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Morphological and Anatomical Studies of Mangroves from Goa, India

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INTRODUCTION

The term 'mangrove' has been applied to the plant species, having the capacity to tolerate total or partial submersion in extreme condition where their roots are penetrating from the ground. Mangroves are plants which grow in-between terrestrial and sea (Giri et al., 2010; Dhargalkar et al., 2014). They are usually known as halophytes since they are salt tolerant trees. These plants grow as shrub in blackish water or saline areas with cluster of roots. Mangroves are the plants having tangled roots, which grow above the ground appearing out of substrate. They comprise salt filtration root systems which are very complex dealing with saline condition and wave action. Viviparous germination is a unique way of reproduction which is observed in mangroves (Dhargalkar et al., 2014).

Mangroves are combination of two words which come from two different origins one is Portuguese word "mangal" and English word "Grove". "Mangal" word is used for the community of mangroves. Mangrove ecosystem is termed as the region where these plants occur and are usually seen on the tropical and subtropical intertidal region which are commonly known as salt tolerant plant (Surya et al., 2017).

In the evolutionary biology the most important is the plants adaptation to its environments. The different plant species have adapted many morphological traits in order to survive in saline condition. Mangrove plant species are good example to regulate salt absorption; they develop various mechanisms which are associated with anatomical as well as physiological characteristics (Lobo et al., 2014).

Mangroves are characterized by several structural characters, such as reduction of leaf surface, epidermis of cell wall is increased in thickness and on the abaxail surface the stomata is present. These are the characters which make the mangroves an adapted ideal model (Kumar et al., 2014).
In mangrove community *Acrostichum* is belonging to pteridophyte genus found in the brackish water. It grows luxuriantly with clumped distribution with golden yellow leathery fronds and is called as "golden leather fern" (Marsi et al., 2014).
Mangroves are restricted with the respect to distribution is particularly due to sensitivity towards the frost and cold temperature. There are total 36 families, 52 genera and 82 species of mangroves. The largest distribution of mangroves cover is found mainly in Asia followed by Africa.
In India mangroves are spread in about 4,639 sq.km area, which account for 0.14% of Asian mangroves. This distribution is mainly attributed to the large estuaries viz. Bay of Bengal which poured by two main rivers that is Ganga and Brahmaputra with large deltas including muddy slopes create ideal place/sites for growth of mangroves species (Dhargalkar et al., 2014).

Goa is situated on the central west coast of India and borders the Arabian Sea and extends from north to south. Approximate 105 km is the total length of Goa and around seven fringed of mangroves are present. Mangroves are intricate network of creeks and blackwater. The water bodies within the estuaries reach the luxuriant growth of mangroves and associated swamps plot of mangrove are observed. (Dhargalkar et al., 2014).

Ecologists believe that mangroves are highly productive in ecological system. Mangroves help the system by statists and contributing to soil formation. The mangroves system serves as habitat for organisms like crab, fish, birds and reptiles. Mangroves also contribute to production of offshore water by producing large amount of detritus. Coastal communities are being protected by storm such as hurricanes which ultimately protecting the areas.

REVIEW OF LITERATURE

Acrostichum Aureum L. was studied for the adaptation with respect to anatomical features with relationship to its habitat. In this study the different anatomical features were highlighted such as the epidermal cells with thick cuticle; stomata were anomocytic and hypostomatic. Starch granules were observed in rhizome. It was concluded that the plant was having different xerophytic and hydrophytes adaptation with relation to biotic factors (Lobo and Krishnakumar, 2014).

Surya and Hari, 2017 selected true mangroves for the study, in Kerala viz. *Avicennia marina*, *Avicennia officinalis* and *Excoecaria agallocha* showed the presences of the impression of growth rings. When comparison was done in the species Acanthus they were linked with sclereids in phloem and large vessel. He also compared Rhizophoraceae members and observed the air cavities in cortex region, scalariform perforation plates, and presence of sclereids.

Rodriguez et al., 2012 studied the structural adaptations of leaves, pneumatophores and roots. He analyzed the morphological and anatomical differences and concluded that Rhizophora has support roots, *Bruguiera, Ceriops* have knee roots, Xylocarpus with buttress roots and *Avicennia*, *Sonneratia* with pnematophores which shows the major inter and intra specific variability among mangroves.

Surya and Hari, 2016 studied the anatomy of three different species of *Bruguiera L*. in Kerala. In these studies, showed the similarities between the species as of its generic closeness but anatomically they were showing the differences in number of vascular bundles and pattern of sclereid. The distinct character was the brachy sclereids present in the three *Bruguiera* species, astero sclereids was unique to *B. Gymnorrhiza*.

Suprayitno, 2015 showed the effectiveness of ripe *R. mucronata* fruit flour is functional food sources for antidiabetic as the plant have tannins, steroid, saponins and flavonoids associated to the phytochemical compounds.

Shufen et al., 2011 studied the plant record in Singapore in 735 ha of mangrove forests, and have 35 'true' mangrove species and with extinction of *Brownlowia argentata* Kurz. IUCN are 'Critically Endangered' mangrove, *Bruguiera hainesii*.

Ragavan et al., 2015 described the new variety from Andaman and Nicobar Islands *Rhizophora mucronata* var. alokii. The distinct morphological features were highlighted four stamens, laterally folded leaves, a short peduncle, thick leathery petals, and a four-sided ovary with a sessile style. A key for the species of Rhizophora of the Andaman and Nicobar Islands is also provided. Zhang et al., 2010 screened *Kandelia candel* and *Rhizophora mangle* species for tannins for their potential antioxidant activities. In most of the mangrove species there is abundant tannin content is present which will avoid the herbivores to consume them (Feller et al., 1999; Hernes et al., 2001).

Mangroves have wide function in leather tanning and different application in antiherpetic, antibacterial, antioxidant and anthelminthic activities (Banerjee et al., 2008; Rahim et al., 2008). Santhiavalli and Jayanthi, 2016 studied *Acanthus ilicifolius* for its anatomical character and observation showed that the vascular regions in the midrib are multi-stranded. The stem consists of the continuous epidermis, large multilayer cortex with hallow vascular with pith in the center. It was observed that the stomata were diacytic.

OBJECTIVES

The study aimed for the collection and identification of different species of mangroves from Goa. Then the collected specimens were used to study the morphology and histochemical characterization.

MATERIALS AND METHODOLOGY

4.1. Study Area

During this study, field trips were conducted monthly at Divar Island, Ribandar and Patto located in Tiswadi Taluka. The plant specimen of different mangroves species was located in the marshy area in saline water of Goa.

4.2. Collection and documentation of mangroves species

The mangrove species was collected from the saline water of Divar Island, Ribandar and Patto. The documentation of all collected mangrove species was done. The plant specimen was collected along with tender stem, leaves, flowers and fruits.

4.3. Taxonomic Identification

Based on the morphological characterization the taxonomical identification of specimen till species level were done using Botanical Monograph and Flora of the Presidency of Bombay.

4.4. Morphology study

The different mangrove species were collected from the marshy area along the river banks. The specimens were studied for its morphological characters like habit, stem and leaf in all the collected species. In few mangrove species flower and fruit character are also studied depending upon the availability of the specimen. The morphological characters were studied in detail using dissection microscope.

4.5. Histochemical characterization of mangroves species

Different species of mangroves was collected from the marshy area and anatomical characterizations were carried out using histochemical techniques. To understand the anatomical structure, the various plant parts viz. stem and leaves were used.

4.5.1. Anatomy of the stem and leaves

Fresh stem and leaf material was collected, then separated from the other plant parts, thoroughly washed and transverse sections (T.S.) of the material were taken using a sharp blade. Then the sections were collected in a Petri dish containing distilled water. Intact sections were selected and stained with safranin washed thoroughly with distilled water, mounted in dilute glycerin (5%) and observed under microscope 45x Standard histochemical procedures were used to carry out the histochemical staining reactions (Pearse, 1972; Bender and Kumar, 1973). Thin sections were placed in 0.1 percent safranin for 2-3 min., and excess stain was removed by placing it in distilled water. After washing, sections were mounted in dilute glycerin and observed under bright-field mode of examination under light microscope (Krishnan and Dayanandan, 2003). To understand anatomy structures of the stem and leaves were sectioned and stained with safranin. The prepared slides were observed and photographed using microscopy. The observation and photographs were taken using Labomed binocular research microscope, attached with Digital Camera. Macro-photographs were taken using digital camera.

RESULTS

The results reported here are based on the survey, collection and observation of the mangroves species. Collected species was studied for morphology and histotaxonomic studies were conducted. The detailed results used for the study is presented in this chapter

5.1. Study Area

During this study, field survey was carried out in Goa, for the collection of mangroves species. Field trips were conducted at Divar Island, Ribander, Panjim Patto located in Tiswadi Taluka. The plant specimen mangroves species was located in the estuaries of Mandovi River.

5.2. Collection and Documentation of mangrove plant

Mandovi River at the region of Divar Island, Ribander, Panjim Patto located in Tiswadi Taluka. The latitude and longitude of the area is 15.529079◦N, 73.905836◦ E. Mangrove grow in patches and bushy in appearance. The details of collection site are given in the Google map (Plate 1e, 3d, 5h, 7d, 9d, 11d, 13d, 15d, 17d, 19d, 21e, 23d) More than 59 species of Mangrove have been recorded

all over the world. Out of which, 45 species are found in India and 16 species are found in Goa. In Goa total 16 species are recorded, out of which 12 are collected for our study.

5.3. Taxonomic identification

Based on the morphological characterization the taxonomical identification was done and the results were summarized.

5.4. Morphology study

The different mangrove species were identified and morphological characters like habit, stem and leaf are summarized as follows.

Classification, Identification and Morphological Descriptions of Mangroves.

Acanthus ilicifolius Linn.

Kingdom: Plantae (Plants)
Subkingdom: Tracheobionta (Vascular plants)
Superdivision: Spermatophyta (Seed plants)
Division: Magnoliophyta
Class: Magnoliopsida
Order: Lamiales
Family: Acanthaceae
Genus: *Acanthus*
Species: *ilicifolius*
Common name: holly mangrove
Habit: a perennial, prickly erect herb grows up to 1m high; woody, dense growth (Plate 1a-d).
Leaves: simple, opposite, oblong or ovate; sinuate margin with spines at each lobe, petiole short; exstipulate (Plate 1b).
Flower: inflorescence raceme; spike, violet in color.
Flowering season: April to December.
Economic importance: stem is used in treatment of blood clotting and asthma treatment; root used in case of snake bite.

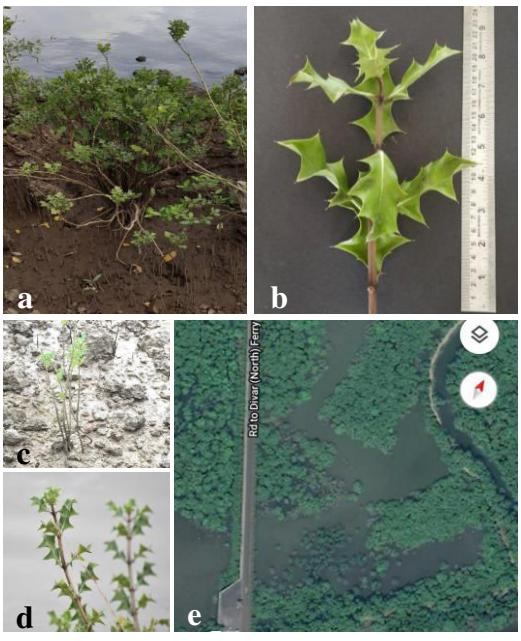


Plate 1: a, c, d. Habit and habitat of *Acanthus ilicifolius* Linn.
b. *Acanthus ilicifolius* Linn. with stem and leaves.
e. Google map image of collection site.

Acrostichum aureum Linnaeus.
Kingdom: Plantae (Plants)
Subkingdom: Tracheobionta (Vascular plants)
Division: Pteridophyta (fern)
Class: Polypodiopsida
Order: Polypodiales
Family: Pteridaceae
Genus: Acrostichum
Species: aureum
Common name: akur
Habit: erect fern, bushy, grow upto 1.5-1m tall; root fibrous without aerial roots (Plate 3a, b).
Leaves: pinnate with terminal leaflet; pinnae stalked; sessile; acute to acuminate, green and yellow sorus observed on maturity (Plate 3c).
Fruit: mature leaves become sporophyllous.
Economic important: tender fronds or leaves are edible as vegetable.

Plate 3: a, b. Habit and habitat of *Acrostichum aureum* Linnaeus.
c. *Acrostichum aureum* Linnaeus with stem and leaves.
d. Google map image of collection site.

Aegiceras corniculatum (*L.*) *Blanco*
Kingdom: Plantae (Plants)
Subkingdom: Tracheobionta (Vascular plants)
Superdivision: Spermatophyta (Seed plants)
Division: Magnoliophyta
Class: Magnoliopsida
Order: Myrtales
Family: Primulaceae
Genus: Aegiceras
Species: corniculatum

Common name: river mangrove
Habit: small tree grows upto 3-4cm long; stem with many branches; brownish bark, glabrous (Plate 5a-e). **Leaves**: ovate, entire margin, petiole alternate, light green (Plate 5f, g).
Inflorescence: umbrellate
Flower: terminal and axillary; subsessile; small white fragrant
Flowering season: July to February.
Fruit: green yellowish to red, sharply pointed, coriaceous.
Economic important: stem use to treat fish poison; tender leaves are edible; wood used as fuel to make charcoal.

