

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

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* (Paguntalan and Buot, 2013; Salvaña and Buot, 2014; Torrefiel and Buot, 2017; Tan and Buot, 2018; 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 (Appendices A–B), 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 subadjacent secondary.

Some of the laminar characteristics of mangrove species examined in this study conform with previous studies. *Bruguiera gymnorhiza* (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 (Ngernsaengsarua *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, 2021), 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 mm²; 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 mm²; 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 mm²; 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 mm²; 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 mm²; 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 mm²; 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 mm²; 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 mm², 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 mm²; 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;



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*

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, 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 mm²; 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 mm²; 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 mm²; 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 mm²; 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 mm²; 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 mm²; 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 mm²; 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 mm²; 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

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Appendix A

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

Characters	Leaf attachment	Leaf arrangement	Leaf organization	Leaflet arrangement	Leaflet attachment	Position of lamina attachment	Lamina size (mm ²)	Blade class	Laminae L:W ratio	Laminae shape
<i>Bruguiera gymnorhiza</i>	Petiolate	Opposite (decussate)	Simple	N/A	N/A	Marginal	2,277 – 3,290	Notophyll	2.6:1 – 3.1:1	Elliptic
<i>Bruguiera cylindrica</i>	Petiolate	Opposite (decussate)	Simple	N/A	N/A	Marginal	3,996 – 5,133	Notophyll – Mesophyll	2:1 – 2.4:1	Elliptic
<i>Bruguiera sexangula</i>	Petiolate	Opposite (decussate)	Simple	N/A	N/A	Marginal	2,295 – 5,720	Notophyll – Mesophyll	2.5:1 – 3.5:1	Elliptic
<i>Rhizophora mucronata</i>	Petiolate	Opposite (decussate)	Simple	N/A	N/A	Marginal	4,017 – 10,732	Notophyll – Mesophyll	1.8:1 – 2:1	Elliptic
<i>Rhizophora stylosa</i>	Petiolate	Opposite (decussate)	Simple	N/A	N/A	Marginal	2,457 – 5,535	Notophyll – Mesophyll	2.05:1 – 2.40:1	Elliptic
<i>Rhizophora apiculata</i>	Petiolate	Opposite (decussate)	Simple	N/A	N/A	Marginal	6,063 – 7,245	Mesophyll	2.6:1 – 2.9:1	Elliptic
<i>Avicennia marina</i>	Petiolate	Opposite (distichous)	Simple	N/A	N/A	Marginal	2,370 – 2,806	Notophyll	1.84:1 – 2.2:1	Elliptic – Ovate
<i>Avicennia alba</i>	Petiolate	Opposite (distichous)	Simple	N/A	N/A	Marginal	1,072 – 2,053	Microphyll – Notophyll	1.62:1 – 2.14:1	Elliptic
<i>Xylocarpus granatum</i>	Petiolate	Opposite (distichous)	Once pinnately compound (even)	Opposite (even- pinnately compound)	Petiolate	Marginal	3,307.5 – 5,124	Notophyll – Mesophyll	1.83:1 – 2.18:1	Elliptic
<i>Xylocarpus moluccensis</i>	Petiolate	Opposite (distichous)	Once pinnately compound (even)	Opposite (even- pinnately compound)	Petiolate	Marginal	1,942 – 2,954	Microphyll – Notophyll	2.35:1 – 2.6:1	Elliptic
<i>Lumnitzera racemosa</i>	Petiolate	Alternate (helical)	Simple	N/A	N/A	Marginal	510 – 598.5	Microphyll	2.2:1 – 2.8:1	Elliptic
<i>Lumnitzera littorea</i>	Petiolate	Alternate (helical)	Simple	N/A	N/A	Marginal	492 – 675	Microphyll	2.5:1 – 3.6:1	Obovate
<i>Sonneratia alba</i>	Petiolate	Opposite (decussate)	Simple	N/A	N/A	Marginal	2,322 – 5,118.75	Notophyll – Mesophyll	1.04:1 – 1.67:1	Obovate

