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Diversity of Anatomical Morphological Characters of Leaves of Mangrove Plant Types in Panimbang Banten

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Abstract

Mangroves are plants that produce seeds (spermatophyta), mangroves also have many benefits, namely as an economic or ecological function. Mangrove plants have different types of leaf shapes. Leaves have the task of absorbing nutrients andgases, as well as processing food through the process of photosynthesis. This study aims to determine the differences in leaf shape based on morphological and anatomical characters. The method used is exploration and preparation of preservedpreparations. The samples used were some mangrove leaves found in Panimbang District. The stages of the research are starting with taking the third leaf sample, observing the morphological characters of the leaves, taking samples. Parameters used to observe morphological characters were leaf shape, base shape, leaf tip, leaf length, width and length of petiole. Anatomical character of shape and number of stomata, shape and length of palidase.

Keywords: Mangrove leaves; Morphology; Anatomy.

INTRODUCTION

Indonesia is one of the countries in the world that is blessed with abundant natural wealth and biodiversity. One of the biodiversity riches in Indonesia is mangrove forests, which have irreplaceable functions and roles. Mangroves have economic and ecological functions, such as reducing the impact of hurricanes and tsunamis, as well as being a buffer for the population and wildlife around them (Kathiresan, 2011). Indonesia has the largest mangrove forest in the world, covering around 21% of the total area of mangroves in the world. Mangroves in Indonesia are spread across islands such as Java, Sumatra, Kalimantan, Sulawesi, to Papua, with varying areas depending on the physical conditions, substrate composition, and climate on the islands (Spalding et al., 2010).

Banten is a province on the island of Java that has various ecosystems, including mangrove ecosystems that provide high value and benefits to the surrounding community. The mangrove forest area in the Pandeglang area, Panimbang District, has various types of mangroves. Pandeglang, as one of the regencies in Banten Province, is famous for its natural and culinary tourism. The pristine natural conditions make the mangrove forest in Panimbang District a new tourist attraction that is starting to be known to many people, with beautiful views of various types of mangroves (Pertiwi, 2021).

The coast of Pandeglang Regency has a large potential for mangrove ecosystems. In 2015, the total number of mangroves along the coast of Pandeglang Regency reached 1,764 ha, but this area decreased by around 18% in 2020. The reduction in mangrove ecosystems was triggered by community activities that cut down mangroves to be used as animal feed, as well as the tsunami disaster on the west coast of Banten in 2018 due to the eruption of Anak Krakatau (Horstman et al., 2014). Riyandani (2017) and Melati (2020) stated that a good mangrove ecosystem can protect coastal areas from tsunami wave energy by up to 50%. The existence of mangrove ecosystems as coastal protectors from climate change mitigation in Banten Province has proven to be very important. Areas protected by mangrove ecosystems experienced minimal damage compared to open areas during the tsunami disaster in 2018 (Horstman et al., 2014).

Mangrove forests are a type of forest that grows in tidal areas, such as protected beaches, lagoons, and river estuaries, which are inundated at high tide and free from inundation at low tide. The mangrove forest area in Panimbang District has a diversity of mangroves that is not yet fully known. The mangrove ecosystem consists of organisms (animals and plants) that interact with environmental factors in the mangrove habitat (Sofian et al., 2012). The structure of mangrove roots that can deposit sediment protects the coast from the ebb and flow of sea water and strong waves, so that mangroves are

useful for preventing coastal abrasion that can erode coastal land (Susanto & Etwin, 2011).

Mangroves have an important function as a habitat for biota, a stopover for migrant fauna, a place for spawning, nurturing, and foraging, a protector of the marine ecosystem, a protector of the coast from abrasion and tsunamis, a preventer of sea water intrusion, and the lungs of the earth. The potential and benefits of mangroves include forest products (timber and non-timber), fish, shellfish, molluscs, food, sources of medicine, and tourist areas (Kordi & Ghufran, 2012). The characteristics of mangrove forests usually grow in intertidal areas with muddy, clayey, and sandy soil, periodically inundated with water every high tide. Waterlogging determines the composition of mangrove forest soil. Mangrove plants have difficulty growing in areas with large waves and strong currents that allow mud to settle. Physically, mangrove forests maintain a stable coastline, prevent sea erosion, and function as wave dampers and waste pollution (Saputra, 2016).

The characteristics of mangrove leaves vary, especially in thickness, surface, tip shape, and base of the leaf. Various types of mangrove leaves can be found in various regions, including in Panimbang District.

The results of this study are expected to be useful for all parties, namely to increase insight into the diversity of morphological and anatomical characters of mangrove leaves, as well as additional information and comparison for further research, providing information on the diversity of morphological and anatomical characters of mangrove leaves.

