and internal characteristics that are often less visible to the naked eye. Botanists and researchers study the arrangement of cells, the presence of specialized structures like vascular bundles, parenchyma, and stomata. This intricate analysis allows for precise species identification and classification based on the unique anatomical features that each plant species possesses (Albrechtova, 2003).

The anatomical structure approach is especially significant in cases where morphological traits alone are insufficient for accurate identification, as some plant species may appear quite similar externally but exhibit distinctive anatomical differences (Lachenbruch *et al.*, 2011). Furthermore, it provides insights into the functional aspects of plant structures and can help elucidate how specific adaptations contribute to a plant's ability to thrive in various environmental conditions (Gratani, 2014). Ultimately, the anatomical approach complements the morphological approach and enhances our understanding of plant diversity, adaptation, and ecological roles, making it an indispensable tool in the field of plant biology and taxonomy.

According to Poompozhi and Kumarasamy (2014) the anatomical characteristics of mangrove species are adapted to their surroundings and stated that

epidermal traits are useful in distinguishing plant species. Vinoth et al. (2019) discovered that mangroves' adaptations are most visible in their succulent vegetation, enlarged mesophyll area, thick cuticle, and wax deposition on the epidermis. These structural characteristics are the foundation of their physiological adaptations to high-salinity settings.



CHAPTER 3

MATERIALS AND METHODS

3.1 PLANT DIVERSITY

3.1.1 Plant collection

Botanical sampling was held from June 2022 until September 2023. Plant samples were collected from 13 locality in Kuantan and Pekan mangrove forests (Table 3.1). The study was conducted using a simple random sampling method along the trails that was accessible. This method was chosen because it gives every individual or unit in the population an equal chance of being selected, reducing selection bias and ensuring the reliability of the findings. This study's target population included all true mangrove and associated species within the defined study area. Due to accessibility limits, the area covered by each sampling trail could not be set. Dense foliage, tidal inundation, and uneven terrain all made access to some portions of the research area difficult. Therefore, changes were made throughout the sampling process to identify alternative accessible trails while maintaining the randomness of the sample approach. Three replicates for each species and two duplicates for each individual plant were collected. This approach enhances the reliability, consistency, and statistical robustness of the study, ensuring accurate and reproducible results. The plants collected fulfil the requirement of having roots, stems, leaves, flowers and fruit with no or minimal damage. All samples were process as herbarium vouchers by following the method of Miller et al., (1995) with some modification.

Table 3.1: Sampling locality

NO.	LOCALITY
1	Cherating
2	Sungai Balok
3	Taman Gelora
4	Tanjung Api
5	Sungai Ular
6	Pantai Sepat
7	Tanjung Lumpur
8	Teluk Sisek
9	Cherok Paloh
10	INOCEM
11	Widad Riverfront Apartment
12	Pekan Mangrove Forest
13	Sungai Nenasi

3.1.2 Herbarium Preparation

3.1.2.1 Soaking process

The samples were subjected to a pressing process using a newspaper to flatten them before being soaked in a solution of methylated spirit. This soaking process took place in biohazard plastic containers and lasted for a duration of seven days. This duration is essential to allow the methylated spirits to penetrate the plant tissues. This immersion is crucial as the methylated spirits act as a preservative, ensuring that the plant's cellular structure and features are maintained without decay. Meanwhile, the reproductive parts of the samples were carefully extracted and preserved separately in sample bottles containing methylated spirits. This dual preservation method ensured that both the vegetative and reproductive components of the samples were effectively preserved for further analysis and study.

3.1.2.2 Pressing

The collected samples were cleaned to remove excessive soil and mud from the sampling area. The collected specimens were then placed within two sheets of old newspaper to ensure the high quality in herbarium collection, and it is important that there was no overlap of the specimens between the newspapers. The parts of specimens will be arranged neatly flat on the cardboard, showing both surfaces of the leaves (abaxial and adaxial surface) and none of them will be folded. An exception is if there will be large leaves that could not fit properly and thus need to be folded. The specimens were pressed between cardboard and a presser. The specimens were ensured to be stacked and tied firmly to ensure that the specimens were neatly organized and wrinkle-free.

3.1.2.3 Drying

Subsequently, the compressed samples were put in an oven to dry at 55 °C for a minimum of two weeks. For selected specimens that remained incompletely dried after this initial period, the drying process was extended until they reached the desired level of dryness. This meticulous approach guaranteed that all specimens were adequately desiccated, minimizing the risk of mold growth or decay during long-term storage.

3.1.2.4 Mounting

The specimens were carefully placed on herbarium sheets once they had completely dried. Then, each specimen was carefully stitched into the sheet using a needle and thread. Through this procedure, it was made sure that the specimens would stay firmly fixed to the sheet and that no pieces would come loose or fall out during handling or long-term preservation.

3.1.2.5 Labelling

The labels on the mounted specimens were carefully attached and included all the information needed for identification and reference. The name of the author, the place

of collection, the date of establishment, the scientific name, and the common name of the plant species were all listed on each label. Because of the thorough labelling, all the important information about each item was easily available, making it easier to identify and use them for research, education, and conservation purposes.

3.1.2.6 Storage

Subsequently, the herbarium specimens were carefully stored in the herbarium Department of Plant Science at the International Islamic University Malaysia, Kuantan Campus. This specialized facility provides a controlled environment conducive to the long-term preservation. The specimens were placed in cabinets to maintain optimal conditions of temperature, humidity, and light levels, ensuring their longevity.

3.1.3 Data collection and morphological observation

Plant characterization entails a comprehensive analysis of both vegetative and reproductive structures, encompassing qualitative and quantitative parameters. Thus, morphological descriptions were recorded by utilizing parameters outlined by Tomlison (1986). In addition, a detailed examination of morphological structures was performed that included roots, stems, leaves, fruits, flowers, and seeds to facilitate species identification and confirmation of species. (Figure 3.1). This comprehensive analysis involved careful observation and documentation of each structural component, noting its distinct characteristics and variations. Root systems were scrutinised for their morphology, depth, and branching patterns, providing insight into the anchorage and nutrient absorption capabilities of the plant. Stem characteristics, such as texture, colour, and presence of nodes or internodes, were evaluated to distinguish differences between species. The morphology of the leaves was examined, including shape, size, venation, and surface texture, as it served as key diagnostic feature for species differentiation. Fruits were examined for their size, shape, colour, texture, and mode of dispersal, while flowers were examined for their arrangement, colour, shape, and presence of reproductive organs. Additionally, seeds were analysed for their size, shape, colour, and surface texture, providing further information on species diversity and classification. Lastly, the vegetative and reproductive structures of the collected

samples were analysed and identified by comparing them with previous publications (Appendix 1 and 2). Moreover, herbarium specimens sourced from the Kepong Herbarium (KEP) and previously recorded species were utilized as cross-references, providing valuable comparative data for accurate identification and characterization.

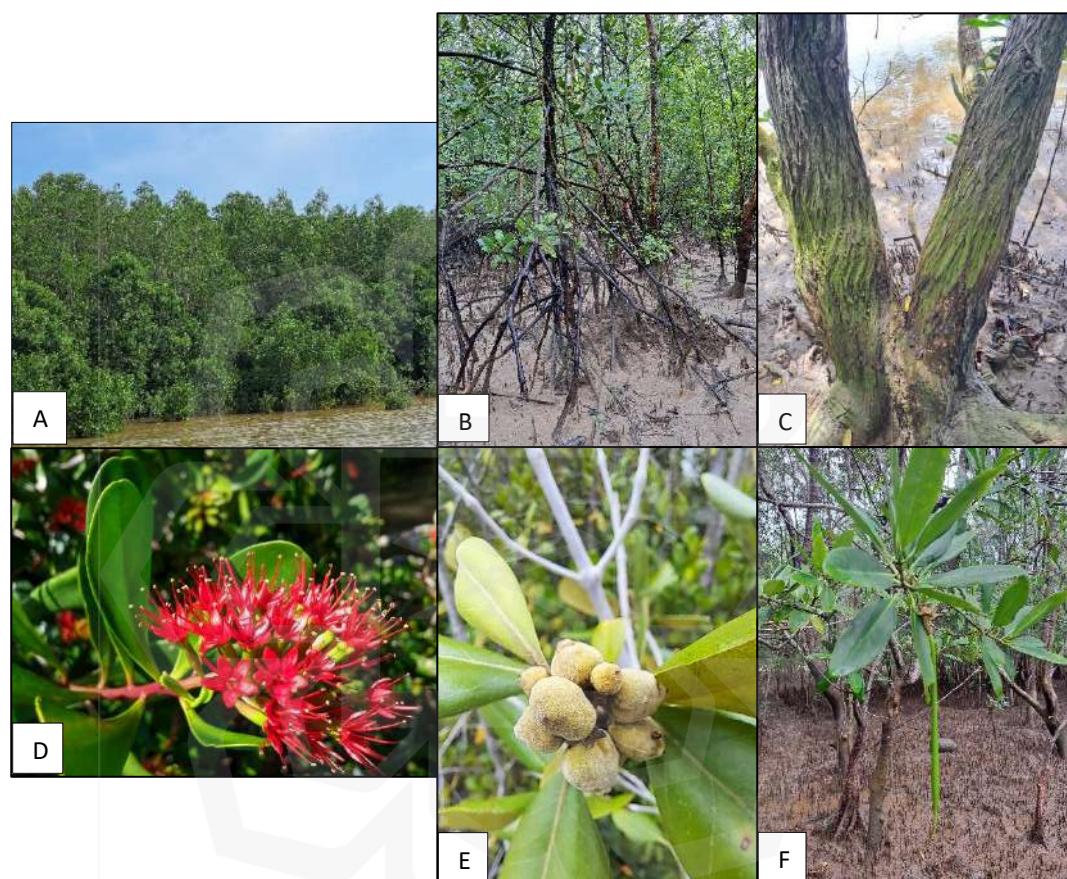


Figure 9: A) Mangrove Forest. B – F) Morphological structure of mangrove species. B) Root. C) Stem. D) Flower. E-F) Fruit.

3.2 LEAF ANATOMY

3.2.1 Sample collections

Ten plant species categorized as shrub and herbaceous were used for objective number two. There are 7 species of true mangrove and 3 species of associated mangrove had been selected for this study (Table 3.2). The selection of true mangrove species provides a thorough representation of plants that are specifically adapted to saline, wet habitats

and serve key roles in mangrove ecosystems, such as coastal protection and biodiversity support. Meanwhile, the three associated mangrove species were chosen to reflect the ecological interactions and diversity within the mangrove habitat, because these species frequently occupy transitional zones and contribute to ecosystem stability. All species were collected from selected mangrove area in Kuantan and Pekan. The mature leaf was selected from each species. As for dicotyledons species, the leaf was selected between number three and five. Besides that, the selected leaf also was free from any disease or abnormalities.

Table 3.2: List of species for used anatomical study

No	Species	Type	Group of plant	Plant habit
1	<i>Acanthus ilicifolius</i>	True mangrove	Dicotyledon	Herbaceous
2	<i>Acrostichum aureum</i>	True mangrove	Pteridophytes	Herbaceous
3	<i>Acrostichum speciosum</i>	True mangrove	Pteridophytes	Herbaceous
4	<i>Lumnitzera littorea</i>	True mangrove	Dicotyledon	Shrub
5	<i>Lumnitzera racemosa</i>	True mangrove	Dicotyledon	Shrub
6	<i>Nypa fruticans</i>	Associated mangrove	Monocotyledon	Herbaceous
7	<i>Pandanus tectorius</i>	Associated mangrove	Monocotyledon	Shrub
8	<i>Pekan accession</i>	Associated mangrove	Dicotyledon	Shrub
9	<i>Sonneratia alba</i>	True mangrove	Dicotyledon	Shrub
10	<i>Sonneratia caseolaris</i>	True mangrove	Dicotyledon	Shrub

3.2.2 Sample preparation

Samples collected were preserved in specific solutions. These fresh samples were first thoroughly cleaned with tap water to remove any dirt. The samples were stored in sample bottles containing acetic acid (AA) solutions made from a 1:3 mixture of 70%

ethanol and 30% acetic acid (Johansen, 1940). All of the steps required to prepare this sample were completed under a fume hood.

3.2.3 Cross section using sliding microtome

Fixation and embedding were performed using the method described by Johansen (1940) and Sass (1940), with appropriate modifications. A sliding microtome was used to section petioles, midribs, leaf lamina, and marginals with thicknesses ranging from 20 to 50 μm . The clamp was supported with pieces of polystyrene. Transverse sections were taken from the middle of fully grown leaves, including the petiole, midrib, secondary venation, and the mid-region of the leaf margin. The sections were cleaned with Clorox bleach, washed and stained with Alcian blue for 3 minutes, then stained with Safranin for 3 minutes before being dehydrated with a series of alcohols: 50, 70, 95, and 100%. The sections were then mounted on Euparal slides and covered with a coverslip. The slides were placed in an oven at 60°C for two weeks. Table 3.3 presents a series of procedures for preparing a permanent slide.

Table 3.3: Series of procedures in slide preparations

Solution	Duration
Soaked in Clorox bleaching agent	30 minutes
Washed using distilled water	-
Soaked in Alcian blue staining solution	3 minutes
Washed using distilled water	-
Soaked in Safranin staining solution	3 minutes
Washed using distilled water	-
Dehydration using 50% alcohol	2 minutes
Dehydration using 70% alcohol	2 minutes
Dehydration using 95% alcohol	2 minutes
Dehydration using 100% alcohol	2 minutes
Mounted on glass slides using Euparal	-

3.2.4 Epidermal Peel

Epidermal peels of the abaxial and adaxial surfaces were created by immersing the specimens in Jeffrey solutions in a petri dish and adding distilled water to keep the solution from becoming too strong. Jeffrey solutions were made with distilled water, potassium dichromate, and nitric acid. The specimens' reaction with the chemical caused the abaxial and adaxial surfaces to separate from the mesophyll cell, allowing stomata to be observed on both sides. The separated specimens were then washed with distilled water and stained. After 3 minutes in the Safranin staining solution, the specimens were washed with distilled water to remove any excess stain.

3.2.5 Observation of leaf anatomy

The observation was carried out using a camera with a built-in light microscope Nikon. The image of the anatomy observed was captured and saved using NIKON software. The analysis of the anatomy results is based on anatomical characteristics reported in previous studies.

3.3 DOCUMENTATION OF IUCN RED LIST (INTERNATIONAL UNION FOR CONSERVATION OF NATURE RED LIST OF THREATENED SPECIES) CATEGORY

The International Union for Conservation of Nature Red List of Threatened Species (IUCN Red List) category was recorded by utilizing data obtained directly from the IUCN Red List database (<https://www.iucnredlist.org/>) (Figure 3.2). This involved the search and retrieval of the most recent evaluations of conservation status and population trends. The IUCN Red List offers standardised and internationally acknowledged evaluations of the conservation status of the collected species. It employs strict criteria and expert assessments to classify species into different threat categories, such as Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (NE). The utilization of data from the IUCN Red List facilitated the documentation process, ensuring precise and current information concerning the

conservation status of each species. Data obtained from the IUCN Red List can be used to develop a future conservation strategy within the research area

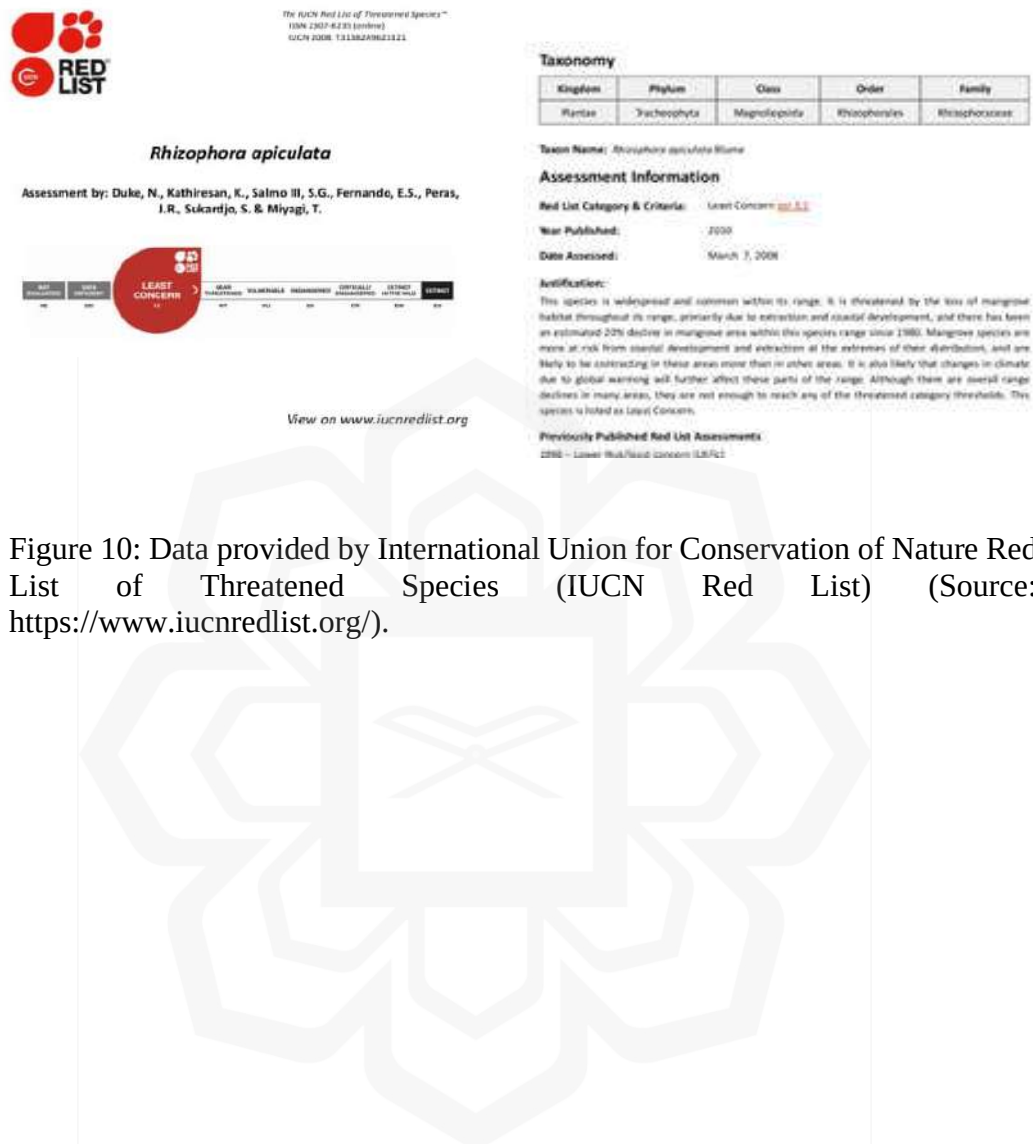


Figure 10: Data provided by International Union for Conservation of Nature Red List of Threatened Species (IUCN Red List) (Source: <https://www.iucnredlist.org/>).

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 DIVERSITY OF TRUE MANGROVE AND ITS ASSOCIATE SPECIES IN KUANTAN AND PEKAN

Plant diversity studies serve as a critical tool in the effective understanding and management of the world's botanical resources, offering a comprehensive overview of plant diversity within specific ecosystems or regions. Therefore, research conducted across thirteen sampling locations in Kuantan and Pekan has revealed the presence of 8 families of true mangrove species and 30 families of associate species, as detailed in Tables 4.1 and 4.2. In total, 26 true mangrove species and 45 species of associated plants have been documented and listed in Tables 4.3 and 4.4. Furthermore, the total number of true mangrove species and their associates at each sampling site was documented and presented in Tables 4.3 and 4.4, respectively.

Table 4.1: Total number of families of true mangrove species.

NO	FAMILY
1	Acanthaceae
2	Combretaceae
3	Lythraceae
4	Meliaceae
5	Primulaceae
6	Pteridaceae
7	Rhizophoraceae
8	Rubiaceae

Table 4.2: Total number of families of associates' species.

NO	FAMILY
1	Aizoaceae
2	Apocynaceae
3	Arecaceae
4	Aspleniaceae
5	Asteraceae
6	Casuarinaceae
7	Chrysobalanaceae
8	Clusiaceae
9	Combretaceae
10	Convolvulaceae
11	Dilleniaceae
12	Euphorbiaceae
13	Fabaceae
14	Flagellariaceae
15	Lamiaceae
16	Lauraceae
17	Malvaceae
18	Melastomataceae
19	Memecylaceae
20	Myrtaceae
21	Pandanaceae
22	Phyllanthaceae
23	Poaceae
24	Primulaceae
25	Rubiaceae
26	Rutaceae
27	Sapindaceae
28	Sapotaceae
29	Verbenaceae
30	Vitaceae

Table 4.3: List of true mangrove species based on location.

NO	SPECEIS	FAMILY	A	B	C	D	E	F	G	H	I	J	K	L	M
1	<i>Acanthus ilicifolus</i> (Jeruju putih)	Acanthaceae									/			/	
2	<i>Acrostichum aureum</i> (Piai raya)	Pteridaceae			/	/					/			/	
3	<i>Acrostichum speciosum</i> (Piai lasu)	Pteridaceae			/	/					/			/	
4	<i>Aegiceras corniculatum</i> (Kacang – kacang)	Primulaceae				/				/		/		/	
5	<i>Avicennia alba</i> (Api-api hitam)	Acanthaceae			/	/		/		/	/	/		/	/
6	<i>Avicennia marina</i>	Acanthaceae				/									/
7	<i>Avicennia officinalis</i>	Acanthaceae			/	/									/
8	<i>Avicennia rumphiana</i> (Api-api bulu)	Acanthaceae			/	/	/	/		/	/	/	/	/	
9	<i>Bruguiera cylindrica</i> (Bakau putih)	Rhizophoraceae			/	/		/		/	/	/		/	
10	<i>Bruguiera gymnorhiza</i> (Tumu merah)	Rhizophoraceae			/	/		/			/	/			/
11	<i>Bruguiera parviflora</i> (Lenggadai)	Rhizophoraceae			/							/			/
12	<i>Bruguiera sexangula</i>	Rhizophoraceae			/	/									
13	<i>Ceriops decandra</i> (Tengar)	Rhizophoraceae			/	/						/			/
14	<i>Ceriops tagal</i>	Rhizophoraceae			/	/				/					
15	<i>Kandellia candel</i> (Berus berus)	Rhizophoraceae											/	/	/
16	<i>Lumnitzera littorea</i> (Teruntum merah)	Combretaceae			/	/				/			/		/
17	<i>Lumnitzera racemosa</i> (Teruntum putih)	Combretaceae											/		
18	<i>Rhizophora apiculata</i> (Bakau minyak)	Rhizophoraceae			/	/		/		/	/			/	/

19	<i>Rhizophora mucronata</i> (Bakau kurap)	Rhizophoraceae			/	/		/			/			/	/
20	<i>Scyphiphora hydrophyllacea</i> (Cengham)	Rubiaceae			/	/									/
21	<i>Sonneratia alba</i> (Perepat)	Lythraceae				/	/	/		/				/	/
22	<i>Sonneratia caseolaris</i> (Berembang)	Lythraceae				/									/
23	<i>Sonneratia ovata</i> (Gedabu)	Lythraceae				/									
24	<i>Xylocarpus granatum</i> (Nyireh)	Meliaceae			/	/				/	/				/
25	<i>Xylocarpus moluccensis</i>	Meliaceae													/
26	<i>Xylocarpus rumphii</i>	Meliaceae													/

A.Pantai Sepat B. INOCEM C. Sg. Balok D. Cherating E. Taman Gelora F. Tanjung Api. G. Teluk Sisek H. Sg. Ular I. Widad J. Tanjung Lumpur K. Cherok Paloh L. Pekan M. Nenasi

Table 4.4: List of associates mangrove species in Kuantan and Pekan

NO	LOCATION	FAMILY	A	B	C	D	E	F	G	H	I	J	K	L	M
1	<i>Acacia auriculiformis</i> (Akasia kuning)	Fabaceae												/	
2	<i>Acacia mangium</i> (Akasia lebar)	Fabaceae												/	
3	<i>Ardisia crispa</i> (Mata pelanduk)	Primulaceae												/	
4	<i>Ardisia elliptica</i>	Primulaceae												/	
5	<i>Asplenium nidus</i>	Aspleniaceae													/
6	<i>Caesalpinia crista</i>	Fabaceae												/	
7	<i>Canavalia maritima</i> (Kacang laut)	Fabaceae	/												
8	<i>Casuarina equisetifolia</i> (Pokok Rhu)	Casuarinaceae					/							/	/
9	<i>Cerbera odollam</i> (Pong pong)	Apocynaceae				/									
10	<i>Cissus hastata</i> (Akar kerayong)	Vitaceae				/									
11	<i>Crotalaria pallida</i> (Kacang kayu)	Fabaceae						/							
12	<i>Dendrolobium umbellatum</i> (Petai belalang)	Fabaceae				/			/						
13	<i>Derris trifoliata</i> (Common derris)	Fabaceae				/									
14	<i>Dodonaea viscosa</i>	Sapindaceae												/	
15	<i>Excoecaria agallocha</i> (Bebuta)	Euphorbiaceae				/					/	/			
16	<i>Flagellaria indica</i>	Flagellariaceae				/									
17	<i>Garcinia xanthochymus</i> (Asam kandis)	Clusiaceae												/	
18	<i>Gardenia tubifera</i>	Rubiaceae				/									
19	<i>Glochidion littorale</i> (Jambu kera)	Phyllanthaceae				/									
20	<i>Heritiera littoralis</i> (Dungun)	Malvaceae				/									
21	<i>Hibiscus tiliaceus</i> (Bebaru)	Malvaceae			/	/		/	/		/	/		/	/
22	<i>Ipomea pes-caprae</i> (Pokok tapak kuda)	Convolvulaceae						/		/					/
23	<i>Ixora congesta</i> (Jarum – jarum)	Rubiaceae							/						

24	<i>Lantana camara</i>	Verbenaceae													/
25	<i>Licania splendens</i> (Merbatu)	Chrysobalanaceae				/									
26	<i>Memecylon edule</i> (Nipis kulit)	Memecylaceae						/							
27	<i>Merope angulata</i> (Limau lelang)	Rutaceae				/									
28	<i>Morinda citrifolia</i> (Mengkudu)	Rubiaceae				/									
29	<i>Neolitsea sp.</i>	Lauraceae				/									
30	<i>Nypa fruticans</i> (Nipah)	Arecaceae				/				/	/				/
31	<i>Pandanus tectorius</i> (Pandan laut)	Pandanaceae	/			/									
32	<i>Pekan accession</i>	Melastomataceae													/
33	<i>Planchonella obovata</i> (Menasi)	Sapotaceae		/		/			/					/	
34	<i>Pluchea indica</i> (Indian camphorweed)	Asteraceae				/									
35	<i>Psydrax sp.</i>	Rubiaceae						/							
36	<i>Rhodymyrtus tomentosa</i> (Kemunting)	Myrtaceae		/											
37	<i>Sesuvium portulacastrum</i>	Aizoaceae												/	
38	<i>Spinifex littoreus</i> (Rumbut bebalin)	Poaceae													/
39	<i>Syzigium granade</i>	Myrtaceae												/	
40	<i>Tamarindus indica</i> (Asam jawa)	Fabaceae												/	
41	<i>Terminalia catappa</i> (Ketapang)	Combretaceae						/							/
42	<i>Tetracera indica</i> (Mempelas)	Dilleniaceae						/							
43	<i>Vitex ovata</i> (Pokok lagundi)	Lamiaceae	/	/											
44	<i>Vitex pinnata</i>	Lamiaceae												/	
45	<i>Volkameria inermis</i> (Bunga pawang)	Lamiaceae	/												

A. Pantai Sepat B. INOCEM C. Sg. Balok D. Cherating E. Taman Gelora F. Tanjung Api. G. Teluk Sisek H. Sg. Ular I. Widad J. Tanjung Lumpur K. Cherok Paloh L. Pekan M. Nenasi

4.1.1 DIVERSITY AND SPECIES COMPOSITION OF TRUE MANGROVE IN KUANTAN AND PEKAN

According to the recorded data, a total of 26 true mangrove species belonging to 8 families have been identified. These families include Acanthaceae, Combretaceae, Lytraceae, Meliaceae, Primulaceae, Pteridaceae, Rhizophoraceae, and Rubiaceae. Among these families, Rhizophoraceae stands out with the highest number of species, boasting nine distinct species spread across four genera. This diversity underscores the ecological significance and adaptability of mangrove ecosystems, showcasing the intricate relationships between various plant families within these unique coastal habitats. Duke *et al.* (1998) reported that out of sixteen genera within the Rhizophoraceae family, only four are known to inhabit mangrove species. Interestingly, the data reveal that both Kuantan and Pekan host all four of these genera, which are *Bruguiera*, *Ceriops*, *Kandelia*, and *Rhizophora* in their mangrove habitats. This highlights the rich diversity and significance of these regions in supporting various mangrove species. Conversely, the families Primulaceae and Rubiaceae exhibit the lowest species diversity, each comprising only one species. Specifically, these species are *Aegiceras corniculatum* (Figure 4.1 A) from the Primulaceae family and *Scyphiphora hydrophyllacea* (Figure 4.1 B) from the Rubiaceae family. Despite their limited presence, these species contribute to the overall biodiversity and ecological dynamics of the mangrove ecosystems in Kuantan and Pekan.



Figure 11: A) *Aegiceras corniculatum* B) *Scyphiphora hydrophyllacea*

In Kuantan and Pekan, a variety of mangrove species thrive, including *Rhizophora apiculata*, *Rhizophora mucronata*, *Avicennia alba*, *Avicennia rumphiana*, *Sonneratia alba*, and *Xylocarpus granatum*, which are among the most commonly encountered species (Figure 4.2). Notably, *R. apiculata* stands out as a dominant species, particularly in the Asia-Pacific region, as highlighted by Ong *et al.* (2004). Its prevalence is attributed to its significant commercial value as a mangrove timber species. Conversely, *Lumnitzera racemosa*, *Sonneratia ovata*, *Xylocarpus moluccensis*, and *Xylocarpus rumphii* represent the less frequently encountered species in the area. These species are limited in distribution, occurring only in select study sites and within a restricted number of individual plants.

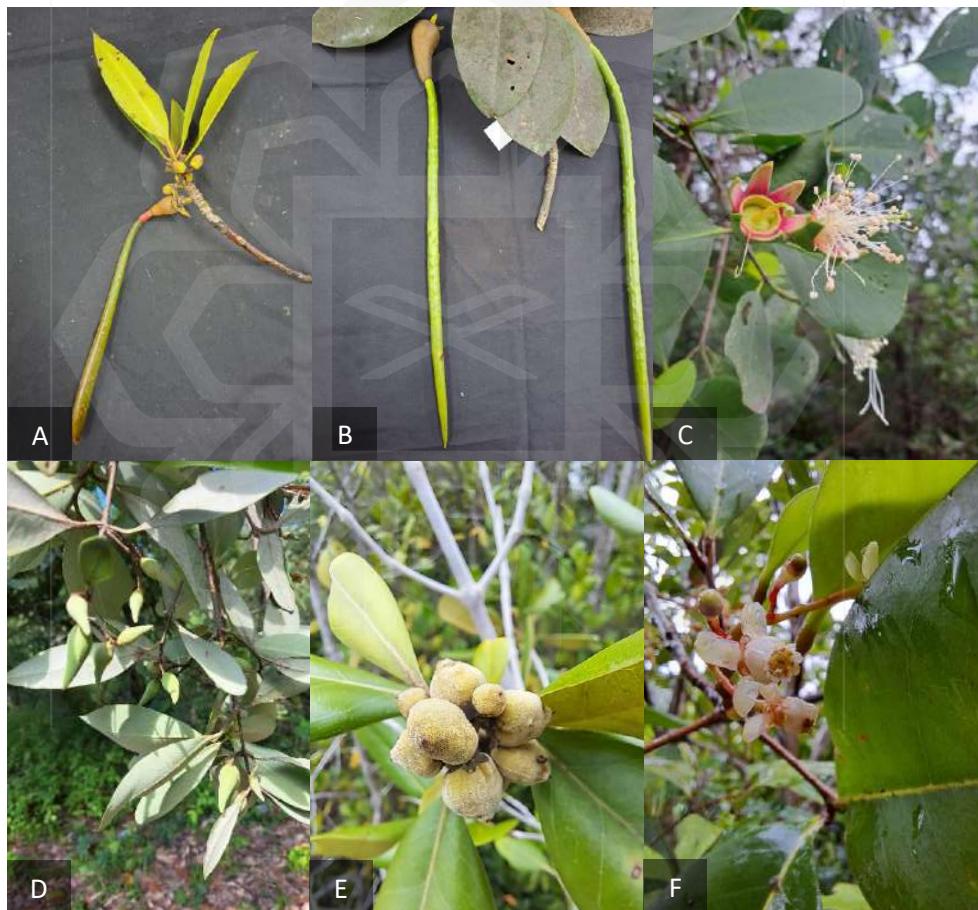


Figure 12: A) *Rhizophora apiculata* B) *Rhizophora mucronata* C) *Sonneratia alba* D) *Avicennia alba* E) *Avicennia rumphiana* F) *Xylocarpus granatum*

Moreover, among the diverse array of species observed, *L. racemosa* (Figure 4.3 A) stands out as a noteworthy find, its presence restricted solely to the locality of

Cherok Paloh within the Kuantan study site. This species has garnered attention due to its rarity, making it a focal point of interest in the ecological assessment of the area. Notably, the total count of *L. racemosa* individuals discovered during the study period remained relatively small, underscoring its status as a less common species within the study area. Furthermore, the exploration of mangrove habitats along the Nenasi River revealed the exclusive occurrence of two additional species, *X. moluccensis* (Figure 4.3 B) and *X. rumphii* (Figure 4.3 C). Similar to *L. racemosa*, these species had a limited range, living only in the Nenasi River. Despite being limited in presence, these species fulfil significant ecological roles within their niche habitats by providing shelter for aquatic organisms such as juvenile shellfish, crabs, and fish. It is noteworthy, however, that the population size of both *X. moluccensis* and *X. rumphii* was observed to be relatively low, further highlighting their status as less abundant species within the Nenasi River.

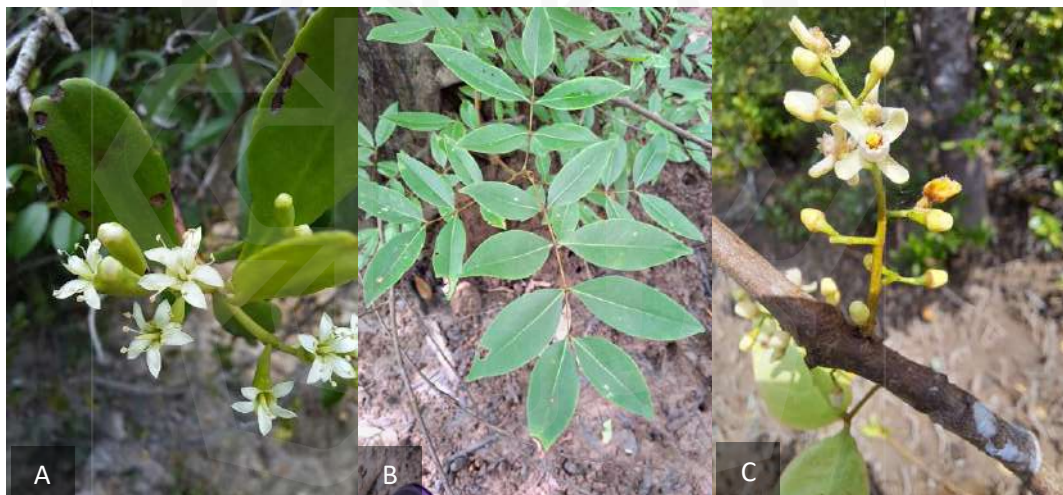


Figure 13: A) *Lumnitzera racemosa* B) *Xylocarpus moluccensis* C) *Xylocarpus rumphii*

Mangrove plant species show amazing resilience, thriving in harsh environments characterized by high salinity, severe storms, strong winds, wet soils, high temperatures, and changeable water levels. These adversities have prompted the evolution of a rich array of structural and functional adaptations among the flora inhabiting these coastal forests. From specialized root systems that anchor them in unstable substrates to mechanisms for salt tolerance and efficient water usage, mangrove plants have evolved an impressive toolkit to thrive in their demanding

environments. Therefore, the presence of a wide variety of structural and functional adaptations among mangrove flora has played a pivotal role in shaping the ecological dynamics and species composition within the mangrove ecosystems of Kuantan and Pekan.

One of the most important characteristics of mangrove species is the specialized root, such as buttress roots, flying buttresses and spreading roots, prop roots, stilt roots, knee roots, pencil roots, and cone-shaped roots (Srikanth *et al.*, 2015). According to the findings of this research, the roots of *Rhizophora* emerge from either the branches or the primary trunk above the ground level, extending outward before penetrating the soil at a distance from the central stem. These elevated roots of *Rhizophora* are commonly known as stilt roots, attributed to their distinctive appearance and their significant function in offering essential structural reinforcement to the main trunk (Figure 4.4 A). Additionally, branching may serve to enhance the root system's penetration into the soil, thereby improving anchorage and augmenting the stability of the tree (Tomlison, 1986; Hogarth, 2015; Mendez-Alonzo *et al.*, 2015; Srikanth *et al.*, 2015).

In this study, it was noted that the buttress roots of *Xylocarpus* (Figure 4.4 B) species grow parallel to the prevailing wind direction, especially on the wind-sheltered side. These roots feature a narrow strip of bark at their base, safeguarding the cambium and conductive tissue while connecting vertical or inclined root branches to the stem. Beyond providing anchorage, buttress roots play a vital role in the long-distance transportation of water and nutrients. They extend into the upper soil layer where primary nutrients abound, and when they spread horizontally, they effectively increase the area for nutrient absorption from the soil surface (Day *et al.*, 2010; Mendez-Alonzo *et al.*, 2015; Srikanth *et al.*, 2015).



Figure 14: A) Stilt root of *Rhizophora apiculata*. B) Buttress root of *Xylocarpus granatum*. C) Pneumatophore root of *Sonneratia alba*.

The surrounding soil of mangrove species is very deficient in oxygen. Therefore, the root of a mature mangrove tree has special adaptation that can help the transfer of gases into and out of the plant system such as cable roots, pneumatophores, feeding roots and anchor roots (Srikanth *et al.*, 2015). Research findings indicate that pneumatophores, particularly in *Avicennia* and *Sonneratia* species (Figure 4.4 C), grow vertically and extend their tips into the air. These pneumatophores are shielded by an impermeable periderm and feature lenticels on their surface, which facilitate gas exchange between the atmosphere and the root's internal structure during low tide. Thus, pneumatophores play a crucial role as specialised ventilation mechanisms, enabling the plant to thrive in anaerobic soil and harsh shoreline conditions (Singh *et al.*, 2004;

Purnobasuki, 2011; Hogart, 2015; Hao *et al.*, 2021). Furthermore, lenticels can also be found on young stilt roots or prop roots, aiding in the supply of oxygen to the underground root system (Srikanth *et al.*, 2015).

However, mangroves face the challenge of regulating their cytosolic salt concentration in intertidal areas characterised by high salinity. Mangrove species employ various mechanisms, such as ultrafiltration, salt secretion, and ion sequestration, tied to their anatomical or physiological characteristics, to control salt absorption and exclusion. Some species possess the ability to accumulate saline ions to maintain equilibrium in transmembrane osmotic potentials. Through a variety of anatomical and physiological strategies for salt management, mangrove species, including *Avicennia marina*, can adapt to high salinity environments. This adaptation elucidates why *A. marina* thrives abundantly in Nenas. This trait confers a survival advantage to these species in salty environments (Kura-Hotta *et al.*, 2001; Mimura *et al.*, 2003; Srikanth *et al.*, 2015).

Besides that, the mangrove leaves also have develop few adaptations for the plant survival. Mangrove leaves are crucial for salt regulation, even though the roots initially block a significant amount of salt (Naskar *et al.*, 2021). The soil pore water has a very low water potential, making it difficult to be absorbed. Thus, water is valuable to mangroves. Mangrove leaves are typically adapted to store water and prevent excessive water loss. Mangrove leaves have xeric adaptations such as a thick cuticle, water storage tissue, enlarged terminal tracheid at vein endings, branched sclereids within mesophyll, compact arrangement of palisade and spongy tissues, and cuticular outgrowth on stomata to reduce stomatal opening. Mangroves must remove accumulated salt from leaves to maintain cellular ionic homeostasis. Some mangroves can excrete excess salt that has accumulated in their leaves through salt glands, such as *Avicennia* (Liang *et al.*, 2008; Naskar *et al.*, 2015; Ahmad *et al.*, 2018; Naskar *et al.*, 2021).

Another important adaptation of mangrove trees is viviparous fruit production. Vivipary in mangroves occurs in two forms: true vivipary and crypto-vivipary (Tomlison, 1986; Aluri, 2013; Yun *et al.*, 2022). True vivipary involves the growth of

the embryo inside the fruit pericarp as a hypocotyl, reaching a significant size before dispersal, typically observed in the Rhizophoraceae family (Figure 4.5 B). Once mature, the propagule detaches from the parent plant and either settles in the same location during low tide or drifts to a different site during high tide. Viviparous mangrove species utilize either self-planting or stranding strategies for establishment, depending on forest conditions, tide, and soil stability. In undisturbed mangrove forests, the self-planting strategy is predominant, while in exploited or open forests, the stranding strategy is more common (Kairo *et al.*, 2001). As a result, findings from studies reveal there are 9 species of mangrove species exhibit true vivipary, including the widely distributed species *R. apiculata* and *R. mucronata*.

Crypto-vivipary is when the embryo keeps developing inside the fruit without coming out before dispersal. This has been seen in *Avicennia* (Figure 4.5 A) and *Aegiceras* species found in selected locations in Kuantan and Pekan. The study emphasises that propagules in *Avicennia* species are small and lightweight, and the entire embryo becomes buoyant when separated from the maternal parent. Aluri (2013) stated that with time, the fruit pericarp decays, leading to the exposure of the fleshy cotyledons to tidal water. Besides, *A. marina* requires a period of stranding for establishment since its propagules continually float in tidal water. These propagules need a period without tidal disturbance to establish in the soil, restricting this species to higher regions of the marsh where tidal flooding occurs less often (Rabinowitz, 1978). On the other hand, *Avicennia* species exhibit a self-planting strategy during low tide and a stranding strategy during high tide in the study of Aluri (2013).

Initially, the salt concentration in viviparous propagules of certain mangrove species is lower than in the mother tree organs, but it rises as the propagules mature. Propagules can acquire a high salt tolerance by absorbing it from their parent trees while remaining attached to them (Liang *et al.*, 2008). In addition to salt management, viviparous propagules possess several other beneficial characteristics that aid in their survival and effective establishment in their environment. Aluri (2013) states that these advantages consist of the prompt growth of roots, which is essential for providing support and absorbing nutrients from the soil. The buoyancy of these propagules is a crucial characteristic that helps them spread across aquatic bodies, allowing the species

to establish in new locations. Dispersal in aquatic or semi-aquatic habitats is crucial for species, as water currents can carry propagules to optimal growing locations.



Figure 15: A) Crypto-vivipary fruit of *Avicennia rumphiana*. B) True vivipary fruit of *Kandelia candel*.

Furthermore, this research successfully identified and documented the existence of two authentic species of mangroves that are part of the Pteridaceae family, commonly referred to as the fern family. These species, *Acrostichum aureum* and *Acrostichum speciosum*, are widely recognized as significant examples of mangrove ferns. These ferns are notable for their unique adaptation to the mangrove ecosystem, showcasing the diversity and ecological importance of mangroves. According to Tomlinson (1986) as cited in Moreno 2016, *Acrostichum*, also known as the "mangrove fern," is a prominent species of fern that exhibits vigorous growth inside mangrove habitats. On the other hand, it predominantly occupies the understory of mangrove backwaters and possesses the unique ability to flourish in brackish water, setting it apart from other fern varieties. Mangrove plant growth is influenced by a diverse range of biotic and abiotic variables. They grow in the unstable marine intertidal zone, which has harsh plant growth conditions such as high salinity, tidal fluctuations, and long-term climate changes (Medina *et al.*, 1990; Naskar *et al.*, 2015). Plants that live in high saline

environments have evolved to minimize water loss to avoid dehydration and to exclude salts that are harmful to their metabolism (Naskar *et al.*, 2015).

Acrostichum is tolerant of a broad spectrum of soil salinities and requires full sun exposure for rapid and optimal development (Medina *et al.*, 1990). Therefore, *Acrostichum* is able to effectively colonise disturbed regions devoid of trees or with limited tree cover due to its ability to thrive in locations with ample sunlight exposure (Moreno *et al.*, 2016). *Acrostichum* preferred habitat is inshore marsh areas that receive some saline water from high tides and some fresh water from inflowing streams (Arnold *et al.*, 1963). *Acrostichum* genus consist of three distinct species, namely. *A. danaeifolium* Langsd. & Fisch., *A. aureum* L., and *A. speciosum* Willd (Adams *et al.*, 1979; Mehltreter *et al.*, 2003; Zhang *et al.*, 2016). Based on previous study, *A. danaeifolium* and *A. speciosum* are restricted to the Atlantic east-Pacific and Indo West-Pacific areas, while *A. aureum* is the only mangrove species found in both areas (Zhang *et al.*, 2016; Duke 1992.). The Malaysian mangrove forest is home to two common species of mangrove fern namely *A. aureum* and *A. speciosum*. *A. aureum*, locally known as ‘*piai raya*’, is a large species of mangrove fern (Arnold *et al.*, 1963; Shin *et al.* 2015).

