IDENTIFICATION OF MANGROVES AND MANGROVE ASSOCIATES OF THRISSUR DISTRICT, KERALA, THEIR ADAPTIVE BIOLOGY, GERMINATION STUDY AND NUTRITIVE VALUE

Final Report

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CERTIFICATE

This is to certify that the Minor Research Project entitled "Identification of Mangroves and Mangrove associates of Thrissur District, Kerala, their adaptive biology, germination study and nutritive value" is original and the data incorporated in the project work are obtained during the investigation.

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INTRODUCTION

Mangroves are halophytes occuring in saline marshy places. The word mangrove is a combination of Portuguese word “Mangue” and English word “Grove”. Macnae (1968) coined a new term to the mangroves i.e., “mangal” for mangrove community and “mangrove” for individual species. Mangroves are salt tolerant plants of tropical and subtropical intertidal regions of the world. The regions where these plants occur are termed as “mangrove ecosystem”.

Mangroves are distinguished by their morphology and physiology. The vegetation consists of evergreen trees and shrubs belonging to several unrelated families and share similar habitats. Mangroves are the prominent component of coastal vegetation occupying flood plains, margins of bays and tidal river in addition of shores. Uniqueness of mangrove ecosystem is that the biota is constantly under physiological stress caused by extreme environmental conditions. Despite extreme conditions, mangroves have been successfully colonized by developing morphological, reproductive and physiological adaptations like pneumatophores, prop roots, stilt roots and viviparous germination which facilitates their growth in aquatic environment (Tomlinson, 1986).

Mangroves are the only trees that are capable of thriving in salt water and form unique intertidal forests at the edge of land and sea. Mangrove forests are regarded as the most productive and biodiverse wetlands on earth, as an important natural reserve of biological diversity. The mangrove ecosystem constitutes a bridge between

terrestrial and marine ecosystem. This ecosystem serve as excellent reservoirs of nutrients and feeding and nursery grounds for a wide variety of organisms such as crabs, oysters, prawns and fishes. The mangrove vegetation stabilizes the shoreline by checking the erosion of land by the sea. This characteristic anchoring of aerial network of stilt roots and pneumatophores trap sediments and help in building up of land, thus mangroves act as land markers. Mangroves serve as nature's shelter belts to minimize loss of life and property caused by cyclones, storms and tsunami. Besides their protective role,the mangrove provide a wide variety of goods to man including food, wood, honey, fibre, tannin, dye, medicine and fodder.

In the mangrove ecosystem, where tides and coastal currents bring unremitting variation to the forest plants and animals adopt continuously to changing, chemical, physical and biological characteristics of their environment. Within these ecosystem the individual plants and animals, the soil microbial populations and the physical environment are linked by processes by which a continuous exchange and assimilation of energy occurs (Singh and Odaki, 2004).

Mangroves occur in two formations viz. Western formation consisting of the coasts of America, the West Indies and West Africa and Eastern formation along the coast of India, East Africa, Malay and so on.

Mangroves of India

In India,mangroves occur along both the western and eastern coasts. Western sea board includes Gujarat, Maharashtra, Goa, Karnataka and Kerala. Eastern sea board includes Andaman and Nicobar

Islands, Sunderbans of West Bengal, Orissa, Andra Pradesh and Tamil Nadu. The total area of mangroves in India is estimated to 6740 sq.km which is about 7% of the world's mangroves. Out of these, Sunderbans of West Bengal occupy the major area, the next being Andaman and Nicobar Islands, both together accounting for 80% of the mangroves in the country.

Mangroves of Kerala

About 70,000 ha. of mangroves once fringed the backwaters of Kerala. Now it has become reduced to 3.5% in a few isolated patches, consisting of a few specimens. Basha (1991) reported that only 1671 ha. of mangroves exist in Kerala coast.

The important mangrove patches existing now in different localities of Kerala are mangroves of Veli, Kollam, Kumarakam, Cochin, Chettuwai, Kadalundy, Nadakkavu, Edakkad, Pappinissery, Thalassery, Kungimangalam and Chiteri (Suma and Joy, 2003). Mangroves of Kerala include *Acanthus ilicifolius, Aegiceras corniculatum. Avicennia officinalis, Bruguiera cylindrica, B. gymnorhiza* and *Rhizophora mucronata.*

Mangroves in Thrissur

The area of estuaries and backwaters in Thrissur district of Kerala is estimated as 1,409 ha. (KSLUB, 1993), Chettuwai, Kodungallur and Azhikode are the major estuaries in Thrissur district. The mangroves which were restricted to an area of hardly 25 ha. in Thrissur district (Mohanan, 1997), had shrunken drastically to 5 ha. and is at

present represented only as relicts at Chettuwai (Kumudranjan and Rabindranath, 1999).

Another main area of mangroves in Thrissur district is Poyya backwaters . Poyya backwaters is located between $10^0$13'N and $10^0$15'N Lat and $76^0$14'E and $76^0$17'E long. (Saritha and Tessy, 2011). Other areas of mangroves in Thrissur district are Chavakkad, Orumanayur, Thekkan Palayur, Venmenad, Kundukadavu, Chakkamkandam, Anjangadi, Blangad, Idianchira, etc.

Importance of Mangrove

In a coastal area, a natural mangrove belt exert protection against encroachment of sea, destructive forces of tides and storms. Its ability to stabilize the coastal area against long-term climatic fluctuations and sea level rise is now globally accepted (Mohanan, 1999). The role of mangroves in soil conservation is very significant. The high nutrient status of mangrove areas resulted by the redistribution of nutrients through the incoming tidal waters and seasonal floods, make mangrove ecosystems a most fertile and productive ecosystem. As a habitat of a variety of organisms, mangrove shelters specialized group of plants and animals which cannot survive outside. Many of the commercially important fishes and crustaceans adopt mangrove ecosystem as nursery, feeding and spawning place.

The mangroves are with multiple benefits to common people. It provide a variety of products directly extracted from mangroves like timber, construction poles, firewood, charcoal, tannin, etc. Mangroves are valued greatly as cattle fodder. Seeds of some mangrove plants are

edible (eg. *Avicennia*). Mangroves also provide recreational and educational values and are ideal spots for environmental education. Tourism is another area of interest.

Present Study

Present study involves locating mangrove areas in Thrissur district, identification of mangroves and mangrove associates in these identified areas, study of adaptations of mangroves, germination study of mangroves and nutritive value of mangrove fruit, seed, leaf, etc., and steps needed for conservation of mangroves in different areas of Thrissur district.

Threats to Mangroves

The threats to mangrove ecosystem could be broadly grouped into two-Natural and Anthropogenic. The natural threats include climatic changes, cyclones and physical processes. Anthropogenic threats include diseases, deterioration, pollution, grazing, agriculture, aquaculture and human encroachment. The major threat to mangroves is the exploitation for timber,firewood,poles and cattle feed by human beings. This lead to a great loss of mangrove biodiversity. In Kerala the conversion of mangrove swamps into fish farm cause great ecological damage.

Therefore conservation of mangrove ecosystem is highly essential. Priority should be given to biodiversity conservation and ecosystem restoration in mangrove area. Large scale afforestation,

control on developmental activities in the mangrove areas, ecotourism, etc. give better results in the conservation of mangroves.

REVIEW OF LITERATURE

Study of mangroves include mangrove ecosystem, habitat, different genera, species, composition, germination study, etc. According to Kar and Satpathy (1995) mangrove forests serve as a link between terrestrial and marine ecosystems. They receive a continuous supply of inorganic nutrients from the adjacent land mass and release dead organic matters to the sea through rivers and estuary. Best development of the mangroves are found at locations with deep well aerated soils, rich in organic matter and low in sand, usually in estuaries. Most species of mangroves have special adaptations, such as vivipary, high salt tolerance, ability to withstand tidal submersion, pneumatophores, succulence of leaf and salt excreting glands.

The composition of mangrove forest encompasses a variety of plants including trees, epiphytes, lianas and algae. Almost all evergreen plants, possess similar physiological and structural adaptations and are salt tolerant. Soil type is one of the main factors for mangrove zonation. *Rhizophora* grows on mud flats and *Avicennia* and *Bruguiera* on sandy soils (Singh and Odaki, 2004).

Adaptations of mangrove plants

Mangrove forests are constantly exposed to high salinity, strong winds and high light intensity. In order to survive under these harsh conditions mangroves have many adaptations. The external and internal structure of the stem, leaf, flower, and fruit have undergone considerable changes to suit the environment. Leaves are succulent eg. *Rhizophora* and

Sonneratia. This feature is to facilitate water storage in the mesophyll. Leaves of *Rhizophora* and *Bruguiera* are succulent and shiny, while, those of *Avicennia* are thinner and covered with a number of hairs on the abaxial side. *Rhizophora* and *Bruguiera* have sunken stomatas. A thick cuticle develops on the leaves of mangrove species. Sclereids are common in spongy parenchyma (Das and Ghose, 1996).

