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# Leaf architecture study of selected mangrove species in Katunggan Coastal Eco-Park, Sultan Kudarat Province, the Philippines

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## ABSTRACT

There is a minimal number of research on the leaf architecture characters of mangrove species in the Southern Philippines, despite the use of these characters especially in delineating taxonomically confusing groups. To address this knowledge gap, this paper provides the leaf architecture of selected seventeen (17) mangrove species in Katunggan Coastal Eco-Park, Sultan Kudarat Province, the Philippines. Ten (10) leaf samples of each species were collected and examined. Results revealed that leaf morphometrics displayed unifying and distinguishing characters that can be used as taxonomic markers in identifying mangrove species. Ten characters— base symmetry, apex shape, surface texture, 2° major vein framework, minor 2° course, perimarginal vein, major 2° attachment, major 2° spacing, variation of major 2° angle, and inter-2° frequency—were shown to be distinct in one species. These unique characters showed that the variations in laminar characters and venation patterns are useful in differentiating different mangrove species. A dichotomous key was constructed based on the leaf architectural characters that were measured and described.

**Keyword:** leaf architecture, mangrove, laminar characters, venation patterns, dichotomous key

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## INTRODUCTION

Mangroves play a crucial ecological role in tropical and subtropical shorelines by stabilizing sediments, regulating coastal erosion, filtering nutrients and pollutants (de Oliveira *et al*., 2025), and providing habitat and breeding grounds for various marine organisms, including fishes and crustaceans (Buot *et al*., 2022). Mangroves are beneficial to humans, as they are good sources of timber for construction materials, fuel wood, medicine, and marine food (Cano-Mangaoang *et al*., 2022).

With half of the worldwide mangrove species present, the Philippines is considered rich in mangrove forests (Buitre *et al*., 2019). However, anthropogenic activities have changed a large portion of the mangrove forests within the Philippines throughout the past century (Long and Giri, 2011). Fringing mangrove forests lining much of the 33,600 km Philippine coastline have mostly vanished due to villagers clearing these forests or converting them to culture ponds (Primavera *et al*., 2011). The estimated area of the Philippine mangrove forests has declined from 295,000 hectares in 1980 to 240,000 hectares in 2005 (FAO, 2007). Of the remaining mangrove forests, an estimated area of 1,107 hectares was in the Province of Sultan Kudarat in Mindanao, Philippines, by 2010 (Long *et al*., 2014). Consequently, the province has an existing mangrove reforestation effort located in the Katunggan Coastal Eco-Park, Barangay Taguisa, municipality of Lebak, Sultan Kudarat. Mangrove restoration and conservation programs were developed to protect the area in cooperation with the Department of Environment and Natural Resources (DENR) (Cano-Mangaoang and Flores, 2019). Comprehensive implementation of tree planting activities was done to restore cleared areas caused by unregulated cutting of mangrove trees (Demapitan *et al*., 2023). An inventory of the mangrove forest in the Katunggan Coastal Eco-Park has revealed that 29 species are present in the area (Cano-Mangaoang and Flores, 2019), including *Camptostemon philippinensis,* which is an endangered species (DENR, 2017).

Despite its diversity, most locals living near mangrove ecosystems are unaware of how many mangrove species exist—and even fewer people can name them (Longépée *et al*., 2021). The difficulty in recognizing the mangrove species can stem from the interesting similarities and differences in leaf anatomy of mangroves under the same family (Tomlinson, 2016) and their frequent co-existence within the same environment (Guo *et al*., 2025). Different mangrove species possess several common morphological traits that make species identification a very confusing task (Garcia *et al*., 2014).

Several taxonomic investigations that had been conducted on confusing taxa were resolved using leaf architecture. Leaf architecture is an effective technique to describe, characterize, and delineate related taxa with various similar characters (Masungsong *et al*., 2023). Leaf architectural studies were conducted to identify the distinct differences in the species of *Hoya* (Salvaña and Buot, 2014; Torrefiel and Buot, 2017; Tan and Buot, 2018 Paguntalan and Buot, 2019; Catones and Buot, 2020); *Shorea* (Pulan and Buot, 2014); *Mussaenda* (Kpadehyea and Buot, 2014); *Terminalia* (Baroga and Buot, 2014); *Diplazium* (Conda *et al*., 2017); *Syzygium* (Viacrucis and Buot, 2021); *Dioscorea* (Antonio and Buot, 2021); and *Cucumis* (Masungsong *et al*., 2022). However, research on the leaf architecture of mangroves in the Philippines is basically nonexistent. Studies done on mangroves in the

Southern Philippines, for example, mostly evaluated their species diversity (Cano-Mangaoang and Flores, 2019; Pototan *et al*., 2021), species composition, stand characteristics, aboveground biomass, and carbon stock (Alimbon and Manseguiao, 2021), species conservation and abundance (Cano-Mangaoang *et al*., 2022), and community structure and regeneration capacity (Demapitan *et al*., 2023). Assessment of mangrove species serves a significant role in the protection and conservation of ecosystems (Pototan *et al*., 2021); hence, the main purpose of this study is to investigate the leaf architectural characters of selected species of mangroves and create a reliable guide in identifying diverse mangrove species. Determining the taxonomic characters that distinguish mangrove species would provide information that can be used in identification, reforestation, and monitoring efforts.

## MATERIALS AND METHODS

### Sample collection and preparation

Ten leaf samples of *Bruguiera gymnorrhiza* (L.) Lam. ex Savigny, *Bruguiera cylindrica* (L.) Blume, *Bruguiera sexangula* (Lour.) Poir., *Rhizophora mucronata* Poir., *Rhizophora apiculata* Blume, *Rhizophora stylosa* Griff., *Avicennia marina* (Forssk.) Vierh., *Avicennia alba* Blume, *Xylocarpus granatum* J. Koenig, *Xylocarpus moluccensis* (Lam.) M. Roem., *Lumnitzera racemosa* Willd., *Lumnitzera littorea* (Jack) Voigt, *Sonneratia alba* Sm., *Ceriops decandra* (Griff.) W. Theob., *Excoecaria agallocha* L., *Camptostemon philippinensis* (S. Vidal) Becc., and *Aegiceras corniculatum* (L.) Blanco were collected from Katunggan Coastal Eco-Park, Lebak, Sultan Kudarat. The identification of samples was assisted by a local expert and verified by Dr. Florence Roy P. Salvaña, a botanist from University of Southern Mindanao. The collection of samples happened during the 4-day field laboratory of the university. A total of 170 leaves were collected. The leaves were orderly placed in uniform-sized newspapers, placed in a plant press, and sun-dried for three weeks.