4.1.2 DIVERSITY AND COMPOSITION OF ASSOCIATES MANGROVE SPECIES IN KUANTAN AND PEKAN

This research highlights the rich biodiversity within the Kuantan and Pekan, revealing the presence of 45 distinct associate mangrove species spread across 30 different families. Among these, two species are classified as monocots: *Nypa fruticans*, commonly known as the Nipa Palm, and *Pandanus tectorius*, also referred to as the Screw Pine. Additionally, the study identified a pteridophyte species, *Asplenium nidus* or known as the Bird's Nest Fern. The Fabaceae family stands out as the most represented family. Fabaceae, commonly known as the legume, pea, or bean family, boast an array of species that play crucial roles in these ecosystems. With eight distinct species identified, the Fabaceae family shows a remarkable diversity that contributes significantly to the ecological functions and resilience of mangrove habitats. The

species of the Fabaceae family include *Acacia auriculiformis* and *Acacia mangium*, which are known for their resilience and fast growth, making them vital for erosion control and reforestation efforts. *Canavalia maritima*, *Caesalpinia crista*, *Crotalaria pallida*, *Dendrolobium umbellatum*, *Derris trifoliata*, and *Tamarindus indica* are also part of this family, each contributing uniquely to the biodiversity and offering various ecological services.

Following the Fabaceae, the Rubiaceae family is the second most represented, with four species: *Gardenia tubifera*, *Ixora congesta*, *Morinda citrifolia*, and *Psydrax* sp. These species are important for maintaining the structural complexity and providing resources such as nectar, fruits, and shelter to a wide range of wildlife. In addition to the remarkable diversity shown by the Fabaceae and Rubiaceae family in the mangrove ecosystems of Kuantan and Pekan, the Lamiaceae family also marks its significant presence in the study area. The Lamiaceae family was represented by three species: *Vitex ovata*, *Vitex pinnata*, and *Volkameria inermis*. The Lamiaceae family, widely recognised for its aromatic herbs, shrubs, and trees, is known not just for its ecological importance but also for its extensive use in traditional and modern medicine. The traits of Lamiaceae species and their essential oils might differ greatly based on their cultivation methods, climate, and geographic location (Ramos da Silva *et al.*, 2021)

In addition, the Malvaceae, Myrtaceae, and Primulaceae families each contribute two species, demonstrating the wide array of plant life that mangrove ecosystems support. The Malvaceae family is represented by *Heritiera littoralis* and *Hibiscus tiliaceus*, which are significant for their wood and fibre, respectively. Myrtaceae include *Rhodomyrtus tomentosa* and *Syzygium grande*, important for their fruits and as habitat for various bird species. Besides, Primulaceae offers *Ardisia crispa* and *Ardisia elliptica*, known for their medicinal properties and as vital components of the understorey vegetation in mangroves. In Malaysia, *Ardisia elliptica* is utilized to alleviate retrosternal discomfort and to treat herpes and measles, while in Thai traditional medicine, it is employed to remedy diarrhoea accompanied by fever. *Ardisia elliptica* is commonly utilized in Southeast Asia for the treatment of scabies and intestinal parasites (Koh *et al.*, 2009; Al-Abd *et al.*, 2017).

The study emphasises that the stability and resilience of a mangrove ecosystem are greatly enhanced by the contributions of mangrove associations. These connections are crucial for defining the various elements that constitute the ecosystem. They have a crucial function in interlacing the intricate biological structure of the mangrove, enhancing its ability to withstand environmental pressures and promote regeneration and long-term viability. The associate floral species in mangroves are crucial for mitigating wave action, promoting sediment accretion and sandbank formation, which in turn enhance vegetation density and water depth (Zaman *et al.*, 2014). According to Zaman *et al.* (2014) associated plant species within mangrove ecosystems also serve a crucial role in bioremediation. These plants contribute to the purification and recovery of the mangrove environment by absorbing and breaking down pollutants, thus enhancing the ecosystem's resilience and health.

This highlights the significance of comprehending and conserving these connections for the general well-being and sustainability of mangrove ecosystems. Utina *et al.* (2014) found that vegetation components within a mangrove ecosystem interact to establish the ecosystem's stability. In addition to their ecological functions, associated plant species also display variability in their plant habits. The variety in structure may be due to adaptations of the species for succeeding in mangrove habitats. These modifications probably improve their capacity to survive the specific challenges presented by the changing conditions of mangrove habitats, such as salinity, tidal fluctuations, and nutrient levels. The diversity in plant structures within mangrove communities emphasises the complexity of these ecosystems and showcases the complicated relationship between species and their surroundings in these constantly changing coastal environments. According to the findings of this study, a diverse range of associate species has been documented, representing various plant types including herbaceous species, shrubs, trees, and climbers. This diversity highlights the intricate web of life within mangrove ecosystems, where each plant type plays a unique role in shaping the environment and supporting biodiversity. Herbaceous plants contribute to ground cover and soil stabilization, while shrubs and trees provide structure and habitat for a multitude of organisms.

Climbers, on the other hand, utilize vertical space and often form intricate networks that enhance overall habitat complexity. Besides, herbaceous plants are well-suited for connecting land and water in floodplains due to their presence in both aquatic and terrestrial environments (Junk *et al.*, 1997). According to McKee *et al.* (2007), The establishment of mangroves in a deforested area in Belize was sped up by the existence of *Sesuvium portulacastrum* (succulent forb) and *Distichlis spicata* (grass), two coastal plant species found widely in the Caribbean. The herbaceous vegetation had a positive overall impact, although its effect on the survival and growth of mangroves differed depending on the species. Various species have different impacts on mangroves due to differences in their vegetative structure and characteristics. These effects include trapping dispersing propagules, offering structural support for seedlings, and improving soil conditions such as temperature and aeration to enhance survival or growth.

Trees and shrubs are the most common types of plants in different natural and semi-natural environments. A tree is a tall perennial plant with a single self-supporting woody stem, whereas a shrub is a short perennial plant with several self-supporting woody branches branching at or near the ground. Trees can have several stems, and the bushes ranged in size from extremely small to huge (Götmark *et al.*, 2016). Shrubs are important in 9 of the 11 worldwide biomes, including a substantial portion of the plant life in tropical savannas, arid regions, Mediterranean ecosystems, and arctic and high alpine tundra. They are frequently found in wetlands on land and in the lower levels and clearings in forests, where both shade-tolerant and pioneer (shade-intolerant) shrubs thrive (Götmark *et al.*, 2016).

4.1.3 THE DISTRIBUTION OF MANGROVE SPECIES AND ITS ASSOCIATES IN KUANTAN AND PEKAN

4.1.3.1 KUANTAN

There are only four associates' species recorded at Pantai Sepat, which are *Canavalia maritima*, *Pandanus tectorius*, *Vitex ovata*, and *Volkameria inermis*. Meanwhile, at the INOCEM study site, only three species were recorded which are, *Planchonella obovata*,

Rhodomyrtus tomentosa and also *Vitex ovata*. For Teluk Sisek, there are seven species recorded from six different families. *Ixora congesta* and *Psydrax sp.* are from the Rubiaceae family, while the other five species are from five different families. *Dendrolobium umbellatum* from Fabaceae family, *Hibiscus tiliaceus* from Malvaceae family, *Memecylon edule* from Memecylaceae family, *Planchonella indica* from Sapotaceae family and *Tetracera indica* from Dilleniaceae family.

The data recorded that there are seven true species from three families and four associate species from four families at the Tanjung Api study site. The families of true mangrove species consisting of Acanthaceae, Rhizophoraceae and Lythraceae. There are two species in the Acanthaceae family which are *Avicennia alba* and *Avicennia rumphiana*, four species in Rhizophoraceae which are *Bruguiera cylindrica*, *Bruguiera gymnorhiza*, *Rhizophora apiculata*, and *Rhizophora mucronata*. Meanwhile, only one species from Lythraceae family which is *Sonneratia alba*. The species recorded at Tanjung Lumpur study site are *Crotalaria pallida* (Fabaceae), *Hibiscus tiliaceus* (Malvaceae), *Ipomea pes-caprae* (Convolvulaceae) and *Terminalia catappa* (Combretaceae).

Meanwhile, at the Tanjung Lumpur study site, there are six families recorded in total for both true mangrove and associate species, three families for each. There are three families of true mangrove species, which are Primulaceae, Acanthaceae, and Rhizophoraceae with one, two, and four species in total, respectively. The true mangrove species are *Aegiceras corniculatum*, *A. alba*, *A. rumphiana*, *B. cylindrica*, *B. gymnorhiza*, *Bruguiera parviflora*, and *Ceriops decandra*. *Excoecaria agallocha*, *Hibiscus tiliaceus*, and *Nypa fruticans* are the associates' species that had been recorded.

The study sites at Tanjung Api and Tanjung Lumpur are characterised by significant coastal development, which primarily supports aquaculture and urbanisation projects. This development has led to the proliferation of tourist facilities, including numerous resorts, hotels, and shopping complexes in the vicinity. Additionally, the area features several jetties constructed along the riverbanks to facilitate the landing of fisheries, indicating the region's economic reliance on maritime resources.

Investigating these sites revealed significant similarities in the species present in both Tanjung Api and Tanjung Lumpur. This finding is particularly intriguing given the limited scope of the study, which was constrained by various factors, including safety concerns and the inaccessibility of certain regions. Despite these limitations, the research provides valuable information on the ecological impact of coastal development on local biodiversity. It underscores the resilience of certain species to environmental changes while highlighting the need for more comprehensive studies to fully understand the broader ecological implications. There has been a notable gap in the scientific literature on the distribution of mangrove species and their associates in both areas. Therefore, the findings from this research represent a significant advancement, contributing novel data and records that enrich our understanding of species diversity in this region. This study not only maps the presence and distribution of various mangrove species and their ecological partners but also sets a foundational benchmark for future biodiversity and ecological research in the area. Thus, the introduction of these new data is crucial, as it provides a comprehensive overview of the local mangrove ecosystem, highlighting the variety and complexity of life forms thriving in this unique habitat.

The Sungai Ular study site has yielded significant findings regarding its mangrove biodiversity. This research has documented the presence of nine species of true mangroves, categorised under six different families, along with a single associated species, *Ipomea pes-caprae*. Among these, the Rhizophoraceae family is predominant, boasting three species: *B. cylindrica*, *Ceriops tagal*, and *R. apiculata*. This diversity underscores the ecological richness and complexity of the mangrove ecosystems in Sungai Ular. Following the Rhizophoraceae, the Acanthaceae family is represented by two species, *A. alba* and *A. rumphiana*, which contribute to the ecological fabric of the area. The discovery of these species highlights the varied mangrove habitats that support a wide range of flora and fauna. Additionally, four other families including Primulaceae, Combretaceae, Lythraceae, and Meliaceae enrich the biodiversity of Sungai Ular. Each family is represented by one species which are *A. corniculatum*, *Lumnitzera littorea*, *S. alba*, and *Xylocarpus granatum*, respectively. These findings illustrate a vibrant and dynamic ecosystem that highlights the ecological importance of mangroves in supporting biodiversity.

However, the Sungai Ular area is not merely a site of ecological interest. It is also a site of intensive aquaculture and urban development activities. This intersection of natural richness and human development presents unique challenges. According to a study by Hamzah *et al.* (2020), the coastal forests of Sungai Ular have undergone considerable transformation, with a reported loss of more than 1.36 hectares of forest cover between 2006 and 2014. This decline is mainly attributed to the construction of high-density urban housing projects adjacent to industrial zones, initiated in 2014. Such developments have raised concerns about the sustainability and conservation of mangrove ecosystems, highlighting the need for balanced approaches that protect these vital ecological areas while accommodating human economic activities

The study also covers the Widad Riverfront Apartment area, which features a varied mangrove ecosystem consisting of seven groups, including true mangrove species and associates. Notable species among companions include *Excoecaria agallocha* from the Euphorbiaceae family, *Hibiscus tiliaceus* from the Malvaceae family, and *Nypa fruticans* from the Arecaceae family. In addition to the companion species, the study also documented the existence of two pteridophyte species from the Pteridaceae family. *Acrostichum aureum* and *Acrostichum speciosum*. Three genuine mangrove species from the Acanthaceae family are *Acanthus ilicifolius*, *Avicennia alba*, and *A. rumphiana*. The Rhizophoraceae family, known for its important role in mangrove forests, consists of species such as *B. gymnorhiza*, *B. cylindrica*, *R. apiculata*, and *R. mucronata*. While *X. granatum* represents the Meliaceae family.

The mangrove region surrounding the Widad Riverfront Apartment was historically open to tourists, allowing them to directly experience the mangrove ecosystem. Given the current state of the site, it is no longer considered appropriate for ecotourism. This condition highlights the need for specific actions aimed at improving and preserve the mangrove forest. The diverse range of mangrove species in the area offers great opportunities for development that enhances the region while simultaneously focussing on conserving its valuable mangrove ecology. These approaches could help revitalise the site's potential as an ecotourism spot while maintaining its natural health.

Only four species of true mangroves have been documented at the Cherok Paloh study site. The species present are *L. littorea*, *L. racemosa*, *Kandelia candel*, and *A. rumphiana*. *L. racemosa* and *K. candel* are two species that had only been recorded at one location in Kuantan study site. The overall number of *L. racemosa* plants is relatively low due to the environment. The study site was a location where development was currently taking place. Although classified as least concern by the IUCN (Manohar, 2021), it is crucial to incorporate this species into conservation programmes to prevent its gradual extinction. *L. racemosa* is a back mangrove species that thrives in stable, muddy, or sandy drier sediments with reduced salinity levels. It is known to be highly resistant to drought and generally grows on estuarine banks in mid to high intertidal zones, slightly away from the main beach (Estomata *et al.*, 2011; Nakhawa *et al.*, 2012; Manohar, 2021).

Although the population of *K. candel* was low in Kuantan, it was abundant in the Pekan mangrove forest. The distribution of *K. candel* in the Kuantan area reveals an interesting ecological information. The species is scarce in Kuantan, suggesting environmental pressures or unique habitat needs, but thrives in the Pekan mangrove forest. This difference highlights the intricate nature of mangrove ecosystems and the diverse circumstances that support the growth of different species. It also emphasises the importance of customised conservation strategies that take into account the unique ecological processes of each specific area. To effectively maintain and improve the biodiversity and ecological integrity of crucial coastal ecosystems, conservation efforts should focus on understanding and addressing the special demands and problems of mangrove species.

A total of 8 genera from 6 plant families were systematically collected at the Balok River study site. The families of true mangroves identified in the study include Acanthaceae, Rhizophoraceae, Combretaceae, Meliaceae, Pteridaceae, and Rubiaceae, the results of this study uncovered the presence of 16 true mangrove species along the Balok River. The current record exceeds the results of the earlier study by Rozainah and Mohamad in 2009, which documented only 12 true mangrove species. Variations in species recorded in this study compared to previous ones can be attributed to differences in sampling locations within the same regency, the year of sampling, and the

methodologies used (Sari *et al.*, 2023). Furthermore, Chowdhury *et al.* (2023) suggests that decreases in organic blue carbon stored in mangrove soil, along with reductions in key nutrients such as nitrogen and phosphorus, play a significant role in altering the community composition of these ecosystems. As for associates, species, only *Hibiscus tiliaceus* was recorded, because the study site only covered along the Balok River.

Moreover, the Rhizophoraceae family exhibited the most notable dominance within the studied ecosystem. This family was represented by eight distinct species, which were distributed across three different genera. This dominance of the Rhizophoraceae family highlights its significant ecological role and diversity in the area, underlining the family's adaptability and resilience across various habitats. The presence of multiple genera within this family also indicates a rich genetic diversity, which could be crucial for the stability and health of the ecosystem they inhabit. Moreover, the results of this investigation have revealed the presence of two pteridophyte species that are classified under the Pteridaceae family.

The growth of ferns is significantly influenced by the levels of salinity (Salachna *et al.*, 2020). The restricted ability of ferns to adapt to high salinity conditions has a notable impact on their spatial distribution within mangrove habitats. Hoppe-Speer (2010) emphasizes that numerous environmental factors play a pivotal role in shaping species distribution, zonation patterns, and successional processes within mangrove ecosystems, while Leng *et al.*, (2020) further illustrate that mangrove species showcase substantial phenotypic adaptability, robust resistance to drought and salinity stress, and a diverse range of water management strategies to successfully thrive in their intertidal habitats.

Besides, *R. apiculata* and *R. mucronata* were found to be the most common mangrove species in the Balok River area. They were present at almost every sampling location, highlighting their significant importance as the dominating species in the local mangrove ecosystem. The *Rhizophora*'s capacity to acclimatize to harsh circumstances (Putri *et al.*, 2023), such as elevated salinity and variable water levels, plays a crucial role in its success within mangrove habitats (Sudhir *et al.*, 2022).

Lastly, the study at Cherating revealed that a total of 22 plant families were systematically collected from the study site. The families of true mangroves and associated mangroves identified in the study include Acanthaceae, Rhizophoraceae, Combretaceae, Lythraceae, Meliaceae, Primulaceae, Pteridaceae, Rubiaceae, Apocynaceae, Arecaceae, Asteraceae, Chrysobalanaceae, Euphorbiaceae, Fabaceae, Malvaceae, Pandanaceae, Phyllanthaceae, Rubiaceae, Rutaceae, Sapotaceae, Vitaceae, and Flagellariaceae. The varying numbers of plant families illustrate the wide range of botanical composition found in the Cherating mangrove area. The present record exceeds the findings of the previous study conducted by Zuhairi *et al.* in 2019, where only seven distinct families of both exclusive and non-exclusive mangrove species were documented. According to Chowdhury *et al.*, (2023), reductions in the organic blue carbon sequestered by mangrove soil and in other important nutrients such as accessible nitrogen and phosphorus contribute to the changes in community composition. Additionally, Rhizophoraceae family demonstrated the greatest dominance, consisting of seven species spread across three genera. Besides, the current study revealed the presence of a one pteridophyte and two monocot plant family in the sampling area. The limited adaptation of ferns and monocot plants to high salinity conditions significantly influences their distribution within the mangrove habitat. According to Hoppe-Speer (2010), various environmental factors impact the distribution of species, zonation patterns, and succession in mangrove forests. Furthermore, mangrove species exhibit significant phenotypic flexibility, strong resistance to drought and salinity, and a wide range of water management methods to effectively adapt to their intertidal habitats (Leng *et al.*, 2020).

The gathered data revealed the presence of 20 true mangrove species and 16 associate mangrove species in the studied area. According to a previous study conducted by Ricklefs *et al.*, (1993), mangrove environments exhibit comparatively lower levels of species richness in comparison to other high biomass tropical ecosystems such as rainforests and coral reefs. In comparison to the previous study conducted by Zuhairi *et al.* in 2019, this study identified an additional 10 species, indicating a notable increase in species diversity in the studied area. The increase in the number of recorded species is also attributed to the expanded number of sampling plots covered in this study, providing a more comprehensive survey of the area compared to earlier research. The

most abundant mangrove species observed in Cherating were *R. apiculata* and *R. mucronata*. These species were found at nearly every sampling site, indicating their dominance within the mangrove ecosystem. The *Rhizophora*'s ability to adapt to extreme conditions (Putri *et al.*, 2023), such as high salinity and fluctuating water levels, is a key factor in its success in mangrove ecosystems (Sudhir *et al.*, 2022). These adaptations allow it to survive and thrive where many other species unable to, thus contributing to its dominance in these unique environments. In contrast to other mangrove species, *Sonneratia caseolaris* and *Sonneratia ovata* were observed to be less common, being found only in a few isolated sites

4.1.3.2 PEKAN

The study sites in Pekan are only divided into two, which are the Pekan mangrove forest and the Sungai Nenasi. Pekan mangrove forest recorded fewer true mangrove species, but more associate species compared to Sungai Nenasi. The difference in the total number of species between Pekan and Kuantan is also due to the limited study area that had been covered.

The data collected from the Pekan mangrove forest revealed the presence of 11 real mangrove species and 14 associate mangrove species in the area. These species belong to 5 and 10 plant families, respectively. The study identified the families of true mangroves and associated mangroves as Acanthaceae, Lythraceae, Primulaceae, Pteridaceae, Rhizophoraceae, Aizoaceae, Casuarinaceae, Clusiaceae, Fabaceae, Lamiaceae, Malvaceae, Myrtaceae, Primulaceae, Sapindaceae, and Sapotaceae. The fluctuating quantities of plant families demonstrate the diverse botanical composition present in the Pekan mangrove area. The Rhizophoraceae family exhibited the highest dominance with four species in three genera, while the Acanthaceae family had three species in two genera. Furthermore, the study found two pteridophyte families of pteridophytes in the area sampled. The limited capacity of ferns to adjust to high salinity conditions significantly influences their presence in the mangrove habitat.

There are 14 species of associated species that have been documented in the inland and terrestrial regions of the Pekan mangrove forest study site. The Fabaceae family has the highest species diversity, consisting of four species: *Acacia auriculformis*, *Acacia mangium*, *Caesalpinia crista*, and *Tamarindus indica*.

Meanwhile, in Sungai Nenasi there are 6 families of true mangrove and 10 families of associates' species that had been collected along the Nenasi River. The families consist of Acanthaceae, Combretaceae, Lythraceae, Meliaceae, Rhizophoraceae, Rubiaceae, Arecaceae, Aspleniaceae, Casuarinaceae, Combretaceae, Convolvulaceae, Fabaceae, Malvaceae, Melastomataceae, Poaceae and Verbanaceae. Sixteen true mangrove species from nine different genera have been documented at the study site. The Rhizophoraceae family has the most recorded species, consisting of six species from four genera. Other than that, *Rhizophora apiculata*, *Rhizophora mucronata*, and *Kandelia candel* were identified as the predominant mangrove species in the Nenasi River region. They were found at nearly every sampling site, underscoring their crucial role as the predominant species in the nearby mangrove ecosystem. In contrast to other mangrove species, *Xylocarpus moluccensis* and *Xylocarpus rumphii* were found to be less common, being found only at a few isolated sites.

There are 9 species of associated species that have been documented in the inland and terrestrial regions of the Nenasi River study site. There are *Asplenium nidus*, *Casuarina equisetifolia*, *Hibiscus tiliaceus*, *Ipomea pes-caprae*, *Lantana camara*, *Nypa fruticans*, *Pekan Acession*, *Spinex littoreus*, and *Terminalia catappa*. *Pekan accession* is a new finding species from Melastomataceae family that grow in the mangrove habitat. According to Lawrence *et al.* (2019), Melastomataceae can be found in a range of forests and open vegetation types, such as lowland savannas, meadows, grasslands, vertical land cuttings, and occasionally in seasonally flooded habitats. *Macairea radula* and *Trembleya parviflora* are two species from the Melastomataceae that have been found in both palm swamps and woodland savannas. These species showed that they can survive in various habitats and vegetation types due to their structural characteristics that enable them to thrive in both floodable and non-floodable soils (Somavilla *et al.*, 2012). Therefore, a further study regarding Pekan accession species can be done in order to understand their characteristic.

The mangrove species were distributed evenly throughout the Pekan mangroves. The existence of a distinct zone, each dominated by different mangrove species, was observed in most of the mangrove study site in Pekan. *R. apiculata* and *R. mucronata* were the main species found in Pekan. Furthermore, a significant population of *K. candel* in Pekan, as compared to Kuantan, indicates that different environmental factors influence the species distribution, zonation patterns, and succession in mangrove forests (Bullock *et al.*, 2017).

Previous studies on Pekan mangrove forests have mostly focused on measuring the size of these crucial ecosystems. The findings of the current study offer new and unparalleled insights on the diversity and distribution of mangrove species and the associated species in Pekan. The town, known as the Royal City of Pahang, attracts tourists with its combination of historic legacy and natural beauty. Mangrove forests have value beyond being natural barriers to coastal erosion and extreme weather situations. Thus, this study highlights the capacity of these ecosystems to act as dynamic centres for ecotourism due to the exceptional variety of real mangroves and related species present in Pekan. The diverse range of plant and animal species enhances the biological landscape of the area and provides the opportunity to include tourists in the complex and captivating mangrove ecosystems.

4.1.4 TAXONOMIC TREATMENT

4.1.4.1 Associates Mangrove Species

4.1.4.1.1 Family Aizoaceae

4.1.4.1.1.1 *Sesuvium portulacastrum* (Figure 4.6)

Genus : *Sesuvium*

Scientific name : *Sesuvium portulacastrum* (L.) L.

Vernacular name : Gelang, Gelang laut (Malay), Sea purslane (Eng.)

Plant description:

Prostrate, creeping to suberect perennial herb with tap root. **Stems** rooting at nodes, 3 – 5 mm thick, 20 – 80 cm long, smooth, glabrous, green sometimes pink-red tinted. **Leaves** sessile; laminae thickly succulent, green, linear, lanceolate or elliptic, have long 1.0 – 3.5 cm, 0.2 – 0.5 cm of wide, glabrous, base sheathing and clasping stem joined to that of opposite leaf, margin entire, apex obtuse to slightly acute, dorsally apiculate, just below the apex; midrib, lateral vein and intercostal venation inconspicuous. **Flowers** solitary in the axil of pair of bracteoles, pedicellate; pedicels glabrous; perianth deeply 5 – lobed, lobes oblong, adaxial side pink to purplish, apex obtuse. **Capsules** oblong, enclosed by the calyx until maturity. **Seeds** reniform, shining black, smooth. (Appendix 1)



Figure 16: *Sesuvium portulacastrum* A) Plant habit B) Plant leave and stem

4.1.4.1.2 Family Apocynaceae

4.1.4.1.2.1 *Cerbera odollam* (Figure 4.7)

Genus : *Cerbera*
Scientific name : *Cerbera odollam* Gaertn.
Vernacular name : Pongpong (Malay.)

Plant description:

Tree or shrub to 12 m tall, to 20 cm diameter. **Branchlets** with very visible leaf scars, glabrous. **Leaves** petiole 1.6 – 2.5 cm long, glabrous; lamina papery to coriaceous, elliptic or lanceolate, 9.5 cm – 16.7 cm long, 2.9 cm – 4.3 cm wide, apex acuminate, base cuneate, glabrous above and beneath. **Inflorescences** few- to many-flowered, lax, robust, glabrous. **Flower** sepals linear, lanceolate or oblanceolate, apex acute or acuminate, glabrous; corolla white with a yellow eye. **Fruits** spherical to ovoid; green when mature; 4.7 – 7.7 cm long, 3.7 – 6.6 cm diameter. (Appendix 1)



Figure 17: *Cerbera odollam* A) Plant habit B) Fruit

4.1.4.1.3 Family Arecaceae

4.1.4.1.3.1 *Nypa fruticans* (Figure 4.8)

Genus : *Nypa*

Scientific name : *Nypa fruticans* Wurm

Vernacular name : Nipah (Malay), Nypa palm, Mangrove palm (Eng.)

Plant description:

Plant: Palm up to 4 – 10 m, stemless, leaf fronds grow directly out of the ground. **Leaf:** Erect fronds, slightly curved, up to 65 - 77 cm long, 3.0 – 4.0 cm wide, entire margin, 100 – 120 leaflets per frond, adaxial shiny green, abaxial powdery green. The stout leaf stalk is 1-1.4 m long and strongly flanged at the base. **Flower:** Bisexual, female and male flower borne separately on inflorescence, female flower spherical (25-30 cm in diameter), male flower bright yellow catkins located below the female head of flowers. **Fruit:** Spherical fruiting body, 45 cm in diameter; the individual brown fruits are obovate, angular and fibrous. There is one white, egg-shaped seed per fruit. (Appendix 1)



Figure 18: *Nypa fruticans* A) Plant habitat B) Plant with fruit

4.1.4.1.4 Family Aspleniaceae

4.1.4.1.4.1 *Asplenium nidus* (Figure 4.9)

Genus : *Asplenium*

Scientific name : *Asplenium nidus* L.

Vernacular name : Paku langsuyar (Malay), Bird's nest fern (Eng.)

Plant description:

Plant: Epiphytic fern having a stout and erect rhizome. **Fronde:** Leaf stalks are stout and almost black, can be as long as 5 cm, leaf length can be up to 150 cm or more and up to 20 cm wide. It narrows gradually, tapering both towards the pointed tip and towards the base. Fronds spread upward and outward to form a vase-shaped, green rosette with a nest-like center. **Sporangia:** develop in clusters called sori, covered by an elongated indusium on the back of the fronds. (Appendix 1)

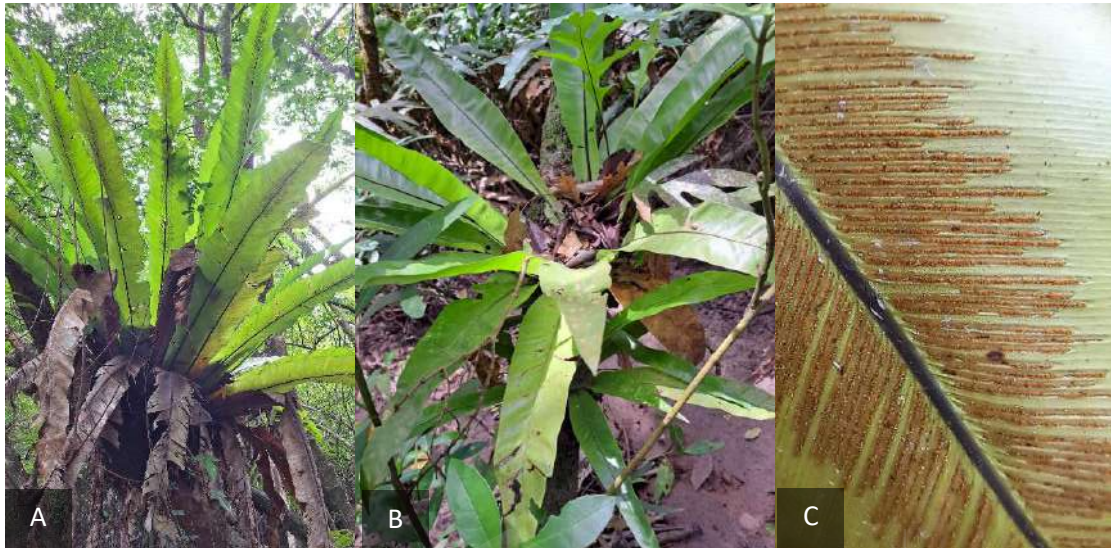


Figure 19: *Asplenium nidus* A - B) Plant habit C) Spores under the leaves

4.1.4.1.5 Family Asteraceae

4.1.4.1.5.1 *Pluchea indica* (Figure 4.10)

Genus : *Pluchea*

Scientific name : *Pluchea indica* (L.) Less.

Vernacular name : Pokok beluntas (Malay), Indian fleabane (Eng.)

Plant description:

Shrub to 2 m tall, much branched; branches puberulous, especially near inflorescence, becoming glabrous. **Leaves** lamina elliptic or obovate, long 2.0 – 5.0 cm, wide 1.0 – 2.0 cm, very shortly petiole, 0.2 – 0.5 cm long, sparsely puberulous to subglabrous on both surfaces, chartaceous, base attenuate, margins strongly dentate, apex acute. **Inflorescence:** comprises an almost corymbose, compact cluster of heads, each having many ray florets, only a few disc florets, subtended by an involucre of 3-7 series of deltoid bracts. Each head about 6-7 mm long, 5 mm broad on a peduncle 0-10 mm long. Individual ray florets with corolla 3-5 mm long; disc florets, 2-7, have a 5-lobed purple corolla (Appendix 1).



Figure 20: Plant sample of *Pluchea indica*.

4.1.4.1.6 Family Casuarinaceae

4.1.4.1.6.1 *Casuarina equisetifolia* (Figure 4.11)

Genus : *Casuarina*

Scientific name : *Casuarina equisetifolia* L.

Vernacular name : Rhu (Malay), Common Rhu (Eng.)

Plant description:

Small to very big tree, 5 -50 m tall, 27 - 100 cm diameter, usually dioecious, rarely monoecious; sometimes with buttresses to 76 cm high; crown symmetrical, sometimes asymmetrical, lowest branches of large trees usually arising at c. 3 m above the ground.

Bark usually greyish brown to grey, sometimes pale red or black, finely scaly-fissured to irregularly coarsely scaly-fissured, easily broken; outer bark brown; inner bark usually pinkish, sometimes pale brown to red, fibrous, soft. Sapwood yellowish to yellow, hard. **Woody twigs** terete, reddish brown to almost black when dry, hairy or glabrous at base, hairy towards the point of attachment of the green twigs, 2-3 mm thick.

Green twigs usually unbranched, terete, usually drying greenish yellow, sometimes reddish brown, to 34 cm long; nodes usually drying yellow, sometimes pale brown, internodes to 1.3 cm long, 0.5-1 mm thick, furrows hairy to glabrous. **Scale leaves** (6-7)(-8) per node, broadest at base, apex narrowly acute; on woody twigs to 4 mm long, base hairy, apex recurved; on green twigs 0.5-1 mm long, base glabrous, apex erect.

Male inflorescences simple elongated spikes about 2.0 – 3.0 cm long. **Female inflorescences** ellipsoid, to 6 mm long, 4 mm diameter (Appendix 1).



Figure 21: *Casuarina equisetifolia* A) Plant habit B) Fruit and female flower C – D) Male flower

4.1.4.1.7 Family Chrysobalanaceae

4.1.4.1.7.1 *Licania splendens* (Figure 4.12)

Genus : *Licania*
Scientific name : *Licania splendens* (Korth.) Prance
Vernacular name : Merbatu, Merbatu kechil (Malay)

Plant description:

Small to medium-sized tree to 25 m tall, bole to 40 cm diameter. **Bark** greyish brown, with yellow patches, smooth to cracking, sapwood white. **Twigs** slender, sparsely lanate when young, soon glabrous. **Stipules** linear-lanceolate, to 3 mm long, caducous. **Leaves:** lamina oblong to broadly elliptic, long 6.5 – 11.0 cm, wide 2.0 – 4.5 cm, petiole 0.1 – 0.2 cm, base cuneate, apex usually acuminate, entire margin, glabrous and papillose beneath; midrib raised above; lateral veins c. 8 pairs, faint, glabrous when mature. **Inflorescences** terminal and axillary panicles of cymules, rachis and branches densely grey-puberulous. **Flowers** receptacle campanulate, slightly swollen to one side, grey-tomentellous outside, tomentose inside, sepals acute, tomentellous on both surfaces; petals greenish white, pubescent outside. **Fruit** ripening bright red, ellipsoid, smooth (Appendix 1)



Figure 22: *Licania splendens*. A - B) Fruits C-D) Leaves

4.1.4.1.8 Family Clusiaceae

4.1.4.1.8.1 *Garcinia xanthochymus* (Figure 4.13)

Genus : *Garcinia*

Scientific name : *Garcinia xanthochymus* Hook. F. ex T. Anders.

Vernacular name : Asam kandis (Malay), Sour mangosteen (Eng.)

Plant description:

Tree grows up to 15m. The **trunk** is short and straight, with grey-brown bark. **Leaves** are oppositely-arranged, stalked leaves have leathery leaf blades that are narrowly oblong, 8.0 -13.9 cm long and 3.7 – 6.0 cm wide, petiole 1.0 – 2.0 cm, apex acute, base cuneate, entire margin, dark green and shiny on the top surface. **Flowers:** male and female are borne on separate plants, or sometimes bisexual flowers are produced. The stalked white flowers are borne in clusters of 4-10, about 1 cm wide. **Fruits** fleshy, subglobose berries with a pointed tip that ends with a persistent stigma, up to 9 cm wide, ripening pale orange to dark yellow. (Appendix 1)

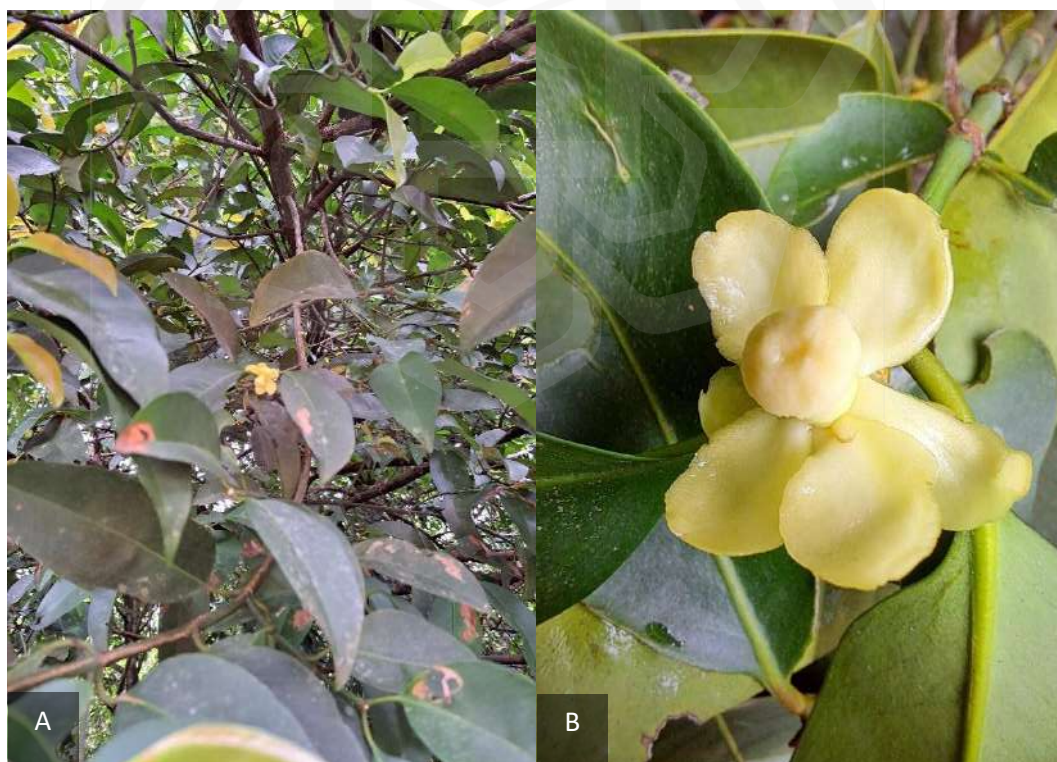


Figure 23: *Garcinia xanthochymus* A) Plant habit B) Flower

4.1.4.1.9 Family Combretaceae

4.1.4.1.9.1 *Terminalia catappa* (Figure 4.14)

Genus : *Terminalia*

Scientific name : *Terminalia catappa* L.

Vernacular name : Ketapang (Malay), Sea almond (Eng.)

Plant description:

Plant: Tree, up to 20 – 35 m tall. **Root:** buttress. **Leaf:** Deciduous, simple, 10.5 – 24.0 cm long, 6.0 – 15 cm wide, petiole 1.0 cm – 1.2 cm long, broadly obovate arranged in close spirals, often crowded toward the ends of the upturned branchlets. Leaves usually with 6-9 pairs of widely-spaced veins, and with a gland located on either side of the base of the midrib. Entire margin, apex obtuse and base acute. **Flower:** Petals cream-coloured, hairy, calyx lobes 4, yellow, fleshy, occur in 2 – 5 flowers in a stalk. The majority of the flowers are male, either without, or with a very short style. Calyx lobes are smooth inside. The stalk of the flower cluster is covered with soft hairs **Fruit:** Brown in colour, pear-shaped, hypocotyl cylindrical, rough and warty, somewhat flattened, hard, green, and later turning dark red. (Appendix 1)



Figure 24: *Terminalia catappa* A) Plant habit. B – C) Leaves. D) Fruit.

4.1.4.1.10 Family Convolvulaceae

4.1.4.1.10.1 *Ipomea pes-caprae* (Figure 4.15)

Genus : *Ipomea*

Scientific name : *Ipomea pes-caprae* (L.) R. Br.

Vernacular name : Tapak kuda(Malay), Beach morning glory, Goat's Foot (Eng.)

Plant description:

Plant: Herbaceous creeper. **Root:** Tap root. **Leaf:** Simple, entire, alternate, oblong to elliptic, kidney-shaped, dark green, apex emarginate, deeply notched apex, base cordate, thick and fleshy. The leaf blades are 3.5 – 4.7 cm long and 4.4 – 6.0 cm wide, petiole 1.5 – 3.5 cm, and often folded upward from the midrib. **Flower:** Axillary, cyme, funnel form, 5 fused petals, purple or violet with darker centre inside. **Fruit:** Ovoid to flattened-globose, dehiscent capsules, green and smooth when immature splitting into four valves at maturity. (Appendix 1)



Figure 25: *Ipomea pes-caprae*. A - B) Plant habit. C) Leaves. D) Flower.

4.1.4.1.11 Family Dilleniaceae

4.1.4.1.11.1 *Tetracera indica* (Figure 4.16)

Genus : *Tetracera*

Scientific name : *Tetracera indica* (Houtt. Ex Christm. & Panz.) Merr.

Vernacular name : Mempelas (Malay)

Plant description:

A woody climber up to 5 m long. **Leaves** are elliptic or obovate, 5.6 – 9.5 cm long, 2.1 – 3.5 cm wide, with a serrate leaf margin petiole 0.3 – 0.5 cm, apex acute, base cuneate. The veins on the underside of the leaf bear a sparse or dense set of stiff, thick bristles. **Flowers** have 3 - 5 petals, 3 - 4 carpels and numerous pink-tipped stamens. Groups of usually 4 - 7 flowers are arranged in terminal inflorescences (5 - 8 cm long). **Fruit** is leathery, round or oblong, typically each have 2 dark brown or black, egg-shaped seeds wrapped in red arils (fleshy tissue). (Appendix 1)



Figure 26: *Tetracera indica*. A) Leaves. B) Fruits

4.1.4.1.12 Family Euphorbiaceae

4.1.4.1.12.1 *Excoecaria agallocha* (Figure 4.17)

Genus : *Excoecaria*

Scientific name : *Excoecaria agallocha* L.

Vernacular name : Bebuta (Malay), Milky mangrove (Eng.)

Plant description:

Tree up to 15 m tall. Its **bark** is greyish-brown, warty, with vertical fissures and lenticels. **Leaves:** simple leaves have papery and slightly fleshy leaf blade, oblong to elliptic with entire margins, apex acute, base obtuse, green above, light green below, 3.0 – 9.3 cm long, 1.0 – 5.7 cm wide, petiole 2.0 – 2.5 cm. **Flowers:** male and female on different individuals. Male flower in axillary catkin spikes, fragrant, yellow, sessile, tepals 3, stamens 3, filaments free, anthers basifixed. The female flowers are in axillary catkin, smaller, pale green, Pedicellate, tepals 3, calyx 3-lobed; ovary superior, **Fruits** are Capsule, depressed globose and 3 seeded. (Appendix 1)



Figure 27: A - B) *Excoecaria agallocha*.

4.1.4.1.13 Family Fabaceae

4.1.4.1.13.1 *Acacia auriculformis* (Figure 4.18)

Genus : *Acacia*

Scientific name : *Acacia auriculformis* A. Cunn. Ex Benth.

Vernacular name : Akasia kuning (Malay), Acacia-tree, Yellow wattle (Eng.)

Plant description:

Tree grows up to 25 – 35 tall. **Bark** is grey or brown. **Phyllodes** are falcate, 7.5 – 14.5 cm long and 1.0 – 2.0 cm wide, petiole 0.2 – 0.5 cm, narrowly elliptic, apex narrowly acute, base narrowly cuneate, entire margin, glabrous, greyish-green and thinly textured. The **inflorescence** is an axillary, somewhat interrupted spike to 8.5 cm long in pairs in the upper axils. **Flowers** are light-golden in colour, 5-merous, bisexual, tiny, sessile, fragrant; calyx tubular, up to 0.1 cm long, shortly lobed, glabrous; corolla to 0.2 cm long; stamens many, about 0.3 cm long; ovary densely pubescent. The **Pods** are strongly curved to form an open coil, flat, flexible but hard, rather woody, glaucous, transversely veined with undulate margins and are about 6.5 cm long by 1.5 cm wide. They are initially straight or curved, but on maturity become twisted and irregularly coiled. The shiny black **seeds**, held transversely in the pod, are broadly ovate to elliptical, and each is encircled by a long red, yellow or orange funicle; areole large, almost enclosed. (Appendix 1)

4.1.4.1.13.2 *Acacia mangium* (Figure 4.18)

Genus : *Acacia*

Scientific name : *Acacia mangium* Willd.

Vernacular name : Akasia lebar (Malay), Brodleaf salwood (Eng.)

Plant description:

Tree grows up to 30m tall. The **bark** surface is rough, pale grey-brown to brown. **Phyllodes**: very large in size when mature, normally 5.5 - 17.7 cm long and 1.2 - 3.3 cm wide, petiole 0.2 – 1.2 cm. They are dark green, entire margin, narrowly elliptic, apex narrowly acute, base narrowly cuneate. **Flowers**: whitish or cream, rather loose

spikes 5-12 cm long on peduncles 0.6-1 cm long, singly or in pairs in the upper axils. The **seed pods** are linear, tightly coiled when ripe, sometimes tightly spirally coiled, slightly woody, 7-8 cm long and 0.3-0.5 cm wide. The **seeds** are black and shiny, longitudinal, ovate to oblong with a yellow or bright orange (rarely red) funicle folded to form an oily, fleshy aril beneath the seed. (Appendix 1)



Figure 28: A- B) Narrow leaves of *Acacia auriculiformis*. C - D) Wide leaves of *Acacia mangium*.

4.1.4.1.13.3 *Canavalia maritima* (Figure 4.19)

Genus : *Canavalia*

Scientific name : *Canavalia maritima*

Vernacular name : Kacang laut (Malay), Sea bean (Eng.)