Plate 5: a-e. Habit and habitat of *Aegiceras corniculatum* (L.) Blanco.
f-g. *Aegiceras corniculatum* (L.) Blanco with stem and leaves.
h. Google map image of collection site.

Avicennia marina
Kingdom: Plantae (Plants)
Subkingdom: Tracheobionta (Vascular plants)
Superdivision: Spermatophyta (Seed plants)
Division: Magnoliophyta (Flowering plants)
Class: Magnoliopsida (Dicotyledons)
Order: Lamiales
Family: Acanthaceae
Genus: Avicennia
Species: marina
Common name: white mangrove, grey mangrove
Habit: small evergreen bush, tree approx. 8-15m.; bark smooth, whitish grey; pneumatophores 3-10cm long, narrow pointed (Plate 7a, b).
Leaves: 3-7cm long, elliptic, oblong, margin smooth, upper surface of leaves cover is bright glossy green, lower surface is light silvery; petiole short, slightly hairy (Plate c).

Flower: pale yellow occurs in cluster of 3-5 in number.
Flowering season: May to December.
Economic important: leaves fed to livestock, used for paper production.

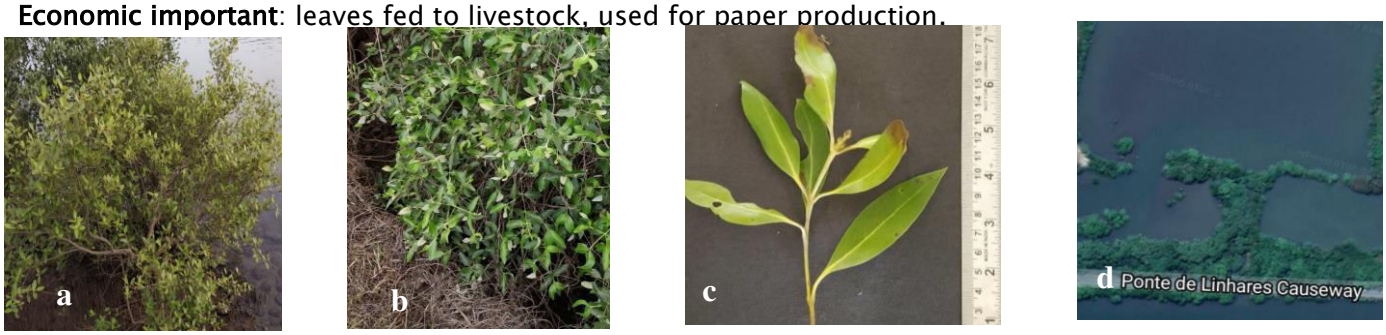


Plate 7: a, b. Habit and habitat of *Avicennia marina.*
c. *Avicennia marina* with stem and leaves.
d. Google map image of collection site.

Avicennia officinalis L
Kingdom: Plantae (Plants)
Subkingdom: Tracheobionta (Vascular plants)
Superdivision: Spermatophyta (Seed plants)
Division: Magnoliophyta (Flowering plants)
Class: Magnoliopsida (Dicotyledons)
Order: Lamiales
Family: Acanthaceae
Genus: *Avicennia*
Species: *officinalis*
Common name: white mangrove/ grey mangrove
Habit: trees dense, bushy, when it matures forms columnar tree, grow upto 15-30m long, commonly distributed all over Goa, pneumatophores approx. 3-10cm (Plate 9 a, b).
Leaves: entire, thick, leathery, coriaceous, obovate, oblong (Plant 9c).
Flower: yellow in colour, clustered, more or less globular in shape.
Flowering season: June to September.
Fruit: Green cluster, compressed capsule.
Economic important: leaf used for cattle fodder; bark for timber, used for making boats; seed used for treating ulcers; bark used to treat scabies; flower used for making honey.

Plate 9: a, b. Habit and habitat of *Avicennia officinalis* L.
c. *Avicennia officinalis* L. with stem and leaves.
d. Google map image of collection site.

Bruguiera cylindrica **(L.)** Blume
Kingdom: Plantae (Plants)
Subkingdom:Tracheobionta (Vascularplants)
Superdivision: Spermatophyta (Seed plants)
Division: Magnoliophyta
Class: Magnoliopsida
Order: Malphigiales
Family: Rhizophoraceae
Genus: Bruguiera
Species: cylindrical
Common name: Small leafed orange mangrove
Habit: medium sized trees, 2-4m tall; grow upto 17m; evergreen; deliquescent; woody, smooth bark, greyin colour; mostly grow on the stuff clay (Plate 11a, b).
Leaves: single, opposite decussate, extipulate; petiolate; elliptic entire margin, glabrous, green in color (Plate 11c).
Flower: inflorescence axillary cyme; each pedicle has 4-6 flowers, yellowish in color.
Flowering season: January to December.
Fruit: elongated tube like, radicle sub cylindrical short sepal lobes, slightly pointed end, germination epigeal, viviparous, hypocotyl.
Economic importance: hard timber, fuel, wood, 25% tannin, leaves used for blood control, young, shoot is edible.

Plate 11: a, b. Habit and habitat of *Bruguiera cylindrica* (L.) Blume.
c. *Bruguiera cylindrica* (L.) Blume with stem and leaves.
d. Google map image of collection site.

Excoecaria agallocha Lin.
Kingdom: Plantae (Plants)
Subkingdom: Tracheobionta (Vascular plants)
Super division: Spermatophyta (Seed plants)
Division: Magnoliophyta (Flowering plants)
Class: Magnoliopsida (Dicotyledons)
Order: Malphigiales
Family: Euphobiaceae

Genus: Excoecaria
Species: agallocha
Common name: Blind your eye mangrove.
Habit: small trees grown up to 12m tall, poisonous milky latex, many branches; bark is grey (Plate 13a, b).
Leaves: simple, thick, alternate, elliptic,3-6cm long, waxy old leaves turned reddish in color (Plate 13c).
Flower: unisexual flower.
Flowering season: February to August.
Fruit: small fruit, green in color, turn greyish black when it gets mature.
Economic importance: timber used as firewood, charcoal.

Plate 13: a, b. Habit and habitat of *Excoecaria agallocha* Lin.
c. *Excoecaria agallocha* Lin. with stem and leaves.
d. Google map image of collection site.

Kandelia candel **(**L.**)** Druce
Kingdom: Plantae (Plants)
Subkingdom: Tracheobionta (Vascular plants)
Superdivision: Spermatophyta (Seed plants)
Division: Magnoliophyta (Flowering plants)
Class: Magnoliopsida (Dicotyledons)
Order: Malpighiales
Family: Rhizophoraceae
Genus: Kandelia
Species: candel
Habit: Small to medium tree, height 3-4m can grow up to 6m high, smooth bark, grayish or reddish brown, without any aerial root (Plate 15a, b).
Leaves: opposite, oblong, elliptic apex, obtuse (Plate 15c).
Flower: inflorescence axillary cyme; long peduncles, petals 5-6 bifid white lobes.
Flowering season: January to December.
Fruit: 10-30cm long, obclavate, viviparous.
Economic importance: hard timber, durable and good quality fuel-wood, contain 15% tannin.

Plate 15: a, b. Habit and habitat of *Kandelia candle* (L.) Druce.
c. *Kandelia candle* (L.) Druce with stem and leaves.
d. Google map image of collection site.

Rhizophora apiculata Blume
Kingdom: Plantae (Plants)
Subkingdom:Tracheobionta (Vascularplants)
Superdivision: Spermatophyta (Seed plants)
Division: Magnoliophyta (Flowering plants)
Class: Magnoliopsida (Dicotyledons)
Order: Malphigiales
Family: Rhizophoraceae
Genus: Rhizophora
Species: apiculate
Common name: tall stilted red mangrove
Habit: evergreen tree, 3–7m high, medium tree, stem supported by numerous, lateral, stilt roots, known as aerial roots. Trunk can reach up to 50cm in diameter, bark is usually grey (Plate 17a, b).
Leaves: 10–18cm in length, 2.5–7.6cm in width; leaf blade elliptic, opposite decussate, tiny black spotted, lanceolate, leaf tip acute, broad, leaf stalks and stipulate often tinged red (Plate 17c).
Flower: inflorescence cyme; sessile, complete bisexual, very short stalk, first flower is developed at the age of about 5 years, 0.8–1.2cm long; sepals 4, ovate, polysepalous, superior ovary, acute entire deciduous; stamen 12 and are yellow and white which vary from pale to dark.
Flowering season: June to October.
Economic importance: bark used for charcoal, dyeing leather, tannin of rhizophora bark used as timber, breeding area for fish and crab.

Plate 17: a-b. Habit and habitat of *Rhizophora apiculata* Blume.
c. *Rhizophora apiculata* Blume with stem and leaves.
d. Google map image of collection site.

Rhizophora mucronata Lamk.
Kingdom: Plantae (Plants)
Subkingdom: Tracheobionta (Vascularplants)
Superdivision: Spermatophyta (Seed plants)
Division: Magnoliophyta (Flowering plants)
Class: Magnoliopsida
Order: Malphigiales
Family: Rhizophoraceae
Genus: Rhizophora
Species: mucronata
Common name: long fruited stilted red mangrove.
Habit: evergreen tree, 13m tall, then other species of Rhizophora (Plate 19 a,b)
Leaves: dark green colored leaves, broad, ovate, opposite decussate, stipules, entire margin (Plate c). **Flower**: axillary cyme inflorescence; yellow in colour, pedicellate, hairy, entire margin.
Flowering season: August to December.
Fruit: coriaceous, hypocotyl, seed germination is modified into epigeal-viviparous seedling, 60-70cm long. **Economic importance**: used as timber, fuel, charcoal, the park contains 20%of tannin used in treatment of diabetes.

Plate 19: a-b. Habit and habitat of *Rhizophora mucronata* Lamk.
c. *Rhizophora mucronata* Lamk. with stem and leaves.
d. Google map image of collection site.

Sonneratia alba J. Sm.
Kingdom: Plantae (Plants)
Subkingdom: Tracheobionta (Vascularplants)
Superdivision: Spermatophyta (Seed plants)
Division: Magnodiophyta (Flowering plants)
Class: Magnoliopsida (Dicotyledons)
Order: Myrtales
Family: Sonneratiaceae
Genus: Sonneratia
Species: alba

Common name: mangrove apple
Habit: branched, moderate size tree, approx. 10-16m tall; pneumatophores found in sandy soil (Plate 21a-c). **Leaves**: globular, simple, opposite, coriaceous, lathery, elliptic broadly drop shape, light green (Plate 21d). **Flower**: terminal, cymes flowers with white petals; calyx tube cup shape, 6-8lobe. **Flowering season**: February to July.
Fruit: peered shape, crown by persistent sepals.
Economic importance: used as fuel, house building, clogs, flowers for honey.

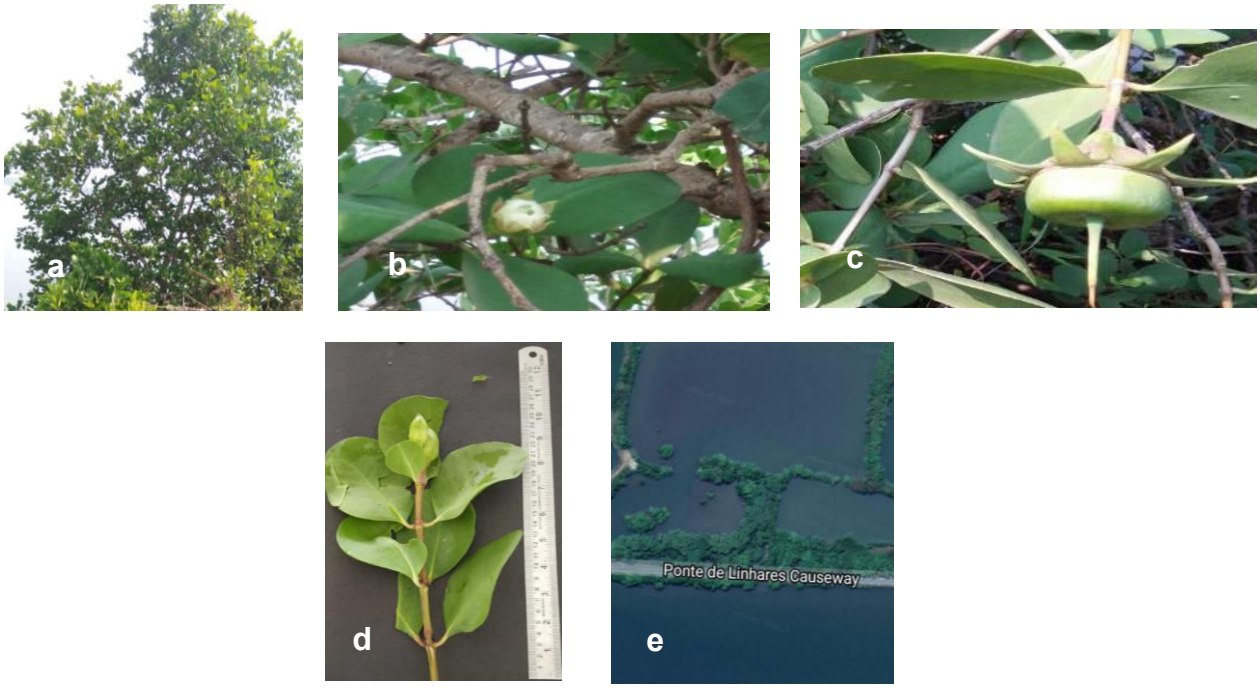


Plate 21: a-c. Habit and habitat of *Sonneratia alba* J. Sm.
e. *Sonneratia alba* J. Sm. with stem and leaves.
d. Google map image of collection site.

