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Universiti Malaysia Terengganu Journal of Undergraduate Research
Journal Homepage: https://journal.umt.edu.my/index.php/umtjur/
eISSN: 2637-1138
DOI: http://doi.org/10.46754/umtjur.2026.10.008

LEAF MICROMORPHOLOGY OF SELECTED COASTAL PLANT SPECIES IN COASTAL AREA OF TELUK KETAPANG IN KUALA TERENGGANU

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ARTICLE INFO

Article History:
Received: 7 August 2025
Revised: 30 December 2025
Accepted: 29 July 2026
Published: 15 October 2026

Keywords:
Epidermal cells, light microscope, stomata density, stomata index, trichome

ABSTRACT

Leaf micromorphology can play a significant role in plant taxonomy by effectively resolving taxonomic issues among different plant species. Nevertheless, studies on the leaf micromorphology of coastal plants are limited. Accordingly, this study aimed to examine the leaf micromorphological features of plant species commonly found in Teluk Ketapang, Kuala Terengganu, Terengganu, a coastal area. The seven species studied were *Terminalia catappa*, *Vitex rotundifolia*, *Scaevola taccada*, *Canavalia rosea*, *Dodonaea viscosa*, *Calotropis gigantea*, and *Ipomoea pes-caprae*. Four characteristic differences were examined: Stomatal types, trichomes, epidermal cell shapes, and anticlinal wall patterns. Three stomatal types were identified: Paracytic, anomocytic, and diacytic. Paracytic stomata were found on both the abaxial and adaxial leaf surfaces of *C. rosea*, *I. pes-caprae*, and *C. gigantea*. In contrast, anomocytic stomata appeared on the abaxial surface of *D. viscosa*, *S. taccada*, and *T. catappa*, with no stomata on the adaxial surface. *V. rotundifolia* uniquely displayed diacytic stomata on the abaxial surface. Regarding trichomes, only non-glandular trichomes were observed, with *C. rosea* possessing cylindrical trichomes on both leaf surfaces. Meanwhile, *T. catappa* and *V. rotundifolia* indicated falcate and unicellular trichomes, respectively, on the abaxial surface. Epidermal cells in both the adaxial and abaxial epidermis of the species studied were polygonal or irregular, with straight-curved or sinuous anticlinal walls. Taken together, the distinct micromorphological characters observed among the studied species demonstrate that leaf micromorphology provides reliable supplementary taxonomic evidence for identifying and differentiating coastal plant species. It also contributes to improved species delimitation in coastal floristic studies.

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Introduction

Coastal vegetation comprises diverse plant communities that have evolved specialised adaptations to survive the harsh environment. These species demonstrate remarkable resilience to environmental stressors including salt spray exposure, nutrient-poor sandy substrates, and water scarcity (Hobohm *et al*., 2021). These plants have evolved notable adaptations to meet these challenges and thrive in harsh environments. These adaptations allow coastal plants to thrive in harsh coastal conditions, contributing to the beauty and diversity of coastal ecosystems (Duarte *et al*., 2013). Malaysia's extensive coastline supports an extraordinary diversity of halophytic flora, with each species exhibiting unique morphological and physiological adaptations to saline conditions. Notable coastal species on Malaysian shores include *Terminalia catappa* (Ketapang), *Cocos nucifera* (Kelapa), *Calophyllum inophyllum* (Penaga laut), *Rhizophora apiculata* (Bakau minyak), *Nypa fruticans* (Nipah), *Talipariti tiliceum* (Bebaru), *Lumnitzera littorea* (Teruntum), *Vigna marina* (Beach pea), and *Ipomoea pes-caprae* (Tapak kuda).