Most species possess a specialized root system such as pneumatophores in *Avicennia* and *Sonneratia*, knee-root in *Bruguiera* and prop roots in *Rhizophora*. These root structures are adaptations for physical anchoring and aeration for the plant, since soil aeration is poor in mangroves (Aksornkoae, 1993).

According to Das and Ghose (1996) mangrove leaves possessed thick cuticle. Colourless water storage tissue is hypodermal in dorsiventral leaves but is deep seated in the mesophyll region of isobilateral leaves. Terminal tracheids at vein endings are commonly found in many species. Branched sclereids present in some species. The presence of water storage tissue and terminal tracheids causes leaf succulence with high water content. According to Zimmermann(1983) both sclereids and tracheids are involved in capillary water storage. Tomlinson (1986) suggested that in addition to water storage, sclereids might also provide mechanical support to leaves with diminished turgor or discourage herbivores. The coriaceous nature of mangrove leaves is due to the presence of sclereids.

Salt excretion is a common phenomenon in various halophytic plant genera. It is found in the mangrove species *Acanthus*, *Avicennia*, *Aegiceras* and *Sonneratia* (Waisel, 1972). Aegiceras regulate its salt

contentv by secreting salt through glands on their leaves. A gland consists of a large number of abutting secretory cells and a single, large basal cell. Salt excretion by slat glands of halophytes is claimed to be the fastest ion transport system in plants (Pollak and Waisel, 1979). These authors reported that sodium excreted from *Aelurops* leaves is more than any other cation.

Salt excretion is an efficient mechanism which prevents accumulation of large quantities of sodium and chloride ions inside the tissues. It is an adaptive characteristic of non-succulent halophytes growing in saline habitats. Succulents release accumulated salts by shedding leaves or other fleshy tissues (Waisel, 1972).

According to Aksornkoae (1983) the function of salt glands is to regulate the salt balance in the plant, through secretion. Salt glands control the salt balance in *Avicennia* by secreting excess salt from the leaves. The glands are sunken in the upper surface of the leaf because there is no trichome to protect them on this side.

Most species of mangroves possess a specialized root system such as pneumatophores in *Avicennia* and *Sonneratia*, knee-roots in *Bruguiera* and prop roots in *Rhizophora*. These root structures are adaptations for physical anchoring and aeration for the plant since soil aeration is poor in mangroves. Mangrove root system contain a large amount of gas space (Chapman, 1976). Lenticels and horizontal structures are responsible for gaseous exchange.

Propagules of certain genera contain viviparous seeds which germinate while still attached to the parent tree. When the ripe

propagules fall from the parent plant, the seedlings germinate rapidly. Air spaces in the propagules or germinating seedlings are modified to facilitate floating or dispersal by water. These can be found in *Rhizophora, Bruguiera, Avicennia* and *Aegiceras.* The propagules of all mangroves are buoyant and are able to disperse by water (Tomlinson, 1986; Aksornkoae, 1993).

MATERIALS AND METHODS

Study areas

Mangrove areas in Thrissur district were identified,starting from south region of Thrissur to north. Azhikode is the extreme south region of Thrissur district. On the way to Azhikode, patches of mangroves were seen in Karupadannna, Kodungallur, etc. *Avicennia officinalis* was common in all these areas.

Poyya backwaters are another mangrove area in Thrissur district. It is located $10^0$13'N and $10^0$15'N latitude and $76^0$14'E and $76^0$17'E longitude. Kadungachira is another mangrove area with plenty of *Avicennia officinalis, Excoecaria agallocha and Acrostichum aureum.* Krishnankotta was a mangrove area in this study. Karupadanna and Pullut (near Kodungallur) with patches of mangroves.

Chettuwai is an important area of mangroves in Thrissur district. It is an estuarine backwater complex of Kerala. It comes under Orumanayur Grama Panchayat of Chavakkad Taluk. This estuary is situated in the latitude of $10^0$32'N and longitude of $76^0$02'E. The area is a significant mangrove zone of Kerala. In this zone the rivers Chettuwai puzha and Karanjira puzha with Arabian Sea, harbour a significant stretch of mangrove vegetation. The area of mangroves in Chettuwai estuary is about 10 acress.

Northern region of Thrissur district is with several areas of mangroves. These are Orumanayur, Chavakkad, Chakkamkandam,

Anjangadi, Blangad, Venmenad, Thekkan Palayur, etc. In Venkitangu Panchayat the mangrove areas are Padur, Pandaramad, Idiyanchira, Enamakkal etc. In Kundazhiyur village, the backwater area is with 22 acres of mangroves. But in Padur and Idiyanchira about 5 acres of mangroves got destroyed.

All the above mentioned areas are with different species of mangroves and mangrove associates. The plant specimens were collected from all the mangrove areas. Herbarium specimens were prepared. For anatomical studies leaf, stem and pneumatophores and stilt roots were collected and preserved in FAA. Mangroves and mangrove associates were identified according to "Flora of Presidency of Madras" (Gamble, 1919) and compared with specimens of Calicut University Herbarium.

Mangrove Flora

Distribution of mangroves was studied in all the study areas. The specimens collected from Chettuwai were *Acanthus ilicifolius,Aegiceras corniculatum, Avicennia officinalis, Bruguiera cylindrica* and *Rhizophora mucronota*. The materials collected from Azhikode were *Avicennia officinalis, Acanthus ilicifolius,* and *Acrostichum aureum*. Mangroves of Pullut were *Aviennia officinalis*, *Acanthus ilicifolius* and *Acrostichum aureum.*

Poyya backwaters are with *Avicennia, Aegiceras, Excoecaria agallocha* and *Acrostichum.* Chakkamkandam and Thekkan Palayur are with *Avicennia, Acanthus* and *Acrostichum*. Venmanad is with *Acanthus, Avicennia*, *Rhizophora* and *Acrostichum.* Near Enamakkal Regulator small patch of mangrove with *Rhizophora, Acanthus* and

Acrostichum. Mangrove areas were visited in different seasons for collecting flowers and fruits.

Germination study in different mangrove species was conducted. Viviparous germination in *Bruguiera* and *Rhizophora*. Seed germinates while it is still attached to the mother plant. Further the seedling grows, emerges from the fruit and is eventually dispersed. The viviparous seedling consists of plumule, hypocotyl and radicle. But in *Avicennia* and *Aegiceras* cryptovivipary is noticed (Tomlinson, 1986).

Anatomical studies

Samples for anatomical studies were collected from different areas. Leaf, stem and root(stilt root and pneumatophores) of 6 genera of mangroves belonging to 5 families were collected and fixed in FAA. Thin transverse hand sections were taken and stained with safranin. Photographs of sections were taken using Ultrascope.

Leaf peeling for stomatal studies were taken and stained with safranin. Structure of salt glands was studied using the leaf peelings. Transverse sections of leaves of *Acanthus,Aegiceras* and *Avicennia* were used for the detailed study of salt glands.

Mangrove associates of all these study areas were collected. Mangrove associates of Azhikode include *Pandanus tectorius, Thespesia populnea, Calophyllum inophyllum* and *Fimbrystylis* sp. Chettuwai with *Derris uliginosa, Clerodendron inermi, Thespesia populnea, Fimbrystylis* sp. etc.

RESULTS

Floral studies

During the study, a total of 7 true mangroves were recorded from the mangrove areas (Table 1.). These belonged to 7 genera and 6 families. Mangrove associates include 9 genera.

Table 1. Distribution of Mangroves.

Sl. No	Scientific Name	Family	Locality
1	*Acanthus ilicifolius* L.	Acanthaceae	Azhikode, Pullut, Poyya, Chettuwai, Orumanayur, Chakkamkandum, Enamakkal
2	*Aegiceras corniculatum* (L.) Blanco	Myrsinaceae	Poyya, Chettuwai
3	*Avicennia officinalis* L.	Avicenniaceae	Azhikode, Pullut, Poyya, Chettuwai, Thekkan Palayur, Chakkamkandam
4	*Bruguiera cylindrica* (L.) Blume	Rhizophoraceae	Chettuwai
5	*Excoecaria agallocha* L.	Euphorbiaceae	Kadungachira, Poyya, Krishnankotta
6	*Rhizophora mucronata* Lamk.	Rhizophoraceae	Chettuwai, Enamakkal
7	*Acrostichum aureum* L. (a fern)	Pteridaceae	Azhikode, Pullut, Poyya,Krishnankotta Kadungachira, Enamakkal, etc.