### Analysis of leaf architecture

The analysis of leaf architecture was done on the samples of mangrove species. Characters and terminologies of seventeen species of mangroves were described using the established leaf architecture guide of Ellis *et al*. (2009). Laminar characters and venation patterns of the primary (1°) and secondary (2°) veins were examined.

All dried leaves were examined using a stereomicroscope. Large measurement characters such as length and width were done using a transparent ruler, while angles of divergence were measured using a protractor.

## RESULTS AND DISCUSSIONS

### Leaf architectural characteristics of seventeen mangrove species

The examined leaves of the seventeen mangrove species are shown in figures 1–17. In Tables 1–2, the leaf architectural characteristics of the mangroves are listed. The leaf samples examined in this study exhibit unifying general features as follows: leaf attachment, petiolate; leaf organization, simple or once pinnately compound (even); position of lamina attachment, marginal; medial symmetry, symmetrical; lobation, unlobed (entire); margin type, untoothed; terminal apex features, mucronate or retuse; primary vein framework, pinnate; naked basal vein, absent; number of basal vein, one; agrophic vein, absent; interior secondaries, present; intersecondary proximal course, parallel to major secondary or perpendicular to midvein; and intersecondary length, less than 50% or more than 50% of subjacent secondary.

Some of the laminar characteristics of mangrove species examined in this study conform with previous studies. *Bruguiera gymnorrhiza* (L.) Lam. ex Savigny leaves opposite, simple, elliptic, petiolate with acute apex (Allen and Duke, 2006). *Bruguiera cylindrica* (L.) Blume leaves opposite, simple, elliptic with acute apex (Rodriguez *et al*., 2012). *Bruguiera sexangula* (Lour.) Poir. leaves opposite, simple, elliptic, petiolate with acute apex, cuneate base, entire margin (Duke and Ge, 2011). *Rhizophora mucronata* Poir. leaves opposite, simple, elliptic, petiolate with acute apex, entire margin (Shamin-Shazwan *et al*., 2021). *Rhizophora stylosa* Griff. leaves decussate (opposite), elliptic, petiolate with mucronate apex, entire margin, intramarginal veins (Ngernsaengsaruay *et al*., 2025). *Rhizophora apiculata* Blume leaves opposite, simple, elliptic, petiolate with acute apex, cuneate base, entire margin (Shamin-Shazwan *et al*., 2021). *Avicennia marina* (Forssk.) Vierh. leaves opposite, ovate to elliptic, petiolate (Farooqui and Dangi, 2018) with acute apex, obtuse and cuneate base, entire margin (Mandal *et al*., 2017). *Avicennia alba* Blume leaves opposite, petiolate (Farooqui and Dangi, 2018), elliptic (Syazana *et al*., 2025). *Xylocarpus granatum* J.Koenig leaves unipinnate compound with rounded apex, entire margin (Maung and Thinn, 2005), acute base (Haron and Taha, 2007). *Xylocarpus moluccensis* (Lam.) M. Roem. leaves compound, opposite, elliptic with acute apex, acute base, entire margin (Haron and Taha, 2009). *Lumnitzera racemosa* Willd. leaves alternate, simple, elliptic (Manohar, 2021), petiolate (Niagara *et al*., 2021). *Lumnitzera littorea* (Jack) Voigt leaves obovate with emarginate apex, entire margin (Mutaqin *et al*., 2017). *Sonneratia alba* Sm. leaves simple, petiolate with obtuse apex, entire margin (Surya and Hari, 2018), obovate with rounded apex (Mutaqin *et al*., 2017). *Ceriops decandra* (Griff.) W.Theob. leaves opposite, simple, elliptic with rounded and obtuse apex, concave and acute base, symmetrical medial (Coronado, 2009). *Excoecaria agallocha* L. leaves alternate, simple, elliptic, petiolate with acuminate apex, entire margin (Hilal and Hilal, 2019). *Camptostemon philippinensis* (S.Vidal) Becc. leaves simple, petiolate with obtuse apex, entire margin (Damayanto *et al*., 2023). *Aegiceras corniculatum* (L.) Blanco leaves pinnate, simple, obovate, petiolate, symmetrical with obtuse apex, acute base, entire margin (Khan *et al*., 2021). These laminar traits are also consistent with the descriptions in different mangrove handbooks and guidebooks (Primavera *et al*., 2004; Duke, 2006; Giesen *et al*., 2007; Hossain, 2015).

However, it was found out that laminar and venation characters such as base symmetry, apex shape, surface texture, 2° major vein framework, minor 2° course, perimarginal vein, major 2° attachment, major 2° spacing, variation of major 2° angle, and inter-2° frequency can be useful taxonomic markers. Among the seventeen species, only *A. marina* and *X. granatum* exhibited basal width asymmetry and base asymmetry, respectively. *Xylocarpus moluccensis* showed an apex shape that is acuminate on the left and straight on the right. Only *B. cylindrica* has a rugose surface texture. 2° major vein craspedodromous is exclusive to *L. racemosa,* while minor 2° course craspedodromous is exclusive to *B. sexangula*. Only *A. marina* lacks a perimarginal vein but contains a proximal secondaries decurrent type of major 2˚ attachment. A major 2˚ spacing that is decreasing proximally and variation of major 2˚ angle that is one pair of acute basal secondaries are unique to *B. gymnorrhiza* and *C. philippinensis,* respectively. Lastly, *C. decandra* have less than one intersecondary in every intercostal area.

