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Phyllanthaceae Martinov is considered the second-largest family that is segregated from Euphorbiaceae. *s.l.* Previous taxonomic studies of Phyllanthaceae relied on phylogeny and the floral minutiae, with gross morphology negligence, which is various and more obvious. In this study, a state of 24 characters were recorded comparatively for a cosmopolitan sample of 37 species belonging to 12 genera of the Phyllanthaceae. The data matrix was subjected to numerical analysis using seven radically different combinations of similarity measures and clustering methods. Of the seven resulting dendrograms, two are nearly identical and show that the species are divisible neatly into two major groups which coincide with and support the two subfamilies Phyllanthoideae and Antidematoideae currently recognized in the phylogenetic classification of the Phyllanthaceae. Similarity between the two groups extends to all levels in the dendrograms. Gross morphology is as important as phylogenetic and anatomical characters and can give a complete vision to group classification, especially leaf morphology, which provides most of the characters that define the groups of species at all hierarchical levels. By comparing these results with previous studies, it's important to refer to that the generic concept in the Phyllanthaceae is fraught with instability and needs a major taxonomic re-appraisal, especially the largest genus *Phyllanthus*.

Keywords: Cluster analysis, dendrograms, morphology, *Phyllanthopsis*, *Phyllanthus*, taxonomy

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INTRODUCTION

The widest concept of the Euphorbiaceae Juss. (or Euphorbiaceae *s.l.*) was last subjected to a comprehensive taxonomic treatment by Webster (1975, 1994a, 1994b), who arranged this vast array of genera and species into five subfamilies (Phyllanthoideae Ascherson, Oldfieldioideae Köhler & Webster, Achalyphoideae Ascherson, Crotonoideae Pax, and Euphorbioideae Boiss.), with 50 tribes and 49 subtribes. Subsequent phylogenetic studies led to its disbanding into seven much smaller families: Euphorbiaceae *s.s.* (or Euphorbiaceae Juss., in a restricted sense), Phyllanthaceae Martynov, Pandaceae Engl. & Gilg, Picrodendraceae Small., Peraceae Klotzsch, Putranjivaceae Endl. ex Meisn., and Centroplacaceae Doweld & Reveal (APG IV, 2016).

The Phyllanthaceae comprises *ca*. 2000 species arranged in 60 genera accepted by APG IV (2016), with the majority of species being aggregated in the type of genus *Phyllanthus* alone. However, the generic concept in the Phyllanthaceae is relatively unsettled through the numerous allocations and re-allocations of species between different genera. Suffice it here to mention that Webster (1994a) was able to count no less than 42 synonyms of the type of genus *Phyllanthus*. Consequently, wide discrepancies exist between the numbers of genera ascribed to the Phyllanthaceae by different authors. They vary from 54 to 60 by sinking some genera into others and by fragmenting some relatively large genera into separate splinter ones (Byng, 2014). For instance, a new monotypic genus *Notoleptopus* was established on *Leptopus decaisnei* (Benth.) Voronts. & Petra Hoffm. by Vorontsova and Hoffmann (2008). Furthermore, the same authors based a new monotypic genus (*Pseudophyllanthus*, with only *P. ovalis* (F. Mey. Ex Sond.) Voronts. & Petra Hoffm.) on *Andrachne ovalis* (E. Mey. Ex Sond.) Müll. Arg., and created a new genus *Phyllanthopsis* to accommodate two species (*P. arida* and *P. phyllanthoides*) by separating *Andrachne arida* and *A. phyllanthoides*, respectively, from the rest of *Andrachne* species. Other phylogenetic studies of the Phyllanthaceae (Samuel *et al*., 2005), and some of its subordinate groups (e.g., Kathriarachchi *et al*., 2005; Kathriarachchi *et al*, 2006; Hoffmann *et al*., 2006; Vorontseva *et al*., 2007) accepted varying numbers of genera in this family. The number of species in the Phyllanthaceae suffers similar uncertainty.

The plants are mostly large trees with a few shrubs and small herbs, monoecious or dioecious, and often lacking in milky latex and resinous secretions. They are predominantly pantropical with major centers of geographical distribution in the tropical parts of sub-Saharan Africa, Asia, N. and S. America, and Australia. The leaves are simple, alternate, mainly in distichous or phyllotactic arrangement, stipulate, leathery, evergreen, with entire margins, but some *Phyllanthus* species (e.g., *P. montanus*) have flattened leaf-like cladodes bearing flowers along their margins, while the true leaves are reduced to tiny, nonphotosynthetic scales with the solitary flowers in their axils. Stipules triangular to filiform and caducous. The inflorescence is commonly a raceme of male, female, or hermaphrodite flowers. Ovary consistently superior with 2-5 locules; each locule with two pendulous ovules on an apical placenta although often only one ovule will develop into one seed. Fruit berry, drupe, schizocarpic capsule, or a 2-winged sypsela (in *Hymenocardia acida*). Seeds vary in shape from globular to ovoid. Seeds of the Phyllanthaceae are usually 'ecarunculate'; absence of the caruncle is among the significant features discriminating between them and members of the Euphorbiaceae *s.s.* (Byng, 2014).

