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Leaf anatomical adaptation of some true mangrove species in Kerala

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Abstract
Mangrove has some unique leaf anatomical features in addition to its morphological characters, which were associated to their adaptation to its saline environments. All the species have thick cuticle and sunken stomata to reduce transpiration. The presence of glandular and non-glandular hairs on the abaxial and adaxial leaf surfaces in some taxa are related to salt secretion of these plants. Numerous water storage tissues occur in the hypodermal or mesophyll tissue of the leaves indicating the modification nature of mangroves in their saline habitat. The presence of terminal tracheids helps with capillary water storage within the leaf. The coriaceous nature of the leaves in some taxa is due to the presence of brachy and astero sclereids with in the mesophyll region.

Keywords: leaf anatomical adaptation true mangrove species morphological characters

1. Introduction
The term "mangrove" refers to grouping of tropical trees and shrubs that grows in the intertidal zone. Mangroves include approximately 16 families and 40 to 50 species. Mangrove distribution is circum global with the majority of populations occurring between the latitudes of 30° N and 30^0 S. These plants possess morphological and physiological adaptation to their habitat. They should be isolated taxonomically from terrestrial relatives. Thus, mangrove is a non-taxonomic term used to describe a diverse group of plants that are all adapted to a wet, saline habitat. The following criteria are required for a species to be designated a "true or strict mangrove": Complete fidelity to the mangrove environment, major role in the structure of the community and has the ability to form pure stands [1].

2. Materials and Methods
Fresh leaf samples of 15 identified mangrove taxa belonging to 9 genera and 7 families were collected from different intertidal zones of Kerala. The species examined were *Acanthus ilicifolius* L., *Acanthus ebracteatus* Vahl., (Acanthaceae), *Aegiceras corniculata* (L.) Blanco., (Primulaceae) *Avicennia marina* (Forssk.) Vierh., *Avicennia officinalis* L., (Avicenniaceae), *Bruguiera cylindrica*(L.) Blume., *Bruguiera gymnorrhiza* (L.) Lam., *Bruguiera sexangula* (Lour.) Poir., *Kandelia candel* (L.) Druce., *Rhizophora mucronata* Lam., *Rhizophora apiculata* Blume., (Rhizophoraceae), *Excoecaria agallocha* L., (Euphorbiaceae), *Sonneratia alba* Sm., *Sonneratia caseolaris* (L.) Engl., (Lythraceae), *Lumintzera recemosa* Willd., (Combretaceae).
The plants were identified by Botanical survey of India, Coimbatore. One of the healthy plant were selected and the mature leaves from fifth and sixth node were taken for anatomical studies. Sections were made at a position approximately half way between the base and apex of a sector from one side of the lamina, stained with Toluidine blue 0 and mounted in 50% glycerin. The slides analysed by trilocular compound microscope model number 10093409 and imaged by using the camera Olympus E-PL3. The Scanning Electron Microscopic images of leaf sample were taken Zeiss ultra 55.