The similarities in surface texture, margin type, and base shape and differences in leaf shape and apex shape can be caused by the variations in phytochemical compound and chlorophyll content and environmental conditions as observed by Nurzaman *et al*. (2018). Similarly, differences in leaf shape, apex shape, leaf size, and margin type were observed by Mutaqin *et al*. (2017) in mangrove leaves with varied phytochemical compound content and environmental parameters. These variations in leaf morphology of several mangrove species were also evident due to long-term exposure to low-temperature stress (Wang *et al*., 2022) and differences in DNA molecular sequences (Coronado, 2009), tannin content (Yuanyue *et al*., 2009) and types of soil substrate in the habitat (Niagara *et al*., 2021).

***Bruguiera gymnorrhiza*** **(L.) Lam. ex Savigny** (Figure 1)

**Leaf** petiolate; opposite (decussate); simple. **Lamina** marginal; area, 2,277–3,290 mm$^2$; notophyll; ratio, 2.6:1–3.1:1; elliptic; medial symmetrical; base symmetrical; unlobed; untoothed; apex, acute and acuminate; base, acute and straight; retuse; smooth. **1˚ vein** framework, pinnate; naked basal vein, absent; basal vein, one; agrophic vein, absent. **2˚ vein** framework, simple brochidodromous; interior 2˚, present; minor 2˚ course, simple brochidodromous; perimarginal vein, intramarginal 2˚; major 2˚ spacing, decreasing proximally; variation of major 2˚ angle, uniform; major 2˚ attachment, excurrent. **Inter-2˚** proximal course, parallel to major secondary; length, more than 50% of subjacent secondary; distal course, parallel to major secondary; frequency, more than one per intercostal area.

***Bruguiera cylindrica*** **(L.) Blume** (Figure 2)

**Leaf** petiolate; opposite (decussate); simple. **Lamina** marginal; area, 3,996–5,133 mm$^2$; notophyll – mesophyll; ratio, 2:1–2.4:1; elliptic; medial symmetrical; base symmetrical; unlobed; untoothed; apex, acute and straight; base, acute and straight; mucronate; rugose. **1˚ vein** framework, pinnate; naked basal vein, absent; basal vein, one; agrophic vein, absent. **2˚ vein** framework, simple brochidodromous; interior 2˚, present; minor 2˚ course, simple brochidodromous; perimarginal vein, intramarginal 2˚; major 2˚ spacing, irregular; variation of major 2˚ angle, uniform; major 2˚ attachment, deflected. **Inter-2˚** proximal course, perpendicular to midvein; length, less than 50% of subjacent secondary; distal course, parallel to major secondary; frequency, more than one per intercostal area.

**Figure 1.** Leaf samples of *B. gymnorrhiza.*

***Bruguiera sexangula* (Lour.) Poir.** (Figure 3)

**Leaf** petiolate; opposite (decussate); simple. **Lamina** marginal; area, 2,295–5,720 mm$^2$; notophyll – mesophyll; ratio, 2.5:1–3.5:1; elliptic; medial symmetrical; base symmetrical; unlobed; untoothed; apex, acute and acuminate; base, acute and straight; mucronate; smooth. **1˚ vein** framework, pinnate; naked basal vein, absent; basal vein, one; agrophic vein, absent. **2˚ vein** framework, simple brochidodromous; interior 2˚, present; minor 2˚ course, craspedodromous; perimarginal vein, intramarginal 2˚; major 2˚ spacing, irregular; variation of major 2˚ angle, inconsistent; major 2˚ attachment, excurrent. **Inter-2˚** proximal course, parallel to major secondary; length, more than 50% of subjacent secondary; distal course, reticulating/ramifying; frequency, more than one per intercostal area.

***Rhizophora mucronata* Poir.** (Figure 4)

**Leaf** petiolate; opposite (decussate); simple. **Lamina** marginal; area, 4,017–10,732 mm$^2$; notophyll – mesophyll; ratio, 1.8:1–2:1; elliptic; medial symmetrical; base symmetrical; unlobed; untoothed; apex, acute and straight; base, obtuse and convex; mucronate; smooth. **1˚ vein** framework, pinnate; naked basal vein, absent; basal vein, one; agrophic vein, absent.

**Figure 2.** Leaf samples of *B. cylindrica.*

**2° vein** framework, simple brochidodromous; interior 2°, present; minor 2° course, simple brochidodromous; perimarginal vein, intramarginal 2°; major 2° spacing, regular; variation of major 2° angle, uniform; major 2° attachment, excurrent. **Inter-2°** proximal course, parallel to major secondary; length, more than 50% of subjacent secondary; distal course, parallel to major secondary; frequency, more than one per intercostal area.

***Rhizophora stylosa* Griff.** (Figure 5)

**Leaf** petiolate; opposite (decussate); simple. **Lamina** marginal; area, 2,457–5,535 $mm^2$; notophyll – mesophyll; ratio, 2.05:1–2.40:1; elliptic; medial symmetrical; base symmetrical; unlobed; untoothed; apex, acute and straight; base, acute – obtuse and concave; mucronate; smooth**. 1° vein** framework, pinnate; naked basal vein, absent; basal vein, one; agrophic vein, absent. **2° vein** framework, simple brochidodromous; interior 2°, present; minor 2° course, simple brochidodromous; perimarginal vein, intramarginal 2°; major 2° spacing, regular; variation of major 2° angle, uniform; major 2° attachment, excurrent. **Inter-2°** proximal course, parallel to major secondary; length, more than 50% of subjacent secondary; distal course, parallel to major secondary; frequency, more than one per intercostal area.

