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Leaf architecture of mindanao cinnamon (*Cinnamomum mindanaense* Elm.) in Cebu Island, Philippines

Roi O. Engkong¹, Rhona Mae G. Manco¹, Mico D. Rosatace¹, Glynis Anne C. Vega¹, Jay P. Picardal^{*1,2}, Esperanza Maribel G. Agoo³

¹Biology Department, College of Arts and Sciences, Cebu Normal University, Cebu City, Philippines

²Research Institute of Tropical Biology and Pharmacological Biotechnology, Cebu Normal University, Cebu City, Philippines

³Plant Taxonomy Research Lab, Biology Department, College of Science, De La Salle University, Manila, Philippines

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Abstract

The use of leaf architecture in defining plant species has been recognized as an important tool in cinnamon taxonomy. However, available literature on the use of leaf architecture for Philippine cinnamon focused only on describing interspecies variability while intraspecies variation of economically-important Philippine cinnamon species is still unreported to date. This study assessed leaf morphological data, developed a general template of the leaves of *C. mindanaense* based on observable foliar characters and identified intraspecific similarities and differences of *C. mindanaense* leaves based on leaf architecture. We utilized 22 leaf morphological characters to examine *C. mindanaense* leaves (30 mature trees) obtained from (a) Nug-as, Alcoy, (b) Cansuje, Argao and (c) San Antonio, Boljoon, Cebu. Leaf architecture comparison was evaluated through quantitative comparison while pattern similarity was analyzed by Image J analysis software. Principal Component Analysis and Cluster Analysis were utilized to identify characters useful for identification and analyze extent of resemblance among morphometric data. Results show that the continuous characters (e.g. leaf length and width) of old vs young leaves were more variable compared to the discrete characters, namely: primary, secondary, tertiary, quaternary and pentary vein categories, areole shape, areole development, veinlets, blade margin, presence of petiole, venation pattern and midrib structures. The study concluded that these discrete characters may define, morphologically, *C. mindanaense* as a species.

*Corresponding Author: Jay P. Picardal ✉ picardalj@cnu.edu.ph

Introduction

Cinnamomum mindanaense (Cebuano local name, *mana*) was first described by Elmer (1910) as a small, aromatic tree reaching up to 10 meters in height and ~ 3 dm. thick, possessing a dense, elongated crown. Its wood possesses moderate hardness, leaf phyllotaxy is either opposite or sub-opposite, inflorescence ascending, and produce ovate spheroid fruits. *C. mindanaense* is suited to live in varying elevations (200-400 meters above sea level) and is widely distributed in the provinces of Davao del Sur (Lach and Van Kley, 1998), Zamboanga and Surigao (Dischoso and Arcilla, 1992), Lanao del Norte, Bohol and Samar and recently, found to be naturally grown in the limestone forests of the municipality of Boljoon, Argao and Alcoy in the province of Cebu (Picardal, 2017). Among the recognized endemic Philippine cinnamon species, *C. mindanaense* has recently gained attention as a subject of taxonomic study because of prevailing difficulty in its field identification due to phenotypic plasticity in its leaf characters (Huang, 1984; Chang, 1995; Lorea-Hernandez, 1996; Celadiña *et al.*, 2012).

Among the commonly-occurring form of phenotypic plasticity in *C. mindanaense*, the most observable type is the incidence of heterophylly, a condition in which different leaf shapes are present in the same plant (Kostermans, 1986; Wells and Pigliucci, 2000). In fact, the first published account of the species' heterophylly was that of Santos (1930), describing the four (4) leaf shape variants of this species, namely: oblong, oblong-ovate, ovate and lanceolate. Another leaf character of interest to cinnamon taxonomist is the disparity of venation patterns, especially those primary veins arising from the petiole where the variants include either a trinerved or triplinerved patterns. *C. mindanaense* closely resembles other endemic Philippine species such as *C. mercadoi* and *C. nanophyllum* (Picardal, 2017), and are indistinguishable to Indonesian cinnamon (*C. burmannii*) in terms of leaf shape, apex and margin (Elmer, 1910; Kostermans, 1986). Identification of these species is also frequently interchanged, especially in the absence of reproductive characters

from fruits and flowers. In other plant species, variations in leaf morphology at the intraspecific level was observed by Pyakurel and Wang (2013) on paper Birch leaves as well as by Capuzzo *et al.*, (2012) on the two species of *Tabebuia*. Heterophylly was also observed in the leaves of *Quercus petraea* due to branch position (Bruschi *et al.*, 2003).

Attempts to resolve this phenotypic plasticity in the genus *Cinnamomum* were initiated by Santos (1930) comparing leaf shapes and margins, and most recently, Celadiña *et al.*, (2002) who utilized leaf architecture. In both studies, comparison was only done at the interspecies level and investigation of any form of variations at the intraspecific level has not been explored, so far. Minimal efforts have been conducted to further examine the potential variants of *C. mindanaense* (if there is any) and as of this writing, published work on this topic is scant, or inexistent to the researchers' knowledge.

Aside from the continuous threat to overharvesting, untimely coppicing and microbial diseases, the challenges posed by climate change is markedly defined by the unavoidable drying of young shoots due to dry weather. In Cebu, the three known localities where *C. mindanaense* thrive are characteristically different in terms of soil parameters and elevation, and these factors may have direct influence in the phenotypic plasticity as well as varying organoleptic properties (e.g. woody smell variation) of cinnamon growing in the different areas (Stuessy, 2009). The observed phenotypic plasticity in cinnamon based on its morphological characters and organoleptic properties demands utmost attention and must be addressed because such forms of plasticity becomes problematic when cinnamon leaves are already used in herbal medicine, and in the future, for drug development and clinical trials. Thus, it is imperative that intraspecific variation based on leaf architecture should be properly investigated (Hickey, 1973; Premoli, 2008; Laraño and Buot, 2010; Baroga and Buot, 2014) to potentially identify variants or cultivars that could be properly propagated and conserved.