From the economic standpoint, numerous *Bridelia* and *Phyllanthus* species (e.g., *Bridelia ferruginea*, *B. balansae*; *P. acidus*, *P. amarus*, *P. niruri*, *P. urinaria*, *P. emblica*, *P. phyllyreifolius*) are rich in a wide range of bioactive substances used in folk medicine to cure diabetes, arthritis, and malaria. Other pharmacological activities in members of the *Phyllanthaceae* include anticancer, hepatoprotective, antimicrobial, and cardioprotective effects (e.g., Zhao *et al.*, 2015; Geethangili and Ding, 2018; Kaur *et al*., 2017; 2018; Tan *et al*., 2020; Yeboah *et al.*, 2022; Prananda *et al.,*2023). The extract of *Phyllanthus atropurpureus* was shown by Abdallah *et al.* (2019) to be a promising inhibitor of acetylcholinesterase, the enzyme which causes the most common form of dementia (Alzheimer's disease), and for which no medication to slow or stop the neuro degeneration process has so far been discovered. Some species are grown as garden ornamentals while others (e.g., *Phyllanthus acidus*, *P. amarus*, *P. emblica*) have edible fruits.

Interest in the phylogenetic classification of the Phyllanthaceae, among other angiosperms, seems to have started with the comprehensive study by Savolainen *et al*. (2000). Phylogenetic studies targeting the Phyllanthaceae were initiated by Wurdack *et al*. (2004), who showed that none of the tribal circumscriptions of this family are supported by *rbcL* sequencing data. These authors also introduced some major changes in the circumscription of this family, including the transfer of *Centroplacus* and *Putranjiva* to other families (Centroplacaceae and Putranjivaceae, respectively), while confirming the placement of *Antidesma*, *Bischofia*, *Hymenocardia*, *Martretia*, and *Uapaca* in the Phyllanthaceae.

The pantropic genus *Phyllanthus* is the largest and most widespread genus of the Phyllanthaceae (Bouman *et al*., (2018). The subdivision of *Phyllanthus* into infra-generic taxa was for decades highly controversial. The checkered history of segregating small groups of species from *Phyllanthus* and raising them to generic status while submerging some others into *Phyllanthus* was detailed by Bouman *et al*. (2018), who recognized 880 species in the genus, classified them into 18 subgenera, 70 sections and 14 subsections, and provided an artificial key to all infra-generic taxa based entirely on attributes of vegetative, floral and pollen morphology. However, circumscription of *Phyllanthus* remains debatable. Owing perhaps to the relatively large number of species, most of the studies dealing with *Phyllanthus* were limited to monographic revisions of its representatives in the various pantropic regions of the world, with various circumscriptions of the genus (e.g., Li, 1987; Santiago *et al*., 2006; Ralimanana and Hoffman, 2011, 2014; Ralimanana *et al.*, 2013).

Emphasis on analysis of phylogenetic data for purposes of classification of the Phyllanthaceae at the family and infra-familial levels resulted in the negligence of the multitude of gross morphological features and its potential taxonomic value. Studies of the gross morphology of the Phyllanthaceae seem to be largely limited to the work of Levin (1986a, 1986b, 1986c), who meticulously scored 43 characters of foliar features in a sample of 259 species representing 51 genera, laying greater emphasis on leaf venation, and subjecting the wealth of comparative data to phenetic and phylogenetic analyses.

While the flowers of most members of the Phyllanthaceae are so minute that using them in a taxonomic study of this family is often fraught with numerous difficulties. In contrast, the numerous features of gross morphology describing the general aspect of plants, their leaves, fruits, and seeds are easily definable and avoids the need for the less easily accessible microscopic characters of the flowers and pollen grains.

Therefore, the present study was undertaken to explore the usefulness of gross morphology in the classification of the Phyllanthaceae and their type of genus *Phyllanthus* by analyzing as much data recorded comparatively from a representative sample of genera and species to numerical analysis.

MATERIALS AND METHODS

Herbarium specimens of 37 species belonging to 12 genera of the Phyllanthaceae were available for the present study in the Cairo University Herbarium (CAI). The number of specimens of a species ranged from one to more than 90 (for *Andrachne aspera*, *Phyllanthus rotundifolius*), with most of the species being represented by 4-8 specimens each, thus covering most of its range of geographical distribution and habitat diversity. The number of species representing a given genus is roughly proportionate to its actual size. Identification of all taxa was scrutinized with the help of keys in appropriate local floras, revisions, and monographs (e.g., Webster, 1970; R.-Smith, 1987; Carter and Smith, 1988; Boulos, 2000; Li Bingtao *et al*., 2008; NSW, 2022; Bingham *et al*., 2023; Levin, 2023), and nomenclature was updated according to the World Flora Online (WFO, 2022).

All specimens were searched for aspects of gross morphological variation which were scored comparatively for each species in a data matrix (Appendix 1). The collection data of each species were presented in (Appendix 2). Measurements expressing variation in length and width of leaf blades and petiole length were scored as the average made from at least the largest five leaves in available specimens of any species. For accurate definition of terms describing different states of leaf morphology, the glossary of botanical terms by Stearn (2004) was resorted to.

The data matrix was subjected to two-way cluster analysis using the program package PC-ord version 5 for Windows (McCune, 1997); characters were abbreviated into eight digits each to suite requirements of the program as shown in Table 2. This program package offers a wide choice of seven distance (or dissimilarity) measures and eight clustering methods with different degrees of clustering intensity. Of the possible 56 combinations, only the seven shown in Table 1 were used because they cover a wide range of specifications with basic algorithmic differences (outlined by Lance and Williams, 1967; Sneath, 1969; Sneath and Sokal, 1973; Milligan, 1989), which are reflected on the resulting classifications. The Euclidean geometric distance (dissimilarity) measure is basically different from the arithmetic Jaccard (similarity) method. Flexible β differs from all other clustering methods by having a variable clustering intensity depending on the value set by the user of this method for the parameter β, while other methods have fixed clustering intensities. The original default value of β set by Lance and Williams (1967) at -0.25 was used.

