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Leaf Architecture of Ten Species of Philippine *Terminalia* Linn. (Combretaceae)

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Abstract

Leaf architectural characters of 10 species of Terminalia (*Combretaceae) were examined. The leaf architectural characters observed in the ten Philippine species of Terminalia were leaf attachment, petiole features, laminar shape, base and apex shape, margin type, blade class of the leaf, 2° and 3° vein category, spacing and angle. A dichotomous key to the 10 species of Terminalia was constructed and distinct description based on the leaf architectural characters for each species was done. Based on the result of this study the leaf architectural characters are of great help in plant taxonomy and systematics, most especially in dealing with sterile plant specimens.*

Keywords: Leaf architecture, Philippine *Terminalia*, blade characters, vein categories.

Introduction

Leaf architecture was first used and described by Hickey to represent the placement and form of those elements constituting the outward expression of leaf structure, including venation pattern, marginal configuration, leaf shape and gland position[1]. Tree to tree variations in wood properties within a species are large and it may be reflected through the variation in anatomical and physical properties[2] suggesting taxonomic value of leaf architecture and foliar anatomy of some families and genera of angiosperms[3] in-vitro micropropagation[4] and even the surface anatomy for animals[5] and other organisms like fungi[6]. The leaf architecture in the case of the family Combretaceae has been poorly studied as a source of taxonomic characters. Thus this study defines its taxonomic usefulness in genus *Terminalia* based only on its leaf architectural characters. *Terminalia* species are also used for food and medicine just like other plants in traditional communities[7-12].

In the past years, numerous workers have successfully used these characters in classifying both extinct and extant plant materials of multifaceted taxonomic groups[13-18]. The study of leaf architecture in the Philippines is not yet given much attention. Only few existing studies about this plant systematic method were known[19-22]. Celadiña and his colleagues[22] had worked on the characteristic of leaf architecture of selected Philippine *Cinnamomum* species based on its marginal ultimate venation comprising two major groups: fimbrial marginal ultimate vein group and looped marginal ultimate vein group. The study of Banaticla and Buot, Jr.[19] on the leaf architecture of ten Philippine species of *Psychotria* was based on marginal ultimate venation, angle of loop-forming branches joining super adjacent secondary veins, areolation, apex shape, leaf texture and the appearance of tertiary and quaternary veins. And the study of Laraño and Buot, Jr.[21] proved that leaf architectural characters such as margin, primary, secondary and tertiary vein patterns indicate taxonomic utility of leaf architecture in addressing taxonomic controversies of the family Malvaceae.

This paper discusses the question whether leaf architectural features are useful for differentiating some species of the genus *Terminalia*. A dichotomous key to the species of *Terminalia* used in this study solely based on leaf architectural characters is presented.

Material and Methods

Plant leaves of 10 different species of *Terminalia* were collected from various locations at the campus of the University of the Philippines at Los Baños (UPLB) Laguna, Philippines. Leaf specimens were then pressed and dried at the UPLB College of Forestry and Natural Resources (CFNR). One species of the genus *Terminalia* (*T. surigaensis*) was collected from Surigao del Sur and five leaves were retrieved from the herbarium collections of Mr. Dennis E. Pulan, a Laboratory Technician II at the Department of Forest Biological Sciences, CFNR.

The leaves of 10 selected *Terminalia* species were officially identified by Mr. Dennis Pulan. The leaf architectural characters of each species were described based on the terminologies of Leaf Architecture Working Group[23]. The characters described were leaf attachment, leaf organization, petiole features, laminar size, blade class, laminar shape and symmetry, laminar ratio, base and apex angle, base and apex shape, position of petiolar attachment, margin type, lobation and vein orders. The leaf vein orders were also examined. The laminar size was made through

measuring the leaves' length and width (in mm), and divided by 2/3 using the ruler. The result of the laminar size gives the idea of what type of blade class the leaves were. The base and apex angles were measured using a protractor.

