COMPARATIVE STUDY OF THE LEAF MORPHOLOGY OF *Epipremnum* SCHOTT AND *Rhaphidophora* HASSK. (ARACEAE) IN THE PHILIPPINES

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ABSTRACT

Leaves of 50 specimens under the genera *Rhaphidophora* and *Epipremnum* were measured and characterized using the Manual of Leaf Architecture. The leaf characters were compared and subjected to phenetic investigation using cluster analysis with the aid of a computer software, PC-ORD (ver 2.11). Generally, the leaves may be categorized into two groups based on lobation. The results of the cluster analyis support the transfer of *R. korthalsii* to the genus *Epipremnum*. Further, the leaf morphology was able to define the interspecific relationship within *Rhaphidophora*. However, in establishing the intergeneric relationship between *Epipremnum* and *Rhaphidophora*, the leaf morphology does not offer conclusive evidence.

Introduction

With the advancement of technology and the growing trend towards multidisciplinary approaches, taxonomy has evolved from the traditional morpho-anatomical methods of study to a more encompassing field as in systematics.

The study of leaf architecture, while seemingly traditional, has progressed, with the development of an accepted system of terms for describing leaf form, combined with utilizing computer-based and other innovative techniques. This approach has been used in part as a tool to resolve taxonomic controversies (Wing et al., 1999).

For instance, while many members of the family Araceae are economically important (Brown, 1941), there remain unresolved issues regarding taxonomic delineations. Particularly in the case of two of its genera, *Epipremnum* and *Rhaphidophora,* there remains uncertainty in their typification (Bakhuizen van der Brink, 1958).

This study compares *Epipremnum* Schott and *Rhaphidophora* Hassk. based on leaf morphological characters to contribute in clearing the controversies regarding their taxonomic delineation. It is in support to a study made recently in the Philippines comparing the two genera based on the anatomy of their stems and leaves (Medecilo, 2000).

MATERIALS AND METHODS

Sources of Plant Specimens

Fifty specimens classified under the genera *Epipremnum* and *Rhaphidophora* collected from the Philippines were studied in the Philippine National Herbarium, the Philippine University Herbarium of the University of the Philippines, and the University of the Philippines Los Baños Museum of Natural History Botanical Herbarium. They were all fixed and dried specimens collected from different parts of the Philippines.

Phenetic Investigation

The following external leaf characters were measured in centimeters using a 12" ruler: (1) leaf length, from base to apex, petiole not included; and (2) leaf width, across the lamina at the widest point in the region between the apex and the base of the leaf. The blade class was then ascertained based on the laminar area parameters described in the Manual of Leaf Architecture (Wing et al., 1999). The length to width ratio was also determined.

Also based on the terminology described in the Manual of Leaf Architecture (Wing et al., 1999), the laminar symmetry, laminar shape, blade margin type and lobation, base angle and base shape, apex angle and apex shape were determined.

Vein angles were measured at three distinct locations where the veins typically change orientation. Using a protractor, the vein angles measured in degrees were: the (1) costal angle, the (2) laminar angle, and the (3) marginal angle (Triplett and Kirchoff, 1991).

The primary vein category, secondary vein category, secondary vein spacing, and secondary vein angle were also ascertained based on the Manual of Leaf Architecture (Wing et al., 1999).

Cluster Analysis

The values for each quantitative character were computed to determine the suitable ranges and categories. Each character state, both qualitative and quantitative, was then assigned a value corresponding to a legend as follows: LLE1-6 for leaf length, LWI1-8 for leaf width, LSZ1-6 for blade class, LWR1-3 for L:W ratio, SYM1-2 for laminar symmetry, LOB1-2 for lobation, SHP1-4 for shape, BAN1-3 for base angle, BSH1-7 for base shape, AAN1-2 for apex angle, ASH1-5 for apex shape, COA1-6 for costal angle, LMA1-6 for laminar angle, MGA1-6 for marginal angle, SVC1-5 for secondary vein category, SVS1-4 for secondary vein spacing, and SVA1-4 for secondary vein angles.