Table 2. Mangrove associates

Sl. No	Scientific Name	Family	Locality
1	*Derris uliginosa* (Roxb.) Benth.	Papilionaceae	Poyya, Chettuwai, Krishnankotta
2	*Clerodendron inerme* (L.) Gaertin	Verbenaceae	Azhikode, Poyya, Chettuwai
3	*Ipomea biloba*	Convolvulaceae	Krishnankotta, Azhikode
4	*Thespesia populnea*	Malvaceae	Azhikode, Chettuwai, Krishnankotta
5	*Sphaeranthus indicus* L.	Asteraceae	Poyya, Krishnankotta
6	*Cyperus* sp.	Cyperaceae	Poyya, Krishnankotta
7	*Pandanus tectorius*	Pandanaceae	Azhikode
8	*Fimbrystylis* sp.	Poaceae	Azhikode
9	*Calophyllum inophyllum*	Clusiaceae	Azhikode

From the Table 1. it is clear that *Acanthus ilicifolius* and *Avicennia officinalis* were common in almost all study areas. *Aegiceras corniculatum* was rare and reported from Chettuwai and Poyya backwaters. Plenty of *Bruguiera cylindrica* and *Rhizophora mucronata* were present only in Chettuwai estuary. In Enamakkal *Rhizophora* was rarely seen. *Excoecaria agallocha* was present in Kadungachira, Poyya and Krishankotta. *Acrostichum aureum* was present in almost all study areas except Chettuwai.

Among mangrove associates *Derris uliginosa* was present in almost all study areas. *Clerodendron inerme* was present in Chettuwai, Poyya and Azhikode. *Thespesia populnea* was present in Azhikode, Chettuwai and Krishnankotta. *Ipomea biloba* was present in

Krishnankotta and Azhikode. *Sphaeranthus indicus* was common in Poyya and Krishankotta. (Table 2.)

Morphological studies

Acanthus ilicifolius L

Family: Acanthaceae

The plant was a twining herb and shrub, attaining a length up to 4m. and highly branched. Plants were spiny with spines in the branches and leaf. *Acanthus* showed bushy and dense growth. Plants with shallow tap roots, but occasionally stilt roots appear from the tap root. Stem with distinct nodes and internodes. Leaf simple, opposite decussate, cauline, with short petiole, nearly sessile, glabrous with slightly sheathing base. Lamina elliptic-oblong, spiny apex, with wavy and spiny margin. Inflorescence racemose, spike with violet flowers. Flowering and fruiting was during May to August. Fruit was a capsule with four kidney-shaped seeds. (Fig 1.)

Aegiceras corniculatum (L.) Blanco

Family: Myrsinaceae

Small tree or shrub upto 4m. in height and profusely branched. Bark was smooth. Well developed tap root system. Leaves simple, alternate, petiolate and glabrous. Leaf with salt glands and excrete salt on the surface. Leaf margin curved downwardly and dorsiventral. Inflorescence was a simple umbel in the shoot apex or on the axillary branches. White flowers, fragrant and pointed in bud condition. Fruit was capsule 2 to 9 cm. long curved with pointed apex. Calyx persistent at the base. Capsule one-seeded and showed cryptovivipary. Flowering

Fig 1.*Acanthus ilicifolius*

Fig 2. *Aegiceras corniculatum*

during January and fruits were seen to hang on the mother plant upto September. Young fruits were green in colour and mature fruits with pink colour. (Fig 2.)

Avicennia officinalis

Family: Avicenniaceae

Small evergreen trees and much branched. Lateral roots produce aerial pneumatophores. Dorsiventral, petiolate leaf. Waxy cuticle on the upper surface of leaf. Lower epidermis of leaf with non-glandular hairs which give a white velvety texture to the leaf. Leaves secrete salt through salt glands during day time and salt crystals are seen on the leaf surface. (Fig 3 & 4)

Bruguiera cylindrica

Family: Rhizophoraceae

Medium to large trees, perennial, evergreen, woody, erect and profusely branched. Bark deep black to grey and fissured. Underground horizontal root deep sunken, knee-like and root buttresses are formed. Leaves simple, opposite, decussate, petiolate and reddish dark green in colour. Lamina is elliptic, dorsiventral and coriaceous. Inflorescence was cymose. Flowers pedicellate, greenish and bisexual. Fruits berry, pendulous with persistant calyx. Hypocoty l upto 16cm. long, green with blunt end. Germination was viviparous. Flowering and fruiting times extended from March to November. But viviparous seedlings were often seen on the mother plants almost throughout the year. (Fig 5.a) & b))

Fig 3.*Avicennia officinalis*

Fig 4.*Avicennia*-pneumatophore

a)

b)

Fig 5.a)*Bruguiera cylindrica*,b)*Bruguiera* - kneeroot

Excoecaria agallocha

Family: Euphorbiaceae

Medium dioecious trees, woody, perennial with dark green leaves and spreading branches. Bark grey, fissured with poisonous milky latex. Root was a taproot system. Stem with nodes and internodes, diffused branching, articulates with almost an envelop of persistent stipules. Leaves simple, alternate, petiolate, glabrous with a minute gland in the base of young leaves. Male plants with male inflorescence which was a catkin, pendulous or erect and deciduous. Male flowers were sessile, bracteate, monochlamydous and small. Female plant with female cymose inflorescence. Female flower was sessile with a pair of bracteoles. Fruit was a trilobed schizocarp. Flowering and fruiting times were February to August. (Fig 6,7.a) & b))

Rhizophora mucronata

Family: Rhizophoraceae

Medium to tall trees upto 15m. Height. Profusely branched trees and branches spreading horizontally. Trunk not conspicuous and supported by profuse prop roots and stilt roots. Bark brownish to whitish grey. Stilt roots developing from the base of the trunk were profuse, corky, woody and cylindrical. Stem much branched and leaves were clustered in the shoot apex. Leaves simple, opposite decussate, petiolate and glabrous. Leaf with mucronate apex. Inflorescence cymose having four flowers. Flowers pedicellate, bisexual, erect and regular. Calyx persistent in the fruits. Corolla with white petals. Fruits with viviparous germination. Fruit was a capsule with hard fleshy pericarp. Flowering and fruiting were during February to October. But viviparous germinated hypocotyl hang in the mother plants almost throughout the year. (Fig 8.)

Fig 6.*Excoecaria agallocha*

a) **b)**

Fig 7.a) *Excoecaria* –male,b) *Excoecaria* –female

Fig 8.*Rhizophora mucronata*

Fig 9.*Acrostichum aureum*

Fig 10. Vivipary-R*hizophora mucronata*

Fig 11. *Aegiceras corniculatum*-Fruits

Acrostichum aureum L.

Family: Pteridaceae

Common fern in tidal coasts all over the tropics. Leaf was pinnately compound and stem was rhizomatous. The golden sporangia were spread all over the lower surface without any district sorus. Upper leaflets are fertile or fertile fronds are separate. (Fig 9.)

Vivipary

In *Rhizophora* and *Bruguiera* the seed germinates while it is still attached to the mother plant. Further, the seedlings grows, emerges from the fruit and is dispersed and it is called vivipary. But in *Avicennia* and *Aegiceras* eedling does not emerge from the fruit prior to dispersal and it is called cryptovivipary. In *Avicennia* sp. the fruit coat splits shortly after the time of dispersal, releasing an embryo with two thick and fleshy cotyledons folded in opposite directions. In *Aegiceras*, the radicle and hypocotyl elongate in the fruit, and at dispersal the torpedo- shaped propagules are released. (Fig 10, 11, 12, 13 & 14)

Mangrove associates

Derris uliginosa

Family : Papilionaceae

Climbing much branched shrub with twining habit evergreen and perennial. Leaves compound, petiolate and imparipinnate. Leaflets elliptic. Inflorescence is a raceme with white flowers. (Fig 15.)

Fig 12.*Aegiceras*-Cryptovivipary

Fig 13.*Avicennia officinalis*-Fruits

Fig 14.*Avicennia*-Cryptovivipary

Pandanus tectorius

Family : Pandanaceae

Shrubs of palm- like habit. It produce aerial stilt roots from the base of the stem, obliquely downwards and act as supporting organs. Leaves are cauline, linear and spinulose on the margins, forming a tuft at the end of the stem and branches. Leaves are spirally arranged on the stem. *Pandanus* is found along the sea-coasts as mangrove associate. (Fig 16.)

Thespesia populnea

Family : Malvaceae

A medium – sized evergreen tree with cordate, petiolate leaves. The younger parts with peltate hairs. Flowers solitary, yellow in colour but fading to purplish pink. *Thespesia* is very common near the sea–shore. (Fig 17.)

Clerodendron inerme

Family : Verbenaceae

A straggling or climbing shrub. Leaves simple opposite, verticillate and entire. Flowers in axillary cymes. Corolla is funnel-shaped with five spreading lobes. It is common along sea-coasts, in tidal forests and also planted in gardens.

Ipomea biloba

Family : Convolvulaceae

The genus is common in coastal area, on sandy shores, river banks as a creeper. It is an extensively creeping and sand-binding plant with a thick long root stock. Leaves are simple and fleshy and lamina is bilobed.

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Fig 15.*Derris uliginosa*

Fig 16.*Pandanus tectorius*

Flowers are purple in colour . Corolla tubular and funnel shaped. (Fig 18.)

Sphaeranthus indicus

Family : Asteraceae

Annual herb with spreading branches. Leaves simple and alternate and with toothed margin. Capitulum is purple in colour and it is heterogamous. Stem with glandular hairs. This genus is common in rice fields and also as a mangrove associate.

Fimbristylis sp.

Family : Poaceae

Erect herbs with a short rhizome and fibrous roots. Stems tufted. Leaves linear. Inflorescence terminal, umbellate with few spikelets. Many flowered spikelets. (Fig 19.)