A dichotomous key to the ten species of *Terminalia* (table 3) was then constructed and the descriptions were based uniquely on leaf architecture characters.

Results and Discussion

The leaf architectural characters of *Terminalia:* Examination of the leaf characters on the ten species of *Terminalia*, tables 1 and 2 showed that leaf architecture characters are indeed good taxonomic markers in plant identification. The most important characters in the study that separate each species with each other were leaf attachment, petiole features, laminar shape, base and apex shape, margin type, blade class of the leaf, 2° and 3° vein category, spacing and angle. Tables 1 and 2 illustrate uniqueness of these leaf architecture characters in the 10 species examined. The study conforms with results of Banaticla and Buot[19], Obico *et al*.[20], Laraño and Buot[21], Celadiña *et al*.[22] and many other. Leaf architectural characters can be very good taxonomic marker especially during off-flowering times. This will even be more useful in species flowering only once in every three or more years, indeed Stace[17] is right in elaborating the taxonomic importance of the leaf surface.

Table- 1
Leaf architecture characters of the ten Philippine species of *Terminalia* (blade characters)

***Terminalia* species**	**Leaf attachment**	**Petiole features**	**Blade class**	**Laminar shape**	**Laminar L:W Ratio**	**Base shape**	**Apex shape**	**Margin type**
T. calamansanai	spiral	pulvinate	mesophyll	obovate	2:1	cuneate	convex	erose
T. catappa	spiral	pulvinate	macrophyll	obovate	2:1	cuneate	convex	erose
T. citrina	opposite	base swollen	notophyll	obovate	7.3:1	cuneate	acuminate	erose
T. chebula	opposite	base swollen	mesophyll	oblong	7.3:1	cuneate	acuminate	entire
T. foetidissima	spiral	pulvinate	mesophylll	obovate	4.3:1	cuneate	acuminate	entire
T. microcarpa	spiral	base swollen	notophyll	obovate	2.4:1	cuneate	acuminate	entire
T. nitens	spiral	pulvinate	mesophyll	obovate	3.1:1	cuneate	acuminate	entire
T. pellucida	spiral	pulvinate	mesophyll	oblong	3:1	cuneate	acuminate	entire
T. polyantha	spiral	base swollen	microphyll	elliptic	10.5:1	convex	convex	entire
T. surigaensis	spiral	pulvinate	mesophyll	oblong	4.2:1	cuneate	convex	entire

Table- 2
Leaf architecture characters of the ten Philippine species of *Terminalia* (vein categories)

***Terminalia* species**	**1° Vein category**	**2° Vein category**	**2° Vein spacing**	**2° Vein angle**	**Inter-2° Veins**	**3° Vein course**	**3° Vein angle to 1°**	**3° Vein angle variability**	**4° Vein category**	**5° Vein category**	**Areolation**
T. calamansanai	pinnate	weak brochidodromous	irregular	smoothly decreasing toward base	strong intersecondaries	admedially ramified	perpendicular	inconsistent	regular polygonal reticulate	regular polygonal reticulate	well developed
T. catappa	pinnate	weak brochidodromous	irregular	smoothly decreasing toward base	weak intersecondaries	admedially ramified	perpendicular	inconsistent	regular polygonal reticulate	regular polygonal reticulate	well developed
T. citrina	pinnate	weak brochidodromous	increasing toward base	smoothly decreasing toward base	strong intersecondaries	admedially ramified	obtuse	decreasing exmedially	regular polygonal reticulate	regular polygonal reticulate	well developed
T. chebula	pinnate	weak brochidodromous	irregular	smoothly decreasing toward base	weak intersecondaries	sinuous	obtuse	decreasing exmedially	regular polygonal reticulate	regular polygonal reticulate	well developed
T. foetidissima	pinnate	brochidodromous	icreasing toward base	smoothly decreasing toward base	strong intersecondaries	sinuous	obtuse	decreasing exmedially	regular polygonal reticulate	regular polygonal reticulate	well developed
T. microcarpa	pinnate	weak brochidodromous	decreasing toward base	uniform	strong intersecondaries	straight	perpendicular	inconsistent	regular polygonal reticulate	dichotomizing	moderately developed
T. nitens	pinnate	weak brochidodromous	decreasing toward base	smoothly decreasing toward base	weak intersecondaries	sinuous	obtuse	increasing basally	alternate percurrent	dichotomizing	moderately developed
T. pellucida	pinnate	weak brochidodromous	irregular	smoothly decreasing toward base	strong intersecondaries	sinuous	obtuse	increasing basally	regular polygonal reticulate	regular polygonal reticulate	well developed
T. polyantha	pinnate	weak brochidodromous	irregular	one pair acute basal secondaries	strong intersecondaries	sinuous	obtuse	increasing basally	regular polygonal reticulate	regular polygonal reticulate	well developed
T. surigaensis	pinnate	weak brochidodromous	increasing toward base	abruptly increasing toward base	strong intersecondaries	admedially ramified	perpendicular	increasing basally	regular polygonal reticulate	regular polygonal reticulate	well developed

