A REVIEW OF THE TAXONOMY OF AFRICAN SAPINDACEAE BASED ON QUANTITATIVE AND QUALITATIVE CHARACTERS

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ABSTRACT

This study was conducted using qualitative and quantitative morphology to characterise and group different representative species of the family Sapindaceae in Africa. The morphological characters used included leaf, stem and fruit. Essentially, the similarities among various taxa in the family were estimated. A total of 28 genera and 106 species were assessed. Members possess compound leaves (paripinnate, imparipinnate or trifoliolate); flowers are in clusters, fruits occur as berry, drupe or capsule and contain seed with white or orange aril. UPGMA dendograms were generated showing relationships amongst taxa studied. The dendograms consists of a single cluster from 0 57 % similarity coefficients suggesting a single line decent of the members of the family. At 65 % two clusters were observed with *Majidea fosterii* being separated from the cluster. Also, at 67 % similarity coefficient, two clusters were discerned separating the climbing forms from the shrubby forms. *Paullinia pinnata* was separated from the other climbing forms at 67 % while *Allophylus* species were separated into two clusters at 91 % similarity coefficient. The dendograms revealed that the family can be separated into eleven (11) clusters based on qualitative morphological data. A key to the identification of genera is presented in this work.

Key words: Clusters, Dendogram, Identification, UPGMA, Sapindaceae.

INTRODUCTION

The forests in Africa are rich in living organisms and the plant community is particularly rich in great woody trees, lianes, vines, arborescent and herbaceous epiphytes and other plant forms. Sapindaceae Juss. is a family of flowering plants comprising about 1900 species which are predominantly of pan-tropical distribution (Buerki *et al.*, 2009). Members of the family grow in the under storey of forests either as shrubs and trees. They contain milky sap and many contain mildly toxic saponins with soap-like qualities in the leaves and/or the seeds, or roots. Usually they have compound spirally alternate leaves which are sometimes (in *Acer, Aesculus*, and a few other genera) opposite (Buerki *et al.,* 2009). They are most often pinnately compound, sometimes bipinnate or palmately compound, or just palmate (*Acer*, *Aesculus*); with a petiole lacking stipules, but having a swollen base (Singh, 2004).

According to Buerki *et al.* (2009), "the circumscription of the family as well as the relationships among subfamilial entities have been widely challenged since the very first worldwide treatment of Sapindaceae *sensu stricto* (*s.s.*) (including subfamilies Sapindoideae and Dodonaeoideae) proposed by Radlkofer (1890; 1933)". Several methods have been adopted to solve this problem but with only a little success. Within Sapindaceae s.s., higher taxonomic entities were originally defined by Radlkofer (1933) based on the leaf type, cotyledon shape, fruit morphology, number and type of ovules per locule as well as presence or absence of an arillode. However, this was revised by Müller and Leenhouts (1976) mainly on the basis of macromorphological and palynological characters. Though, a number of investigations have been carried out on the characterization of the family Sapindaceae, little work has been recorded on the African species. Consequently, this project aims at carrying out morphological characterization on members of the family Sapindaceae in Africa with emphasis on the collection, identification and preservation of voucher specimen in secure repositories as well as classification of taxa with a view to showing the relationships among the plant species.

MATERIALS AND METHODS

The grouping used in this study is based on

morphological (vegetative and reproductive), characteristics of the plants collected, which were as far as possible obtained from herbaria and field studies (Table 1).

Source of Plant Materials

Herbarium, dried and fresh samples were used for the study. Plant materials were collected from fields, botanical gardens, forest reserves and this was complemented with herbarium samples.

Identification of the Plant Samples

Preliminary identification was achieved with the aid of floras including Hutchinson and Daziel, (1958); Fouilloy and Hallé, (1973), Cheek *et al.*, (2000). Voucher specimens were prepared and sent to the Forestry Herbarium, Ibadan for authentication. Further authentication of samples was carried out at the Royal Botanic Gardens Kew, UK**.** The voucher specimens were then deposited at the University of Lagos Herbarium for reference purpose.

Morphological Characterization

Both vegetative and reproductive characters of the plants were used in the description of the family (Table 1).

Vegetative Characterization

Qualitative features such as leaf apex, leaf base, leaf shape and surfaces of leaf and stem were visually assessed or sometimes aided by x10 magnifying hand lens. Quantitative characteristics like leaf size, petiole length, leaf blade length, and plant height were determined using thread and meter rule.