This study aims to determine the diversity of leaves of mangrove plant species in Panimbang, Pandeglang, Banten; to determine the morphological characteristics of mangrove leaves in Panimbang, Pandeglang, Banten; and to determine the anatomical characteristics of leaves of mangrove plant species found in Panimbang District, Pandeglang, Banten.

LITERATURE REVIEW

Mangrove Plants

Description

Mangrove forests are complex ecosystems that significantly affect the surrounding area. This ecosystem is ecologically and economically productive, offering various benefits such as preventing coastal erosion, accelerating land expansion, regulating seawater intrusion, and protecting against waves and tsunamis (Setiawan, 2013). Mangroves also function as wave and storm wind absorbers, coastal protection from abrasion, sediment traps, preventing seawater intrusion, and are able to neutralize water pollution (Wiharyanto & Laga, 2010). Mangroves act as buffer zones and shoreline protection (Lungquist et al., 2017) and are found on the coast that is protected from large waves in tropical and subtropical regions (FAO, 2007). Mangrove forests support coastal fisheries, produce commercial forest products, and protect coastlines (Rotich et al., 2016). These plants live between land and sea in tropical and subtropical latitudes with high salinity conditions, tides, strong winds, high temperatures, and anaerobic soil (Kathires & Bingham, 2001).

Mangroves have the ability to live in areas with high salinity and changing water conditions, with anaerobic soil (Nugraha, 2011). This vegetation grows on muddy soil in tidal areas, beaches, and river estuaries (Hotden, 2014).

Mangrove Classification

Plant grouping depends on the variety of organs and plant parts that form a unit, and these structures are given binomial names to describe their complexity. Higher taxon terms are broader and less concrete (Aziz et al., 2021).

Figure 1. Rhizophora mucronata

Rhizophora mucronata (Noor, 2012) is included in the Kingdom Plantae, Division Magnoliophyta, Class Magnoliopsida, Order Malpighiales, Family Rhizophoraceae, and Genera Rhizophora. Avicennia marina (Rizky, 2019) is also in the Kingdom Plantae, Division Magnolyophyta, Class Magnoliopsida, Order Lamiales, Family Acanthaceae, and Genera Avicennia. Avicennia is known as a mangrove pioneer that grows on the shores of the sea and rivers. This tree is useful as a medicine and soap ingredient. It grows in muddy places with upright breathing roots, smooth skin, and leaves with spots on the surface (Noor et al., 2006).

Figure 2. Bruguiera cylindrica.

Bruguiera cylindrica (Maghfiroh, 2010) is included in the Kingdom Plantae, Division Magnoliophyta, Class Magnoliopsida, Order Myrtales, Family Rhizophoraceae, and Genera Bruguiera. B. cylindrica grows on mature substrates with respiratory roots to obtain oxygen. The flowers are light and floating, and are used as firewood. The flowers are in groups of three with yellowish green petals (Rosadi, 2013).

Figure 3. *Rhizophora apiculate.*

Rhizophora apiculata (Saptarini et al., 2012) is included in the Kingdom Plantae, Division Magnoliophyta, Class Magnoliopsida, Order Malpighiales, Family Rhizophoraceae, and Genera Rhizophora. R. apiculata grows in muddy and flooded soil, with elliptical leaves with small black spots. The flowers are paired with brownish yellow corollas, and hypocotyls that are green when young and red when old (Saptarini et al., 2012).

Leaf Morphological Characteristics

Characteristics comes from the English word "character" which implies nature or character. In Indonesian, character means a trait that shows the appearance or condition of an item. In science, characteristics are often associated with the morphological life system and quality of each plant. Plant characteristics must be visible from the roots, stems, and leaves.

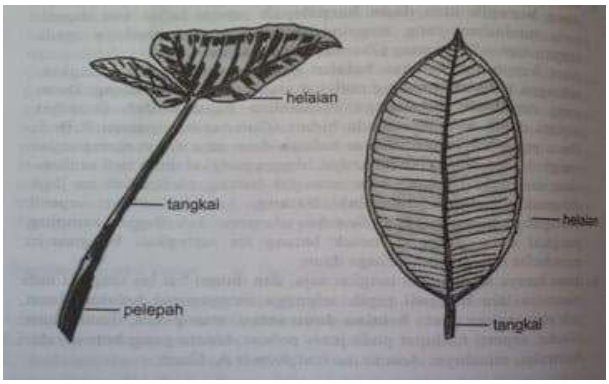

Figure 4. Morfology leaves.

Leaves are important organs for plants, usually thin, wide, and green in color due to chlorophyll. Leaves play a role in photosynthesis, gas exchange, and water evaporation. Leaves have parts such as stalks (petiolus), blades (lamina), and sometimes sheaths (vagina). Complete leaves have all three parts, while incomplete leaves only have blades and stalks.