Table- 3
Key to the ten Philippine *Terminalia* species based on leaf architecture characters

1 Leaf simple and opposite in attachment ……..…… 2
2 Margin type erose; 2° veins weak brochidodromous, increasing towards base; strong inter-2°s and admedially ramified 3° veins forming an obtuse angle to 1°
……..……..… *Terminalia citrina*
2' Margin type entire; 2° veins weak brochidodromous, irregular; weak inter-2°s and sinuous 3° veins forming an obtuse angle to 1°…….… *Terminalia chebula*
1' Leaf simple and spiral in attachment ……..…….……..... 3
3 Petioles pulvinate attached in a marginal position ……..…….. 4
4 Lamina obovate and cuneate base shape …… 5
5 Apex convex ……..…..… 6
6 1° pinnate, 2° irregular, weak brochidodromous; inter-2° veins strong; areolation well developed …… *T. calamansanai*
6' 1° pinnate, 2° irregular, weak brochidodromous; inter-2° veins weak; areolation well developed ……..……..*T. catappa*
5' Apex acuminate ……. 7
7 2° veins brochidodromous, increasing towards the base; sinuous 3°s decreasing exmedially……..…… *T. foetidissima*
7' 2° veins weak brochidodromous, decreasing towards the base; sinuous 3°s increasing basally……..……..… *T. niten*
4' Lamina oblong and cuneate base shape ……...…….…… 8
8 Primary vein pinnate, 2° irregular weak brochidodromous forming angle in smoothly decreasing towards base; 3° sinuous forming an obtuse angle to 1°……...… *T. pellucida*
8' Primary vein pinnate, 2° increasing towards base forming angle in abruptly increasing towards base; 3° admedially ramified forming a perpendicular angle to 1°……..... *T. surigaensis*
3' Petioles have base swollen attached in a marginal position ……..… 9
9 Margin entire; base cuneate; apex acuminate; decreasing towards base 2° vein spacing with uniform angle; 3° straight, inconsistent in perpendicular angle
……..……...……. *T. microcarpa*
9' Margin entire; base and apex convex; irregular 2° vein spacing with one pair basal 2° angle; 3° sinuous, increasing basally in obtuse angle
…….....……...…. *T. polyantha*

General characteristics of *Terminalia* Linn.: The *Terminalia* examined in this study exhibit unifying features as follows: leaf attachment spiral or opposite; leaf organization simple; petiole features, pulvinate or base swollen; laminar shape, obovate, oblong, or elliptic; laminar symmetry, symmetrical; angles of divergence, acute or obtuse; base shape, cuneate, rounded or convex; position of petiolar attachment, marginal; apex shape, convex or acuminate, margin type, entire or erose; lobation, unlobed. In terms of the vein orders: 1° vein category, pinnate; 2° vein category, weak brochidodromous or brochidodromous; 2° vein spacing, irregular, increasing toward, or decreasing toward; 2° vein angle smoothly decreasing, uniform, one pair acute basal secondaries or abruptly increasing toward base; inter-2° veins, strong or weak; 3° vein course, admedially ramified, sinuous, or straight; 3° vein angle, perpendicular or obtuse; regular polygonal reticulate or alternate percurrent 4° vein category; regular polygonal reticulate or dichotomizing 5° vein category; areolation, well developed or moderately developed.