All the data were used to construct a table. A separate table was made with Microsoft Excel using the encoded data and saved in the Lotus .wk1 format.

The Excel file in .wk1 format was entered in the computer program PC-ORD (ver. 2.11) for Cluster Analysis. The distance measure used was Euclidean, and

the group average method was used for the group linkage. The phenogram width was set as narrow, and spacing as double-spaced.

Principal Components Analysis (PCA) and Two-way Indicator Species Analysis (TWINSPAN) were also performed using PC ORD ver 2.11 to assist in interpreting the Cluster Analysis results. For PCA the cross products matrix used was correlation.

Analysis of data was done after the processing of data using PC-ORD (ver. 2.11), as provided by the Philippine National Herbarium.

RESULTS and DISCUSSIONS

All fifty specimens, four *Epipremnum* and forty-six *Rhaphidophora,* have leaves with entire margins and which fall into the pinnate primary vein category. They can be divided into two general groups according to lobation (Figure 1). The larger group consists of those with unlobed lamina: *R. acuminata*, *R. elmeri*, *R. foraminifera*, *R. liukiuensis*, *R. lobbii*, *R. montana*, *R. monticola*, and *R. perkinsiae*. The second group consists of those with pinnately lobed lamina: *R. merrilli*, *R. pinnata*, and *E. pinnatum*. *R. korthalsii* included both lobed and unlobed specimens.

Another character that may be used

1. Blade unlobed
   2. Apex shape acuminate or truncate
      3. Secondary vein angles smoothly decreasing toward base . . . . . *R. korthalsii*
      3. Secondary vein angles smoothly increasing toward base
         4. Base angle acute
            5. Blade shape oblong . . . . . *R. lobbii*
            5. Blade shape ovate . . . . . *R. elmeri*
         4. Base angle obtuse
            5. Base shape rounded
               6. Leaf shape ovate . . . . . *R. elmeri*
               6. Leaf shape elliptic . . . . . *R. monticola*
            5. Base shape convex
               6. Secondary vein spacing decreasing toward base . . . . . *R. liukiuensis*
               6. Secondary vein spacing uniform
                  7. Laminar angles greater than or equal to 45º . . . . . *R. perkinsiae*
                  7. Laminar angles less than or equal to 45º . . . . . *R. monticola*
   2. Apex shape convex
                  8. Apex angle obtuse . . . . . *R. monticola*
                  8. Apex angle acute

9. Secondary vein category eucamptodromous . . . . . *R. korthalsii*
9. Secondary vein category weak brochidodromous
10. Leaf symmetrical, blade shape ovate, base angle obtuse, base shape concavo-convex, secondary vein spacing uniform, secondary vein angles smoothly increasing toward base . . . . . *R. foraminifera*
10. Whole lamina asymmetrical, blade shape elliptic, base angle acute, base shape convex, secondary vein spacing decreasing toward base, secondary vein angles uniform . . . . . *R. montana*

1. Blade lobed
11. Apex shape acuminate and secondary vein category reticulodromous . . . . . *R. merilli*
11. Apex shape truncate and secondary vein category weak brochidodromous
12. Marginal angles less than 20º . . . . . *R. korthalsii*
12. Marginal angles greater than or equal to 20º
13. Base angle acute . . . . . *R. pinnata*
13. Base angle obtuse . . . . . *E. pinnatum*

Figure 1. An indented dichotomous key to the identification of Philippine *Rhaphidophora* and *Epipremnum* using leaf characteristics

Another character that may be used to divide the group into two is apex angle, but its taxonomic importance is less apparent than that of lobation when the species that fall into the two groups are compared. The character showing the most variety is base shape, having 7 character states.