Plant description:

Plant: The climber (2-10m long) creeps over other coastal plants. The end of the plant sometimes twines and often it roots from the nodes. **Leaf:** Compound leaf with three fleshy, leaflets are obovate or broadly oval, 5.0 – 5.5 cm of long and 4.0 – 4.5 cm of wide, petiole 0.3 – 0.5 cm. Entire margin, apex rounded, with a distinct notch or ending abruptly, and often with a triangular tip. **Flower:** Reddish-violet with a white streak down the middle, and are upside down when fully opened (2-2.5cm). The flower clusters occur in the leaf axils and have long stalks. Several flowers on a long stalk and are sweetly scented. **Fruit:** bean-like pods, straight or slightly curved, 9.5 cm long - 2.5 cm wide, with 2-10 seeds, brown oval. (Appendix 1)

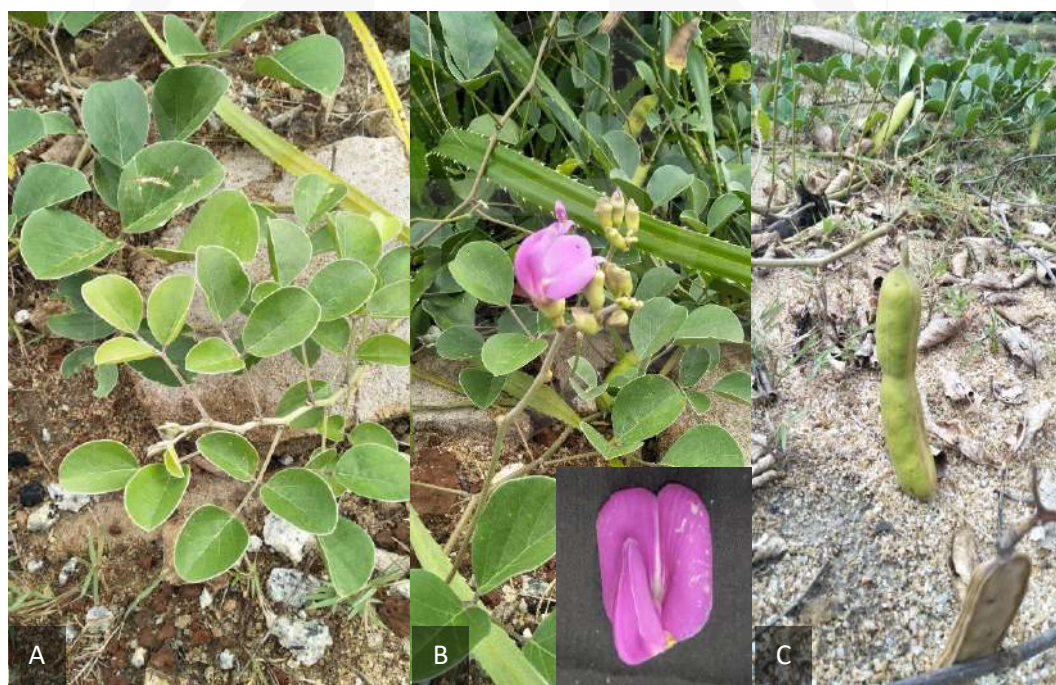


Figure 29: *Canavalia maritima*. A) Plant habit B) Flower. C) Fruit.

4.1.4.1.13.4 *Caesalpina crista* (Figure 4.20)

Genus : *Caesalpina*

Scientific name : *Caesalpina crista* L.

Vernacular name : Kuku tupai (Malay), Crested fever nut (Eng.)

Plant description:

A large, prickly, prostrate or climbing, evergreen shrub up to 20 m tall. **Branchlets** finely grey-downy, armed with hooked and straight hard yellow prickles. **Leaves:** alternate, bipinnate, **leaflets** 2 pairs per pinna, 4.5 – 5.2 cm long and 2.2 - 2.9 cm wide, petiole 3.0 – 3.4 cm, prickly, petiolule 0.4 – 0.5 cm, membranous, elliptic-oblong, base rounded to acute, apex rounded, margins curved, upper surface shiny, lower dull. **Flowers:** yellow, fragrant, borne in axillary and terminal racemes 15-60 cm long; bracts squarrose, linear, acute, to 1 cm long, fulvous-hairy; calyx 6-8 mm long, lobes obovate-oblong, obtuse; petals oblanceolate, yellow. **Fruits:** somewhat swollen, oblong, prickly, dark brown to black, 1 or 2-seeded, beaked. **Seeds:** orbicular or ovoid to reniform, black, polished, hard. (Appendix 1)



Figure 30: *Caesalpina crista*. A) Plant habit. B-C) Flower. D) Fruit

4.1.4.1.13.5 *Crotalaria pallida* (Figure 4.21)

Genus : *Crotalaria*

Scientific name : *Crotalaria pallida* Aiton.

Vernacular name : Kacang kayu (Malay), Rattlebox (Eng.)

Plant description:

Plant: A shrub up to 2 m. The stout stem is hairy and has longitudinal grooves. **Root:** Taproot. **Leaf:** Trifoliate compound, leaflets oblong-elliptic, 2.0 – 4.0 cm long and 1.0 – 2.0 cm wide, margin entire, apex obtuse, base acute with leaf stalk 2.2 - 6.7 cm long, adaxial hairless, abaxial sparsely covered with silky hair **Flower:** Raceme, 10-40 yellow flowers are arranged in a spike-like inflorescence about 15-40 cm long. Petals are yellow with lines near base, standard petal 0.9-1.2 cm long, 7-9 mm wide, keel petals striated, with non-twisted prolonged beak. Pods brown at maturity, 3.5-3.8 cm long. **Fruit:** Elongated legume, 3-4 cm long, 0.5-0.8 cm wide, contain 20-30 seeds, green, softly hairy when immature but become hairless at maturity. (Appendix 1)



Figure 31: *Crotalaria pallida*. A) Plant habit. B) Leaves. C) Flowers. D) Fruits.

4.1.4.1.13.6 *Dendrolobium umbellatum* (Figure 4.22)

Genus : *Dendrolobium*
Scientific name : *Dendrolobium umbellatum* (L.) Benth.
Vernacular name : Petai belalang (Malay)

Plant description

It is a tree up to 6 m tall. **Leaves:** pinnate, stalked leaves have leaflets that are elliptic to broadly egg-shaped, the underside of which are covered with fine hairs. The terminal leaflet is 6.0 – 7.1 cm long – 4.5 – 5.1 cm wide, lateral leaflets 5.0 – 5.5 cm long – 3.3 – 3.5 cm wide, apex obtuse, base rounded and entire margin. **Flowers:** cluster, 13 mm-long, white flowers. **Fruits:** thick, elongated, leathery fruit pods consist of 3–8 segments that are 1-seeded, broadly elliptical-oblong to oblong, and 5–10 by 3.5–5 mm. (Appendix 1)

4.1.4.1.13.7 *Derris trifoliata* (Figure 4.23)

Genus : *Derris*
Scientific name : *Derris trifoliata* Lour.
Vernacular name : Common derris

Plant description:

It is an erect shrub up to 2 m tall, or a woody climber up to 15 m long. **Leaves:** stalked, pinnate leaves consist of 3–7 leaflets. Its opposite, stalked leaflets have leathery leaf blades that are egg- to lance-shaped or oval, entire margin and 3.9 – 6.8 cm long, 1.5 – 2.7 cm wide, petiole 0.2- 0.5 cm with gradually, narrowing tips, apex acute, base obtuse. **Flowers** are about 9–12 mm long, with cream-white to lavender or pinkish petals. **Fruits:** disc-like fruits are 1 or 2-seeded, rounded on the lower side, and narrowly winged on the upper side. Its brown seeds are compressed, wrinkled, kidney-shaped (Appendix 1).



Figure 32: *Dendrolobium umbellatum*. A) Plant habit. B) Fruits.
C) Flowers.



Figure 33: Plant sample of *Derris trifoliata*.

4.1.4.1.13.8 *Tamarindus indica* (Figure 4.24)

Genus : *Tamarindus*

Scientific name : *Tamarindus indica* L.

Vernacular name : Asam jawa (Malay), Tamarind (Eng.)

Plant description:

Tree up to 30m tall. **Leaves:** pinnately compound, 10.0 – 14.0 cm long, with 15 pairs of leaflets, and are slightly arching. Individual leaflets are small, about 1.5 - 2cm long, 0.4 – 0.6 cm wide, petiole 0.7 – 0.8 cm, apex rounded, base rounded and narrowly oblong. The effect is that the leaves appear fine and fern-like. **Flowers:** The zygomorphic flowers are quite small, and resemble orchids, about 2cm in diameter, pale yellow with purple or red veins. They are produced in small, drooping clusters. **Fruit** is a legume. The pod is long, between 3.5 -7.0 cm in length: brown, thick and velvety. Each fruit contains 8-10 hard and flat seeds, surrounded by a yellow-brown edible pulp. (Appendix 1)

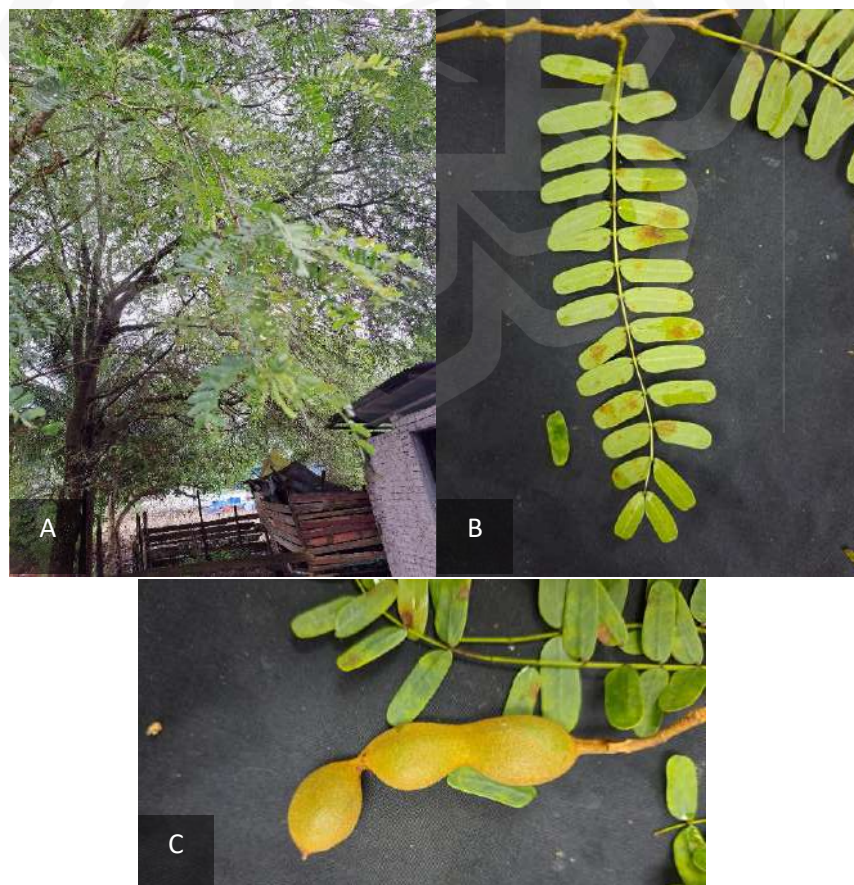


Figure 34: *Tamarindus indica*. A) Plant habit. B) Leaves. C) Fruits.

4.1.4.1.14 Family Flagellariaceae

4.1.4.1.14.1 Flagellaria indica (Figure 4.25)

Genus : *Flagellaria*

Scientific name : *Flagellaria indica* L.

Vernacular name : Rotan dini (Malay), False rattan (Eng.)

Plant description:

Plant: Climber, up to 15 m long. **Leaf:** Stalkless, 14.5 – 18 cm long, 1.4 – 1.5 cm wide, entire, alternate, lance-shaped to linear, apex tapering into tendrils, base rounded, sessile, leaf has sheath covering the stem, adaxial and abaxial green. **Flower:** Erect, small, 0.1 – 0.3 cm long, found in dense spike at the end of branch (Appendix 1).



Figure 35: *Flagellaria indica*. A) Part of the plant. B) Leaves. C) Flowers.

4.1.4.1.15 Family Lamiaceae

4.1.4.1.15.1 *Vitex ovata* (Figure 4.26)

Genus : *Vitex*
Scientific name : *Vitex ovata* Thunb.
Vernacular name : Lagundi (Malay)

Plant description:

Plant: Shrub, ground lying to creeping, occasionally a small tree; 1-3 m. Entire plant especially the leaves are strongly aromatic. **Leaf:** Obovate to spoon-shaped, ovate-elliptic, broadly oblong-elliptic, 2.0 – 5.5 cm long and 1.0 – 2.0 cm wide, petiole 0.2 – 0.5 cm, covered with silky hairs, usually pale dull green, margin entire, apex rounded, base cuneate, tip abruptly pointed to rounded. Leaves mostly 1-3-foliolate. **Flower:** Compact terminal cylindrical or ovate cluster. Purplish mauve to lilac blue, surface is hairy. Calyx cup-shaped, 4-5 mm, slightly 2-lipped, with 5 teeth, outside covered with minute silky hairs and glands, inside smooth, long shaggy hairs in tube and inside on lower half of large front lobe of lower lip. Stamens and style protruding **Fruit:** Dark (reddish) brown when dry, round. (Appendix 1)



Figure 36: *Vitex ovata*. A) Plant habit. B – C) Flowers.

4.1.4.1.15.2 *Vitex pinnata* (Figure 4.27)

Genus : *Vitex*

Scientific name : *Vitex pinnata* L.

Vernacular name : Leban, Leban tanduk, Halban (Malay)

Plant description:

Tree is 1 – 15 m (rarely 25 m) high with 10 – 45 cm (rarely 120 cm). **Bark:** yellowish grey or light brown, smooth to flaky and sometimes fluted. **Leaves:** compound, leaflets 1 – 3 pairs, central elliptic, 8.2 – 16.5 cm long and 3 – 6.4 cm wide, smaller side leaflet, 9.5 – 12.0 cm and 3.5 – 6.0 cm wide, yellowish greens hair, glands underside leaves. **Inflorescence:** 8 – 20 cm long **Flower:** 5 white to violet petals which are fragrant; leaf-like bracteoles, 7 – 15 mm long 6 mm wide; calyx, yellowish to brownish green, 5-lobed and has flatten hairs. **Fruits:** are purplish black, 5 – 8 cm diameter, round, shiny and fleshy with seeds enclosed in stone hard endocarp. (Appendix 1)



Figure 37: *Vitex pinnata*. A) Plant habit. B - C) Flowers. D) Fruits.

4.1.4.1.15.3 *Volkameria inermis* (Figure 4.28)

Genus : *Volkameria*

Scientific name : *Volkameris inermis*

Vernacular name : Bunga pawang (Malay), Wild jasmine (Eng.)

Plant description:

Plant: Erect, dropping shrub, up to 3 m tall or climber up to 13 m long, stem woody and smooth, with drooping branches and purplish young twigs that are densely covered with short hairs. **Leaf:** Simple, opposite, margin entire, ovate to elliptical, apex acute, base cuneate, petiole 0.5 – 1.0 cm, 2.6 – 4.5 cm long and 0.9 – 2.0 cm wide, adaxial green, thin and fleshy. On the lower surface the leaves have dark green dots and near the base of the stalk they often have a few large, sunken glands. **Flower:** inflorescence is axillary, Cymes or umbels usually comprised of 3 flowers joined at a common base point. White flowers with a 3.5-5.5 cm long narrow tube ending in 5 petals. Four purple stamens, 1.5-3 cm long, protrude out of the flower. **Fruit:** Round shaped with flattened top, blackens, dries and breaks into 4 lobes each bearing a thick, corky wall upon maturing. (Appendix 1)



Figure 38: *Volkameris inermis*. A) Leaf. B - C) Flowers

4.1.4.1.16 Family Lauraceae

4.1.4.1.16.1 *Neolitsea* sp. (Figure 4.29)

Genus : *Neolitsea*
Scientific name : *Neolitsea* sp.
Vernacular name : Lagundi (Malay)

Plant description:

Trees or shrubs, evergreen, dioecious. **Leaves:** alternate, clustered, or verticillate, rarely subopposite, triplinerved, rarely pinninerved or subtriplinerved. Elliptic, 8.7 – 13.7 cm long, 3.2 – 5.5 cm wide, entire margin, apex acuminate, base cuneate. **Inflorescence:** Umbel's solitary or fasciculate, pedunculate or not; bracts opposite, large, late deciduous; perianth segments 4, in 2 whorls. **Flowers:** unisexual. **Male flowers:** fertile stamens 6 in 3 whorls of 2 each; filaments of 1st and 2nd whorls eglandular, of 3rd whorls 2-glandular at base; anthers all introrse, 4-celled. **Female flowers:** staminodes 6, clavate, of 1st and 2nd whorls glandular, of 3rd whorls 2-glandular at base; ovary superior; style conspicuous; stigma peltate. **Fruit** seated on slightly enlarged disciform or concave perianth tube; pedicel often slightly thickened. (Appendix 1)



Figure 39: Plant sample of *Neolitsea* sp.

4.1.4.1.17 Family Malvaceae

4.1.4.1.17.1 *Heritiera littoralis* (Figure 4.30)

Genus : *Heritiera*

Scientific name : *Heritiera littoralis* Aiton.

Vernacular name : Dungun (Malay), Mangrove dungun, Looking-Glass Tree (Eng.)

Plant description:

Tree up to 25m tall, low-branching and bushy tree. **Leaves:** spirally arranged, stalked leaves have leathery and stiff leaf blades that are oblong-elliptical to egg-shaped-elliptical, long 8.9 – 14.4 cm, wide 3.8 – 6.3 cm, petiole 1.5 – 1.7 cm, margin entire or slightly wavy, dark green above, scaly silvery white to brown on the underside. Base cuneate, apex acute. **Flowers:** are unisexual, in which each flower only has either the male or female sexual organ, dull purple, bell-shaped with 4–6 teeth, 6.3 mm wide, and in 5–18 cm, yellowish flower clusters inserted at the leaf axils. **Fruits** are woody, ellipsoid to oblong-egg-shaped, glossy brown or purple, and each possesses a keel on one side, and 1 seed. Its seeds are oblong-ellipsoid, flattened, brown (Appendix 1).

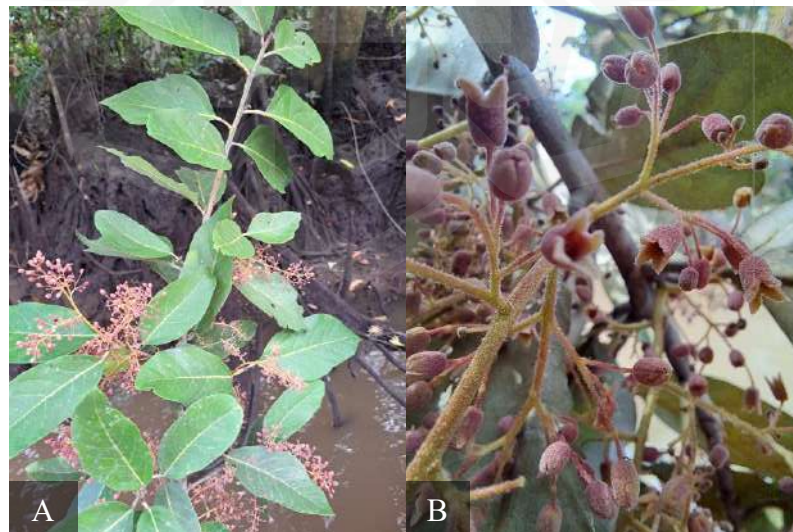


Figure 40: *Heritiera littoralis* A- B) Flowers

4.1.4.1.17.2 *Hibiscus tiliaceus* (Figure 4.31)

Genus : *Hibiscus*

Scientific name : *Hibiscus tiliaceus* L.

Vernacular name : Bebaru (Malay), Sea hibiscus, Beach hibiscus (Eng.)

Plant description:

Plant: Shrub, up to 2 – 3 m tall, **Trunk:** Greyish brown, mottled, smooth bark and a trunk that may measure up to 30 cm diameter at breast height. **Leaf:** Simple, leathery leaves by 7.5 – 16.4 cm long, 8.5 – 16.2 cm wide, serrate, spirally arranged along stem, apex rounded, base cordate, cordate or cordiform shape, petiole 4.5 – 14.0 cm, adaxial dark green, pubescent, abaxial whitish green, slightly hairy, interstipule present. They have 1-3 glands and large, 1.0 – 2.7 cm, broad leaflets at the base of the leaf stalk. **Flower:** Large, yellow in colour, turns dull orange in afternoon and sepals form a pointed-tip cup. The base of the elongated flower cluster stalk is enclosed by a pair of enveloping leaflets that later fall and leave a conspicuous, ring-like scar. The bisexual flowers are typically ‘hibiscus-like’, with the surfaces of the petals, stamen tube and style covered with glandular hairs. The pale yellow flowers have a dark brownish-purple centre, large 5-7.5 cm across and showy. They are yellow on the evening they open but turn purple at the end of the following day, when they fall off before withering. Flowers have a conspicuously 5-toothed calyx. **Fruit:** Rounded explosive capsules, brown when mature, splitting into 5 parts to disperse numerous small kidney-shaped and minutely hairy seeds. (Appendix 1)

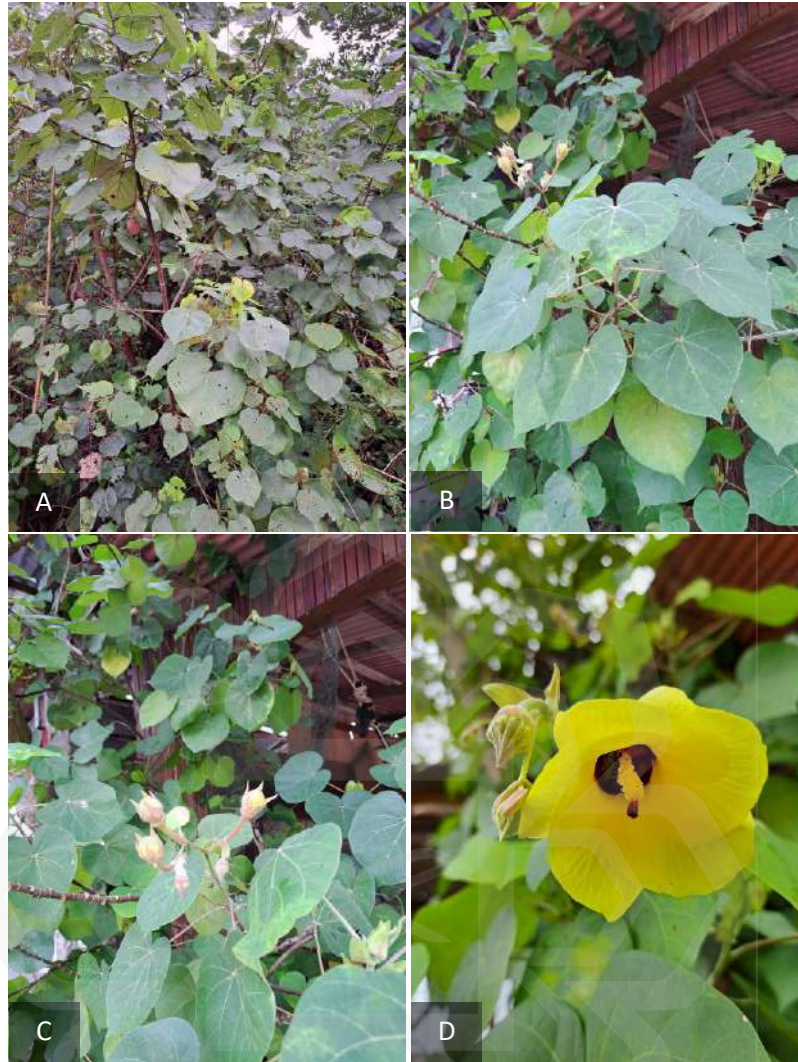


Figure 41: *Hibiscus tiliaceus* A) Plant habit B) Leaves C) Fruits D) Flower

4.1.4.1.18 Family Melastomataceae

4.1.4.1.18.1 Pekan accession (Figure 4.32)

Plant description:

Habit: shrub, 0.5 – 2 m tall. **Leaves:** long 2.0 – 7.8 cm, wide 0.5 – 2.6 cm, petiole 0.5 – 1.5 cm, elliptic, apex acute, base cuneate, entire margin. **Inflorescences:** branched or panicle, axillary cymes, few to many flowered, 2-3 flowers. **Flowers:** white pinkish, 5 petals; stamen 10, white; style white; hypanthium green. **Fruits** are urceolate-globular, hairy, green in colour



Figure 42: *Pekan accession* A) Plant habit B) Leaves C) Flowers D) Fruits

4.1.4.1.19 Family Memecylaceae

4.1.4.1.19.1 Memecylon edule (Figure 4.33)

Genus : *Memecylon*

Scientific name : *Memecylon edule* Roxb.

Vernacular name : Delek ayer, Nipis kulit (Malay)

Plant description:

Small tree 5-10 m tall; boles often numerous and crooked, 5-15 cm diameter. **Twigs** pale brown, 2 grooved, terete when mature, internodes 1.5-4 cm apart. **Leaves:** petioles 1.0 - 1.2 cm, lamina 4.5 – 11.5 cm long, 2.5 – 6.5 cm wide, somewhat coriaceous, drying greenish or dark brown above slightly paler below, elliptic lanceolate, entire margin, base obtuse, apex acute to shortly acuminate; midrib sunken above, prominent below. **Inflorescences:** many-flowered compound dichasia; glabrous. **Flowers:** pedicel slender, conspicuous bracteoles absent; calyx campanulate, greenish or yellowish, truncate to shallowly 4-lobed, **Fruits:** berry globose often slightly flattened at the poles, green when immature ripening to dark blue-purple/black via yellow (never red), drying brownish or blackish, calyx remnant slightly raised (Appendix 1).



Figure 43: *Memecylon edule* A) Plant habit B) Leaves

4.1.4.1.20 Family Myrtaceae

4.1.4.1.20.1 *Rhodomyrtus tomentosa* (Figure 4.34)

Genus : *Rhodomyrtus*

Scientific name : *Rhodomyrtus tomentosa* (Aiton) Hassk.

Vernacular name : Kemunting (Malay), Rose myrtle (Eng.)

Plant description:

Plant: Shrub, up to 4 m tall. **Leaf:** Simple, opposite, elliptic to obovate-elliptic, hairy on the lower surface. Sparsely white woolly below when young, lamina 4.0 – 5.5 cm long and 2.0 – 3.0 cm wide, with three distinct longitudinal veins. Petioles are 0.2–0.5 cm long. Entire margin, apex rounded, base cuneate. **Flower:** Asymmetrical, 5 petals, pink or purplish with numerous stamens at the centre of flower. One to five flowers in axillary cymes, each flower subtended by 2 small bracts; sepals orbicular, 3–4 mm long, tomentose; petals rose pink, approx. 10–13 mm long. **Fruit:** berries, green when young and turning to dark purple when mature, fleshy, sweet, and aromatic with persistent sepals at the tip, and contain many tiny, deltoid seeds embedded in the purplish pulp. (Appendix 1)



Figure 44: *Rhodomyrtus tomentosa* A) Plant habit B) Flowers C) Leaves

4.1.4.1.20.2 *Syzigium grande* (Figure 4.35)

Genus : *Syzigium*

Scientific name : *Syzigium grande* (Wight) Walp.

Vernacular name : Jambu Air Laut (Malay), Sea Apple (Eng.)

Plant description:

Plant: Tree, oblong to irregular crown, up to 45 m tall, and 75 cm diameter. **Bark:** is rough with shallow fissures, greyish buff or pinkish in colour with inner bark pale pink to dark reddish and pale yellow near the surface. **Leaves:** opposite, stalked leaves that are leathery, 1.4 – 1.5 cm long, broadly elliptic, 9.4 –11.7 cm long by 7.7 – 8.0 cm wide, darker green above, lighter green below, down-turned leaf tip. **Flowers:** 2.5-3 cm when expanded, very fragrant, petals and stamens white. **Fruits:** somewhat globular, urn-shaped to ellipsoid berries, green when ripe, 1-2 cm in length, containing a single seed. (Appendix 1)



Figure 45: *Syzigium grande* A) Plant habit B) Leaves C) Fruits D) Flowers

4.1.4.1.21 Family Pandanaceae

4.1.4.1.21.1 *Pandanus tectorius* (Figure 4.36)

Genus : *Pandanus*

Scientific name : *Pandanus tectorius* Parkinson

Vernacular name : Pandan laut, Mengkuang laut (Malay), Screw pine (Eng.)

Plant description:

Plant: Bush to small tree, up to 4 – 18 m tall, widely branching, sometimes with several trunks. **Root:** Stilt roots around the stem, have numerous aerial roots from branches, and prop roots. **Leaf:** Linear leaves, 82.0 cm long and 3.0 cm wide, pointed tip, spirally arranged and clustered at branch apices, dark green, spinose margin and midrib. **Flower:** Dioecious; male flower small, white and fragrant, borne on a raceme which is subtended by a large, white bract. Male flower heads arranged singularly, in a pendulous ‘cone’, stamens arranged in bunches on short side-branches; leaflets around the male flowers are linear-lanceolate, keeled, yellowish-white, and emit a pleasant odour. Female flower heads also singularly arranged. Female flower is pineapple-like. **Fruit:** Multiple fruit, oval shaped resemble pineapple, turning orange-yellow. (Appendix 1)



Figure 46: *Pandanus tectorius* A) Leaves B) Fruits

4.1.4.1.22 Family Phyllanthaceae

4.1.4.1.22.1 *Glochidion littorale* (Figure 4.37)

Genus : *Glochidion*

Scientific name : *Glochidion littorale* Blume

Vernacular name : Jambu kera (Malay). Monkey apple (Eng.)

Plant description:

Shrub or small tree that grows up to 6 m tall. **Leaves:** smooth, alternate leaves are obovate 2.0 – 8.0 cm long, 1.5 – 5.0 cm wide, with entire leaf margin, short petioles, petiole 0.1 -0.5 cm, apex rounded, base obtuse. **Flowers:** small, unisexual flowers lack petals and occur in dense clusters in the leaf axil. Female flowers are composed of 6 slightly fused sepals that form an egg-like shape. Male flowers are also composed of 6 sepals, but they are arranged in 2 overlapping sets of 3 sepals. **Fruits:** shiny, red fruits are donut-shaped with longitudinal grooves and a deep dimple at the apex. It is classified as a capsule, splitting apart at the grooves into 10 to 15 pieces that each contain 2 red seeds. (Appendix 1)



Figure 47: *Glochidion littorale* Fruit

4.1.4.1.23 Family Poaceae

4.1.4.1.23.1 *Spinifex littoreus* (Figure 4.38)

Genus : *Spinifex*

Scientific name : *Spinifex littoreus* (Burm.f.) Merr.

Vernacular name : Rumpit bebalin (Malay)

Plant description:

Stolons. Culms 40-80 cm long; woody. **Leaves:** Ligule a fringe of hairs. Leaf-blades involute; 2.0 – 12.0 cm long; 1 - 3 mm wide; indurate; stiff; glaucous. Leaf-blade apex acuminate; pungent. **Inflorescence:** Dioecious, racemes, **Male inflorescence:** sessile; single raceme, 2 flowered; 10 mm long. Male spikelet glumes 2. Male spikelet lemma 7-9 -veined with numerous pedunculate racemes, 0–120 mm, bearing up to 15 silky-villous spikelets. **Spikelets** comprising 1 basal sterile floret; 1 fertile floret; without rachilla extension. Spikelets lanceolate; dorsally compressed; 9-10 mm long; falling entire; deciduous with accessory branch structures. (Appendix 1).



Figure 48: *Spinifex litooreus* A – B) Plant habit
C) Flowers inflorescence

4.1.4.1.24 Family Primulaceae

4.1.4.1.24.1 *Ardisia crispa* (Figure 4.39)

Genus : *Ardisia*
Scientific name : *Ardisia crispa* (Thunb.) A.DC.
Vernacular name : Mata pelanduk (Malay)

Plant description:

Shrubs or subshrubs 0.6-1.5 m tall, with creeping rhizomes. **Stems** usually minutely puberulent or sparsely brown scaly when young. **Leaves:** petiole 0.5 – 1.0 cm; leaf blade elliptic-lanceolate to narrowly lanceolate, 7.0 – 10.5 cm long, 2.5 – 3.0 cm wide, membranous or subpapery, glabrous adaxially, usually finely brown scaly abaxially, base cuneate, margin entire or shallowly crenulate, recurved, punctate, apex long acuminate or rarely acute. **Inflorescences** terminal, subumbellate, simple, on curved specialized lateral branches 5-10 cm. **Flowers** white or pink, 4-5 mm. Pedicel 1-1.5 cm, puberulent. Sepals' oblong-ovate or lanceolate, ca. 1.5 mm, sparsely punctate, glabrous, apex acute or narrowly rounded. Petals ovate, 4-5 mm, punctate, glabrous outside, minutely puberulent inside, apex acute. **Fruit** reddish, globose, 5-6 mm in diameter. (Appendix 1)

4.1.4.1.24.2 *Ardisia elliptica* (Figure 4.40)

Genus : *Ardisia*
Scientific name : *Ardisia elliptica* Thunb.
Vernacular name : Mata pelanduk, Mata itek, Mempenai (Malay)

Plant description:

Shrubs 1-2 m tall. **Leaves:** alternate, stalked leaves have fleshy or leathery leaf blades that are elliptic, and 3.5 – 10.5 long and 1.5 – 3.5 cm wide, reddish or green petioles, entire margin, acute or obtuse apex. **Inflorescences:** axillary or subterminal on basally thickened lateral branches, subumbellate or umbellate. **Flowers** are leathery, pink or white, sepals broadly ovate, densely black punctate, base rugose and subauriculate, margin subentire, scarious, minutely ciliate, apex rounded. Petals almost free, broadly

ovate, densely punctate, glabrous, margin hyaline, scarious, entire, apex long attenuate.
Fruit subglobose, red or purplish black, ca. 8 mm in diameter, minutely punctate, fleshy
(Appendix 1).



Figure 49: *Ardisia crispa* A) Plant habit B) Leaves C) Flowers D) Fruits



Figure 50: *Ardisia elliptica* A-B) Fruits C - D) Leaves

4.1.4.1.25 Family Rubiaceae

4.1.4.1.25.1 *Gardenia tubifera* (Figure 4.41)

Genus : *Gardenia*

Scientific name : *Gardenia tubifera* Wall. Ex Roxb.

Vernacular name : Delima Hutan (Malay), Water Gardenia (Eng.)

Plant description:

Plant: tree, up to 12 m tall with light grey-brown to dark brown smooth bark. **Leaves:** obovate, 21.5 – 26.5 cm long and 8.0 – 12.5 cm wide, opposite, acute to cuneate apex, cuneate base, stipule is fused and forming a cylindrical tubular structure and minutely hairy (puberulent) on the outside, tip of the stipule is slightly 2-lobed to subtruncate, petiole is 0.7 – 0.5 cm long, covered with minute hairs. **Flowers:** solitary, cream to

yellow coloured, salver-shaped with long slender tube and 6 – 8 lobes, hairy at the throat and comprises of 6 – 9 stamens, the style is glabrous while the stigma is club-like and protrudes out of the flower throat; calyx is subtruncate, loosely sheathing the corolla tube, surface is smooth. **Fruits:** globose, with a persistent calyx at the tip (Appendix 1)



Figure 51: *Gardenia tubifera* A – C) Leaves D) Leaves arrangement

4.1.4.1.25.2 *Ixora congesta* (Figure 4.42)

Genus : *Ixora*

Scientific name : *Ixora congesta* Roxb.

Vernacular name : Jarum – jarum (Malay), Malayan Ixora (Eng.)

Plant description:

Big woody shrub or small understorey tree, reaching 6-7m tall. **Leaves** Elliptic, 4.5 – 11.0 cm long and 2.7 – 6.1 cm wide, petiole 0.2 – 0.5 cm, elliptical to oblong, fairly thick and leathery. Apex acute, base cuneate, margin entire. Lateral veins distinctly-depressed, thus imparting a bullate appearance to upper leaf surface. **Flowers**: Trumpet-shaped, emerging bright yellow and turning reddish-orange, scentless. **Fruits**: Globose berries with thin pulp, 7-12mm across, ripening from green to red to purplish-black, each containing 1-2 relatively large seeds. (Appendix 1)



Figure 52: *Ixora congesta* A) Leaves B) Flowers

4.1.4.1.25.3 *Morinda citrifolia* (Figure 4.43)

Genus : *Morinda*

Scientific name : *Morinda citrifolia* L.

Vernacular name : Mengkudu (Malay), Noni, Great Morinda (Eng.)

Plant description:

Plant: Shrub or small tree, 3 -10 m tall. **Leaf:** Simple, large, 10.0 - 15.5 cm long, 4.0 – 6.0 cm wide, entire, opposite, glossy, elliptic to ovate, apex acute, base cuneate, petiole 0.5 – 1.3 cm long, adaxial dark green, abaxial green, stipule present on leaf node. **Flower:** Perfect, white in colour. **Fruit:** Egg-shaped, yellowish green, fleshy and soft. (Appendix 1)



Figure 53: *Morinda citrifolia* A) Plant habit B) Fruits

4.1.4.1.25.4 *Psydrax* sp. (Figure 4.44)

Genus : *Psydrax*

Scientific name : *Psydrax* sp.

Vernacular name : -

Plant description:

Shrubs or small trees. **Leaves:** opposite, persistent, interpetiolar or shortly fused to petioles or united around stem, generally triangular to ovate. Elliptic, 8.8 – 11.2 cm long, 5.9 – 6.3 cm wide, petiole 0.5 -1.0 cm, entire margin, apex acute, base obtuse. **Inflorescences** axillary, cymose and several flowered, sessile to pedunculate, bracteate or bracts reduced. **Flowers** subsessile to pedicellate, bisexual, monomorphic. Calyx limb truncate or 4- or 5-dentate. Corolla white to yellow, tubular to funnelform, inside variously pubescent; lobes 4 or 5, valvate in bud, markedly reflexed at anthesis. **Fruit** generally yellow, drupaceous, fleshy, subglobose to ellipsoid or sometimes dicocous, with calyx limb persistent; pyrenes 2, 1-celled with 1 seed, bony or cartilaginous; seeds medium-sized, ellipsoid, cylindrical, or plano-convex. (Appendix 1)



Figure 54: *Psydrax* sp. A) Plant habit B) Leaves

4.1.4.1.26 Family Rutaceae

4.1.4.1.26.1 *Merope angulata* (Figure 4.45)

Genus : *Merope*

Scientific name : *Merope angulata* (Willd.) Swingle

Vernacular name : Limau lelang (Malay), Mangrove lime (Eng.)

Plant description:

Erect shrub, with multiple branches, stems sparse and arising from a root crown.

Leaves: Alternate, thickly leathery, aromatic leaves have transparent dots and measure 5.7 – 8.5 cm long, 2.2 – 3.5 cm wide, leaf stalks are unwinged, 0.5 – 0.7 cm long, leaf edges are slightly notched, leaf tip blunt or slightly pointed. **Flowers:** White, bisexual flowers about 2 cm long, fragrant, solitary, occur in leaf axils either in pairs or clusters of only a few flowers, stamens 10 and petals are 7 - 9 mm long. **Fruits:** Ovoid, angular berry, with 3-4 flattened sides, aromatic when crushed. (Appendix 1)



Figure 55: *Merope angulata* A) Flower B) Stem

4.1.4.1.27 Family Sapindaceae

4.1.4.1.27.1 *Dodonaea viscosa* (Figure 4.46)

Genus : *Dodonaea*

Scientific name : *Dodonaea viscosa* Jacq.

Vernacular name : Kayu Bertih (Malay), Hopbush (Eng.)

Plant description:

Habit: shrub, 3 m tall. **Leaves:** Simple, opposite, long 7.4 – 9.5 cm, wide 3.6 – 5.1 cm, petiole 0.4 – 0.4 cm long, elliptic to oblong, apex acuminate to acute, base cuneate, entire margin. **Flowers:** Axillary, cymes. **Fruits** Capsules ca. 0.8-1 cm wide, subglobose, 5 lobed (Appendix 1).



Figure 56: *Dodonaea viscosa* A-B) Leaves C-D) Fruits

4.1.4.1.28 Family Sapotaceae

4.1.4.1.28.1 *Planchonella obovata* (Figure 4.47)

Genus : *Planchonella*

Scientific name : *Planchonella obovata* (R. Br.) Pierre

Vernacular name : Menasi (Malay), Sea Gutta, Northern Yellow Boxwood (Eng.)

Plant description:

It is a small or medium-sized tree, up to 28 m tall. **Leaves:** alternate, stalked leaves have papery to somewhat leathery leaf blades that are elliptic or obovate, entire margin, dark glossy green and hairless above, densely reddish-brown hairy below, 6.5 – 9.8 cm long and 2.5 – 3.9 cm of wide. Petiole 1.5 cm. Base cuneate and apex acute. **Flowers:** greenish-white flowers are 6 mm wide, female or bisexual, in small axillary clusters. **Fruits:** 1-5 seeded fruits are obovoid to somewhat round, pale-yellow to reddish-brown upon ripening. Seeds 1-3 per fruit, yellow, with distinct linear scar. (Appendix 1)



Figure 57: *Planchonella obovata* A) Leaves B) Flowers

4.1.4.1.29 Family Verbenaceae

4.1.4.1.29.1 *Lantana camara* (Figure 4.48)

Genus : *Lantana*

Scientific name : *Lantana camara* L.

Vernacular name : Bunga Tahi Ayam (Malay), Common Lantana (Eng.)

Plant description:

Plant: medium-sized perennial aromatic shrub, 2-5 m tall, with quadrangular stems, sometimes having prickles. The posture may be sub-erect, scrambling, or occasionally clambering, multiple stems arise from ground level. **Leaves:** oval or broadly lance-shaped, 3.6 – 5.8 cm long, 1.5 – 3.5 cm wide, having a rough surface and a yellow-green to green colour, petiole 0.5 – 1.5 cm long, entire margin, apex acute, base cuneate. **Inflorescence:** may be yellow, orange, white, pale violet, pink, or red. **Flowers:** are small, multicoloured, in stalked, dense, flat-topped clusters to 4 cm across. **Fruit:** is a round, fleshy, 2 seeded drupes, about 5 mm wide, green turning purple then blue-black. (Appendix 1)



Figure 58: *Lantana camara* A) Plant habit. B - D) Flowers

4.1.4.1.30 Family Vitaceae

4.1.4.1.30.1 *Cissus hastata* (Figure 4.49)

Genus : *Cissus*

Scientific name : *Cissus hastata* Miq.

Vernacular name : Akar kerayong (Malay), White Steamed Button Vine (Eng.)

Plant description:

An herbaceous climber with a four-winged stem, with red wings and a waxy white bloom and growing corky with age, tendrils red and bifid. **Leaves:** ovate to lanceolate, often red on the margins and sometimes below, with a pronounced hastate, cordate to auriculate base, petiole is angular. **Inflorescence** umbellate, 1–2.5 cm across. **Flowers:** four petals that are cream above and reddish below with a yellow disc. **Fruits:** berry ripens black through red, and is about 5 mm across (Appendix 1).



Figure 59: *Cissus hastata* A) Plant habit. B) Flowers

4.1.4.2 True Mangrove Species

4.1.4.2.1 Family Acanthaceae

4.1.4.2.1.1 Acanthus ilicifolius (Figure 4.50)

Genus : *Acanthus*
Scientific name : *Acanthus ilicifolius* L.
Vernacular name : Jeruju putih (Malay)

Plant description:

Plant: A shrub up to 0.3 – 0.5 m. **Stem:** Shiny green. **Leaf:** Simple, 12.5 – 18.5 cm long, 4.5 – 5.0 cm wide, petiole 0.5 – 1.0 cm, entire-spiny, margin less lobed than *A. ebracteatus*, young leaf may not have spine, opposite-decussate, oval to oblong, apex acute, base cuneate, leaf glabrous, petiole short, 1 – 2 cm. **Flower:** Perfect, normally white in colour. **Fruit:** Green, flattened, ovoid

4.1.4.2.1.2 Avicennia alba (Figure 4.51)

Genus : *Avicennia*
Scientific name : *Avicennia alba* Blume.
Vernacular name : Api – api (Malay)

Plant description:

Plant: A tree up to 5 – 10 m. **Root:** A pencil-like pneumatophore. The latter are thin, finger-like (or asparagus-like) and covered with numerous lenticels. The outer bark is greyish or brownish, and may be either warty or smooth. On older stem parts a pale, powdery mould often occurs. Trunk may attain a diameter of 50 cm at breast height. **Leaf:** Simple, oblong-lanceolate, 7.5 – 14 cm long, 3.0 – 5.1 cm wide, apex acute, base narrowly cuneate, petiole 0.8 – 1.6 cm, entire margin and adaxial glossy dark green, abaxial pale whitish, glabrous. **Flower:** Complete, actinomorphic, orange-yellow measure 3-4 mm across, 1.5-3 cm long, stamens 4, peduncle 1 cm long. The lowest pair of flowers is somewhat distantly located from other flowers of the cluster. **Fruit:** Pale-green, elongated and thin chili-shaped, woolly, up to 1.5 – 2 cm long. (Appendix 2)



Figure 60: *Acanthus ilicifolius* A) Plant habit B) Leaves C) Stem modification D) Flowers



Figure 61: *Avicennia alba* A) Plant habit B) Leaves C) Flowers D) Fruits

4.1.4.2.1.3 *Avicennia marina* (Figure 4.52)

Genus : *Avicennia*
Scientific name : *Avicennia marina* (Forssk.) Vierh.
Vernacular name : Api-api jambu (Malay)

Plant description:

Plant: Medium to large tree growing up to 30 m. **Bark:** Smooth, or slightly flaky grey bark. **Root:** a pencil-like pneumatophore, grow up to 15 – 20 cm. **Leaf:** simple, elliptic or ovate-elliptic to elliptic-lanceolate, 5.5 – 9.5 cm long, 3.0 – 5.5 cm wide, petiole 0.8 – 1.0 cm, entire margin, rounded at the apex, cuneate at the base, green or yellow-green

and glabrous above, minutely silvery grey or whitish tomentose beneath, glaucous, sometimes blackening on drying, long, gradually passing into the lamina. **Flower:** small dense heads with 3 heads per terminal inflorescence but lateral branches originating from lower leaflets or leafy nodes; sometimes a pair of additional opposite flowers borne on central peduncle well below the head; bracts and bracteoles ovate or round, concave, adpressed to calyx, 2–4 mm. long, 1.5–3 mm. wide, acute, ciliate. **Fruit:** Capsule subglobose, broadly ellipsoid or ovoid, usually not beaked when mature, 1.2–3 cm. long, 0.7–2.5 cm. wide, velvety scaly-tomentose. (Appendix 2)



Figure 62: *Avicennia marina* A) Plant habit. B) Leaves
C) Flowers

4.1.4.2.1.4 *Avicennia officinalis* (Figure 4.53)

Genus : *Avicennia*

Scientific name : *Avicennia officinalis*

Vernacular name : Api-api ludat (Malay)

Plant description:

Plant: A tree up to 2 – 3 m tall, bark smooth, light brown. **Root:** a pencil-like pneumatophore. **Leaf:** simple, 7.5 – 10.0 cm long, 2.5 – 4.9 cm wide, entire margin, opposite-decussate, obovate, apex rounded, base cuneate, petiole 0.5 – 1.5 cm, petiole base slightly black, adaxial dark green, abaxial yellowish green, glabrous and leathery. **Flower:** complete, sympetalous, petal 4, actinomorphic, orange-yellow in colour, stamens 4, adnate. **Fruit:** broadly ovate with short apical beak, covered with short hairs (Appendix 2).