3. Result
Cuticle is considerably thick in *Aegiceras corniculatum*. Leaves in general dorsiventral and hypostomatic in most of the species except in *K. candal, S. caseolaris, S. alba,* L. *racemosa* where the leaves are isobilateral and amphistomatic. Usually mangrove leaves are succulent. The cuticular surface is usually smooth except *Avicennia* species where, it is interrupted by non-glandular and glandular trichomes.
In most of the species adaxial epidermal cells are larger in size compare to those of abaxial cells. The epidermal cells are polygonal in outline with more or less straight walls in all species studied except *E. agallocha*, the wall of epidermal cells were wavy.
Ranunculaceous types of stomata found in *A. corniculata, B. gymnorrhiza, B. sexangula, E. agallocha L. recemosa, S. alba* and *S. caseolaris,*. Rubiaceous and ranunculaceous in *B. cylindrica.* Cyclocytic in *R. apiculata, R. mucronata* and *K, candel.* In *Acanthus* cruciferous type were found. In *Avicennia* presence of non-glandular trichomes stomata difficult to identify.
Both glandular and non-glandular trichomes were observed in leaves of *Avicennia* species. Each glandular trichome or salt gland having found on both adaxial and abaxial surfaces of leaves, 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, where as non-glandular trichomes are multicellular with a stalk of 2 to 3 cells with an awl shaped terminal cell observed abundantly all over the lower epidermis. Glandular trichomes similar to that of *Avicennia* is also observed in *A. corniculatum*
In all species studied, the mesophyll differentiated into palisade and spongy tissues except *L. racemosa, K. candal, S. caseolaris and S. alba*. The palisade tissue below the upper epidermis is two layers in thickness in *A. illicifolius, A. ebracteatus* and species and one layer thickness in *B. cylindrica* and more than two layers in thickness in the rest. Water storing tissues of varying proportions has been observed in all species. In most of the species, the water storing tissue found as a hypodermis except *L. racemosa,* K. candel, *S. alba* and *S. caseolaris* where

it is centrally located in between the upper and lower palisade layer; biseriate in *A. ebracteatus*, *B. sexangula and B. cylindrica*. multiseriate in rest of the species. In *L. racemosa*, the palisade tissue found in two layers on both sides of the epidermis. Idioblasts and stellate sclerieds are observed in the mesophyll of *B. gymnorrhiza*,, and *R. mucronata*. (Fig 1-15)