The morphological characteristics of leaves include the overall shape, base tip, surface, and leaf layout. Leaf shape is important in taxonomic morphology because it is a characteristic of a species. In compound leaves, special attention is paid to the leaflets. Morphological characters are also used in the classification and grouping of plants.

Leaf anatomy includes oxalate crystals, fibers in the vascular bundles, and five main tissue layers: adaxial epidermis, hypodermis, palisade, sponge, and abaxial epidermis. Observations were made using the paraffin and leaf clearing methods to see the stomatal index and palisade ratio.

The leaf epidermis consists of one or more layers of cells, often experiencing cuticle thickening. Stomata in the epidermis function as a place for gas and water exchange. The compact structure of the epidermis and the presence of cuticles help in the reinforcing function of the leaf.

Mesophyll is a layer of basic tissue between the upper and lower epidermis, consisting of parenchyma rich in chloroplasts for photosynthesis. The columnar and spongy tissues in the mesophyll help in gas exchange and photosynthesis efficiency.

The transport tissue in the leaf forms the leaf veins, consisting of xylem and phloem. In dicotyledonous plants, the leaf veins form a net, while in monocotyledons they form parallel rows.

The reinforcing tissue in the form of collenchyma and sclerenchyma is located near the leaf veins and the edges of the leaf. Collenchyma has cell walls coated with cellulose and pectin, helping in the mechanical strength of the leaf.

Secretory tissue in the form of glands that secrete secretions, found on the surface or inside of the leaf. These glands secrete various kinds of secretions and can function in defense against insect attacks.

Trichomes are epidermal derivatives in the form of hairs that grow on epidermal cells, functioning in defense against insects. Trichomes are divided into non-glandular and glandular, with various shapes and structures.

Stomata are modifications of epidermal cells that play a role in gas and water exchange. Stomata are surrounded by neighboring cells that regulate the width of the gap, helping in controlling evaporation and photosynthesis efficiency.

Framework of Thought

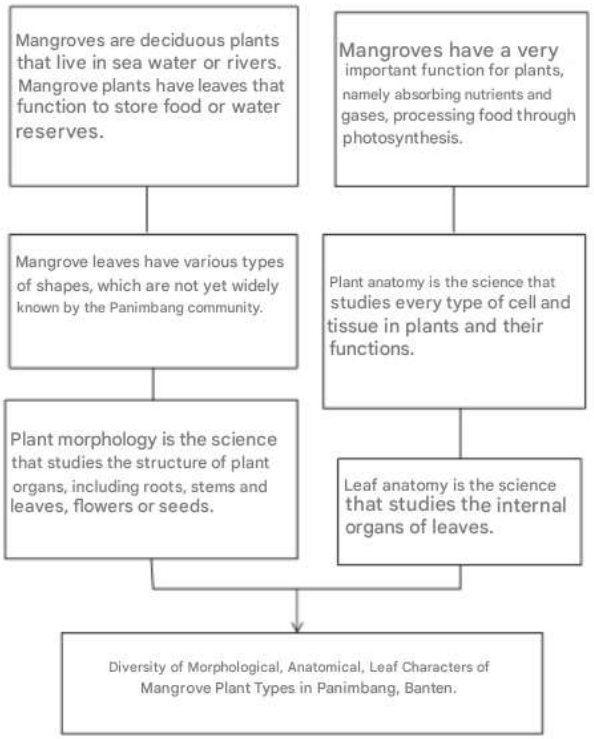

Figure 5. Framework of Thought

Hypothesis

H1 = Several leaves of mangrove plants in the Panimbang Banten area have different morphological forms.

H2 = Mangrove leaves in the Panimbang sub-district have the same anatomical structure as the others

Relevant Research

Hadi et al. (2016) studied the morpho-anatomical characteristics of the vegetative structure of the Rhizophora apiculata species and found that the morphological leaves of Rhizophora apiculata have leaf stalks 10-50 cm long and are whitish brown in color (Jurnal Pendidikan, 1(9): 166-1692). Tihurua et al. (2020) found cuticles with different thicknesses and water storage tissue in mangroves in the form of sub-epidermis in the mangrove zonation area in the Banggai Islands, Central Sulawesi (Jurnal Kelautan Tropical, 23(2): 255-264). Tobing et al. (2021) observed Avicennia marina leaf preparations consisting of upper (adaxial) and lower (abaxial) epidermis tissue (Bulletin of Anatomy and Physiology, 6(1): 2541-0083). Rizki et al. (2015) noted that the morphology of the Bruguiera cylindria plant has elliptical-ovate leaves and green hypocotyl (Jurnal Sainstek, 9(1): 26-32). Sabandar et al. found that the Rhizophora apiculata mangrove has an anomastic stomata type with neighboring cells surrounding the stomata cells and various epidermal cell shapes, ranging from square to octagonal with irregular lengths (Jurnal Biologi Science dan Education, 10(1): 2252-858).