**Figure 3.** Leaf samples of *B. sexangula*

**Figure 4.** Leaf samples of *R. mucronata*.


**Figure 5.** Leaf samples of *R. stylosa*

**Figure 6.** Leaf samples of *R. apiculata.*

***Rhizophora apiculata* Blume** (Figure 6)

**Leaf** petiolate; opposite (decussate); simple. **Lamina** marginal; area, 6,063–7,245 $mm^2$; mesophyll; ratio, 2.6:1–2.9:1; elliptic; medial symmetrical; base symmetrical; unlobed; untoothed; apex, acute and straight; base, acute and straight; mucronate; smooth**.** **1˚ vein** framework, pinnate; naked basal vein, absent; basal vein, one; agrophic vein, absent. **2˚ vein** framework, simple brochidodromous; interior 2˚, present; minor 2˚ course, simple brochidodromous; perimarginal vein, intramarginal 2˚; major 2˚ spacing, regular; variation of major 2˚ angle, uniform; major 2˚ attachment, excurrent. **Inter-2˚** proximal course, parallel to major secondary; length, more than 50% of subjacent secondary; distal course, parallel to major secondary; frequency, more than one per intercostal area.

***Avicennia marina* (Forssk.) Vierh.** (Figure 7)

**Leaf** petiolate; opposite (distichous); simple. **Lamina** marginal; area, 2,370–2,806 $mm^2$; notophyll; ratio, 1.84:1–2.2:1; elliptic–ovate; medial symmetrical; base symmetrical–basal width asymmetrical; unlobed; untoothed; apex, acute and straight; base, acute–obtuse and convex; mucronate; smooth. **1˚ vein** framework, pinnate; naked basal vein, absent; basal vein, one; agrophic vein, absent. **2˚ vein** framework, festooned brochidodromous; interior 2˚, present; minor 2˚ course, simple brochidodromous; perimarginal vein, absent; major 2˚ spacing, irregular; variation of major 2˚ angle, smoothly decreasing proximally; major 2˚ attachment, proximal secondaries decurrent. **Inter-2˚** proximal course, perpendicular to midvein; length, more than 50% of subjacent secondary; distal course, reticulating/ramifying; frequency, more than one per intercostal area.

***Avicennia alba* Blume** (Figure 8)

**Leaf** petiolate; opposite (distichous); simple**. Lamina** marginal; area, 1,072–2,053 $mm^2$, microphyll–notophyll; ratio, 1.62:1–2.14:1; elliptic; medial symmetrical; base symmetrical; unlobed; untoothed; apex, obtuse and convex; base, acute and straight; mucronate; smooth. **1˚ vein** framework, pinnate; naked basal vein, absent; basal vein, one; agrophic vein, absent. **2˚ vein** framework, eucamptodromous; interior 2˚, present; minor 2˚ course, simple brochidodromous; perimarginal vein, intramarginal 2˚; major 2˚ spacing, irregular; variation of major 2˚ angle, inconsistent; major 2˚ attachment, deflected. **Inter-2˚** proximal course, parallel to major secondary; length, less than 50% of subjacent secondary; distal course, basiflexed but not joining the subjacent secondary at right angles; frequency, usually one per intercostal area.

***Xylocarpus granatum* J.Koenig** (Figure 9)

**Leaf** petiolate; opposite (distichous); once-pinnately compound (even); leaflet arrangement, opposite (even-pinnately compound); leaflet attachment, petiolulate. **Lamina** marginal; area, 3,307.5–5,124 $mm^2$; notophyll–mesophyll; ratio, 1.83:1–2.18:1; elliptic; medial symmetrical; base asymmetrical; unlobed; untoothed; apex, acute and rounded; base, acute–obtuse and convex; retuse; smooth. **1˚ vein** framework, pinnate; naked basal vein, absent; basal

**Figure 7.** Leaf samples of *A. marina.*

**Figure 8.** Leaf samples of *A. alba.*

**Figure 9.** Leaf samples of *X. granatum.*

**Figure 10.** Leaf samples of *X. moluccensis.*

vein, one; agrophic vein, absent. **2° vein** framework, simple brochidodromous; interior 2°, present; minor 2° course, simple brochidodromous; perimarginal vein, intramarginal 2°; major 2° spacing, irregular; variation of major 2° angle, smoothly decreasing proximally; major 2° attachment, excurrent. **Inter-2°** proximal course, parallel to major secondary; length, less than 50% of subjacent secondary; distal course, reticulating/ramifying; frequency, usually one per intercostal area.

***Xylocarpus moluccensis*** **(Lam.) M.Roem.** (Figure 10)

**Leaf** petiolate; opposite (distichous); once-pinnately compound (even); leaflet arrangement, opposite (even-pinnately compound); leaflet attachment, petiolulate. **Lamina** marginal; area, 1,942–2,954 $mm^2$; microphyll–notophyll; ratio, 2.35:1–2.6:1; elliptic; medial symmetrical**;** base symmetrical; unlobed; untoothed; apex, acute and acuminate on the left and straight on the right; base, acute and concave; mucronate; smooth**. 1° vein** framework, pinnate; naked basal vein, absent; basal vein, one; agrophic vein, absent. **2° vein** framework, festooned brochidodromous; interior 2°, present; minor 2° course, simple brochidodromous–semicraspedodromous; perimarginal vein, intramarginal 2°; major 2° spacing, irregular; variation of major 2° angle, uniform; major 2° attachment, excurrent. **Inter-2°** proximal course, parallel to major secondary; length, less than 50% of subjacent secondary; distal course, reticulating/ramifying; frequency, more than one per intercostal area.

***Lumnitzera racemosa*** **Willd.** (Figure 11)

**Leaf** petiolate; alternate (helical); simple. **Lamina** marginal; area, 510–598.5 $mm^2$; microphyll; ratio, 2.2:1–2.8:1; elliptic; medial symmetrical**;** base symmetrical; unlobed; untoothed; apex, acute and emarginate; base, acute and decurrent; mucronate; smooth. **1° vein** framework, pinnate; naked basal vein, absent; basal vein, one; agrophic vein, absent. **2° vein** framework, craspedodromous**;** interior 2°, present; minor 2° course, simple brochidodromous; perimarginal vein, intramarginal 2°; major 2° spacing, regular; variation of major 2° angle, smoothly decreasing proximally; major 2° attachment, excurrent. **Inter-2°** proximal course, perpendicular to midvein; length, less than 50% of subjacent secondary; distal course, reticulating/ramifying; frequency, usually one per intercostal area.