Cyperus sp.

Family : Cyperaceae

Perennial erect herbs. Leaves radical flat or terete. Inflorescence is compound umbel.

Anatomical studies

Acanthus ilicifolius L.

Family: Acanthaceae

Leaf dorsiventral and petiolate with thick cuticle. Epidermis single layered both in upper and lower layers. Salt glands present in both surfaces of the lamina. Each salt gland was one celled, surrounded by 5-6 jacket cells. Stomata confined to the lower epidermis. In the lower

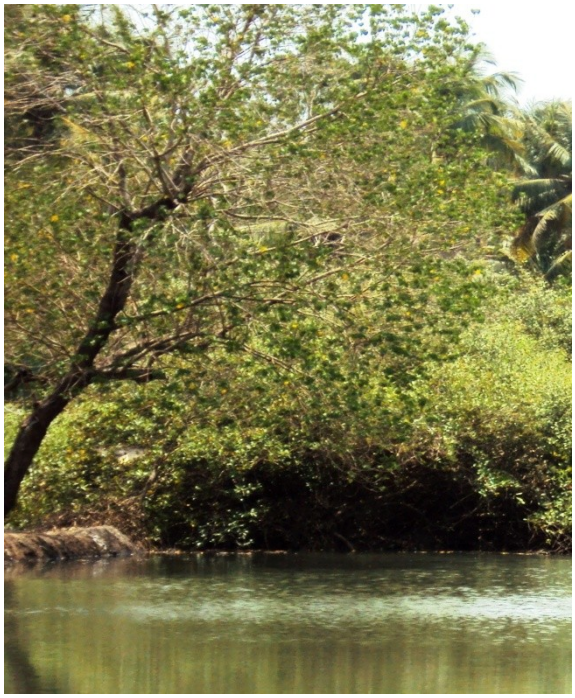

Fig 17.*Thespesia populnia*

Fig 18.*Ipomea biloba*

Fig 19.*Fimbristylis* sp.

epidermis both salt glands and stomata were intermingled. Hypodermis or water storage tissue was two layered thick below the upper epidermis. This tissue maintain succulence of the leaf. Mesophyll with upper two layered palisade and lower spongy tissue consisting of loosely arranged cells.

Stem with two layered thick epidermis. Cortex multilayered with compactly arranged parenchymatous cells. Stem with secondary growth. Pith was very large with compactly arranged parenchymatous cells. (Fig 20, 21 a) & b))

Aegiceras corniculatum (L.) Blanco
Family: Myrsinaceae

Leaf dorsiventral and petiolate with thick cuticle. Epidermis single layered in both surfaces. Salt glands were present in both upper and lower surfaces. Each gland was composed of a large number of excretory cells and a single large basal cell. Stomata confined to the lower epidermi s and sunken. In the lower epidermis both salt glands and stomata were intermingled. Hypodermis two layered thick below the upper epidermis. Mesophyll tissue consisted of upper two-layered thick palisade and lower spongy tissue with loosely arranged cells. Vascular bundles collateral and closed with sclrenchyma on the outer side.

Stem with multilayered and thick cork, covered with wax. Cortex multi-layered and made up of parenchyma. Solitary sclereids scattered in the cortex. Stelar region with secondary phloem, vascular cambium and secondary xylem. Central parenchymatous pith with selereids and tannin cells. (Fig 22 & 23)

ANATOMICAL STUDIES

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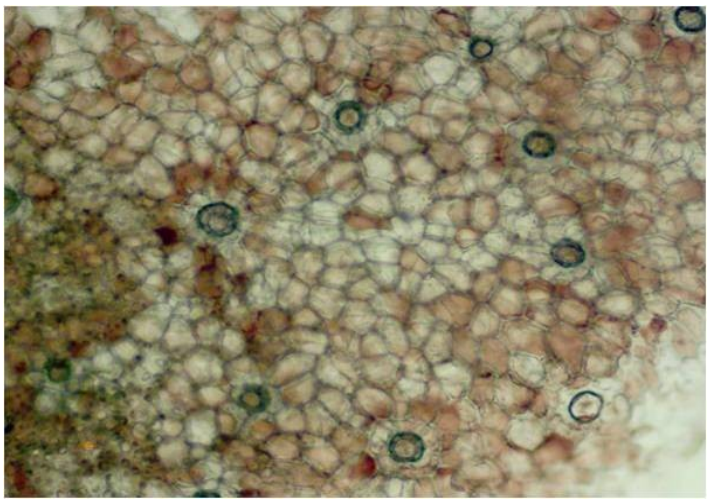
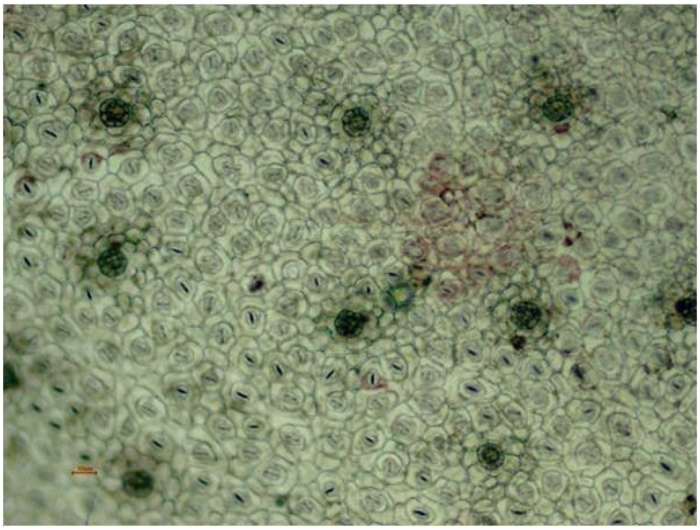
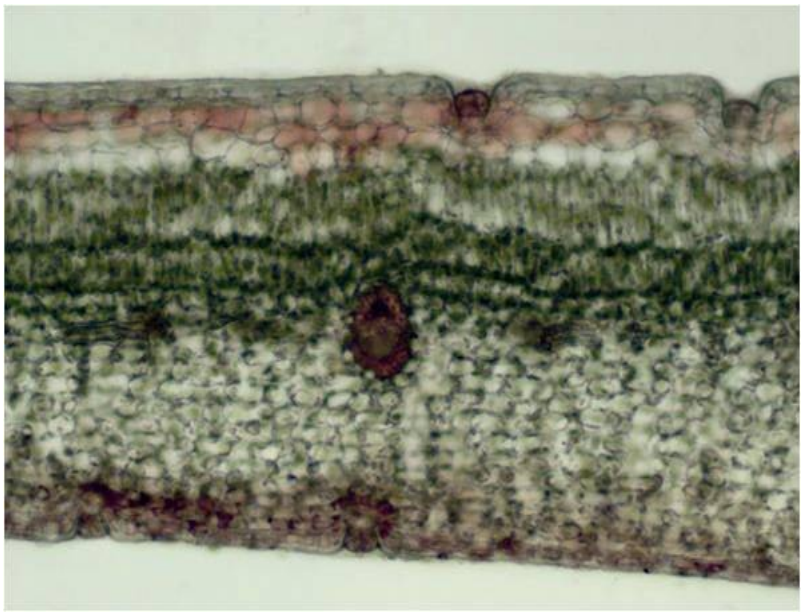


a)

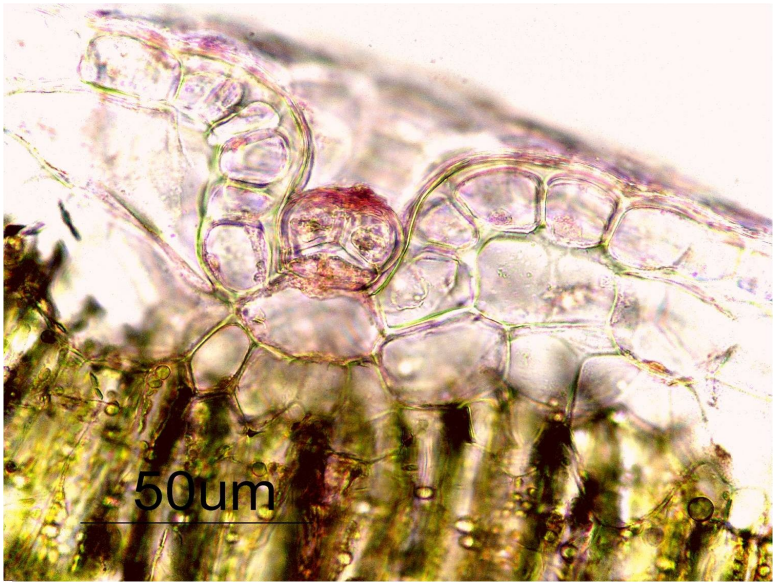


b)

Fig 20.a)*Acanthus*-leaf upper epidermis salt glands,b)lower epidermis



a)



b)