RESEARCH METHOD

This study uses a qualitative field research type. According to Melong (2013), qualitative research involves direct observation in the field to understand phenomena in a particular context. The approach used is naturalistic, with exploration techniques in the field and in the Mathla'ul Anwar University Laboratory. Preparation of preparations was carried out at the Structure and Development Laboratory of Gadjah Mada University (UGM). Research on the morphological and anatomical characteristics of mangrove leaves in Panimbang District was carried out from November 2023 to February 2024.

Research Tools and Materials

The tools used in leaf morphology research include a digital camera, knife or scissors, pencil, description book, label, plastic bag, cardboard, and ruler. While the tools used in leaf anatomy research include a sliding microtome, petri dish, surgical blade, cutter, dropper pipette, flacon, small brush, hotplate, object glass, cover glass (18 mm x 18 mm), label paper, magnifying glass, light microscope, slide glass, micrometer object, micrometer eyepiece, and microphotography.

The materials used in the leaf morphology study were several types of mangrove plants taken from Panimbang District. Meanwhile, the materials used for leaf anatomy observations were samples in the form of leaves from three types of mangrove plants originating from Panimbang District, Pandeglang Regency. The chemicals used to make anatomical preparations included 70%, 80%, 95%, and absolute alcohol, xylol, a mixture of alcohol-xylol with various concentrations (3:1, 1:1, 1:3), Canadian balsam, glycerin or albumin, chloral hydrate, distilled water, and nail polish.

Work Procedure

1) Sampling

The sampling technique is carried out using two methods: first, through the field exploration method which includes direct observation of the morphology of various types of mangrove leaves for inventory, identification, and description such as shape, blade, tip, base, edge, and color of the upper and lower surfaces of the leaves. Second, for research in the structure and development laboratory, the samples used are leaves from various types of mangroves found in Panimbang District, Pandeglang. The leaf morphology work stage includes observation and measurement of various characteristics such as leaf shape, base, tip, color of the upper and lower surfaces, texture, color of the leaf stalk, venation, phyllotaxis, and measurement of dimensions

such as leaf width, leaf length, stalk length, and stalk diameter.

2) Leaf Anatomy Observation Work Procedure

The initial stage includes cutting the leaves to a size of 1x1 cm, then soaking them in a plakon bottle containing 70% alcohol for fixation. After 24 hours, dehydration was carried out with graded alcohol solutions (70%, 80%, 95%, 100%) for two times with 30 minutes each. The dealcoholization process was carried out with alcohol/xylol solutions in a ratio of 3:1, 1:1, 1:3, followed by pure xylol twice for 30 minutes. Furthermore, the samples were infiltrated with a mixture of xylol/paraffin 1:9 at a thermostat of 57°C for 24 hours, then pure paraffin was used for one hour before making paraffin blocks in a petri dish smeared with 15% glycerin. Paraffin slices with a thickness of 12 microns were made using a rotary microtome, then the slices were placed on a glass object smeared with glycerin/albumin and distilled water, then heated on a hot plate at 45°C to stretch the paraffin. Staining was carried out with pure xylol, a mixture of alcohol/xylol, and graded alcohol solutions, followed by 1% safranin staining in 70% alcohol. After staining, it was continued with graded alcohol and a mixture of alcohol/xylol before being covered with Canadian balsam. The preparations were dried on a 45°C hot plate and labeled before being observed using a microscope with 4x, 10x, and 40x objective lenses. The parameters observed included the shape and type of stomata, as well as other characteristics such as leaf thickness, epidermis, trichomes, palisade, stomatal density, vascular tissue, and leaf veins.

Research Flowchart

Observation of Leaf Morphological Characters

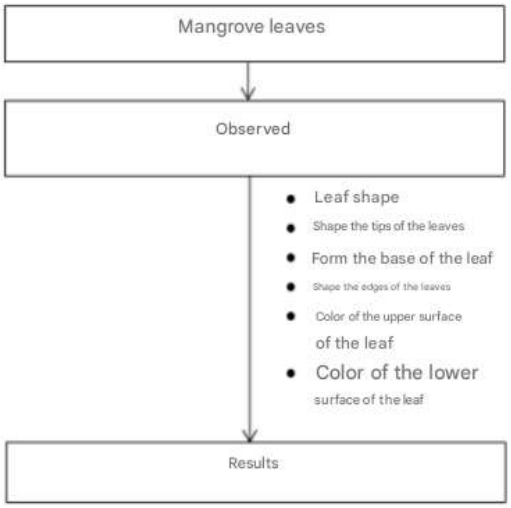

Figure 6. Observation of Leaf Morphological Characters.