The comparison of the leaf morphology of the *Epipremnum* and *Rhaphidophora* showed that the two genera could not be separated. However, two groups were formed based on leaf lobation — the pinnately lobed and the unlobed. *R. merrilli*, *R. pinnata*, *E. pinnatum* and most of the *R. korthalsii* are grouped together by their pinnate lobation. The rest are grouped by the absence of it. This kind of relationship is in agreement with the proposal made according to stem anatomical evidences that *R. merrilli* and *R. korthalsii* resemble *E. pinnatum* (Medecilo, 2000). *R. korthalsii* closely resembles *Epipremnum* by the absence of secretory cavities and the presence of intercellular spaces. *R. merrilli* closely resembles *E. pinnatum* by having intercellular spaces which are scattered in the periphery and central cylinder. Furthermore, it was reported that *R. pinnata* is synonymous to *E. pinnatum*. It can be suggested then that there is strong evidence that these species may belong to one genus, *Epipremnum,* as proposed. However, it should be also noted that not all *R. korthalsii* have pinnate lobation. Some are unlobed. These specimens range

from being a notophyll to mesophyll as compared with the lobed *R. korthalsii* species, which are megaphyll. The reason for this deviation is perhaps due to the maturity of the leaves. *Epipremnum* and *Rhaphidophora* have two patterns of leaf development. The young leaves usually start out unlobed and become pinnatifid as they grow older. *R. korthalsii* that are in the notophyll and megaphyll blade classes may be suspected as young leaves, hence, the absence of lobation. This explains the discrepancy between some *R. korthalsii* species (Medecilo, 2000).

However, some characters are unique in some species. *R. sp.* 11 was the only one to have secondary vein angles that increase abruptly toward the base. *R. foraminifera* is unique in possessing the concavo-convex base shape. *R. sp.* 9 has a concave base shape. *R. sp.* 12 has a round apex shape. *R. korthalsii* 8 has a leaf width ranging from 52-58 cm. *R. korthalsii* 7 has a leaf length of 108-127 cm. *R. sp.* 16 is the only one which has an acrodromous basal secondary vein category. *R. sp.* 15 has 64-75° marginal angles. *R. sp.* 14 has the only one who has retuse apex shape. *R. merrilli* has a reticulodromous secondary vein category. Both cuneate base shape and 5:1-6:1 length-width ratio are exclusive to *R. sp.* 7. Lastly, *R. montana* is the only one to have a microphyll to notophyll blade class.

Even though the use of leaf morphology could not be used to delineate the genus level taxa, leaf morphological traits could define and separate the different species of *Rhaphidophora*.

The phenogram shows 10 clusters (Figure 2). Cluster 1 consists of 10 species, including *Rhaphidophora sp.* 1, *R. sp.* 5, *R. sp*. 3, *R. sp.* 6, *R. sp.* 8, *R. lobbii*, *R. sp*. 2, *R. perkinsiae* 1, *R. Montana*, and *R. sp.* 7. The species are similar in 5 characters, which are: weak brochidodromous secondary vein category, acute apex angle, 4-15° marginal angle, unlobed margin, and 1:1-1:2 length-width ratio. *R. sp.* 1, *R. sp.* 5, *R. sp.* 3, *R. sp.* 6 and *R. sp.* 8 are closely related to each other by having 11 similar characters: weak brochidodromous secondary vein category, truncate apex shape, acute apex angle, asymmetrical leaf, convex base shape, 4-15° marginal angle, unlobed margin, leaf length 8-27 cm, leaf width 3-9cm, 3:1-4:1 length-width ratio, and acute base angle. *R. sp.* 8 differs from the rest by having secondary vein angles that are uniform instead of increasing smoothly towards the base. The identity of the 5 species is closely related to *R. lobbii*. They share 10 similar characters. The only difference of *R. lobbii* from the other species is that its leaf length falls under the class above 8-27 cm, that is, 28-47 cm. *R. sp*. 2 is more closely related to *R. perkinsiae,* having 10 similar characters and *R. perkinsiae* is closely related to *R. montana,* having 6 similar characters. *R. sp.* 7 is the least related from the rest.