Fig 21.a)*Acanthus*-leaf T.S.,b)salt gland

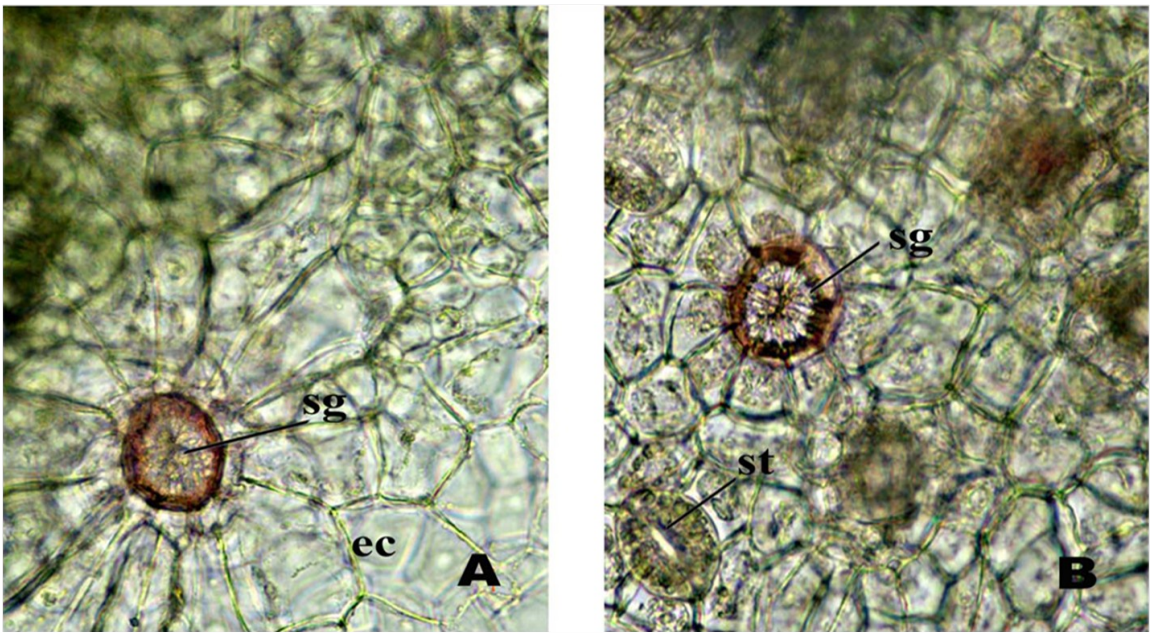
Avicennia officinalis L.

Family: Avicenniaceae

Leaf dorsiventral and petiolate. Cuticle waxy on the upper surface. Epidermis one layer thick. Upper epidermis with a large number of salt glands. The salt glands were seen in shallow pits on the upper surface. Each salt gland consisted of 2-4 basal cells, a stalk cell and a terminal cell that are covered by a thin cuticle. Salt was deposited in the subcuticular cavity of the gland and then ultimately reaches the leaf surface. Salt glands excreted salt as crystals on the leaf surface in bright day time and a solution of salt in the evening. Lower epidermis of leaf with non-glandular uniseriate hairs, providing white velvet appearance to the lower surface. Stomata were deeply sunken in the lower epidermis. Due to the thick growth of non-glandular hairs in the lower epidermis, stomata were not clearly visible as in the case of other mangrove leaves.

Beneath the upper epidermis hypodermis was 4-layered thick. Mesophyll consisted of multilayered upper palisade and 3-4 layered thick lower spongy tissue. In midrib region the vascular bundle was surrounded by sclerenchymatous cells. Tannin cells are abundant in *Avicennia*.

Pneumatophores is an important adaptation of Avicennia. These are aerial roots developing from the lateral roots. Outer region of pneumatophore was with multilayered cork which was ruptured at the outer surface to form lenticels. Cortex was broad, parenchymatous having numerous air cavities. Secondary growth was seen in pneumatophores. Vascular cylinder with inner secondary xylem,



Aegiceras corniculatum

Fig 22.*Aegiceras*-salt gland

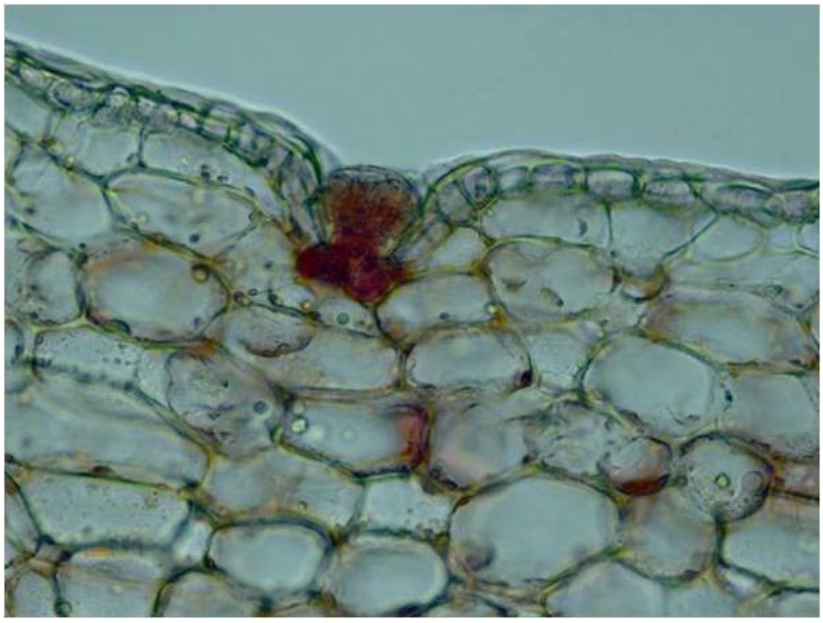


Fig 23.*Aegiceras*-Leaf T.S.

cambium and outer secondary phloem. Pith consisted of parenchymatous cells with large intercellular space. (Fig 24 & 25)

Bruguiera cylindrica (L.) Blume

Family: Rhizophoraceae

Leaf epidermis single layered with thick waxy cuticle. Stomata confined to the lower epidermis. Hypodermis one layer thick below the upper epidermis and above the lower epidermis. Mineral crystals like druses occur in the hypodermal cells. Mesophyll with upper palisade consisting of three layers of cells. Spongy tissue was multilayered. Stomata were deeply sunken and confined to the lower epidermis. Large air cavities present in the midirib and mesophyll. Vascular bundle collateral and closed.

Stem with multilayered cork in the outer region. Cortex was thick, multilayered and parenchymatous. Sphaeraphides occur in the cortical cells. Stem shows secondary growth. Pith was large and parenchymatous. Large number of tannin cells occur in both cortex and pith. Sclereids also present in the cortex and pith.

Stilt roots were aerial roots developed for mechanical support for the stem. Outer region of stilt roots was protected by cork consisting of suberized cells. Cortex was thick with large intercellular spaces, arranged radiately around the stele. (Fig 26.a), b) & c))

Excoecaria agallocha

Family: Euphorbiaceae

Leaf dorsiventral and petiolate. Two glands were present on the base of lamina. Thick cuticle. Hypodermis single layered below the upper

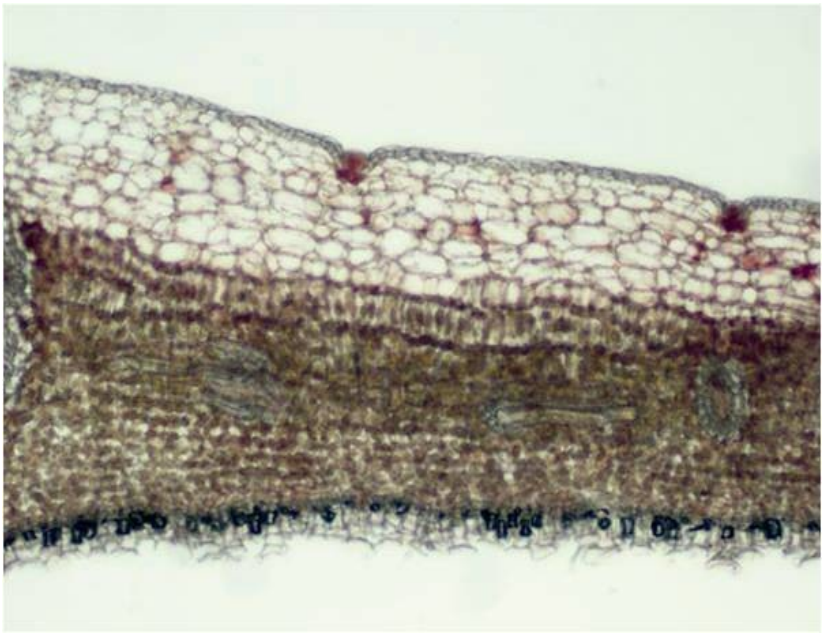
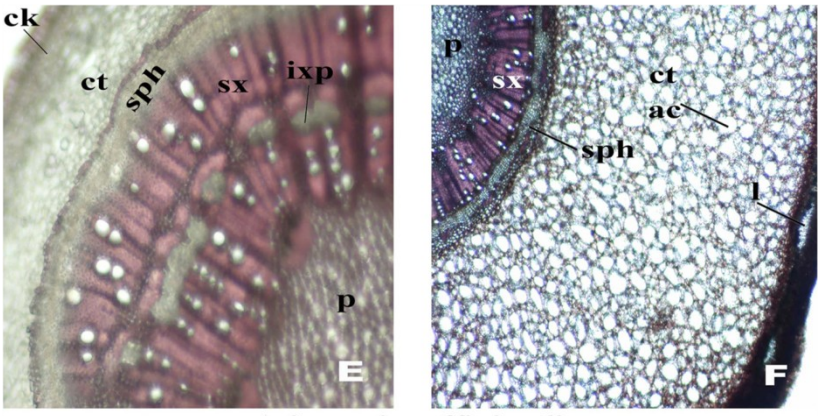


Fig 24. *Avicennia officinalis* - Leaf T.S.