Observation of Leaf Anatomy

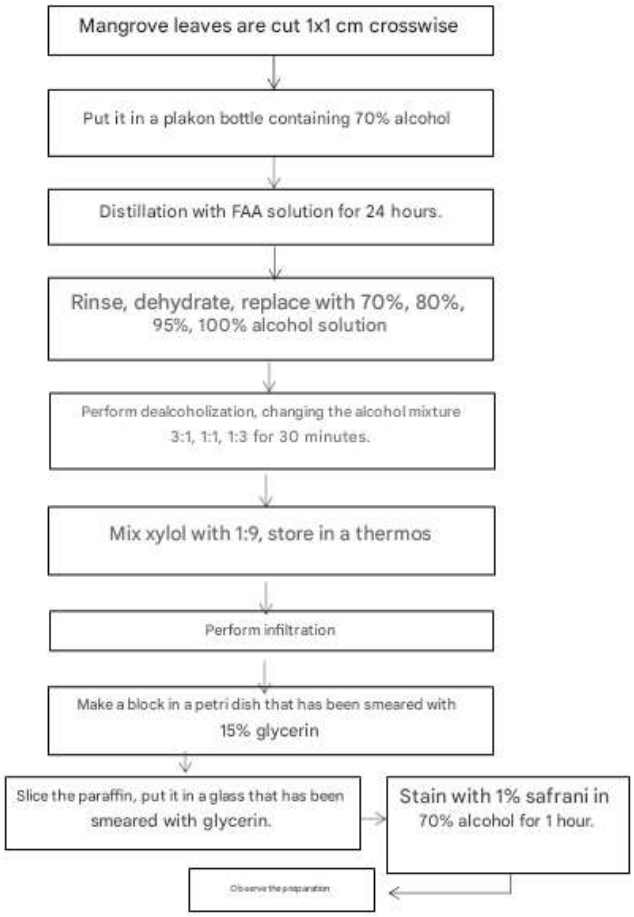

Figure 7. Observation of Leaf Anatomy.

Data Analysis

Morphological and anatomical characteristics of mangrove plant leaves were conducted by observing plants in the field as they are. No special planting was carried out on the plants. Descriptive analysis methods will be used to examine the data collected for this investigation. The purpose of descriptive analysis is to provide a description of the topic of the variable data collected from the subjects studied.

RESULTS AND DISCUSSION

Types of *Mangroves* found

The types of mangroves found in Panimbang sub-district are 5 types of mangrove species, and several families. The names of the types of mangroves found can be seen in the following table.

Table 1. The names of the types of mangroves.

No	Local Name	Scientific Name	Family Name
1.	Red Mangrove	*Rhizophora stylosa*	*Rhizophoraceae*
2.	Feather fire	*Avicennia rumphiana*	*Verbenaceae*
3.	Broadleaf fires	*Avicennia officinalis*	*Acanthaceae*
4.	Sea slug	*Sonneratia alba*	*Lythraceae*
5.	White mangrove	*Bruguiera cylindria*	*Rhizophoraceae*

From the data from the table above, 5 types of mangroves were found in the Panimbang sub-district, namely R. stylosa, A. rumphiana, A. officinalis, S. alba, and B. cylindria. Of the 5 types of mangroves, they have several different morphological characteristics of the leaves, which are presented in the table below:

Table 2. Morphological characteristics of the leaves.

No	*Morfologis*daun	*R. stylosa*	*A. rumphiana*	*A. officinalis*	*S. alba*	*B. cylindria*
1	Leaf shape	Oval, widened	elips	oval	oval	elips
2	Length	6 cm	8-9 cm	10 cm	7 cm	10 cm
3	Width	6,5 cm	6 cm	5 cm	3 cm	5 cm
4	Tip	sharp	pointed	rounded	blunt	tapered
5	Base	blunt	pointed	blunt	rounded	blunt
6	Upper surface color	green	green	dark green	green	yellowish green
7	Lower surface color	green	yellowish green	yellowish green	green	green
8	PA ITD color	green	green	green	green	green
9	PB ITD color	green	green	green	green	green
10	Edge shape	smooth	wavy	flat	flat	wavy
11	Upper surface texture	flat	smooth	smooth	smooth	smooth
12	Stalk lenght	3,5 cm	4 cm	2,5 cm	5 cm	3,6 cm
13	Stalk diameter	2 cm	2,5 cm	3 cm	3 cm	0,8
14	Stalk color	green	yellow	green	green	green
15	Venation	pinnate	pinnate	pinnate	pinnate	pinnate
16	Phylotaxis	alternate	alternate	alternate	alternate	alternate

Observation results in Panimbang District show that Bruguiera cylindria and Rhizophora stylosa have the longest leaves, 10 cm and 9.5 cm respectively. The leaves with the shortest size are found in Sonneratia alba. Bruguiera cylindria has leaves with a length of about 15 cm. Can be seen in the following table:

Table 3. Leaves length of mangrove.