This study aimed to assess leaf morphological data, developed a general template of the leaves of *C. mindanaense* based on observable foliar characters and identified intraspecific similarities and differences of *C. mindanaense* leaves based on leaf architecture.

Materials and methods

Prior informed consent

In accordance with the provisions of EO 247 (Bio prospecting) and RA 9147 (Wildlife Resources Conservation and Protection Act), a letter and preliminary site visit were secured as prior informed consent from the community where the *C. mindanaense* trees are found. The researchers utilized a Wildlife Gratuitous Permit issued by the Department of Environment and Natural Resources–7 (DENR-7) with permit number 2015-07 to collect leaf samples of *C. mindanaense* found in the province of Cebu.

Research environment

The leaves of *C. mindanaense* were collected from the three locations, namely: Cansuje, Argao, Cebu (N 9° 55' 6.47", E 123° 29' 53.71"); Nug-as, Alcoy, Cebu (N 9° 42' 0.50", E 123° 25' 46.70") and San Antonio, Boljoon, Cebu (N 9° 41' 09.50", E 123° 24' 58.00"). These localities were pre-selected based on the known occurrence of *C. mindanaense* which are either naturally-grown or cultivated from the wild. Leaf clearing, staining and imaging procedures were conducted at the Biology Laboratory of Cebu Normal University, Osmeña Boulevard, Cebu City.

Leaf sampling protocol

Ten mature *C. mindanaense* trees were selected from each study site. At least 100 mature leaves with no sign of herbivory or pathogen damage were collected from each tree by cutting the leaf at the base of the petiole. The collected leaves were stored in a plastic zipper bag (Zip-Lock™) containing 5g silica gel as desiccant (Cornlissen *et al.*, 2003). Species identity of the collected cinnamon species was confirmed by the Plant Taxonomy Research Lab of Cebu Normal University and respective voucher specimens were

kept at the CNU Biology Herbarium. The final leaf samples (n=30/site) used in the study were randomly selected using MS XLStat 2016 software.

Data collection protocol

Leaf apex and base angles were measured by an Orion™ protractor. Vernier caliper was used to measure the length and width of the leaves and petioles. Morphological characters (e.g. leaf shape, apex type, base type) that do not need measurements were evaluated after Harris and Harris (2000). A hand lens with 10x magnification was used to observe the vein categories, areolation and veinlets.

The leaves were cleared following the methods of Buechler (2010) and Vasco *et al.*, (2014) with slight modifications, as follows. Briefly, the collected leaves were soaked in a 5% NaOH solution and heated in the oven (30°C) until the leaves were translucent. The translucent leaves were washed with distilled water and soaked for 10 minutes to remove the NaOH. After clearing, the leaves were bleached with 5.25% NaOCl solution for 20 min., soaked in distilled water for 10 minutes and were stained with methylene blue for 3–5 hours until the desired color was achieved. The leaves were then destained using 95% ethanol, air-dried (Correa *et al.*, 2003) and were photographed individually using the camera function of Apple™ iPhone 6 (8mp; f2.2). Imaging procedure was performed on a white cardboard on top of a lightbox (200 cm³; 11 watts LED light), where each leaf was placed prior to photodocumentation.

Except for the leaf shape which is highly variable in *C. mindanaense*, all leaf architecture characters were initially measured and evaluated following the works of Hickey (1973) and Manual of Leaf Architecture (1999) for the definitions of morphological characters and character states (Table 1).

For the leaf shape, the researchers created a modified protocol for measurement and evaluation of the character states. The leaf is divided into four equal parts or region where apex, upper middle, lower middle and basal regions of the lamina were

illustrated (Fig. 1). The basal region is where the three primary lateral veins (i.e. triveined) originates from the petiole. The lower middle region is the area where no clear or defined secondary veins is visible. The upper middle region is the area where secondary veins arise from the middle primary, lateral veins (i.e. also known as midrib in cinnamon leaves) and this is also the region where the lateral veins ends evanescently to the leaf margin. The apical region is where the leaf apex length varies, particularly in terms of length and shape. Here, the width of the 4 parts was measured with a caliper and was used as the basis for the evaluation of leaf shape and other character states (Fig. 2).

Data analysis

Raw data were encoded in MS Excel spreadsheet, with first column listing the arbitrary code of the samples (e.g. CT₁S₁, NT₂S₂, ST₃S₂) where **C** codes for samples collected from Cansuje, Argao, **N** codes for samples collected from Nug-as, Alcoy, **S** codes for samples collected from San Antonio, Boljoon. **T**, followed by **S** codes for trees and leaf sample number

in each sampling sites, respectively. Second column to the third column were allocated for the sampling site and tree codes, respectively; and the fourth to 25th column was assigned for the morphological characters and corresponding character states of leaf samples examined. In order to observe similar and disparate leaf morphological characters of *C. mindanaense* from the three sampling sites, groupings and clustering patterns of these morphological characters were analyzed using Principal Component Analysis (PCA) and Cluster Analysis (CA) of XLStat 2016 for Windows.

Results and discussion

General morphological characteristics

A total of 270 leaves were collected from three different sampling sites. Twenty-two (22) leaf morphological characters were selected based on the study of Hickey (1973) and Manual of Leaf Architecture (1999) and were used to assess the morphological intraspecies variation of *C. mindanaense* in Cebu.

Table 1. Morphological characters of *C. mindanaense* leaves used for morphometric analysis. Morphological characters are represented by both continuous characters and discrete units, with corresponding units of measurements and codes, respectively.