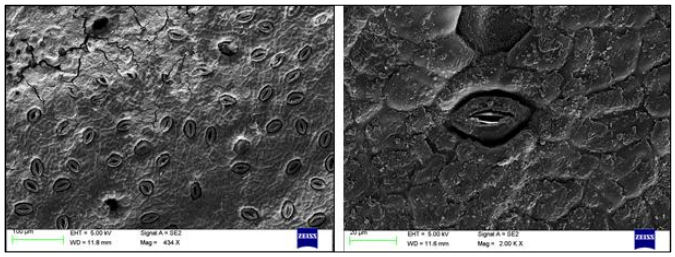

Fig 1: *Aegiceras corniculata*- Lower epidermis

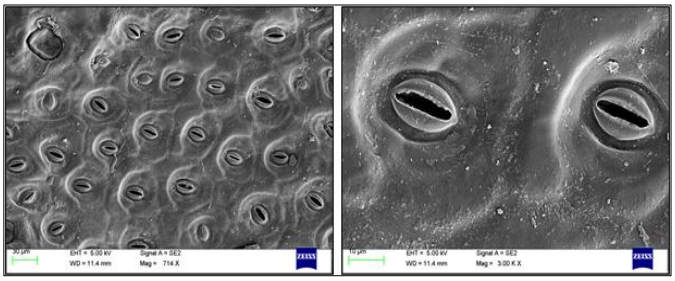

Fig 2: *Acanthus ilicifolius*- Lower epidermis

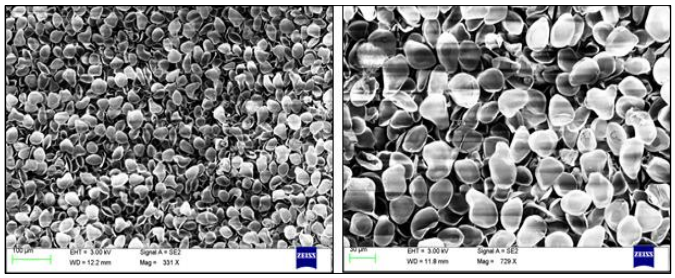

Fig 3: *Avicennia officinalis*- Lower epidermis

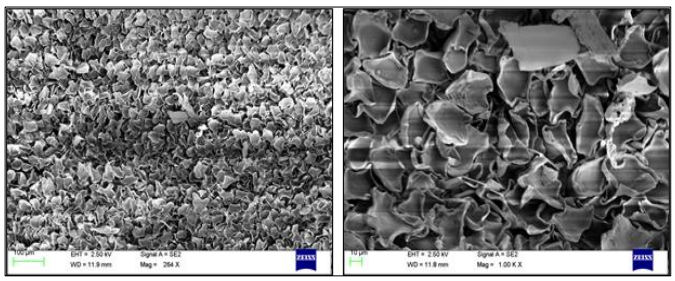

Fig 4: *Avicennia marina*- Lower epidermis

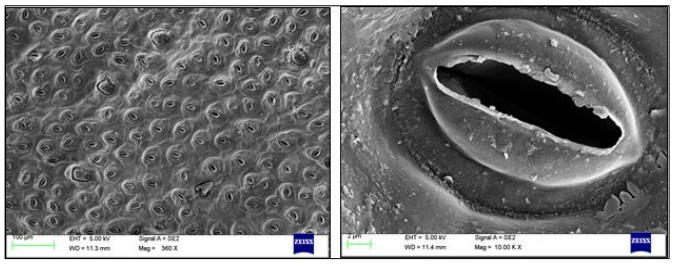

Fig 5: *Acanthus ebracteatus* - Lower epidermis

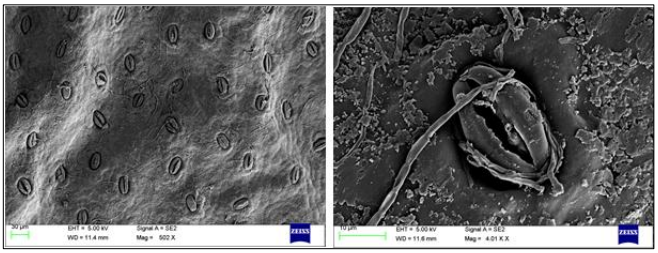

Fig 6: *Bruguiera gymnorrhiza*- Lower epidermis

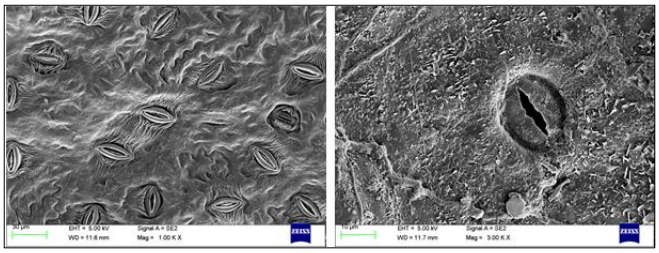

Fig 7: *Bruguiera cylindrica*- Lower epidermis

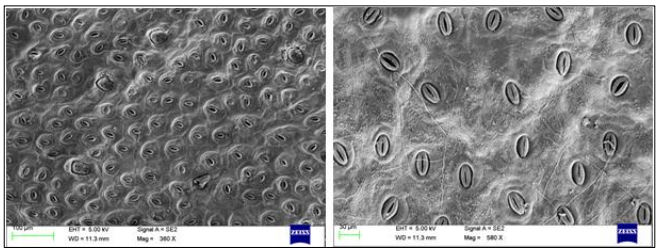

Fig 8: *Bruguiera sexangula*- Lower epidermis

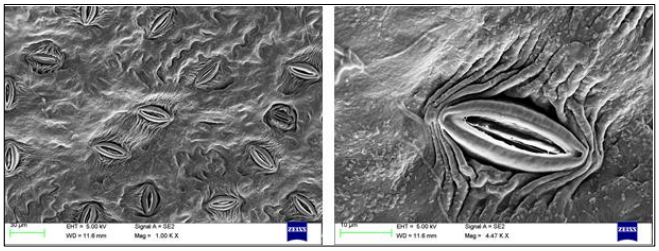

Fig 9: *Excoecaria agallocha*- Lower epidermis

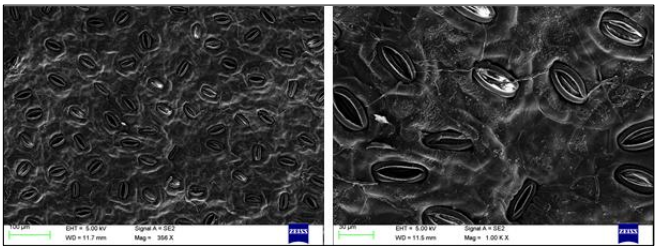

Fig 10: *Kandelia candel*- Lower epidermis

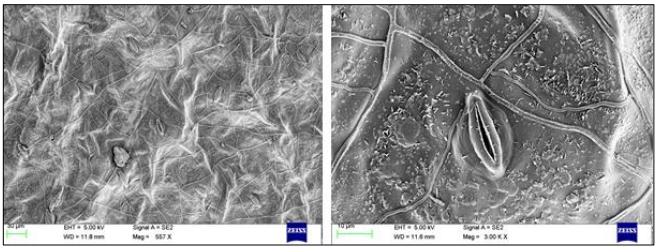

Fig 11: *Lumnitzera racemosa*.- Lower epidermis

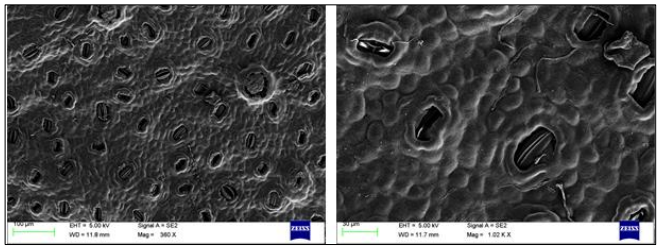

Fig 12: *Rhizophora apiculata*- Lower epidermis

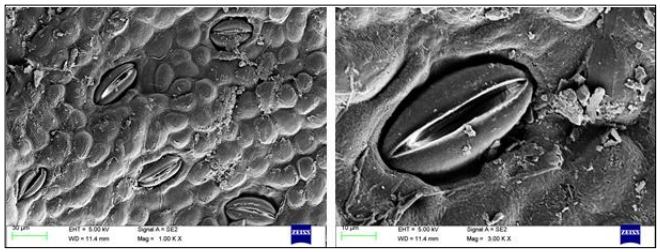

Fig 13: *Rhizophora mucronata*- Lower epidermis

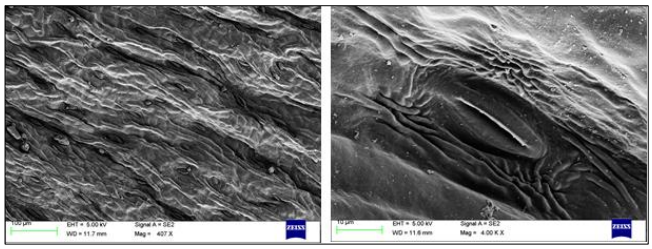

Fig 14: *Sonneratia caseolaris*- Lower epidermis

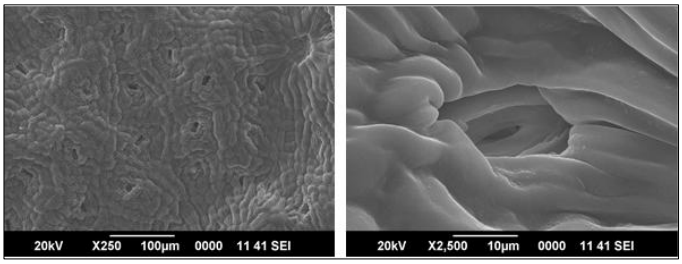

Fig 15: *Sonneratia alba* - Lower epidermis