Figure 63: *Avicennia officinalis* A-B) Leaves. C) Fruits.

4.1.4.2.1.5 *Avicennia rumphiana* (Figure 4.54)

Genus : *Avicennia*

Scientific name : *Avicennia rumphiana* Ridley.

Vernacular name : Api – api bulu (Malay)

Plant description:

Plant: A tree up to 30 m and 3 m girth. **Stem** not buttressed but cylindrical, with a straight trunk when growing in a closed stand. **Bark** is dark grey and smooth. **Root:** A pencil-like pneumatophore. **Leaf:** Simple, elliptic, 5.2 – 10.8 cm long, 2.9 – 5.7 cm wide, petiole 1.0 – 1.6 cm, entire margin, opposite, apex rounded, base cuneate, adaxial dark green, covered with dense, flannel-like tawny or yellowish-white, powdery hairs beneath. Midrib of leaf is prominent beneath, covered with hairs like the rest of the underside. **Flower:** Clustered in three-branched heads, densely covered in fine hairs, 4-lobed, orange-yellow. **Fruit:** Pale-green, broadly ovoid, compressed, not more than about 18 mm long and covered with dense woolly hairs. Woolly flat capsule containing one seed, green to yellowish brown. (Appendix 2)



Figure 64: *Avicennia rumphiana* A) Plant habit B) Leaves C) Fruits D) Flowers

4.1.4.2.2 Family Combretaceae

4.1.4.2.2.1 *Lumnitzera littorea* (Figure 4.55)

Genus : *Lumnitzera*

Scientific name : *Lumnitzera littorea* (Jack) Voigt.

Vernacular name : Teruntum merah (Malay), Red-flower black mangrove (Eng.)

Plant description:

Plant: Tree, up to 5 – 6 m tall. **Root:** Knee-like pneumatophore. **Bark:** dark brown, fissured. **Leaf:** Simple, 4.7 – 6.4 cm long, 1.3 – 2.4 cm wide, entire margin, alternate, obovate, apex rounded, base narrowly cuneate, petiole 0.2 - 0.5 cm, shortly-stalked, adaxial and abaxial almost the same, green to dark green, slightly thick and fleshy. **Flower:** Petals 5, bright red, shortly stalked, peduncle 1 cm, fused sepal green. **Fruit:** Ellipsoid-oblong, corky and buoyant, 1.7 cm long, 0.6 cm wide (Appendix 2).



Figure 65: *Lumnitzera littorea* A) Plant habit
B) Leaves C) Fruits D) Flowers

4.1.4.2.2.2 *Lumnitzera racemosa* (Figure 4.56)

Genus : *Lumnitzera*

Scientific name : *Lumnitzera racemosa* Willd.

Vernacular name : Teruntum putih (Malay)

Plant description:

Plant: Evergreen, erect and much-branched tree up to 10 m tall. **Leaves:** simple, alternate, 4.0 – 6.5 cm long and 1.5 -2.5 cm wide, succulent, obovate in shape with an indent in the tip, leaf margin is slightly wavy **Flowers:** small, erect with green tube-like calyx, divided into five lobes at the tip, petals five, white, stamens ten, arranged in two whorls **Fruit:** vase-shaped, 1 to 2 cm long, yellowish green, glossy, corky **Seeds:** single seed in each fruit, oblong ovoid. (Appendix 2)



Figure 66: *Lumnitzera racemosa* A) Plant habit
B) Leaves C) Flowers D) Flower bud

4.1.4.2.3 Family Lythraceae

4.1.4.2.3.1 *Sonneratia alba* (Figure 4.57)

Genus : *Sonneratia*

Scientific name : *Sonneratia alba* Sm. & J.J. Sim.

Vernacular name : Perepat (Malay), Mangrove apple (Eng.)

Plant description:

Small tree 6 – 12 m tall; pneumatophores 20 – 40 cm tall, thickened at base, blunt at apex. **Twigs** (sub)terete, erect. **Leaves:** petiole 0.5 – 0.8 cm long; lamina 7.0 - 8.1 cm long, wide 4.7 - 7.0 cm, broadly obovate, entire margin, apex broadly rounded, cuneate base often emarginate; veins obscure on upper surface. **Flowers** solitary or 3 together, buds ellipsoid, terete, 2 – 3.4 cm long; calyx tube obconical, ridged, lobes 6 – 7, shorter than the tube, inner surface often reddish; petals inconspicuous, narrow, white or red at base, resembling filaments; filaments and style white, as long as petals. **Berry:** calyx tube in fruit cup-shaped, faintly ridged, calyx-lobes reflexed (downward curved), style massive, persistent. (Appendix 2)



Figure 67: *Sonneratia alba* A) Plant habit B) Leaves
C) Flowers D) Fruits

4.1.4.2.3.2 *Sonneratia caseolaris* (Figure 4.58)

Genus : *Sonneratia*

Scientific name : *Sonneratia caseolaris* (L.) Engl.

Vernacular name : Berembang (Malay), Crabapple mangrove (Eng.)

Plant description:

Small tree 8 – 20 m tall; pneumatophores slender and strong, to 1 m tall, often forked at apex. **Twigs** 4-angular, young twigs drooping. **Leaves:** petiole 0.2 – 0.6 cm long, elliptic or narrowly ovate or obovate, 3.5 – 7.5 cm long, 1.0 – 3.5 cm of wide, entire

margin, base attenuate, narrowed towards acute apex, with tip bluntish or subacute. **Flowers** mostly solitary or in pairs; buds obovoid, terete, apex acute; calyx tube shallowly cup-shaped, ridged, lobes 6 – 7, longer than the tube, 1.5 – 2 cm long, spreading, inner surface tinged reddish; petals red, lanceolate; filaments white above, red in lower part. **Berry:** tube in fruit shallow, flat, including horizontally spreading lobes. (Appendix 2)

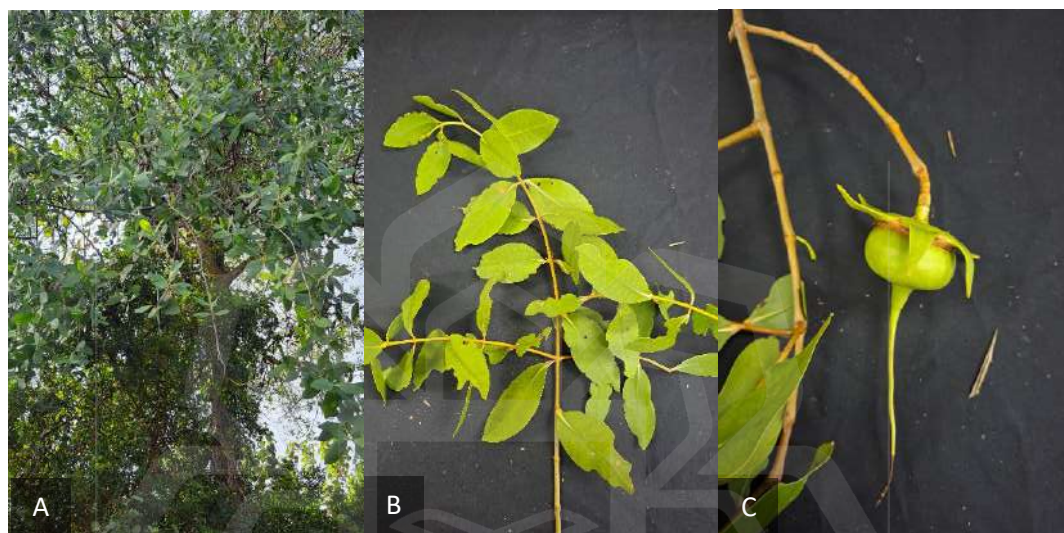


Figure 68: *Sonneratia caseolaris* A) Plant habit B) Leaves C) Fruits

4.1.4.2.3.3 *Sonneratia ovata* (Figure 4.59)

Genus : *Sonneratia*

Scientific name : *Sonneratia ovata* Backer.

Vernacular name : Gedabu (Malay), Mangrove apple (Eng.)

Plant description:

Small tree 5 – 15 m tall; pneumatophores slender, 15 – 25 cm tall, pointed. **Twigs** often more-or-less angular, erect. **Leaves:** petiole 0.2 – 1.0 cm long, broadly ovate to obovate, or suborbicular, 3.8 – 6.4 cm of long, 2.0 – 4.5 cm of wide, entire margin, base cuneate, apex rounded. **Flowers** solitary or 2 – 3 together, buds broadly ellipsoid-obovoid, 2 – 3 cm long, finely granulate-ridged, apex obtuse, lobes 6, about as long as the tube, inner surface tinged with red; petals absent; filaments white. **Berry:** ripening yellowish; calyx

tube in fruit shallowly cup-shaped, ridged, with the calyx lobes up-curved, more-or-less appressed to the berry. (Appendix 2)



Figure 69: *Sonneratia ovata* Leaves

4.1.4.2.4 Family Meliaceae

4.1.4.2.4.1 *Xylocarpus granatum* (Figure 4.60)

Genus : *Xylocarpus*

Scientific name : *Xylocarpus granatum* J. Koenig.

Vernacular name : Nyireh bunga (Malay), Cannonball mangrove (Eng.)

Plant description:

Small tree shrub, up to 20m tall; bole to 90 cm diameter; buttresses thin, branched, ribbon-like, spreading out from base; pneumatophores absent. **Bark** thin, smooth scaling as irregular flakes, whitish to yellow-brown; inner bark reddish or pink. **Leaves** rachis 2.0 – 4.0 cm long, petioles to 2.5 – 5.0 cm long; leaflets coriaceous, 1 – 3 pairs; petiolules 0.4 – 0.5 cm long, swollen; laminas elliptic, 6.0 - 11.5 cm long, 2.2 - 5.4 cm wide, base cuneate, apex obtuse, entire margin, venation prominent on both surfaces. **Inflorescences** 3 – 6 cm, more-or-less squarrose, borne on new and older twigs, frequently forked with indistinct main axis; bracts and bracteoles 0.5 mm, granaducous. **Flowers** pedicels 3 – 9 mm long, conspicuously swollen towards the

calyx; calyx lobes 1 – 3 mm long; petals oblong, creamy-white or pinkish. **Capsules** depressed globose. (Appendix 2)



Figure 70: *Xylocarpus granatum* A) Plant habit B) Leaves
C) Flowers D) Fruits

4.1.4.2.4.2 *Xylocarpus moluccensis* (Figure 4.61)

Genus : *Xylocarpus*

Scientific name : *Xylocarpus moluccensis* (Lam.) M.Roem.

Vernacular name : Nyireh batu (Malay)

Plant description:

Small to medium-size tree, 6 – 20 m tall; bole usually solitary, cylindric and not coppicing, to 70 cm diameter; buttresses small but not ribbon-like; pneumatophores many, pointed. **Bark** rough with longitudinal fissures, falling as oblong flakes. **Leaves**

to 10 cm long, sometimes with persistent apical spikes to 1 mm long; leaflets 1 – 4 pairs; laminas elliptic-oblong or lanceolate to oblanceolate, base cuneate, more-or-less asymmetrical, apex acute to obtuse; venation prominent on both surfaces. **Inflorescences** 3 – 13 cm long, often produced with the new leaves, somewhat lax, main axis distinct. **Flowers** pedicels 3 – 8 mm long, not conspicuously swollen near calyx, petals oblong to obovate, creamy-white, lobes acute to apiculate or bifid to retuse. **Capsules** depressed globose or obscurely 4-lobed, 6 – 11 cm diameter. (Appendix 2)

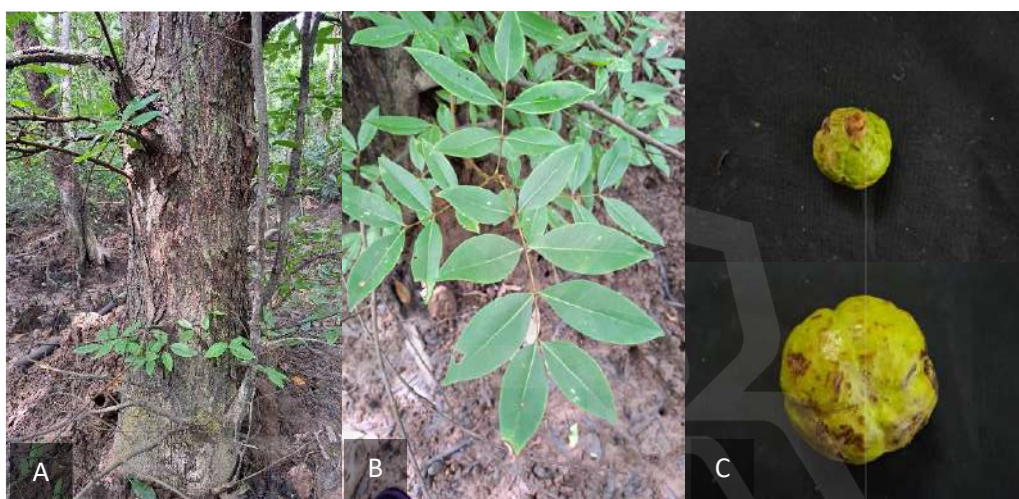


Figure 71: *Xylocarpus moluccensis* A) Bark B) Leaves C) Fruit

4.1.4.2.4.3 *Xylocarpus rumphii* (Figure 4.62)

Genus : *Xylocarpus*
Scientific name : *Xylocarpus rumphii* (Kostel.) Mabb.
Vernacular name : Nyireh (Malay)

Plant description:

Small tree 4 – 18 m tall with neither conspicuous buttresses nor pneumatophores; bole usually solitary, to 50 cm diameter, frequently gnarled. **Bark** lenticellate to finely fissured, greyish. **Leaf** rachis 3.7 – 5.5 cm long, petiole 4.0 – 5.0 cm long, leaflets in 2 – 5 pairs; petiolules 0.2 – 0.3 cm long, swollen; laminas ovate to cordate, entire margin sometimes more-or-less falcate, base broadly cuneate or obtuse, asymmetric, apex acute to acuminate. **Inflorescences** thyrses, pendent, main axis distinct, lateral branches to 8 cm long; bracts and bracteoles c. 0.5 mm, narrowly triangular, persistent, pedicels 3 –

8 mm long, not conspicuously swollen near calyx. **Flowers** calyx lobes 1 – 1.5 mm long; petals 3.5 – 6 x 2 – 2.5 mm, elliptic-oblong, creamy-white, lobes apiculate or bifid to retuse. **Capsules** globose, 6 - 8 cm diameter (Appendix 2).



Figure 72: *Xylocarpus rumphii* A-B) Leaves C) Flowers

4.1.4.2.5 Family Primulaceae

4.1.4.2.5.1 *Aegiceras corniculatum* (Figure 4.63)

Genus : *Aegiceras*

Scientific name : *Aegiceras corniculatum* (L.) Blanco

Vernacular name : Kacang kacang (Malay), River mangrove (Eng.)

Plant description:

Low evergreen tree or shrub with multiple stems up to 6 m tall. **Bark**: smooth, greyish with lenticels and roots that run along the soil surface. **Leaves** are leathery, elliptic to spoon-shaped, 7.0 – 8.5 cm long, 4.0 – 4.7 cm wide, petiole 0.5 – 0.7 cm. Entire margin, apex rounded and base cuneate. The midrib is prominent below, tinged with red. Salt crystals are often encrusted on the leaf surface. **Flowers** are borne in an inflorescence, found on both the tips of branches or at the leafless axils. The open flowers are fragrant, tubular, 5-petalled, dense hairs can be found at the mouth of the tube. The **fruit** is a crescent-shaped, single-seeded capsule between 4.0 – 5.0 cm long resembling a chili. (Appendix 2)



Figure 73: *Aegiceras corniculatum* A) Plant habit
B) Leaves C) Flowers D) Fruits

4.1.4.2.6 Family Pteridaceae

4.1.4.2.6.1 *Acrostichum aureum* (Figure 4.64)

Genus : *Acrostichum*

Scientific name : *Acrostichum aureum* L.

Vernacular name : Piai raya (Malay), Leather fern, Mangrove fern (Eng.)

Plant description:

Plant: Fern, 1 – 4 m tall. **Rhizome:** Stout, erect, base of stalk covered with large scales.

Stem: They are thickened towards the base, dark brown with a broad, pale, thin margin, mixed with narrow, thin scales. **Frond:** Large (1-3 m long), pinnae many (not more than 30 leaflets), 20 – 23 cm long, 3.0 cm wide, alternate, entire margin, slightly wavy, narrowly oblong, apex rounded, base cuneate, adaxial dark green, abaxial pale green, young frond reddish in colour, fertile pinnae near the tip, stipe about 0.3 m. The leaflets may be spaced far apart and are often irregularly distributed. The lowest leaflets are always widely spaced, with long stalks that measure up to 3 cm. The tops of fertile leaves are rusty-brown coloured, later turning dark brown. The undersides of these 10-20 topmost leaflets are uniformly covered with large sporangia. Tips of the longer, sterile leaflets are abruptly rounded or blunt, with a short tip. Spines (= midrib of shed leaflet) are frequent and black. **Leaf venation** is net-like. The broad scales, up to 1 cm long, are restricted to the base of the fronds; they have a thickened middle, an entire edge and leave no prominent scar. **Spores** are large and have a tetrahedral shape.

(Appendix 2)



Figure 74: *Acrostichum aureum* A) Plant habit B) Leaves

4.1.4.2.6.2 *Acrostichum speciosum* (Figure 4.65)

Genus : *Acrostichum*

Scientific name : *Acrostichum speciosum* Willd.

Vernacular name : Piai lasu (Malay), Mangrove fern (Eng.)

Plant description:

Plant: Fern, 1 – 4 m tall. **Rhizome:** stout, erect, base of stipes covered with dark brown scale. Scales on the rhizome are up to about 8 mm long. **Leaf** frond large, 27 – 33 cm long, 3.0 – 4.0 cm wide, pinnae many, entire margin, pinnately compound, narrowly elliptic, apex acute, base cuneate, adaxial dark green, abaxial pale green, young frond brownish-green in colour, fertile pinnae near the tip, form dark brown sporangia, smaller than sterile pinnae, stipe about 0.3 m. These are uniformly covered with large sporangia. Leaflets measure about 28 by 10 cm, and the tips of the smaller, sterile leaflets are narrowly pointed. **Leaf venation** is net-like. The broad scales, up to 1 cm long, are restricted to the base of the leaves. Scales have a thickened middle and an entire margin. **Spores** are large and tetrahedral in shape. (Appendix 2)



Figure 75: *Acrostichum speciosum* A) Plant habit B) Leaves

4.1.4.2.7 Family Rhizophoraceae

4.1.4.2.7.1 *Bruquiera cylindrica* (Figure 4.66)

Genus : *Bruquiera*

Scientific name : *Bruquiera cylindrica* (L.) Blume.

Vernacular name : Bakau putih, Berus – berus (Malay), White mangrove (Eng.)

Plant description:

Plant: A small-butressed, evergreen tree, up to 15 – 23 m tall, bark dark grey that has a few small, corky lenticels. **Root:** A knee-like pneumatophore. **Leaf:** Simple, 8.7 – 10.4 cm long, 4.0 – 4.6 cm wide, entire margin, opposite, oval to elliptic, apex acute, base cuneate, petiole 1.8 – 2.7 cm, adaxial green, abaxial light green, thin and leathery. **Inflorescence:** Axillary cymes, usually unbranched. Flowers are arranged in a cluster of three and rarely up to six flowers and are pendulous. **Flower:** Complete, usually 3-flowered, actinomorphic, calyx 8-lobed, each lobe having 2-3 bristles at the top; they are white, but rapidly turn brown with age. The outer margins of the flowers are usually fringed with white hairs along the lower part light green, 2 - 4 flowers per stalk, peduncle 1 cm long. **Fruit:** Simple, hypocotyl cylindrical, 10.5 – 11.5 cm, slightly curved, green (Appendix 2)



Figure 76: *Bruguiera cylindrica* A) Leaves B) Fruits C) Flowers

4.1.4.2.7.2 *Bruguiera gymnorhiza* (Figure 4.67)

Genus : *Bruguiera*

Scientific name : *Bruguiera gymnorhiza* (L.) Lam.

Vernacular name : Tumu merah (Malay), Black mangrove (Eng.)

Plant description:

Plant: A tree, up to 30 – 35 m tall, bark dark grey. **Root:** Knee-like pneumatophore.

Leaf: Opposite, Simple, 6.3 – 17.5 cm long, 5.0 – 7.0 cm wide, entire margin, opposite-decussate, elliptic, apex acute, base cuneate to obtuse, petiole 2.0 – 4.5 cm, reddish in colour, adaxial dark green, abaxial light green, glabrous, leathery and thick, young shoot reddish **Flower:** perfect, axillary, calyx is typically reddish to almost scarlet, occasionally pale yellow, white or green, characteristically smooth or with grooves above lobe junctures, rarely ribbed, with 10-13 lobes, acutely pointed, narrow. Style is

pale green, filiform, 3-4 lobes **Fruit:** Cigar-shaped, hypocotyl slightly ridged, 15 cm long and 1.1 cm wide. (Appendix 2)



Figure 77: *Bruguiera gymnorhiza* A-B) Plant habit
C) Flowers D) Fruits

4.1.4.2.7.3 *Bruguiera sexangula* (Figure 4.68)

Genus : *Bruguiera*

Scientific name : *Bruguiera sexangula* (Lour.) Poir.

Vernacular name : Tumu mata buaya (Malay), Black mangrove (Eng.)

Plant description:

Trees up to 7 m, with knee roots, bark grey. **Leaves** elliptic to elliptic-oblong, 11.5 – 14.0 cm of long and 4.0 – 6.0 cm of wide, entire margin, apex acute, base cuneate, lateral veins 10-11 pairs, visible to obscure; petioles 1.5-3.5 cm; stipules green to yellow-green, 3.5-4 cm long before dropping. **Flower** solitary, at the upper 3 (2) nodes of shoot. Pedicels 6-10 mm long, yellow or yellow-green. Calyx lobes 10-12, 1.8 – 2.0 cm long, yellow, tube 1.3-1.5 cm long, distinctly ridged outside. Petals 1.5 cm long, bifid, densely covered with transparent hairs on the outer margins from the base to the apex; lobes half the length of the petal, each without or with 1- 3 short bristles less than 1 mm long or so and not or hardly exceeding the tip, sinus bristle shorter than the lobe, 4-5 mm long. Stamens twice the number of petals. **Hypocotyl** up to 11.5 cm, slightly ridged, with narrow blunt end. (Appendix 2)

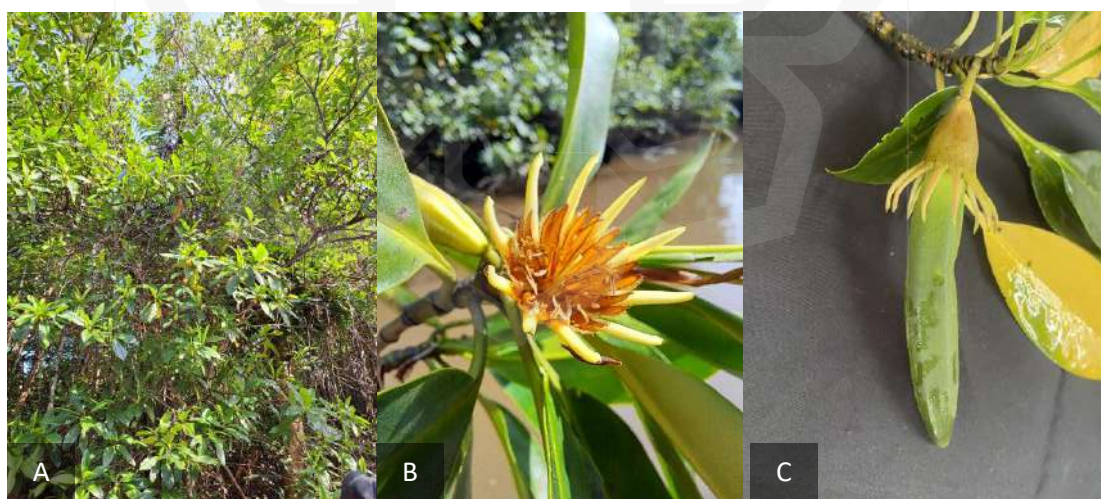


Figure 78: *Bruguiera sexangula* A) Plant habit B) Flower C) Fruit

4.1.4.2.7.4 *Bruguiera parviflora* (Figure 4.69)

Genus : *Bruguiera*

Scientific name : *Bruguiera parviflora* (Roxb.) Wight & Arn. ex Griff.

Vernacular name : Lenggadai (Malay)

Plant description:

Plant: Tree, up to 5 m tall. **Root:** Knee-like pneumatophore. **Leaf:** Simple, 5.5 – 16.8 cm long, 1.8 – 5.3 cm wide, entire, opposite-decussate, elliptic, apex acute, base narrowly cuneate, petiole 1.0 – 5.3 cm, slender, light green in colour, adaxial dark green, abaxial light green, turns yellowish when ages, glabrous, leathery, young shoot light green. **Flower:** Yellowish-green petals, actinomorphic, pedicel 1 cm long, calyx 8 lobes, slender. **Fruit:** Thin, hypocotyl cylindrical, curved and smooth, about 10 cm long. (Appendix 2)



Figure 79: *Bruguiera parviflora* A) Plant habit B) Fruits

4.1.4.2.7.5 *Ceriops decandra* (Figure 4.70)

Genus : *Ceriops*

Scientific name : *Ceriops decandra* (Griff.) W. Theob.

Vernacular name : Tengar (Malay)

Plant description:

Plant: A shrub to small trees reaching 2 - 5 m in height. **Bark:** Light grey, smooth to flaky bark and a flanged stem base. The trunk may attain a diameter of 15-20 cm at breast height which peels off into thin flakes. **Leaf:** Oval to obovate, glossy-green, 4.0 – 8.0 cm long and 2.5–5.0 cm wide, petiole 1.4 -2.5 cm, opposite, margin entire, apex emarginate, base cuneate. **Flower:** Inflorescences are axillary and in compact, bifurcate cyme-like. The flower is 5-merous with petals white turning brownish with age. The corolla is 2.5-4 mm long, white. Stamens have a short filament, equal to or shorter than the anther, which ends in an appendage. **Fruit:** Ovoid 6–10 cm long and 0.4 – 0.6 cm wide, and the hypocotyl is clavate of 8–13 cm long. (Appendix 2)



Figure 80: *Ceriops decandra* A) Plant habit B) Leaves C) Flowers

4.1.4.2.7.6 *Ceriops tagal* (Figure 4.71)

Genus : *Ceriops*

Scientific name : *Ceriops tagal* (Perr.) C. B. Rob.

Vernacular name : Tengar (Malay)

Plant description:

Plant: Tree, up to 10 – 12 m tall. **Root:** Stilt-like pneumatophore. **Leaf:** Simple, 5.5 - 8.5 cm long, 3.0 – 5.5 cm wide, entire, often have inwardly curled margin, opposite-decussate, elliptic-oblong, apex rounded, base cuneate, petiole 1.0 – 2.0 cm, adaxial dark green, abaxial light green, glossy, glabrous and leathery. **Flower:** Petals white, turns brown when ages, calyx lobes 5, erect in flower. **Fruit:** Brown in colour, calyx lobes recurved in fruits, hypocotyl up to 26.5 cm, slightly ridged, angular. (Appendix 2)



Figure 81: *Ceriops tagal* A-B) Plant habit

4.1.4.2.7.7 *Kandelia candel* (Figure 4.72)

Genus : *Kandelia*

Scientific name : *Kandelia candel* (L.) Druce

Vernacular name : Berus berus, Pisang pisang (Malay)

Plant description:

A small shrub or tree growing to 7m tall. No buttresses or pneumatophores. **Bark** smooth, greyish or reddish brown. **Leaves** elliptic with 11.0 – 12.5 cm of long, 3.6 – 4.0 cm of wide, petiole 1.6 – 2.0 cm, entire margin, apex acute, base cuneate, glossy, arranged opposite one another. Leaf stalks sometimes pinkish. Stipules flattened but slightly twisted at the tip. **Flowers** 1.5-2cm long white, calyx usually with 5-6 slender lobes, in clusters of usually 4 up to 9 flowers. **Propagule** slender and tapered at each end, capped by the persistent sepals whose tips bend backwards to the fruit stalk. (Appendix 2)



Figure 82: *Kandelia candel* A) Plant habit B) Flower C) Fruits

4.1.4.2.7.8 *Rhizophora apiculata* (Figure 4.73)

Genus : *Rhizophora*

Scientific name : *Rhizophora apiculata* Blume.

Vernacular name : Bakau minyak (Malay), Tall-stilt mangrove (Eng.)

Plant description:

Plant: Erect tree, up to 5 – 30 m tall with a trunk that can be 50 cm in diameter. **Root:** Stilt-like pneumatophore, extending up to 5 m up the stem, and occasionally has aerial roots from the branches. Bark is dark grey and chequered. The trunk may be clear for the first 10-12 m. **Leaf:** Simple, 10 – 15.5 cm long, 3.9 – 5.6 cm wide, entire margin, opposite-decussate, elliptic, apex acute, base cuneate, petiole 1.5 – 2.3 cm, adaxial dark green, abaxial light green, glabrous and leathery. They are dark green with a distinct light green zone along the midrib, which is tinged reddish underneath. The leaf stipules is tinged red, 5.0 cm long. **Flower:** Petals cream-coloured, calyx lobes 4, yellow in colour, fleshy, occur in pair, peduncle 0.8 – 1 cm, stalk usually shorter than *R. mucronata*. Flower heads occur in the axils of leaf scars, each bearing two bisexuals. Buds are broadly elliptic and finely fissured. **Fruit:** The oblong to pear-shaped, brown fruits are rough, 2-3.55 cm long, and contain one fertile seed. The cylindrical hypocotyl green with purple, club shaped, up to 28.5 cm. (Appendix 2)



Figure 83: *Rhizophora apiculata* A) Plant habit B) Fruit C) Leaves

4.1.4.2.7.9 *Rhizophora mucronata* (Figure 4.74)

Genus : *Rhizophora*

Scientific name : *Rhizophora mucronata* Lamk,

Vernacular name : Bakau kurap (Malay), Mangrove tree (Eng.)

Plant description:

Plant: Erect tree, up to 10 – 27 m tall trunk up to 70 cm in diameter with a dark, almost black bark that is horizontally fissured. **Root:** Stilt-like pneumatophore **Leaf:** Simple, 13.5 - 17.7 cm long, 5.8 – 9.5 cm wide, entire margin, opposite, broadly elliptic, apex acute, base cuneate, petiole 2.5 – 4.0 cm, adaxial dark green, abaxial light green with tiny black dots, glabrous and leathery. The leaf stipules is green, 7.5 cm long. **Flower:** Petals cream-coloured, hairy, calyx lobes 4, yellow, fleshy, occur in 2 – 5 flowers in a stalk, peduncle 3 cm, pedicel 2 cm, usually longer than *R. apiculata*. The buds are widest near the base and have two 2-lobed leaflets near the base. The four white petals have densely hairy margins, are sparsely hairy on the back. There are eight stemless stamens. **Fruit:** The dull, brownish-green fruit is elongated to egg-shaped, often rough at the base, single seeded. The cylindrical is rough and warty, 36-64 cm long and up to 2 cm wide. (Appendix 2)



Figure 84: *Rhizophora mucronata* A) Plant habit B) Leaves
C) Flower D) Fruits

4.1.4.2.8 Family Rubiaceae

4.1.4.2.8.1 *Scyphiphora hydrophyllacea* (Figure 4.75)

Genus : *Scyphiphora*

Scientific name : *Scyphiphora hydrophyllacea* Gaertn.

Vernacular name : Cengham (Malay)

Plant description:

Plant: Erect, evergreen, often much-branched shrub or small tree, up to 3 m tall, with rough, brown bark, resinous young shoots. **Root:** Prop-root in larger tree. **Leaf:** Simple, 2.5 – 7.0 cm long, 1.6 – 4.5 cm wide, entire margin, opposite, oval to obovate, apex rounded, base attenuate to narrowly cuneate, petiole 1.3 – 2.5 cm, reddish in colour, adaxial green, shiny, abaxial light green, leaf glabrous, glossy. The glandular leaflets at the base of the leaf stalk form a hairy sheath. **Flower:** The bisexual, almost stemless, usually white flowers occur in dense clusters in leaf axils on stalks that measure up to 15 mm. The calyx tube is coiled and 5 mm long; the end of the tube is cup-shaped, and crowned by four-minute teeth. The cylindrical corolla tube is sometimes tinged with red, 2-4 mm long, with a rough-hairy mouth, broadly elliptic petals. **Fruit:** cylindrical, green and ribbed along its length, appearing 6-8 angular, corky inside, 8 mm long, and tipped with the remnants of the calyx. It does not open when ripe. Fruits contain four cylindrical seeds with 6 – 8 ridges, green in colour, turns brown when mature. (Appendix 2)



Figure 85: *Scyphiphora hydrophyllacea* A) Leaves B) Flowers

4.2 LEAF ANATOMY FOR SELECTED SPECIES

4.2.1 Anatomical Characteristic of Margin, Lamina, Petiole and Midrib

4.2.1.1 *Acrostichum aureum*

a) Leaf Lamina (Figure 4.76)

Cuticle layer: one thick layer, presence at the adaxial and abaxial surface. **Epidermal cells:** one layer with ratio oh height: width 1:1. **Hypodermal cells:** two layers underneath epidermis. **Chlorenchyma cells: palisade mesophyll;** two layers of palisade mesophyll cells present equal to 1/2 of leaf thickness, **spongy mesophyll;** 3 – 4 layers of spongy mesophyll cells, aerenchyma cells present in between spongy mesophyll cells. **Vascular tissues: primary vascular bundle;** prominent, flat on the adaxial and abaxial epidermis. **Bundle sheath extension:** presence in the laminar region. **Sclerenchyma cells:** presence around the vascular bundle sheath. **Collenchyma cells:** absence. **Trichome:** absence.

b) Leaf marginal (Figure 4.76)

Outline of leaf marginal: rounded with U-shaped outline, recurved 45° towards abaxial epidermis, the size decreasing gradually towards edge of margin. **Hypodermal cells:** presence. **Mesophyll palisade:** absence. **Vascular tissues:** presence at the edge of margin. **Sclerenchyma cells:** absence. **Collenchyma cells:** a cluster of collenchyma cells presence at the edge of the margin.

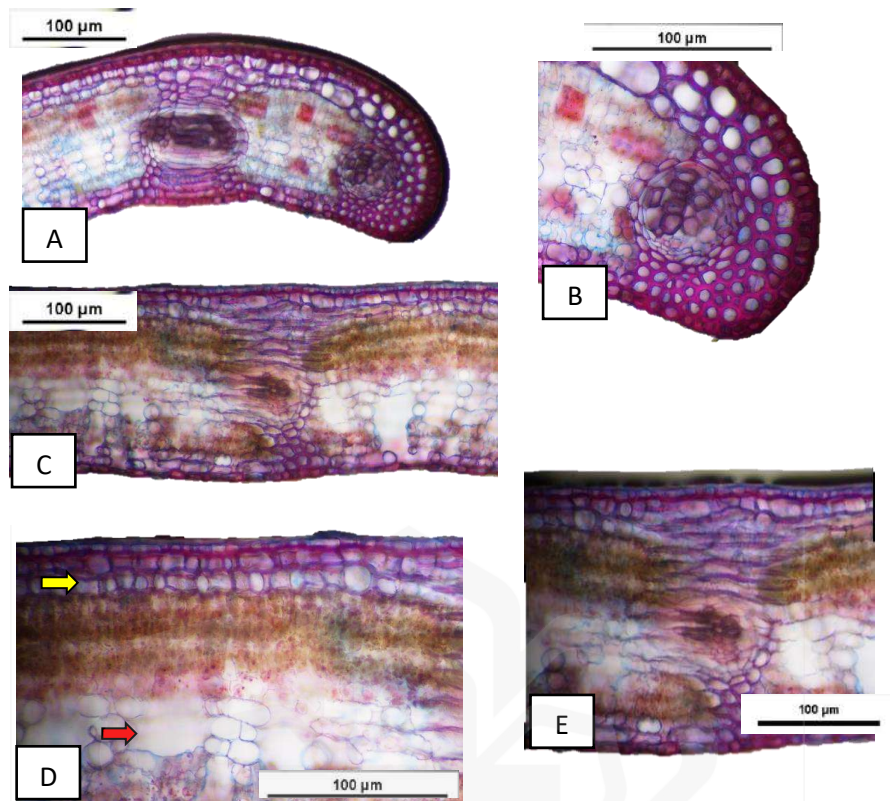


Figure 86: *Acrostichum aureum*: A) marginal leaf. B) edge of leaf marginal. C) cross section of lamina. D) hypodermal cells (yellow arrow), spongy mesophyll with aerenchyma (red arrow). E) bundle sheath extension

c) Leaf Petiole (Figure 4.77)

Petiole outline: adaxial surface (*ad*) slightly concave, abaxial surface (*ab*) U-shaped. **Epidermal cells:** one layer with ratio height: width 1:1. **Vascular tissues:** Closed type, hydrocentric, 19 vascular bundle scattered within the ground tissue, largest vascular tissue at the upper central region, size reduced towards the hypodermis, presence of endodermis around vascular bundle. **Sclerenchyma cells:** presence around the vascular bundle sheath. **Mucilage cells:** present at parenchyma cortex. **Cell inclusion:** absence. **Idioblast tannins:** absence. **Outer parenchyma:** presence. **Collenchyma cells:** ca. 4 – 6 layers of cells presence underneath the epidermis. **Intercellular space:** presence at parenchyma cortex. **Trichome:** simple, unicellular trichomes, short, pointed end.



Figure 87: *Acrostichum aureum*: A) overall view of petiole cross-section. B) vascular bundle of petiole and endodermis cells (red arrow). C) mucilage cells at parenchyma cortex (yellow arrow). D) mucilage cells at epidermis (yellow arrow). E) simple trichome.

d) Leaf Midrib (Figure 4.78)

Midrib outline: adaxial surface (*ad*) flat, abaxial surface (*ab*) U-shaped. **Vascular tissues:** closed type, hydrocentric, 8 vascular bundle scattered within the ground tissue. **Sclerenchyma cells:** presence around the vascular bundle sheath. **Epidermal cells:** one layer with ratio height: width 1:1. **Cell inclusion:** absence. **Mucilage cells:** present at parenchyma cortex. **Outer parenchyma:** presence. **Collenchyma cells:** ca. 3 – 5 layers underneath the epidermis. **Trichomes:** absence.

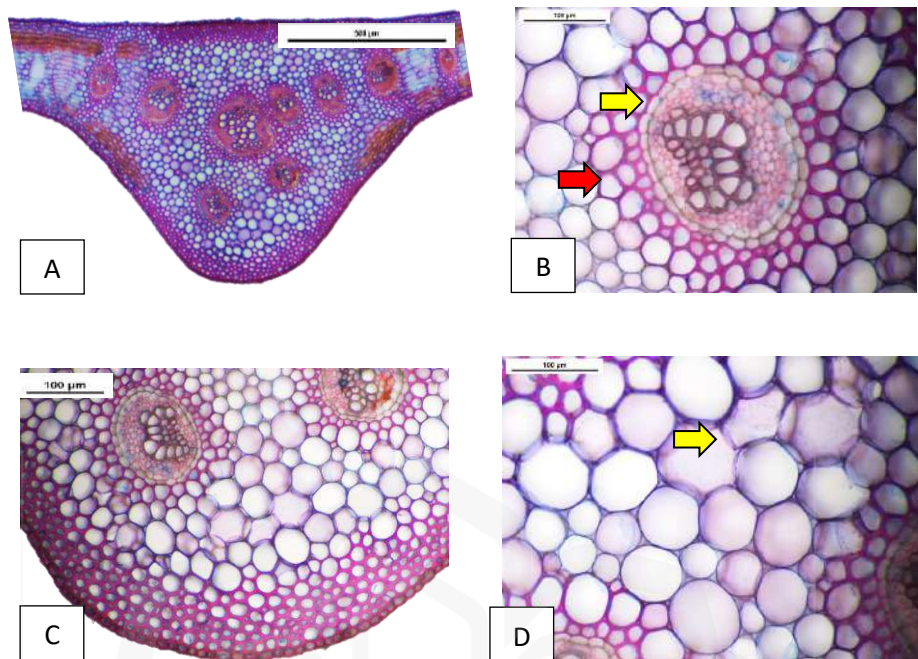


Figure 88: *Acrostichum aureum*: A) overall view of midrib cross-section. B) vascular bundle of midrib and endodermis cells (red arrow), fibre of sclereid (red arrow). C) abaxial of leaf midrib. D) mucilage cells at parenchyma cortex (yellow arrow).

4.2.1.2 *Acrostichum speciosum*

a) Leaf Lamina (Figure 4.79)

Cuticle layer: one thick layer, presence at the adaxial and abaxial surface. **Epidermal cells:** one layer with ratio of height: width 1:1. **Hypodermal cells:** two layers underneath epidermis. **Chlorenchyma cells: palisade mesophyll;** two layers of palisade mesophyll cells present equal to 1/2 of leaf thickness, **spongy mesophyll;** 3 – 4 layers of spongy mesophyll cells, aerenchyma cells present in between spongy mesophyll cells. **Vascular tissues: primary vascular bundle;** prominent, flat on the adaxial and abaxial epidermis. **Bundle sheath extension:** presence in the laminar region. **Sclerenchyma cells:** presence around the vascular bundle sheath. **Trichome:** absence.

b) Leaf marginal (Figure 4.79)

Outline of leaf marginal: pointed with U-shaped outline, recurved 45° towards abaxial epidermis, the size decreasing gradually towards edge of margin. **Hypodermal cells:** presence. **Mesophyll palisade:** absence. **Vascular tissues:** presence at the edge of margin. **Sclerenchyma cells:** absence. **Collenchyma cells:** a cluster of collenchyma cells presence at the edge of the margin.

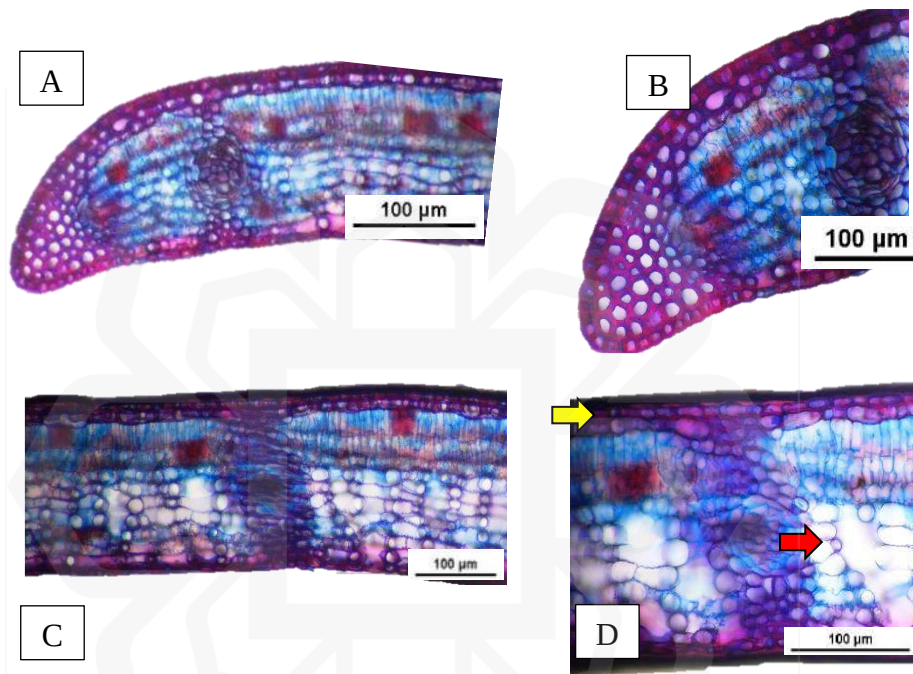


Figure 89: *Acrostichum speciosum* A) marginal leaf. B) edge of marginal leaf. C) leaf lamina. D) hypodermal cells (yellow arrow), spongy mesophyll with aerenchyma (red arrow).

c) Leaf Petiole (Figure 4.80)

Petiole outline: adaxial surface (*ad*) flat, abaxial surface (*ab*) wide U-shaped. **Epidermal cells:** one layer with ratio height: width 1:1. **Vascular tissues:** Closed type, hydrocentric, 54 vascular bundle scattered within the ground tissue, largest vascular tissue at the upper central region, size reduced towards the hypodermis, presence of endodermis around vascular bundle. **Mucilage cells:** present at parenchyma cortex. **Sclerenchyma cells:** presence around the vascular bundle sheath. **Cell inclusion:** absence. **Idioblast tannins:** absence. **Outer parenchyma:** presence. **Collenchyma cells:** ca. 3 – 7 layers of cells presence underneath the epidermis. **Intercellular space:** presence at parenchyma cortex. **Trichome:** absence

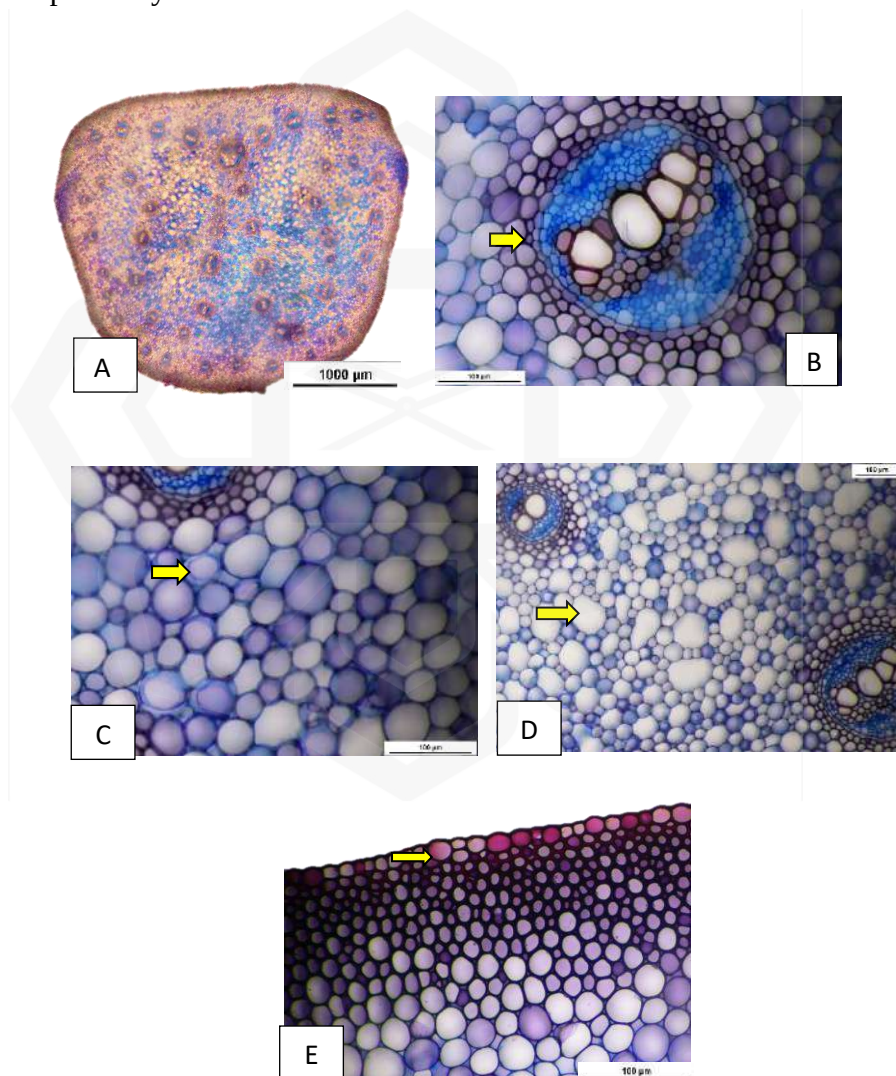


Figure 90: *Acrostichum speciosum* A) overall view of petiole cross-section. B) vascular bundle of petiole, endodermis cells (yellow arrow). C) mucilage cell at parenchyma cortex. D) intercellular space (yellow arrow). E) epidermal cells.

d) Leaf Midrib (Figure 4.81)

Midrib outline: adaxial surface (*ad*) V-shaped, abaxial surface (*ab*) U-shaped. **Epidermal cells:** one layer with ratio height: width 1:1. **Vascular tissues:** closed type, hydrocentric, 7 vascular bundle scattered within the ground tissue. **Sclerenchyma cells:** presence around the vascular bundle sheath. **Cell inclusion:** absence. **Mucilage cells:** present at parenchyma cortex. **Outer parenchyma:** presence. **Collenchyma cells:** ca. 4 – 6 layers underneath the epidermis. **Trichomes:** absence.