Sonneratia caseolaris (L.) Engler.
Kingdom: Plantae (Plants)
Subkingdom:Tracheobionta (Vascularplants)
Superdivision: Spermatophyta (Seed plants)
Division: Magnodiophyta (Flowering plants)
Class: Magnoliopsida (Dicotyledons)
Order: Myrtales
Family: Sonneratiaceae
Genus: Sonneratia
Species: caseolaris
Common name: mangrove apple
Habit: small to medium sized tree, approx. 10-15m high, found in deeply muddy soil, along with the tidal creek. woody erect branches horizontal twig slender, prefer low salinity. (Plate 23a-d).
Leaves: simple opposite, decussate, short, pediculate, minute
Flower: solitary cymes,ebracteate, pedicellate, bisexual, pink petals; calyxtube shape, 6 lobes, polypetalous.
Flowering season: February to July.

Fruit: berry, green, peared shape crown by the persistent sepals.
Economic importance: used as fuel, flower used for honey, edible fruit.

Plate 23: a-c. Habit and habitat of *Sonneratia caseolaris* (L.) Engler.
e. *Sonneratia caseolaris* (L.) Engler. with stem and leaves.
d. Google map image of collection site.

5.5. Histochemical characterization of mangroves species

The anatomical structure of stem and leaves were studied using histochemical techniques and the results are summarized as follows.

Acanthus ilicifolius Linn.

Stem

Cuticle

a. outermost thick single layer present above the epidermis.

Epidermis

a. single layer with thin walled cells.

Phelloderm

a. present below the epidermis, 4-5 layers thin walled.
b. forms a secondary cortex.

Cortex

a. multilayer, parenchymatous cells with crystalliferous cells and intercellular air spaces.

Sclereids

a. they are reduced forms of parenchymatous cells, present along with the phloem.

Vascular Bundle

a. conjoint, closed and collateral.
b. protoxylem towards the pith and metaxylem towards the periphery i.e. endarch.
c. phloem present towards the periphery.

Pith

a. multi-layered with parenchymatous cells (Plate 2a; Figure 1a).

Acanthus ilicifolius Linn.

Leaf

Cuticle

a. Outermost thick single layer present above the epidermis.

Epidermis

a. double layer with thin walled cells.

Palisade tissue

a. present below the epidermis with 2-3 layer with vertically elongated cells.

intercellular spacecontaining chloroplast.
Spongy cells
a. irregular shaped parenchyamatous cells with chloroplast present below the palisade cells.
Vascular bundle
a. closed, with no differentiation of cells. Three distinct vascular bundles are present.
b. xylem is surrounded by phloem.
Cortex
a. multi-layered parenchymatous cells.
Lower epidermis
a. single layer cells present on lower surface of leaf (Plate 2b; Figure 1b).

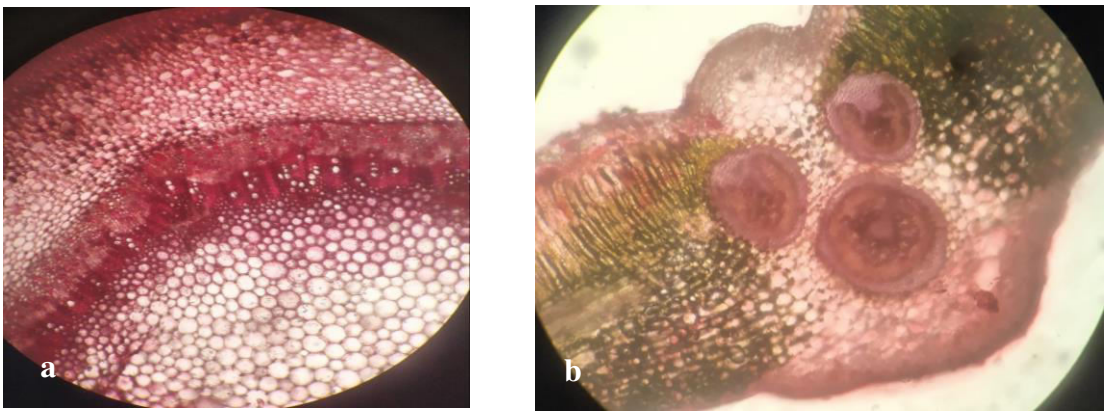


Plate 2: a. Transverse section of a stem *Acanthus ilicifolius* Linn.

b. Transverse section of a leaf *Acanthus ilicifolius* Linn.

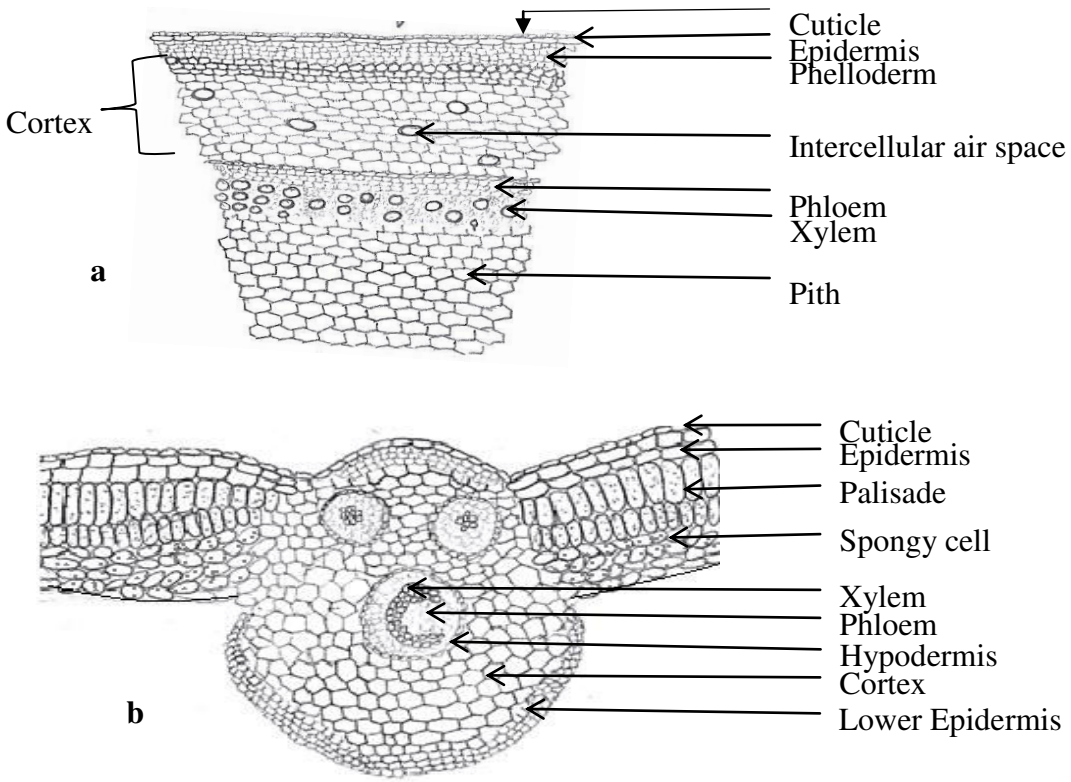


Figure 1: a. Transverse section of a stem *Acanthus ilicifolius* Linn.

b. Transverse section of a leaf *Acanthus ilicifolius* Linn.

Acrostichum aureum Linnaeus

Stem

Epidermis

a. single layer with thin walled cells.

Phelloderm

a. present below the epidermis, 4-5 layers thin walled.

b. forms a secondary cortex.

Cortex

a. multi-layered parenchyma cells

Vascular Bundle

a. conjoint, closed and collateral.

b. protoxylem towards the pith and metaxylem towards the periphery i.e. endarch.

c. phloem present towards the periphery.

Pith

a. multi-layered with parenchymatous cells (Plate 4a; Figure 2a).

Acrostichum aureum Linnaeus

Leaf

Epidermis

a. single layer with thin walled cells.

Palisade tissue

a. present below the epidermis with 1-2 layer with vertically elongated cells.

b. intercellular spacecontaining chloroplast.

Spongy cells

a. irregular shaped parenchymatous cells with chloroplast present below the palisade cells.

Vascular bundle

a. scattered and closed.

Hypodermis

a. xylem and phloem is surrounded by Hypodermis.

Cortex

a. multi-layered parenchymatous cells.

Lower epidermis

a. single layer cells present on lower surface of leaf (Plate 4b; Figure 2b).

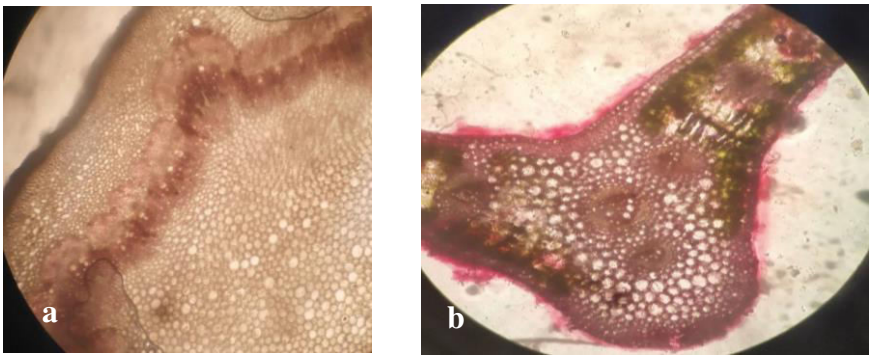


Plate 4: a. Transverse section of a stem *Acrostichum aureum* Linnaeus.

b. Transverse section of a leaf *Acrostichum aureum* Linnaeus.

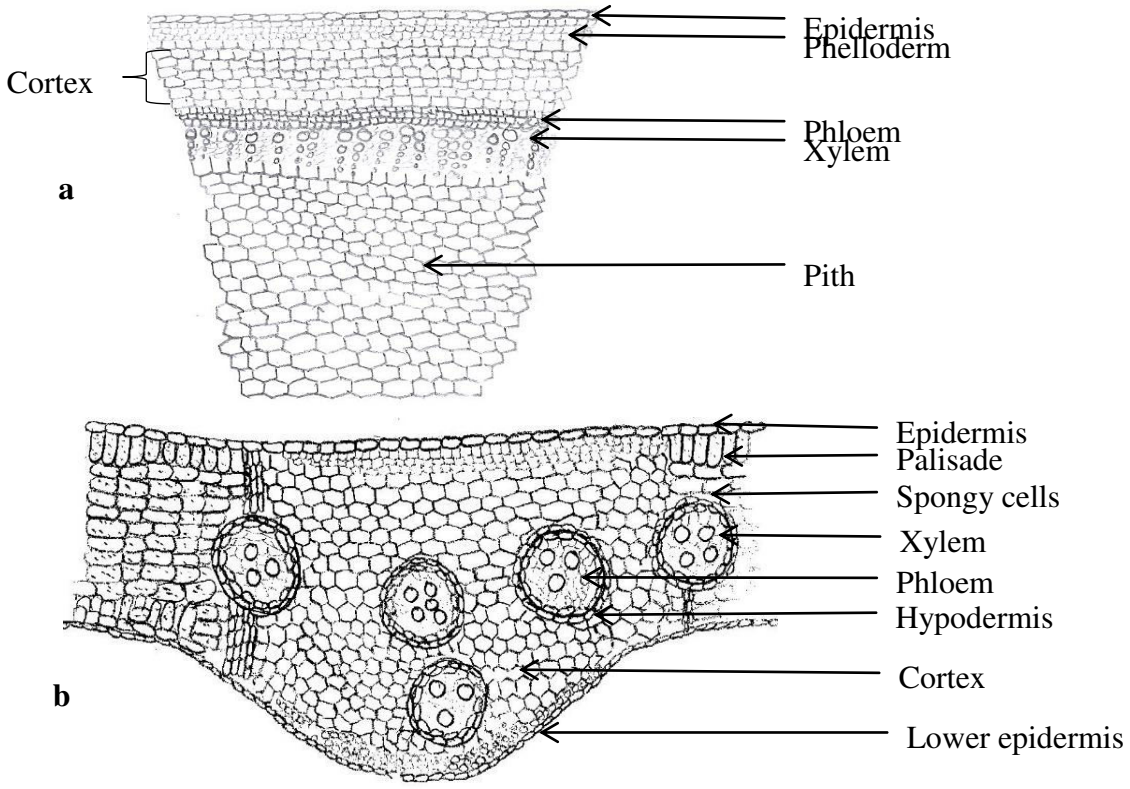


Figure 2: a. Transverse section of a stem *Acrostichum aureum* Linnaeus.
b. Transverse section of a leaf *Acrostichum aureum* Linnaeus.