Succulent leaves are a common feature of most mangroves. The highest leaf thicknesses occur in *A. ilicifolius* (89.02 µm) and lowest in *L. recemosa* (66.07 µm). The cuticle is considerably thick in *A. corniculatum* (2.42µm), and thin in *S. caseolaris* (0.42 µm). Lower cuticle thickness highest in *L. racemosa* (0.82 µm) and lowest in *B. sexangula and B. cylindrica* (0.21 µm). Upper epidermal thickness highest in *B. gymnorrhiza* (2.84 µm) and lowest in *L. racemosa and R. apiculata* (1.35 µm). Lower epidermal thickness highest in *A. corniculatum* (1.90 µm) and lowest in *S. caseolaris* (0.79 µm). Upper hypodermal thickness highest in *R. apiculata* (18.18 µm) and lowest in *A. marina* (11.82 µm). Palisade length highest in *E. agallocha* (12.95 µm) and lowest in *A. corniculatum* (4.82 µm). Palisade width highest in *A. officinali* (2.89 µm) and lowest in *S. caseolaris* (1.13 µm). Spongy thickness highest in *B. sexangula* (44.99 µm) and lowest in *R. apiculata* (25.52 µm). Stomatal length highest in *L. racemosa* (18.02 µm) and lowest in *A. illicifolius* (3.60 µm). Stomatal width highest in *S. caseolaris* (9.68 µm) and lowest in *A. ebracteatus* (0.90) µm.(Table 1)

Table 1: Laminar characters of some mangroves (µm).

Characters	*Acanthus ebracteatus*	*Acanthus ilicifolius*	*Aegiceras corniculatum*	*Avicennia marina*	*Avicennia officinalis*	*Bruguiera cylindrica*	*Bruguiera gymnorrhiza*	*Bruguiera sexangula*