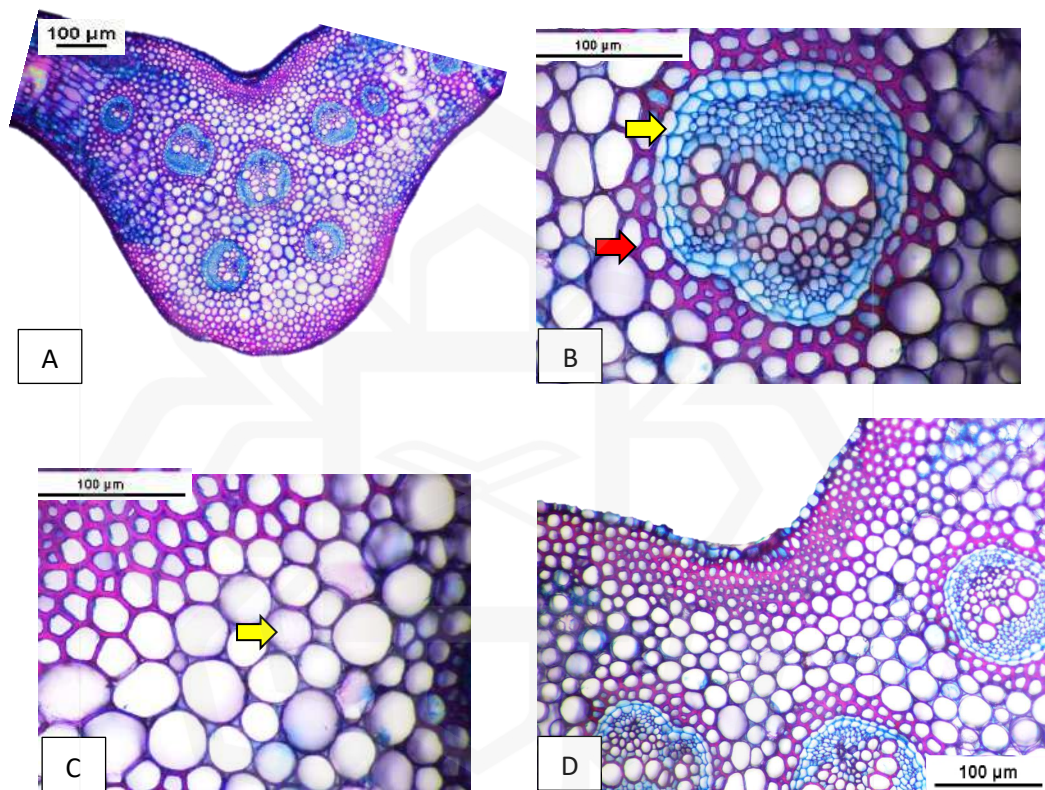


Figure 91: *Acrostichum speciosum* A) overall view of midrib cross-section. B) vascular bundle of midrib, endodermis cells (yellow arrow), fibre of sclereid (red arrow). C) mucilage cell at parenchyma cortex. D) adaxial surface of midrib.

4.2.1.3 *Nypa fruticans*

a) Leaf Lamina (Figure 4.82)

Cuticle layer: one thick layer, presence at the adaxial and abaxial surface. **Epidermal cells:** one layer with ratio of height: width 1:1. **Hypodermal cells:** two layers underneath epidermis. **Chlorenchyma cells: palisade mesophyll;** two layers of palisade mesophyll cells present equal to 1/2 of leaf thickness, **spongy mesophyll;** 3 – 4 layers of spongy mesophyll cells, aerenchyma cells present in between spongy mesophyll cells. **Mucilage cells:** absence. **Cell inclusion:** absence. **Vascular tissues: primary vascular bundle;** prominent, flat on the adaxial and abaxial epidermis, **secondary vascular bundle;** prominent, flat on abaxial and adaxial, simple vascular bundle. **Bundle sheath extension:** presence in the laminar region. **Sclerenchyma cells:** presence around the vascular bundle sheath, presence of fibre of sclerotic sheath in laminar region. **Collenchyma cells:** absence. **Trichome:** absence.

b) Leaf marginal (Figure 4.82)

Outline of leaf marginal: pointed with V-shaped outline, recurved 45° towards abaxial epidermis, the size decreasing gradually towards edge of margin. **Hypodermal cells:** presence. **Mesophyll palisade:** absence. **Vascular tissues:** presence at the edge of margin. **Sclerenchyma cells:** fibre of sclerotic sheath presence at the edge of margin. **Collenchyma cells:** a cluster of collenchyma cells presence at the edge of the margin.

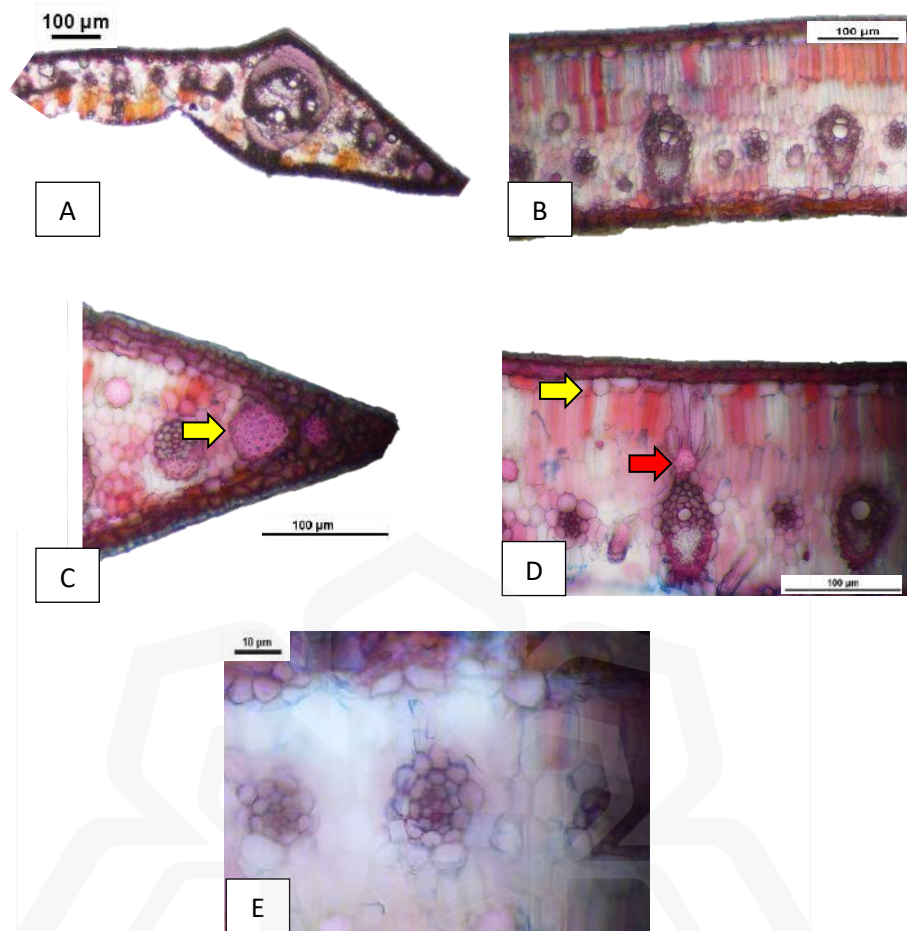


Figure 92: *Nypa frusticans* A) leaf marginal. B) margin edge, fibre of sclereid (yellow arrow), collenchyma cells (red arrow). C) leaf lamina. D) hypodermal cells (yellow arrow), fibre of sclereid (red arrow). E) secondary vascular bundle.

c) Leaf Midrib (Figure 4.83)

Midrib outline: rhombus. **Vascular tissues:** closed type, hydrocentric, 22 vascular bundle scattered within the ground tissue. **Epidermal cells:** one layer with ratio of height: width 1:2. **Cell inclusion:** absence. **Mucilage cells:** present at parenchyma cortex. **Outer parenchyma:** presence. **Sclerenchyma cells:** presence at ground tissues surrounded the vascular bundle. **Collenchyma cells:** ca. 3 – 5 layers underneath the epidermis. **Trichomes:** absence.

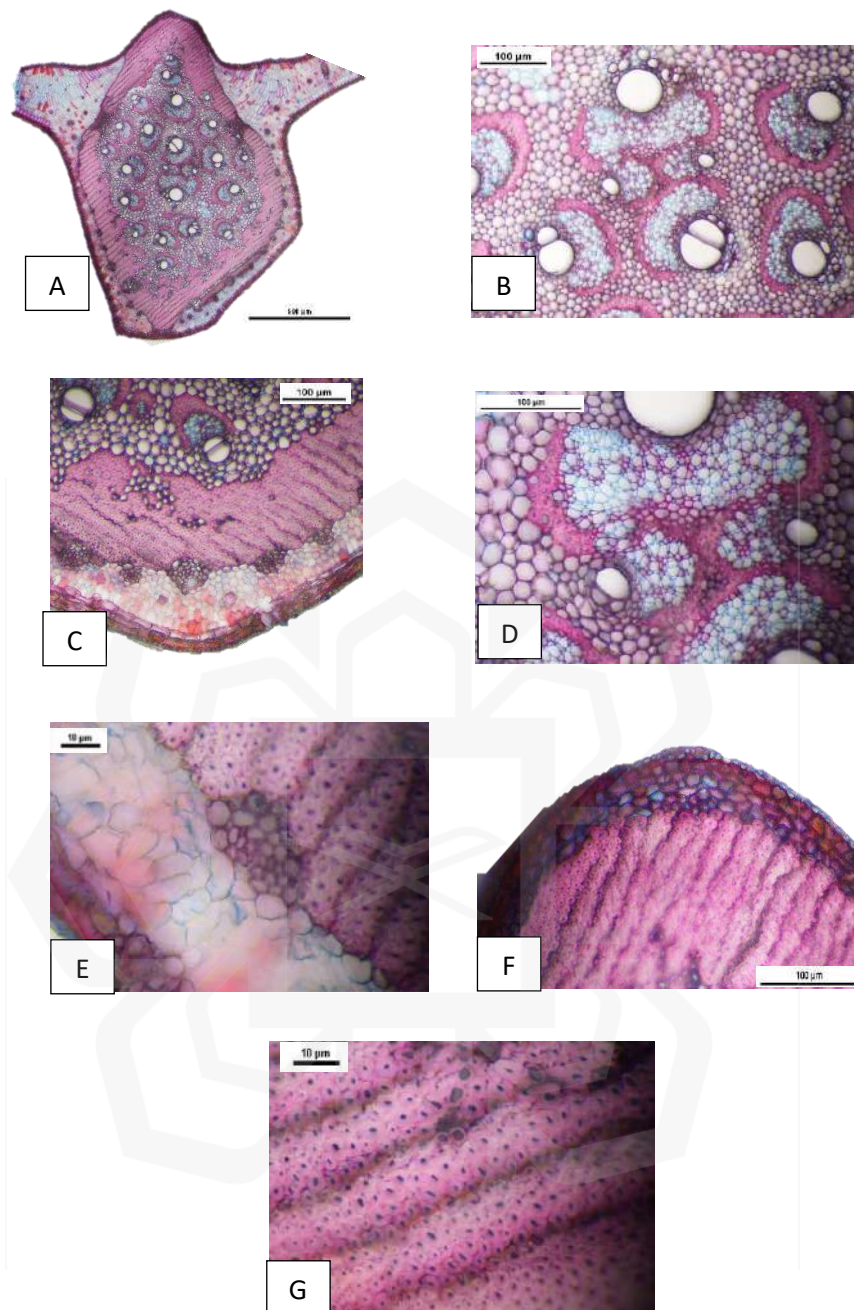


Figure 93: *Nypa fruticans* A) overall view of midrib cross-section. B – C) vascular bundle of midrib. D – E) epidermis of midrib. F) adaxial of midrib. G) fibre of sclereid.

4.2.1.4 *Pandanus tectorius*

a) Leaf Lamina (Figure 4.84)

Cuticle layer: one thick layer, presence at the adaxial and abaxial surface. **Epidermal cells:** one layer with ratio of height: width 1:1. **Hypodermal cells:** three layers underneath adaxial epidermis. **Chlorenchyma cells:** **palisade mesophyll;** two layers of palisade mesophyll cells present equal to 1/3 of leaf thickness, **spongy mesophyll;** 3 – 4 layers of spongy mesophyll cells, aerenchyma cells present in between spongy mesophyll cells. **Cell inclusion:** absence. **Vascular tissues:** **primary vascular bundle;** prominent, flat on the adaxial and abaxial epidermis. **Bundle sheath extension:** presence in the laminar region. **Sclerenchyma cells:** presence around the vascular bundle sheath. **Trichome:** absence.

b) Leaf marginal (Figure 4.84)

Outline of leaf marginal: pointed with U-shaped outline, slightly recurved towards abaxial epidermis, the size decreasing gradually towards edge of margin. **Hypodermal cells:** presence. **Mesophyll palisade:** absence. **Vascular tissues:** presence at the edge of margin. **Sclerenchyma cells:** presence around the vascular bundle sheath. **Collenchyma cells:** a cluster of collenchyma cells presence at the edge of the margin.

c) Leaf Midrib (Figure 4.85)

Midrib outline: adaxial surface (*ad*) concave, abaxial surface (*ab*) narrow V-shaped. **Epidermal cells:** one layer with ratio height: width 1:1. **Parenchyma cortex:** 4 – 5 layers of mesophyll palisade at adaxial epidermis. **Vascular tissues:** closed type, hydrocentric, 7 vascular bundle scattered within the ground tissue. **Cell inclusion:** absence. **Mucilage cells:** present at parenchyma cortex. **Outer parenchyma:** presence. **Sclerenchyma cells:** presence around the vascular bundle. **Collenchyma cells:** ca. 3 – 5 layers underneath the epidermis. **Trichomes:** absence.

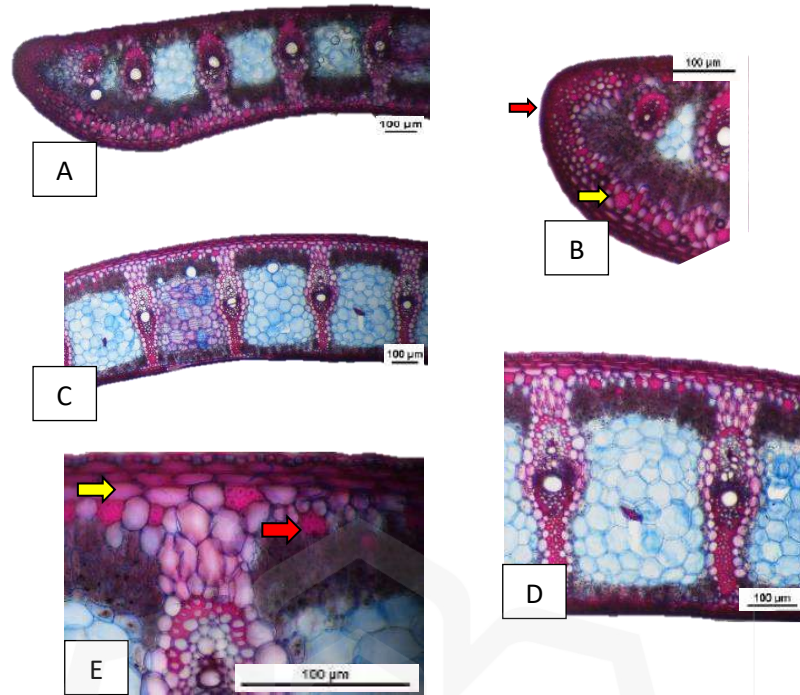


Figure 94: *Pandanus tectorius* A) leaf marginal B) edge of margin, fibre of sclereid (yellow arrow), chlorenchyma cells (red arrow). C) leaf lamina. D) bundle sheath extension E) hypodermal cells (yellow arrow), fibre of sclereid (red arrow).

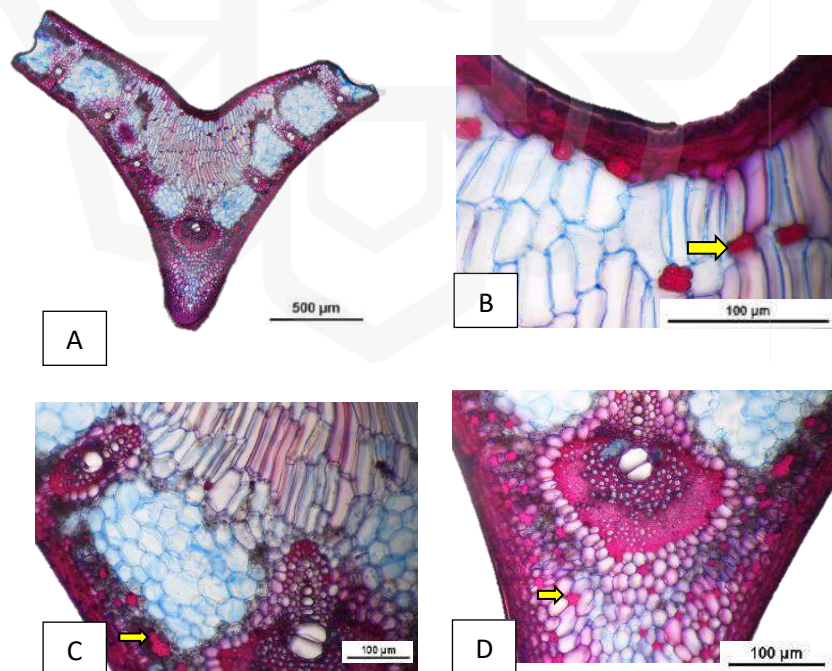


Figure 95: *Pandanus tectorius* A) overall view of midrib cross-section. B) mesophyll palisade at adaxial surface of midrib, fibre of sclereid (yellow arrow). C) vascular bundle at side of midrib, fibre of sclereid (yellow arrow). D) vascular bundle at abaxial of midrib, fibre of sclereid (yellow arrow).

4.2.1.5 *Acanthus ilicifolius*

a) Leaf Lamina (figure 4.86)

Cuticle layers: one thick layer, presence at adaxial and abaxial surface. **Epidermal cells:** one layer with ratio height: width 1:1. **Hypodermal cells:** a single layer underneath the adaxial epidermis. **Chlorenchyma cells: palisade mesophyll;** three layers of palisade mesophyll cells equal to 1/2 of leaf thickness, **spongy mesophyll;** 3 – 4 layers of spongy mesophyll cells, aerenchyma cells present in between spongy mesophyll cells. **Vascular tissues: primary vascular bundle:** prominent, flat on the adaxial and abaxial surface. **Sclerenchyma cells:** sclereid sheath presence around the vascular bundle. **Mucilage cells:** absence.

b) Leaf Marginal (Figure 4.86)

Outline leaf margin: rounded with U-shaped, straight towards the end of margin, the size remains the same at the end of margin. **Hypodermal cells:** presence. **Mesophyll palisade:** absence. **Vascular tissues:** presence at the edge of margin. **Sclerenchyma cells:** absence. **Collenchyma cells:** absence

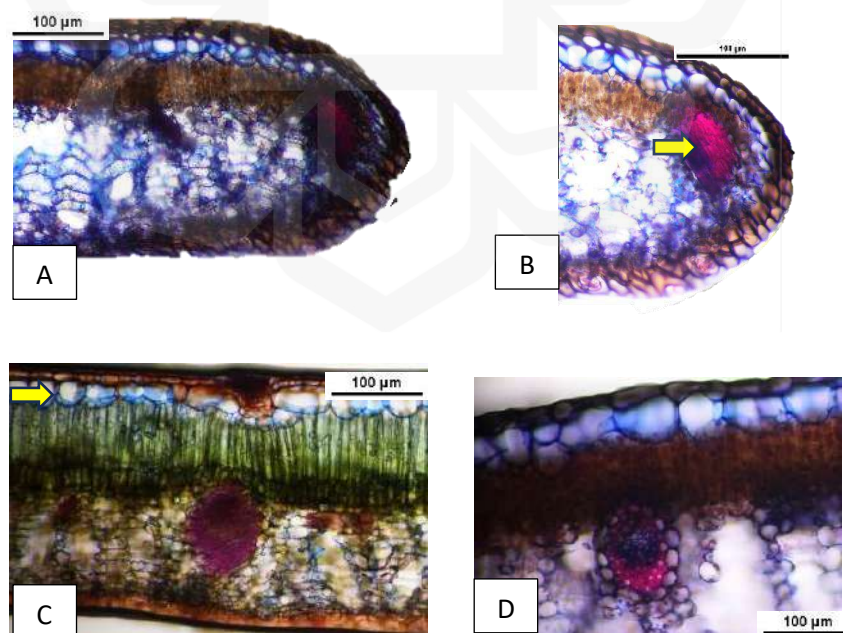


Figure 96: *Acanthus ilicifolius* A) leaf marginal B) edge of leaf marginal, vascular tissues (yellow arrow) C - D) leaf lamina, hypodermal cell (yellow arrow)

c) Leaf Petiole (Figure 4.87)

Outline petiole: adaxial surface (*ad*) slightly convex, abaxial surface (*ab*) U-shaped.

Epidermal cells: one layer with ratio height: width 1:1. **Vascular tissues:** main vascular bundle (opened type with O-shaped non-continuous ring of vascular bundle, collateral); additional vascular bundle on adaxial (open system with four continuous rings of vascular bundle). **Cell inclusion:** absence. **Mucilage cells:** presence at vascular tissues and parenchyma cortex. **Idioblast tannin:** absence. **Outer parenchyma:** ca. 6 – 14 layers or parenchyma cortex. **Collenchyma cells:** ca. 4 – 7 layers of angular collenchyma cells presence underneath epidermis. **Intercellular space:** presence

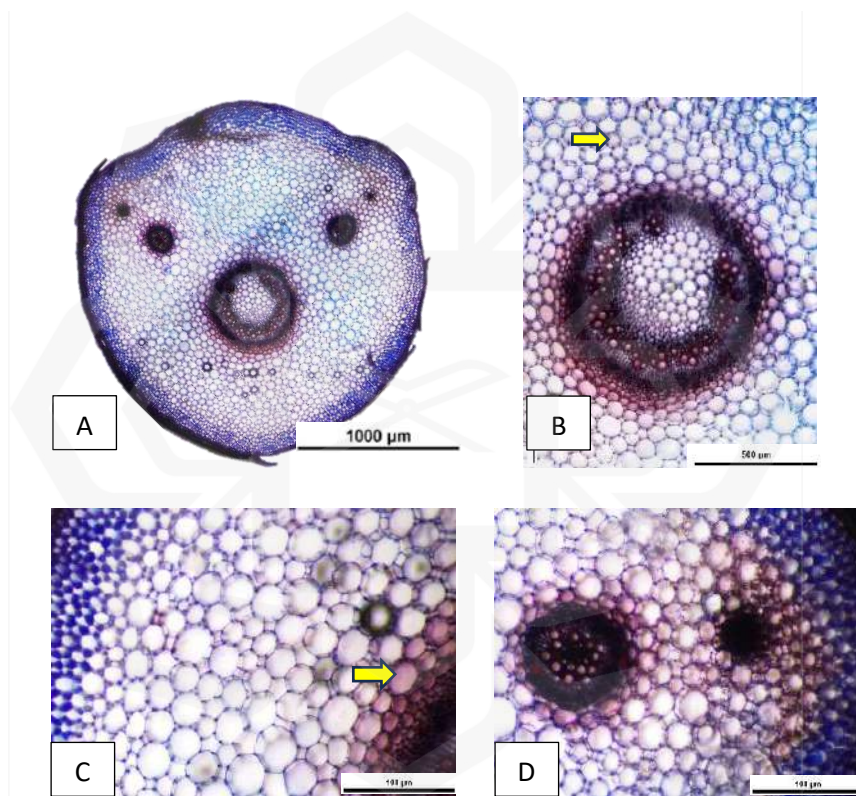


Figure 97: *Acanthus ilicifolius* A) overall view of petiole cross-section. B) main vascular bundle, mucilage cell (yellow arrow). C) parenchyma cortex of petiole, mucilage cell (yellow arrow). D) additional vascular bundle at adaxial

d) Leaf Midrib (Figure 4.88)

Outline midrib: adaxial surface (*ad*) convex, abaxial surface (*ab*) rounded U-shaped. Epidermal cells: one layer with ratio height: width 1:1. **Vascular tissues:** main vascular bundle (closed system with non-continuous ring of vascular bundle, O-shaped, collateral); additional vascular bundle on adaxial (closed system with two non-continuous rings of vascular bundle). **Cell inclusions:** absence. **Mucilage cells / canal:** mucilage cells; presence at parenchyma cortex, mucilage canal; presence at the pith parenchyma. **Outer parenchyma:** ca. 6 – 9 layers of parenchyma cortex. **Collenchyma cells:** ca. 3 – 5 layers of angular collenchyma cells presence under epidermis cells. **Sclerenchyma cells:** presence at the vascular bundle.

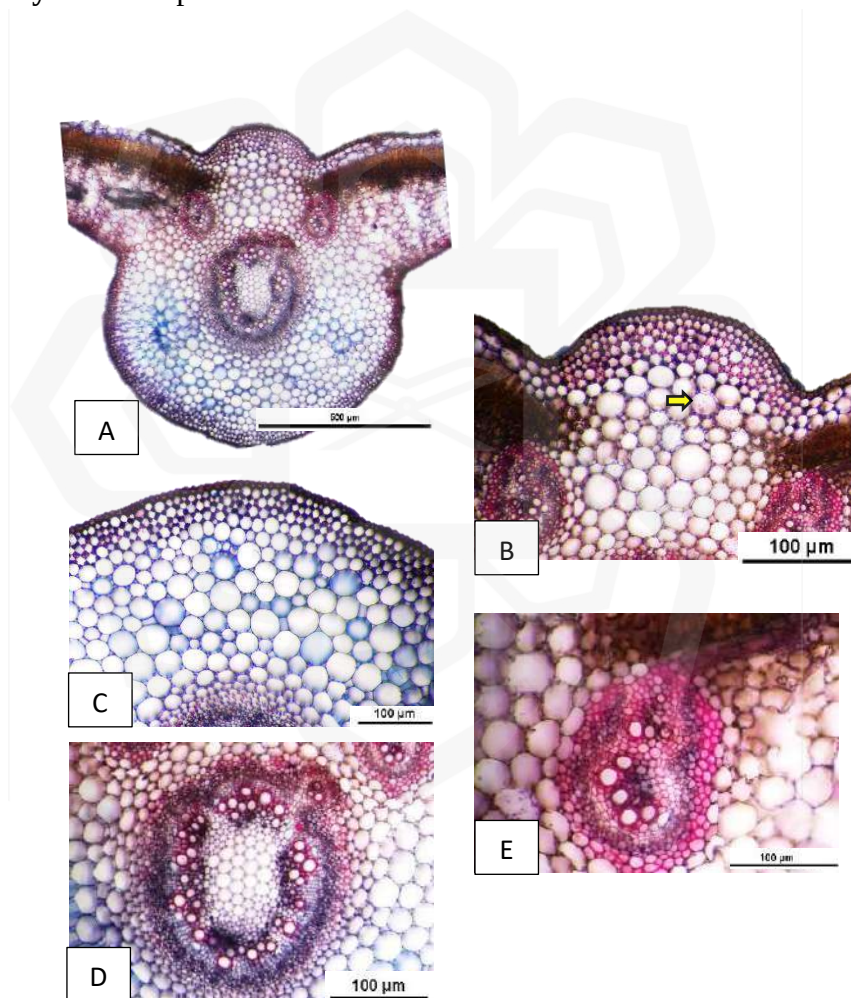


Figure 98: *Acanthus ilicifolius* A) overall view of midrib cross-section. B) adaxial of midrib, mucilage cell (yellow arrow). C) parenchyma cortex and collenchyma cell at abaxial of midrib. D) main vascular bundle. E) additional vascular bundle at adaxial.

4.2.1.6 *Lumnitzera littorea*

a) Leaf Lamina (Figure 4.89)

Cuticle layers: one thick layer, presence at adaxial and abaxial surface. **Epidermal cells:** one layer with ratio height: width 1:1. **Hypodermal cells:** one layer of hypodermal cell underneath the adaxial and abaxial epidermis. **Chlorenchyma cells:** **palisade mesophyll;** two layers of palisade mesophyll cells equal to 1/2 of leaf thickness, **spongy mesophyll;** 3 – 4 layers of spongy mesophyll cells, aerenchyma cells present in between spongy mesophyll cells. **Vascular tissues:** **primary vascular bundle:** prominent, flat on the adaxial and abaxial surface. **Sclerenchyma cells:** absence. **Cell inclusions:** presence of druse in mesophyll palisade. **Mucilage cells:** absence.

b) Leaf Marginal (Figure 4.89)

Outline leaf margin: rounded with U-shaped, recurved 45° towards abaxial epidermis, the size decreasing gradually towards edge of margin. **Hypodermal cells:** one layer of hypodermal cells presence underneath adaxial and abaxial epidermis. **Mesophyll palisade:** absence. **Vascular tissues:** presence at the edge of margin. **Sclerenchyma cells:** absence. **Collenchyma cells:** absence

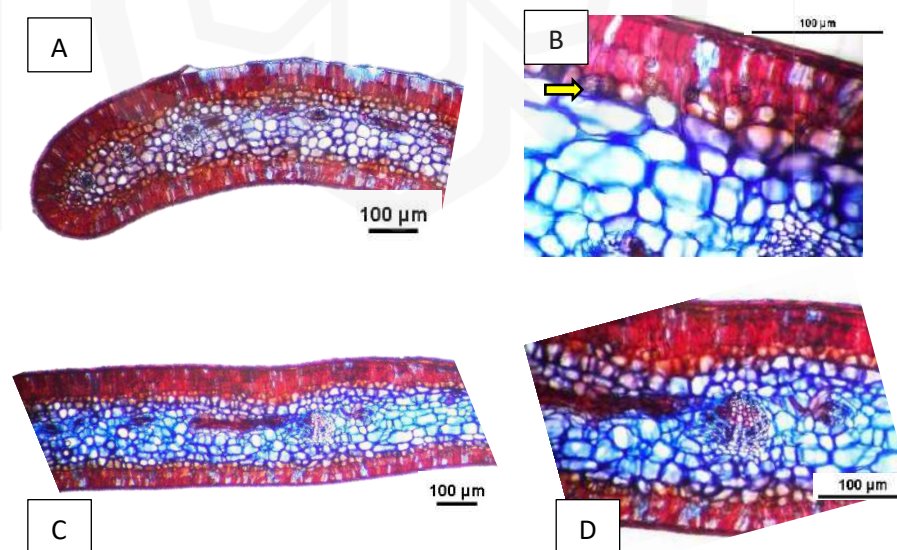


Figure 99: *Lumnitzera littorea* A) marginal leaf. B) druse (yellow arrow) at mesophyll palisade in lamina. C – D) leaf lamina

c) Leaf Petiole (Figure 4.90)

Outline petiole: adaxial surface (*ad*) convex, abaxial surface (*ab*) U-shaped. **Epidermal cells:** one layer with ratio height: width 1:1. **Vascular tissues:** main vascular bundle (opened type with crescentic continuous ring of vascular bundle, collateral); additional vascular bundle on adaxial (open system with five continuous rings of vascular bundle). **Cell inclusion:** presence of druse in parenchyma cortex. **Mucilage cells:** presence. **Idioblast tannin:** presence around vascular bundle. **Outer parenchyma:** ca. 10 – 15 layers or parenchyma cortex. **Collenchyma cells:** ca. 2 – 4 layers of cells presence underneath epidermis. **Intercellular space:** presence at parenchyma cortex.

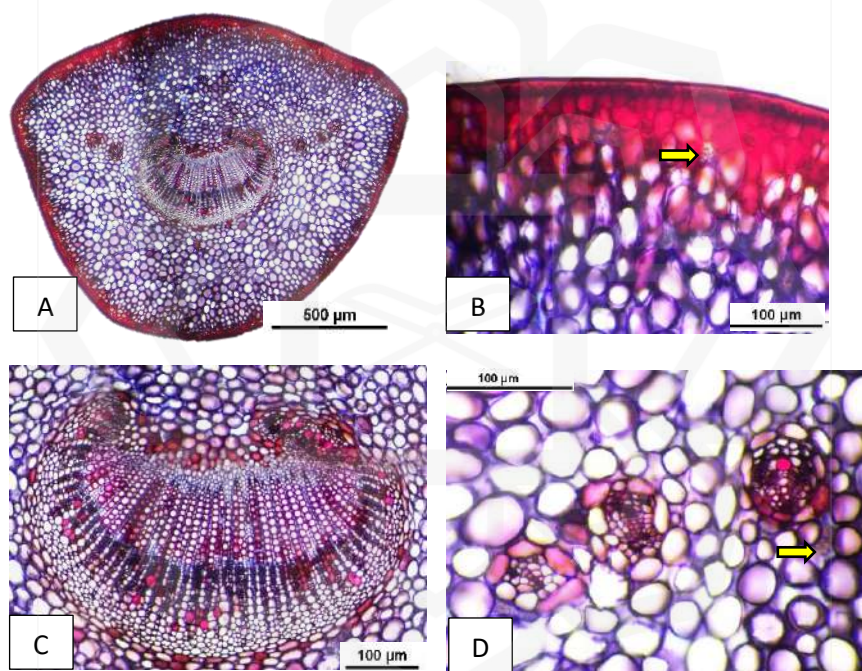


Figure 100: *Lumnitzeria littorea* A) overall view of petiole cross section. B) druse (yellow arrow). C) main vascular bundle. D) additional vascular bundle, druse (yellow arrow) in parenchyma cortex

d) Leaf Midrib (Figure 4.91)

Outline midrib: adaxial surface (*ad*) flat, abaxial surface (*ab*) wide V-shaped.

Epidermal cells: one layer with ratio height: width 1:1, presence of two layers mesophyll palisade on under adaxial epidermis.

Vascular tissues: main vascular bundle (open type with crescent shaped continuous ring of vascular bundle, collateral); additional vascular bundle on adaxial (open system with six continuous rings of vascular bundle).

Cell inclusions: presence of druse at mesophyll palisade.

Mucilage cells: presence.

Outer parenchyma: ca. 5 – 10 layers of parenchyma cortex.

Collenchyma cells: ca. 3 – 4 layers of cells underneath epidermis.

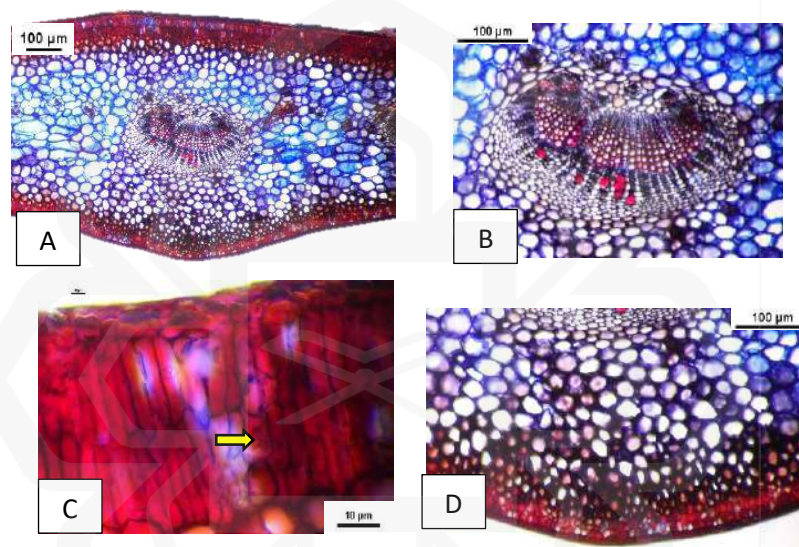


Figure 101: *Lumnitzera littorea* A) overall view of midrib cross section. B) main vascular bundle. C) druse (yellow arrow) at mesophyll palisade layers. D). parenchyma cortex and collenchyma cell of abaxial midrib

4.2.1.7 *Lumnitzera racemosa*

a) Leaf Lamina (Figure 4.92)

Cuticle layers: one thick layer, presence at adaxial and abaxial surface. **Epidermal cells:** one layer with ratio height: width 1:1. **Hypodermal cells:** presence. **Chlorenchyma cells: palisade mesophyll;** two layers of palisade mesophyll cells equal to 1/3 of leaf thickness, **spongy mesophyll;** 3 – 4 layers of spongy mesophyll cells, aerenchyma cells present in between spongy mesophyll cells. **Vascular tissues: primary vascular bundle:** prominent, flat on the adaxial and abaxial surface. **Sclerenchyma cells:** absence. **Cell inclusions:** presence of druse in mesophyll palisade. **Mucilage cells:** absence.

b) Leaf Marginal (Figure 4.92)

Outline leaf margin: rounded with U-shaped, recurved 30° towards abaxial epidermis, the size decreasing gradually towards edge of margin. **Hypodermal cells:** presence. **Mesophyll palisade:** absence. **Vascular tissues:** presence at the edge of margin. **Sclerenchyma cells:** absence. **Collenchyma cells:** absence

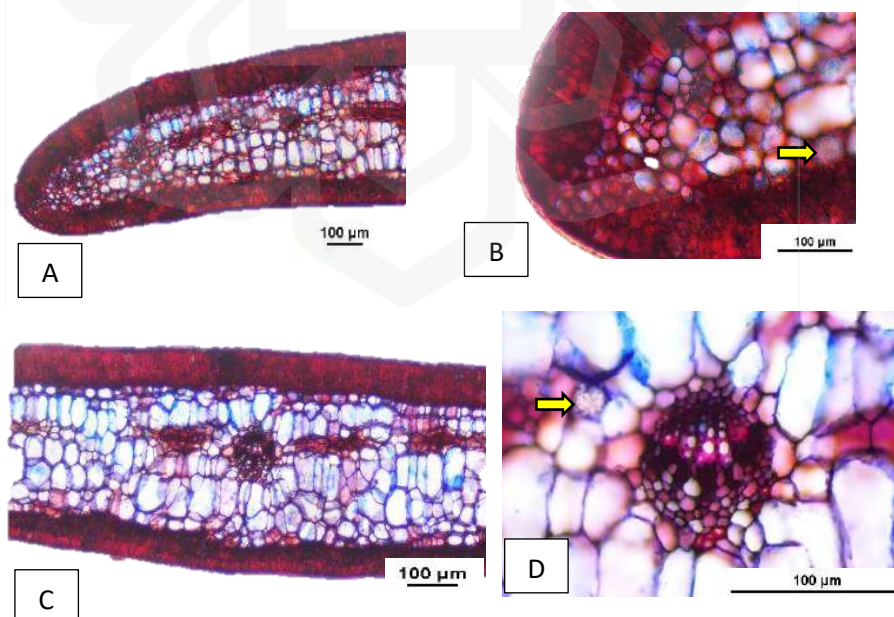


Figure 102: *Lumnitzera racemosa* A) marginal leaf. B) presence of druse (yellow arrow) at edge of margin C) leaf lamina. D) vascular bundle, druse (yellow arrow).

c) Leaf Petiole (Figure 4.93)

Outline petiole: adaxial surface (*ad*) convex, abaxial surface (*ab*) U-shaped. **Epidermal cells:** one layer with ratio height: width 1:1. **Vascular tissues:** main vascular bundle (opened type with crescentic continuous ring of vascular bundle, collateral); additional vascular bundle on adaxial (open system with four continuous rings of vascular bundle). **Cell inclusion:** presence of druse in parenchyma cortex and vascular bundle. **Mucilage cells:** presence. **Idioblast tannin:** absence. **Outer parenchyma:** ca. 9 – 13 layers or parenchyma cortex. **Collenchyma cells:** ca. 2 – 4 layers of cells presence underneath epidermis. **Intercellular space:** presence at parenchyma cortex.



Figure 103: *Lumnitzera racemosa* A) overall view of petiole cross section. B) main vascular bundle. C) parenchyma cortex and collenchyma cell of abaxial petiole. D) druse (yellow arrow), mucilage cells (red arrow).

d) Leaf Midrib (Figure 4.94)

Outline midrib: adaxial surface (*ad*) flat, abaxial surface (*ab*) wide V-shaped.

Epidermal cells: one layer with ratio height: width 1:1, presence of two layers mesophyll palisade on under adaxial epidermis. **Vascular tissues:** main vascular bundle (open type with crescent shaped continuous ring of vascular bundle, collateral); additional vascular bundle (open system with four continuous rings of vascular bundle).

Cell inclusions: presence of druses at parenchyma cortex. **Mucilage cells:** presence at parenchyma cortex. **Outer parenchyma:** ca. 3 – 7 layers of parenchyma cortex.

Collenchyma cells: ca. 3 – 5 layers of cells underneath epidermis.

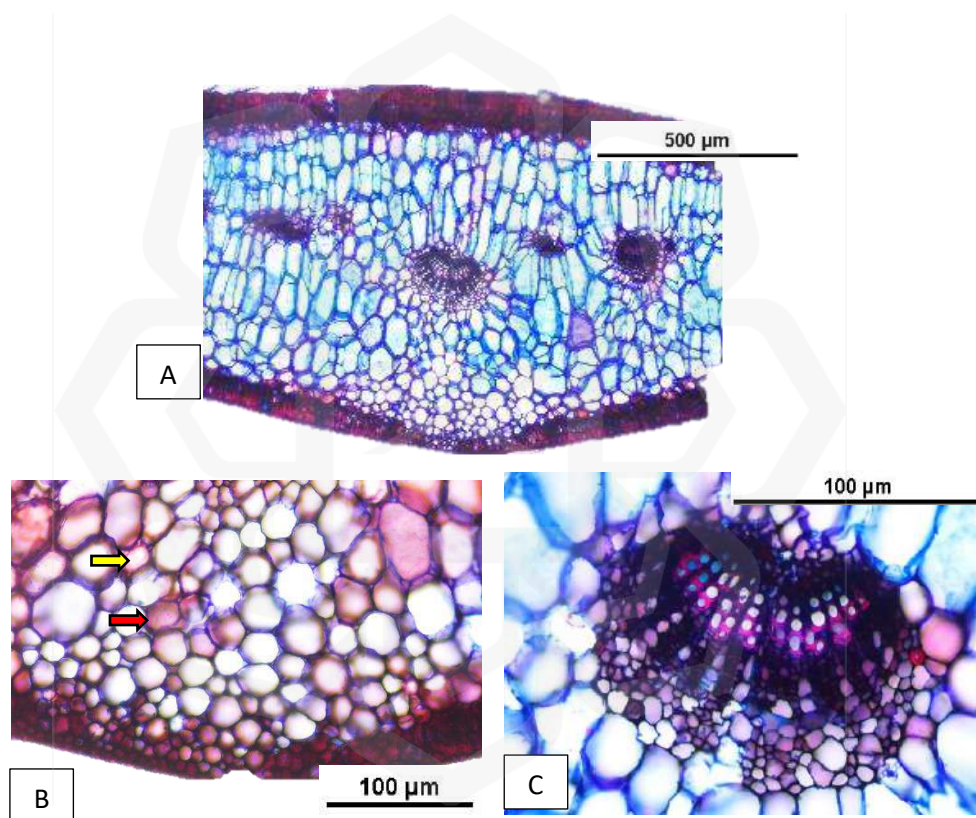


Figure 104: *Lumnitzera racemosa* A) overall view of midrib cross section. B) druse (yellow arrow), mucilage cell (red arrow). C) main vascular bundle.