Aegiceras corniculatum (L.) Blanco

Stem

Cuticle

a. outermost thick single layer present above the epidermis.

Epidermis

a. multilayer with thick walled cells.

Cortex

a. multi-layered parenchymatous cells with tannin.

Sclereids

a. they are reduced forms of parenchymatous cells, present along withthe phloem.

Vascular Bundle

a. conjoint, closed and collateral.

b. protoxylem towards the pith and metaxylem towards the periphery i.e. endarch.

c. phloem present towards the periphery.

Pith

a. multi-layered with parenchymatous cells (Plate 6a; Figure 3a).

Aegiceras corniculatum (L.) Blanco

Leaf

Cuticle

a. outermost thick single layer present above the epidermis.

Epidermis

a. multilayer with thin walled cells.

Palisade tissue

a. present below the epidermis with 2-3layer with vertically elongated cells.

b. chloroplast present.

c. intercellular space present.

Spongy cells

a. irregular shaped parenchymatous cells with chloroplast present below the palisade cells.

Vascular bundle

a. conjoint, closed, collateral.

b. xylem is surrounded by phloem

c. metaxylem present towards the periphery and protoxylem towards the centre.

Cortex

a. multi-layered parenchymatous cells.

Lower epidermis

a. single layer cells present on lower surface of leaf (Plate 6b; Figure 3b).

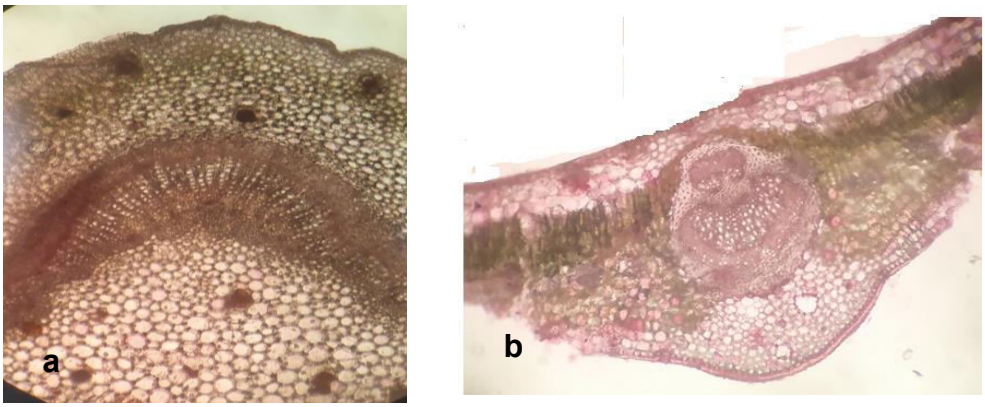


Plate 6: a. Transverse section of a stem *Aegiceras corniculatum* (L.) Blanco.
b. Transverse section of a leaf *Aegiceras corniculatum* (L.) Blanco.

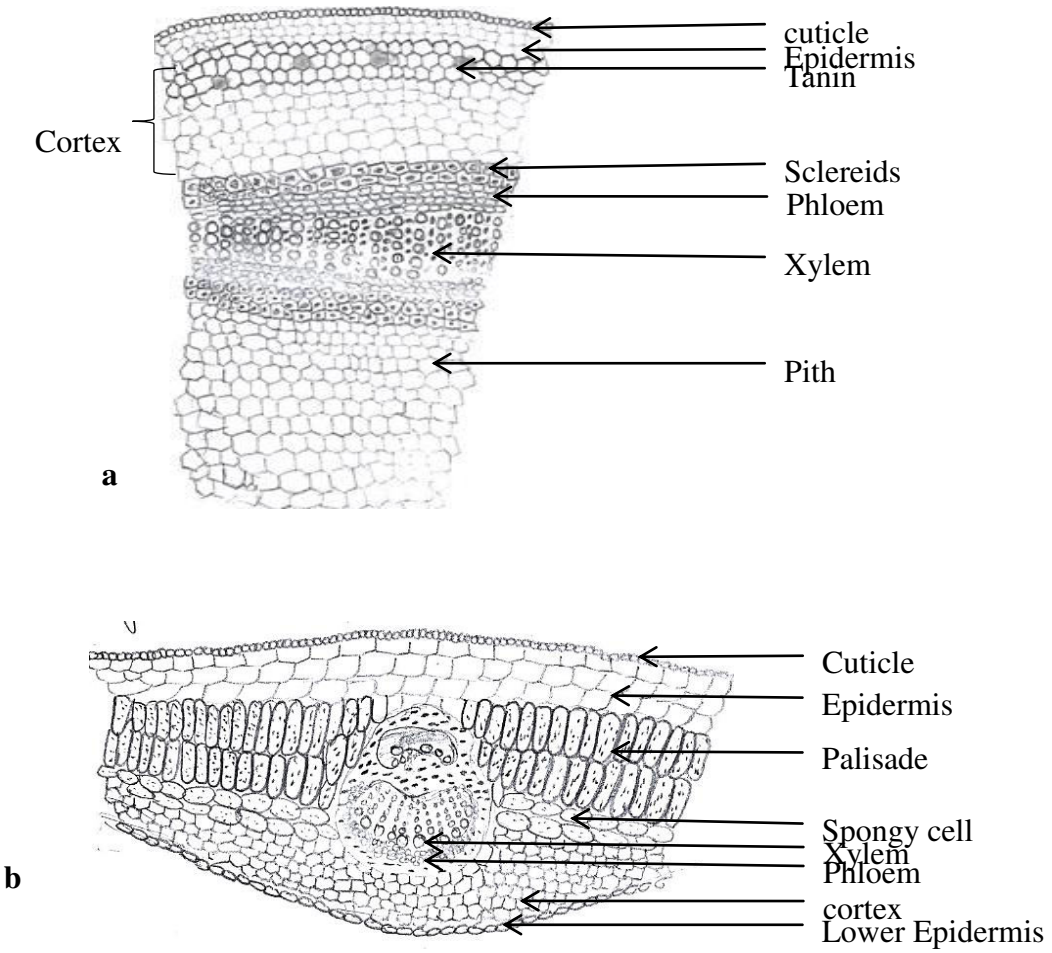


Figure 3: a. Transverse section of a stem *Aegiceras corniculatum* (L.) Blanco.
b. Transverse section of a leaf *Aegiceras corniculatum* (L.) Blanco.

Avicennia marina

Stem

Cuticle

a. outermost thin single layer present above the epidermis.

Epidermis

a. single layer with thin walled cells.

Cortex

a. multi-layered parenchymatous cells.

b. outer layer is chlorenchyma cells.

c. inner layer is with parenchyma cells with air spaces.

Vascular bundle

a. conjoint, closed and collateral.

b. protoxylem towards the pith and metaxylem towards the periphery i.e. endarch.

c. phloem present towards the periphery.

Sclereids

a. they are reduced forms of parenchymatous cells, present along withthe phloem.

Pith

a. multi-layered with parenchymatous cells (Plate 8a; Figure 4a).

Avicennia marina

Leaf

Cuticle

a. outermost thick single layer present above the epidermis.

Epidermis

a. multilayer with thick walled cells.

Palisade tissue

a. present below the epidermis with 2-3 layer with vertically elongated cells.

b. chloroplast present.

c. intercellular space present.

Spongy cells

a. irregular shaped parenchymatous cells with chloroplast present below the palisade cells.

Vascular bundle

a. conjoint, closed, collateral.

b. protoxylem towards the centre and metaxylem toward the periphery. i.e. endarch.

c. phloem towards the periphery.

Cortex

a. multi-layered parenchymatous cells.

T- shape cell

a. present on the lower epidermis, T shape inverted cells.

b. they help in excretion of salt.

Lower epidermis

a. single layer cells present on lower surface of leaf(Plate 8b; Figure 4b).

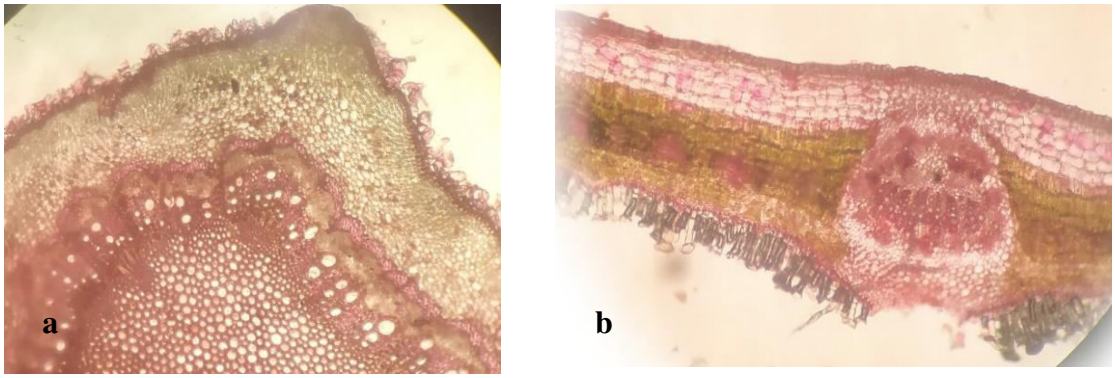


Plate 8: a. Transverse section of a stem *Avicennia marina*.
b. Transverse section of a leaf *Avicennia marina*.

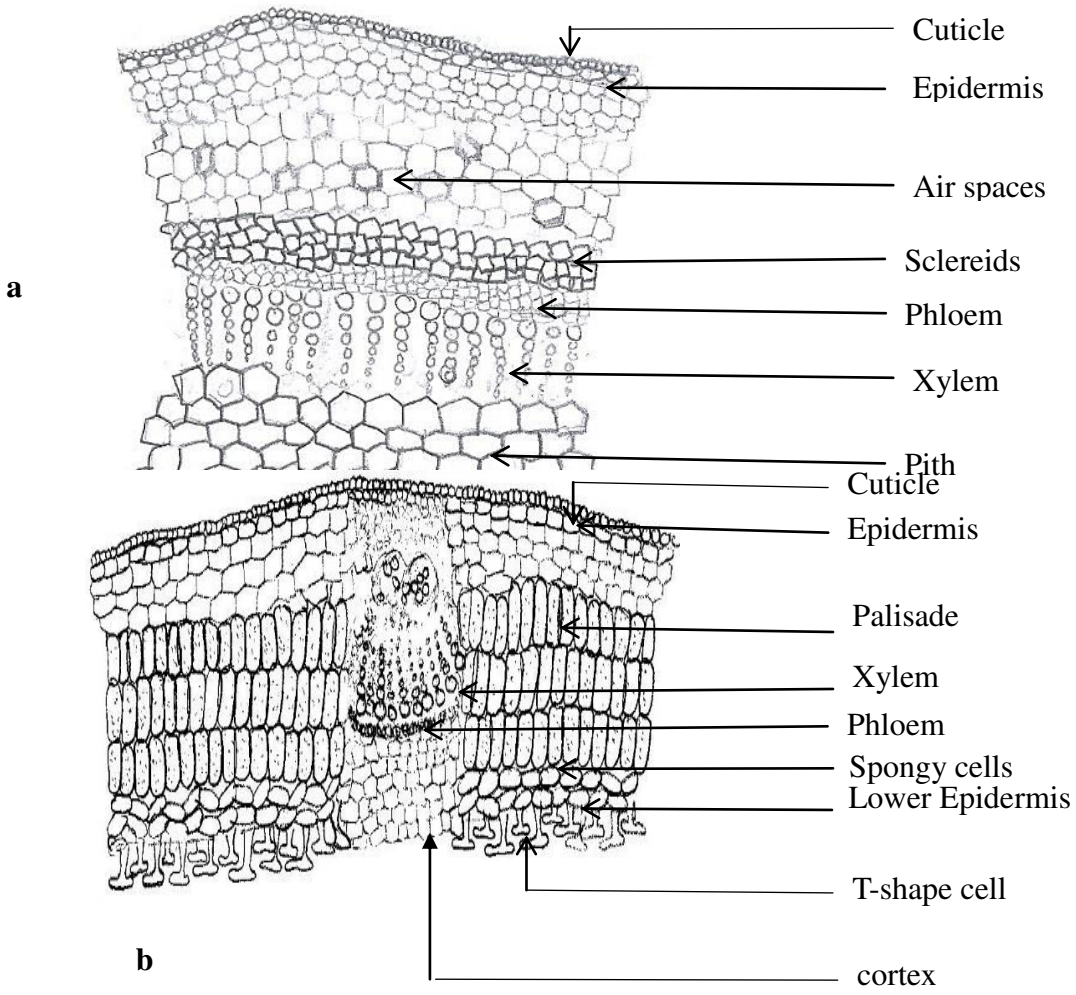


Figure 4: a. Transverse section of a stem *Avicennia marina.*
b. Transverse section of a leaf *Avicennia marina.*

Avicennia officinalis L.

Stem

Epidermis

a. is thin single layer.

Phelloderm

a. 4-5 layer present below the epidermis

b. is the secondary cortex

Cortex

a. multilayered with parenchymatous cells.

b. along with tannin in between.

Vascular bundle

a. conjoint, closed, collateral.

b. protoxylem toward the pith and metaxylem towards the periphery i.e. endarch.

c.present towards the periphery.