Leaf parts	Morphological characters	Unit of measurements (for continuous characters) and codes for morphometric analysis (for discrete characters)
petiole	length	mm
	width	mm
leaf	length	mm
	width	mm
	length to width ratio	ratio
	shape	0=elliptic; 1=oblong; 2=lanceolate; 3=ovate; 4=lanceolate-elliptic; 5=lanceolate-oblong
	leaf apex type	0=acute; 1=narrowly acuminate; 2=broadly acuminate
	leaf base type	0=cuneate; 1=oblique; 2=rounded; 3=obtuse
	blade margin	0=entire; 1=undulate
venation	pattern	0=trinerved; 1=triplinerved
	region where the primary lateral veins end evanescently	0=base region; 1=middle region; 2=upper middle region; 3=apex region
	primary lateral vein structure adaxial	0=slightly impressed; 1=flat; 2=slightly raised; 3=strongly raised
	primary lateral vein structure abaxial	0=slightly impressed; 1=flat; 2=slightly raised
	midrib structure	0=flat; 1=raised

	no. of secondary veins	0= 5 and below; 1= 6 to 11; 2= above 11
	branching origin of the primary lateral veins	0=same point of origin; 1=different point of origin
veinlets	branching	0=absent; 1=unbranched; 2=branched; 3=absent and unbranched
vein category	primary (1 ^o)	0=acrodromous basal; 1=acrodromous suprabasal
	secondary (2 ^o)	0=acrodromous basal; 1=acrodromous suprabasal
	tertiary (3 ^o)	0=opposite percurrent; 1=alternate percurrent; 2=mixed (opposite/alternate) percurrent
	quaternary (4 ^o)	0=opposite percurrent; 1=alternate percurrent; 2=regular polygonal reticulate
areolation	pentary (5 ^o)	0=regular polygonal reticulate; 1=dichotomizing
	areole development	0=lacking; 1=poorly developed; 2=moderately developed; 2=well-developed
	areole shape	0= 3 sided; 1= 4 sided; 2= 5 or more

Table 2. Eigen vectors for the continuous characters in the first three principal component analyzed for *C. mindanaense*.

	Principal Component 1	Principal Component 2	Principal Component 3
Eigenvalue	1.758	1.406	1.095
Variability (%)	35.15	28.12	21.89
Cumulative %	35.15	63.27	85.16

Out of 22 characters, ten characters were highly variable among the leaf samples. This variation is probably due to the phenotypic plasticity of these characters (Celadiña *et al.*, 2012). On the other hand, 12 characters are similar throughout the samples. The similarity between the twelve characters, specifically in vein categories is probably less phenotypically plastic, making them generally fixed (Laraño and

Buot, 2010). Results showed that *C. mindanaense* leaves possess petioles with 3-11 mm length and 1-3mm width; 57-147mm of leaf length, 21-66mm leaf width and 1.9-4.3 leaf length to width ratio. The large range of variation in the continuous leaf characters may suggest that these characters are not consistent, and could not be utilized as reliable phenotypic markers.

Table 3. Eigenvectors of the continuous characters in relation to the principal components.

Characters	Principal Component 1	Principal Component 2	Principal Component 3
Length of petiole	0.138	-0.495	0.481
Width of petiole	0.255	-0.323	0.603
Leaf length	0.624	0.452	0.111
Leaf width	0.712	-0.056	-0.300
Leaf length to width ratio	-0.138	0.665	0.550

C. mindanaense has a generally raised midrib abaxially, leaf blade is entire and possessed triplinerved primary veins. The species also possessed veins where the 1^o and 2^o are acrodromous suprabasal, 3^o alternate percurrent, 4^o and 5^o regular polygonal reticulate with well-developed areolation, oftentimes 4-5 side areolation, and unbranched

veinlets. In a previous examination of 2 exsiccatae of *C. mindanaense*, Celadiña *et al.*, (2012) also noted that secondary veins are suprabasal acrodromous, as well as unbranched veinlets. In this study, the leaf shape of *C. mindanaense* manifested at least six (6) character states and this high variability may imply that such character, when used alone, will not ensure

consistency of identification of the species. Meanwhile, the use of primary to pentary veins are considered useful as identification tool for seemingly cryptic species that may exhibit phenotypic plasticity of its foliar characters.

However, taxonomists noted its limitations in terms of its wider applicability because leaf architecture are not directly observable compared to common phenotypic markers such as leaf shape, basal and apical structures (Hickey 1973).

Table 4. Eigenvectors for the discontinuous (discrete) characters in the first three principal component analyzed for *C. mindanaense*.

	Principal Component 1	Principal Component 2	Principal Component 3
Eigenvalue	1.431	1.275	1.070
Variability (%)	17.88	15.94	13.37
Cumulative %	17.88	33.82	47.19

The dark areas of the *C. mindanaense* leaf template (Fig.3e) indicate the presence of the structures across the 270 samples. It can then be inferred that all the samples possessed suprabasal acrodromous primary veins. The dark area under the leaf apex also suggests

the pronounced secondary veins that arise in the upper-middle part of the lamina. On the other hand, the lighter areas of the Fig. 3a-3d suggest that the structures found on that area are varied and less pronounced across the samples.

Table 5. Eigenvectors of the discontinuous (discrete) characters in relation to the principal components.

Characters	PC 1	PC 2	PC 3
Number of Secondary Veins	-0.174	-0.641	-0.082
Leaf Shape	-0.451	0.330	0.174
Leaf Apex Type	-0.479	-0.422	0.122
Leaf Base Type	-0.264	-0.031	-0.353
Region Where the Primary Lateral Veins End Evanescently	0.621	-0.215	-0.083
Leaf Primary Vein Structures Adaxial (Top)	0.011	-0.164	-0.624
Leaf Primary Vein Structures Abaxial (Bottom)	0.233	-0.477	-0.072
Branching Origin of the Primary Lateral Veins	0.162	-0.007	0.650

The general template (Fig.3e) can be ambiguous because of the wide variation of the morphology of the sampled leaves due to leaf phenotypic plasticity, as supported by Lorea-Hernandez (1996) for cinnamon species in Mexico. However, the vein categories of the leaves were generally similar across the sampled leaves.