Cluster 2 consists of 8 species: *R. sp.* 17, *R. merrilli, R. sp*. 19, *R. acuminata, R. perkinsiae* 2, *R. perkinsiae* 3, *R. elmeri* 1, *R. elmeri* 2. They are similar in 5 characters which are 1:1-2:1 length-width ratio, smoothly increasing toward the base secondary vein angles, acute apex angle, whole lamina asymmetry, 8-27 cm leaf length. It can be noted that *R. sp*. 17 and *R. merrillii* are closely related to each other by having 9 similar characters. *R. sp.* 19 is more closely related to *R. acuminata*, *R. perkinsiae* 2, *R. perkinsiae* 3. The latter are linked together by 12 similar charac-

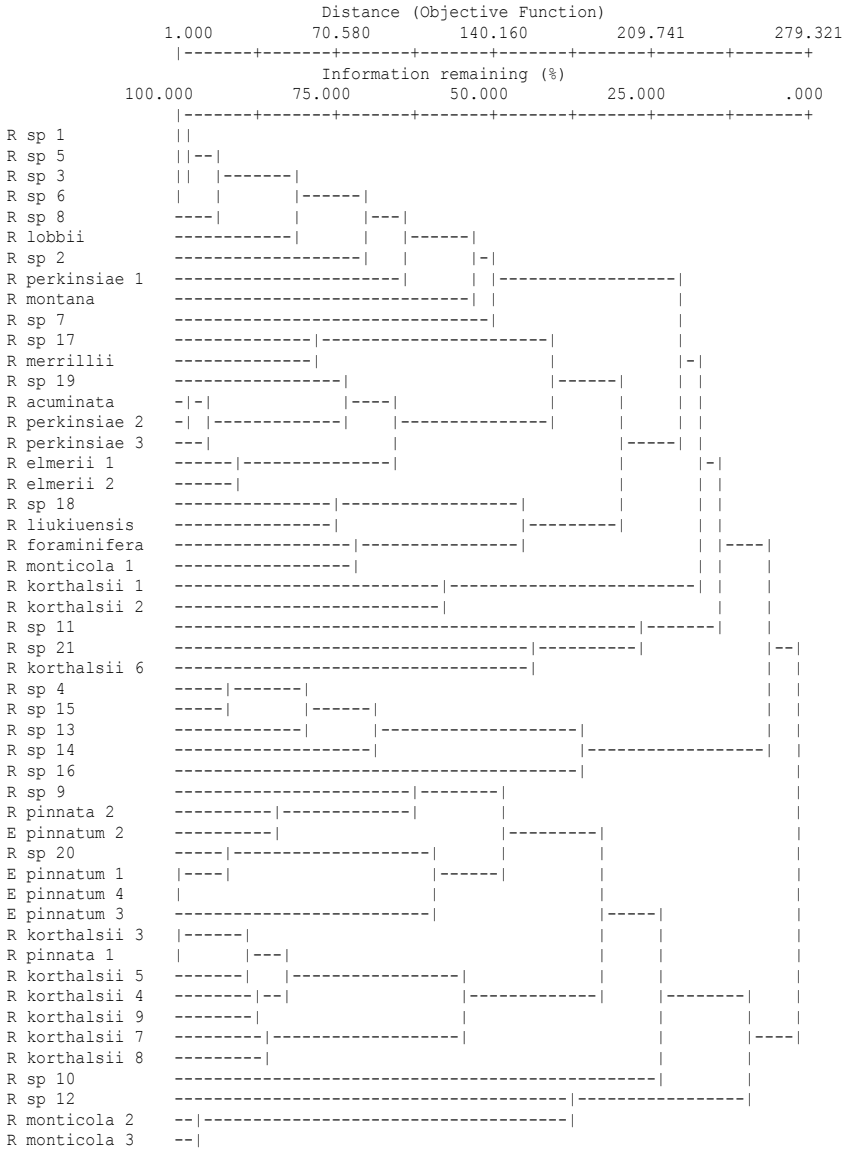

Figure 2. Phenogram showing relationships between *Rhaphidophora* and *Epipremnum* specimens based on external leaf morphology

ters. *R. perkinsiae* 3 differs only by having marginal angle of 10° and falling under the mesophyll to macrophyll blade class. *R. elmeri* 1 and *R. elmeri* 2 are closely related to each other by having 13 similar characters.