Pith

a. multilayer with parenchymatous cells with tannin in between (Plate 10a; Figure 5a).

Avicennia officinalis L.

Leaf

Cuticle

a. thick single layer present above the epidermis.

Epidermis

a.it is multilayered.

Palisade

a.2-3 layered they are vertically elongated cells, containing chloroplast.

Spongy cells

a. irregular shaped, parenchymatous cells with chloroplast in them, lies below the palisade cells.

Vascular bundle

a. conjoint, closed, collateral.

b. xylem is surrounded by phloem.

c.metaxylem present towards the periphery and protoxylem towards the centre.

d. phloem is present towards periphery.

Lower epidermis:

a. single layer present on lower surface of leaf.

T-Shape cells

a. present below the lower epidermis, helps in excretion of salt (Plate 10b; Figure 5b).

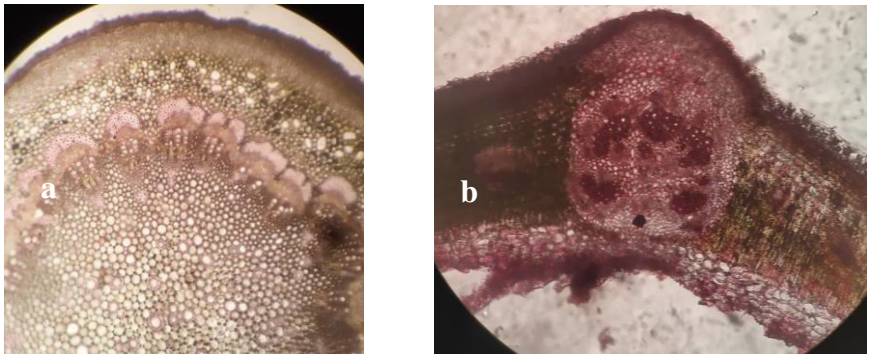
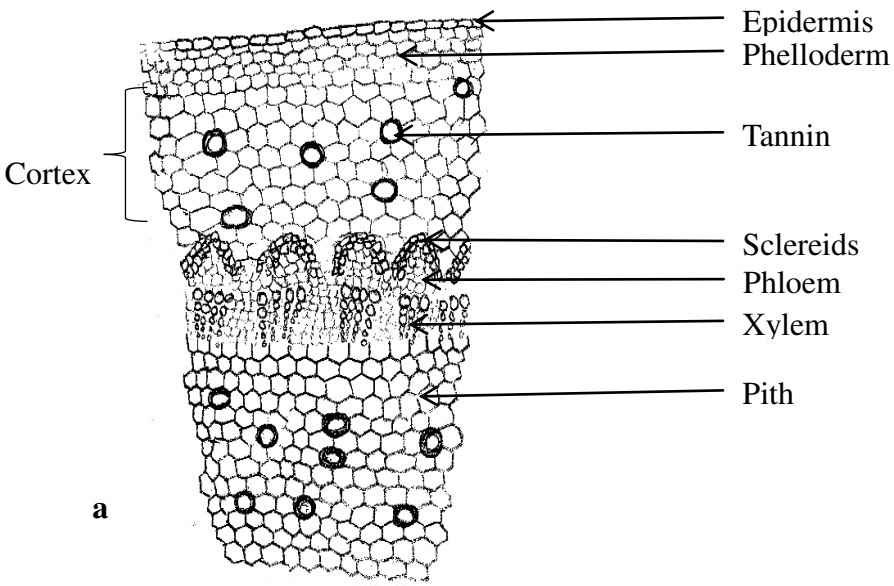


Plate 10: a. Transverse section of a stem *Avicennia officinalis* L.
b. Transverse section of a leaf *Avicennia officinalis* L.



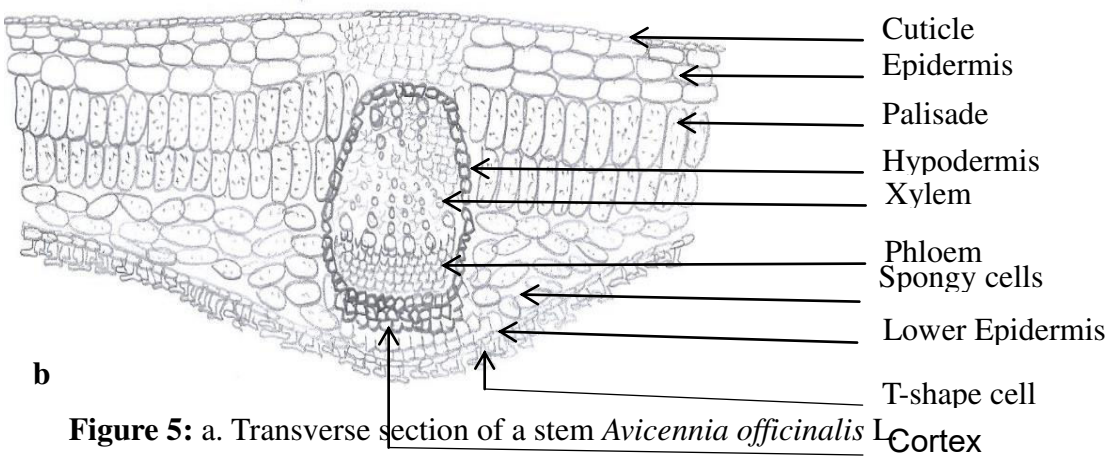


Figure 5: a. Transverse section of a stem *Avicennia officinalis* L.

b. Transverse section of a leaf *Avicennia officinalis* L.

Bruguiera cylindrical (L.) Blume

Stem

Epidermis

a.it is double layer.

Cortex

a. made up of parenchymatous cells with intercellular air space.

Vascular bundle

a. conjoint, collateral and enclosed.

b. protoxylem towards the pith and metaxylem towards the centre.

c.phloem present towards the periphery.

Pith

a. made up of parenchymatous cells with crystalliferous cells (Plate 12a; Figure 6a).

Bruguiera cylindrical (L.) Blume

Leaf

Cuticle

a. thick single layer present above the epidermis.

Epidermis

a. double layer.

Palisade tissue

a. present below the epidermis with 2-3 layer with vertically elongated cells.

b. chloroplast present, with intercellular space.

Spongy cells

a. irregular shaped parenchyamatous cells with chloroplast which lies below the palisade cells.

Vascular bundle

a. conjoint, collateral and closed.

b. protoxylem towards the pith and metaxylem toward the centre. i.e.endarch.

c.phloem present towards the periphery.

Cortex

a. made up of parenchymatous cells.

Lower epidermis

a. single layer present on the lower surface of the leaf (Plate 12b; Figure 6b).

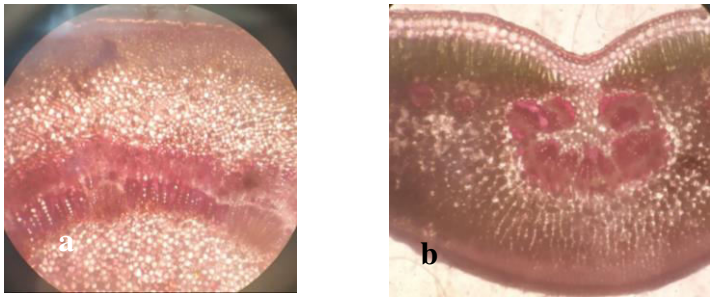


Plate 12: a. Transverse section of a stem *Bruguiera cylindrica* (L.) Blume.
b. Transverse section of a leaf *Bruguiera cylindrica* (L.) Blume.

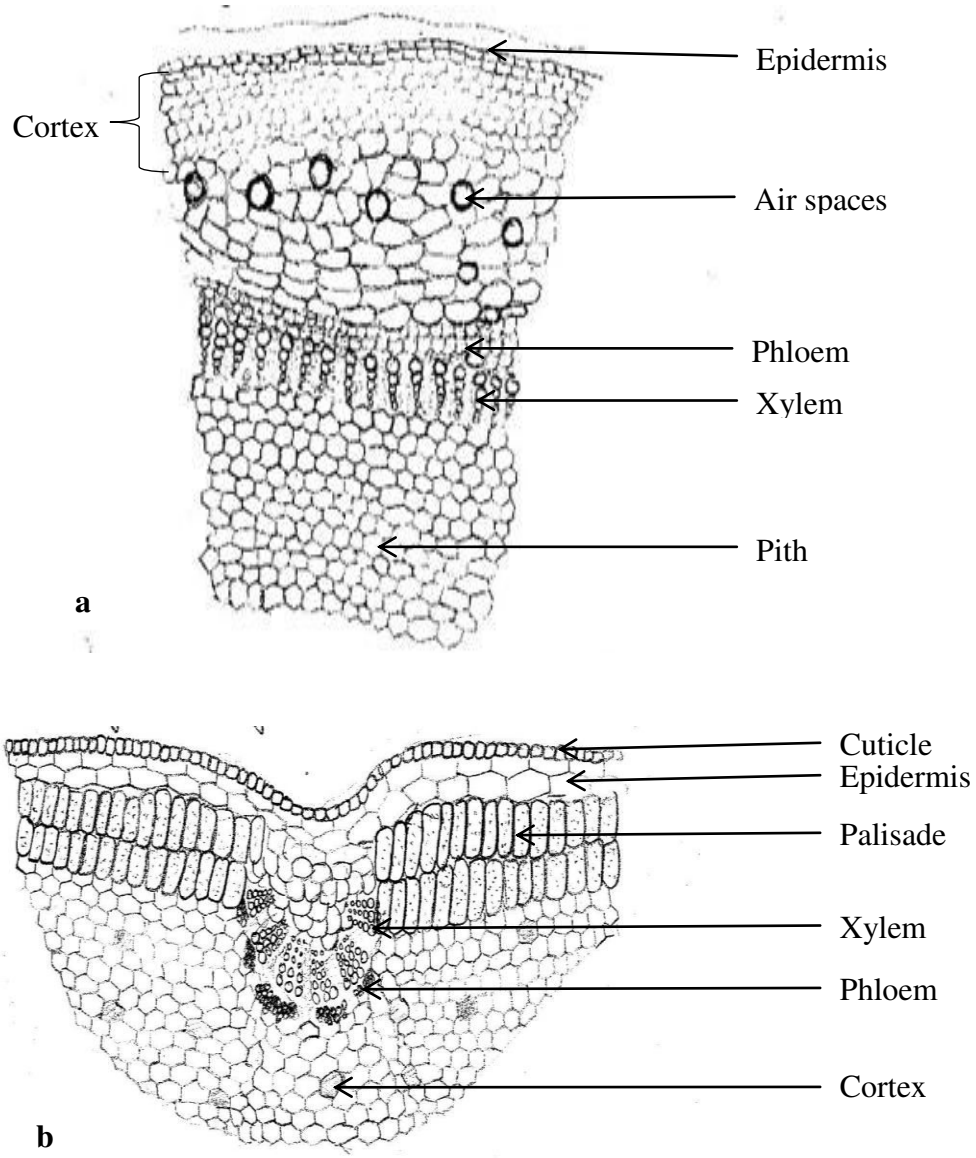


Figure 6: a. Transverse section of a stem *Bruguiera cylindrica* (L.) Blume.
b. Transverse section of a leaf *Bruguiera cylindrica* (L.) Blume.

Excoecaria agallocha Lin.

Stem

Epidermis

a.is single layered.

Cortex

a. made up parenchymatous cells with intercellular space in between.

Vascular bundle

a. conjoint, collateral and enclosed.

b. protoxylem towards the pith and metaxylem towards the periphery.

c.phloem is present towards the periphery.

Pith

a. made up of parenchymatous cells (Plate 14a; Figure 7a)

Excoecaria agallocha Lin.

Leaf

Epidermis

a. bilayer with thick walled cells.

Palisade tissue

a. present below the epidermis with 2-3 layer with vertically elongated cells.

b. chloroplast present.

c. intercellular space present.

Spongy cells

a. irregular shaped parenchymatous cells with chloroplast present below the palisade cells.

Vascular bundle

a. conjoint, closed, collateral.

b. xylem is surrounded by phloem

c. metaxylem present towards the periphery and protoxylem towards the centre.

Cortex

a. multi-layered parenchymatous cells.

Lower epidermis

a. single layer cells present on lower surface of leaf (Plate 14b; Figure 7b).

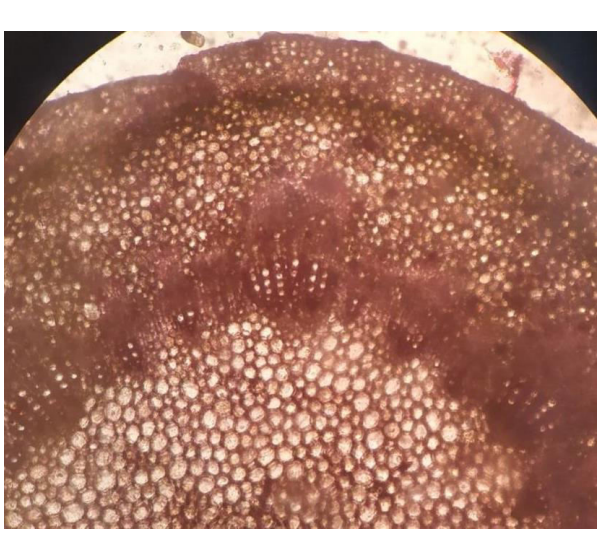


Plate 14: a. Transverse section of a stem *Excoecaria agallocha* Lin.

b. Transverse section of a leaf *Excoecaria agallocha* Lin.