RESULTS

Observations

The leaves are the richest and most obvious source of morphological variation in members of the Phyllanthaceae (characters 6-18 in Table 2). They are invariably simple, alternate, distichous or phyllotactic, and with entire margins. Blade outline differs widely from species to species and is sometimes slightly different in specimens of the same species. Therefore, variation in the blade shape was set in four clearly distinct states each of which is covering the entire range of blade shapes of any given species. Blade length varies from 1 cm or less (e.g., in *Andrachne telephioides*, *Phyllanthus capillaris*) to 12(-18) cm (e.g., in *Antidesma bunius*, *Uapaca kirkiana*), while most of the species have leaf blade length within the range of 6-10 cm. Leaf blade width ranges between 3 cm (in *Phyllanthus maderaspatensis*, *Ph. amarus*, *Ph. emblica*), to 6 cm or more (in *Bridelia micrantha*, *B. brideliifolia*). Accordingly, the blade length-width ratio is highly variable. The position of the widest part of the leaf blade (xy/xz) is markedly different from species to species (Figures 1-3). Similarly, the petiole-bade length ratio is variable. Leaf blades may be thin and lean or thick and shining leathery. When leaf blades are exceedingly longer than the stem internodes thus hiding them, they seem closely aggregated along the stem and were termed ‘overlapping’ (e.g., *Phyllanthus rotundifolius*; character 7 in Table 2).

The numerical analyses

Each of the seven combinations of dissimilarity measures and clustering methods in Table 1 resulted in a two-way hierarchical scheme of classification, with the contribution of each character in the clustering of every species in each group expressed in color. While six schemes had some degree of resemblance to each other in terms of expressing taxonomic relatedness among the genera and species and in the close values of the chaining percentages (4.34-6.51%), the scheme based on the combination of Euclidean distance and McQuitty’s clustering method has a 13.02% chaining and seemed taxonomically outlandish as it differed profoundly from all others. Furthermore, the two schemes named Phyllanthaceae2 (based on Jaccard’s measure and Ward’s method) and Phyllanthaceae5 (generated

Table 1. Seven combinations of distance measures and clustering methods used in the numerical analysis of a data matrix comprising 24 characters recorded comparatively for 37 species belonging to 12 genera of the Phyllanthaceae. The chaining % obtained by each combination is shown.

Name	Distance measure	Clustering method	Chaining %
Phyllanthaceae 1	Sørensen	Flexible β	4.34
Phyllanthaceae 2	Jaccard	Ward's	4.73
Phyllanthaceae 3	Jaccard	Flexible β	4.34
Phyllanthaceae 4	Euclidean	Ward's	6.51
Phyllanthaceae 5	Euclidean	Flexible β	5.52
Phyllanthaceae 6	Sørensen	McQuitty's	7.30
Phyllanthaceae 7	Euclidean	McQuitty's	13.02

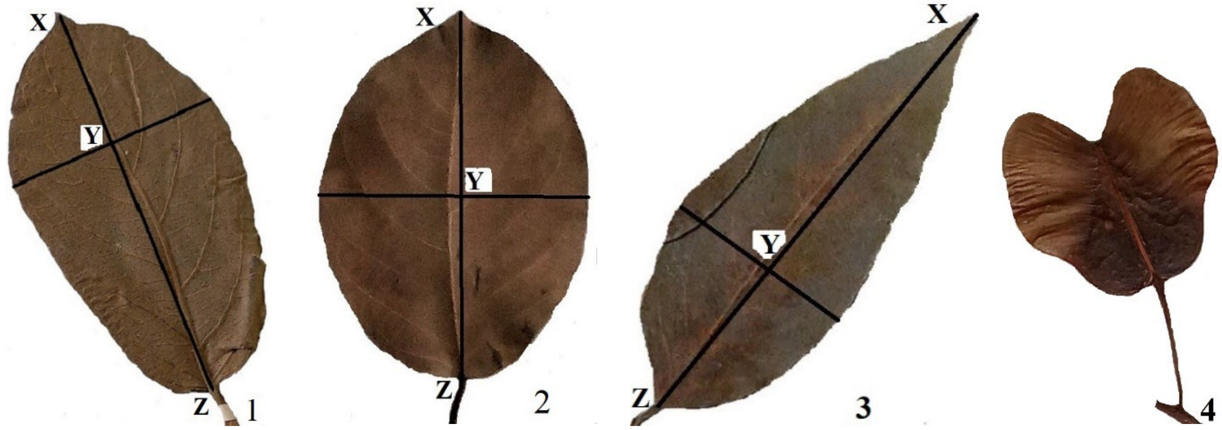

Figure 1. Aspects of gross morphological variation in the Phyllanthaceae. 1-3: images of simple leaves of *Antidesma venosum*, *Pseudolachnostylis maproneifolia*, and *Phyllanthus distichus*, respectively, with symmetrical blade base and the two measurements (xy) and (xz) determining the position of the widest part of the blade (xy/xz). 4: the 2-winged sypsela of *Hymenocardia acida*. All images are made from herbarium specimens.

Table 2. List of the 24 characters, their character-states, abbreviations, and types recorded comparatively for 37 species belonging to 12 genera of the Phyllanthaceae and subjected to numerical analysis C = qualitative or 2-state character; M = multistate character; Q = quantitative or measured character.