The cluster analysis, however, showed a total of 16 major classes to the left of the vertical dashed line, or phenon line (index of dissimilarity=2). The smallest index of dissimilarity where the samples form nodes is 1, which is attributed to the dissimilarity of the samples based on the region where the primary lateral veins end evanescently, the other nodes are attributed to the differences of the average value of the samples for the variables. Class 5 (red vertical line) which is comprised of samples ST1S9, CT1S10, CT1S37, CT3S24 and NT2S16 has the largest index of dissimilarity compared to the other classes. Similarly, Fig.5 illustrates this dissimilarity because the samples that comprise class 5 are located farther from the axes.

The UPGMA dendrogram (Fig.4) generated from Agglomerative Hierarchical Clustering based on Euclidean distance of discontinuous characters displays no distinct clustering among the samples; and this observation is similar to the results of the Principal Component Analysis.

The morphological character that is common to these five samples is an elliptic leaf shape. This agrees with the study of Santos (1930) and Picardal (2017) which

account for elliptic shape as the least occurring shape of *C. mindanaense* leaves.

Table 6. Correlation matrix between variables (morphological characters of *C. mindanaense* leaves) and factors (principal components).

Characters	Factors		
	PC 1	PC 2	PC 3
Continuous Characters			
Length of Petiole	0.183	-0.587	0.503
Width of Petiole	0.338	-0.383	0.631
Leaf Length	0.828	0.536	0.116
Leaf Width	0.944	-0.067	-0.314
Leaf length to width ratio	-0.182	0.789	0.575
Discontinuous Characters			
Number of Secondary Veins	-0.208	0.724	-0.085
Leaf Shape	-0.539	-0.373	0.180
Leaf Apex Type	-0.573	-0.476	0.126
Leaf Base Type	-0.316	-0.035	-0.365
Region where the Primary Lateral Veins end evanescently	0.743	-0.242	-0.086
Leaf Primary Vein Structures (Adaxial)	0.013	-0.185	-0.645
Leaf Primary Vein Structures (Abaxial)	0.279	-0.539	-0.075
Branching origin of the Primary Lateral Veins	0.193	-0.008	0.672

The scatter plot (Fig. 5) illustrates no clear separation between the samples based on the continuous morphological characters of the leaves collected on three different sampling sites.

The dispersion of the samples, regardless of the sampling site, is probably due to different variable responses of plants in general, to extremely localized abiotic (e.g. soil humidity, temperature, altitude) and biotic interactions (Hulshof and Swenson, 2010).

The PCA of the continuous characters resulted to a total of five principal components, where the first three components explain more than 85% of the whole variability (Table 2). The first component explained 35.15% of the total variation which showed high eigenvector values for leaf width and leaf length. The second component explained 28.12% of the total variation which showed high eigenvector values for leaf length-width ratio and length of petiole.

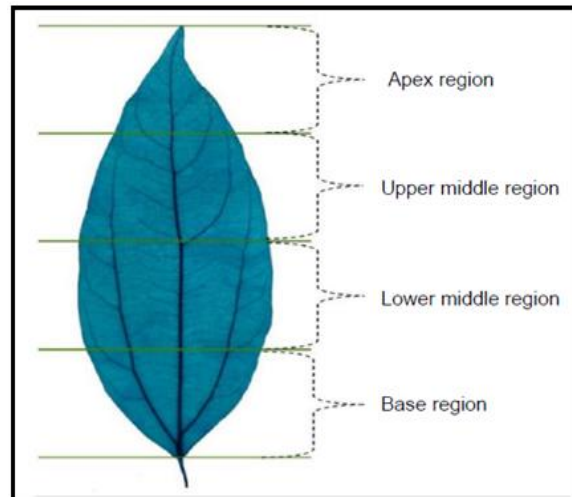


Fig. 1. Four divisions of the *C. mindanaense* leaf as basis for the evaluation of the leaf shape. Each leaf sample is equally divided into four equal parts, each part corresponds to a region shown in the image.

The third component explained 21.89% of the total variation which showed a high eigenvector value for width of petiole (Table 3).

In PCA, Eigenvalues represent the relative contribution of each principal component in presenting the variability of the examined cinnamon leaf samples of the same species, and its numerical value is a direct indicator of the weight of a specific component in the overall variability of a set of data (Kucharczyk *et al.*, 2012; Picardal 2017). Eigenvectors (in bold) are those which possess threshold factor loadings >0.3, and are considered as the most

important characters that could best differentiate the *C. mindanaense* leaf samples from the three collection sites. Table 3 also suggest that although leaf length is the most remarkable character that may show variability in the samples, other supporting characters that must be considered include leaf width, ratio of the leaf length to its width, as well as width of the petiole.