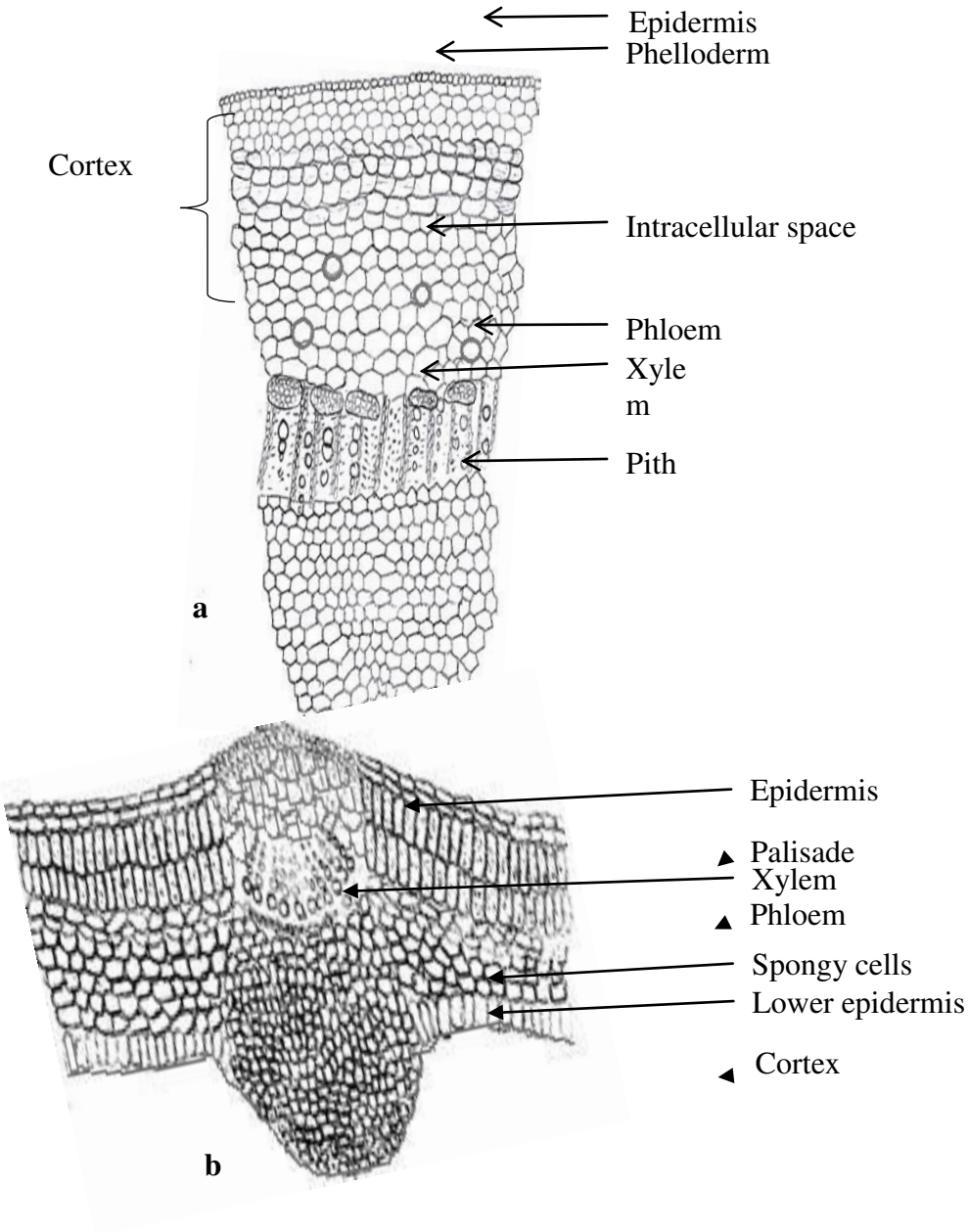


Figure 7: a. Transverse section of a stem *Excoecaria agallocha* Lin.

b. Transverse section of a leaf *Excoecaria agallocha* Lin.

Kandelia candle (L.) Druce

Stem

Epidermis

a. made up of 2-3 layer of cells.

Cortex

a. multi-layered, crystalliferous and phenolic cells are observed.

Vascular bundle

a. conjoint and collateral

b. protoxylem towards pith and metaxylem towards the periphery, i.e. endarch position.

Pith

a. is made up of parenchymatous cells with crystalliferous cells (Plate 16a; Figure 8a).

Kandelia candle (L.) Druce

Leaf

Cuticle

a. thick layer present above the epidermis.

Epidermis

a.is double layer.

Palisade tissue

a. present below the epidermis with 2-3 layer with vertically elongated cells.

b. chloroplast present.

Spongy cell

a. irregular shaped parenchymatous cell with chloroplast, present below the palisade layer.

Vascular bundle

a. conjoint and collateral.

b. metaxylem towards the periphery and protoxylem towards the pith.

c.phloem present on the outer side of the xylem tissue (Plate 16b; Figure 8b).

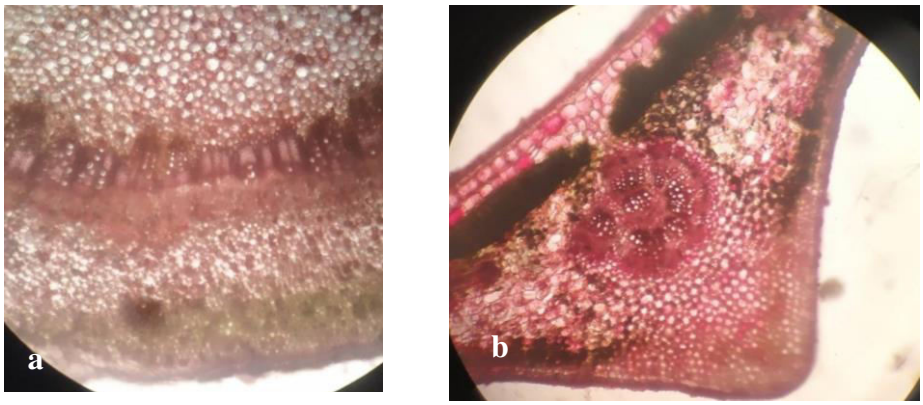


Plate 16: a. Transverse section of a stem *Kandelia candle* (L.) Druce.
b. Transverse section of a leaf *Kandelia candle* (L.) Druce.

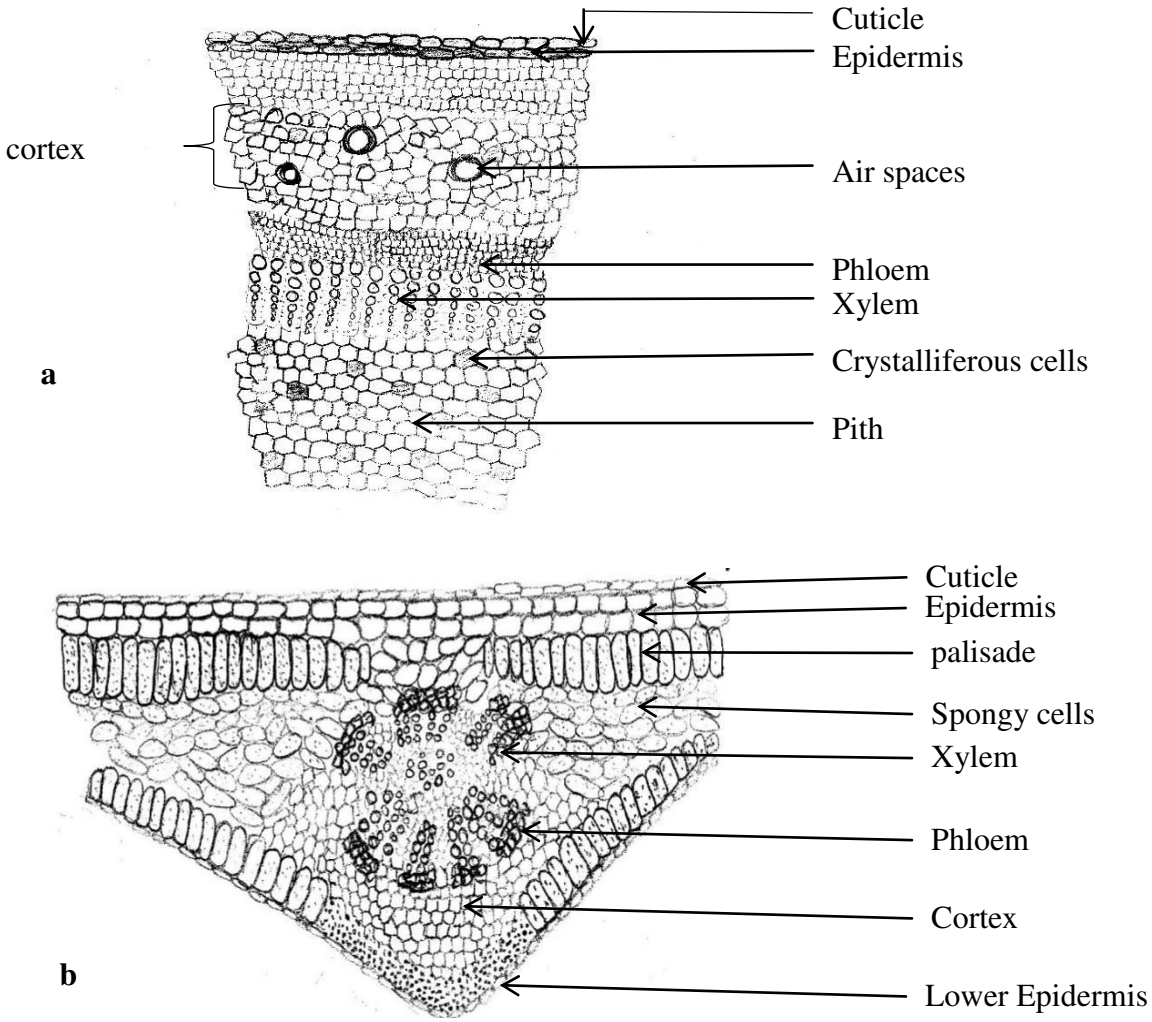


Figure 8: a. Transverse section of a stem *Kandelia candle* (L.) Druce.
b. Transverse section of a leaf *Kandelia candle* (L.) Druce.

Rhizophora apiculate Blume

Stem

Epidermis

a. multilayer with thick walled cells.

Cortex

a. multilayer with parenchymatous cells with intercellular spaces.

Vascular bundle

a. conjoint and collateral.

b. metaxylem towards the periphery and protoxylem towards the pith.

c.phloem present on the outer side of the xylem tissue

Pith

a.is multilayer parenchymatous cells with crystalliferous cells (Plate 18a; Figure 9a).

Rhizophora apiculata Blume.

Leaf

Cuticle

a. outermost thick single layer present above the epidermis.

Epidermis

a. multilayer with thick walled cells.

Palisade tissue

a. present below the epidermis with 1-2layer with vertically elongated cells.

b. intercellular space containing chloroplast.

Vascular bundle

a. conjoint and collateral.

b. metaxylem towards the periphery and protoxylem towards the pith.

c.phloem present on the outer side of the xylem tissue

Hypodermis

a. xylem and phloem is surrounded by Hypodermis.

Spongy cells

a. irregular shaped parenchymatous cells with chloroplast present below the palisade cells.

Lower epidermis

a. single layer cells present on lower surface of leaf (Plate 18b; Figure 9b).