#	Characters and character-states	Abbreviations	Types
1	Plant: herb 1/ shrub 2/ tree 3	H/Sh/Tr	M
2	Plant: glabrous 1/ hairy 0	Glab/Hr	C
3	Milky latex: present 1/ absent 0	late p/a	C
4	Stem: cylindrical 1/ angled 0	St cyl/a	C
5	Spiny wings of stem: present 1/ absent 0	spin P/a	C
6	Leaf blade: elliptical-lanceolate 1/ oblanceolate-obovate 2/ ovate-cordate 3/ orbicular-suborbicular 4	Lf Shape	M
7	Leaves: overlapping 1/ not overlapping 0	Lvs over	C
8	Leaf veins: prominent 1/ not prominent 0	V pro/n	C
9	Base of leaf blade: rotund 1/ cordate 2/ cuneate 3	Base	M
10	Leaf blade: thin 1/ thick and leathery 0	Bl thin/thk	C
11	Leaf blade length (in cm)	lf lengt	Q
12	Leaf blade width (in cm)	lf width	Q
13	Leaf blade length/width ratio	l/w rati	Q
14	Position of the widest part of leaf blade (xy/xz in Figs. 1-3)	wid posi	Q
15	Leaf blade apex: rotund 1/ acute 2/ acuminate 3/ mucronate 4	apex	M
16	Leaf blade base: symmetrical 1/ asymmetrical 0	bas sy/a	C
17	Petiole length (in cm)	pet leng	Q
18	Petiole/blade length ratio	Pe/Bl ra	Q
19	Fruit: drupe 1/ capsule 2/ 2-winged sypsela 3 (Fig. 4)	fr d/c/s	M
20	Number of seeds per fruit: one 1/ two 2/ more 3	Sd num	M
21	Seed surface: variegated 1/ not variegated 0	Sd var/n	C
22	Seed surface: rugose 1/ smooth 2/ pitted 3	se r/s/p	M
23	Seed shape: angular 1/ globular-ovoid 2/ oblong-ellipsoid 3	sd shape	M
24	Caruncle: present 1/ absent 0	car p/a	C

by using Euclidean distance and Flexible β) were nearly identical, despite the major mathematical differences between the methods used in their generation. The two schemes are presented in Figs. 5 and 6, respectively, and were selected for further discussion.

DISCUSSION

The two main groups A and B in each of the two dendrograms in Figs. 5 and 6 are identical in terms of their content of genera and species despite the basic algorithmic differences between the Jaccard and Euclidean distance measures (detailed by Sneath and Sokal, 1973), and between the Flexible β and Ward's clustering methods (defined by Lance and Williams, 1967; Sneath,1969; Dallwitz, 1988) used in their construction. This uniformity in composition of the two classifications is a source additional support for them and attests to their taxonomic robustness. Furthermore, the secondary groups of Group A (AC and AD) in both dendrograms are identical. The minor differences between the two classifications in Figs. 5 and 6 are limited to the pattern of fusion between a few individual species in the lowest levels of both hierarchies owing to the migration of these species from one terminal group to another within the same main group.

Groups A and B are not only identical, but they also respectively support the two subfamilies Phyllanthoideae and Antidematoideae recognized in the phylogenetic classification of the Phyllanthaceae by Hoffmann *et al.* (2006). This is one of the rare examples in which phenetic and phylogenetic classifications are in mutual agreement and, hence, are mutually supportive. The relatively small sample of genera and species included in the present study does not allow further comparison between the minor groups C1, C2, D1, D2 and B with the groups of lower ranks in the detailed phenetic and phylogenetic classifications by Webster (1994a and 1994b) and Hoffmann *et al*. (2006), respectively.

The similarity between the two schemes in Figures 5 and 6 extends to the treatment of individual genera. Of the 12 genera included in the present study, six (*Breynia*, *Margaritaria*, *Hymenocardia*, *Leptopus*, *Phyllanthopsis*, *Pseudolachnostylis*) are represented by a single species each. The remaining six genera are distinguished into two categories: (i) those whose representative species emerged together in only one of the five low-level groups A-C1, AC-2, AD1, AD2 and B, and (ii) those with species falling in more than one low-level group as follows:

	in Phyllanthaceae 2 (Fig. 5)	**in Phyllanthaceae 5 (Fig. 6)**
Category (i):	*Andrachne* (2 spp. in AC-1) *Fluggea* (2 spp. in AD-1) *Antidesma* (4 spp. in B)	*Andrachne* (2 spp. in AC-1) *Fluggea* (2 spp. in AD-1) *Antidesma* (4 spp. in B)
Category (ii):	*Bridelia* (2 in AD-1; 4 spp. in B) *Uapaca* (1 sp. in AD-1; 1 sp. in B) *Phyllanthus* (5 spp. in AC-1; 6 spp. in AC 2. ;1 sp. in AD-1; 3 spp. in AD2).	*Bridelia* (1sp. in AD-1; 1 sp. in AD-2; 4 in B) *Uapaca* (1 sp. in AD-1; 1 sp. in B) *Phyllanthus* (5 spp. in AC-1; 5 spp. in AC-2; 2 spp. in AD-1; 3 spp. in AD-2).

This is further corroborated by the arrangement of the 15 species representing the largest genus in the family (*Phyllanthus*) in our sample. Figures 5 and 6 and Table 3 show that apart from the slight differences in the pattern of fusions among individual species and the migration of *P. muellerianus* from group A-C-C2 in Fig. 5 to group A-D-D1 in Figure 6, the distribution of all other *Phyllanthus* species among the four low-level groups is essentially the same in the two analyses Phyllanthaceae 2 and Phyllanthaceae 5.