Anatomical features of both vegetative and reproductive structures in flowering plants play a crucial role in plant taxonomy, offering valuable insights into taxonomic uncertainties and evolutionary relationships (Singh, 1981). While anatomical characteristics serve as supplementary evidence rather than primary classification criteria, they complement external morphological features that form the foundation of traditional taxonomic systems (Metcalfe & Chalk, 1950; Ullah *et al.*, 2018; Mata *et al*., 2022). Comparative anatomical studies of stems, leaves, and reproductive parts have presented distinguishing characters that aid species delimitation and systematic placement (Priya & Hari, 2021). Furthermore, it provides valuable information for identifying and classifying plants, understanding their evolutionary relationships, resolving taxonomic controversies, and uncovering hidden diversity.

Building on this, the micromorphological characteristics of plants in coastal areas are fascinating and play a crucial role in their adaptation to this challenging environment (Amri *et al*., 2019). However, this anatomical study requires a comprehensive understanding of the anatomical structures found in plant species inhabiting coastal environments. Beach-dune environments are globally distributed across tropical and temperate coastlines, making coastal plant micromorphology an important area of research with various potential applications. Plants growing in more saline environments have thicker cuticles and more trichomes than those growing in less saline environments (Parida & Das, 2005). This suggests that leaf micromorphology is an important trait for assessing salinity responses to environmental changes, particularly climate change. Thus, this study aims to describe and compare the leaf micromorphological features of selected coastal plant species from Teluk Ketapang, Kuala Terengganu.

Materials and Methods

Sample Collection

Fresh leaf samples of *Canavalia rosea*, *I. pes-caprae*, *Dodonaea viscosa*, *Scaevola taccada*, *Calotropis gigantea*, *T. catappa*, and *Vitex rotundifolia* were used in this study. These plants were selected based on their abundance

and ecological importance in the study area, as well as their representation of diverse taxonomic groups and growth forms commonly found in coastal vegetation. These samples were collected from Pantai Teluk Ketapang, Kuala Terengganu. Four mature leaf specimens were collected from each tree and then preserved in 70% ethanol: 30% acetic acid solution at a 3:1 ratio.

Epidermal Peeling

Epidermal preparations were obtained by carefully removing tissue layers from both the abaxial and adaxial leaf surfaces until a thin, translucent epidermal layer was exposed (Hussin *et al*., 2000; Talip *et al*., 2005). Following this, each sample was stained in 1% safranin, mounted, and examined under a light microscope.

Stomata and Trichome Identification

Stomata and trichome types were subsequently identified according to Talip *et al.* (2019). Stomata can be classified by the presence, arrangement, and number of subsidiary cells, whereas trichomes can be classified by type, shape, and cell number.

Sample Collection

Stomatal density and index were calculated using the formula from Poole and Kürschner (1999), presented as:

$$Stomatal\ density = \frac{Number\ of\ stomata}{Area\ of\ view\ (mm^2)},$$

$$Stomatal\ index = \frac{Number\ of\ stomata}{(Number\ of\ stomata + Number\ of\ epidermal\ cells)} \times 100\%.$$

Results and Discussion

A comparison of leaf micromorphological characteristics of both the adaxial (upper) and abaxial (lower) leaf surfaces, as observed under a light microscope, is presented in Table 1 and Figure 1. All examined species exhibited two types of arrangement, namely amphistomatic (stomata were present on both the upper and lower surfaces of the leaf) and hypostomatic (stomata were present only on the lower surface of the leaf). Stomata were randomly distributed across the entire adaxial and abaxial leaf surfaces, with a higher abundance on the abaxial surface. Meanwhile, trichomes were observed in only three species.

Epidermal Cell

Epidermal cells on both the adaxial and abaxial surfaces were polygonal and irregular in shape. The polygonal shape was the most common, resembling a polyhedral figure such as a pentagon or hexagon. Different species exhibited different epidermal cell sizes. Figures 1 (A) to (I) illustrate the leaf epidermis of several specimens examined.

Trichomes

Simple, unicellular trichomes were found in the three species studied (*C. rosea*, *T. catappa*, and *V. rotundifolia*). The trichomes were scattered on the abaxial leaf surface. Figures 1 (G) to (I) display the types of trichomes in the species examined.