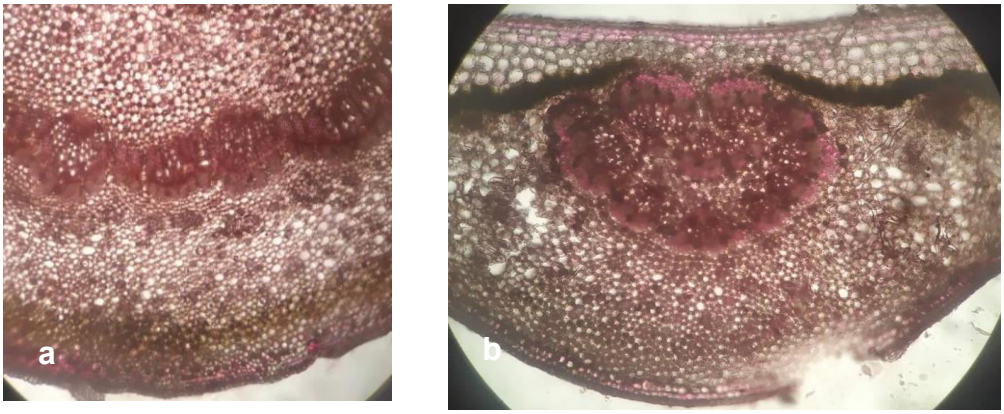
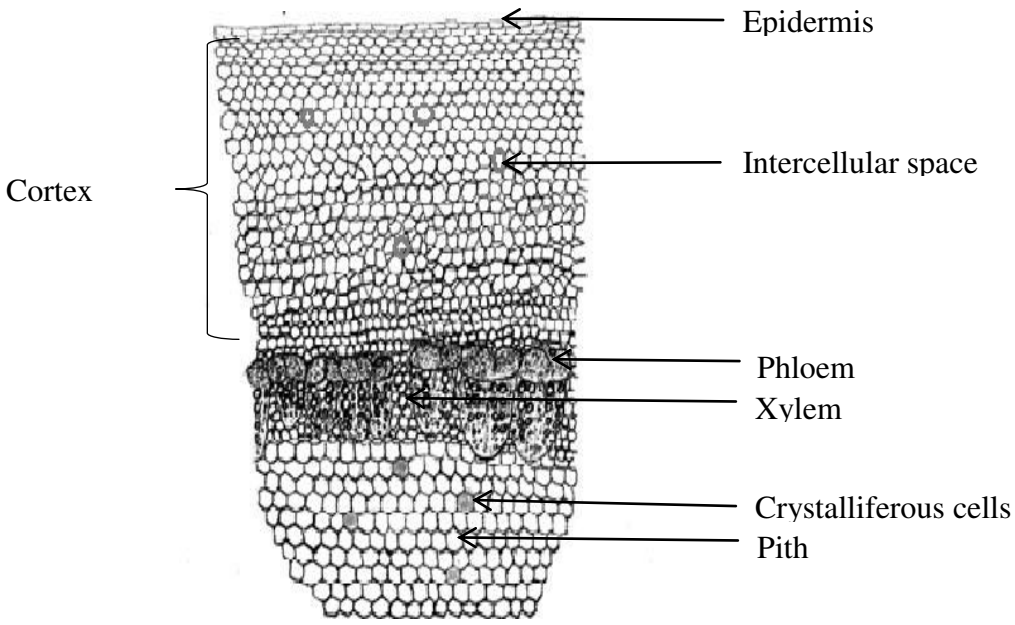


Plate 18: a. Transverse section of a stem *Rhizophora apiculata* Blume.
b. Transverse section of a leaf *Rhizophora apiculata* Blume.



a

b

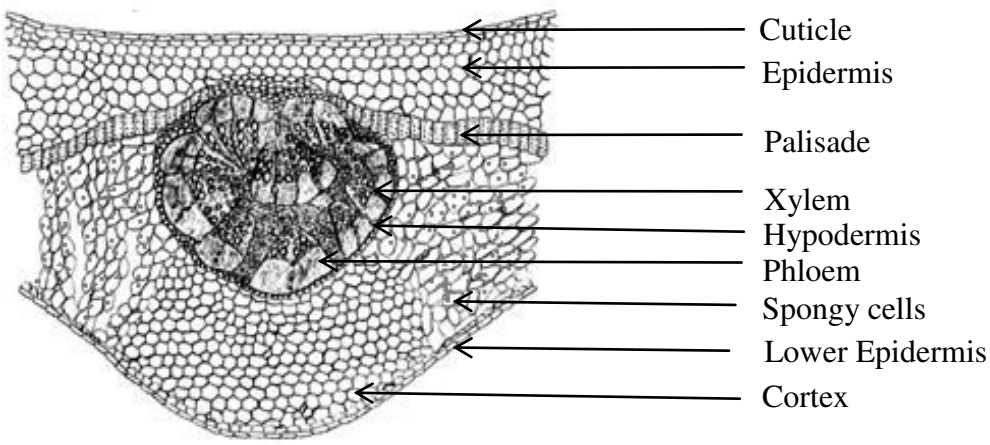


Figure 9: a. Transverse section of a stem *Rhizophora apiculata* Blume.

b. Transverse section of a leaf *Rhizophora apiculate* Blume.

Rhizophora mucronata Lamk.

Stem

Epidermis

a.is thin single layer.

Phelloderm

a. present below the epidermis, 4-5 layers thin walled.

b. forms a secondary cortex.

Cortex

a. is multilayered with parenchymatous cells with crystalliferous cells.

Sclereids

a. they are reduced form of parenchymatous cells present along with phloem.

Vascular bundle

a. conjoint, closed, collateral.

b. protoxylem toward the pith and metaxylem towards the periphery i.e. endarch.

c.phloem present towards the periphery.

Pith

a. multilayer with parenchymatous cells with tannin (Plate 20a; Figure 10a).

Rhizophora mucronata Lamk.

Leaf

Cuticle

a. thick single layer present above the epidermis.

Epidermis

a. is multilayered.

Palisade tissue

a. present below the epidermis with 2-3 layer with vertically elongated cells.

b. chloroplast present.

Vascular bundle:

a. conjoint, collateral and closed.

Xylem

a. protoxylem towards the pith and metaxylem toward the centre.i.e. endarch.
b. phloem is present towards the periphery.
Cortex
a. made up of parenchymatous cells (Plate 20b; Figure 10b)

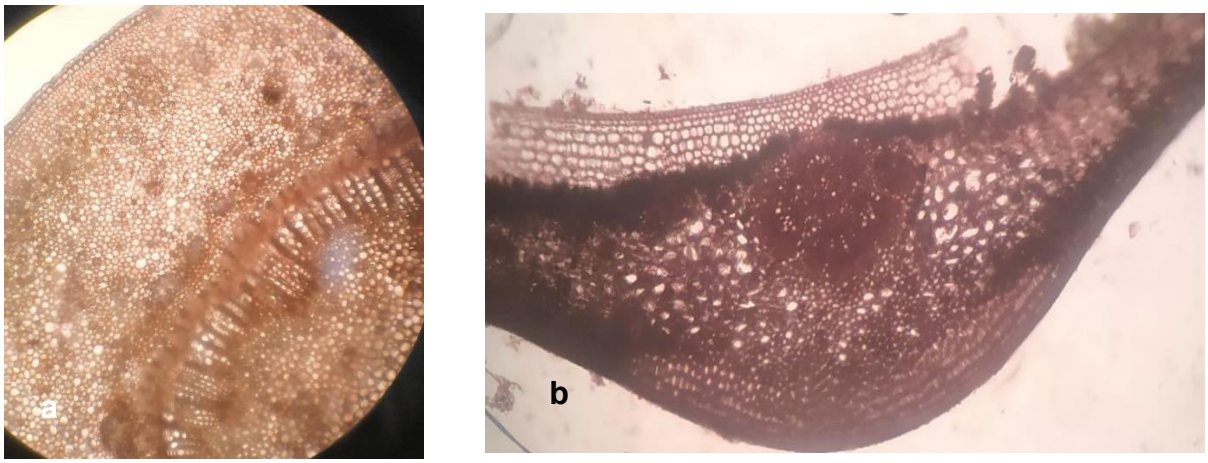


Plate 20: a. Transverse section of a stem *Rhizophora mucronata* Lamk.
b. Transverse section of a leaf *Rhizophora mucronata* Lamk.

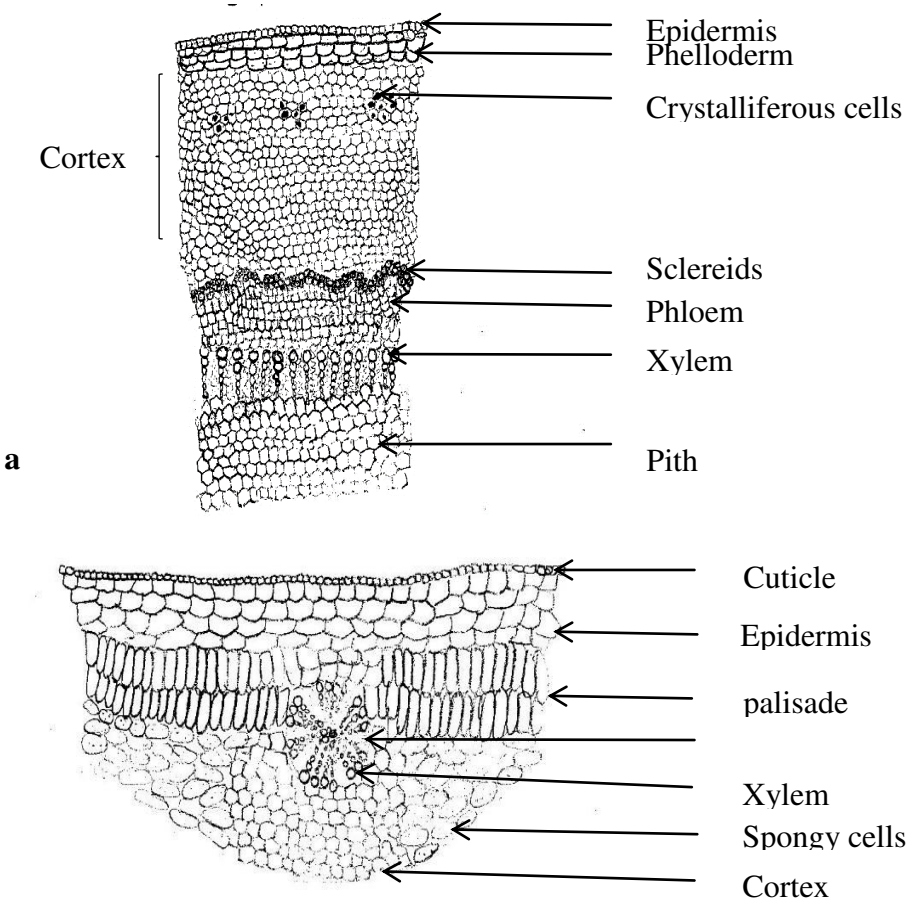


Figure 10: a. Transverse section of a stem *Rhizophora mucronata* Lamk.
b. Transverse section of a leaf *Rhizophora mucronata* Lamk.

Sonneratia alba J.Sm.

Stem

Epidermis
a. single layer with thin-walled cells.
Cortex
a. multilayer with Parenchymatous cells.
Vascular bundle
a. closed, with no differentiation of cells. Three distinct vascular bundles are present.
b. xylem is surrounded by phloem.
Pith
a. multilayer parenchymatous cells with crystalliferous cells (Plate 22a; Figure 11a).
Sonneratia alba J.

Leaf
Epidermis
a.is thin single layer.
Palisade tissue
a. present below the epidermis with 1-2 layer with vertically elongated cells.
b. chloroplast present.
Vascular bundle
a. conjoint, Collateral and closed.
b. protoxylem towards the pith and metaxylem toward the periphery.i.e. endarch.
c. phloem is present towards the periphery.
Cortex
a. made up of parenchymatous cells and cannot be differentiated into spongy cells.
Lower epidermis
a. is single layer present on lower surface of leaf (Plate 22b; Figure 11b).

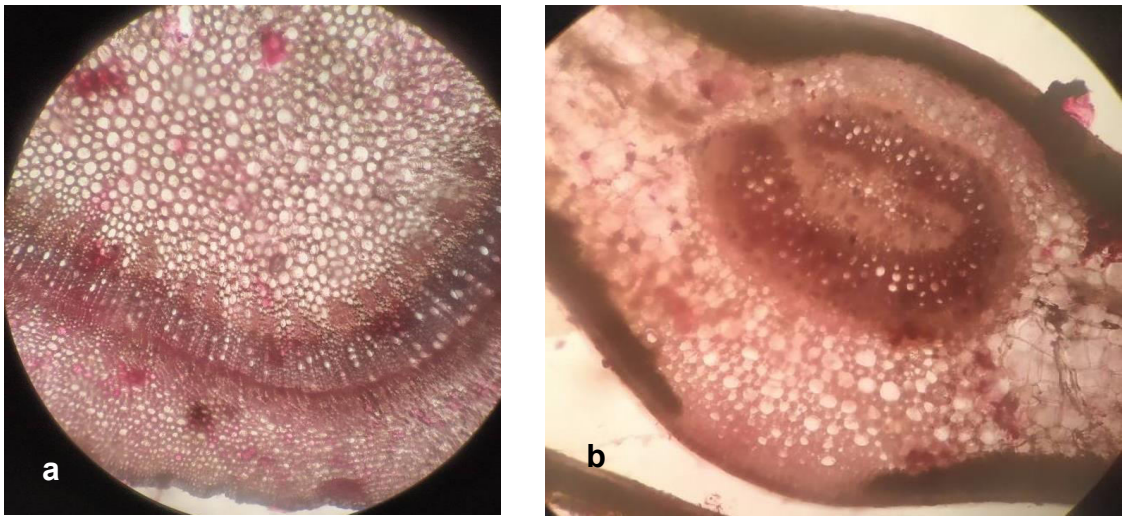


Plate 22: a. Transverse section of a stem *Sonneratia alba* J. Sm.
b. Transverse section of a leaf *Sonneratia alba* J. Sm.