Avicennia officinalis

a) **b)**

Fig 25.a) *Avicennia* stem T.S.,b)Pneumatophore T.S.

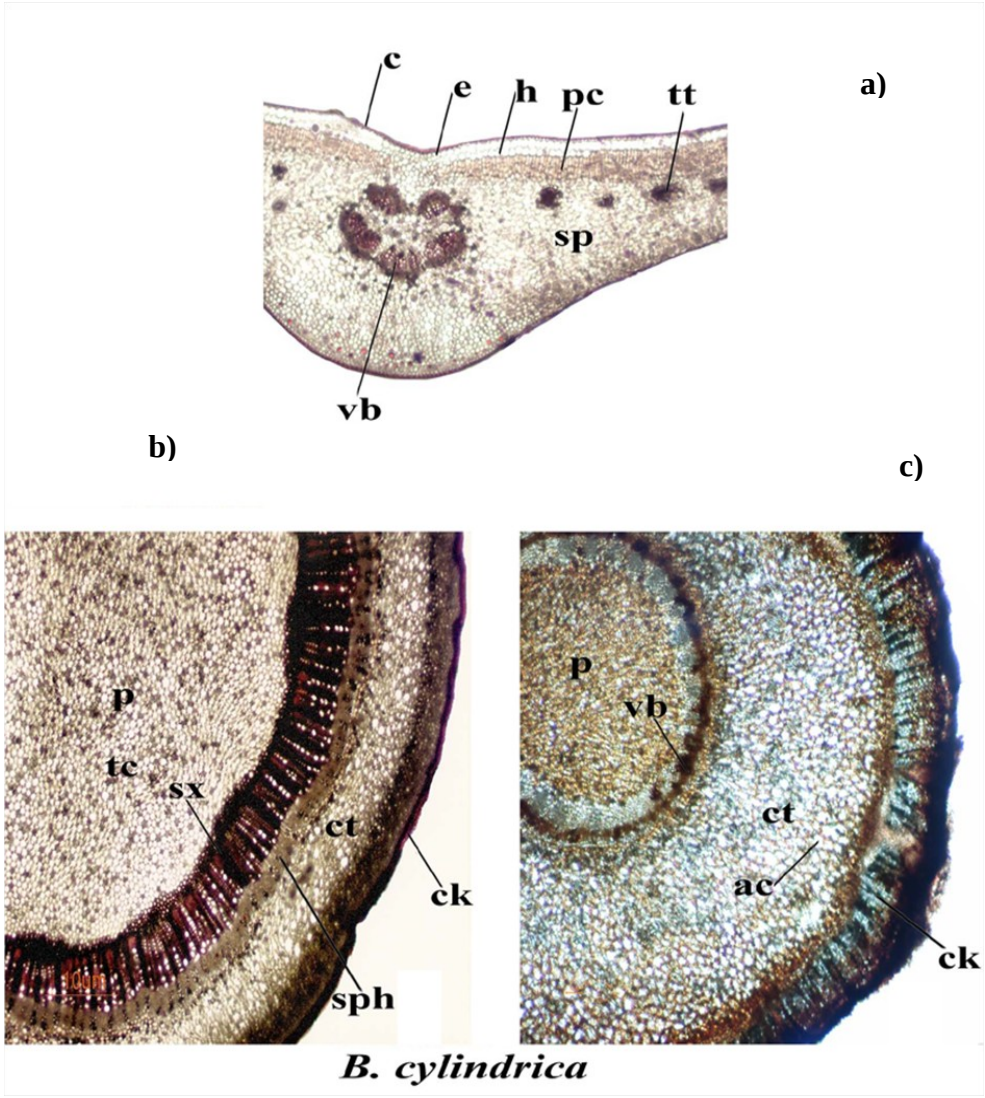


Fig 26.a)*Bruguiera*-Leaf T.S.,b)Stem T.S.,c)Stilt root T.S.

c-cuticle,e-epidermis,h-hypodermis, pc-palisade cells,sp-spongy cells,tt-terminal tracheides,vb-vascular bundle,ck-cork,ac- aerenchyma, ct-cortex,p –pith,sx-secondary xylem,p-pith,tc-tannin cells

epidermis. Stomata confined to the lower epidermis. Mesophyll with upper two-layered palisade and lower spongy tissue. Vascular bundle was collateral and closed.

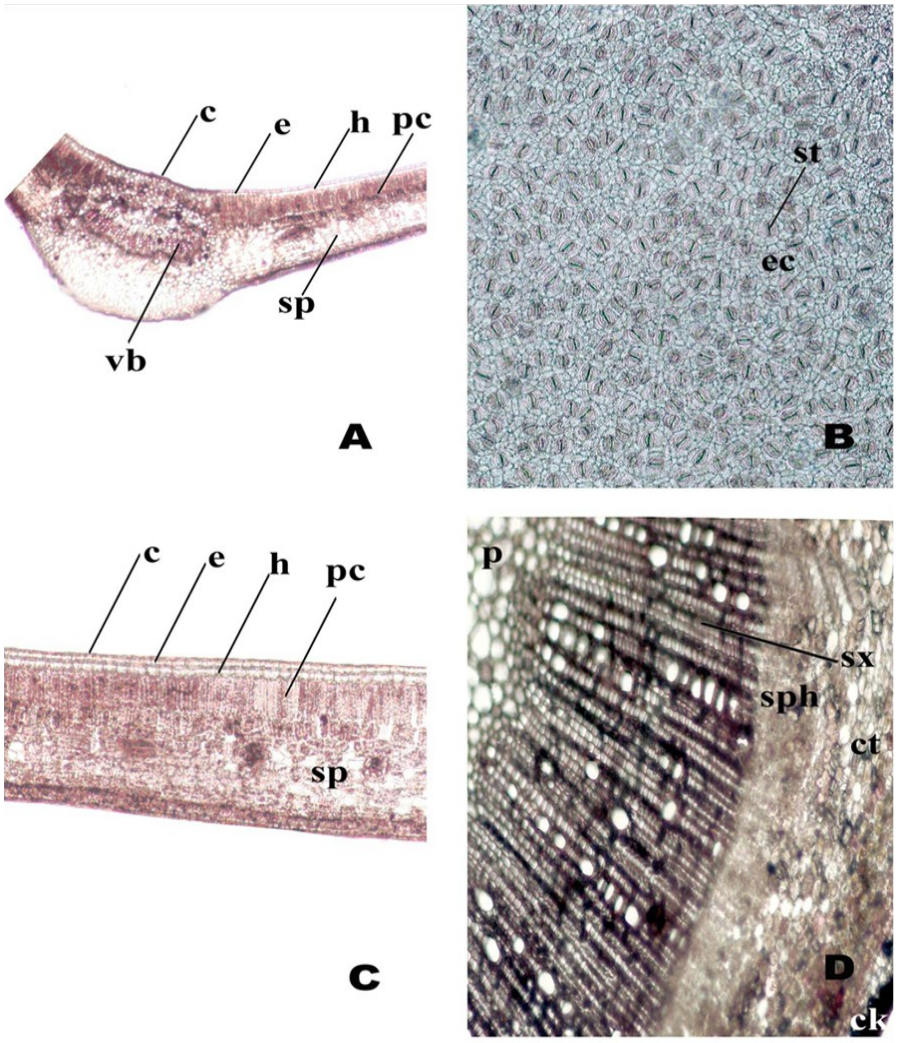
Stem with cork in the outer region. Cortex was multilayered and parenchymatous. Secondary growth was present. Leaf and stem with latex cells. Tannin cells were also present (Fig 27.a),b),c) & d))

Rhizophora mucronata

Family: Rhizophoraceae

Leaf dorsiventral and petiolate. Lamina with black circular spots in the lower surface, known as cork warts. Cuticle was thick and waxy. Epidermis two layered in the upper epidermis and single layered in the lower epidermis. Hypodermis multilayered. Stomata were sunken and present in the lower epidermis. Mesophyll with one-layered palisade cells. Lower spongy tissue with large intercellur spaces. Sphaeraphides were present in the hypodermis.