Appendix A

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

Characters	Leaf attachment	Leaf arrangement	Leaf organization	Leaflet arrangement	Leaflet attachment	Position of lamina attachment	Laminar size (mm ²)	Blade class	Laminar L:W ratio	Laminar shape
<i>Ceriops decandra</i>	Petiolate	Opposite (distichous)	Simple	N/A	N/A	Marginal	1,065.75 – 3,780	Microphyll – Notophyll	1.56:1 – 1.73:1	Elliptic
<i>Excoecaria agallocha</i>	Petiolate	Alternate (helical)	Simple	N/A	N/A	Marginal	1,522 – 2,178	Microphyll – Notophyll	2.3:1 – 2.4:1	Elliptic
<i>Campostemon philippinensis</i>	Petiolate	Alternate (helical)	Simple	N/A	N/A	Marginal	2,236.5 – 4,480.5	Notophyll – Mesophyll	1.5:1 – 1.9:1	Elliptic
<i>Aegiceras corniculatum</i>	Petiolate	Alternate (helical)	Simple	N/A	N/A	Marginal	1,386 – 4,333	Microphyll – Notophyll	1.6:1 – 1.9:1	Obovate

Table 1. (continued)

Characters	Medial symmetry	Base symmetry	Lobation	Margin type	Apex angle	Apex shape	Base angle	Base shape	Terminal apex features	Surface texture
<i>Bruguiera gymnorhiza</i>	Symmetrical	Symmetrical	Unlobed (entire)	Untoothed	Acute	Acuminate	Acute	Straight (cuneate)	Retuse	Smooth
<i>Bruguiera cylindrica</i>	Symmetrical	Symmetrical	Unlobed (entire)	Untoothed	Acute	Straight	Acute	Straight (cuneate)	Mucronate	Rugose
<i>Bruguiera sexangula</i>	Symmetrical	Symmetrical	Unlobed (entire)	Untoothed	Acute	Acuminate	Acute	Straight (cuneate)	Mucronate	Smooth
<i>Rhizophora mucronata</i>	Symmetrical	Symmetrical	Unlobed (entire)	Untoothed	Acute	Straight	Obtuse	Convex	Mucronate	Smooth
<i>Rhizophora stylosa</i>	Symmetrical	Symmetrical	Unlobed (entire)	Untoothed	Acute	Straight	Acute – Obtuse	Concave	Mucronate	Smooth
<i>Rhizophora apiculata</i>	Symmetrical	Symmetrical	Unlobed (entire)	Untoothed	Acute	Straight	Acute	Straight (cuneate)	Mucronate	Smooth
<i>Avicennia marina</i>	Symmetrical	Base symmetrical – basal width asymmetrical	Unlobed (entire)	Untoothed	Acute	Straight	Acute – Obtuse	Convex	Mucronate	Smooth