No	Mangrove types long	Short leaf size
1.	*B. cylindria*	10 cm
2.	*R. stylosa*	9,5 cm
3.	*S. alba*	7 cm

Anatomical

The results of microscopic observations show that the cross-section of mangrove leaves in Panimbang District generally have the same structure but with different sizes, especially in leaf thickness, palisade thickness, cuticle thickness, upper and lower epidermis thickness, and stomata position and type. The upper epidermis is usually thicker than the lower epidermis. The epidermis generally consists of one layer. The following are the results of leaf anatomy in the cross-section of mangrove leaves.

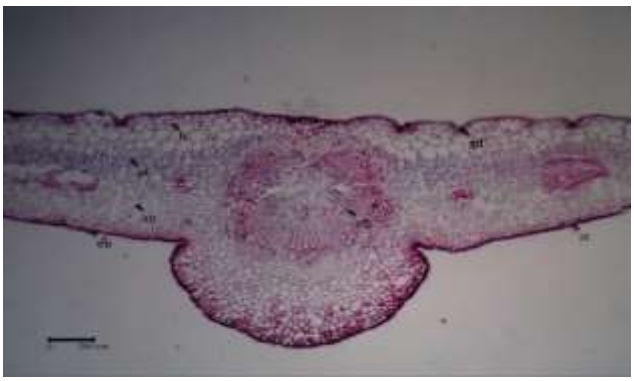

Figure 8. Anatomical cross section of A. rumphiana leaf.

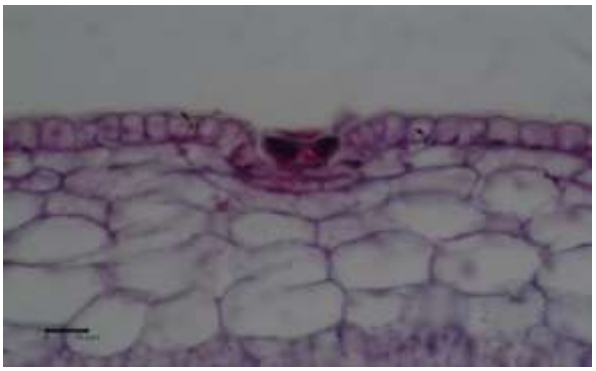

Figure 9. glandular trichomes of A. rumphiana leaves.

Figure 9 above shows the presence of glandular trichomes on A. rumphiana leaves in the upper epidermis with multicellular glands that are round and adjacent to the cuticle. Leaf anatomy research found differences in leaf thickness, palisade thickness, cuticle thickness, upper and lower epidermis thickness, stomata position and type, and stomata density. The following are the anatomical data of the leaves:

Table 4. Anatomical data of the leaves.

Anatomical Analysis of Mangrove Leaves (Third Leaf)

No	Sample	Test	Leaf thickness (µm)	Palisade thickness (µm)	Cuticle thickness (µm)	Upper epidermis thickness (µm)	Lower epidermis thickness (µm)	Position and type of stomata	Stomatal density (/mm2)
1	A	1	594.33	65.42	6.48	13.99	10.64	abaxial, cryptophor	62.50
		2	606.44	66.78	6.45	15.41	9.89		78.00
		3	613.24	65.44	6.89	13.31	11.03		70.00
		average	**604.67**	**65.88**	**6.61**	**14.24**	**10.84**		**70.17**
		.....	**9.58**	**0.78**	**0.25**	**1.07**	**0.28**		**7.75**
2	B	1	700.86	179.54	8.34	18.04	15.70	abaxial, panerophore	242.00
		2	709.12	176.61	7.36	18.45	15.66		242.00
		3	705.33	180.40	7.02	19.02	14.54		258.00
		average	604.67	65.88	6.61	14.24	10.84		247.33
		.....	4.13	1.99	0.69	0.49	0.66		9.24
3	C	1	400.64	115.12	not found	20.98	17.17	abaxial, panerophore	93.75
		2	447.13	104.08	not found	23.78	16.10		94.00
		3	432.22	111.90	not found	23.12	17.10		94.00
		average	**426.66**	**110.37**	not found	**22.63**	**16.79**		**93.92**
		.....	**23.74**	**5.68**	not found	**1.46**	**0.60**		**0.14**
4	D	1	533.00	108.63	10.58	18.87	12.31	abaxial, panerophore	47.00
		2	536.24	111.30	10.58	19.23	11.99		62.00
		3	535.00	110.40	9.78	19.44	12.56		62.00
		average	**534.75**	**110.11**	**10.31**	**19.18**	**12.29**		**57.00**
		.....	**1.63**	**1.36**	**0.46**	**0.29**	**0.29**		**8.66**
5	E	1	442.34	96.98	7.50	10.10	13.70	abaxial, panerophore	203.00
		2	473.00	96.74	8.00	11.68	12.40		205.00
		3	445.23	95.66	8.30	10.67	12.50		204.00
		average	**453.52**	**96.46**	**7.93**	**10.82**	**12.87**		**204.00**
		.....	**16.93**	**0.70**	**0.40**	**0.80**	**0.72**		**1.00**