The subdivision of *Phyllanthus* into infra-generic taxa remains controversial and comparing the arrangement in Table 3 with a plausible phenetic or phylogenetic classification of this genus seems futile. Separation of the two species *Andrachne arida* and *A. phyllanthoides* from *Andrachne* to establish the new genus *Phyllanthopsis* by Vorontsova and Hoffmann (2008) on phylogenetic bases is not supported by morphological features since one of the two species in the new genus (*P. phyllanthoides*) is deeply immersed with other *Andrachne* and *Phyllanthus* species and appears consistently with them in the same low-level group A-C-C1. The generic concept in the Phyllanthaceae remains largely unsettled and seems in need of a detailed re-appraisal in which comparative gross morphology should be taken more adequately into consideration.

The deeper the blue color in Figures 5 and 6, the greater the contribution of a character in the set of attributes defining a group of taxa and in discriminating between two groups united to form a common group of higher rank. For instance, leaf length, leaf width, and petiole length are the main discriminating features between Groups A and B. Similarly, the leaf length/width ratio and position of

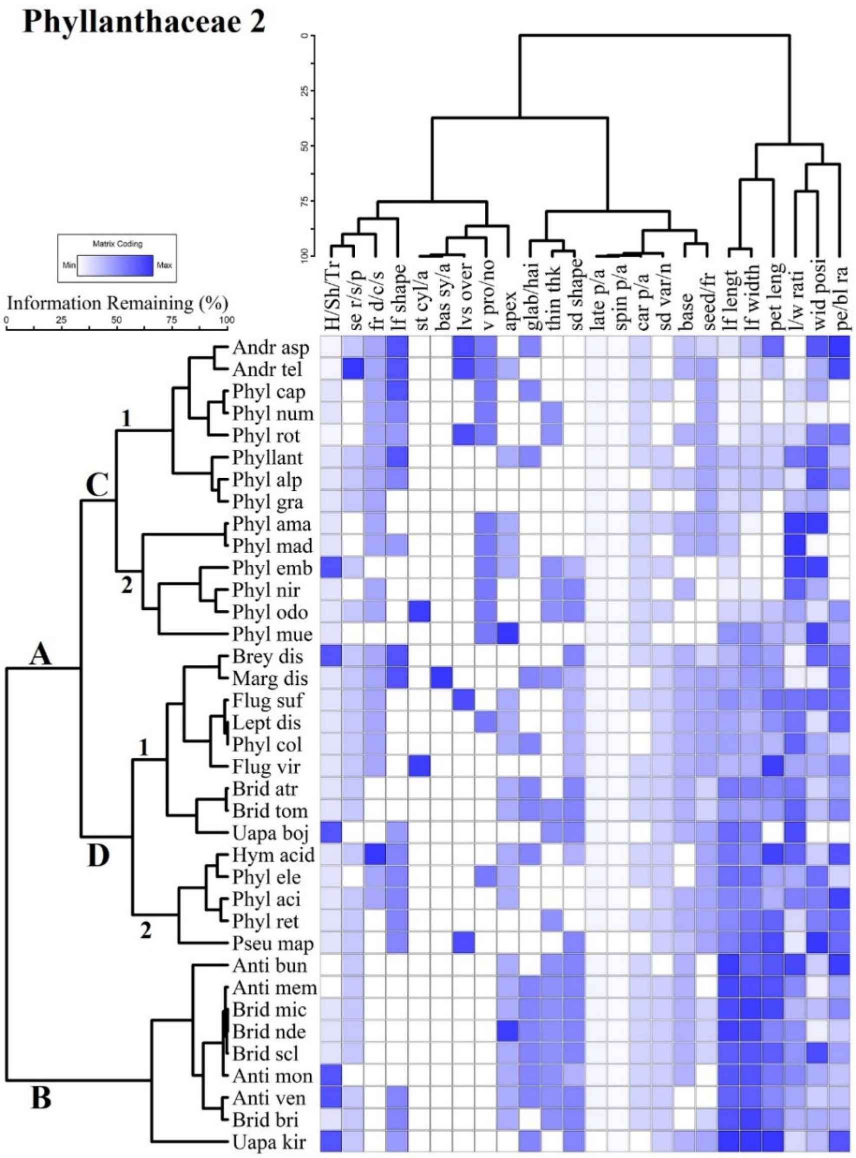

Figure 5. Two-way cluster dendrogram illustrating the phenetic relationships among 37 species belonging to 12 genera of the Phyllanthaceae, generated by numerical analysis of a data matrix comprising 24 characters by Jaccard's similarity measure and Ward's clustering method, the chaining percentage for the species hierarchy is 4.73%. Abbreviations of character names are presented in Table 2.

Full names of taxa in the same sequence in each Group are as follows:

Group AC-C1: *Andrachne aspera* Spreng., *Andrachne telephioides* L., *Phyllanthus capillaris* Schumach. & Thonn., *Phyllanthus nummulariifolius* subsp. *nummulariifolius, Phyllanthus rotundifolius* Klein ex Willd., *Phyllanthopsis phyllanthoides* (Nutt.) Voronts. & Petra Hoffm., *Phyllanthus alpestris* Beille, *Phyllanthus gardnerianus* (Wight) Baill.

AC-C2: *Phyllanthus amarus* Schum., *Phyllanthus maderaspatensis* L., *Phyllanthus emblica* L., *Phyllanthus niruri* L., *Phyllanthus odontadenius* Mull.Arg., *Phyllanthus muellerianus* (Kuntze) Exell

Group AD-D1: *Breynia disticha* J.R. Forst. & G. Forst., *Margaritaria discoidea* (Baill.) Webster, *Flueggea suffruticosa* (Pall.) Baill., *Leptopus chinensis* (Bunge) Pojark., *Phyllanthus columnaris* Muell.Arg., *Flueggea virosa* (Roxb. ex Willd.) Royle, *Bridelia atroviridis* Müll.Arg., *Bridelia tomentosa* Blume var. *chinensis* Müll.Arg., *Uapaca bojeri* Baill.