4.2.1.8 *Pekan* accession

a) Leaf Lamina (Figure 4.95)

Cuticle layers: one thick layer, presence at adaxial and abaxial surface. **Epidermal cells:** one layer with ratio height: width 1:1. **Hypodermal cells:** two layers of hypodermal cell underneath the adaxial epidermis. **Chlorenchyma cells:** **palisade mesophyll;** two layers of palisade mesophyll cells equal to 1/2 of leaf thickness, **spongy mesophyll;** 3 – 4 layers of spongy mesophyll cells, aerenchyma cells present in between spongy mesophyll cells. **Vascular tissues:** **primary vascular bundle:** prominent, flat on the adaxial and abaxial surface. **Sclerenchyma cells:** absence. **Cell inclusions:** presence of druse. **Mucilage cells:** presence

b) Leaf Marginal (Figure 4.95)

Outline leaf margin: rounded with U-shaped, straight towards the edge, the size remains the same towards edge of margin. **Hypodermal cells:** presence. **Mesophyll palisade:** presence. **Vascular tissues:** presence at the edge of margin. **Sclerenchyma cells:** absence. **Collenchyma cells:** absence

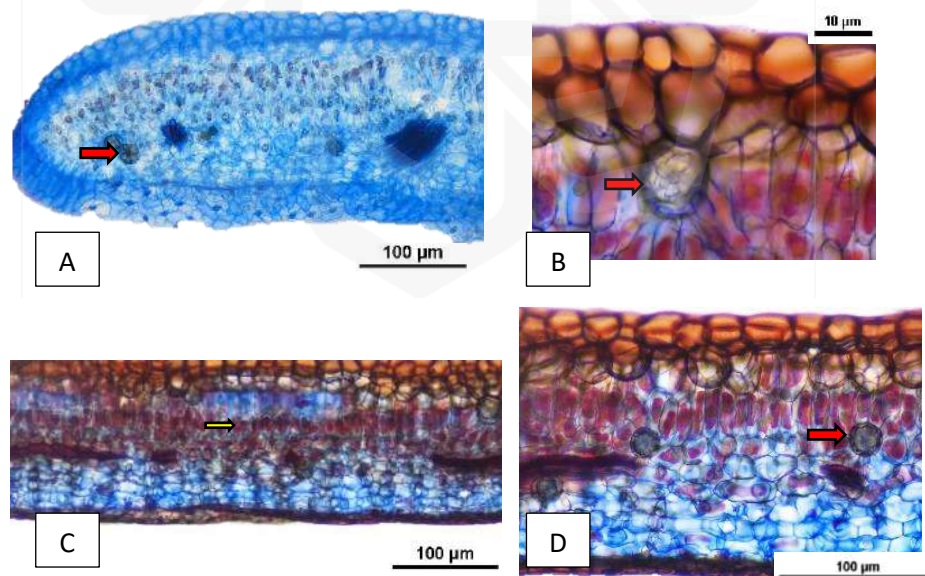


Figure 105: *Pekan* accession A) marginal leaf. B) druse (red arrow) in lamina. C – D) leaf lamina, druse (red arrow)

c) Leaf Petiole (Figure 4.96)

Outline petiole: adaxial surface (*ad*) V-shaped, abaxial surface (*ab*) wide U-shaped. **Epidermal cells:** one layer with ration height: width 1:1. **Vascular tissues:** main vascular bundle (opened type with U-shaped continuous ring of vascular bundle, bicollateral); additional vascular bundle on adaxial (open system with four continuous rings of vascular bundle). **Cell inclusion:** presence of druse in parenchyma cortex. **Mucilage cells:** presence at the parenchyma cortex. **Idioblast tannin:** absence. **Outer parenchyma:** ca. 5 – 10 layers or parenchyma cortex. **Collenchyma cells:** ca. 3 – 5 layers of cells presence underneath epidermis. **Intercellular space:** presence at parenchyma cortex.

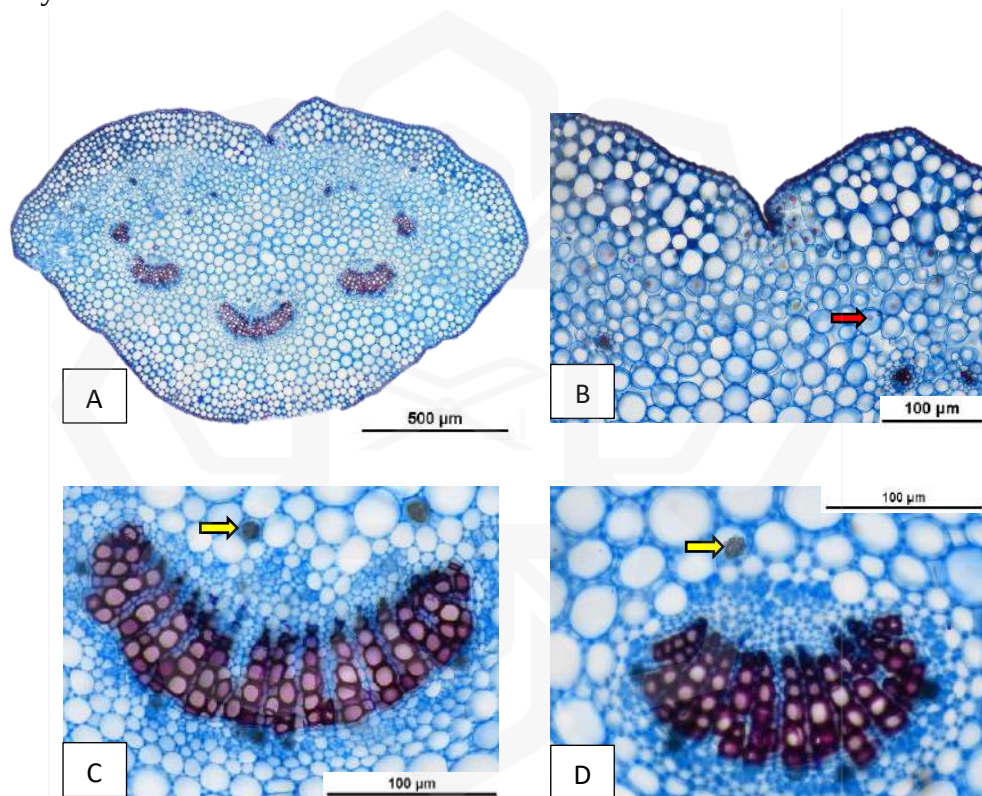


Figure 106: *Pekan accession* A) overall vie of petiole cross section. B) mucilage cell (red arrow) in parenchyma cortex. C) main vascular bundle, druse (yellow arrow). D) additional vascular bundle at adaxial, druse (yellow arrow)

d) Leaf Midrib (Figure 4.97)

Outline midrib: adaxial surface (*ad*) flat with slightly concave, abaxial surface (*ab*) U-shaped. **Epidermal cells:** one layer with ratio height: width 1:1. **Vascular tissues:** main vascular bundle (open type with U-shaped continuous ring of vascular bundle, bicollateral). **Cell inclusions:** presence of druse in parenchyma cortex and vascular bundle. **Mucilage cells:** presence. **Outer parenchyma:** ca. 5 – 7 layers of parenchyma cortex. **Collenchyma cells:** ca. 2 – 4 layers of cells underneath epidermis.

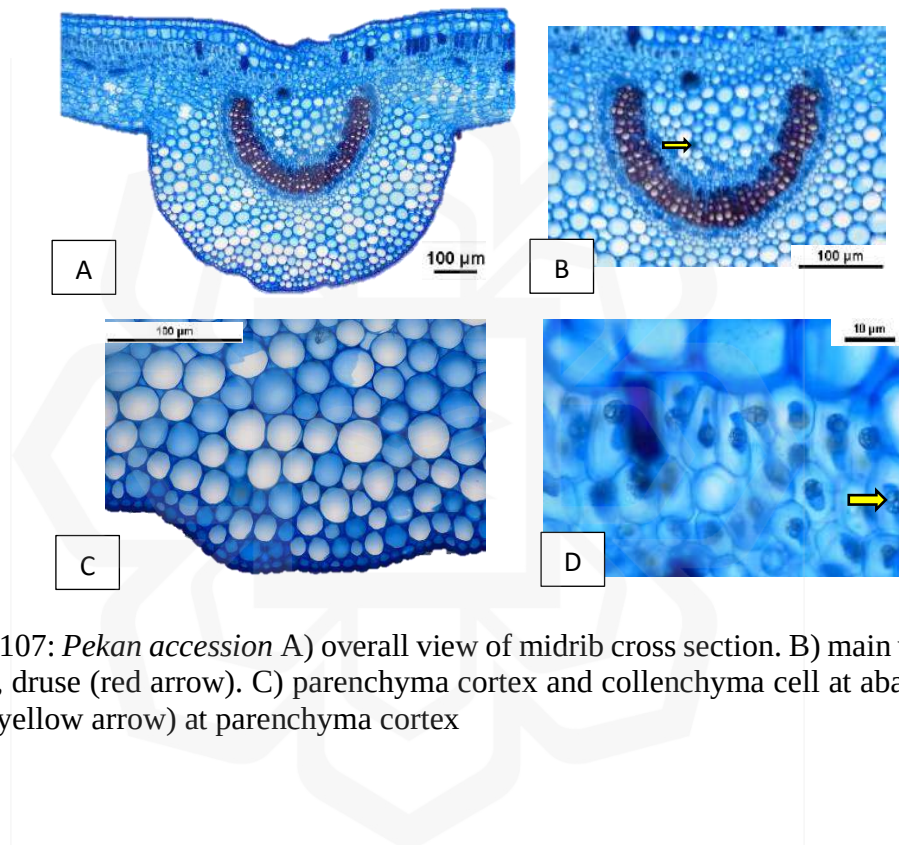


Figure 107: *Pekán* accession A) overall view of midrib cross section. B) main vascular bundle, druse (red arrow). C) parenchyma cortex and collenchyma cell at abaxial. D) druse (yellow arrow) at parenchyma cortex

4.2.1.9 *Sonneratia alba*

a) Leaf Lamina (Figure 4.98)

Cuticle layers: one thick layer, presence at adaxial and abaxial surface. **Epidermal cells:** one layer with ratio height: width 2:1. **Hypodermal cells:** one layer of hypodermal cell underneath the adaxial and abaxial epidermis. **Chlorenchyma cells:** **palisade mesophyll;** two layers of palisade mesophyll on adaxial, three layers of mesophyll palisade on abaxial cells equal to 1/2 of leaf thickness, **spongy mesophyll;** 3 – 4 layers of spongy mesophyll cells, aerenchyma cells present in between spongy mesophyll cells. **Vascular tissues:** **primary vascular bundle:** prominent, flat on the adaxial and abaxial surface. **Sclerenchyma cells:** absence. **Cell inclusions:** presence of druse in mesophyll palisade and spongy mesophyll. **Mucilage cells:** presence.

b) Leaf Marginal (Figure 4.98)

Outline leaf margin: rounded with U-shaped, straight towards the edge of margin, the size remains the same towards edge of margin. **Hypodermal cells:** presence. **Mesophyll palisade:** absence. **Vascular tissues:** presence at the edge of margin. **Sclerenchyma cells:** absence. **Collenchyma cells:** absence

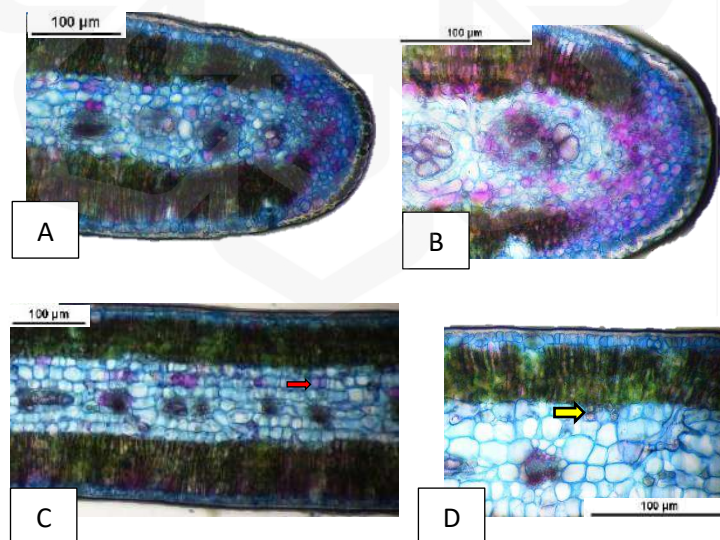


Figure 108: *Sonneratia alba* A – B) marginal leaf. C) leaf lamina, mucilage cell (red arrow) D) druse (yellow arrow) at leaf lamina

c) Leaf Petiole (Figure 4.99)

Outline petiole: rounded. **Epidermal cells:** one layer with ratio height: width 1:2. **Vascular tissues:** main vascular bundle (closed type with oval shaped non-continuous ring of vascular bundle, bicollateral). **Cell inclusion:** absence. **Mucilage cells:** presence at the parenchyma cortex. **Idioblast tannin:** absence. **Outer parenchyma:** ca. 18 – 22 layers or parenchyma cortex. **Collenchyma cells:** ca. 3 – 5 layers of cells presence underneath epidermis. **Intercellular space:** presence at parenchyma cortex.

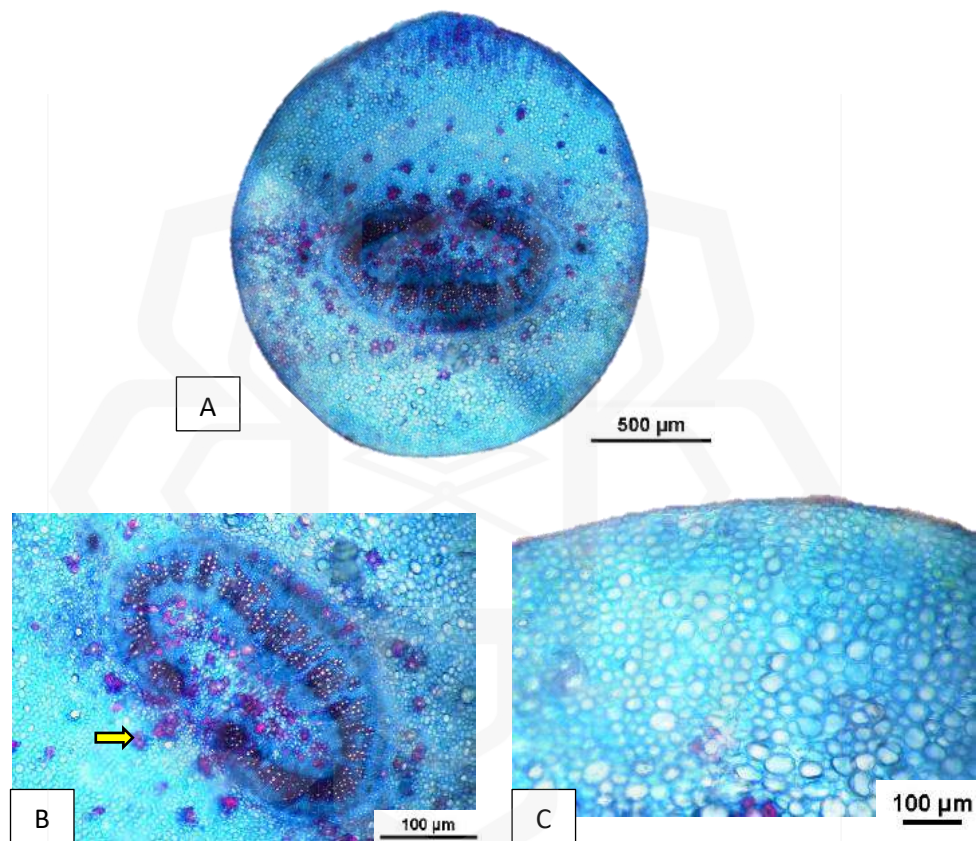


Figure 109: *Sonneratia alba* A) overall view of petiole cross section. B) main vascular bundle, mucilage cell (yellow arrow). C) parenchyma cortex of petiole

d) Leaf Midrib (Figure 4.100)

Outline midrib: adaxial surface (*ad*) convex, abaxial surface (*ab*) wide U-shaped. **Epidermal cells:** one layer with ratio height: width 1:1, presence of two layers mesophyll palisade on under adaxial epidermis. **Vascular tissues:** main vascular bundle (closed type with oval shaped non-continuous ring of vascular bundle, bicollateral). **Cell inclusions:** absence. **Mucilage cells / canal:** mucilage cell; presence at parenchyma cortex, mucilage canal; presence at pith parenchyma. **Outer parenchyma:** ca. 8 – 15 layers of parenchyma cortex. **Collenchyma cells:** ca. 3 – 5 layers of cells underneath epidermis.

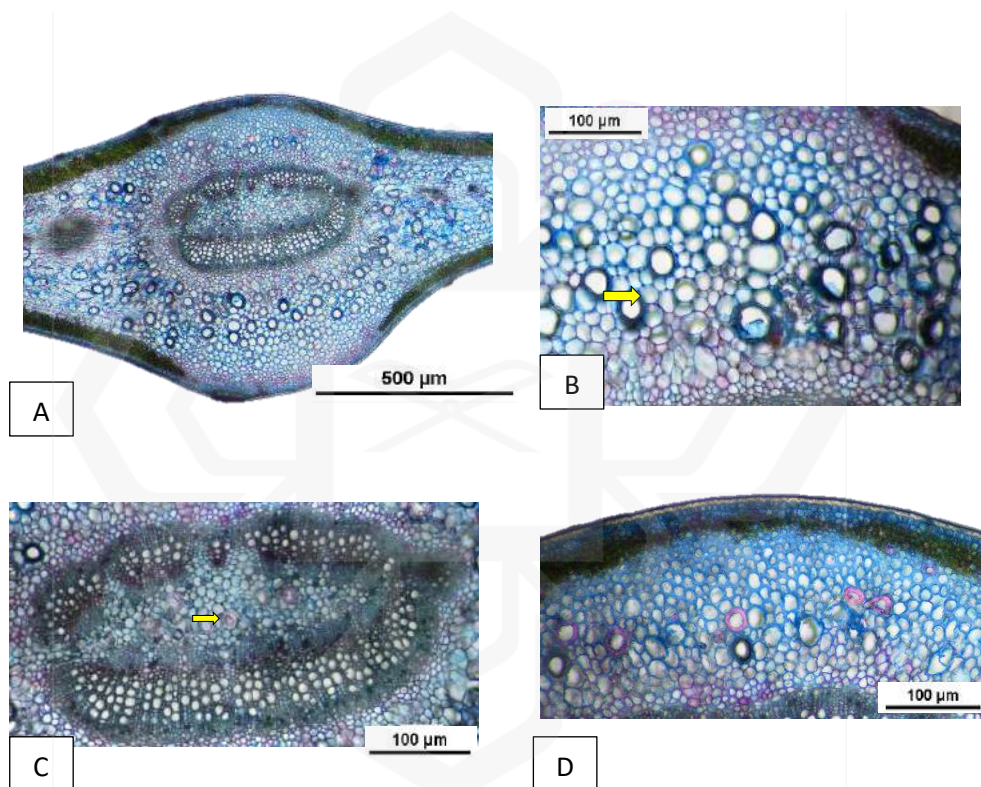


Figure 110: *Sonneratia alba* A) overall view of midrib cross section. B) mucilage cell (yellow arrow) in parenchyma cortex. C) vascular bundle, mucilage canal (red arrow) D) parenchyma cortex of midrib

4.2.1.10 *Sonneratia caseolaris*

a) Leaf Lamina (Figure 4.101)

Cuticle layers: one thick layer, presence at adaxial and abaxial surface. **Epidermal cells:** one layer with ratio height: width 2:1. **Hypodermal cells:** one layer of hypodermal cell underneath the adaxial and abaxial epidermis. **Chlorenchyma cells:** **palisade mesophyll;** three layers of palisade mesophyll cells on both adaxial and abaxial epidermis, size equal to 1/2 of leaf thickness, **spongy mesophyll;** 3 – 4 layers of spongy mesophyll cells, aerenchyma cells present in between spongy mesophyll cells. **Vascular tissues: primary vascular bundle:** prominent, flat on the adaxial and abaxial surface. **Sclerenchyma cells:** absence. **Cell inclusions:** absence. **Mucilage cells:** presence.

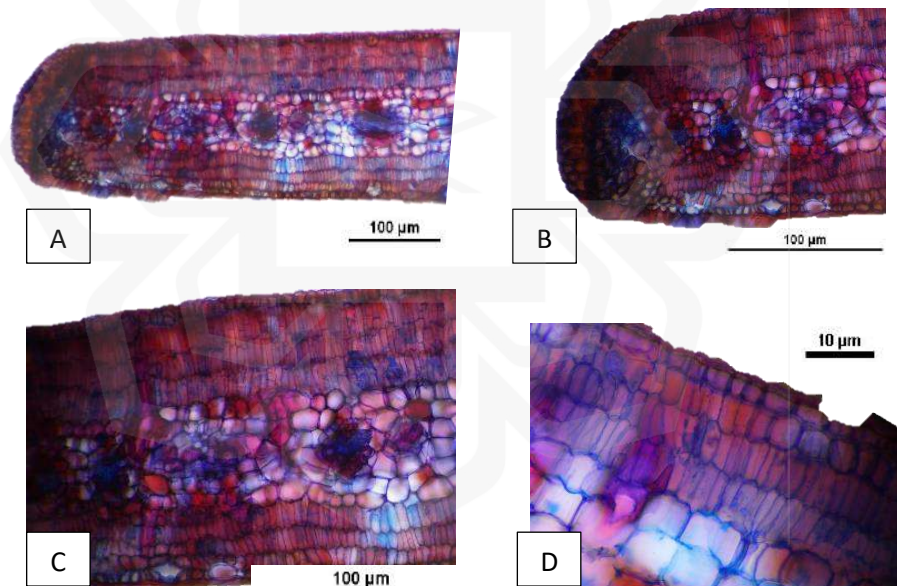


Figure 111: *Sonneratia caseolaris* A – B) marginal leaf. C – D) leaf lamina

b) Leaf Marginal (Figure 4.101)

Outline leaf margin: rounded with U-shaped, straight toward the edge of margin, the size remains the same towards edge of margin. **Hypodermal cells:** presence. **Mesophyll palisade:** absence. **Vascular tissues:** presence at the edge of margin. **Sclerenchyma cells:** absence. **Collenchyma cells:** absence

c) Leaf Midrib (Figure 4.102)

Outline midrib: adaxial surface (*ad*) flat slightly concave towards lamina, abaxial surface (*ab*) wide U-shaped. **Epidermal cells:** one layer with ratio height: width 1:2, presence of three layers mesophyll palisade on under adaxial epidermis. **Vascular tissues:** main vascular bundle (closed type with oval shaped non-continuous ring of vascular bundle, bicollateral). **Cell inclusions:** absence. **Mucilage cells / canal:** mucilage cells; presence at parenchyma cortex, mucilage canal; presence at pith parenchyma. **Outer parenchyma:** ca. 5 – 9 layers of parenchyma cortex. **Collenchyma cells:** ca. 3 – 4 layers of cells underneath epidermis. **Sclerenchyma cells:** presence at the vascular bundle.

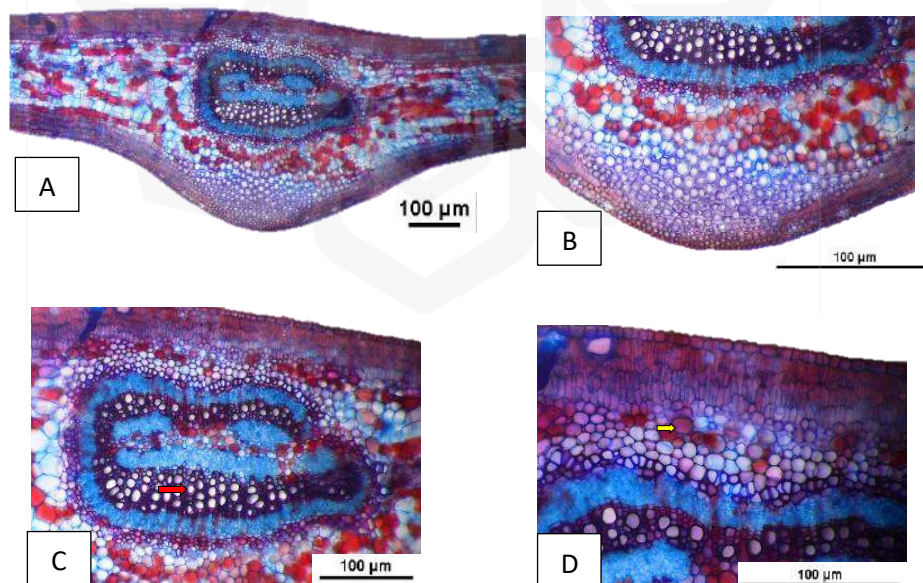


Figure 112: *Sonneratia caseolaris* A) overall view of midrib cross section. B) parenchyma cortex of midrib. C) vascular bundle, mucilage canal (red arrow). D) mucilage cell (yellow arrow) in parenchyma cortex

4.2.2 Anatomical Characteristic of Leaf Epidermis

4.2.2.1 *Acrostichum aureum*

Anticlinal wall of abaxial epidermis: wavy to sinuous. **Anticlinal wall of adaxial epidermis:** sinuous. **Stomata:** hypostomatic (present on abaxial only), densely scattered, paracytic and anomocytic (Figure 4.103).

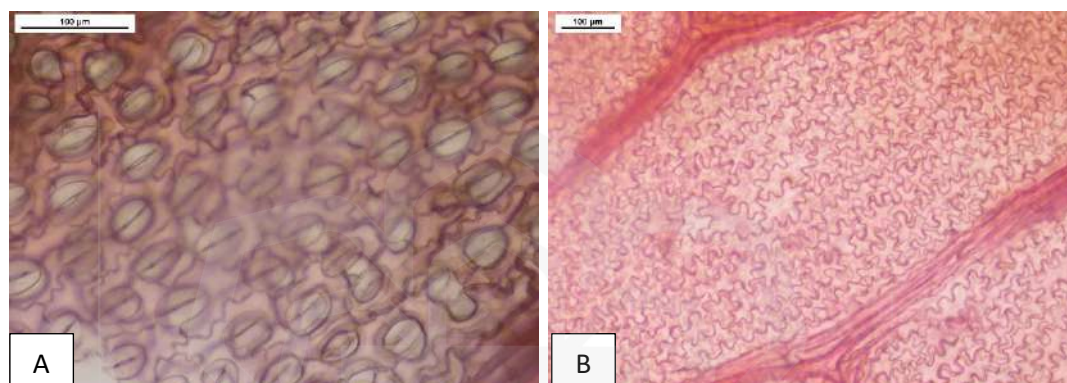


Figure 113: A) Wavy to sinuous anticlinal wall, paracytic and anomocytic stomata on abaxial epidermis. B) Wavy to sinuous anticlinal wall on adaxial epidermis.

4.2.2.2 *Acrostihum speciosom*

Anticlinal wall of abaxial epidermis: wavy to sinuous. **Anticlinal wall of adaxial epidermis:** Sinuous. **Stomata:** hypostomatic (present on abaxial only), densely scattered, anomocytic (Figure 4.104).

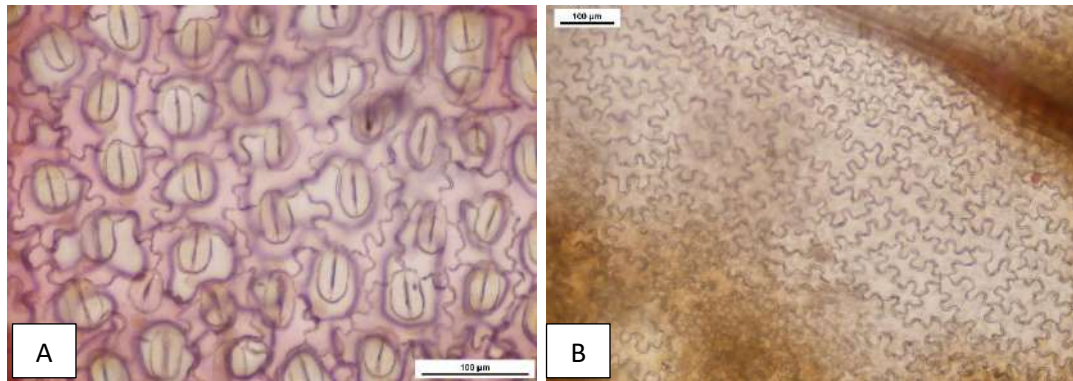


Figure 114: A) Wavy to sinuous anticlinal wall and anomocytic stomata on abaxial epidermis. B) Wavy to sinuous anticlinal wall on adaxial epidermis.

4.2.2.3 *Nypa fruticans*

Anticlinal wall of abaxial epidermis: wavy to sinuous. **Anticlinal wall of adaxial epidermis:** straight to wavy. **Stomata:** hypostomatic (present on abaxial only), densely scattered, paracytic (Figure 4.105).

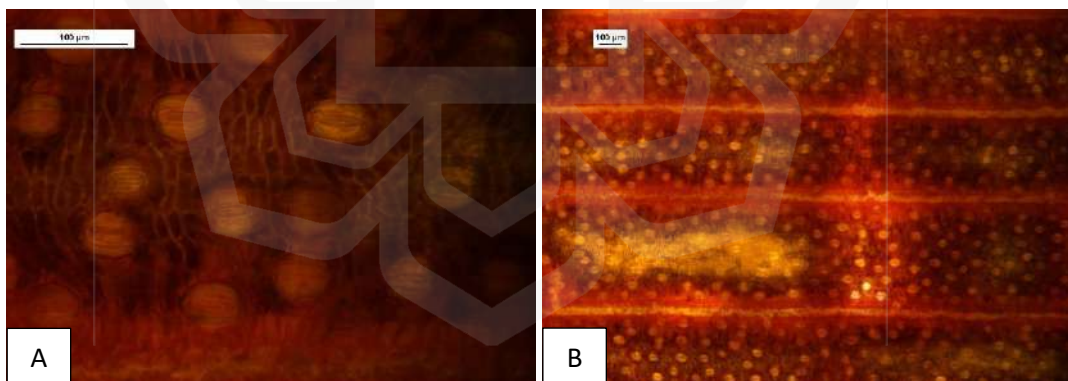


Figure 115: A - B) Straight to wavy anticlinal wall and paracytic stomata on abaxial epidermis.

4.2.2.4 *Pandanus tectorius*

Anticlinal wall of abaxial epidermis: straight to wavy. **Anticlinal wall of adaxial epidermis:** straight to wavy. **Stomata:** hypostomatic (present on abaxial only), densely scattered, paracytic (Figure 4.106).

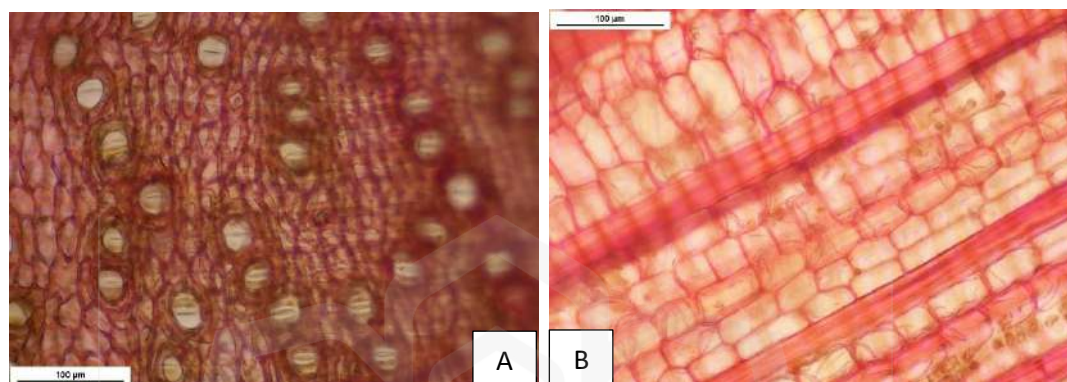


Figure 116: A) Straight to wavy anticlinal wall and paracytic stomata on abaxial epidermis. B) Straight to wavy anticlinal wall on adaxial epidermis.

4.2.2.5 *Acanthus ilicifolius*

Anticlinal wall of abaxial epidermis: straight to wavy. **Anticlinal wall of adaxial epidermis:** straight to wavy. **Stomata:** hypostomatic (present on abaxial only), densely scattered, diacytic (Figure 4.107).

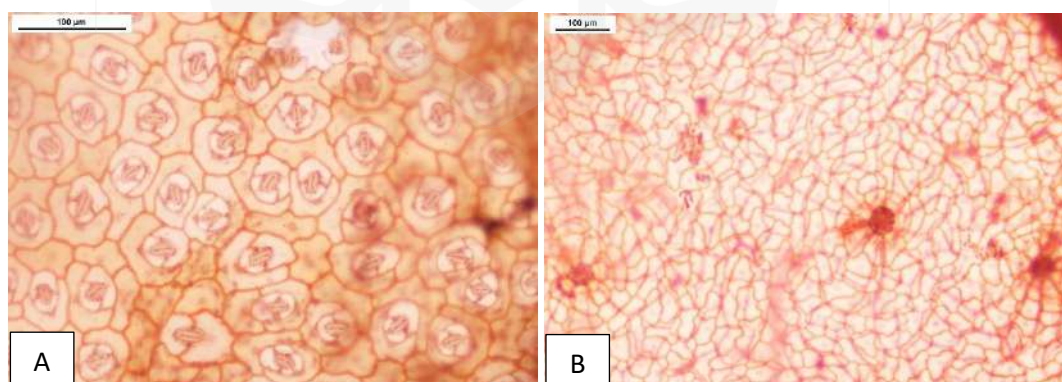


Figure 117: A) Straight to wavy anticlinal wall and diacytic stomata on abaxial epidermis. B) Straight to wavy anticlinal wall on adaxial epidermis.

4.2.2.6 *Lumnitzera littorea*

Anticlinal wall of abaxial epidermis: straight to wavy. **Anticlinal wall of adaxial epidermis:** straight to wavy. **Stomata:** amphistomatic (present on abaxial and adaxial), densely scattered, anisocytic and tetracytic stomata (Figure 4.108).

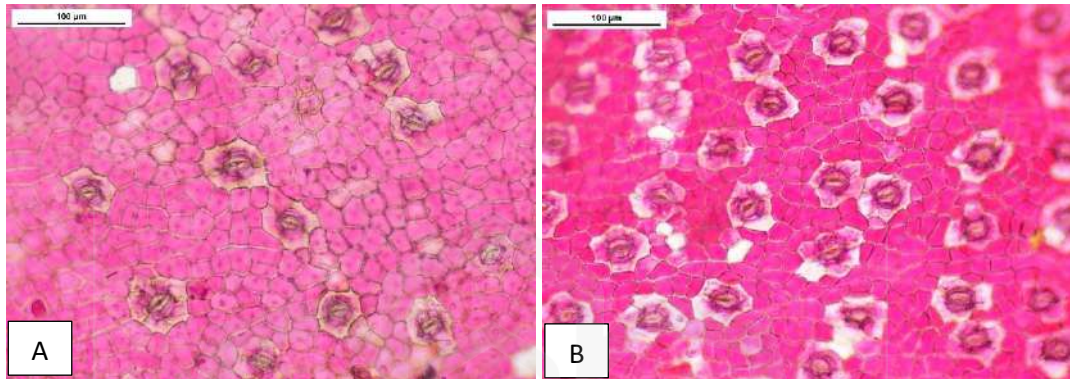


Figure 118: A) Straight to wavy anticlinal wall, anisocytic and tetracytic stomata on abaxial epidermis. B) Straight to wavy anticlinal wall on adaxial epidermis, anisocytic and tetracytic stomata on abaxial epidermis

4.2.2.7 *Lumnitzera racemosa*

Anticlinal wall of abaxial epidermis: straight to wavy. **Anticlinal wall of adaxial epidermis:** straight to wavy. **Stomata:** amphistomatic (present on abaxial and adaxial), densely scattered, anisocytic and tetracytic stomata (Figure 4.109).

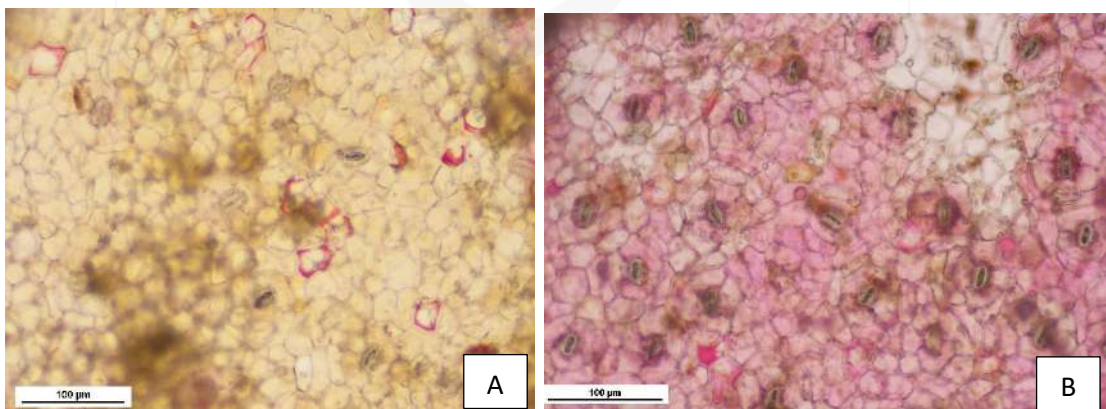


Figure 119: A) Straight to wavy anticlinal wall, anisocytic and tetracytic stomata on abaxial epidermis. B) Straight to wavy anticlinal wall, anisocytic and tetracytic stomata on adaxial epidermis.

4.2.2.8 *Pekan accession*

Anticlinal wall of abaxial epidermis: wavy to sinuous. **Anticlinal wall of adaxial epidermis:** straight to wavy. **Stomata:** hypostomatic (present on abaxial only), densely scattered, anomocytic (Figure 4.110).

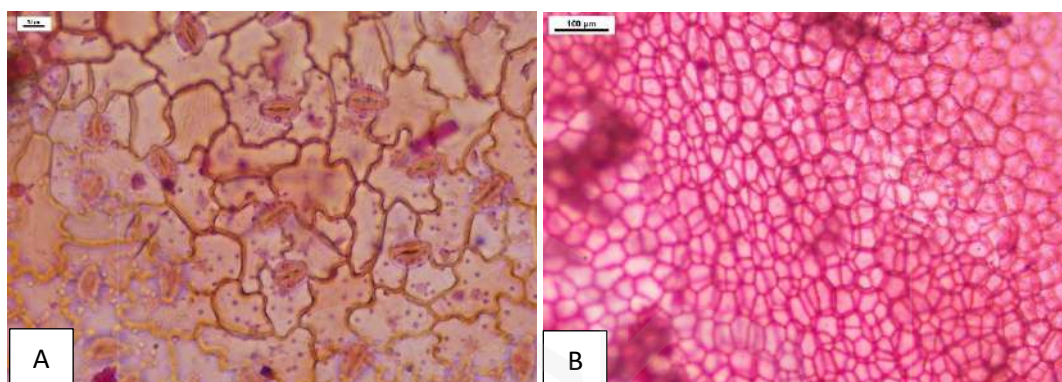


Figure 120: A) Wavy to sinuous anticlinal wall and anomocytic stomata on abaxial epidermis. B) Straight to wavy anticlinal wall on adaxial epidermis.

4.2.2.9 *Sonneratia alba*

Anticlinal wall of abaxial epidermis: straight to wavy. **Anticlinal wall of adaxial epidermis:** straight to wavy. **Stomata:** amphistomatic (present on abaxial and adaxial), densely scattered, paracytic (Figure 4.111).

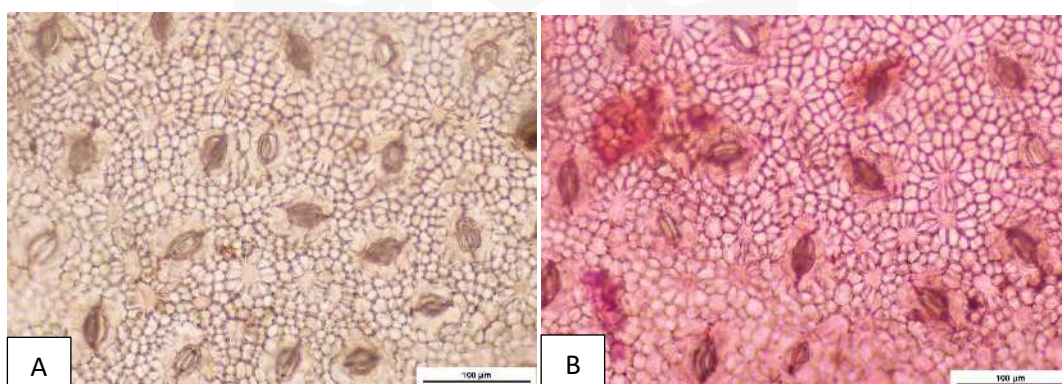


Figure 121: A) Straight to wavy anticlinal wall and paracytic stomata on abaxial epidermis. B) Straight to wavy anticlinal wall and paracytic stomata on adaxial epidermis.

4.2.2.10 *Sonneratia caseolaris*

Anticlinal wall of abaxial epidermis: straight to wavy. **Anticlinal wall of adaxial epidermis:** straight to wavy. **Stomata:** amphistomatic (present on abaxial and adaxial), densely scattered, tetracytic (Figure 4.112).

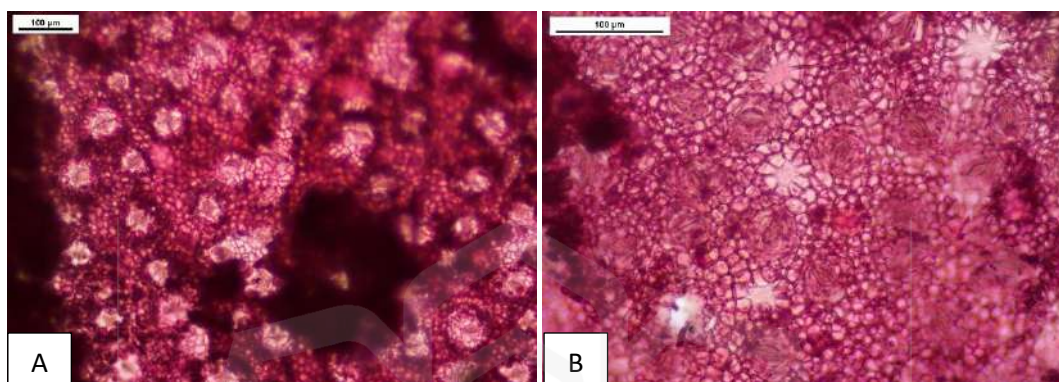


Figure 122: Straight to wavy anticlinal wall and tetracytic stomata on abaxial epidermis. B) Straight to wavy anticlinal wall and tetracytic stomata on adaxial epidermis.

4.2.3 Characteristics of Leaf Anatomy of *Acrostichum* (Pteridophytes).

Ferns are the second largest group of vascular plants in the world, with more than 10,000 species found in a variety of habitats including rainforests, temperate forests, aquatic habitats, semi-arid deserts, savannas, high alpine mountains, and mangroves (Schneider *et al.*, 2004; de Arruda *et al.*, 2021). Consequently, these plants have a variety of morphological, anatomical, and physiological adaptations (Page, 2002). *Acrostichum* Linnaeus, a rhizomatous fern belonging to the Pteridaceae family, holds significant ecological value as a constituent species within the mangrove community. Based on this study, the results showed some common and variation of characteristic in *Acrostichum* leaf anatomy that can be used as supporting data for identification and classification of the species. The common characteristic found from this study include presence of cuticle layers, presence of hypodermal layers, presence of mucilage cells, presence of bundle sheath extension, hypostomatic stomata, wavy to sinuous anticlinal wall, hydrocentric and scattered vascular bundle, presence of collenchyma cells and additional characters in marginal. Meanwhile, the variation characteristic of

Acrostichum can be found on the petiole outline, midrib outline, marginal outline, type of stomata and presence of trichome in petiole.

4.2.3.1 Common Characteristics of Leaf Anatomy of *Acrostichum* (Pteridophytes).

4.2.3.1.1 Epidermal Cells and Presence of Cuticle Layers

For the *Acrostichum*, one layered of uniseriate epidermal cells with ratio height: width, 1:1 had been observed. The epidermis is the outermost layer of cells that surrounds the plant body and performs vital functions such as protection, growth regulation, and environmental interactions (Glover, 2000; Javelle *et al.*, 2011). The leaf epidermis has various crucial functions such as controlling the exchange of gases, water, and nutrients, responding to external threats like pathogens and herbivores, withstanding mechanical strain, detoxifying harmful substances, and providing structural support while maintaining the necessary flat and flexible shape for optimal light absorption (Dietz *et al.*, 1996; Glover, 2000, Javelle *et al.*, 2011; Jacques *et al.*, 2014; Zuch *et al.*, 2022). According to Lucena *et al.* (2011), leaves with a uniseriate epidermis absorbed more light energy, which is required for photosynthesis.

Besides that, a thick layer of cuticle was also presence in *Acrostichum*. The plant cuticle is the outermost layer that covers leaves, fruits, flowers, and non-woody stems of higher plants. It shields plants from drought, extreme temperatures, UV radiation, chemical damage, physical harm, and pathogen or pest invasion. It also offers mechanical support and acts as a barrier to prevent organ fusion (Wen, 2009; Yeats *et al.*, 2013). The presence of cuticle in mangrove plant is an important adaptation in leaves to prevent water loss (Das, 1999; Soniya *et al.*, 2014; Naskar *et al.*, 2015; de Arruda *et al.*, 2021). Other than that, cuticle thickness is believed to perform an important role in water conservation, protection against photochemical damage from UV radiation, and mechanical resistance to diverse forces such as winds and high tides (Lucena *et al.*, 2011; de Arruda *et al.*, 2021).