Reproductive Characterization

Qualitative characters such as bract colour, bract margin, bract surface, colour of style and seed, seed shape and fruit surface were determined with naked eyes and sometimes aided by x10 magnifying hand lens. Quantitative features such as length of inflorescence and other cells, sizes of fruit and seed were determined with meter rule while inflorescence number per plant was estimated by direct counting.

Data Analysis

Pair-wise distances (similarity) matrices were computed for all the morphological data using sequential, hierarchical and nested (SAHN) clustering option of the NTSYS-pc 2.02j software package (Rohlf, 1993). The program generated dendograms, which grouped the test lines on the basis of Nei genetic distances using Unweighted Pair Group Method with arithmetic Average (UPGMA) cluster analysis (Sneath and Sokal, 1973).

RESULTS

Sample exploration revealed that members of the family can be largely grouped into trees (*Aporrhiza, Atalaya, Blighia, Chytranthus, Deinbollia, Dodonaea, Eriocoelum, Ganophyllum, Lecaniodiscus, Lepisanthes, Litchi, Lychnodiscus, Majidea, Melicoccus, Nephelium, Placodiscus, Radlkofera, Sapindus, Schleichera* and *Zanha*), shrubs (*Allophylus, Glenniea, Haplocoelum, Harpullia, Laccodiscus* and *Pancovia*) and climbers (*Cardiospermum and Paullinia*).

Members of the family Sapindaceae have compound leaves, paripinnate or trifoliolate leaves with exception to *Dodonaea* (Plate 1). The leaf surface is papery and glossy as in *Litchi chinensis*, glabrous or pubescent (e.g. *Laccodiscus ferrugineus* and *Allophylus hirtellus*). The margin is serrated in some taxa i.e. *Allophylus* and *Cardiospermum* while in others it is entire. The leaves are arranged in either sub-opposite or alternate form. Petiole is present, usually bulbous and short with tendrils in the climbing forms and sometimes pubescent in some taxa.

Table 1: List of Characters, Character States and Codes used in Numerical Analysis

Characters	Character States and Code
Habit	1. Climber 2. Shrub 3. Tree
	Stem Characters
Stem girth	Actual mean value for each taxon
Stem surface	1. Glabrous 2. Pubescent
	Foliar Characters
Leaf apex	1. Acuminate 2. Acute
Leaf arrangement	1. Alternate 2. Sub-opposite
Leaf base	1. Acute 2. Cuneate
Leaf blade length	Actual mean value
Leaf length	Actual mean value
Leaf margin	1. Entire 2. Dentate 3. Serrate
Leaf surface	1. Papery/Leathery/Glossy 2. Pubescent
Leaf type	1. Compound imparipinnate 2. Compound paripinnate 3. Simple
Leaf venation	1. Pinnate 2. Reticulate
Leaf width	Actual mean value
Number of Leaflets	Actual mean value
Overall leaf shape	1. Elliptic 2. Oblong 3. Obovate
Petiole length	Actual mean value
Petiole surface	1. Glabrous 2. Pubescent
	Inflorescence Characters
Inflorescence length	Actual mean value
Inflorescence type	1. Cyme 2. Raceme
	Floral Characters
Flower colour	1. Pink 2. Pinkish white 3. Creamy white 4. Red 5. Yellow
Flower Symmetry	1. Actinomorphic 2. Zygomorphic
Petal colour	1. White 2. Green 3. Yellow
Number of petals	Actual mean value
Sepal colour	1. White 2. Green
Number of sepals	Actual mean value
	Fruit Characters
Fruit size	Actual mean value
Fruit type	1. Berry 2. Capsule 3. Drupe 4. Inflated 5. Dehiscent 6. Indehiscent 7. Schizocarp
Fruit shape	1. Ellipsoidal 2. Ovoid 3. Flat/trilobed 4. Obovoid 5. Cocci 6. Subglobose/Subspherical 7. Globose/Spherical
Fruit wings	1. 2-winged 2. Trigonous (3-winged) 3. No wings
Fruit colour	1. Red 2. Green 3. Orange
Number of seeds	Actual mean value
Seed shape	1. Globose 2. Oval
Seed size	Actual mean value

Plate 1: Members of Sapindaceae showing Leaves, Flowers and Fruit
(a) *Allophylus africanus* showing berry fruit; (b) *Allophylus spicatus* showing trifoliolate leaves and fruits; (C) *Cardiospermum grandiflorum* showing flower; (d) *Blighia sapida* showing capsule fruit; (e) *Glennia africanus* showing berry fruits; (f) *Laccodiscus ferrugineus showing leaves*. Scale bars: 20 mm