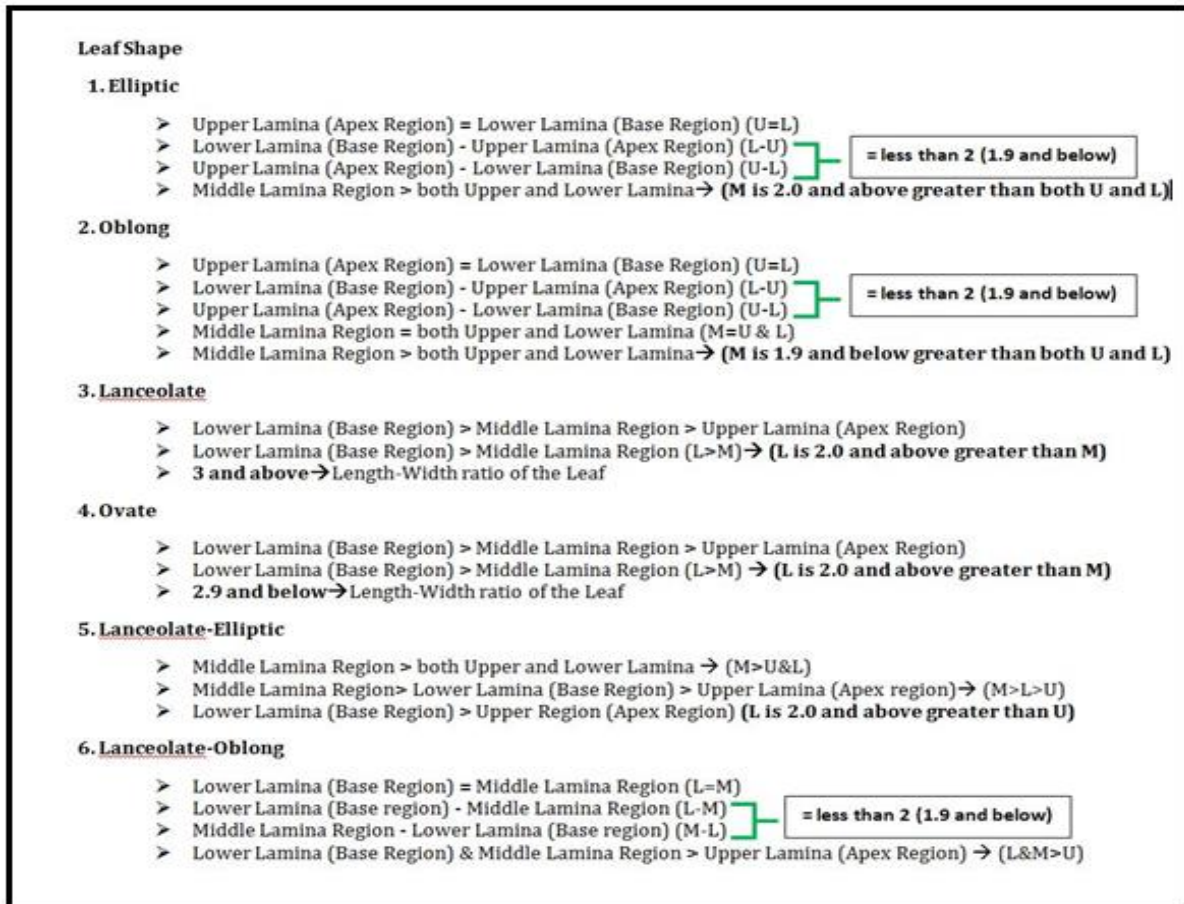


Fig. 2. Basis for evaluating the possible leaf shapes of *C. mindanaense*. At least six (6) major character states for leaf shape are commonly observable in the species and for each leaf shape, corresponding leaf shape rules apply.

The high variability of the continuous characters of the leaves is likely attributed to phenotypic plasticity in other plant genera, as discussed by Kpadehyea and Buot, (2014) and Peppe *et al.*, (2011).

The result of the principal component analysis of the continuous characters implies that the first principal component increases with increasing scores in (1) width of the petiole, (2) leaf length and (3) leaf width.

From these correlated characters, the first principal component could be interpreted as the leaf width (r = 0.944) because of the strong correlation of this character state to the component. Concurrently, the second principal component increases with increasing scores in (1) leaf length and (2) leaf length to width ratio, hence, the second principal component could be interpreted as the leaf length to width ratio (r = 0.789) because of the strong correlation of this character state to the component.

Lastly, the third principal component strongly correlates with the width of the petiole ($r = 0.338$), thus, the third principal component could be interpreted as the width of the petiole. However, it must be noted that the findings may imply that the high variability of the continuous characters of the leaves can be largely attributed to phenotypic plasticity, as discussed by Kpadehaya and Buot (2014) and Peppe *et al.*, (2011).