Characters	Medial symmetry	Base symmetry	Lobation	Margin type	Apex angle	Apex shape	Base angle	Base shape	Terminal apex features	Surface texture
<i>Avicennia alba</i>	Symmetrical	Symmetrical	Unlobed (entire)	Untoothed	Obtuse	Convex	Acute	Straight (cuneate)	Mucronate	Smooth
<i>Xylocarpus granatum</i>	Symmetrical	Asymmetrical	Unlobed (entire)	Untoothed	Acute	Rounded	Acute – Obtuse	Convex	Retuse	Smooth
<i>Xylocarpus moluccensis</i>	Symmetrical	Symmetrical	Unlobed (entire)	Untoothed	Acute	Acuminate on the left and straight on the right	Acute	Concave	Mucronate	Smooth
<i>Lumnitzera racemosa</i>	Symmetrical	Symmetrical	Unlobed (entire)	Untoothed	Acute	Emarginate	Acute	Decurrent	Mucronate	Smooth
<i>Lumnitzera littorea</i>	Symmetrical	Symmetrical	Unlobed (entire)	Untoothed	Obtuse	Emarginate	Acute	Straight (cuneate)	Retuse	Smooth
<i>Sonneratia alba</i>	Symmetrical	Symmetrical	Unlobed (entire)	Untoothed	Obtuse	Rounded	Acute – Obtuse	Concave	Mucronate	Smooth
<i>Ceriops decandra</i>	Symmetrical	Symmetrical	Unlobed (entire)	Untoothed	Obtuse	Rounded	Acute	Concave	Retuse	Smooth
<i>Excoecaria agallocha</i>	Symmetrical	Symmetrical	Unlobed (entire)	Untoothed	Acute	Acuminate	Obtuse	Convex	Mucronate	Smooth
<i>Campostemon philippinensis</i>	Symmetrical	Symmetrical	Unlobed (entire)	Untoothed	Acute – Obtuse	Convex – Rounded	Obtuse	Convex	Retuse	Smooth
<i>Aegiceras corniculatum</i>	Symmetrical	Symmetrical	Unlobed (entire)	Untoothed	Obtuse	Emarginate	Acute	Decurrent	Retuse	Smooth

Appendix B
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
<i>Bruguiera gymnorhiza</i>	Pinnate	Absent	1	Absent	Simple brochidodromous	Present	Simple brochidodromous	Intramarginal secondary
<i>Bruguiera cylindrica</i>	Pinnate	Absent	1	Absent	Simple brochidodromous	Present	Simple brochidodromous	Intramarginal secondary
<i>Bruguiera sexangula</i>	Pinnate	Absent	1	Absent	Simple brochidodromous	Present	Craspedodromous	Intramarginal secondary
<i>Rhizophora mucronata</i>	Pinnate	Absent	1	Absent	Simple brochidodromous	Present	Simple brochidodromous	Intramarginal secondary
<i>Rhizophora stylosa</i>	Pinnate	Absent	1	Absent	Simple brochidodromous	Present	Simple brochidodromous	Intramarginal secondary
<i>Rhizophora apiculata</i>	Pinnate	Absent	1	Absent	Simple brochidodromous	Present	Simple brochidodromous	Intramarginal secondary
<i>Avicennia marina</i>	Pinnate	Absent	1	Absent	Festooned brochidodromous	Present	Simple brochidodromous	N/A
<i>Avicennia alba</i>	Pinnate	Absent	1	Absent	Eucamptodromous	Present	Simple brochidodromous	Intramarginal secondary
<i>Xylocarpus granatum</i>	Pinnate	Absent	1	Absent	Simple brochidodromous	Present	Simple brochidodromous	Intramarginal secondary
<i>Xylocarpus moluccensis</i>	Pinnate	Absent	1	Absent	Festooned brochidodromous	Present	Simple brochidodromous – Semicraspedodromous	Intramarginal secondary
<i>Lumnitzera racemosa</i>	Pinnate	Absent	1	Absent	Craspedodromous	Present	Simple brochidodromous	Intramarginal secondary
<i>Lumnitzera littorea</i>	Pinnate	Absent	1	Absent	Eucamptodromous	Present	Semicraspedodromous	Intramarginal secondary
<i>Sonneratia alba</i>	Pinnate	Absent	1	Absent	Simple brochidodromous	Present	Simple brochidodromous	Intramarginal secondary
<i>Ceriops decandra</i>	Pinnate	Absent	1	Absent	Simple brochidodromous	Present	Simple brochidodromous	Intramarginal secondary