Table 1: The stomatal characteristics of plant species in the coastal area of Pantai Teluk Ketapang, Kuala Terengganu

Plant Taxa	Adaxial Leaf Epidermis					Abaxial Leaf Epidermis					Trichome
	Epidermal Cell Shape	**Anticlinal Cell Wall**	**Stomata Type**	**Stomata Density (Mm^2)**	**Stomata Index (%)**	**Epidermal Cell Shape**	**Anticlinal Cell Wall**	**Stomata Type**	**Stomata Density (Mm^2)**	**Stomata Index (%)**	
Canavalia rosea	Polygonal	Straight-curved	Paracytic	125.63	3.148	Polygonal	Straight-curved	Paracytic	109.93	2.849	Non-glandular
Calotropis gigantea	Polygonal	Straight-curved	Paracytic	111.50	1.364	Polygonal	Straight-curved	Paracytic	158.61	2.405	Absent
Dodonaea viscosa	Polygonal	Straight-curved	-	-	-	Irregular	Straight-curved	Anomocytic	183.73	2.195	Absent
Ipomoea pes-caprae	Polygonal	Straight-curved	Paracytic	45.54	0.983	Polygonal	Straight-curved	Paracytic	42.40	0.874	Absent
Scaevola taccada	Polygonal	Straight-curved	-	-	-	Irregular	Sinuous	Anomocytic	166.46	3.114	Absent
Terminalia catappa	Irregular	Sinuous	-	-	-	Irregular	Sinuous	Anomocytic	138.19	2.599	Non-glandular
Vitex rotundifolia	Irregular	Sinuous	-	-	-	Irregular	Sinuous	Diacytic	521.36	9.148	Non-glandular



Figure 1: Leaf epidermis of selected coastal plant species. A to C: Adaxial epidermis showing epidermal cell morphology of (A) *D. viscosa*, (B) *T. catappa*, and (C) *I. pes-caprae*. D to G: Abaxial epidermal cells and stomatal distribution of (D) *C. rosea*, (E) *S. taccada*, (F) *V. rotundifolia*, and (G) *T. catappa*. H to I: Representative non-glandular trichomes observed in (H) *T. catappa* and (I) *V. rotundifolia*

Note: Images are representative of species exhibiting similar micromorphological characters; scale bar = 20 µm

Stomata

Based on the results, two stomatal patterns were observed: Stomata on both leaf surfaces (amphistomatic) and stomata exclusively on the lower leaf surface (hypostomatic) (Table 1). *D. viscosa*, *S. taccada*, *T. catappa*, and *V. rotundifolia* were the only species where the stomata were hypostomatic. Furthermore, while stomatal sizes differed across species, ranging from 15.2 to 20.5 µm × 8.5 to 10.7 µm, they were constant on both surfaces. In particular, three types of stomata were observed in all species studied: Paracytic (two subsidiary cells arranged parallel to the long axis of the stomata), anomocytic (no subsidiary cells), and diacytic (two subsidiary cells arranged laterally/parallel to the

stomatal pore). Stomata were randomly arranged in all studied species. Figures 1 (D) to (G) illustrate the types of stomata in species examined.

Stomata Density and Index

The highest stomatal density on the abaxial leaf surface was recorded by *V. rotundifolia* (521.36 mm^2), while *I. pes-caprae* had the lowest (42.405 mm^2). The highest stomatal density on the adaxial leaf surface was obtained from *C. gigantea* (111.50 mm^2), while the lowest was obtained from *I. pes-caprae* (45.54 mm^2). The highest stomatal index on the abaxial leaf surface was produced by *V. rotundifolia* (9.148%), while the lowest was produced by *I. pes-caprae* (0.874%). The highest stomatal index on the adaxial surface was in *C. rosea* (3.148%), while the lowest was in *I. pes-caprae* (0.983%). Notably, there are clear differences between abaxial and adaxial leaf surfaces, with the abaxial surface consistently indicating higher stomatal density. In contrast, the stomatal index presents relatively smaller variation between abaxial and adaxial leaf surfaces.