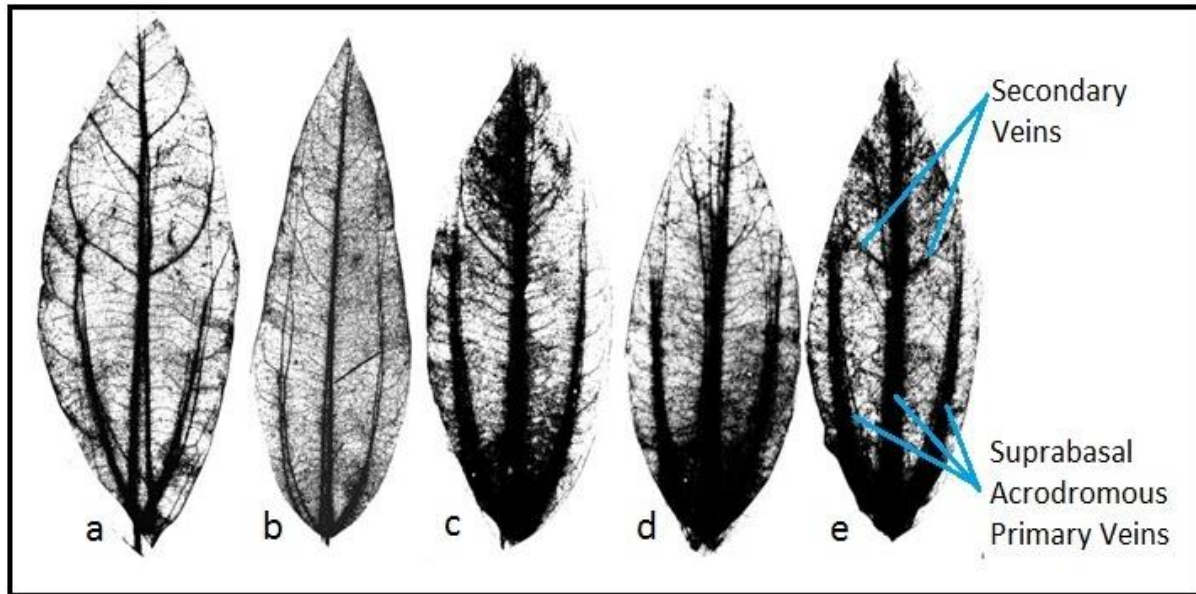


Fig. 3. Leaf amalgamation templates of the four most common character states for leaf shape (3a-3d): (a) elliptic, (b) lanceolate, (c) lanceolate-elliptic, (d) lanceolate-oblong. Fig. 3e represents a highly amalgamated illustration of 270 leaf images superimposed upon each other, showing the remarkable suprabaasal primary veins and secondary veins emerging from the middle primary veins as the defining leaf morphological markers of all *C. mindanaense* species.

The cluster analysis performed also confirms this observation by showing no clear separation among the samples, as manifested by low and undefined morphological variability.

The PCA of the discrete characters, on the other hand, had a total of eight components, with the first three components explaining 47% of the whole variability (Table 4). The first component explained 17.88% of the total variation which showed high eigenvector values for the region where the primary lateral veins end evanescently.

The second component which explained 15.94% of the total variation showed high eigenvector values for the number of secondary veins.

Fig. 6 illustrates no clear separation between individuals based on the discrete morphological characters of the leaves collected from 3 different sampling sites, which suggests that the samples cannot be differentiated clearly based on discontinuous/discrete characteristics alone.

The third component which explained 13.37% of the total variation showed high eigenvector value for the branching origin of the primary lateral veins. Among the discontinuous characters, the most important characters that could best distinguish intraspecific similarity are region where the primary lateral veins end evanescently, leaf shape and branching origin of the primary lateral veins (all with threshold factor loadings ≥ 0.3) (Table 5).

Similarly, the high eigenvector values of the discrete variables indicate the large contribution of the variables to the formation of the components. These findings reveal the relatively smaller variability of the discontinuous characters compared to the continuous characters.

Also, 12 discontinuous character states, which includes: petiole, leaf blade margin, venation pattern, midrib structure, 1⁰-5⁰ vein categories, areolation development, areolation shape and veinlets were similar across all the samples, regardless of sampling site, which is similar to the findings of Pacheco-Trejo *et al.*, (2009) and Roth-Nebelsick *et al.*, (2001).

Furthermore, the findings of this study with regards to the leaf architecture of the *C. mindanaense* species could be used as a taxonomic tool to identify the *C. mindanaense* species as others like Celadina (2012), Baroga and Buot (2014), Lariano and Buot (2010) have attested to the great utility of leaf architecture as a taxonomic tool.