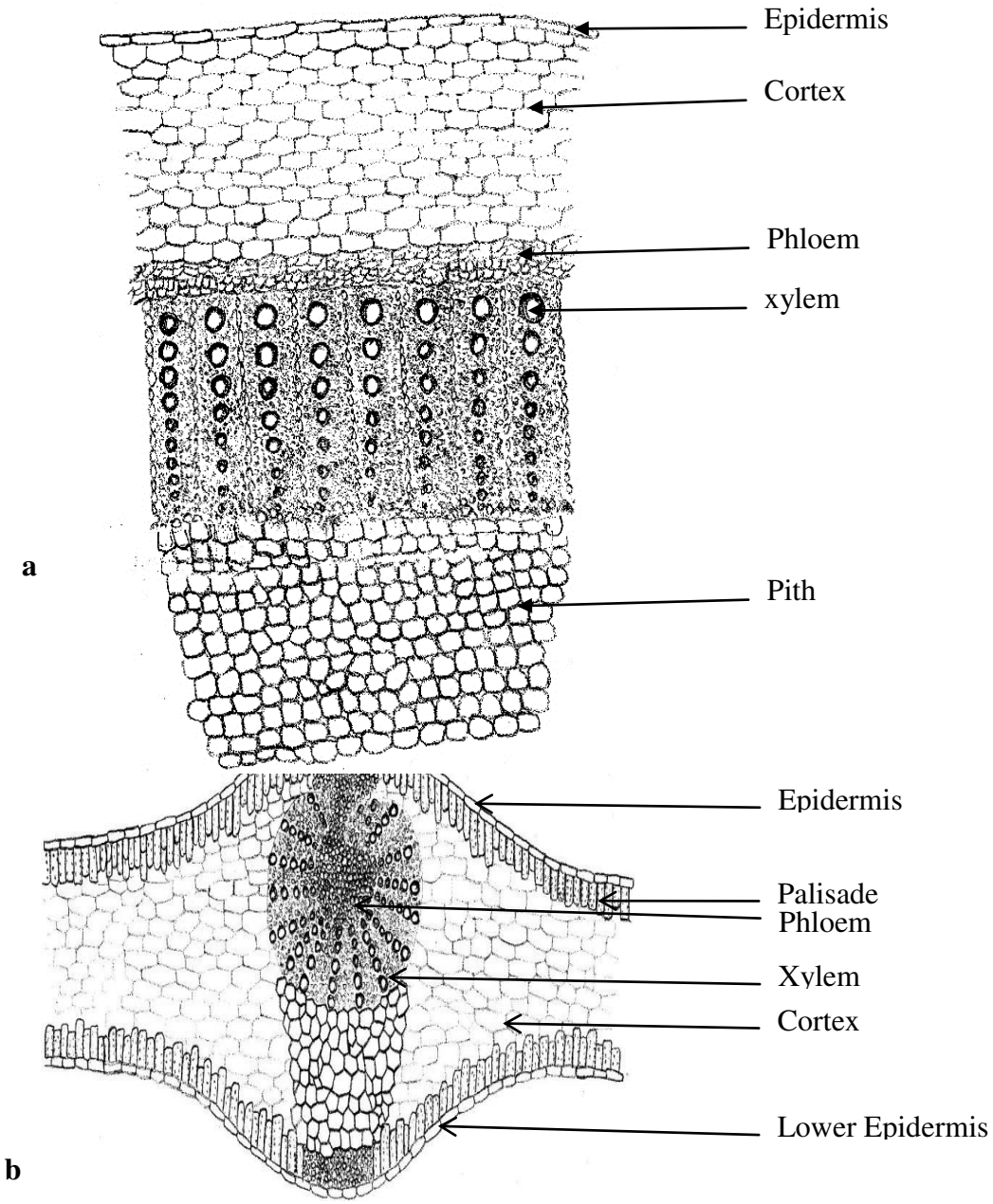


Figure 11: a. Transverse section of a stem *Sonneratia alba* J. Sm.
b. Transverse section of a leaf *Sonneratia alba* J. Sm.

Sonneratia caseolaris (L.) Engler

Stem

Epidermis

a.is single layer.

Phelloderm

a. present below the epidermis, 4-5 layers thin walled.

b. forms a secondary cortex.

Cortex

a.is multilayer with parenchymatous cells with intercellular air spaces.
Vascular bundle
a. conjoint, collateral and enclosed.
a. protoxylem towards the pith and metaxylem towards the periphery.
b. phloem is present towards the periphery.
Pith
a. is made up of parenchymatous cells with crystalliferous cells.

Sonneratia caseolaris (L.) Engler
Leaf
Epidermis
a. made up of single layer.
Palisade tissue
a. present below the epidermis with 2-3 layer with vertically elongated cells.
b. chloroplast present.
Spongy cells
a. irregular shaped parenchyamatous cells with chloroplast.
Hypodermis
a. xylem and phloem is surrounded by hypodermis.
Vascular bundle
a. conjoint, collateral and closed.

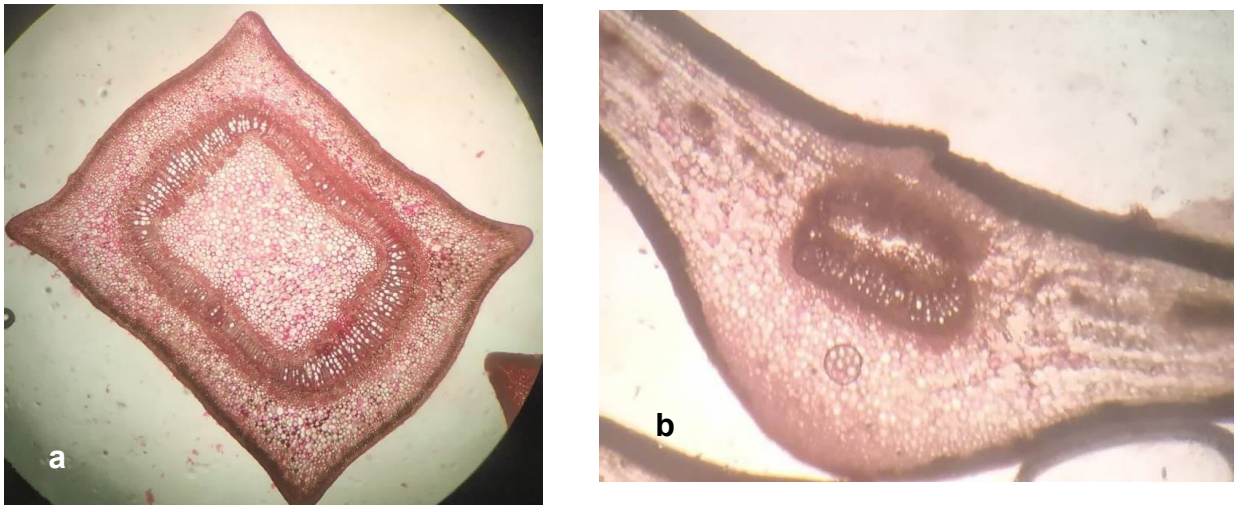


Plate 24: a. Transverse section of a stem *Sonneratia caseolaris* (L.) Engler.

b. Transverse section of a leaf *Sonnaretia caseolaris* (L.) Engler.

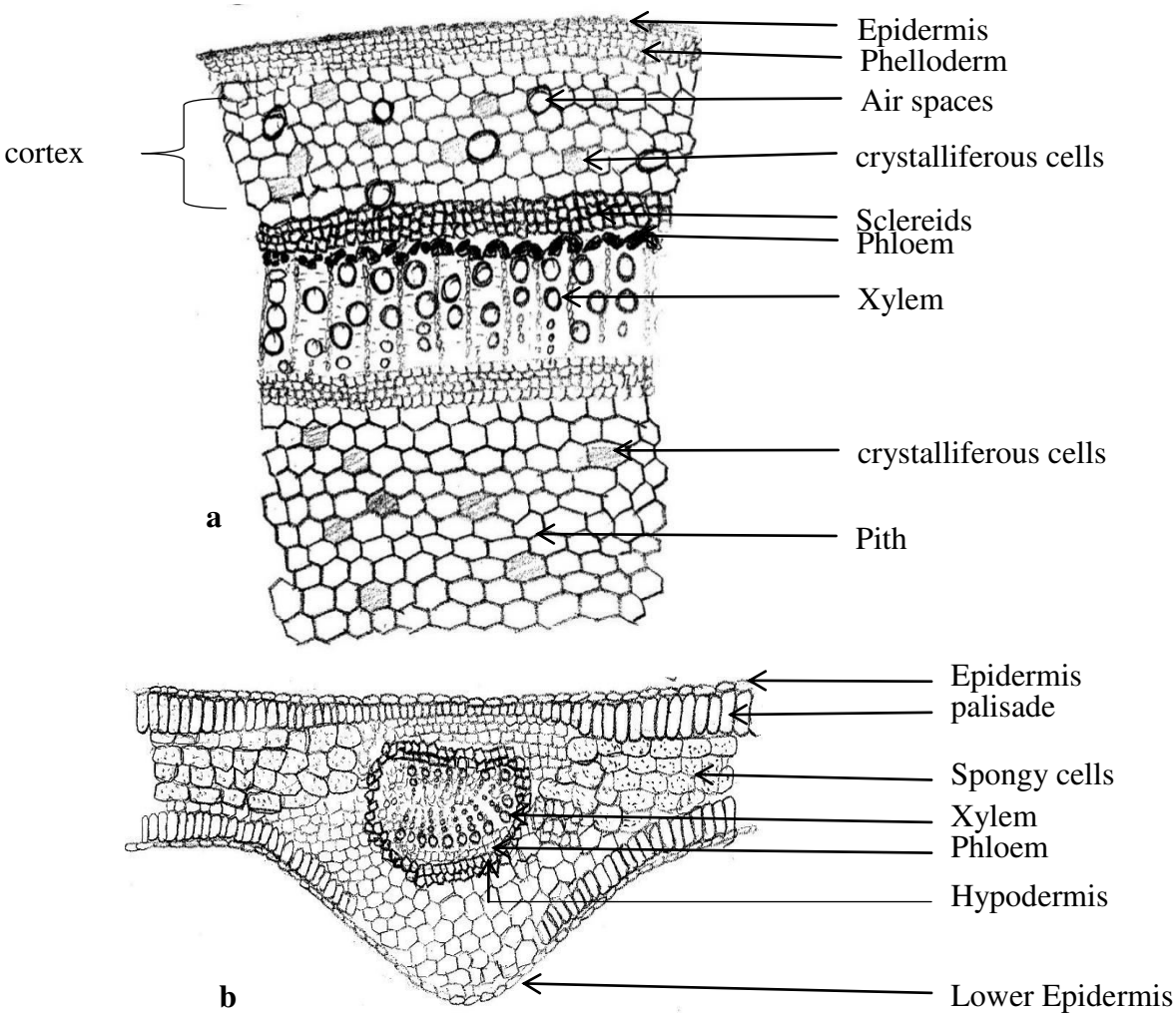


Figure 12: a. Transverse section of a stem *Sonneratia caseolaris* (L.) Engler.
b. Transverse section of a leaf *Sonneratia caseolaris* (L.) Engler.

DISCUSSION

The anatomical study illustrated that *Acanthus ilifolius* stem showed the presence of phelloderm, crystalliferous cells and intercellular spaces. In leaves there is no differentiation of xylem and phloem. Surya and Hari, 2018 showed the presences of tannin in the transverse section of the stem.

In *Acrostichum aureum* showed a distinct cortex made up of collenchyma and parenchymatous cells with air spaces. In leaves, vascular bundle was scattered with the presence of hypodermis. Transverse section of *Aegiceras corniculatum* stem showed cortex with tannin and sclereids attached to cortex. In leaves section large palisade with spongy cells were observed.

Avicennia marina and *A. officinalis* in leaf showed the presence of T-shaped cells, which help in excretion of salt. Stem of *Avicennia* marina collenchyma was absent and presences of air spaces

were observed. According to Surya and Hari, 2018 in *Avicennia* marina showed collenchyma and presence of air spaces in stem.

In *Avicennia offcinalis* the stem showed the presence of phelloderm. Chlorenchyma and aerenchyma were absent and showed the presence of tannin in pith as well as in cortex. In *Kandelia* candle the presence of air spaces in cortex and crystalliferous cells were observed. And the leaf midrib appearance is somewhat triangular in shape. As per study of Surya and Hari, 2018 phenolics and crytalliferous cells in cortex as well as in pith were encountered.

Rhizophora apiculata the stem showed the presence intercellular space in cortex and crystalliferous cells in pith. The cortex of stem in *Rhizophora mucronata* crystalliferous cells in cortex and sclereids were observed .And in leaf multilayer epidermis is seen. *Rhizophora mucronata* the cortex shows the presence of air cavities and sclereids were absent .In stem of *sonneratia caseolaris*, cortex phelloderm and air spaces, crystallifeous cells were studied. In the leaf presence of hypodermis was seen.

SUMMARY AND CONCLUSION

The mangrove species were collected for the Diwar Island, Ribandar, Panjim and Panjim patto .The morphological and anatomical study was done in 12 species of mangroves. The section of the leaf and stem was taken and different anatomical characters were studied. Different variations were observed in the all the mangrove species studied.

In morphological character the distinct characters were observed in the arrangement of leaves, stem, roots and pneumatophores etc. These specialized characters allow the mangroves to survive under stressful salinity condition and to classify them into families, genus and species. Anatomical character shows the variations with presences of air spaces, sclereids, crystalliferous cells, tannin, vascular bundle epidermis etc.

Due to environmental factors and human activities lots of mangroves are destroyed and fall under endangered category. Mangroves play an important role in marine life for shelter and serves as the nursery for their young ones. In ecosystem mangroves play a very important role in prevention of coastal zones from erosion, tsunami, floods and storm. This study is useful to compare the anatomical and morphological differences and similarities.

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