Our results indicate that the seven coastal plant species examined exhibited diverse leaf micromorphological characteristics. The epidermal cells across all species were generally polygonal to irregular in shape with straight-wavy to sinuous anticlinal wall patterns. Previous anatomical studies have reported that wavy or undulate anticlinal epidermal cell walls are common in coastal plants. These patterns may contribute to leaf mechanical strength and provide endurance against strong winds and salt spray (Carpenter, 2005). In addition, straight to wavy anticlinal walls were identified in the abaxial and adaxial surfaces of *C. rosea*, *C. gigantea*, *D. viscosa*, and *I. pes-caprae,* while sinuous anticlinal walls were observed in the abaxial and adaxial surfaces of *T. catappa* and *V. rotundifolia*. This finding supports the previous study that epidermal cells of *I. pes-caprae* are mostly straight to wavy type (Amri *et al*., 2019). Stomatal types can also be taxonomically valuable for species identification (Metcalfe & Chalk, 1950), providing supporting evidence during plant identification (Vaten & Berggman, 2012). In this study, *C. rosea*, *C. gigantea*, and *I. pes-caprae* have paracytic stomata, while *D. viscosa*, *S. taccada*, and *T. catappa* have anomocytic stomata. *V. rotundifolia* possesses diacytic stomata.

The results also suggested that stomatal density and index vary across species, with each species indicating the highest or lowest values (Table 1). Micromorphological traits such as stomatal density and trichome structure provide valuable insights into both evolutionary processes and ecological adaptation. Previous studies demonstrate that stomatal density is strongly influenced by climatic conditions, with its current form shaped through microevolutionary adjustments across successive generations (Willmer & Fricker, 1996; Hetherington & Woodward, 2003; Franks *et al*., 2012; Shabala, 2013). In parallel, trichomes have long been recognised for their significant taxonomic value, serving as diagnostic features for distinguishing species and genera (Metcalfe & Chalk, 1950; Werker, 2000). In the current study, the leaf surfaces of *C. rosea*, *T. catappa*, and *V. rotundifolia* were observed to bear simple, unicellular trichomes. This observation is consistent with earlier reports confirming the unicellular nature of trichomes in *C. rosea* and *T. catappa* (Mohajer *et al*., 2017; Zan, 2020). Such congruence underscores the reliability of trichome morphology as a diagnostic character for species identification.

Beyond taxonomy, these micromorphological features also reflect adaptive strategies to coastal environments, where structural traits may contribute to resilience against abiotic stressors such as salinity, desiccation, and high irradiance.

Conclusions

A comparative analysis of leaf micromorphology in seven coastal plant species from Pantai Teluk Ketapang, Kuala Terengganu revealed distinct differences between adaxial (upper) and abaxial (lower) surfaces. This study demonstrates that leaf micromorphology can provide additional information for identifying coastal plant species. The seven species examined indicated variation in stomatal type, stomatal density and index, trichome type, epidermal cells, and anticlinal wall patterns. Overall, these micromorphological traits provide reliable diagnostic features for species identification and highlight coastal plants' adaptive strategies to their environment.

Acknowledgements

The authors thank the Faculty of Science and Marine Environment, Universiti Malaysia Terengganu (UMT), for providing the facilities to conduct this study.

Author Contributions Statement

Nur Syuhadah conducted the laboratory work, performed data analysis and drafted the manuscript. Salwa supervised the study, interpreted the results, led the review and revisions, and approved the submitted manuscript.

Conflict of Interest Statement

The authors agree that this research was conducted without any self-benefit, commercial, or financial conflicts and declare no conflicts of interest with the funders.

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