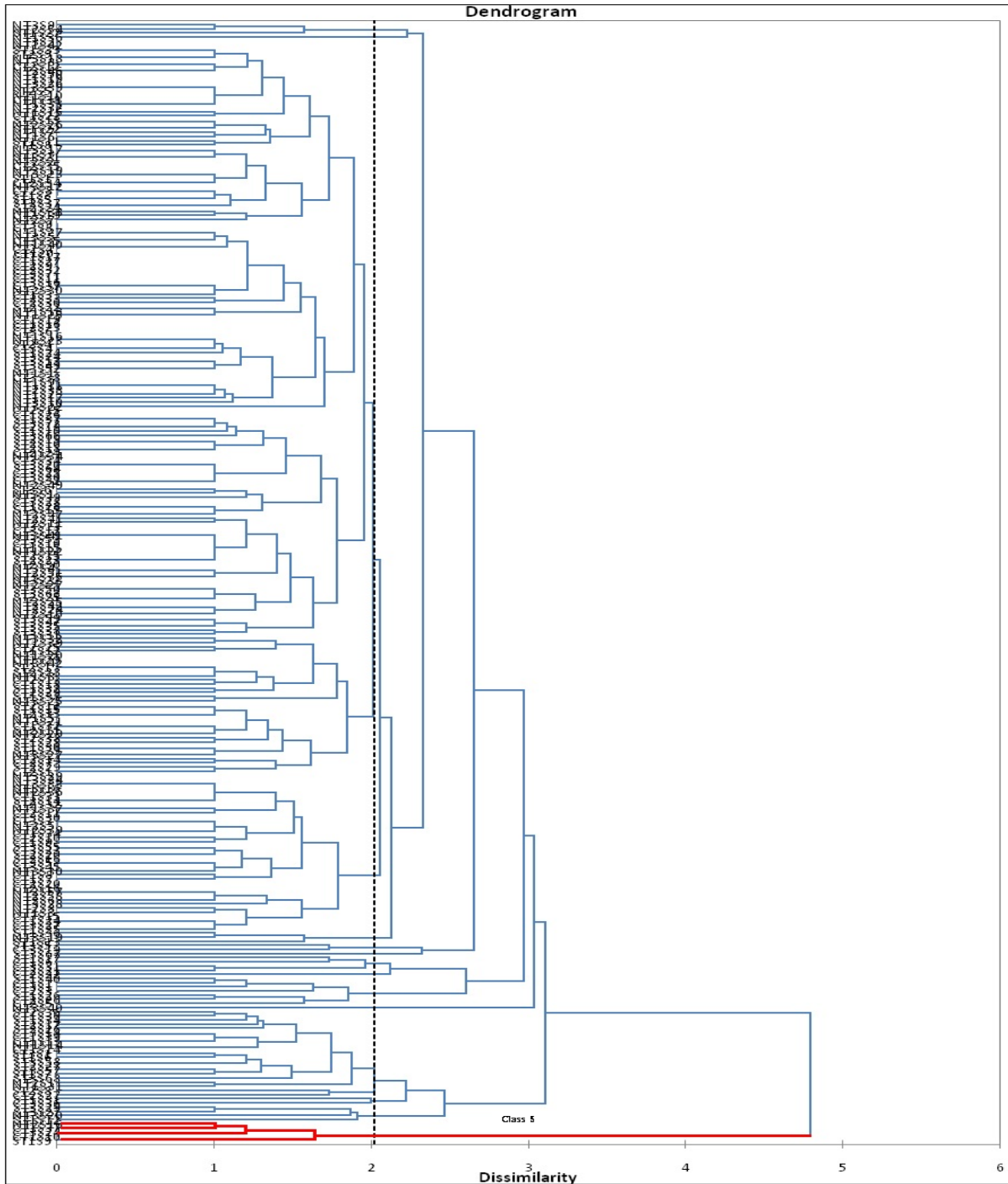


Fig. 4. Dendrogram generated from discontinuous characters shows the non-distinct clustering of *C. mindanaense* leaf samples according to collection sites.

The correlation matrix table of the variables (i.e. the morphological characters of cinnamon leaves: continuous and discontinuous), and its corresponding factors (i.e. the principal components) shows the characters that could be used to recognize the *Cinnamomum mindanaense* (Table 6).

Meanwhile, the result of the principal component analysis of the discrete characters implies that the first component increases with the increasing scores

in (1) region where the primary lateral veins end evanescently and (2) primary vein structure (abaxial).

Thus, the first principal component could be interpreted as the region where the primary lateral veins end evanescently ($r=0.743$) because of the strong correlation of this character state to the component. This paper recorded four (4) regions, namely; (1) base region, (2) middle region, (3) upper-middle region and (4) apex region.

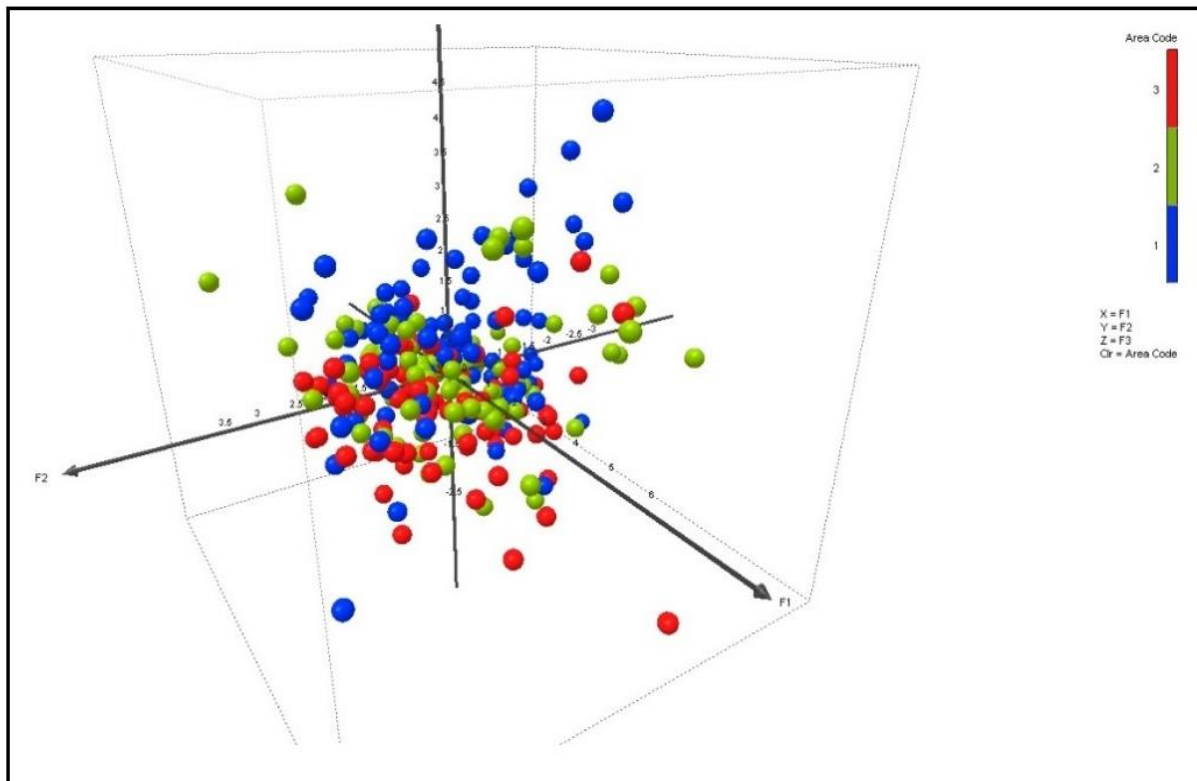


Fig. 5. Three-dimensional scatter plot for the PCA factor scores of continuous characters showing no distinct grouping of samples.

The upper-middle region is observed to be the most common region where the primary veins end evanescently and is shared among 179 leaf samples out of 270 leaf samples from the three (3) localities. Similarly, the second principal component strongly correlates with the number of secondary veins present on the leaves ($r= 0.724$), hence, the second principal component could be interpreted as the number of secondary veins. The character consists of the three (3) character states: (1) 0-5, (2) 6-11 and (3) >11, with (1) 0-5 observed to be the most common, present in 142 out of 270 leaf samples, followed closely by (2) 6-

11 with 121 leaf samples and (3) >11 which stands last, present only at merely 7 leaf samples.

Lastly, the third component correlates strongly with the origin of the primary lateral veins ($r=0.672$) and thus the third component could be interpreted as the origin of the primary lateral veins.