UCT	2.02	1.84	2.42	2.13	1.79	0.99	1.11	0.94
LCT	0.56	0.61	0.63	0.53	0.52	0.21	0.31	0.21
UET	2.59	1.75	2.63	2.59	2.49	2.31	2.84	1.58
LET	1.89	1.57	1.90	1.58	1.47	1.78	1.71	1.89
UHT	12.51	12.89	12.38	11.82	11.90	14.84	12.54	11.89
LHT	5.69	5.99	5.27	8.32	6.10	10.33	10.97	12.96
PT	34.73	36.61	35.94	31.21	30.21	20.10	23.17	23.68
PL	10.85	7.62	4.82	10.45	7.32	9.58	12.10	11.18
PW	2.63	1.83	2.17	2.79	2.89	2.00	2.00	1.89
LT	87.30	89.02	85.51	78.21	76.63	83.04	84.99	81.69
ST	40.34	44.73	36.40	39.16	39.14	44.71	42.82	44.99
SL	3.93	3.60	3.91	-	-	13.70	13.32	11.73
SW	0.90	1.71	1.57	-	-	2.65	1.36	2.07

UCT- Upper cuticle thickness; LCT- Lower cuticle thickness; UET- Upper epidermal thickness; LET- Lower epidermal thickness; UHT- Upper hypodermal thickness; LHT – Lower hypodermal thickness; LT- Lamina thickness; PT- Palisade thickness; PL- Palisade length; PW- Palisade width; Spongy thickness.

Table 2

Characters	*Excoecaria agallocha*	*Kandelia candel*	*Lumnitzera racemosa*	*Rhizophora mucronata*	*Rhizophora apiculata*	*Sonneratia alba*	*Sonneratia caseolaris*
UCT	1.08	0.74	0.56	0.64	0.52	0.61	0.42
LCT	0.33	0.42	0.82	0.67	0.44	0.61	0.74
UET	2.00	1.47	1.36	1.47	1.36	1.38	1.79
LET	1.69	1.87	0.84	0.83	0.91	0.83	0.79
UHT	13.50	12.84	-	16.12	18.18	-	-
LHT	11.30	11.29	-	6.10	3.90	-	-