Stilt roots with outer region protected by cork which was ruptured by lenticels. Hypodermis consisted of compactly arranged parenchymatous cells. Cortex was multilayered, parenchymatous and with solitary sclereids. Tannin cells were also present in the cortex. Vascular strand amphicribral in which central xylem was surrounded by phloem. Pith was parenchymatous. (Fig 28.a) b) & c))



Excoecaria agallocha

Fig 27.A-C:Leaf;D:Stem T.S.

c-cuticle,e-epidermis,h-hypodermis,st-stomata,ec-epidermal cells,sph-sphaeraphide,p-pith,pc-palisade cells,sp-spongy cells.

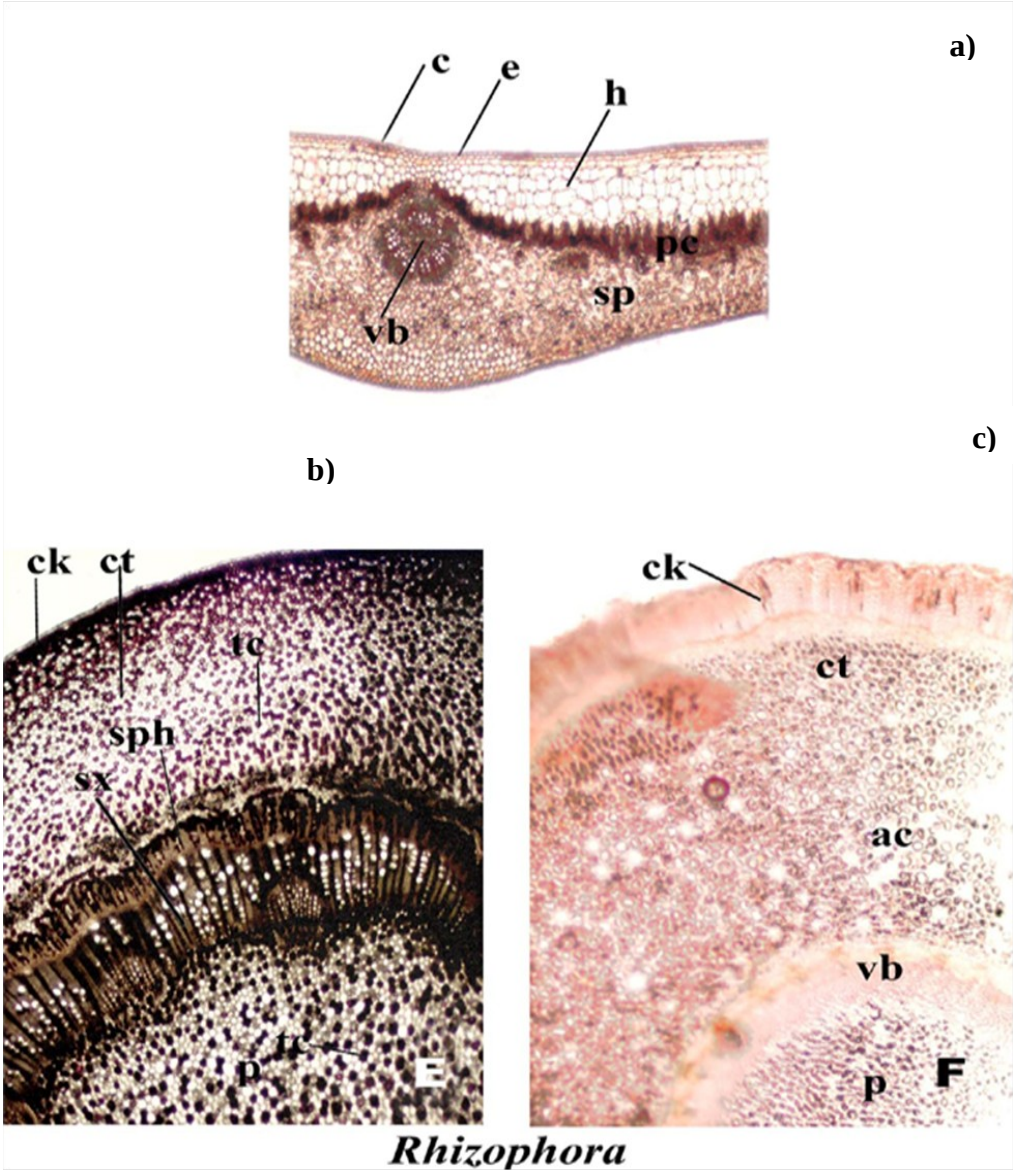


Fig 28.a)Leaf T.S.,b)Stem T.S.,c)Stilt root T.S.

c-cutcle,e-epidermis,h-hypodermis,pc-palisade cells,vb-vascular bundle,ck-cortex,ct-cortex,vb-vascular bundle,pc-palisade cells,sp-spongy cells,ac-aerenchyma,p-pith,ac-aerenchyma.

ADAPTIVE BIOLOGY OF MANGROVES

Mangroves grow in the intertidal areas and were salt tolerant group of plants. These salt tolerant plants possess similar physiological and structural adaptations. These plants suffer from want of water due to high salt concentration of the habitat and they possess high osmotic potential and transpire like xerophytes. Mangroves have been successfully colonized by developing morphological, reproductive and physiological adaptations like pneumatophores, prop roots, stilt roots, knee roots and viviparous germination.

Adaptive biology includes morphological, anatomical, reproductive and physiological adaptations like pneumatophores, stilt roots, prop roots, knee roots, chlorophyll fluorescence and viviparous germination of seeds. These special adaptations of mangroves enabled them to grow in the saline habitat. Mangroves showed xerophytic characters because they were growing in a physiological dryness habitat.

Peculiar anatomical characters of mangroves were thick, waxy cuticle of leaf, water storage tissue in the hypodermal region, short tracheids in the vein endings; sclereids of various shapes in the mesophyll and succulent nature of leaf. Salt glands in mangrove leaves was an important adaptation for excreting excess salt from plants (eg. *Acanthus, Aegiceras,* and *Avicennia*). In *Rhizophora* salt regulation is through salt exclusion mechanism. *Rhizophora* leaf with cork warts through which it excrets excess salt, probably by the removal of these apertures. In *Bruguiera* also salt exclusion mechanism was seen for the removal of salt from the plant. Cracks or fissures on the bark of tress was

an area for removal of salt. In *Excoecaria* excess salt was removed through the old leaves and also bark. Sunken stomata in most of the mangrove genera was an adaptive feature which is another xerophytic character of mangrove.

Pneumatophores in *Avicennia* was an adaptation in saline habitat. These were negatively geotropic unbranched or rarely branched roots. These pneumatophores were with lenticels and arenchymatous cortex for gaseous exchange in the anaerobic soil condition. The stilt roots, prop roots and knee roots in *Bruguiera* and *Rhizophora* were developed for giving additional support to the main trunk and protect them from different calamities like erosion, cyclones, sea waves, etc.

As the coastal saline environment play very dynamic role in the swamp habitat, these mangrove flora have been provided with suitable adaptations and succession mechanism by the modification of morphological, anatomical and reproductive structures. To survive in this saline, intertidal environment, mangroves must have adaptations of both mechanical and physiological processes i.e., modification of vegetative parts and reproductive parts. Also seed germination and seedling development help to protect their progenies in these typical tidal and saline environment.

GERMINATION STUDY OF MANGROVES

Vivipary

The most distinctive and remarkable feature of *Bruguiera and Rhizophora* (of family Rhizophoraceae) was viviparous germination i.e., seed germination occurred within the fruits, while still hanging or attached to the mother plants. Hypocotyls of the viviparous germinated seedlings enlarge through the embryo development, without taking any dormancy period. This type of germination plays a significant role in the mangrove environment. These propagules or seedlings can float and dispersed by water. All these propagules are green in colour and can do photosynthesis, until it becomes rooted in a suitable substratum and produces leaves. When they get launched in its habitat, it became erect and establish root quickly and show vegetative growth. The shoot apex grows and produces leaves. Thus the mother plant with lot of seedlings around it in a season.

Cryptovivipary

Cryptovivipary was observed in *Avicennia and Aegiceras*. In these genera seed germination and enlargement takes place within fruit, when it remain attached to the mother plant i.e., the germination is hidden within the fruit. The hypocotyls do not come out from the fruit. This type of germination is known as cryptovivipary or incipient vivipary. These fruits with seedlings (propagules) can float and dispersed by water currents. The propagules of *Avicennia officinalis* establish during monsoon months in less saline substratum.

The fruit of *Avicennia* was with two thick fleshy cotyledons folded in opposite directions. When these fruits fall on a less saline habitat, the fruit wall splits releasing an embryo with plumule, small hypocotyls, radicle and two thick fleshy cotyledons. The fruit of *Avicennia* was green in colour in young stage and the colour of fruit wall changed to yellowish green when it was ready for dispersal

In *Aegiceras*,fruits are long with pointed apex. It was green in colour when young but changed the colour to pinkish green when mature. The seeds germinate and embryo develops within the fruit, but not come out of the pericarp. These fruits with germinated seeds behave as propagules which may disperse and establish in suitable habitat. The fruit wall splits from the pointed apex backwards and the radicle and hypocotyls elongate in the fruit and at dispersal the torpedo- shaped propagules are released from the plant.