Cluster 3 consists of 4 species, *R. sp.* 18, *R. liukiuensis*, *R. foraminifera*, and *R. monticola* 1. *R. sp.* 18 is closely related to *R. liukiuensis* by having 12 similar characters i.e. 10-16 cm leaf width, unlobed margin, macrophyll blade, 64-74° laminar angle, obtuse base angle, weak brochidodromous secondary vein category, ovate shape, smoothly increasing toward the base secondary vein angles, acute apex angle, asymmetrical leaf, convex base shape, 4-15° marginal angle. *R. foraminifera* and *R. monticola* 1 are closely related by having 11 similar characters which are unlobed, uniform secondary vein spacing, macrophyll blade class, 17-23 leaf width, 28-47 cm leaf length, 64-74° laminar angle, obtuse base angle, weak brochidodromous secondary vein category, 1:1-2:1 length-width ratio, smoothly increasing toward the base secondary vein angles, acute apex angle, and 4-15° marginal angle.

Cluster 4 consists of 2 species, *R. korthalsii* 1 and *R. korthalsii* 2. They are closely related by having 11 similar characters: smoothly increasing toward base secondary vein angles, acute apex angle, whole lamina asymmetry, 4-15° marginal angle, convex apex shape, unlobed margin, 8-27 cm leaf length, eucamptodromous secondary vein category, 31-41° laminar angle, 3-9 cm leaf width, and notophyll-mesophyll blade.

Cluster 5 consists of 3 species: *R. sp.*11, *R. sp* 21, and *R. korthalsii* 6. They are closely related by having 6 similar characters: 8-27 cm leaf length, 3-9 cm leaf width, mesophyll, 1:1-2:1 L:W ratio, unlobed margin, and 5-15° costal angle. *R. sp.* 11 is closely related to *R. sp.* 21 and *R. korthalsii* 6. *R. sp*. 21 is closely related to *R. korthalsii* 6 by having 7 similar characters. They differ with *R. sp*. 11 by having 16-27° marginal angles and elliptic blade shape.

Cluster 6 consists of 5 unidentified species of *Rhaphidophora,* which includes *R. sp.* 4, *R. sp*. 15, *R. sp.* 13, *R. sp*. 14, and *R. sp*. 16. They are similar in 6 characters which are ovate blade shape, 1:1-2:1 length-width ratio, whole lamina asymmetry, unlobed margin, 10-16 cm leaf width and 8-27 leaf length. Among the 5 species, *R. sp*. 16 is least related to them.

Cluster 7 includes 7 species, which are *R. sp*. 9, *R. pinnata* 2, *Epipremnum pinnatum* 2, *R. sp*. 20, *E. pinnatum* 1, *E. pinnatum* 4, and *E. pinnatum* 3. They are similar in having 5 characters: pinnately lobed margin, weak brochidodromous secondary vein category, 1:1-2:1 length-width ratio, smoothly increasing toward the base secondary vein angles, truncate apex shape. *R. sp*. 9 is closely related to *R. pinnata* 2 and *E. pinnatum* 2 by having 10 similar characters. *R. sp*. 9 differs by having uniform secondary vein spacing instead of having irregular secondary vein spacing. *R. sp*. 20 is closely related to *E. pinnatum* 1, *E. pinnatum* 3 and *E. pinnatum* 4 by having 9 characters in common with them. *E. pinnatum* 3 differs from the group by having a megaphyll blade class instead of macrophyll, a leaf length of 65 cm, and 20° marginal angle.