***Lumnitzera littorea*** **(Jack) Voigt** (Figure 12)

**Leaf** petiolate; alternate (helical); simple. **Lamina** marginal; area, 492–675 $mm^2$; microphyll; ratio, 2.5:1–3.6:1; obovate; medial symmetrical; base symmetrical; unlobed; untoothed; apex, obtuse and emarginate; base, acute and straight; retuse; smooth. **1° vein** framework, pinnate; naked basal vein, absent; basal vein, one; agrophic vein, absent. **2° vein** framework, eucamptodromous; interior 2°, present; minor 2° course, semicraspedodromous; perimarginal vein, intramarginal 2°; major 2° spacing, irregular; variation of major 2° angle, inconsistent; major 2° attachment, excurrent. **Inter-2°** proximal course, parallel to major secondary; length, more than 50% of subjacent secondary; distal course, reticulating/ramifying; frequency, usually one per intercostal area.

**Figure 11.** Leaf samples of *L. racemosa.*

**Figure 12.** Leaf samples of *L. littorea.*

***Sonneratia alba* Sm.** (Figure 13)

**Leaf** petiolate; opposite (decussate); simple. **Lamina** marginal; area, 2,322–5,118.75 $mm^2$; notophyll–mesophyll; ratio, 1.04:1–1.67:1; obovate; medial symmetrical; base symmetrical; unlobed; untoothed; apex, obtuse and rounded; base, acute–obtuse and concave; mucronate; smooth. **1° vein** framework, pinnate; naked basal vein, absent; basal vein, one; agrophic vein, absent. **2° vein** framework, simple brochidodromous; interior 2°, present; minor 2° course, simple brochidodromous; perimarginal vein, intramarginal 2°; major 2° spacing, regular; variation of major 2° angle, uniform; major 2° attachment, decurrent. **Inter-2°** proximal course, parallel to major secondary; length, more than 50% of adjacent secondary; distal course, basiflexed but not joining the subjacent secondary at right angles; frequency, usually one per intercostal area.

***Ceriops decandra* (Griff.) W.Theob.** (Figure 14)

**Leaf** petiolate; opposite (distichous); simple. **Lamina** marginal; area, 1,065.75–3,780 $mm^2$; microphyll–notophyll; ratio, 1.56:1–1.73:1; elliptic; medial symmetrical; base symmetrical; unlobed; untoothed; apex, obtuse and rounded; base, acute and concave; retuse; smooth. **1° vein** framework, pinnate; naked basal vein, absent; basal vein, one; agrophic vein, absent. **2° vein** framework, simple brochidodromous; interior 2°, present; minor 2° course, simple brochidodromous; perimarginal vein, intramarginal 2°; major 2° spacing, regular; variation of major 2° angle, uniform; major 2° attachment, decurrent. **Inter-2°** proximal course, parallel to major secondary; length, less than–more than 50% of subjacent secondary; distal course, reticulating/ramifying; frequency, less than one per intercostal area.

***Excoecaria agallocha* L.** (Figure 15)

**Leaf** petiolate; alternate (helical); simple. **Lamina** marginal; area, 1,522–2,178 $mm^2$; microphyll–notophyll; ratio, 2.3:1–2.4:1; elliptic; medial symmetrical; base symmetrical; unlobed; untoothed; apex, acute and acuminate; base, obtuse and convex; mucronate; smooth. **1° vein** framework, pinnate; naked basal vein, absent; basal vein, one; agrophic vein, absent. **2° vein** framework, eucamptodromous; interior 2°, present; minor 2° course, simple brochidodromous; perimarginal vein, intramarginal 2°; major 2° spacing, irregular; variation of major 2° angle, uniform; major 2° attachment, excurrent. **Inter-2°** proximal course, perpendicular to midvein; length, less than 50% of subjacent secondary; distal course, parallel to major secondary; frequency, usually one per intercostal area.

***Camptostemon philippinensis* (S.Vidal) Becc.** (Figure 16)

**Leaf** petiolate; alternate (helical); simple. **Lamina** marginal; area, 2,236.5–4,480.5 $mm^2$; notophyll–mesophyll; ratio, 1.5:1–1.9:1; elliptic; medial symmetrical**;** base symmetrical; unlobed; untoothed; apex, acute–obtuse and convex–rounded; base, obtuse and convex; retuse; smooth. **1° vein** framework, pinnate; naked basal vein, absent; basal vein, one; agrophic vein, absent. **2° vein** framework, festooned brochidodromous; interior 2°, present; minor 2° course, simple brochidodromous; perimarginal vein, intramarginal 2°;

**Figure 13**. Leaf samples of *S. alba.*

**Figure 14**. Leaf samples of *C. decandra.*

**Figure 15**. Leaf samples of *E. agallocha.*

**Figure 16**. Leaf samples of *C. philippinensis*.

major 2˚ spacing, irregular; variation of major 2˚ angle, one pair of acute basal secondaries; major 2˚ attachment, decurrent. **Inter-2˚** proximal course, parallel to major secondary; length, less than 50% of subjacent secondary; distal course, reticulating/ramifying; frequency, more than one per intercostal area.

***Aegiceras corniculatum*** **(L.) Blanco** (Figure 17)

**Leaf** petiolate; alternate (helical); simple. **Lamina** marginal; area, 1,386–4,333 $mm^2$; microphyll–notophyll; ratio, 1.6:1–1.9:1; obovate; medial symmetrical; base symmetrical; unlobed; untoothed; apex, obtuse and emarginate; base, acute and decurrent; retuse; smooth. **1˚ vein** framework, pinnate; naked basal vein, absent; basal vein, one; agrophic vein, absent. **2˚ vein** framework, eucamptodromous; interior 2˚, present; minor 2˚ course, simple brochidodromous; perimarginal vein, marginal–intramarginal 2˚; major 2˚ spacing, irregular; variation of major 2˚ angle, smoothly decreasing proximally; major 2˚ attachment, decurrent. **Inter-2˚** proximal course, parallel to major secondary; length, less than 50% of subjacent secondary; distal course, reticulating/ramifying; frequency, usually one per intercostal area.