The character has two (2) character states, namely: (1) Same point of origin, observed in 104 out of 270 leaf samples, and (2) Different point of origin, which is more common, observed in 166 out of 270 leaf samples.

The results of the principal component analyses may suggest that none of the characters vary together, and thus each character should be studied individually for identification. However, the results of the principal component analyses could also be seen as a helpful guide when identifying *C. mindanaense* based on the characters revealed by the principal component analyses. As revealed by the principal component analyses, the characters that could possibly identify *C. mindanaense* would be the region where the primary lateral veins end evanescently (upper-middle region), number of secondary veins (0-5 and 6-11), and branching origin of the primary lateral veins.

While these characters could be useful for taxonomists and foresters in the field, it is important to note that these characters are still affected by phenotypic plasticity, such as heterophylly (Wells and Pigliucci 2000). Furthermore, the leaf clearing method employed by the researchers has revealed that the 5 vein categories, areolation shape, areole development and veinlets, along with the presence of petiole, leaf blade margin, venation pattern and midrib structure, are similar across all the samples and are likely more stable characters that could be utilized in identifying *C. mindanaense* as a species, regardless of its provenance and preferred growth conditions.

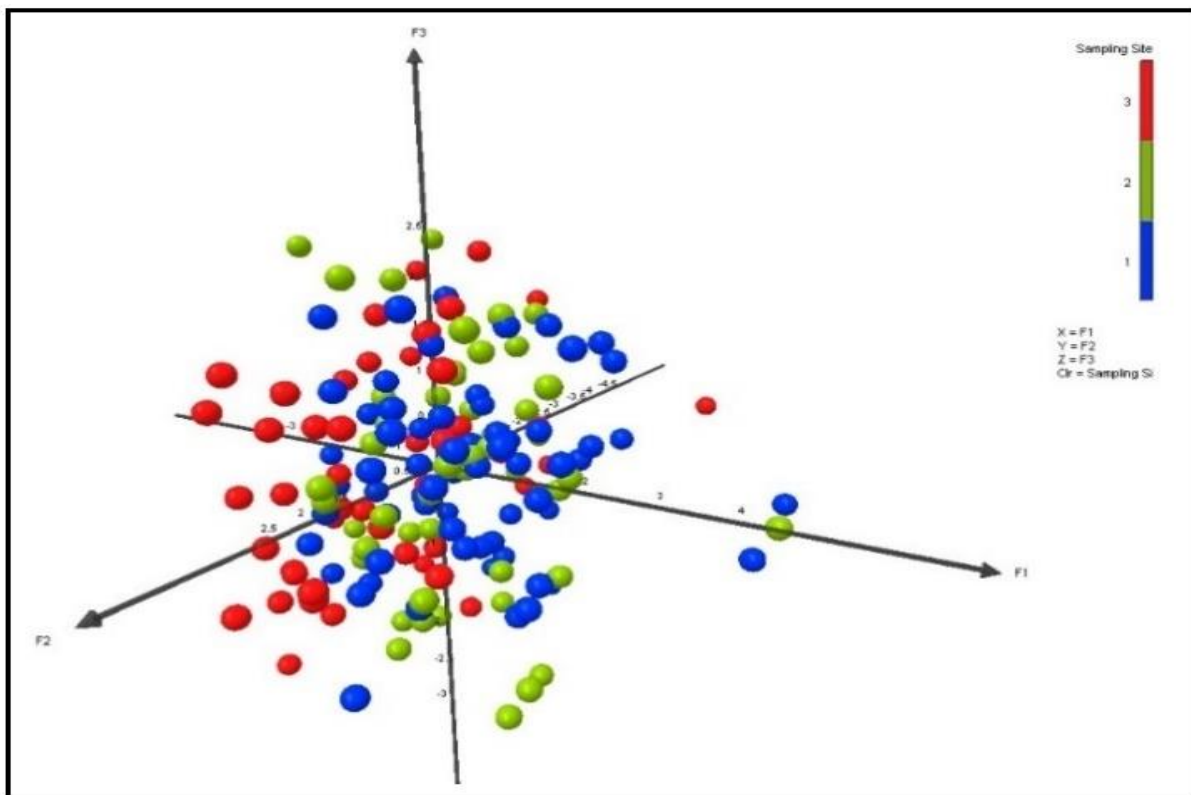


Fig. 6. Three dimensional scatter plot for the PCA factor scores of discontinuous characters showing no distinct grouping of leaf samples.

The findings of this study may suggest that there is no distinct character limited to the leaf samples gathered from one (1) specific locality that could be used to distinguish it from the rest of the leaf samples found in other localities. However, there are characters (e.g. 5 vein categories, areole development and areolation shape) that were present and similar across all the leaf samples, regardless of the sampling site. These characters are significantly useful in identifying

Cinnamomum mindanaense and possibly, in distinguishing this species from other *Cinnamomum* species.

Conclusion

Based on the results, this study found that the continuous characters (e.g. leaf length, leaf width) were more variable compared to the discontinuous characters and this may indicate that the continuous

characters exhibit a higher degree of phenotypic plasticity. Among the discontinuous characters, the 1^o, 2^o, 3^o, 4^o and 5^o vein categories, areole shape, areole development, veinlets, blade margin, presence of petiole, venation pattern and midrib structure were similar across the samples, suggesting that these characters are reliable enough to group seemingly variable leaves to be exhibited by the same *C. mindanaense* species.

Recommendation

Comparison with closely-related species, *C. burmannii*, at the leaf architecture level may provide insights on anatomical similarities and differences with *C. mindanaense*. Mature and fully expanded sun-exposed leaves are the recommended samples in order to lessen the variations in leaves owing to ontogeny or shading. Ecological landscape of each cinnamon tree should also be investigated to determine its effect on the differences manifested in the leaf morphology.

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