Leaf architectural characteristics of the ten selected species of *Terminalia* in the Philippines *Terminalia citrina* (Gaertn.) Roxb. *ex* Flem. (figure 1a): **Blade:** Leaf simple, opposite with base swollen petioles, shape of the lamina, obovate or oblong with cuneate or rounded base and acuminate apex, symmetrical, 33-154 mm long and 18-58 mm wide, 7.3:1 ratio, notophyll, erose and unlobed.

Venation: Pinnate 1° vein, 2°s weak brochidodromous; angle of divergence, smoothly decreasing towards base and increasing towards base; inter-2°s strong; 3° admedially ramified; angle with respect to 1° vein, obtuse, decreasing exmedially; regular polygonal reticulate 4° and 5°; well-developed areolation.
Exsicc.: *JBBaroga 6498* (PBDH)

***Terminalia chebula* Retz.** (figure 1b): **Blade:** Leaf simple, opposite with base swollen petioles, shape of the lamina, oblong with cuneate base and acuminate apex, symmetrical, 44-172 mm

long and 25-65 mm wide, 7.3:1 ratio, mesophyll, entire and unlobed.

Venation: Pinnate 1° vein, 2°s weak brochidodromous; angle of divergence, smoothly decreasing towards base and irregular; inter-2°s weak; 3° sinuous; angle with respect to 1° vein, obtuse, decreasing exmedially; regular polygonal reticulate 4° and 5°; well-developed areolation.
Exsicc.: *JBBaroga 6499* (PBDH)

***Terminalia calamansanai* (Blco.) Rolfe** (figure 2a): **Blade:** Leaf simple, spiral with pulvinate petioles, shape of the lamina, obovate with cuneate base and convex apex, symmetrical, 63-166 mm long and 32-82 mm wide, 2:1 ratio, mesophyll, erose and unlobed.

Venation: Pinnate 1° vein, 2°s weak brochidodromous; angle of divergence, smoothly decreasing towards base and irregular; inter-2°s strong; 3° admedially ramified; angle with respect to 1° vein, perpendicular, inconsistent; regular polygonal reticulate 4° and 5°; well-developed areolation.
Exsicc.: *JBBaroga 6496* (PBDH)

***Terminalia catappa* L.** (figure 2b): **Blade:** Leaf simple, spiral with pulvinate petioles, shape of the lamina, obovate with cuneate base and convex apex, symmetrical, 54-300 mm long and 28-158 mm wide, 2:1 ratio, macrophyll, erose and unlobed.

Venation: Pinnate 1° vein, 2°s weak brochidodromous; angle of divergence, smoothly decreasing towards base and irregular; inter-2°s weak; 3° admedially ramified; angle with respect to 1° vein, perpendicular, inconsistent; regular polygonal reticulate 4° and 5°; well-developed areolation.
Exsicc.: *JBBaroga 6497* (PBDH).

Figure- 1
Leaves of (a) *T. citrina* and (b) *T. chebula*

***Terminalia foetidissima* Griff.** (figure 2c): **Blade:** Leaf simple, spiral with pulvinate petioles, shape of the lamina, obovate with cuneate base and acuminate apex, symmetrical, 112--300 mm long and 39-93 mm wide, 4.3:1 ratio, mesophyll, entire and unlobed.