**Figure 17**. Leaf samples of *A. corniculatum.*

**Dichotomous key of 17 mangrove species**

1. Leaf arrangement opposite ........................................ 2
    2. Decussate ........................................ 3
        3. Apex angle obtuse ........................................ *Sonneratia alba*
        3. Apex angle acute ........................................ 4
            4. Surface texture rugose ........................................ *Bruguiera cylindrica*
            4. Surface texture smooth ........................................ 5
                5. Terminal apex feature retuse ........................................ *Bruguiera gymnorrhiza*
                5. Terminal apex feature mucronate ........................................ 6
                    6. Minor 2° course craspedodromous ........................................ *Bruguiera sexangula*
                    6. Minor 2° course simple brochidodromous ........................................ 7
                        7. Base with no curvature (straight) ........................................ *Rhizophora apiculata*
                        7. Base with curvature ........................................ 8
                            8. Base shape convex ........................................ *Rhizophora mucronata*
                            8. Base shape concave ........................................ *Rhizophora stylosa*
    2. Distichous ........................................ 9
        9. Leaf organization simple ........................................ 10
            10. Perimarginal vein intramarginal 2° absent ........................................ *Avicennia marina*
            10. Perimarginal vein intramarginal 2° present ........................................ 11
                11. Major 2° spacing irregular ........................................ *Avicennia alba*
                11. Major 2° spacing regular ........................................ *Ceriops decandra*
        9. Leaf organization once pinnately compound (even) ........................................ 12
            12. Base asymmetrical ........................................ *Xylocarpus granatum*
            12. Base symmetrical ........................................ *Xylocarpus moluccensis*
1. Leaf arrangement alternate (helical) ........................................ 13
    13. Laminar shape elliptic ........................................ 14
        14. Distal course parallel to major 2° ........................................ *Excoecaria agallocha*
        14. Distal course reticulating/ramifying ........................................ 15
            15. Blade class notophyll to mesophyll ........................................ *Camptostemon philippinensis*
            15. Blade class microphyll ........................................ *Lumnitzera racemosa*
    13. Laminar shape obovate ........................................ 16
        16. Major 2° attachment excurrent ........................................ *Lumnitzera littorea*
        16. Major 2° attachment decurrent ........................................ *Aegiceras corniculatum*

**Table 1.** Leaf Architectural Character States of Seventeen Mangrove Species: Laminar Characters.

| | Leaf attachment | Leaf arrangement | Leaf organization | Leaflet arrangement | Leaflet attachment | Position of lamina attachment | Laminar size (mm²) | Blade class | Laminar L:W ratio | Laminar shape |
|---|---|---|---|---|---|---|---|---|---|---|
| *Bruguiera gymnorrhiza* | Petiolate | Opposite (decussate) | Simple | N/A | N/A | Marginal | 2,277–3,290 | Notophyll | 2.6:1–3.1:1 | Elliptic |
| *Bruguiera cylindrica* | Petiolate | Opposite (decussate) | Simple | N/A | N/A | Marginal | 3,996–5,133 | Notophyll–Mesophyll | 2.0:1–2.4:1 | Elliptic |
| *Bruguiera sexangula* | Petiolate | Opposite (decussate) | Simple | N/A | N/A | Marginal | 2,295–5,720 | Notophyll–Mesophyll | 2.5:1–3.5:1 | Elliptic |
| *Rhizophora mucronata* | Petiolate | Opposite (decussate) | Simple | N/A | N/A | Marginal | 4,017–10,732 | Notophyll–Mesophyll | 1.8:1–2:1 | Elliptic |
| *Rhizophora stylosa* | Petiolate | Opposite (decussate) | Simple | N/A | N/A | Marginal | 2,457–5,535 | Notophyll–Mesophyll | 2.1:1–2.4:1 | Elliptic |
| *Rhizophora apiculata* | Petiolate | Opposite (decussate) | Simple | N/A | N/A | Marginal | 6,063–7,245 | Mesophyll | 2.6:1–2.9:1 | Elliptic |
| *Avicennia marina* | Petiolate | Opposite (distichous) | Simple | N/A | N/A | Marginal | 2,370–2,806 | Notophyll | 1.8:1–2.2:1 | Elliptic–Ovate |
| *Avicennia alba* | Petiolate | Opposite (distichous) | Simple | N/A | N/A | Marginal | 1,072–2,053 | Microphyll–Notophyll | 1.6:1–2.1:1 | Elliptic |
| *Xylocarpus granatum* | Petiolate | Opposite (distichous) | Once pinnately compound (even) | Opposite (even- pinnate-ly compound) | Petiolulate | Marginal | 3,308–5,124 | Notophyll–Mesophyll | 1.8:1–2.2:1 | Elliptic |
| *Xylocarpus moluccensis* | Petiolate | Opposite (distichous) | Once pinnately compound (even) | Opposite (even- pinnate-ly compound) | Petiolulate | Marginal | 1,942–2,954 | Microphyll–Notophyll | 2.4:1–2.6:1 | Elliptic |
| *Lumnitzera racemosa* | Petiolate | Alternate (helical) | Simple | N/A | N/A | Marginal | 510–598 | Microphyll | 2.2:1–2.8:1 | Elliptic |
| *Lumnitzera littorea* | Petiolate | Alternate (helical) | Simple | N/A | N/A | Marginal | 492–675 | Microphyll | 2.5:1–3.6:1 | Obovate |
| *Sonneratia alba* | Petiolate | Opposite (decussate) | Simple | N/A | N/A | Marginal | 2,322–5,118 | Notophyll–Mesophyll | 1.0:1–1.7:1 | Obovate |
| *Ceriops decandra* | Petiolate | Opposite (distichous) | Simple | N/A | N/A | Marginal | 1,066–3,780 | Microphyll–Notophyll | 1.6:1–1.7:1 | Elliptic |
| *Excoecaria agallocha* | Petiolate | Alternate (helical) | Simple | N/A | N/A | Marginal | 1,522–2,178 | Microphyll–Notophyll | 2.3:1–2.4:1 | Elliptic |
| *Camptostemon philip-pinensis* | Petiolate | Alternate (helical) | Simple | N/A | N/A | Marginal | 2,236–4,480 | Notophyll–Mesophyll | 1.5:1–1.9:1 | Elliptic |
| *Aegiceras corniculatum* | Petiolate | Alternate (helical) | Simple | N/A | N/A | Marginal | 1,386–4,333 | Microphyll–Notophyll | 1.6:1–1.9:1 | Obovate |