Table 1. Summary of cluster analysis

CLUSTER	SPECIES WITHINCLUSTER	SIMILAR CHARACTERS
1	Rhaphidophora sp. 1, R. sp. 5, R. sp. 3, R. sp. 6, R. sp. 8, R. lobbii, R. sp. 2, R. perkinsiae 1, R. Montana, and R. sp. 7	weak brochidodromous secondary vein category, acute apex angle, 4-15o marginal angle, unlobed margin, 1:1-1:2 L:W ratio
2	R. sp. 17, R. merrilli, R. sp. 19, R. acuminata, R. perkinsiae 2, R. perkinsiae 3, R. elmeri 1, R. elmeri 2	1:1-2:1 L:W ratio, smoothly increasing toward the base secondary vein angles, acute apex angle, whole lamina asymmetry, 8-27 cm leaf length
3	R. sp. 18, R. liukiuensis, R. foraminifera, and R. monticola 1	10-16 cm leaf width, unlobed margin, macrophyll blade, 64-74o laminar angle, obtuse base angle, weak brochidodromous secondary vein category, ovate shape, smoothly increasing toward the base secondary vein angles, acute apex angle, asymmetrical leaf, convex base shape, 4-15o marginal angle
4	R. korthalsii 1 and R. korthalsii 2	smoothly increasing toward base secondary vein angles, acute apex angle, whole lamina asymmetry, 4-15o marginal angle, convex apex shape, unlobed margin, 8-27 cm leaf length, eucamptodromous secondary vein category, 31-41o laminar angle, 3-9 cm leaf width, notophyll-mesophyll blade
5	R. sp.11, R. sp 21, and R. korthalsii 6	8-27 cm leaf length, 3-9 cm leaf width, mesophyll, 1:1-2:1 L:W ratio, unlobed margin, 5-15o costal angle
6	R. sp. 4, R. sp. 15, R. sp. 13, R. sp. 14, and R. sp. 16	ovate blade shape, 1:1-2:1 length-width ratio, whole lamina asymmetry, unlobed margin, 10-16 cm leaf width, 8-27 leaf length
7	R. sp. 9, R. pinnata 2, Epipremnum pinnatum 2, R. sp. 20, E. pinnatum 1, E. pinnatum 4, and E. pinnatum 3	pinnately lobed margin, weak brochidodromous secondary vein category, 1:1-2:1 length-width ratio, smoothly increasing toward the base secondary vein angles, truncate apex shape
8	R. korthalsii 3, R. pinnata 1, R. korthalsii 5, R. korthalsii 4, R. korthalsii 9, R. korthalsii 7, and R. korthalsii 8	pinnately lobed margin, megaphyll blade class, irregular secondary vein spacing, obtuse base angle, weak brochidodromous secondary vein category, 1:1-2:1 length-width ratio, smoothly increasing toward the base secondary vein angles, truncate apex shape
9	R. sp. 10	--
10	R. sp. 12 , R. monticola 2, and R. monticola 3	macrophyll blade, truncate apex shape, symmetrical lamina, weak brochidodromous secondary vein category, 27-37o costal angle, ovate shape, 1:1-2:1 length-width ratio, smoothly increasing toward base secondary vein angles

Cluster 8 includes 7 species: *R. korthalsii* 3, *R. pinnata* 1, *R. korthalsii* 5, *R. korthalsii* 4, *R. korthalsii* 9, *R. korthalsii* 7, and *R. korthalsii* 8. They have 8 similar characters: pinnately lobed margin, megaphyll blade class, irregular secondary vein spacing, obtuse base angle, weak brochidodromous secondary vein category, 1:1-2:1 length-width ratio, smoothly increasing toward the base secondary vein angles, and truncate apex shape. *R. korthalsii* 3, *R. pinnata*, and *R. korthalsii* 5 are closely related by 9 similar characters. *R. korthalsii* 5 differs by having a leaf length of 88-107cm, 64-74^{o} laminar angles, and a rounded base shape. *R. korthalsii* 4 is akin to *R. korthalsii* 9 by 13 characters. *R. korthalsii* 7 and *R. korthalsii* 8 are closely related to each other, having 12 characters in common.

Cluster 9 consists of a single species, *R. sp.* 10. It is distantly related to clusters 7 and 8.

Cluster 10 consists of 3 species, *R. sp*. 12 , *R. monticola* 2, and *R. monticola* 3. They are similar in having 8 characters: macrophyll blade, truncate apex shape, symmetrical lamina, weak brochidodromous secondary vein category, 27-37^{o} costal angle, ovate shape, 1:1-2:1 length-width ratio, smoothly increasing toward base secondary vein angles. *R. sp*. 12 differs from the two by the presence of 17-23 cm leaf width, round apex shape, irregular secondary vein spacing, 4-15^{o} marginal angle, 8-27 cm leaf length.