Figure 10. Mangrove leaf anatomy

The leaf thickness ratio in A. officinalis is higher than other species with a value of 603.16 µm, indicating a greater water storage capacity to cope with drought. A. rumphiana and A. officinalis have the highest palisade thickness, which is 132.31 µm and 110.37 µm, respectively, which are important for photosynthesis. The cuticle in mangroves varies, with A. officinalis having a thin cuticle and S. alba being thick reaching 10.31 µm. The upper epidermis of A. officinalis is the thickest (22.63 µm) and B. cylindria the thinnest (10.82 µm). The lower epidermis is thickest in B. cylindria (17.24 µm).

All species have hypostomatic leaves (stomata on the underside of the leaf) with anomostic, anisocytic, cyclocytic, and staurocytic stomata types. R. stylosa has cryptophorous stomata (on the underside of the leaf), while A. rumphiana, A. officinalis, S. alba, and B. cylindria have abaxial (underside) and panerophorous stomata (parallel to the epidermal cells). Stomatal density varies, with A. rumphiana having the highest density (247.33 stomata/mm²) and S. alba the lowest (57.00 stomata/mm²).

Morfologycal Leaf

Rhizophora stylosa

Rhizophora stylosa, or known as red mangrove, has distinctive morphological characteristics. The leaves are

dark green with spots on the underside, elliptical and wide with a tapered tip. The fruit is about 2 cm long, similar to a pear and brown in color, with a forked flower stalk that reaches 2-4 cm in length. The stem is quite tall, reaching 10 meters, with gray bark and supporting roots and aerial roots. The natural habitat of *Rhizophora stylosa* is sandy and muddy areas. According to Jalaludin et al. (2020), this plant can reach a height of 15 meters, with a blackish gray stem surface and leaves about 8 cm long. Red mangrove flowers consist of 4-16 single flowers with ivory yellow petals, white crowns, and 8 stamens, while the fruit extends up to 20-60 cm. In Indonesia, *Rhizophora stylosa t*hrives on sandy or muddy beaches, including on the coast of Panimbang, Banten, which has a mangrove forest potential of 2,214.45 ha. Indonesia has 38 species of true mangroves, with *Rhizophora* as a genus that has abundant seedlings and durable propagules. Classification-wise, *Rhizophora stylosa* is included in the kingdom *Plantae,* division *Magnoliophyta,* class *Magnoliopsida,* order *Myratales,* family *Rhizophoraceae,* and genus *Rhizophora.*

Avicennia rumphiana

The *A. rumphiana* mangrove found in Panimbang District has leaves with a green upper surface and a yellowish green lower surface. The leaves are oval with a pointed tip, smooth texture on the upper surface, and rough on the lower surface. The leaf stalks are about 18-20 mm long. According to Hardy et al. (2018), A. rumphiana leaves are elliptical with rounded tips and pointed bases. The flowers grow in clusters at the end of the bunch, are yellow to orange, with 4 brown stamens and 4 flower petals. The fruit is heart-shaped and usually appears at the end of the stalk with a pale green color. The leaf stems are dark brown with rough bark, and the tree can reach a height of 16 m. The respiratory roots are pointed like pencils and appear above the ground from shallow waters. The classification of Avicennia rumphiana is as follows: Kingdom *Plantae,* Division *Spermatophyta,* Class *Magnoliopsida,* Order *Lamiales,* Family *Verbenaceae,* Genera *Avicennia,* Species *Avicennia rumphiana.*

Avicennia officinalis

Mangrove Avicennia officinalis, known as one of the prominent species in Panimbang sub-district, Banten, is a fairly tall tree that can reach 15 to 30 meters. The trunk is relatively low compared to other mangroves, brown in color with distinctive white spots. The leaves are oval with rounded tips, about 8-10 cm long, and have a shiny green upper surface, while the underside has fine hairs. The fruit is oval-shaped like a capsule. Anatomically, *A. officinalis* leaves have a dark green upper surface and a yellowish green underside, and concave glands that cover the upper part of the leaf. The leaves are simple, opposite each other, with a shape similar to a breech egg, flat edges, tapering base, and rounded tips. Its scientific classification according to Maghfirah (2010) is in the kingdom *Plantae,* class *Magnoliopsida,* order *Scrophulariales,* family *Acanthaceae,* genera *Avicennia,* and species *Avicennia officinalis.* This mangrove is also known as a compound flower that grows at the end of the stalk, forming 2-10 flowers per bunch.