**Table 1.** Leaf Architectural Character States of Seventeen Mangrove Species: Laminar Characters. (continued)

| | Medial symmetry | Base symmetry | Lobation | Margin type | Apex angle | Apex shape | Base angle | Base shape | Terminal apex features | Surface texture |
|---|---|---|---|---|---|---|---|---|---|---|
| *Bruguiera gymnorrhiza* | Symmetrical | Symmetrical | Unlobed (entire) | Untoothed | Acute | Acuminate | Acute | Straight (cuneate) | Retuse | Smooth |
| *Bruguiera cylindrica* | Symmetrical | Symmetrical | Unlobed (entire) | Untoothed | Acute | Straight | Acute | Straight (cuneate) | Mucronate | Rugose |
| *Bruguiera sexangula* | Symmetrical | Symmetrical | Unlobed (entire) | Untoothed | Acute | Acuminate | Acute | Straight (cuneate) | Mucronate | Smooth |
| *Rhizophora mucronata* | Symmetrical | Symmetrical | Unlobed (entire) | Untoothed | Acute | Straight | Obtuse | Convex | Mucronate | Smooth |
| *Rhizophora stylosa* | Symmetrical | Symmetrical | Unlobed (entire) | Untoothed | Acute | Straight | Acute–Obtuse | Concave | Mucronate | Smooth |
| *Rhizophora apiculata* | Symmetrical | Symmetrical | Unlobed (entire) | Untoothed | Acute | Straight | Acute | Straight (cuneate) | Mucronate | Smooth |
| *Avicennia marina* | Symmetrical | Base symmetri-cal–basal width asymmetrical | Unlobed (entire) | Untoothed | Acute | Straight | Acute–Obtuse | Convex | Mucronate | Smooth |
| *Avicennia alba* | Symmetrical | Symmetrical | Unlobed (entire) | Untoothed | Obtuse | Convex | Acute | Straight (cuneate) | Mucronate | Smooth |
| *Xylocarpus granatum* | Symmetrical | Asymmetrical | Unlobed (entire) | Untoothed | Acute | Rounded | Acute–Obtuse | Convex | Retuse | Smooth |
| *Xylocarpus moluccensis* | Symmetrical | Symmetrical | Unlobed (entire) | Untoothed | Acute | Acuminate on the left and straight on the right | Acute | Concave | Mucronate | Smooth |
| *Lumnitzera racemosa* | Symmetrical | Symmetrical | Unlobed (entire) | Untoothed | Acute | Emarginate | Acute | Decurrent | Mucronate | Smooth |
| *Lumnitzera littorea* | Symmetrical | Symmetrical | Unlobed (entire) | Untoothed | Obtuse | Emarginate | Acute | Straight (cuneate) | Retuse | Smooth |
| *Sonneratia alba* | Symmetrical | Symmetrical | Unlobed (entire) | Untoothed | Obtuse | Rounded | Acute–Obtuse | Concave | Mucronate | Smooth |
| *Ceriops decandra* | Symmetrical | Symmetrical | Unlobed (entire) | Untoothed | Obtuse | Rounded | Acute | Concave | Retuse | Smooth |
| *Excoecaria agallocha* | Symmetrical | Symmetrical | Unlobed (entire) | Untoothed | Acute | Acuminate | Obtuse | Convex | Mucronate | Smooth |
| *Camptostemon philippinensis* | Symmetrical | Symmetrical | Unlobed (entire) | Untoothed | Acute–Ob-tuse | Convex–Rounded | Obtuse | Convex | Retuse | Smooth |
| *Aegiceras corniculatum* | Symmetrical | Symmetrical | Unlobed (entire) | Untoothed | Obtuse | Emarginate | Acute | Decurrent | Retuse | Smooth |

**Table 2.** Leaf Architectural Character States of Seventeen Mangrove Species: Venation Patterns.

| Characters | 1° vein framework | Naked basal veins | Number of basal veins | Agrophic veins | 2° major vein framework | Interior secondaries | Minor 2° course | Perimarginal veins |
|---|---|---|---|---|---|---|---|---|
| *Bruguiera gymnorrhiza* | Pinnate | Absent | 1 | Absent | Simple brochidodromous | Present | Simple brochidodromous | Intramarginal secondary |
| *Bruguiera cylindrica* | Pinnate | Absent | 1 | Absent | Simple brochidodromous | Present | Simple brochidodromous | Intramarginal secondary |
| *Bruguiera sexangula* | Pinnate | Absent | 1 | Absent | Simple brochidodromous | Present | Craspedodromous | Intramarginal secondary |
| *Rhizophora mucronata* | Pinnate | Absent | 1 | Absent | Simple brochidodromous | Present | Simple brochidodromous | Intramarginal secondary |
| *Rhizophora stylosa* | Pinnate | Absent | 1 | Absent | Simple brochidodromous | Present | Simple brochidodromous | Intramarginal secondary |
| *Rhizophora apiculata* | Pinnate | Absent | 1 | Absent | Simple brochidodromous | Present | Simple brochidodromous | Intramarginal secondary |
| *Avicennia marina* | Pinnate | Absent | 1 | Absent | Festooned brochidodromous | Present | Simple brochidodromous | N/A |
| *Avicennia alba* | Pinnate | Absent | 1 | Absent | Eucamptodromous | Present | Simple brochidodromous | Intramarginal secondary |
| *Xylocarpus granatum* | Pinnate | Absent | 1 | Absent | Simple brochidodromous | Present | Simple brochidodromous | Intramarginal secondary |
| *Xylocarpus moluccensis* | Pinnate | Absent | 1 | Absent | Festooned brochidodromous | Present | Simple brochidodromous –Semicraspedodromous | Intramarginal secondary |
| *Lumnitzera racemosa* | Pinnate | Absent | 1 | Absent | Craspedodromous | Present | Simple brochidodromous | Intramarginal secondary |
| *Lumnitzera littorea* | Pinnate | Absent | 1 | Absent | Eucamptodromous | Present | Semicraspedodromous | Intramarginal secondary |
| *Sonneratia alba* | Pinnate | Absent | 1 | Absent | Simple brochidodromous | Present | Simple brochidodromous | Intramarginal secondary |
| *Ceriops decandra* | Pinnate | Absent | 1 | Absent | Simple brochidodromous | Present | Simple brochidodromous | Intramarginal secondary |
| *Excoecaria agallocha* | Pinnate | Absent | 1 | Absent | Eucamptodromous | Present | Simple brochidodromous | Intramarginal secondary |
| *Camptostemon philippinensis* | Pinnate | Absent | 1 | Absent | Festooned brochidodromous | Present | Simple brochidodromous | Intramarginal secondary |
| *Aegiceras corniculatum* | Pinnate | Absent | 1 | Absent | Eucamptodromous | Present | Simple brochidodromous | Marginal–Intramarginal secondary |