The cluster analysis shows that there is no clear separation between the two genera according to external leaf characteristics. In the cluster analysis, the *Epipremnum* species appeared in the lower middle of the dendogram. This occurred because of the close relationship of the *Epipremnum* species (Cluster 7) with the *R. korthalsii* species (Cluster 8) by the presence of pinnate lobation, weak brochidodromous secondary vein, length-width ratio of 1:1-2:1, smoothly increasing toward the base secondary vein angles, and truncate apex shape. The close relationship of the two species was such that it was proposed that *R. korthalsii* should be placed within the genus *Epipremnum,* because of its high similarity with *Epipremnum pinnatum* based on morphological and anatomical evidences (Medecilo, 2000).

The presence of overlapping of some characters defining each cluster may also be noted. The clusters cannot be represented exclusively by a single character or by a number of similar characters. A combination of certain numbers of similar characters is needed to allow a given group to be linked together in a cluster. The number of similar characters tends to increase as the distance among the species decreases. On the other hand, the number decreases as the distance increases.

It may also be stated that leaf characters are varied. The reason for the said variation could be accounted for by the phenotypic plasticity of the leaves or the maturity of the leaves as exhibited by the presence of suspected juvenile specimens of R. korthalsii in the herbarium collections.

CONCLUSIONS

Generally, the specimens under the genera *Epipremnum* and *Rhaphidophora* could be categorized into two groups based on the presence or absence of lobation. *Epipremnum* species have pinnately lobed margins while *Rhaphidophora* species do not except for *Rhaphidophora korthalsii*, *R. merrilli*, and *R. pinnata* (= *Epipremnum pinnatum*). The phenetic relationship between *Epipremnum* and *Rhaphidophora* based on leaf morphological similarities was ascertained through the use of cluster analysis. The cluster analysis showed that the leaf morphology alone was not able to define the intergeneric relationship of *Rhaphidophora* and *Epipremnum*. However, it proved to support the proposal of Medecilo (2000) regarding the transfer of *R. korthalsii* to the genus *Epipremnum* due to leaf morphological and anatomical similarities. Leaf morphology showed that *R. korthalsii* is closely related to *Epipremnum* by the presence of pinnate lobation, weak brochidodromous secondary vein, length-width ratio of 1:1-2:1, smoothly increasing toward the base secondary vein angles, and truncate apex shape. Further, although leaf morphology was not able to define the intergeneric relationship of the two genera, it was able to separate specimens up to the species level. *R. sp*. 11 was the only one to have secondary vein angles that increases abruptly toward the base. *R. foraminifera* possesses only the concavo-convex base shape. *R. sp* 9 has a concave base shape. *R. sp.* 12 has a round apex shape. *R. korthalsii* 8 has a leaf width ranging from 52-58 cm. *R. korthalsii* 7 has a leaf length of 108-127 cm. *R. sp* 16 is the only one which has an acrodromous basal secondary vein category. *R. sp.* 15 has 64-75^{o} marginal angles. *R. sp.* 14 has the only one who has retuse apex shape. *R. merrilli* has a reticulodromous secondary vein category. Both cuneate base shape and 5:1-6:1 length-width ratio are exclusive to *R. sp*. 7. Lastly, *R. montana* is the only one to have a microphyll to notophyll blade class.

Taxonomy involves the collection, identification, and classification of specimens. As such, it is recommended that live specimens be collected instead of relying only on available specimens in the herbarium. The latter resulted in the probable inclusion of juvenile species in the study and may have caused some discrepancies. Since the study was only limited to herbarium specimens, there was a minimal possibility of discerning the maturity of the leaves.

Further it is recommended that the leaf anatomy and the leaf morphology data both be incorporated in one phenogram to allow better understanding of the relationship of the two genera, *Epipremnum* and *Rhaphidophora*.

Lastly, it would be very much helpful if studies in palynology, physiology, genetics, evolution and biochemistry were conducted to corroborate the relationship of *Epipremnum* and *Rhaphidophora*.

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