Venation: Pinnate 1° vein, 2°s brochidodromous; angle of divergence, smoothly decreasing towards base and increasing towards base; inter-2°s strong; 3° sinuous; angle with respect to 1° vein, obtuse, decreasing exmedially; regular polygonal reticulate 4° and 5°; well-developed areolation.
Exsicc.: *JBBaroga 6500* (PBDH)

***Terminalia nitens* Presl.** (figure 2d): **Blade:** Leaf simple, spiral with base swollen petioles, shape of the lamina, obovate with cuneate base and acuminate apex, symmetrical, 95-184 mm long and 38-70 mm wide, 3.1:1 ratio, mesophyll, entire and unlobed.

Venation: Pinnate 1° vein, 2°s weak brochidodromous; angle of divergence, smoothly decreasing towards base and decreasing towards base; inter-2°s weak; 3° sinuous; angle with respect to 1° vein, obtuse, increasing basally; alternate percurrent 4° and dichotomizing 5°; moderately developed areolation.
Exsicc.: *JBBaroga 6502* (PBDH)

***Terminalia pellucida* Presl.** (figure 3a): **Blade:** Leaf simple, spiral with pulvinate petioles, shape of the lamina, oblong with cuneate base and acuminate apex, symmetrical, 99-252 mm long and 39-85 mm wide, 3:1 ratio, mesophyll, entire and unlobed.

Venation: Pinnate 1° vein, 2°s weak brochidodromous; angle of divergence, smoothly decreasing towards base and irregular; inter-2°s strong; 3° sinuous; angle with respect to 1° vein, obtuse, increasing basally; regular polygonal reticulate 4° and 5°; well-developed areolation.
Exsicc.: *JBBaroga 6503* (PBDH)

***Terminalia surigaensis* Merr.** (figure 3b): **Blade:** Leaf simple, spiral with pulvinate petioles, shape of the lamina, oblong with cuneate base and convex apex, symmetrical, 187-226 mm long and 53-58 mm wide, 4.2:1 ratio, mesophyll, entire and unlobed.

Venation: Pinnate 1° vein, 2°s weak brochidodromous; angle of divergence, abruptly increasing towards base and increasing towards base; inter-2°s strong; 3° admedially ramified; angle with respect to 1° vein, perpendicular, increasing basally; regular polygonal reticulate 4° and 5°; well-developed areolation.
Exsicc.: *DEPulan 6505* (PBDH).

***Terminalia microcarpa* Decne** (figure 4a): **Blade:** Leaf simple, spiral with base swollen petioles, shape of the lamina, obovate with cuneate base and acuminate apex, symmetrical, 34-118 mm long and 19-53 mm wide, 2.4:1 ratio, notophyll, entire and unlobed.

Venation: Pinnate 1° vein, 2°s weak brochidodromous; angle of divergence, uniform and decreasing towards base; inter-2°s strong; 3° straight; angle with respect to 1° vein, perpendicular, inconsistent; regular polygonal reticulate 4° and dichotomizing 5°; moderately developed areolation.
Exsicc.: *JBBaroga 6501* (PBDH)

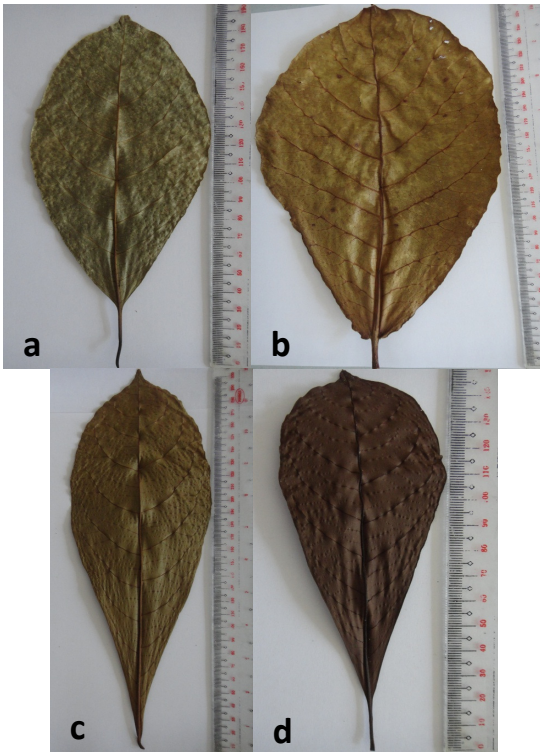

Figure- 2
Leaves of (a) *T. calamansanai*, (b) *T. catappa*, (c) *T. foetidissima* and (d) *T. nitens*