NUTRITIVE VALUE OF MANGROVES

Little is known about the nutritive value of mangrove. Protein analyses of all the mangroves were done in all seasons. Maximum protein content was shown by *Rhizophora* leaf and stem. Protein content gives an idea about the nutritive value of mangrove species.The leaves of *Rhizophor a* were used as fodder. Local people near Chettuwai estuary use seeds of *Avicennia officinalis* as food. They cooked these seeds after removing tannin content. For this they soaked the seeds after removing fruitwall in water overnight. Then they cooked and taste is similar to dhal.

Extracts of *Rhizophora* and *Avicennia* have been used for making toniics, wines and fruit drinks. It implies the medicinal use of mangroves. *Rhizophora* and *Bruguiera* leaves were used as fodder.

DISCUSSION

Mangroves are the only trees and shrubs that are capable of thriving in salt water and unique intertidal forests at the edge of land and sea. The mangrove areas of Thrissur District are Azhikode, Kodungallur, Poyya, Kadungachira, Pethuruthu, Krishnankotta, Chenthuruthy, Pullut, Chettuwai, Orumanayur, Blangad, Chakkamkandam, Anjangadi, Thekkan Palayur, Idianchira, Enamakkal, Pandaramad, etc. Of these Azhikode, Chettuwai and Poyya are the important mangrove areas. Azhikode with *Avicennia officinalis, Acanthus ilicifolius* and *Acrostichum aureum* (fern). But Chettuwai estuary with *Acanthus ilicifolius, Aegiceras corniculatum, Avicennia officinalis, Bruguiera cylindrical* and *Rhizophora mucronata.* Poyya with *Acanthus, Aegiceras, Avicennia, Acrostichum* and *Excoecaria agallocha*. All other areas with *Acanthus, Avicennia* and *Acrostichum.*

Chettuwai is a significant mangrove zone in Kerala. The mangroves in Chettuwai are seen as small islands and it is actually a swamp. The basal parts of trees are covered with water. So the mangrove vegetation of this area is also different from other areas. *Acrostichum aureum* is completely absent in Chettuwai. The soil texture of Chettuwai is clay and some areas sandy. So sand mining is prominent in this area which affect mangrove flora.

All other areas with mainly *Avicennia officinalis, Acanthus ilicifolius* and *Acrostichum aureum, Aegiceras Corniculatum* is present in Chettuwai estuary and Poyya backwaters. It is a rare species in

Thrissur Dist. Similary *Rhizophara mucronata* is plenty in Chettuwai and a few plants are seen in Enamakkal. *Excoecaria agallocha* is seen in Poyya, Krishnankotta, and Kadungachira and absent in all other areas.

The distribution of mangroves in different areas is an indication of different types of soil. Soil texture is an important factor for species distribution. In all these areas mangrove associates like *Derris uliginosa, Clerodendrom inerme, Thespesia populnea, Pandanus*, etc. are common.

The way in which the plants function is determined by their physiology and the internal structural organization and arrangement. Anatomical data are capable of predicting many of the most important physiological and ecological features of species.The important analomical features of mangrove leaves are the presence of colourless water storage tissue at hypodermal layers, short tracheids at the vain endings, sclereids of various shapes, etc. These features may be interpreted as an adaptation to climate and habitat.

The presence of water storage tissue and terminal tracheids cause leaf succulence with high water content (Das and Ghose,1966). According to Zimmermann (1983), both sclereids and tracheids are involved in capillary water storage. Tomlinson (1986) suggested that in addition to water storage, sclereids might provide mechanical support to leaves with diminished turgor.

The significance of succulence is to reduce the rate of water loss and to reduce the concentration of salt in the cells through the absorption

of water. The thick cuticle is an adaptive feature of mangroves (Waisel, 1972).

The isolated specialized cells such as sclereids (*Rhizophora)*, oil cells (*Bruguiera*), Sphaeraphides (*Bruguiera and Rhizophora*), tannin cells (*Rhizophora and Bruguiera*) and laticiferous cells (*Excoecaria*) are an adaptive feature of mangroves. Among the mangrove leaves studied, there are different structural types. *Rhizophora*, *Bruguiera*, *Avicennia, Acanthus* and *Aegiceras* with many layered water storage tissue. *Excoecaria agallocha* with single layered water storage tissue. The water storage tissue is a characteristic feature of mangrove leaves. The thickness of this tissue causes leaf succulence with increased water content.

The occurrence of salt gland in mangroves is an adaptation for marshy habitat, because salt cannot accumulate in plant tissues beyond a limit. Salt glands are found abundantly on leaves, though their number is lesser than that of stomata in the lower epidermis. The morphology of salt glands varies from the simple to multicellular structures. Gland cells differ from normal mesophyll cells in shape and arrangement. Cells are without chloroplast. The salt glands are meant for excreting excess salts accumulated in mangroves, thus maintaining a salt balance to the plants.

In the leaf of *Avicennia*, the lower epidermis possesses thick growth of non-glandular uniseriate hairs with short stalk. These hairs give a white velvety texture to the lower surface and protect sunken stomata, thereby reducing transpiration.

The stem mangroves showed secondary growth, which is anomalous type in *Avicennia*. All the species showed the abundance of tannin cells in the cortex and pith. So the stem possess significant tannin content. Wood anatomical features of the true mangroves do not show any uniformity, although all of them belong to the same ecological environment.

Pneumatophores in *Avicennia* show a large number of lenticels on the surface. The periderm of pneumatophores is both water-air-tight resulting in gases kept in the root system and water out. The greater the cross sectional area of the internal gas space (aerenchyma) the greater the maximum oxygen conductance of the pneumatophore.

In *Rhizophora,* stilt roots arise from the trunk and lowest branches and anchor the tree into muddy substrate. In the cortex of the still roots in *Rhizophora,* branched cells joined together by round tannin cells and scattered trichosclereids are observed. The cortex contains aerenchymatous cells. The aerial roots in mangroves are adapted for aeration with numerous lenticels in the periderm and aerenchyma which has air spaces that act as reservoirs. Root hairs are absent in all subterranean roots of mangroves.

CONCLUSION

The floral studies of mangroves reveal the morphological adaptations of mangroves in the saline habitat. *Avicennia* with pneumatophores, *Bruguiera* with knee roots and *Rhizophora* with stilt roots and prop roots. Mangrove taxa apart from their morphological characters, have some unique leaf anatomical features which are very much related to their adaptation as the plant grow in unstable, variable and saline environments with regular tidal influence, especially in estuaries. Sunken stomata, thick and waxy cuticle reduce transpiration rates in many taxa.

Presence of salt glands in *Acanthus, Aegiceras* and *Avicennia* on the adaxial or a abaxial surfaces are related to salt excretion of these plants. Large amount of water storage tissue occur in the hypodermal region of *Acanthus, Avicennia, Aegiceras, Bruguiera, Excoecarea* and *Rhizophora*, reflecting the adaptive nature of mangroves in their stressful habitat. The tissue increases succulence of leaf. Anatomical data are capable of predicting many of the important physiological and ecological features of mangrove species.

Viviparous germination of seeds in *Bruguiera* and *Rhizophora* is well adapted in saline habitat. Cryptovivipary in *Aegiceras* and *Avicennia* is also an important physiological adaptation in mangroves. The mangrove habitat is physiologically dry because of salinity. So the mangroves show xerophytic characters like thick cuticle, thick waxy coating on leaf surface, sunken stomata and distribution of sclereids in leaf.

Mangroves are important due to their strange morphological and anatomical adaptations and special physiology like osmotic potential of cell sap, reaction to salinity and vivipary. Mangrove ecosystem is commercially very significant and provide many direct and indirect services to man. So mangrove ecosystem must be conserved. Seeds of *Avicennia* are edible and it is used by local people.

Threats to mangrove ecosystem

The mangrove vegetation that exists today in Kerala coast is just a vestige of what existed in the recent past. The mangroves which were retracted to an area of hardly 25 ha. in Thrissur district had shrunken drastically to 5 ha. and its major part is at Chettuwai. The main threats to the mangrove ecosystem are pollution, grazing, agriculture, aquaculture and human encroachment. Mangrove ecosystem must be protected and conserved because of its great use to human beings, other animals like fish, crab, molluscs etc.

In Mullassery Panchayat (Thrissur district), there is a Mission to save mangroves and organizes awareness programmes and mangroves. Mangrove cultivation and replenishment initiatives have become an effective people's movement at Mullassery. School students and a few science enthusiasts have grown into a mass movement. Mangroves have been grown in several areas in Mullassery Panchayat. The species of mangroves being grown in Mullassery include *Bruguiera cylindrica, Aegiceras corniculatum, Acanthus ilicifolius,Acrostichum aureum,Avicennia officinalis, A. marina, Rhizophara mucronata, R. apiculata* and *Excoecaria agallocha.*

Growing mangroves is an important step in the fight against coastal erosion. Intensive afforestation ensure formation of rich mangrove forests.

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