4.2.3.1.2 Presence of Hypodermal Cells in Lamina and Margin

One of the leaf adaptations for the *Acrostichum* to survive in the harsh condition of mangrove area is the presence of hypodermal cell (Lucena *et al.*, 2011; Ankure *et al.*, 2023). The results showed two layers of hypodermal cell underneath adaxial epidermis of leaf lamina on both *Acrostichum*. Moreover, hypodermal cells also been recorded at the leaf margin. The hypodermal cells in mangrove fern may offer supplementary safeguarding to photosynthetic tissues, as the upright positioning of leaves exposes the leaf surface to significant light exposure during certain periods of the day or year. Moreover, the hypodermis may serve as a mechanism to prevent excessive salt accumulation, as it has the ability to potentially store salts (Das *et al.*, 1996; de Arruda *et al.*, 2021).

4.2.3.1.3 Presence of Mucilage Cells in Petiole and Midrib

Mucilage is a substance that is abundant in polysaccharides (Ghanem *et al.*, 2010), but it also contains proteins (Behbahani *et al.*, 2018) and lipids (Amicucci *et al.*, 2019). Mucilage is excreted by various parts of plants, such as roots, seeds, leaves, and stems, depending on the species (Galloway *et al.*, 2020). Foliar mucilage's play an important role as it contribute to wound healing (Clarke *et al.*, 1979), interactions between plants and pathogens (Davis *et al.*, 1986), water transportation and responses to non-living environmental factors (Zimmermann *et al.*, 1994). The presence of mucilage cells in the parenchyma cortex of petiole and midrib was also discovered in both species of *Acrostichum*. There was evidence supporting the existence of viscous mucilage cell comprise of acid polysaccharides in mangrove species roots such as *Rhizophora mangle*, that help in prevent water loss and reduce the transpiration rate (Srikanth *et al.*, 2015).

4.2.3.1.4 Bundle Sheath Extension

The leaves of both *Acrostichum* species were classed as heterobaric due to the presence of bundle sheath extensions (BSEs) formed by sclerenchyma cells surrounding the vascular bundle and extending towards both epidermises (Kenzo *et al.*, 2007). The

mangrove habitat faces various challenges such as osmotic and drought stress, tidal inundation, high winds, high temperature, and high ultraviolet (UV) radiation. These factors impact the gas exchange rates of leaves and the survival of plants. Bundle sheath extensions (BSEs) are crucial components of leaf anatomy, primarily consisting of transparent parenchyma cells that encircle veins and reach out to the upper and lower epidermis. Angiosperm dicotyledon leaves are classified as heterobaric or homobaric based on the presence or absence of BSEs. Heterobaric leaves have their internal space divided into numerous small compartments, while homobaric leaves lack this division (Wylie, 1952; Kenzo *et al.*, 2007; Liakoura *et al.*, 2009; Kawai *et al.*, 2017). Bundle sheath extensions play a role in the physiological and ecological distinctions between heterobaric and homobaric species.

4.2.3.1.5 Spongy Mesophyll and Palisade Layers

The results indicate the presence of double palisade layer beneath the adaxial epidermis that equal to $\frac{1}{2}$ of leaf thickness in both species. Other than that, results also showed 3 to 4 layers of spongy parenchyma in the central region of the lamina within aerenchyma cells for both *Acrostichum* species. Intercellular gaps inside the spongy parenchyma of *Acrostichum* have also been seen in other mangrove angiosperms, such as *Bruguiera gymnorhiza*, *Excoecaria agallocha*, *Heritiera fomes*, *Phoenix paludosa*, and *Xylocarpus granatum* (Nandy *et al.*, 2007). The thickness of leaves lamina is a crucial factor in the functioning of both leaves and plants, as it is closely linked to the strategies that species employ to acquire and utilize resources. The amount of light absorption and CO₂ diffusion in a leaf are influenced by the lamina thickness (Givnish., 1979; Agusti *et al.*, 1994; Syvertsen *et al.*, 1995).

4.2.3.1.6 Anticlinal Wall of Leaf Epidermis

Notably, some anatomical studies have shown that anticlinal wall of leaf epidermis gave significant values for identification of Schisandraceae species by (Ao, 2006), Asteraceae species as reported by (Adedeji *et al.*, 2008), and *Osonoma* species by (AKÇİN *et al.*, 2013). According to the result from this research, it was showed that both species possess the wavy to the sinuous anticlinal wall on the abaxial surface and

sinuous anticlinal wall on the adaxial surface. This finding was supported by de Arruda et al., (2021) for *Acarostichum aureum*. A similar type of abaxial anticlinal wall also occur in the species *Dryopteris thelypteris* (Korn, 1976).

4.2.3.1.7 Hydrocentric and Scattered Vascular Bundle

Both species of *Acrostichum* exhibited variations in the size of their vascular bundles, which were dispersed within the ground tissue. Notably, the largest vascular bundle was found in the upper central region of the ground tissue. The vascular bundles next to the hypodermis have a reduced size compared to those located in the central region. According to the research conducted by Martinez et al. (2012) and Palacios-Rios et al. (2019), it has been proven that the configuration of vascular bundles in the petiole and the morphology of xylem can serve as distinguishing factors among species within the *Pteris* genus.

The vascular bundle in the midrib for both species are also scattered. The vascular bundle arrangement was corresponding with the studied by Rashid et al. (2020). Similar to another fern (Bercu. 2007; Sârbu et al., 2017; Popovici et al., 2018), the vascular bundle within the midrib exhibited a hydrocentric pattern, same goes with petiole, characterised by the positioning of the xylem cells encircled by the phloem. Besides that, according to research conduct by Vasco et al., (2013), the vascular bundles in the petiole play a significant role in fern taxonomy, as they provide valuable information regarding their number and arrangement. The differentiation between Eupolypods I and II holds significant significance in fern taxonomy.

4.2.3.1.8 Presence of Collenchyma Cells

Collenchyma is characterized by three distinct morphological features: (1) elongated cells along the axis, (2) thickened cell walls, and (3) living protoplasts. Collenchyma cells possess the capacity to elongate and expand during the process of differentiation. However, in the case of collenchyma, the cell walls undergo thickening both during elongation and frequently after elongation. Collenchyma cell walls are typically translucent to facilitate photosynthesis by allowing light to pass through to the

chloroplasts in underlying tissues (Leroux, 2012). According to the findings, both species had collenchyma cells in their petiole, margin and midrib. However, the number of collenchyma layers were differed between the two species.

4.2.3.1.9 Additional Characters of Leaf Marginal

Other than the marginal outline, the results also showed the presence of hypodermal cells, sclerenchyma cells and vascular bundle at the end of leaf margin for both *Acrostichum*. The primary functions of plant leaves are to intercept light and utilize light energy for photosynthesis (Oguchi *et al.*, 2018). Nevertheless, if the intensity of light surpasses the tolerance gradient, plants will decrease water loss by closing their stomata, which leads to a decline in photosynthesis during midday (Kong *et al.*, 2016). Therefore, plants have developed multiple adaptation mechanisms to endure the combined stress caused by unfavourable light levels and other environmental factors (Vogelman *et al.*, 2014).

4.2.3.2 Variation Characteristic of Leaf Anatomy of *Acrostichum* (Pteridophytes)

4.2.3.2.1 Petiole Outline

A plant leaf typically consists of a petiole and a leaf blade. The petiole serves as a connection between the leaf blade and the plant stem, and it bears a structural resemblance to a cantilever beam. The petiole possesses the necessary flexibility to sustain external forces, such as the weight of the blade, regardless of whether it is caused by rain, snow, moisture, or even the mass of an insect (Pasini *et al.*, 2006). A research conduct by Mzoughi *et al.*, (2012) and Le *et al.*, (2014) had been used the leaf petiole characteristic as the main key for plant identification. Based on the observation, it was noted that the petiole of *Acrostichum aureum* exhibited a small concavity on the adaxial side and a convex shape on the abaxial side. In contrast, the petiole of *A. speciosum* displayed a flat surface on the adaxial side and a U-shaped contour on the abaxial side.

4.2.3.2.2 Midrib Outline

The findings of the present study also demonstrated a distinct variation in the midrib outline of *Acrostichum*. The outlines of the midrib were described by considering the adaxial and abaxial outlines. The adaxial surface of *Acrostichum aureum* exhibits a flat line, but the adaxial surface of *Acrostichum speciosum* displays a U-shape. Conversely, the abaxial surface of both species is concave in shape. Leaves possess a wide variety of internal structures that could potentially retain information for distinguishing patterns. One of the structures is the midrib, which varies significantly between species in its shape and composition of vascular and fundamental tissues. The leaf midrib consists of specialized tissues such as phloem and xylem, along with other cells that are typically consistent among individuals of the same species. The midrib is a stable region that maintains its structures well during image acquisition (Keating, 1984; da Silva *et al.*, 2015). Mantovani *et al.* (2009) suggest that the midrib outline can serve as a diagnostic characteristic for taxonomic purposes within the *Anthurium*, section *Urospadix* subsection *Flavescentiviridia* of the Araceae family. In addition, Adeniran *et al.* (2020) have also documented the importance of midrib outline in the taxonomic classification of taxa belonging to the genera *Isolona* and *Monodora* within the Annonaceae family.

4.2.3.2.3 Marginal Outline

The transverse section of the leaf margin exhibits a downward outline in both *Acrostichum* species. However, *Acrostichum aureum* displays a rounded end, whereas *Acrostichum speciosum* exhibits a pointy end. According to Noraini *et al.* (2009), the margin of *Parashorea* species showed same shaped, obtuse and rounded, for all studied species. Furthermore, it is worth noting that while the margin outline has been employed in the categorization of *Mangifera* species, the resulting taxonomy only encompasses two major groupings (Norfaizal *et al.*, 2013; Tipmontiane *et al.*, 2018).

4.2.3.2.4 Presence of Trichomes in Petiole

Based on this study, there is also a presence of trichome at the epidermis *Acrostichum aureum* petiole. The trichome are simple, unicellular, short and had pointed end. Plant trichomes are specialized protrusions formed by epidermal cells on the surface of plants. They serve as a defense mechanism against both biotic and abiotic stresses. Trichomes can exist as unicellular, bicellular, or multicellular structures, which may have numerous branches or no branches at all. Unicellular trichomes typically do not secrete substances, while multicellular trichomes consist of both secretory and non-secretory hairs (Han *et al.*, 2022). The various type and shape of trichome in plant cell give a promising identification aid. For instance, a study by Thomson *et al.*, (1996) proved that the presence of trichomes had been one of the diagnostic characters found in the identification of *Pteridium*. Besides that, trichome were used as the characterization of water fern *Salvinia* (Barthlott *et al.*, 2009), in identification of medicinal fern at Tasik Chini, Pahang (Nurnida *et al.*, 2015), in studying the leaf defense syndrome in tropical fern (Farias *et al.*, 2020).

4.2.3.2.5 Type of Stomata

Stomata are cellular pores found on plant leaves that regulate the intake of carbon dioxide (CO₂) for photosynthesis and control the loss of water through evaporation (Nunes *et al.*, 2020). This research examined stomata are only present on the abaxial surface (hypostomatic type) for both *Acrostichum* species. The stomata are densely scattered on the surfaced and possessed anomocytic and paracytic types in *Acrostichum aureum*. Meanwhile, only anomocytic stomata has been recorded in *Acrostichum speciosom*. This finding was in contrast with the previous studies by de Arruda *et al.*, (2021) which stated that *A. aureum* had an amphistomatic leaf but still possessed an anomocytic type.

4.2.3.3 Dichotomous Key of Leaf Anatomy of *Acrostichum* (Pteridophytes)

Key to the species based on leaf anatomical structure

1. a. Margin downwards, rounded end. Midrib flat line adaxial, concave adaxial. Petiole small concavity on adaxial, concave abaxial, presence of trichome on epidermis, anomocytic and paracytic stomata..... *A. aureum*
- b. Margin downwards, pointy end. Midrib U-shaped adaxial, concave abaxial. Petiole flat surface adaxial, U-shaped contour abaxial, absence of trichome, anomocytic stomata..... *A. speciosum*

4.2.4 Characteristics of Leaf Anatomy of Monocotyledon Species

The Monocotyledonae, also known as "Liliatae" in certain modern taxonomic texts, are usually considered as a distinct group that is contrasted with and of equal rank to the dicots, also known as "Magnoliatae" (Meeuse, 1975). According to Tomlison (1970), monocotyledonous crops are commonly found in lowland tropical regions in the field of tropical agronomy. These crops include coconut, oil-palm, banana, sisal, sugar-cane, pineapple, yams, coco-yams, arrowroot, and ginger, which are often grown in plantations. In this study, there are two monocot species that had been recorded throughout all research sites, which are *Nypa fruticans* from Arecaceae family and *Pandanus tectorius* from Pandanaceae family.

Nypa fruticans, also known as nipah, is a species of mangrove palm that thrives in tranquil estuaries and coastal areas. The species can thrive in both uncomplicated channels and intricate tributaries, bays, tidal flats, and creeks, provided that there is a tidal cycle and a flow of freshwater exiting the area (Rozainah *et al.*, 2010). *Pandanus tectorius*, also commonly known as pandan or screw pine, is a significant shrub or small tree that has great cultural, health, and economic value in the Pacific region. It is second in importance only to coconuts and atolls. The species complex is highly variable and primarily grows in semi-natural vegetation in littoral habitats across the tropical and

subtropical Pacific. It has the ability to tolerate drought, strong winds, and salt spray (Thomson *et al.*, 2006).

Based on this study, the results showed some common and variation of characteristic of leaf anatomy in both monocot species. The variation of characteristic of both species can be used as supporting data for identification and classification. The common characteristic found from this study include presence of cuticle layers, presence of hypodermal layers, presence of mucilage cells, presence of bundle sheath extension, hypostomatic stomata, straight to wavy anticlinal wall, hydrocentric and scattered vascular bundle, presence of collenchyma cells and sclerenchyma cells. Meanwhile, the variation characteristic of both species can be found on the midrib outline, marginal outline, vascular tissues in lamina and presence of palisade layers in midrib.

4.2.4.1 Common Characteristics of Leaf Anatomy of Monocotyledon Species

4.2.4.1.1 Presence of Cuticle Layers

Based on the results, there is a presence of thick layered of cuticle on both adaxial and abaxial surface in both monocot species. The epidermis and cuticle serve as the plant's primary defence mechanism against a hostile environment. Throughout history, plants have consistently played a crucial role in protecting themselves from drying out, as well as from the attacks of harmful microorganisms and insects (Juniper *et al.*, 1973). In today's world, the cuticle also serves as the primary defence against harmful chemicals and air pollution (Norms *et al.*, 1968; Juniper *et al.*, 1973). The plant cuticle is a lipid layer composed of cutin that is intertwined and covered with waxes. It covers almost all above-ground parts of the plant and serves to limit the loss of water through transpiration (Kosma *et al.*, 2009). This characteristic of plant cuticle is really important to prevent water loss as both monocot species can grow in harsh environment.

4.2.4.1.2 Presence of Hypodermal Cells in Lamina and Margin

The study showed the presence of two layers hypodermal cell in *Nypa fruticans* lamina and three layers of hypodermal cells in *Pandanus tectorius* lamina. Besides, the hypodermal cell also presence at the leaf marginal of both species. According to Horn *et al.* (2009), mangrove palm exhibits distinct characteristics that set it apart from other palm species. The hypodermal cells of *Nypa* are unique among all palm species as they have thick walls and are lignified. The layers of hypodermal cell in *Pandanus tectorius* for this study is contrast with the study by Rahayu *et al.* (2012), which the *Pandanus tectorius* had only two layers of hypodermal cell.

4.2.4.1.3 Presence of Mucilage Cells in Midrib

The results showed the presence of mucilage cell in parenchyma cortex of leaf midrib for both *Nypa fruticans* and *Pandanus tectorius*. Mucilage is a soluble adhesive substance found in various parts of plants, such as the outer layer of seeds, bark, leaves, and buds. It is composed of carbohydrates and uranic acids (Mukherjee *et al.*, 2019). Mucilage in leaves does not serve as a storage substance (Naglschmid *et al.*, 1982), unlike mucilage found in rhizomes, roots, and seed endosperm, which primarily functions as an energy reserve (Franz, 1979). Generally, it has been believed that mucilage in leaves is only a byproduct of plant metabolism (Naglschmid *et al.*, 1982).

4.2.4.1.4 Bundle Sheath Extension

According to the study, the results show the present of bundle sheath extension (BSEs) in both *Nypa fruticans* and *Pandanus tectorius*. BSEs act as "windows" in gas exchange, directing light to the lower mesophyll layer (Karabourniotis *et al.*, 2000; Nikolopoulos *et al.*, 2002). Heterobaric species, which possess leaves with bundle sheath extensions (BSE), show higher photosynthetic rates compared to homobaric species, given the same leaf thickness and dry mass per area (Liakoura *et al.*, 2009). BSEs also act as barriers that hinder the sideways movement of CO₂ between adjacent compartments, leading to uneven stomatal responses and nonuniform photosynthesis on the leaf surface in heterobaric species, particularly during drought (Terashima, 1992; Mott *et al.*, 1999; West *et al.*, 2005; Pieruschka *et al.*, 2010; Kamakura *et al.*, 2011). BSEs function as

effective water conduits transferring water from veins to the mesophyll and epidermis layers where evaporation takes place (Wylie, 1952; Buckley *et al.*, 2011).

4.2.4.1.5 Spongy Mesophyll and Palisade layers

Most plant leaves consist of two layers of photosynthetic tissue, known as the palisade and spongy mesophyll. While the palisade mesophyll is composed of densely arranged columnar cells, the organization of the spongy mesophyll is not clearly defined and is often regarded as a haphazard collection of cells with irregular shapes (Borsuk *et al.*, 2022). According to the finding, *Nypa fruticans* indicate the presence of double palisade layer beneath adaxial epidermis that equal to 1/2 of the leaf thickness. Meanwhile, *Pandanus tectorius* showed the presence of double palisade layers that equal to 1/3 of the leaf thickness. Both species also showed the presence of 3 – 4 layers of spongy parenchyma in the central region of lamina with aerenchyma cell.

4.2.4.1.6 Type of Stomata

Stomata are tiny openings located on the surface of plant leaves and stems. Stomata are essential for gas exchange in plants, facilitating the entry of carbon dioxide (CO₂) for photosynthesis and the release of oxygen (O₂) and water vapor. Every stoma, which is the singular form of stomata, is encircled by a duo of specialized cells known as guard cells. These guard cells regulate the aperture and closure of the pore. This regulation facilitates the plant's control over water loss and ensures the maintenance of appropriate gas exchange, enabling the plant to adapt to environmental factors such as humidity, light, and CO₂ levels (Hedrick *et al.*, 2018). The results show that the stomata are densely scattered and possessed paracytic type on the abaxial surface (hypostomatic leaves) for both *Nypa fruticans* and *Pandanus tectorius*.

4.2.4.1.7 Anticlinal Wall of Leaf Epidermis.

The morphology of an individual epidermal cell is typically apparent at lower levels of magnification using scanning electron microscopy (SEM) or light microscopy. The boundaries formed by two cell walls that intersect at a right angle are referred to as anticlines or anticlinal walls. Meanwhile, the outer region of the cell surface is known

as the periclinal wall (Koch *et al.*, 2009). Based on the finding, it was showed that both species possess straight to wavy anticlinal wall on both adaxial and abaxial surface. This finding was supported by Antunes *et al.*, (2015) for palm species and Rahayu *et al.*, (2012) for *Pandanus* species.

4.2.4.1.8 Presence of Collenchyma Cells

Collenchyma tissue consists of elongated living cells with unevenly thick primary walls, containing hemicellulose, cellulose, and pectic substances. It offers support, structure, mechanical strength, and flexibility to the petiole, leaf veins, and stem of juvenile plants, facilitating bending without fracture. Collenchyma tissue is located directly beneath the epidermis in young stems, petioles, and leaf veins (Carrillo-López *et al.*, 2019). Based on the findings, both species had collenchyma cells in their margin and midrib. The number of collenchyma layers in midrib was approximately 3 – 5 layers. According to O'Neill, (2010) in his study of *Justicia brandegeana* (Acanthaceae) shows the presence of a thick layer of collenchyma cells on the stem and also the petioles can help this herbaceous plant species to become stronger and stronger strong especially when in windy areas.

4.2.4.1.9 Presence of Sclerenchyma Cells

Sclerenchyma cells (sclereids and fibers) possess unique attributes of strength, elasticity, and indigestibility due to their thick, often heavily lignified secondary cell wall (McDougall *et al.*, 1993). Based on the finding, there is a presence of fibre of sclerotic sheath surrounded the vascular bundle in lamina, midrib and leaf marginal marginal in all species studied. The presence of sclerenchyma cell also been reported in other high plant species such as a study on several species in *Rondeletia* L. (Rubiaceae) which shows the presence of sclerenchyma clusters surrounding the vascular bundles of leaf bones either continuously or discontinuously which can be used to identify plant species (Kocsis *et al.*, 2004).

4.2.4.2 Variation Characteristics of Leaf Anatomy of Monocotyledon Species

4.2.4.2.1 Midrib Outline

The results of the present study showed a distinct variation in the midrib outline of *Nypa fruticans* and *Pandanus tectorius*. The midrib outline for *Nypa fruticans* showed a clear rhombus shaped, while for *Pandanus tectorius* it showed a concave on the adaxial surface and narrow V-shape for the abaxial surface. The variation in midrib outlines along with the leaf lamina proved valuable for identifying the species studied, as demonstrated by certain taxonomic groups in *Flavescentiviridia* (Araceae) (Mantovani *et al.* 2009).

4.2.4.2.2 Marginal Outline

Based on the observation, it was showed that leaf marginal of *Nypa fruticans* had a pointed with V shaped that recurved 45° towards abaxial and decreasing gradually towards the end. Meanwhile, leaf marginal for *Pandanus tectorius* showed a pointed U-shaped that slightly recurved towards abaxial and also decreasing gradually towards the end. Noraini *et al.* (2005) also reported that the variations of marginal outlines in *Alpinia* (Zingiberaceae) species could be taxonomic important in the identification process. Other plant families have also demonstrated the taxonomic significance of marginal outlines. For example, four species of *Nepenthes* which are *Nepenthes domei*, *Nepenthes latiffiana*, *Nepenthes benstonei*, and *Nepenthes sanguinea* have been identified using these outlines, and each species demonstrates variations in this characteristic (Norfaizal *et al.*, 2020).

4.2.4.2.3 Presence of Palisade Layers in Midrib

In the natural environment, light fluctuates in duration, intensity, and spectral composition. Leaves that form in high sunlight uptake (sun leaves) are typically thick and possess a well-defined palisade layer with a significant proportion of columnar cells. Conversely, leaves that form in low sunlight uptake (shade leaves) exhibit a poorly defined palisade layer and possess a greater chlorophyll concentration per unit leaf

volume (Volgemann *et al.*, 1993). According to the results, the presence of palisade layer in *Pandanus tectorius* not only occur in the leaf lamina, but there is also the presence of 4 – 5 layers of mesophyll palisade at the adaxial surface of the leaf midrib.

4.2.4.2.4 Vascular Bundle in Lamina.

The vascular system comprises two primary conductive tissues, xylem and phloem, which are distinct from the meristematic tissues, namely procambium and vascular cambium (Aloni, 1987). Vascular tissues are composed of specialized conductive cells that act as tubes or vessels to transport water and nutrients throughout the plant. These vessels function as efficient conduits that connect all plant organs and facilitate the long-distance transportation of water and various materials. Lamina of *Nypa fruticans* showed a primary and secondary vascular bundle that were prominent and flat on both abaxial and adaxial surface. Meanwhile, for *Pandanus tectorius*, showed only the presence of primary vascular bundle.

4.2.4.3 Dichotomous Key of Leaf Anatomy of Monocotyledon Species

Key to the *Nypa fruticans* species.

1. Margin downwards, pointed V-shaped; Presence of primary and secondary vascular bundle in lamina; Midrib rhombus; Absence of palisade layer in midrib.
..... *Nypa fruticans*

Key to the *Pandanus tectorius* species.

1. Margin downwards, rounded U-shaped; Presence only primary vascular bundle in lamina; Midrib concave adaxial, narrow V-shape abaxial. Presence of palisade layer in midrib.
..... *Pandanus tectorius*

4.2.5 Characteristics of Leaf Anatomy of Dicotyledon Species

Among the 26 species of true mangrove that had been recorded in this study, five species consisting of herbaceous and shrub plants had been selected for the anatomical analysis. The species are *Acanthus ilicifolius*, *Lumnitzera littorea*, *L. racemosa*, *Sonneratia alba*, and *S. caseolaris*. In addition, this study included a new discovery of Melastomataceae species collected from the Pekan mangrove sampling site. The harsh conditions of mangrove forests—characterized by elevated salinity, low oxygen levels, and unstable substrates—have led mangrove species to evolve specialized leaf anatomy that facilitates their survival and differentiates them from other type of vegetation. Examining these anatomical characteristics can yield essential insights for distinguishing mangrove species from other vegetation types, facilitating precise identification and classification.

According to the finding, the results showed some common and variation of characteristic of leaf anatomy in the six species of dicotyledons. The variation of characteristic can be used as supporting data for identification and classification for genus and species level. The common characteristic found from this study include presence of cuticle layers, presence of hypodermal layers, presence of collenchyma cells, presence of outer parenchyma and straight to wavy anticlinal walls. Meanwhile the variation characteristic for the species can be found on the midrib outline, margin outline, petiole outline, presence of cell inclusion and mucilage cell, type of vascular tissues and type of stomata.

4.2.5.1 Common Characteristics of Leaf Anatomy of Dicotyledon Species

4.2.5.1.1 Epidermal Cells and Cuticle Cells

The epidermal cells of mangrove species leaves are highly specialized to facilitate their survival in harsh coastal environments. These cells are essential for safeguarding the plant and regulating water and salt equilibrium. The results show the presence of one thick layer of cuticle at both adaxial and abaxial surface for all species. This finding is

corresponding with the previous study by Das et al., (1996) and Quadros et al., (2021). The thick cuticle serves as a waterproof barrier that markedly reduces water loss via evaporation. This is particularly crucial in mangrove ecosystems, where freshwater is frequently limited, and the vegetation endures intense sunlight and wind, potentially elevating transpiration rates (Hoste, 2011; Arora et al., 2019).

4.2.5.1.2 Presence of Hypodermal Cells in Lamina and Margin

Another adaptation of mangrove species in order to survive the harsh condition is the presence of hypodermal layers in lamina and margin. According to the study by Lechthaler *et al.* (2016) for other mangrove species such as *Rhizophora* and *Bruguiera*, both genera possessed a thick hypodermis layer that giving them a succulent appearance and large water storage capacity. Based on the results, *Acanthus ilicifolius* and both *Lumnitzera* species showed the presence of one layer of hypodermal cells on adaxial, meanwhile *Pekan accession* showed double layer of hypodermal on adaxial. As for both *Sonneratia* species, they possessed one layer of hypodermal cell on both underneath of adaxial and abaxial epidermis which supported from the study by Seshavatharam *et al.*, (1989) for the same genus. The more layer of hypodermal presence in the cell, indicates higher level of leaf water content (Suárez *et al.*, 2000; Lechthaler *et al.*, 2016).

4.2.5.1.3 Spongy Mesophyll and Palisade Layers

In most dicotyledonous plants, the leaf mesophyll is divided into two distinct tissues: the palisade and spongy tissues. The tissues differ in their location within the leaf, cellular composition, and functional characteristics. In dorsiventral mesophyll plants, the palisade layer is located on the upper (adaxial) side, whereas the spongy tissue is found on the lower (abaxial) side of the leaf (Wylie, 1939; Wylie, 1946; Wylie, 1951; Ivanova *et al.*, 2002). The result showed different layers of palisade layers in each species. *Acanthus ilicifolius* showed three layers of palisade mesophyll on adaxial that equal to 1/2 of the leaf thickness. Both *Pekan accession* and *L. littorea* possessed double palisade layers on adaxial that equal to 1/2 of the leaf thickness. As for *L. racemosa*, it possessed double palisade layer on adaxial but its equal to 1/3 of the leaf thickness.

As for *Sonneratia*, both species showed the presence of palisade layer on both adaxial and abaxial epidermis. *S. alba* had double palisade layer on adaxial and three palisade layers on abaxial that equal to 1/2 of the leaf thickness and *S. caseolaris* had three layers of palisade mesophyll on both adaxial and abaxial that equal to 1/2 of the leaf thickness. The finding was supported by Seshavatharam *et al.*, (1989) and Tatongjai *et al.*, (2021). All species showed the presence of 3 – 4 layers of spongy parenchyma in the central region of lamina with aerenchyma cell.

4.2.5.1.4 Anticlinal Walls of Leaf Epidermis

The epidermis of plant leaves offers protection and serves as a barrier against pathogen entry (Naeem *et al.*, 2019). According to Jacques *et al.*, (2014) a vast array of plant species exhibits considerable variation in leaf morphology and structure. At the cellular level, a variety of shapes and sizes are present. An example is the irregular undulating contour of epidermal cells, delineated by their anticlinal walls, as observed in *Arabidopsis thaliana* and various other plants. The results showed all six species possessed a straight to wavy anticlinal walls on both adaxial and abaxial epidermis. However, there was a slightly differences for Pekan accession where its adaxial possessed a wavy to sinuous anticlinal wall.

4.2.5.1.5 Presence of Collenchyma Cells

Leaf cells typically consist of fibrous composite biomaterials formed by three integrated tissues: epidermis, collenchyma, and parenchyma, each possessing distinct characteristics. The ability of an organism to endure deformation from an applied load depends on its body structure and the mechanical properties of its tissues (Faisal *et al.*, 2010). The growth and proliferation of collenchyma cells can be affected by mechanical stress. In leaves subjected to strong winds or frequent physical disturbances, the collenchyma tissue may become more prominent, thereby augmenting the plant's capacity to withstand damage. According to Venning (1966) the presence of wind increased the formation of collenchyma in the petioles of celery. Based on the results, all species exhibited the presence of various layers of collenchyma cells in the petiole and midrib.

4.2.5.2 Variation Characteristics of Leaf Anatomy of *Dicotyledon* Species

4.2.5.2.1 Petiole Outline

Petioles are crucial for plant survival as they link the lamina and stem. Petioles fulfil two primary functions for the leaf blade. Initially, they position the leaf blade away from the stem to minimize self-shading and enhance light interception, serving a mechanical purpose. Petioles function as the conduit between the stem and lamina, facilitating the upward movement of water within the plant and the downward transport of photo-assimilates from the leaf blade, serving a physiological role (Pasini *et al.*, 2006; Faisal *et al.*, 2010; Ray, 2018).

The results from the study, showed there are 4 different types of petiole outline. *Acanthus ilicifolius* possessed a slightly concave on its adaxial and a U-shaped on the abaxial (Type 1). As for *Pekan accession*, the adaxial showed a V-shape while the abaxial side showed a wide U-shape (Type 2). Both species of *Lumnitzera* exhibit a convex shaped on the adaxial and U-shaped on the abaxial side (Type 3). However, *Sonneratia alba* showed a clear round shaped for its petiole (Type 4).

4.2.5.2.2 Midrib Outline

According to the findings of the present study, the results showed 5 different type of midrib outline in all six species. The midrib outline of *Acanthus ilicifolius* showed a convex shaped on the adaxial side and rounded U-shaped on the abaxial side (Type 1). *Pekan accession* have a flat line with slightly concave shape on the adaxial and U-shaped on the abaxial (Type 2). Similar with petiole outline, both *Lumnitzera* species shared a same midrib outline that exhibit flat line on the adaxial and wide V-shape on the abaxial (Type 3). *Sonneratia alba* showed convex shaped on adaxial and wide U-shaped on abaxial (Type 4), while *S. caseolaris* showed a flat line with slightly concave on the adaxial and wide U-shaped on the abaxial (Type 5). The variation of midrib outline had played a role in the taxonomic classification of taxa belonging of Myrtaceae in Thailand (Kantachot *et al.*, 2007). Besides that, the variation of midrib outlines also help in differentiate among the *Terminalia* species (Ekeke *et al.*, 2022).

4.2.5.2.3 Marginal Outline

The results showed 3 different type of leaf marginal outline in this recent study. *Acanthus ilicifolius*, *Pekan accession*, *Sonneratia alba*, and *S. caseolaris* shared a same marginal outline. The transverse section of the leaf margin for these four species showed a straight rounded end with U-shaped and the size remain the same until end of margin (Type 1). Both *Lumnitzera littorea* and *L. racemosa*, exhibit a rounded U-shaped that recurved downward to abaxial at 45° (Type 2) and 30° (Type 3) respectively. The size also gradually decreasing towards the end of margin.

4.2.5.2.4 Types of Vascular Tissues in Petiole and Midrib

The plant vascular system is a complex network of conducting tissues that connects all organs and facilitates the transport of water, minerals, organic compounds, and various signaling molecules throughout the organism. This system comprises two primary tissue types—xylem and phloem—that originate from the vascular meristem (Jung *et al.*, 2007). The primary role of xylem is to convey substantial volumes of water and solutes (De Boer *et al.*, 2003), whereas phloem is responsible for the distribution of nutrients, defensive substances, and signalling information within vascular plants (Turgeon *et al.*, 2009).

There are four types of vascular bundle in plant, which are collateral bundle, bicollateral bundle, concentric bundle and radial bundle (Crang *et al.*, 2018). In this study, *Acanthus ilicifolius*, *Lumnitzera littorea* and *L. racemosa* possessed a collateral vascular bundle, while *Pekan accession*, *Sonneratia alba* and *S. caseolaris* possessed a bicollateral vascular bundle. Both types are a conjoint vascular bundle where, the phloem was on the abaxial side on xylem for collateral, and for bicollateral the phloem was on the two side of the xylem (Crang *et al.*, 2018).

Besides, in this study the vascular bundle arrangement in petiole of *Acanthus ilicifolius* showed a O-shaped of opened system with non-discontinuous ring (Type 1). As for *Pekan accession*, the vascular bundle showed an opened system U-shaped with continuous ring (type 2). Both *Lumnitzera* species exhibit an opened system with

continuous ring of crescentic shaped for the main vascular bundle (Type 3). Lastly, for *Sonneratia alba*, the species showed an oval shaped of closed system vascular tissue with non-continuous ring (Type 4).

Meanwhile for the vascular tissue arrangement in the midrib, the results also showed 4 different types in all six species: (1) O-shaped with non-continuous ring of closed systems, (2) U-shaped with continuous ring of opened system, (3) crescentic shaped with continuous ring of open system, (4) oval shaped with non-continuous ring of closed system. Type 1 is possessed by *Acanthus ilicifolius*, while Type 2 is possessed by *Pekan accession*. Type 3 is presence in both *Lumnitzera littorea* and *L. racemosa*. Meanwhile, both *Sonneratia* species showed the Type 4 of vascular tissue in the midrib.

4.2.5.2.5 Presence of Calcium Oxalate in Petiole, Midrib and Lamina.

Calcium oxalate is a significant and widely distributed biomineral in plants. Calcium oxalate crystals are present across all taxonomic levels of photosynthetic organisms, ranging from unicellular algae to angiosperms and large gymnosperms. The biosynthesis of calcium oxalate is regarded as a fundamental and significant physiological process in higher plants (Baran *et al.*, 2008). Calcium oxalate crystal that are found in many organs of plant have different morphological forms, such as druse, prism, styloid, raphides and crystal sand (Lersten *et al.*, 2000; Hartls *et al.*, 2007). The finding showed the presence of druse at parenchyma cortex of petiole, lamina and midrib in *Pekan aceesion*, *Lumnitzera littorea* and *L. racemosa*. Besides that, the results also indicate the presence of druse in mesophyll palisade of lamina in *Sonneratia alba*.

4.2.5.2.6 Presence of Mucilage cells

According to the result of recent study, there is a presence of mucilage cell in lamina of both *Sonneratia* species. Other than that, there is also the presence of mucilage in parenchyma cortex of petiole of *Acanthus ilicifolius*, *Pekan accession*, *Lumnitzera littorea*, *L. racemosa* and *Sonneratia alba*. As for *Acanthus ilicifolius*, the mucilage cell also presents in the vascular bundle of the petiole. Meanwhile in transverse section of midrib for *Acanthus ilicifolius*, *S. alba* and *S. caseolaris* showed the presence of

mucilage cell in the parenchyma cortex and mucilage canal in the pith parenchyma. As for *Pekan accession*, *Lumnitzera littorea* and *L. racemosa*, the result show only the presence of mucilage cell in parenchyma cortex.

4.2.5.2.7 Type of Stomata

Stomata regulate leaf diffusive conductance, thereby affecting water loss and carbon assimilation (Webb *et al.*, 1992; Buckley, 2005). Most vascular plant species exhibit distinct distributions of stomata on their leaf surfaces. A significant proportion of woody dicotyledonous species are hypostomatic, possessing stomata exclusively on the lower (or abaxial) leaf surface, while a minority are epistomatic, featuring stomata on the upper surface. Nevertheless, numerous other woody dicots possess stomata on both surfaces (i.e., they are amphistomatic), and this trait has been significantly associated with either open vegetation or arid climates (Jordan *et al.*, 2014).

The result of this research showed two types of leave, which are hypostomatic and amphistomatic. The hypostomatic leaves is referred to *Acanthus ilicifolius* and *Pekan accession*, while amphistomatic leaves is referred to both *Lumnitzera* and *Sonneratia* species. Besides that, the result also showed five types of stomata, which are anisocytic, anomocytic, diacytic, paracytic and tetracytic. The diacytic stomata are possessed by *Acanthus ilicifolius*. *Pekan accession* showed the presence of anomocytic stomata. As for both *Lumnitzera* species, they possessed two type stomata, which are anisocytic and tetracytic. Last but not least, *Sonneratia alba* possessed a paracytic stomata, while *Sonneratia caseolaris* possessed a tetracytic stomata.

4.2.5.3 Dichotomous Key of Leaf Anatomy of Dicotyledon Species

Key to the *Lumnitzera* species based on leaf anatomical structure

1. a. Palisade mesophyll equal to 1/2 leaf size. Margin rounded U-shaped, recurved 45° towards abaxial. Presence of idioblast tannin around vascular bundle in petiole *Lumnitzera littorea*

- b. Palisade mesophyll equal to 1/3 leaf size. Margin rounded U-shaped, recurved 30° towards abaxial..... *Lumnitzera racemosa*

Key to the *Sonneratia* species based on leaf anatomical structure

1. a. Midrib convex adaxial, wide U-shaped abaxial. Paracytic stomata..... *Sonneratia alba*
- b. Midrib flat slightly concave, wide U-shape abaxial. Tetracytic stomata..... *Sonneratia caseolaris*

4.2.6 The Variation of Anatomical Characteristic for True Mangrove Species and its Associated.

Based on the results, the leaf anatomical characters of true mangrove species and associated mangrove species reveal both shared and distinct features that reflect their ecological adaptations. True mangroves exhibit unique traits such as the presence of thick cuticle layers, hypodermal cells in the lamina and margin, mucilage cells in the petiole and midrib, aerenchyma cells, and druse crystal, notably in *Acanthus*, *Sonneratia*, and *Lumnitzera*. These features likely enhance their ability to tolerate saline, waterlogged environments by facilitating water retention, salt regulation, and structural support. Similarly, associated mangrove species share features like cuticle layers, epidermal cells, hypodermal cells, mucilage cells, and spongy mesophyll and palisade layers. However, they also possess distinct traits such as sclerenchyma cells in *Nypa* and *Pandanus*, and druse crystals in *Pekan species*, indicating adaptations for structural reinforcement and defence mechanisms in less saline or transitional zones. These results highlight the anatomical diversity and functional specializations that enable true and associated mangroves to thrive in their respective ecological niches, supporting their classification and ecological roles within mangrove ecosystems.

4.3 INTERNATIONAL UNION FOR CONSERVATION OF NATURE (IUCN) RED LIST OF MANGROVE PLANT SPECIES AND ITS ASSOCIATES

Based on this study, a total of 26 True Mangrove and 45 associate's mangrove species were collected and documented from 13 sampling site in district of Kuantan and Pekan. The International Union for Conservation of Nature Red List of Threatened Species (IUCN Red List) categories of each species and population trend were listed in Table 4.5 and Table 4.6.

Table 4.5: IUCN Red list category and population trend of true mangrove plant collected from Kuantan and Pekan.

NO	SCIENTIFC NAME	LOCAL NAME	IUCN STATUS	POPULATION TREND	LAST ASSESSMENT
1	<i>Acanthus ilicifolus</i>	Jeruju putih	Least Concern	UNKNOWN	21/2/2010
2	<i>Acrostichum aureum</i>	Piai raya	Least Concern	STABLE	7/3/2008
3	<i>Acrostichum speciosum</i>	Piai lasu	Least Concern	STABLE	7/3/2008
4	<i>Aegiceras corniculatum</i>	Kacang-kacang	Least Concern	DECREASING	7/3/2008
5	<i>Avicennia alba</i>	Api-api hitam	Least Concern	DECREASING	7/3/2008
6	<i>Avicennia marina</i>	Api-api jambu	Least Concern	DECREASING	7/3/2008
7	<i>Avicennia officinalis</i>	Api-api ludat	Least Concern	DECREASING	7/3/2008
8	<i>Avicennia rumphiana</i>	Api-api bulu	Vulnerable	DECREASING	7/3/2008
9	<i>Bruguiera cylindrica</i>	Bakau putih	Least Concern	DECREASING	7/3/2008

10	<i>Bruguiera gymnorhiza</i>	Tumu merah	Least Concern	DECREASING	7/3/2008
11	<i>Bruguiera parviflora</i>	Lenggadai	Least Concern	DECREASING	7/3/2008
12	<i>Bruguiera sexangula</i>	Tumu Putih	Least Concern	DECREASING	7/3/2008
13	<i>Ceriops decandra</i>	Tengar	Near Threatened	DECREASING	7/3/2008
14	<i>Ceriops tagal</i>	Tengar	Least Concern	DECREASING	7/3/2008
15	<i>Kandelia candel</i>	Berus – berus	Least Concern	DECREASING	7/3/2008
16	<i>Lumnitzera littorea</i>	Teruntum merah	Least Concern	DECREASING	7/3/2008
17	<i>Lumnitzera racemosa</i>	Teruntum putih	Least Concern	DECREASING	7/3/2008
18	<i>Rhizophora apiculata</i>	Bakau minyak	Least Concern	DECREASING	7/3/2008
19	<i>Rhizophora mucronata</i>	Bakau kurap	Least Concern	DECREASING	7/3/2008
20	<i>Scyphiphora hydrophylacea</i>	Cengham	Least Concern	DECREASING	7/3/2008
21	<i>Sonneratia alba</i>	Perepat	Least Concern	DECREASING	7/3/2008
22	<i>Sonneratia caseolaris</i>	Berembang	Least Concern	DECREASING	7/3/2008
23	<i>Sonneratia ovata</i>	Gedebu	Near Threatened	DECREASING	7/3/2008
24	<i>Xylocarpus granatum</i>	Nyireh bunga	Least Concern	DECREASING	7/3/2008
25	<i>Xylocarpus moluccensis</i>	Nyireh batu	Least Concern	DECREASING	7/3/2008

26	<i>Xylocarpus rumphii</i>	Nyireh	Least Concern	NOT AVAILABLE	2013
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Table 4.6: IUCN Red list category and population trend of associates mangrove species collected from Kuantan and Pekan.