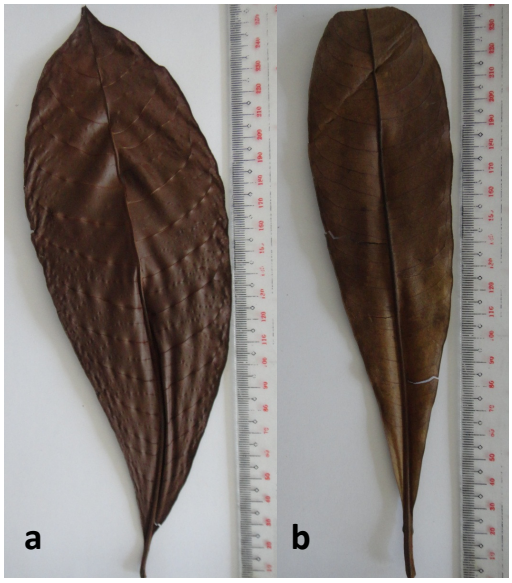

Figure- 3
Leaves of (a) *T. pellucida* and (b)*T. surigaensis*

***Terminalia polyantha* Presl.** (figure 4b) **Blade:** Leaf simple, spiral with base swollen petioles, shape of the lamina, elliptic with convex base and apex, symmetrical, 29-59 mm long and 11-24 mm wide, 10.5:1 ratio, microphyll, entire and unlobed.

Venation: Pinnate 1° vein, 2°s weak brochidodromous; angle of divergence, with one pair acute basal secondaries and irregular; inter-2°s strong; 3° sinuous; angle with respect to 1° vein, obtuse, increasing basally; regular polygonal reticulate 4° and 5°; well-developed areolation.
Exsicc.: *JBBaroga 6504* (PBDH)

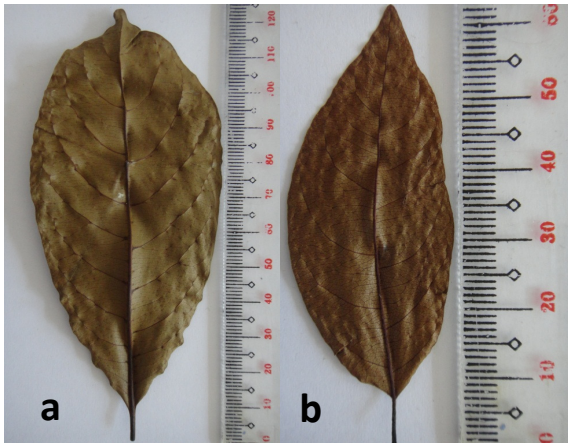

Figure- 4
Leaves of (a) *T. microcarpa* and (b) *T. polyantha*

Conclusion

A total of ten species of *Terminalia L.* under the Combretaceae family were collected and preserved, observed, measured and characterized based on leaf architecture characters. A key table of the ten species of *Terminalia* was constructed and a distinct description of each species based on leaf architecture was done. The results proved that leaf architecture characters are good taxonomic markers in plant identification and classification. The leaf attachment, petiole features, laminar shape, base and apex shape, margin type, blade class of the leaf are important diagnostic characteristics in the study. The 2° and 3° vein category, spacing and angle are the most useful characters in separating the ten species from each other. Therefore, leaf architecture characters could be of great help in plant taxonomy and systematics, most especially in dealing with sterile plant specimens.

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