Appendix B

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

Characters	1° vein framework	Naked basal veins	Number of basal veins	Agrophic veins	2° major vein framework	Interior secondaries	Minor 2° course	Perimarginal veins
<i>Excoecaria agallocha</i>	Pinnate	Absent	1	Absent	Eucamptodromous	Present	Simple brochidodromous	Intramarginal secondary
<i>Camptostemon philippinensis</i>	Pinnate	Absent	1	Absent	Festooned brochidodromous	Present	Simple brochidodromous	Intramarginal secondary
<i>Aegiceras corniculatum</i>	Pinnate	Absent	1	Absent	Eucamptodromous	Present	Simple brochidodromous	Marginal – Intramarginal secondary

Table 2. (continued)

Characters	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
<i>Bruguiera gymnorhiza</i>	Decreasing proximally	Uniform	Excurrent	Parallel to major secondary	More than 50% of secondary	Parallel to major secondary	More than one per intercostal area
<i>Bruguiera cylindrica</i>	Irregular	Uniform	Deflected	Perpendicular to midvein	Less than 50% of secondary	Parallel to major secondary	More than one per intercostal area
<i>Bruguiera sexangula</i>	Irregular	Inconsistent	Excurrent	Parallel to major secondary	More than 50% of secondary	Reticulating or ramifying	More than one per intercostal area
<i>Rhizophora mucronata</i>	Regular	Uniform	Excurrent	Parallel to major secondary	More than 50% of secondary	Parallel to major secondary	More than one per intercostal area
<i>Rhizophora stylosa</i>	Regular	Uniform	Excurrent	Parallel to major secondary	More than 50% of secondary	Parallel to major secondary	More than one per intercostal area
<i>Rhizophora apiculata</i>	Regular	Uniform	Excurrent	Parallel to major secondary	More than 50% of secondary	Parallel to major secondary	More than one per intercostal area
<i>Avicennia marina</i>	Irregular	Smoothly decreasing proximally	Proximal secondaries decurrent	Perpendicular to midvein	More than 50% of secondary	Reticulating or ramifying	More than one per intercostal area
<i>Avicennia alba</i>	Irregular	Inconsistent	Deflected	Parallel to major secondary	Less than 50% of secondary	Basiflexed but not joining the subjacent 2° at right angles	Usually one per intercostal area
<i>Xylocarpus granatum</i>	Irregular	Smoothly decreasing proximally	Excurrent	Parallel to major secondary	Less than 50% of secondary	Reticulating or ramifying	Usually one per intercostal area

Characters	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
<i>Xylocarpus moluccensis</i>	Irregular	Uniform	Excurrent	Parallel to major secondary	Less than 50% of subadjacent secondary	Reticulating or ramifying	More than one per intercostal area
<i>Lumnitzera racemosa</i>	Regular	Smoothly decreasing proximally	Excurrent	Perpendicular to midvein	Less than 50% of subadjacent secondary	Reticulating or ramifying	Usually one per intercostal area
<i>Lumnitzera littorea</i>	Irregular	Inconsistent	Excurrent	Parallel to major secondary	More than 50% of subadjacent secondary	Reticulating or ramifying	Usually one per intercostal area
<i>Sonneratia alba</i>	Regular	Uniform	Decurrent	Parallel to major secondary	More than 50% of subadjacent secondary	Basiflexed but not joining the subadjacent 2° at right angles	Usually one per intercostal area
<i>Ceriops decandra</i>	Regular	Uniform	Decurrent	Parallel to major secondary	Less than – More than 50% of subadjacent secondary	Reticulating or ramifying	Less than one per intercostal area
<i>Excoecaria agallocha</i>	Irregular	Uniform	Excurrent	Perpendicular to midvein	Less than 50% of subadjacent secondary	Parallel to major secondary	Usually one per intercostal area
<i>Camptostemon philippinensis</i>	Irregular	One pair of acute basal secondaries	Decurrent	Parallel to major secondary	Less than 50% of subadjacent secondary	Reticulating or ramifying	More than one per intercostal area
<i>Aegiceras corniculatum</i>	Irregular	Smoothly decreasing proximally	Decurrent	Parallel to major secondary	Less than 50% of subadjacent secondary	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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