Sonneratia alba

The *S. alba mangrove* found in Panimbang sub-district is a tall tree that grows around the coast. The leaves have a green upper surface with fine hairs on the underside, and round leaf tips with opposite positions. The trunk is dark white to brownish with a smooth and longitudinal peeling skin texture. The roots of the *S. alba mangrove* are cone-shaped and brown, forming respiratory roots that protrude above the ground. According to Noor (2006), *S. alba* can reach a height of 15 meters, with egg-shaped leaves and rounded tips, measuring around 5-12.5 x 3-9 cm. This mangrove grows in coastal ecosystems with high adaptation to environmental dynamics. In terms of scientific classification, *S. alba* is included in the kingdom *Plantae,* division *Magnoliophyta,* class *Magnoliopsida,* order *Myrtales,* family *Lythraceae,* genera *Sonneratia,* and species *Sonneratia alba.* These mangroves also have the ability to produce secondary metabolites such as flavonoids, which act as antioxidants to protect plants from oxidative stress produced by their environment (Hastuti et al., 2020).

Bruguiera cylindria L

Mangrove B. cylindria L is found in coastal areas with trees reaching 23 meters in height. The bark is brown mixed with white, has a spotted texture. The leaves are elliptical with pointed tips, wavy at the edges, and yellowish green. The roots are in the form of wide boards and spread at the base of the tree. *Mangrove B. cylindria* flowers are grouped into three at the end of the stem, with a white crown, yellowish green petals, and are tubular about 3-4 mm. The hypocotyl is cylindrical or sometimes curved, 8-15 cm long and 5-10 mm in diameter, green in color. Growing in areas with soil mixed with a little mud, this type of tree has slow growth and relies on respiratory roots to get enough oxygen, an adaptation that allows it to survive waterlogging. Scientifically classified, *Bruguiera cylindria* is included in the kingdom *Plantae,* class *Magnoliopsida,* order *Myrtales,* family *Rhizophoraceae,* genera *Bruguiera,* and species *Bruguiera cylindria.*

Leaf Anatomical Characters

The anatomical components of the leaf from the upper surface to the abaxial surface are respectively the upper epidermis (ea), hypodermis tissue (h), palisade parenchyma tissue (pl), sponge parenchyma (sp), vascular bundles (vb), and stomata (st). The results of the analysis showed that R. stylosa leaves have high leaf thickness (604.67µm), indicating greater water

absorption capacity. Bareja (2013) confirmed that increasing leaf thickness is related to high heat storage capacity, causing higher leaf temperatures, thereby increasing transpiration.

The hypodermis tissue is located under the upper epidermis, with large and dense cells, functioning as a place to store water to prevent drought in high temperature habitats (Jacoeb et al., 2011).

The cuticle is located on the outermost layer of the leaf, thick in S. alba leaves to control the rate of transpiration and maintain water content. The epidermis consists of the upper epidermis (adaxial) and the lower epidermis (abaxial), both covered by the cuticle and composed of a single layer of thin cells. Palisade parenchyma tissue is a mesophyll tissue located below the hypodermis tissue and above the sponge parenchyma. Palisade cells are elongated, small, and numerous, important for CO2 binding in photosynthesis, especially in drought conditions (Peel et al., 2017). Stomatal density affects transpiration and water balance in mangrove plants.

All mangrove leaf species have mesophyll tissue consisting of palisade and sponge. The genus Sonneratia has two layers of palisade tissue, which is an ecophysiological adaptation supported by high stomatal density.

The transport bundle consists of xylem and phloem, playing an important role as a transportation system. Xylem is on the inside, while phloem is on the outside, located in the leaf veins. Phloem is a complex tissue with various elements and types.

Stomata are derivatives of the epidermis, in the mangrove leaves of A. rumphiana, A. officinalis, S. alba, and B. cylindria have panerophore stomata that are parallel to the epidermis, while R. stylosa has cryptophore stomata that are deeper than the leaf surface (Samsuri, 2013). Stomata types based on the thickening of the guard cells according to Schwendener (in Sutrian, 2011):

a) Amaryllidaceae type: kidney-shaped, thin dorsal wall, thick abdominal wall, with thickened cuticle.
b) Helleborus type: thick central guard cells, thin wall ends.
c) Thin wall type and ends.
d) Mnium type: kidney-shaped, thin abdominal wall, other walls are thin or thick (Sarjani et al., 2017).

CONCLUSION

In Panimbang District, five types of mangrove plants were found, namely Rhizophora stylosa, Avicennia rumphiana, Avicennia officinalis, Sonneratia alba, and Bruguiera cylindria. The morphology and anatomy of mangrove leaves vary depending on the type, with characteristics of thick leaves, thick cuticles, and stomata types. Species that face the coast, such as Sonneratia alba and Bruguiera cylindria, have thicker cuticles.

Suggestions

Further research should deepen the diversity of morphological and anatomical characteristics of leaves of mangrove plant species in Panimbang District. In addition, this research needs to be further developed because the existing results are not yet fully adequate.

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