Group A-D-D2: *Hymenocardia acida* Tul., *Phyllanthus elegans* Wall. ex Müll.Arg., *Phyllanthus acidus* Skeels, *Phyllanthus reticulatus* Poir., *Pseudolachnostylis maprouneifolia* Pax

Group B: *Antidesma bunius* (L.) Spreng., *Antidesma membranaceum* Müll.Arg., *Bridelia micrantha* (Hochst.) Baill., *Bridelia ndellensi*s Beille, *Bridelia scleroneura* Müll.Arg., *Antidesma montanum* Blume, *Antidesma venosum* E. Mey. ex Tul., *Bridelia brideliifolia* (Pax) Fedde subsp. *pubescentifolia* J. Léonard, *Uapaca kirkiana* Muell.Arg.

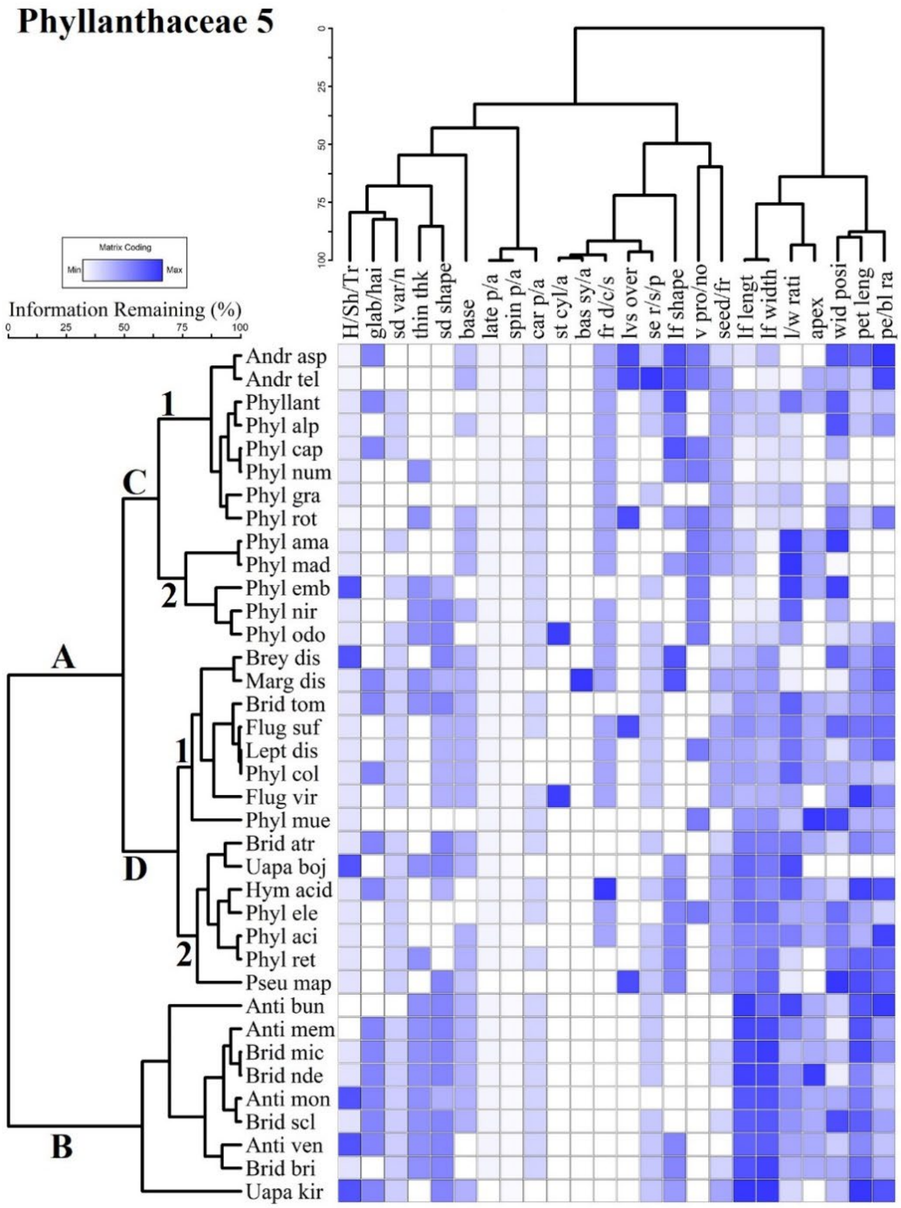

Figure 6. Two-way cluster dendrogram illustrating the phenetic relationships among 37 species belonging to 12 genera of the Phyllanthaceae, generated by numerical analysis of a data matrix comprising 24 characters by a combination of Euclidean distance measure and Flexibleβ (-0.25) clustering method. The chaining percentage for the species hierarchy is 5.52 %. Abbreviations of character names are presented in Table 2.

Full names of taxa in the same sequence in each Group are as follows:

Group AC-C1: *Andrachne aspera* Spreng., *Andrachne telephioides* L., *Phyllanthopsis phyllanthoides* (Nutt.) Voronts. & Petra Hoffm., *Phyllanthus alpestris* Beille, *Phyllanthus capillaris* Schumach. & Thonn., *Phyllanthus nummulariifolius* subsp. *nummulariifolius, Phyllanthus gardnerianus* (Wight) Baill., *Phyllanthus rotundifolius* Klein ex Willd.