**Table 2.** Leaf Architectural Character States of Seventeen Mangrove Species: Venation Patterns. (continued)

| | **Major 2° spacing** | **Variation of major 2° angle** | **Major 2° attachment** | **Inter-2° proximal course** | **Inter-2° length** | **Inter-2° distal course** | **Inter-2° frequency** |
|---|---|---|---|---|---|---|---|
| *Bruguiera gymnorrhiza* | Decreasing proximally | Uniform | Excurrent | Parallel to major secondary | More than 50% of subjacent secondary | Parallel to major secondary | More than one per intercostal area |
| *Bruguiera cylindrica* | Irregular | Uniform | Deflected | Perpendicular to midvein | Less than 50% of subjacent secondary | Parallel to major secondary | More than one per intercostal area |
| *Bruguiera sexangula* | Irregular | Inconsistent | Excurrent | Parallel to major secondary | More than 50% of subjacent secondary | Reticulating or ramifying | More than one per intercostal area |
| *Rhizophora mucronata* | Regular | Uniform | Excurrent | Parallel to major secondary | More than 50% of subjacent secondary | Parallel to major secondary | More than one per intercostal area |
| *Rhizophora stylosa* | Regular | Uniform | Excurrent | Parallel to major secondary | More than 50% of subjacent secondary | Parallel to major secondary | More than one per intercostal area |
| *Rhizophora apiculata* | Regular | Uniform | Excurrent | Parallel to major secondary | More than 50% of subjacent secondary | Parallel to major secondary | More than one per intercostal area |
| *Avicennia marina* | Irregular | Smoothly decreasing proximally | Proximal secondaries decurrent | Perpendicular to midvein | More than 50% of subjacent secondary | Reticulating or ramifying | More than one per intercostal area |
| *Avicennia alba* | Irregular | Inconsistent | Deflected | Parallel to major secondary | Less than 50% of subjacent secondary | Basiflexed but not joining the subjacent 2° at right angles | Usually one per intercostal area |
| *Xylocarpus granatum* | Irregular | Smoothly decreasing proximally | Excurrent | Parallel to major secondary | Less than 50% of subjacent secondary | Reticulating or ramifying | Usually one per intercostal area |
| *Xylocarpus moluccensis* | Irregular | Uniform | Excurrent | Parallel to major secondary | Less than 50% of subjacent secondary | Reticulating or ramifying | More than one per intercostal area |
| *Lumnitzera racemosa* | Regular | Smoothly decreasing proximally | Excurrent | Perpendicular to midvein | Less than 50% of subjacent secondary | Reticulating or ramifying | Usually one per intercostal area |
| *Lumnitzera littorea* | Irregular | Inconsistent | Excurrent | Parallel to major secondary | More than 50% of subjacent secondary | Reticulating or ramifying | Usually one per intercostal area |
| *Sonneratia alba* | Regular | Uniform | Decurrent | Parallel to major secondary | More than 50% of subjacent secondary | Basiflexed but not joining the subjacent 2° at right angles | Usually one per intercostal area |
| *Ceriops decandra* | Regular | Uniform | Decurrent | Parallel to major secondary | Less than–More than 50% of subjacent secondary | Reticulating or ramifying | Less than one per intercostal area |
| *Excoecaria agallocha* | Irregular | Uniform | Excurrent | Perpendicular to midvein | Less than 50% of subjacent secondary | Parallel to major secondary | Usually one per intercostal area |
| *Camptostemon philippinensis* | Irregular | One pair of acute basal secondaries | Decurrent | Parallel to major secondary | Less than 50% of subjacent secondary | Reticulating or ramifying | More than one per intercostal area |
| *Aegiceras corniculatum* | Irregular | Smoothly decreasing proximally | Decurrent | Parallel to major secondary | Less than 50% of subjacent | Reticulating or ramifying | Usually one per intercostal area |

## CONCLUSION

The paper demonstrated the use and importance of leaf architectural characters in showing the similarities and differences of seventeen mangrove species. Descriptions of the laminar characters and venation patterns up to the secondary vein were given for each species. The findings indicated that several characters were common among the seventeen species, and other characters, namely base symmetry, apex shape, surface texture, 2° major vein framework, minor 2° course, perimarginal vein, major 2° attachment, major 2° spacing, variation of major 2° angle, and inter-2° frequency, are useful in delineating mangroves.

Leaf characters, especially a combination of laminar and venation characters, can be used in combining or separating numerous species. In this study, laminar characters are sufficient in distinguishing mangrove species from different genera. However, mangroves of the same genus share more similarities than differences in their lamina and veins, as in the case of *Bruguiera* and *Rhizophora* spp. Hence, it is recommended to perform examinations of the higher-order venation of the leaves to provide additional taxonomic markers for closely related taxa.

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