PT	23.07	18.69	14.95	17.69	17.17	14.21	14.39
PL	12.95	9.28	8.05	7.02	8.42	7.26	6.33
PW	1.16	1.38	1.38	1.36	1.83	2.11	1.13
LT	86.16	80.64	66.07	70.44	68.26	72.71	69.09
ST	44.26	45.60	22.42	23.89	25.52	26.21	24.96
SL	12.85	10.55	18.02	17.98	15.20	15.78	17.66
SW	1.27	2.86	8.29	9.27	9.43	9.68	9.34

SL- Stomatal length SW- Stomatal width; LVDM- Leaf vessel diameter; LVDN- Leaf vessel density; SVDM- Stem vessel diameter; SVDN- Stem vessel density; VL- Vessel length; VW- Vessel width; IVL- Inter vessel length; IVW- Inter vessel width; CT- Cortex thickness.

Discussion

Cuticle is greatly thick in all taxa and the outer epidermis cutinized wholly [2], non-stomatal water loss prevented by cutinized thickened epidermal cells. Presence of cuticle is the adaptive feature of mangrove. The epidermal cells were, rectangular polygonal or isodiametric with thick or thin, straight or sinuous anticlinaI walls [3].

All taxa have some specialized isolated cells such as brachy sclereids, crystalliferous cells, laticiferous cells, mucilaginous cells [4], brachy scleredis in *R. mucronata.* Leaf succulence of mangroves increased with increased the salinity of substrate [5]. Sclereids and tracheids are elaborate in capillary water storage and also studied that in mangrove leaves fleshy texture and high water content increased with age [6]. Sclereids might be provide mechanical support in addition to water storage in leaves with diminished turgor or discourage herbivores [1].

Transverse section of *Excoecaria* leaf as isolateral [7], but present study it is dorsiventral with clear differentiation of abxial spongy parenchyma and adaxial palisade tissue and stomata present only in abaxial side. Besides [1] *Kandelia* leaves as dorsiventral in nature. Isolateral characteristics like palisade cells beneath each epidermis, colourless water storage tissue occupy the middle region of mesophyll; [8] presense of stomata in abaxial and adaxial surfaces. But the present study shows both dorsiventral and isolateral nature. Presence of salt secreting glands of *R. apiculata* and *R. mucronata* in its abaxial surface [9]. But we did not found any glandular structure in the genus *Rhizophora.*

All members showing xeromorphic characters like thick cuticle, water storage tissue, extensive palisade, salt glands, trichomes, terminal tracheids, branched sclereids exhibited by most of the mangrove species appears to eco anatomical adaptations [8]. This character includes isobilateral nature of leaves in some plants like *L. recemosa* and *K. candal.* Every species showed some peculiar features which facilitates adaptation for stress environment.

All three species were hypostomatic, except *Kandelia* and *Lumnitzera*. ranunculaceous stomata were found in *B. gymnorrhiza* [9, 10]. In *B. cylindrica* rubiaceous type were reported [8, 11] observed cruciferous and rubiaceous type. In present study observed rubiaceous and ranunculaceous type stomata. Cyclocytic stomata found in *Rhizophora* and *Kandelia* species [8, 10]. observed the same.

The depth to which stomata are sunken may depend on the leaf age [7]. In *Avicennia*, glandular hairs occur in both abaxial surfaces of the leaf; on the adaxial side, the glandular hairs are sunken dispersed in crypts, whereas on the abaxial distributed non-glandular hairs. In *Avicennia*, glandular and non-glandular hairs are formed similarly up to the three-celled primordium stage, but after this two types of hairs start to appear [12]. The salt is secreted by the cytoplasm of the secretary cells into the large vacuole and that secretary cells dry out with the aging of the leaf and salt remains on the leaf surface as a white, powdery layer [13]. The glandular hairs are responsible for secretary function in *Avicennia.* Non-glandular hairs are only present on the abaxial surface of the leaf in *Avicennia* [14].

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