Group AC-C2: *Phyllanthus amarus* Schum., *Phyllanthus maderaspatensis* L., *Phyllanthus emblica* L., *Phyllanthus niruri* L., *Phyllanthus odontadenius* Mull.Arg.

Group AD-D1: *Breynia disticha* J.R. Forst. & G. Forst., *Margaritaria discoidea* (Baill.) Webster, *Bridelia tomentosa* Blume var. *chinensis* Müll.Arg., *Flueggea suffruticosa* (Pall.) Baill., *Leptopus chinensis* (Bunge) Pojark., *Phyllanthus columnaris* Muell.Arg., *Flueggea virosa* (Roxb. ex Willd.) Royle, *Phyllanthus muellerianus* (Kuntze) Exell

Group AD-D2: *Bridelia atroviridis* Müll.Arg., *Uapaca bojeri* Baill., *Hymenocardia acida* Tul., *Phyllanthus elegans* Wall. ex Müll.Arg., *Phyllanthus acidus* Skeels, *Phyllanthus reticulatus* Poir., *Pseudolachnostylis maprouneifolia* Pax

Group B: *Antidesma bunius* (L.) Spreng., *Antidesma membranaceum* Müll.Arg., *Bridelia micrantha* (Hochst.) Baill., *Bridelia ndellensis* Beille, *Bridelia scleroneura* Müll.Arg., *Antidesma montanum* Blume, *Antidesma venosum* E. Mey. ex Tul., *Bridelia brideliifolia* (Pax) Fedde subsp. *pubescentifolia* J. Léonard, *Uapaca kirkiana* Muell.Arg.

Table 3. Comparison between the distribution of 15 *Phyllanthus* species in the four low-level groups (AC-C1, AC-C2, AD-D1, and AD-D2) in Figs. 5 and 6.

groups	Phyllanthaceae 2 (Fig. 5)	Phyllanthaceae 5 (Fig. 6)
AC-C1	*P. alpestris*, *P. capillaris*, *P. gardnerianus P. nummulariifolius*, *P. rotundifolius*	*P. alpestris*, *P. capillaris*, *P. gardnerianus*, *P. nummulariifolius*, *P. rotundifolius*
AC-C2	*P. amarus*, *P. maderaspatensis*, *P. emblica*, *P. niruri*, *P. odontadenius*, *P. muellerianus*	*P. amarus*, *P. maderaspatensis*, *P. emblica*, *P. niruri*, *P. odontadenius*
AD-D1	*P. columnaris*	*P. columnaris*, *P. muellerianus*
AD-D2	*P. elegans*, *P. acidus*, *P. reticulatus*	*P. elegans*, *P. acidus*, *P. reticulatus*

the widest part of leaf blade contributed considerably to the distinction between groups AC-1 and AC-2. While leaf morphology and measurements provided most of the characters defining the groups at all hierarchical levels in Figs. 5 and 6, seed features and numbers were the least taxonomically useful.

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Appendix 1: Data matrix of variation in 24 gross morphological characters scored comparatively for 37 species representing 12 genera (with appreviations) of the Phyllanthaceae is available in**:** https://docs.google.com/spreadsheets/d/1d0z-3ajjknju9hk0kKAHQx_LnHSRVWJO40spfmUMAB0/edit?usp=sharing

Appendix 2: Collection data of all 37 taxa of Phyllanthaceae as recorded in the label mounted on the herbarium sheet of each species:

Taxa	Collection data
Andrachne aspera Spreng.	Lofty Boulos; S.n; 10.3.1954; Wadi Alqaba; Red Sea Coast; CAI. M. Kassas, M.O. Mobarak, and Hamad A. Omar; 677; 14.12.1966; Jebel Asohiba, part Sudan; CAI. M. Kassas, M.O. Mobarak, and Hamad A. Omar; 44; 5.12.1966; Erckuit, Red Sea District; CAI. Nabil el Hadidy; s.n.; 10/5/56; Gebl El-Deir near the Monastery st. Catherine; Sinai; CAI. Ahmed Megahed; 32; 16.2.1992; El Haer Area; CAI. M. Kassas, H. Fawzy, et al; 1873; 8.2.1692; Slope hill of Wadi Aideib; CAI.
Andrachne telephioides L.	Ahmed Khattab & M. Nabil El Hadidi; K388; 23.8.1966; Kuba Madina, Saudi Arabia; CAI. Lotfy Boulos; 8; 18/3/1955; Wadi El-Arish; CAI. Ahmed G. Fahmy; s.n.; 1988; Saad El- Rauffaa, N. Sinai, CAI.
Antidesma bunius (L.) Spreng.	Mohammed El Mahdi; 34; 20/5/1969; Plant Island, Assuan; CAI.
Antidesma membranaceum Müll.Arg.	Mohammed El Mahdi; 2363; 23 Nov.1967; Burundi –Teritoire Bubanza, Route de Musigati; CAI.
Antidesma montanum Blume	J. W. Helfer; 19; 1937; India orientalis, in Bengalia circa Calcuttam; CAI.
Antidesma venosum E. Mey. ex Tul.	Lewalle; 999; 19 June 1966; Burundi; CAI.
Breynia disticha J.R. Forst. & G. Forst.	Mohammed El Mahdi; s.n.; 16/7/1963; Orman Garden, Giza; CAI.
Bridelia atroviridis Müll.Arg.	Mohammed El Mahdi; 3390; 23 Mars 1969; Burundi; CAI.
Bridelia brideliifolia (Pax) Fedde subsp. *pubescentifolia* J. Léonard	Mohammed El Mahdi; 4061; 14 Nov. 1969; Bugarama; CAI.
Bridelia micrantha (Hochst.) Baill.	J. Lewalle; 1970; 26/5/1967; Burundi, Cib Itoke; CAI. A.S. Mkeya & E. Masangulla; 1172; 9 December 1999; Arusha, Arumeru District; CAI.
Bridelia ndellensis Beille	Mohammed Drar; 2437; 15/5/1988; Kabe, Gebel Marra, Darfur; CAI.
Bridelia scleroneura Müll.Arg.	J. Lewalle; 2831; 14 fevr. 1968; Gihanga, champ de tir, Savane boisee; CAI. Amin Michaiel; 719; 20/10/1984; Yambio Equatoria, Sudan; CAI.
Bridelia tomentosa Blume var. *chinensis* Müll.Arg.	J. W. Helfer; 12; 1937; India orientalis, in Bengalia circa Calcuttam; CAI.
Flueggea suffruticosa (Pall.) Baill.	Webster, s.n.; 19.8.1965; Kaba Mountain Woods, Japan, Hondo; CAI.
Flueggea virosa (Roxb. ex Willd.) Royle	Amin Michail; 716; 1954; Botanie Garden, Sudan; CAI.
Hymenocardia acida Tul.	M. Drar & M. El Mahdi; 1175; 11/4/1938; Kaggalo, Way to Yei; CAI.
Leptopus chinensis (Bunge) Pojark	M. Kocmomov; s.n.; 1978; Caucasia, Russia; CAI.
Margaritaria discoidea (Baill.) Webster	J. Lewalle; 1240; 15 Nov.1966; Burundi; CAI.
Phyllanthopsis phyllanthoides (Nutt.) Voronts. & Petra Hoffm.	Vivi Tackholm and Ibrahim Elsayed; s.n.; 24/5/ 1962; Alfred Bircher's Garden, El Saff; CAI. "Kept as *Andrachne roemeriana* Muell.Arg."
Phyllanthus acidus Skeels	Vivi Tackholm and Ibrahim Elsayed; s.n.; 21/7/ 1963; Alfred Bircher's Garden, El Saff; CAI.
Phyllanthus alpestris Beille	J. G. Adam; 28786; 27 Juillet 1974; Liberia Mont Nimba; CAI.
Phyllanthus amarus Schum.	M. Kassas, M. D. Elkhalifa & M. O. Mobarak, 961; 25/12/1965; Fasher – Qoz, Darfur, Khartoum; CAI.
Phyllanthus capillaris Schumach. & Thonn.	J. G. Adam; 29029; 1974; Liberia Mont Nimba; CAI.
Phyllanthus columnaris Muell. et Arg.	J. W. Helfer; 22; 1937; India orientalis, in Bengalia circa Calcuttam; CAI.
Phyllanthus elegans Wall. ex Müll.Arg.	J. W. Helfer; *s. n.;* 1936; Bengalia circa, Calcutta; CAI.
Phyllanthus emblica L.	T. Labib; *s. n*.; 27.9.2007; Donato farm, Khatatteba, Egypt; CAI. V. Tackholm and I. ElSayed; s. n.; 22.11.1962; North Garden, El Saff, Egypt; CAI.
Phyllanthus gardnerianus (Wight) Baill.	V. V. Shivara Jan*; s. n.;* 2.8.1972; Calient; CAI.
Phyllanthus maderaspatensis L.	M. Kassas, M.O. Mobarak, B. Fadlallah, M. Othman and Hamad A. Omar; E614; 19.12.1967; Doka-Gallabat, Sudan; CAI. G. Tackholm; *s. n*.; 1929; Gebel Elba, Egypt; CAI.
Phyllanthus muellerianus (Kuntze) Exell	M. Drar; 1148; 11.4.1938; Bahr el ghazal, southern Sudan; CAI.
Phyllanthus niruri L.	M. Drar; E254; 28.2.1938; Mogran, White Nile, Sudan; CAI. M. Kassas, M.O. Mobarak, B. Fadlallah, M. Othman and Hamad A. Omar; E415; 13.12.1967; Kassala district, Sudan; CAI. Bror pettersson; 16782; 1962; Northern provience, Wadi Halfa; Sudan; CAI.
Phyllanthus nummulariifolius subsp. *nummulariifolius*	M. Kassas, M.O. Mobarak, and Hamad A. Omar*; s.n*.; 196; Sudan; CAI.
Phyllanthus odontadenius Mull. Arg.	J. G. Adam; 29014; 1974; Liberia Mont Nimba; CAI.
Phyllanthus rotundifolius Klein ex Willd.	V. Tackholm, M. kassas, H. Fawzy, F. Shalaby, M. Samy; *s. n*.; 20.1.1962; Gebel Elba; CAI. A. Migahed; 16; 1970; Salbokh area, Saudi Arabia; CAI. M. Kassas, M.O. Mobarak, and Hamad A. Omar;761; 16.12.1966; Khan Arbat, Sudan; CAI.
Phyllanthus reticulatus Poir.	M. Kassas, M.D. ElKhalifa and M. O. Mobarak; 818; 22.2.1965; Sudan; CAI. El-Shafei M. Badawi; 348; 2011; Darfour, Dalingi, Banjadeed, Sudan; CAI.
Pseudolachnostylis maproneifolia Pax	J. Lewalle; 2663; 9 Jan. 1968; Burundi; CAI.
Uapaca bojeri Baill.	Christina Brydolf; *s.n*.; 27.2.1967; Madgascar; CAI.
Uapaca kirkiana Muell. Arg.	J. Lewalle; 3983; 2 Nov. 1969; Burundi; CAI.