NO	SCIENTIFIC NAME	LOCAL NAME	IUCN STATUS	POPULATION TREND	LAST ASSESSMENT
1	<i>Acacia auriculiformis</i>	Akasia kuning	Least Concern	STABLE	8/2/2010
2	<i>Acacia mangium</i>	Akasia lebar	Least Concern	UNKNOWN	31/12/2018
3	<i>Ardisia crispa</i>	Mata pelanduk	Not Available	NOT AVAILABLE	NOT AVAILABLE
4	<i>Ardisia elliptica</i>	Mata itek	Not Available	NOT AVAILABLE	NOT AVAILABLE
5	<i>Asplenium nidus</i>	Paku langsuyar	Not Available	NOT AVAILABLE	NOT AVAILABLE
6	<i>Caesalpinia crista</i>	Kuku tupai	Not Available	NOT AVAILABLE	NOT AVAILABLE
7	<i>Canavalia maritima</i>	Kacang laut	Least Concern	NOT AVAILABLE	NOT AVAILABLE
8	<i>Casuarina equisetifolia</i>	Pokok rhu	Least Concern	STABLE	21/9/2018
9	<i>Cerbera odollam</i>	Pong pong	Least Concern	STABLE	12/6/2018
10	<i>Cissus hastata</i>	Akar kerayong	Not Available	NOT AVAILABLE	NOT AVAILABLE
11	<i>Crotalaria pallida</i>	Kacang kayu	Not Available	NOT AVAILABLE	NOT AVAILABLE
12	<i>Dendrolobium umbellatum</i>	Petai belalang	Least Concern	DECREASING	18/8/2020

13	<i>Derris trifoliata</i>	Derris	Not Available	NOT AVAILABLE	NOT AVAILABLE
14	<i>Dodonaea viscosa</i>	Kayu bertih	Least Concern	STABLE	12/6/2018
15	<i>Excoecaria agallocha</i>	Bebuta	Least Concern	DECREASING	7/3/2008
16	<i>Flagellaria indica</i>	Rotan dini	Not Available	NOT AVAILABLE	NOT AVAILABLE
17	<i>Garcinia xanthochymus</i>	Asam kandis	Least Concern	STABLE	20/8/2020
18	<i>Gardenia tubifera</i>	Delima hutan	Not Available	NOT AVAILABLE	NOT AVAILABLE
19	<i>Glochidion littorale</i>	Jambu kera	Least Concern	STABLE	12/6/2018
20	<i>Heritiera littoralis</i>	Dungun	Least Concern	DECREASING	7/3/2018
21	<i>Hibiscus tiliaceus</i>	Bebaru	Least Concern	UNKNOWN	6/3/2017
22	<i>Ipomea pes-caprae</i>	Pokok tapak kuda	Least Concern	STABLE	2/12/2020
23	<i>Ixora congesta</i>	Jarum – jarum	Not Available	NOT AVAILABLE	NOT AVAILABLE
24	<i>Lantana camara</i>	Bunga tahi ayam	Not Available	NOT AVAILABLE	NOT AVAILABLE
25	<i>Licania splendens</i>	Merbatu	Least Concern	UNSPECIFIED	1/1/1998
26	<i>Memecylon edule</i>	Nipis kulit	Least Concern	UNKNOWN	14/3/2023
27	<i>Merope angulata</i>	Limau lelang	Least Concern	STABLE	1/3/2021
28	<i>Morinda elliptica</i>	Mengkudu	Not Available	NOT AVAILABLE	NOT AVAILABLE

29	<i>Neolitsea sp.</i>		Not Available	NOT AVAILABLE	NOT AVAILABLE
30	<i>Nypa fruticans</i>	Nipah	Least Concern	NOT AVAILABLE	NOT AVAILABLE
31	<i>Pandanus tectorius</i>	Pandan laut	Least Concern	UNKNOWN	31/12/2018
32	<i>Pekan accession</i>		Not Available	NOT AVAILABLE	NOT AVAILABLE
33	<i>Planchonella obovata</i>	Menasi	Not Available	NOT AVAILABLE	NOT AVAILABLE
34	<i>Pluchea indica</i>	Pokok beluntas	Not Available	NOT AVAILABLE	NOT AVAILABLE
35	<i>Psydrax sp.</i>		Not Available	NOT AVAILABLE	NOT AVAILABLE
36	<i>Rhodomyrtus tomentosa</i>	Kemunting	Least Concern	STABLE	12/6/2018
37	<i>Sesuvium portulacastrum</i>	Gelang laut	Least Concern	STABLE	4/12/2020
38	<i>Spinifex littoreus</i>	Rumput bebaling	Not Available	NOT AVAILABLE	NOT AVAILABLE
39	<i>Syzygium grande</i>	Jambu air laut	Not Available	NOT AVAILABLE	NOT AVAILABLE
40	<i>Tamarindus indica</i>	Asam jawa	Least Concern	STABLE	8/3/2017
41	<i>Terminalia catappa</i>	Ketapang	Least Concern	STABLE	31/12/2018
42	<i>Tetracera indica</i>	Mempelas	Not Available	NOT AVAILABLE	NOT AVAILABLE
43	<i>Vitex ovata</i>	Pokok lagundi	Not Available	NOT AVAILABLE	NOT AVAILABLE
44	<i>Vitex pinnata</i>	Leban	Least Concern	STABLE	12/6/2018

45	<i>Volkameria inermis</i>	Bunga pawang	Not Available	NOT AVAILABLE	NOT AVAILABLE
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As indicated by the IUCN Red List of Threatened Species and referenced in Polidoro et al. (2010), the status of all true mangrove species was identified as least concern (LC) except for *Ceriop decandra*, *Sonneratioa ovata* and *Avicennia rhumphiana*. *Avicennia rumphiana* is declared as vulnerable due to its susceptibility to various threats. The population of *A. rhumphiana* is on a declining curve, and the mangrove habitat within its range has experienced a substantial reduction of at least 30% between 1980 and 2005 (Chan et al., 2022). Besides, the biodiversity of the coastal regions of Asian countries like India, Sri Lanka, Indonesia, Burma, Thailand, Singapore, and Malaysia, was severely impacted by the 9.15-magnitude super earthquake and the ensuing tsunami on December 26, 2004. (Nehru et al, 2012).

Coastal development, deforestation, and aquaculture expansion are serious threats to *Avicennia rumphiana* populations due to habitat loss and degradation. From 2000 to 2012, mangrove forests in Southeast Asia saw an average yearly loss rate of 0.18% due to conversion to other land uses influenced by specific circumstances and commodities demands (Richards et al., 2016). Mangroves, vital elements of coastal ecosystems, are being encroached upon and their habitats altered, which is disturbing their delicate balance and jeopardising the species' capacity to flourish. Pollution, especially from industrial runoff and agricultural operations, worsens the difficulties experienced by *A. rumphiana* by affecting water quality and ecosystem health. In contrast, *Sonneratia ovata* and *Ceriops decandra* are designated as near threatened, indicating their populations face potential risks that warrant monitoring and conservation efforts. The decline in *Sonneratia* species is mostly caused by climate change and human disturbance, and inadequate self-regeneration is a barrier to population size recovery (Zhang et al., 2022).

Besides, the survival of *Ceriop decandra* species is under significant threat due to the widespread removal of mangrove areas for coastal development within its entire range (Gomathinayagam et al., 2015). Despite the 'Least Concern' (LC) status, their

declining populations suggest a need for attention and potential conservation efforts, emphasizing the importance of addressing their decreasing numbers.



CHAPTER 5

CONCLUSION AND FUTURE RECOMMENDATION

In general, the study on the diversity of mangrove species and its associates in Kuantan and Pekan has provided preliminary data on their distribution area. A total of 71 species of true mangrove and its associates had been recorded throughout 13 sampling sites at Kuantan and Pekan mangrove area. There are 26 species of true mangrove from 8 families and 45 species of mangrove associates from 30 families. Based on the study, 4 species from Rhizophoraceae family, which are *Bruguiera gymnorhiza*, *B. cylindrica*, *Rhizophora apiculata*, *R.a mucronata*, were observed to be dominance in Kuantan and Pekan. Meanwhile, *Lumnitzera racemosa*, *Sonneratia ovata*, *Xylocarpus moluccensis*, and *X. rumphii* were recorded as the least species found. The study also recorded two species of mangrove fern known as *Acrostichum aureum* and *Acrostichum speciosum*.

As for mangrove associated, *Hibiscus tiliaceus* was recorded as the most dominant species. Other than that, one unknown species noted as *Pekan accession* from Melastomataceae was found at Pekan sampling site. Therefore, a further study regarding *Pekan accession* species should be done in order to understand their characteristic. The remarkable distinctive features of true mangrove and its associates can be seen from its roots, stem, vegetative, and reproductive parts. These distinct characteristics can be used to differentiate between family, genus, and species. The true mangrove species are grown towards the river and sea, meanwhile associates species were found more towards inland and far from the sea.

Among 71 species recorded in this study, 10 selected species from three different group, Pteridaceae, Monocotyledon and Dicotyledon, had been chosen for anatomical analysis. Results indicated that anatomical characteristics can serve as supplementary data for distinguishing between genera and species. The examination of Pteridaceae, Monocotyledon, and Dicotyledon uncovers unique patterns in their shared and varying traits. All three groups exhibit common characteristics, including epidermal

cells with a cuticle layer, hypodermal cells in the lamina and margin, collenchyma cells, and the presence of spongy mesophyll and palisade layers.

Besides that, Pteridaceae and Monocotyledons display a hydrocentric and scattered arrangement of vascular bundles, whereas Dicotyledon species exhibit various shapes of vascular bundles. Both Pteridaceae and Monocotyledons species also showed the presence of bundle sheath extension at their vascular tissues. These groups vary in structural characteristics, including the outline of the petiole, midrib, and margin. Significant distinctions are observed in the type of stomata and the occurrence of mucilage cells, which manifest in various plant regions. Monocotyledons uniquely possess sclerenchyma cells, whereas some Dicotyledons species showed the presence of calcium oxalate.

As for between species in Pteridaceae group, the variation can be seen in the presence of trichome at petiole of *Acrostichum aureum* and type of stomata between the two species. Meanwhile, the difference between two genera in Monocotyledon can be seen in the midrib, where *Pandanus* showed the presence of palisade layer, while the scattered vascular bundle in *Nypa* midrib were enclosed by the sclerenchyma cells. The arrangement and type of vascular tissues can help to differentiate among genera in the Dicotyledon species. Other than that, the type of stomata also can be used as supporting evidence in differentiate between the 4 genera in this study. Results showed that anatomical traits can be used as supporting data in differentiate among the genus and species. There is a clear variable in the arrangement of vascular bundle at petiole and midrib of Pteridaceae and Monocotyledon species with the Dicotyledon species.

Besides that, detailed examination of leaf anatomical features, such as the presence of hypodermal cells, mucilage cells, and aerenchyma, as well as structural adaptations like thick cuticle layers and presence of druse not only facilitate taxonomic delimitation but also shed light on the ecological strategies these species employ to survive in harsh saline environments. This research underscores the value of integrating anatomical analysis into species identification to strengthen biodiversity assessments and inform conservation efforts.

Therefore, future research should prioritize the application of advanced anatomical analysis techniques, such as scanning electron microscopy (SEM). SEM enables high-resolution imaging of cellular structures, stomatal patterns, and surface features, offering greater precision in identifying subtle anatomical differences between species. Such detailed analysis can uncover additional diagnostic traits, enhancing the accuracy of taxonomic studies. Furthermore, combining anatomical and morphological analyses with molecular tools, such as DNA barcoding or phylogenetics, can provide a more comprehensive understanding of species relationships and evolutionary histories, ensuring robust species identification frameworks.

The majority of mangrove plant species are categorized as ‘Least Concern’ by the IUCN, while two species are categorized as ‘Near Threatened’ and one species as ‘Vulnerable’. However, the population trend of true mangrove is showed as decreasing. As for mangrove associated, only 23 species were categorized as ‘Least Concern’ by IUCN while the other status was unknown. Among the 23 species, 13 species were showed stable population trend, 3 species showed decreasing trend, 4 species were unknown and 3 species were unspecified.

This comprehensive species inventory is crucial for understanding the ecological diversity of the area. The findings underscore the richness and complexity of the mangrove ecosystem in Kuantan and Pekan, highlighting the importance of these habitats for biodiversity conservation and ecological research. Such data is essential for informed conservation strategies and underscores the significance of preserving mangrove ecosystems.

Lastly, the findings from this study can be applied to conservation and restoration efforts. For instance, anatomical traits could serve as indicators of stress tolerance, helping to identify species suitable for specific restoration projects. This would not only aid in conserving biodiversity but also ensure the long-term success of mangrove rehabilitation programs. By addressing these recommendations, future research can build upon this study to enhance our understanding of mangrove taxonomy and contribute to the sustainable management of these critical ecosystems.

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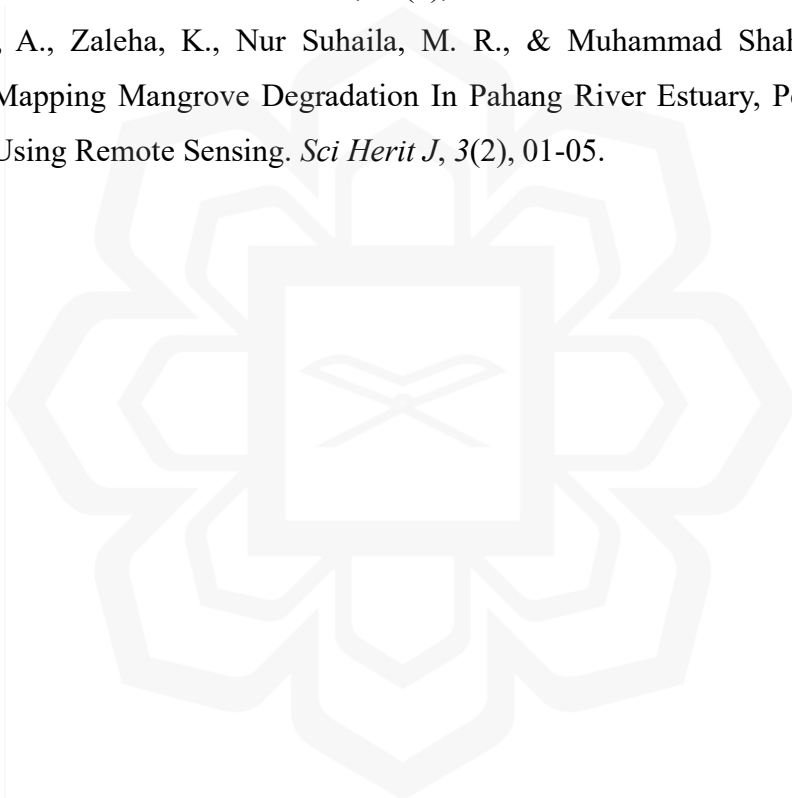
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APPENDIX I

Table 1: List of Publication and Website Used as References for Description and Identification of Associates Mangrove Species

SPECIES	TITTLE	AUTHOR	PUBLICATION	YEAR
<i>Acacia auriculiformis</i>	Acacia auriculiformis (northern black wattle)	J Velez-Gavilan	CABI Compendium	2016
<i>Acacia mangium</i>	Acacia mangium (brown salwood)	Marianne Jennifer Datiles, Pedro Acevedo-Rodriguez	CABI Compendium	2017
<i>Ardisia crispa</i>	Myrsinaceae (Flora of China, Volume 15)	Jie Chen, John J. Pipoly, III	Missouri Botanical Garden Press	1996
<i>Ardisia elliptica</i>	Myrsinaceae (Flora of China, Volume 15)	Jie Chen, John J. Pipoly, III	Missouri Botanical Garden Press	1996
<i>Asplenium nidus</i>	<i>Asplenium nidus</i> L. var. <i>nidus</i>	Flora Fauna Web – National Parks Board (NParks)	Singapore Government Agency Website	2023
<i>Caesalpinia crista</i>	Morphology, Phytochemistry, Traditional Uses of Plant <i>Caesalpinia crista</i> : A Review	Hemant Brijay, Balbir Singh, Zubreena Khan, Rohit Kumar Bijauliya	International Journal of Pharmacy & Pharmaceutical Research	2022
<i>Canavalia maritima</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Casuarina equisetifolia</i>	Casuarinaceae, Flora of Peninsular Malaysia (Volume 1)	Nor Ezzawanis Abdullah Thani	Forest Research Institute Malaysia (FRIM)	2010
<i>Cerbera odollam</i>	Apocynaceae, Flora of Peninsular Malaysia (Volume 2)	David John Middleton	Forest Research Institute Malaysia (FRIM)	2011

<i>Cissus hastata</i>	Conservation Status of <i>Cissus</i> L. (Vitaceae) Of Singapore: With A Special Note on <i>Cissus Repens</i> Lam.	C. K. Yeo, W. F. Ang, Alvin F. S. L. Lok and K. H. Ong	National University of Singapore	2012
<i>Crotalaria pallida</i>	Morphological, Anatomical Characters and Antimicrobial Activity of <i>Crotalaria pallida</i> Aiton.	Thaw Maw Moe	3 rd Myanmar Korea Conference Researc Journal Vol 3, No.3	2020
<i>Dendrolobium umbellatum</i>	<i>Dendrolobium umbellatum</i> (L.) Benth.	Flora Fauna Web – National Parks Board (NParks)	Singapore Government Agency Website	2023
<i>Derris trifoliata</i>	<i>Derris trifoliata</i> Lour.	Flora Fauna Web – National Parks Board (NParks)	Singapore Government Agency Website	2023
<i>Dodonaea viscosa</i>	Sapindaceae, Flora of Peninsular Malaysia (Volume 6)	Peter C. van Welzen	Forest Research Institute Malaysia (FRIM)	2017
<i>Excoecaria agallocha</i>	A study on morphological and anatomical features of <i>Acanthus ilicifolius</i> L. and <i>Excoecaria agallocha</i> L. selected from Ayiramthengu of Kollam district, Kerala	Fouzia Hilal, Soumya Hilal	The Pharma Innovation Journal	2019
<i>Flagellaria indica</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Garcinia xanthochymus</i>	<i>Garcinia xanthochymus</i> Hook. f. ex T. Anders.	Flora Fauna Web – National Parks Board (NParks)	Singapore Government Agency Website	2023
<i>Gardenia tubifera</i>	<i>Gardenia tubifera</i> Wall.	Flora Fauna Web – National Parks Board (NParks)	Singapore Government Agency Website	2023

<i>Glochidion littorale</i>	<i>Glochidion littorale</i> Blume	Flora Fauna Web – National Parks Board (NParks)	Singapore Government Agency Website	2023
<i>Heritiera littoralis</i>	<i>Heritiera littoralis</i> Aiton	Flora Fauna Web – National Parks Board (NParks)	Singapore Government Agency Website	2023
<i>Hibiscus tiliaceus</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Ipomea pes-caprae</i>	Convolvulaceae, Flora of Peninsular Malaysia (Volume 5)	GeorgemWilliam Staples, Syahida Emiza Suhaimi	Forest Research Institute Malaysia (FRIM)	2015
<i>Ixora congesta</i>	<i>Ixora congesta</i> Roxb.	Flora Fauna Web – National Parks Board (NParks)	Singapore Government Agency Website	2023
<i>Lantana camara</i>	<i>Lantana camara</i> (lantana)	Sarah Elizabeth Thomas	CABI Compendium	2015
<i>Licania splendens</i>	Chrysobalanceae, Flora of Peninsular Malaysia (Volume 3)	Ghilleen Tolime Prance	Forest Research Institute Malaysia (FRIM)	2013
<i>Memecylon edule</i>	Memecylacaceae, Flora of Peninsular Malaysia (Volume 4)	Mark Hughes	Forest Research Institute Malaysia (FRIM)	2013
<i>Merope angulata</i>	<i>Merope angulata</i> (Willd.) Swingle	Flora Fauna Web – National Parks Board (NParks)	Singapore Government Agency Website	2023
<i>Morinda citrifolia</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Neolitsea sp.</i>	NEOLITSEA (Benthams & J. D. Hooker) Merrill, Philipp. J. Sci. 1(Suppl. 1): 56. 1906, nom. Cons (Flora of China, Volume 7)	Huang Puhua, Henk van der Werff	Missouri Botanical Garden Press	2008

<i>Nypa fruticans</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Pandanus tectorius</i>	<i>Pandanus tectorius</i> (pandanus)	Lex A.J. Thomson, Lois Englberger, Luigi Guarino, R.R Thaman, Craig R. Elevitch	Species Profile Island Agroforestry	2006
<i>Planchonella obovata</i>	<i>Planchonella obovata</i> (R. Br.) Pierre	Flora Fauna Web – National Parks Board (NParks)	Singapore Government Agency Website	2023
<i>Pluchea indica</i>	<i>Pluchea indica</i> (Indian camphorweed)	Chris Parker	CABI Compendium	2012
<i>Psydrax</i> sp.	Rubiaceae (Flora of China Volume 19)	Tao Chen, Xianrui Luo, Hua Zhu, Charlotte M. Taylor, Friedrich Ehrendorfer, Henrik Lantz, Michele Funston, Christian Puff	Missouri Botanical Garden Press	2011
<i>Rhodomyrtus tomentosa</i>	<i>Rhodomyrtus tomentosa</i> (Downy rose-myrtle)	Danieelle Frohlich	CABI Compendium	2012
<i>Sesuvium portulacastrum</i>	Aizoaceae, Flora of Peninsular Malaysia (Volume 7)	Syahida Emiza Suhaimi	Forest Research Institute Malaysia (FRIM)	2018
<i>Spinifex littoreus</i>	<i>Spinifex littoreus</i> (Burm.f.) Merr.	Royal Botanic Garden, Kew	Royal Botanic Garden, Kew	2023
<i>Syzygium grande</i>	<i>Syzygium grande</i> (sea apple)	M. J Datiles	CABI Compendium	2015
<i>Tamarindus indica</i>	<i>Tamarindus indica</i> L.	Flora Fauna Web – National Parks Board (NParks)	Singapore Government Agency Website	2023
<i>Terminalia catappa</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Tetracera indica</i>	<i>Tetracera indica</i> (Christm. & Panz.) Merr.	Flora Fauna Web – National Parks Board (NParks)	Singapore Government Agency Website	2023

<i>Vitex ovata</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Vitex pinnata</i>	<i>Vitex pinnata</i>	Flora Fauna Web – National Parks Board (NParks)	Singapore Government Agency Website	2023
<i>Volkameria inermis</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007



APPENDIX II

Table 1: List of Publication and Website Used as References for Description and Identification of True Mangrove Species

SPECIES	TITLE	AUTHOR	PUBLICATION	YEAR
<i>Acrostichum aureum</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Acrostichum speciosum</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Aegiceras corniculatum</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Avicennia alba</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Avicennia marina</i>	<i>Avicennia marina</i> (Forssk.) Vierh.	Flora Fauna Web – National Parks Board (NParks)	Singapore Government Agency Website	2023
<i>Avicennia officinalis</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Avicennia rumphiana</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Bruguiera cylindrica</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Bruguiera gymnorhiza</i>	<i>Bruguiera gymnorhiza</i> (large-leafed mangrove)	James A. Allen, Norman C. Duke	Species Profiles for Pacific Agroforestry	2006
<i>Bruguiera parviflora</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Bruguiera sexangula</i>	The <i>Bruguiera</i> (Rhizophoraceae) Species in the Mangroves of Singapore,	Chiou-Rong Sheue, Jean W. H. Yong, Yuen-Po Yang	National Taiwan University	2005

	especially on the New Record and the Rediscovery			
<i>Ceriops decandra</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Ceriops tagal</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Kandelia candel</i>	<i>Kandelia candel</i> (L.) Druce	Flora Fauna Web – National Parks Board (NParks)	Singapore Government Agency Website	2023
<i>Lumnitzera littorea</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Lumnitzera racemosa</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Rhizophora apiculata</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Rhizophora mucronata</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Scyphiphora hydrophylacea</i>	Mangrove Guidebook for Southeast Asia	Wim Giesen, Stephan Wulffraat, Max Zieren, Liesbeth Scholten	Wetlands International	2007
<i>Sonneratia alba</i>	Lythraceae, Flora of Peninsular Malaysia (Volume 8)	Willem J.J.O De Wilde, Brigitta E.E Duyfjes, Siti Munirah Mat Yunoh	Forest Research Institute Malaysia (FRIM)	2021
<i>Sonneratia caseolaris</i>	Lythraceae. Flora of Peninsular Malaysia (Volume 8)	Willem J.J.O De Wilde, Brigitta E.E Duyfjes, Siti Munirah Mat Yunoh	Forest Research Institute Malaysia (FRIM)	2021
<i>Sonneratia ovata</i>	Lythraceae, Flora of Peninsular Malaysia (Volume 8)	Willem J.J.O De Wilde, Brigitta E.E Duyfjes, Siti Munirah Mat Yunoh	Forest Research Institute Malaysia (FRIM)	2021
<i>Xylocarpus granatum</i>	Meliaceae, Flora of Peninsular Malaysia (Volume 4)	David John Mabberly, Caroline Mary Pannel, Toona by Jennifer M. Edmond	Forest Research Institute Malaysia (FRIM)	2013

<i>Xylocarpus moluccensis</i>	Meliaceae, Flora of Peninsular Malaysia (Volume 4)	David John Mabberly, Caroline Mary Pannel, Toona by Jennifer M. Edmond	Forest Institute (FRIM)	Research Malaysia	2013
<i>Xylocarpus rumphii</i>	Meliaceae, Flora of Peninsular Malaysia (Volume 4)	David John Mabberly, Caroline Mary Pannel, Toona by Jennifer M. Edmond	Forest Institute (FRIM)	Research Malaysia	2013



APPENDIX III

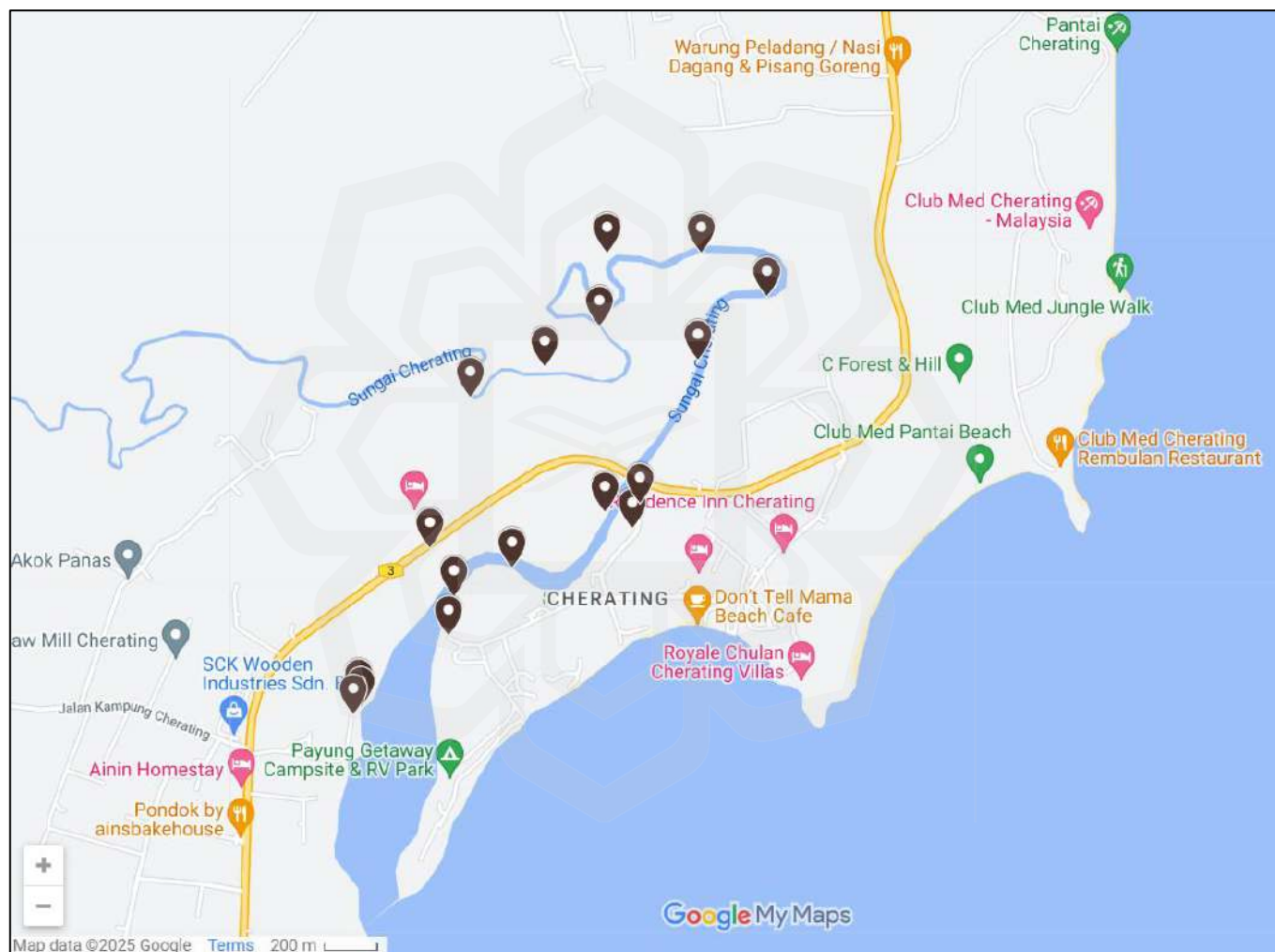


Figure 1: Species distribution at Cherating, Kuantan

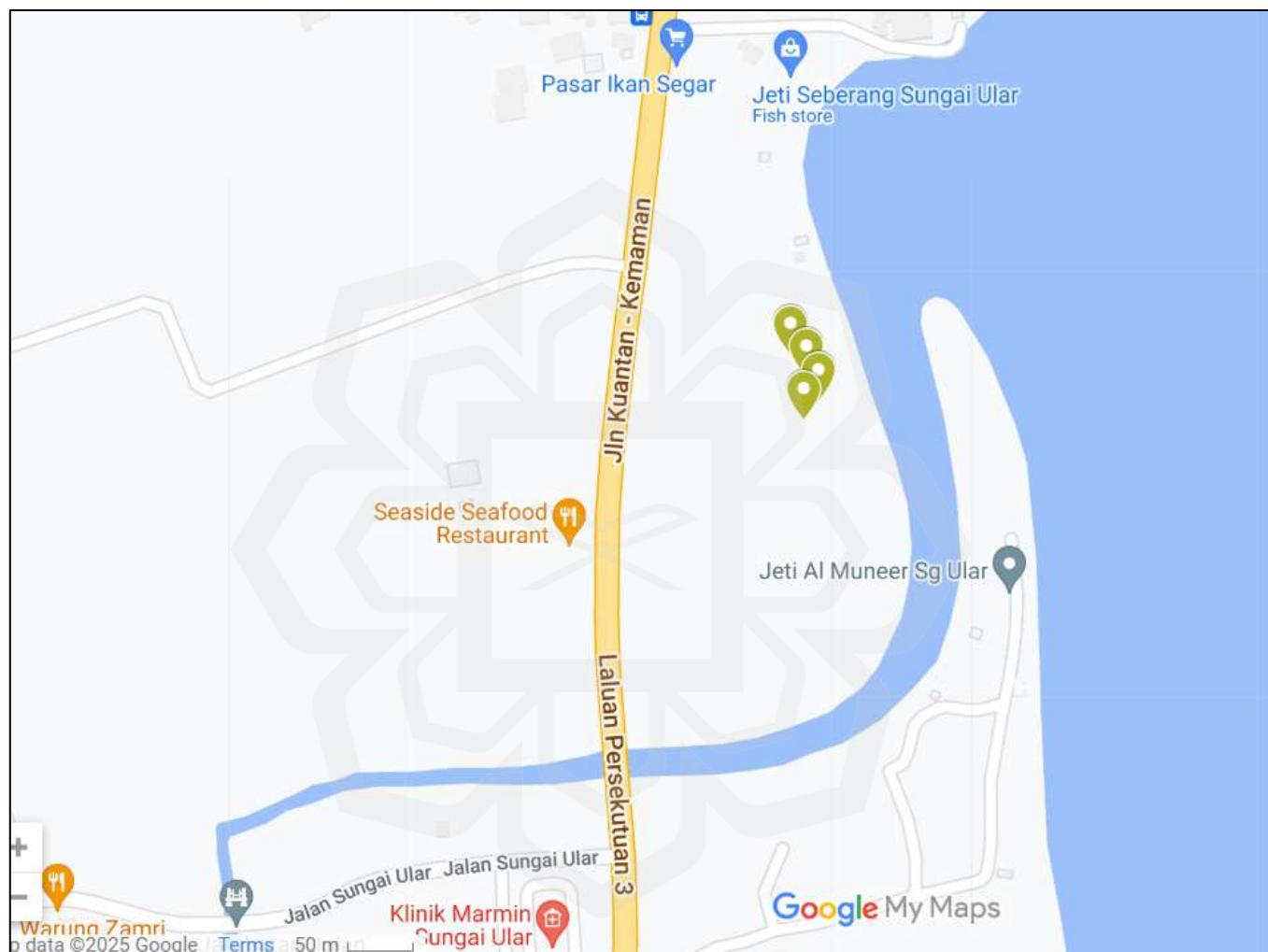


Figure 2: Species distribution at Sg.Ular , Kuantan

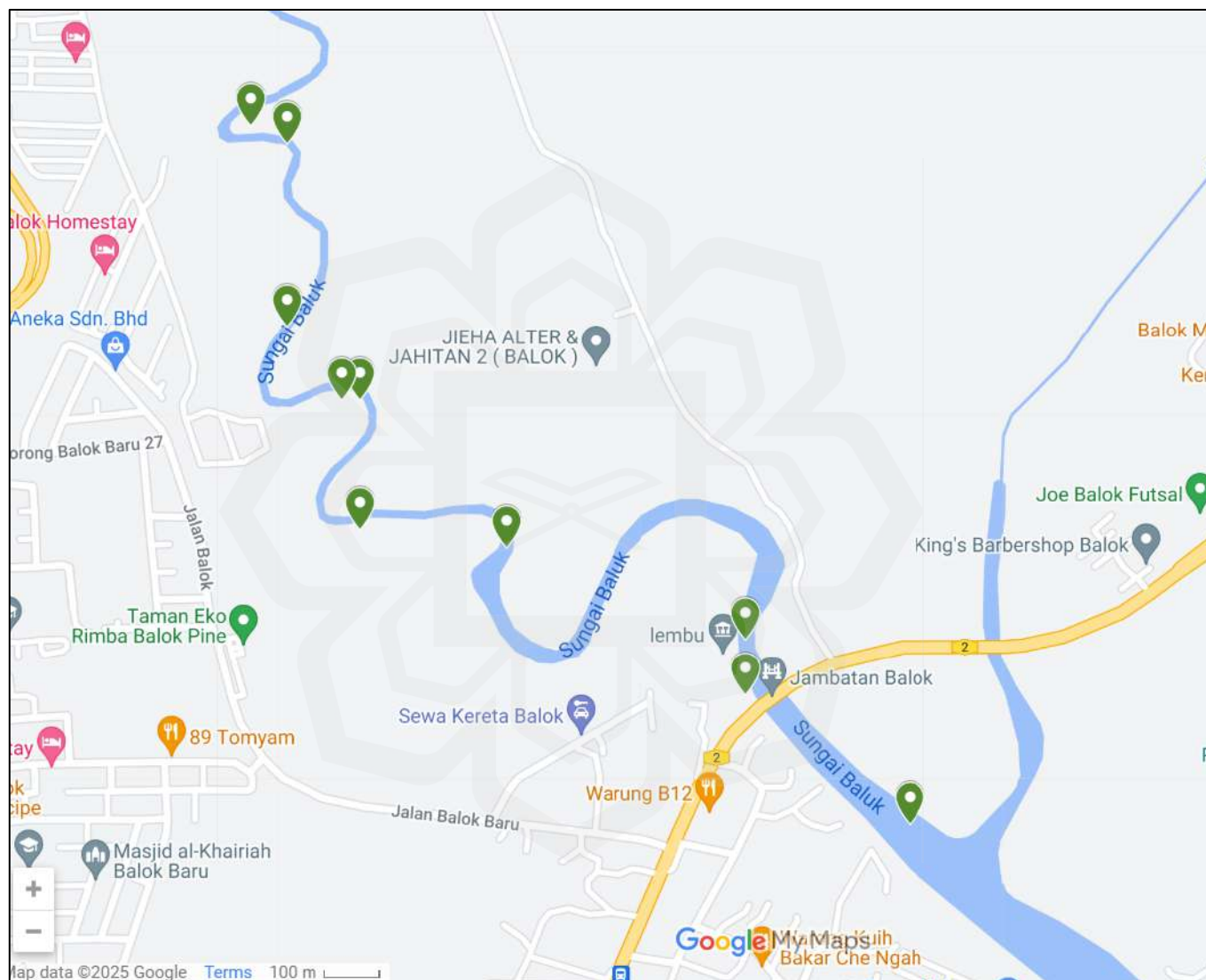


Figure 3: Species distribution at Sg. Balok, Kuantan

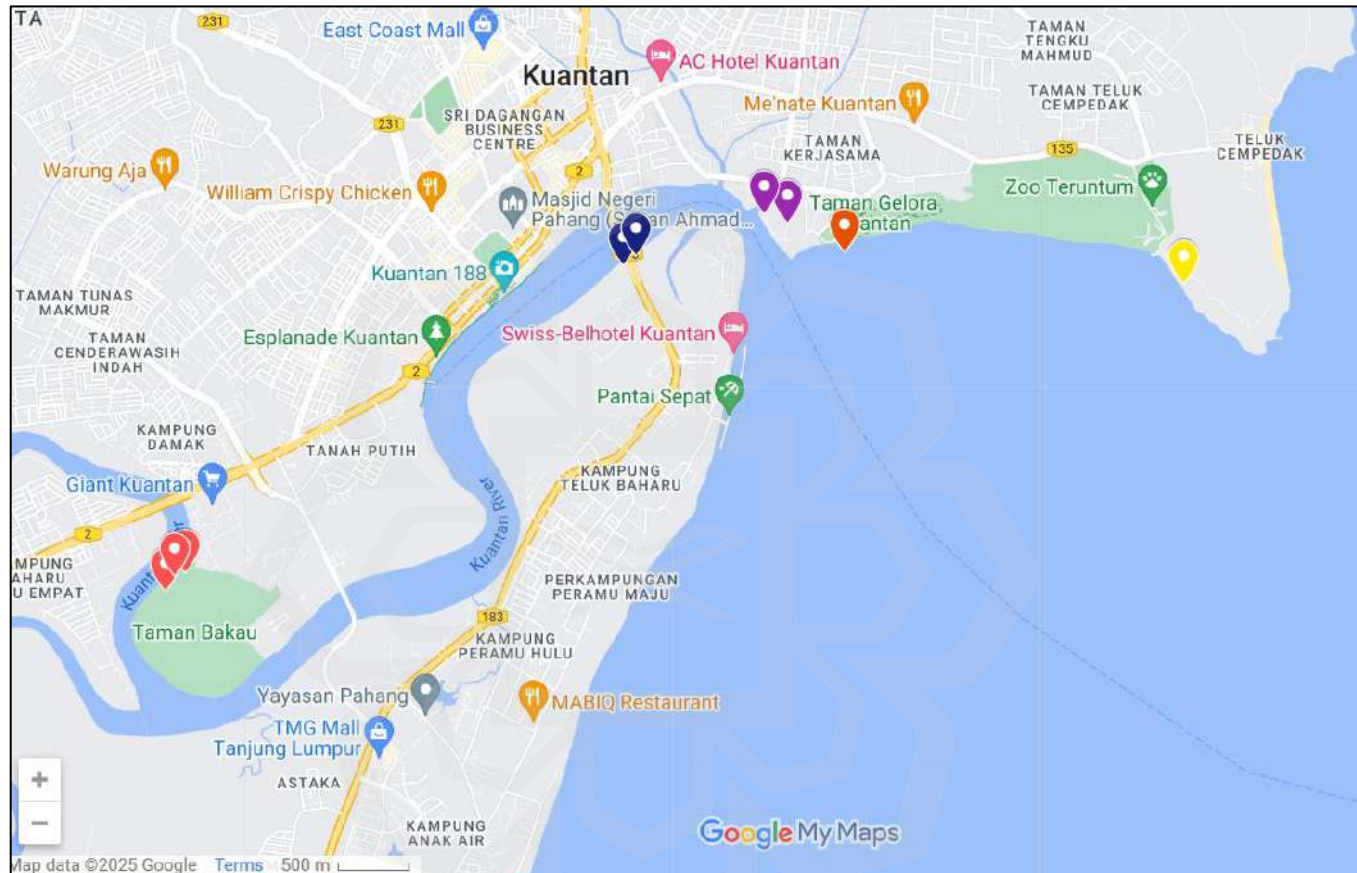


Figure 4: Species distribution at Teluk Sisek (Yellow), Taman Gelora (Red), Tanjung Api (Purple), Tanjung Lumpur (Blue), Widad Riverfront Apartment (Pink), Kuantan.

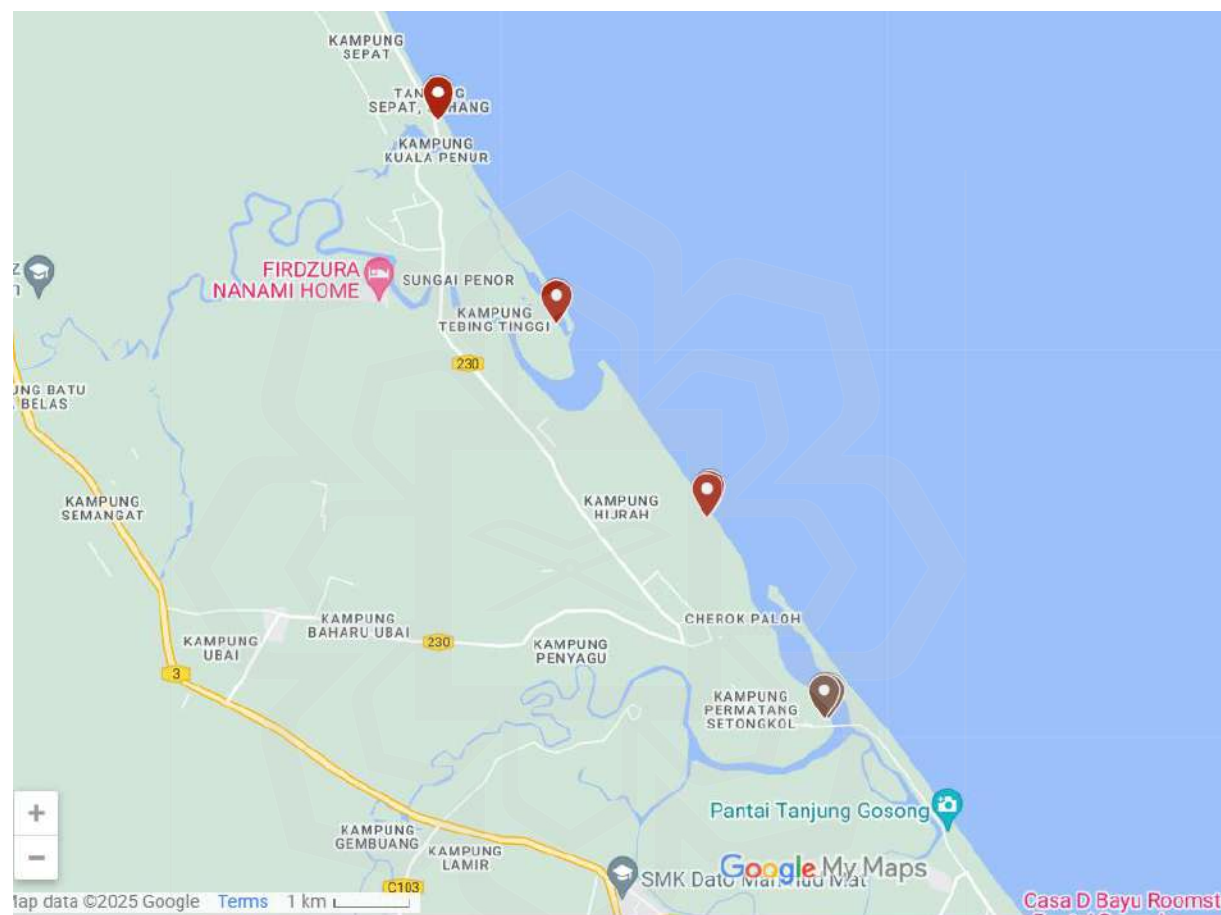


Figure 5: Species distribution at Pantai Sepat (Maroon) and CheroK Paloh (Grey) Kuantan

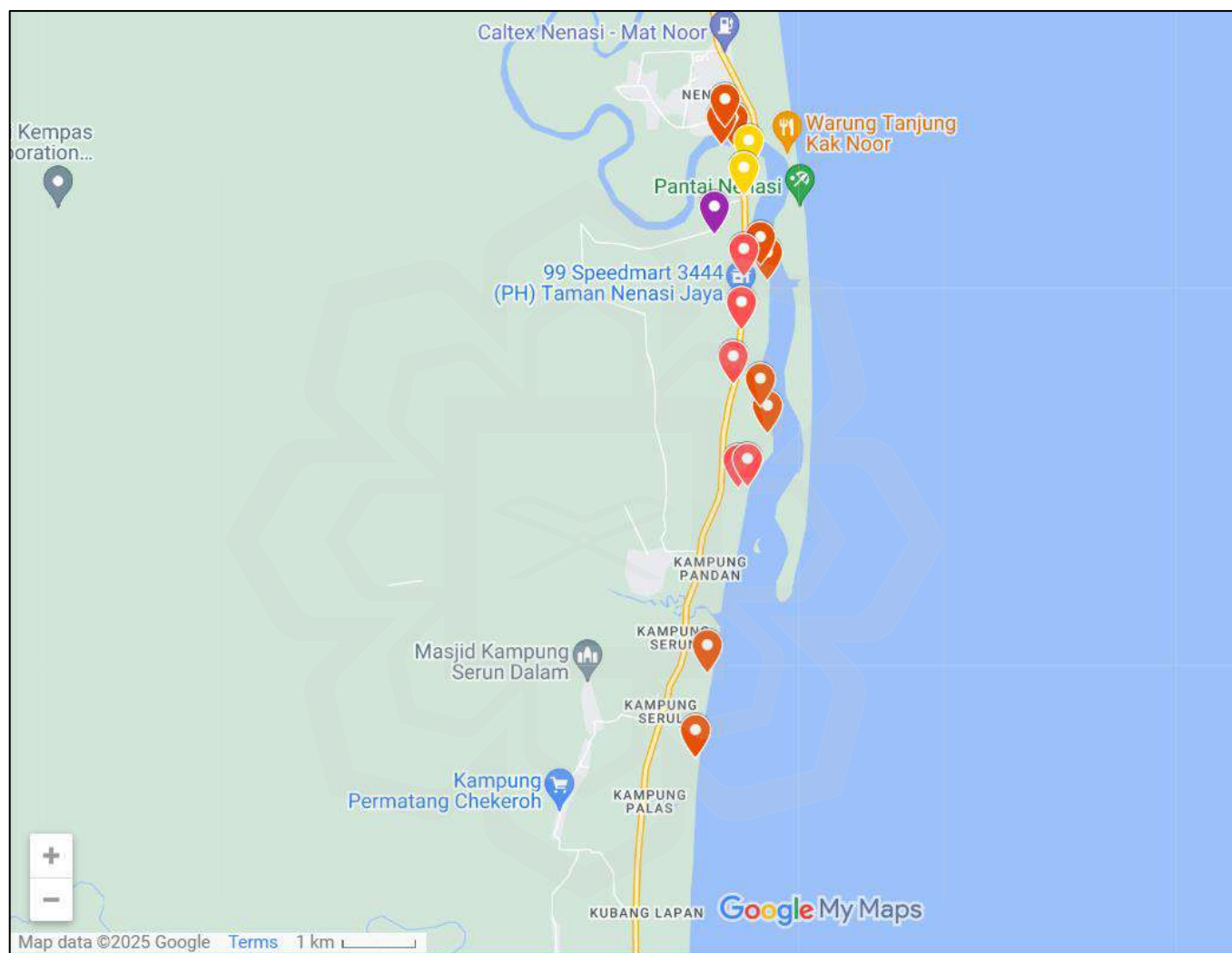


Figure 6: Species distribution at Sg. Nenasi and Pekan