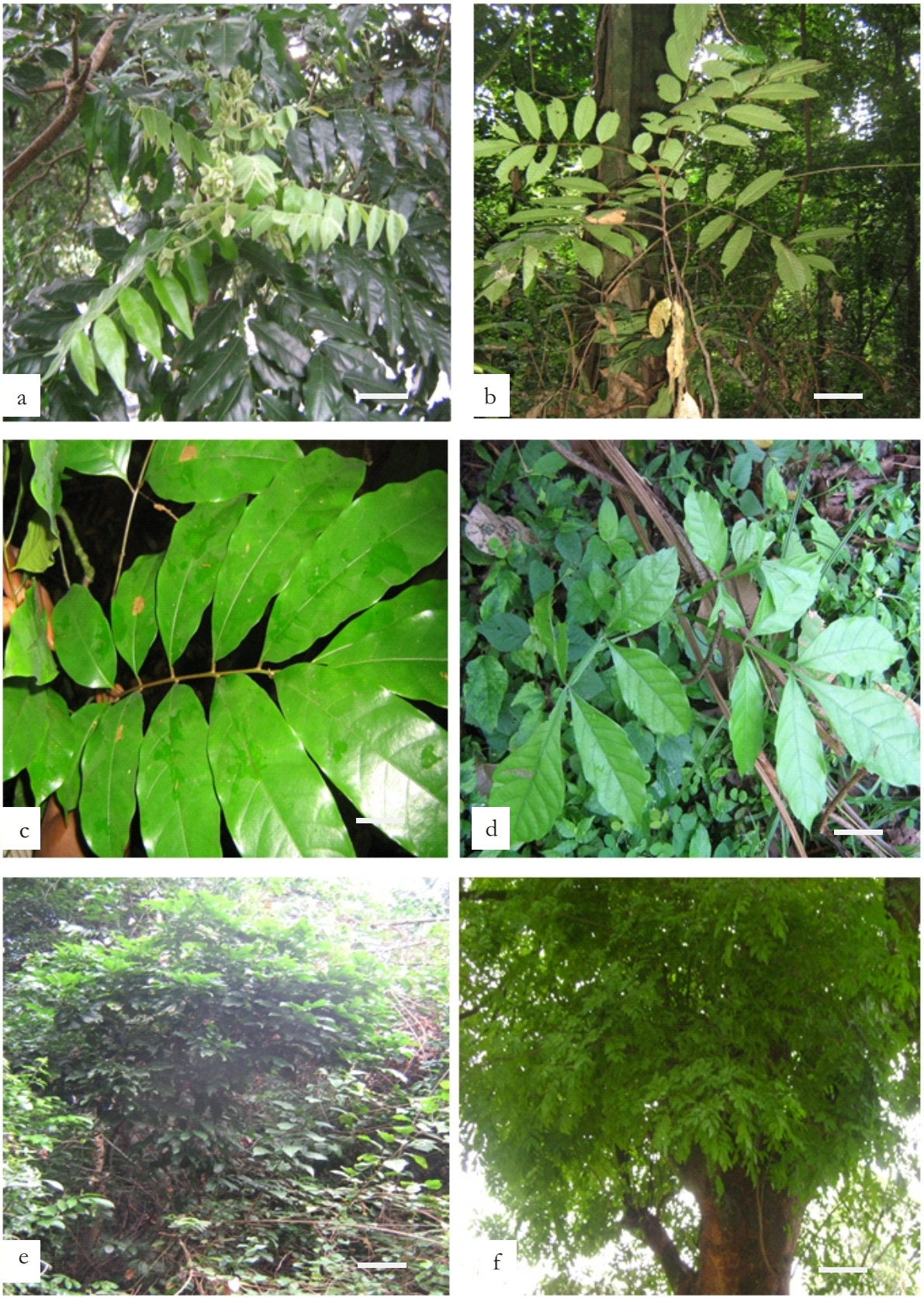

Plate 2: Some members of Sapindaceae in Africa
(a) *Majidea fosterii* showing leaves and white flowers; (b) *Placodiscus* sp *showing leaves; (c) Pancovia sp showing paripinnate leaves; (d) Paullinia pinnata showing imparipinnate leaves; (e) Radlkofera calodendron showing paripinnate leaves;* (f) *Zanha golugensis showing paripinnate leaves* and trunk. Scale bars: 20 mm

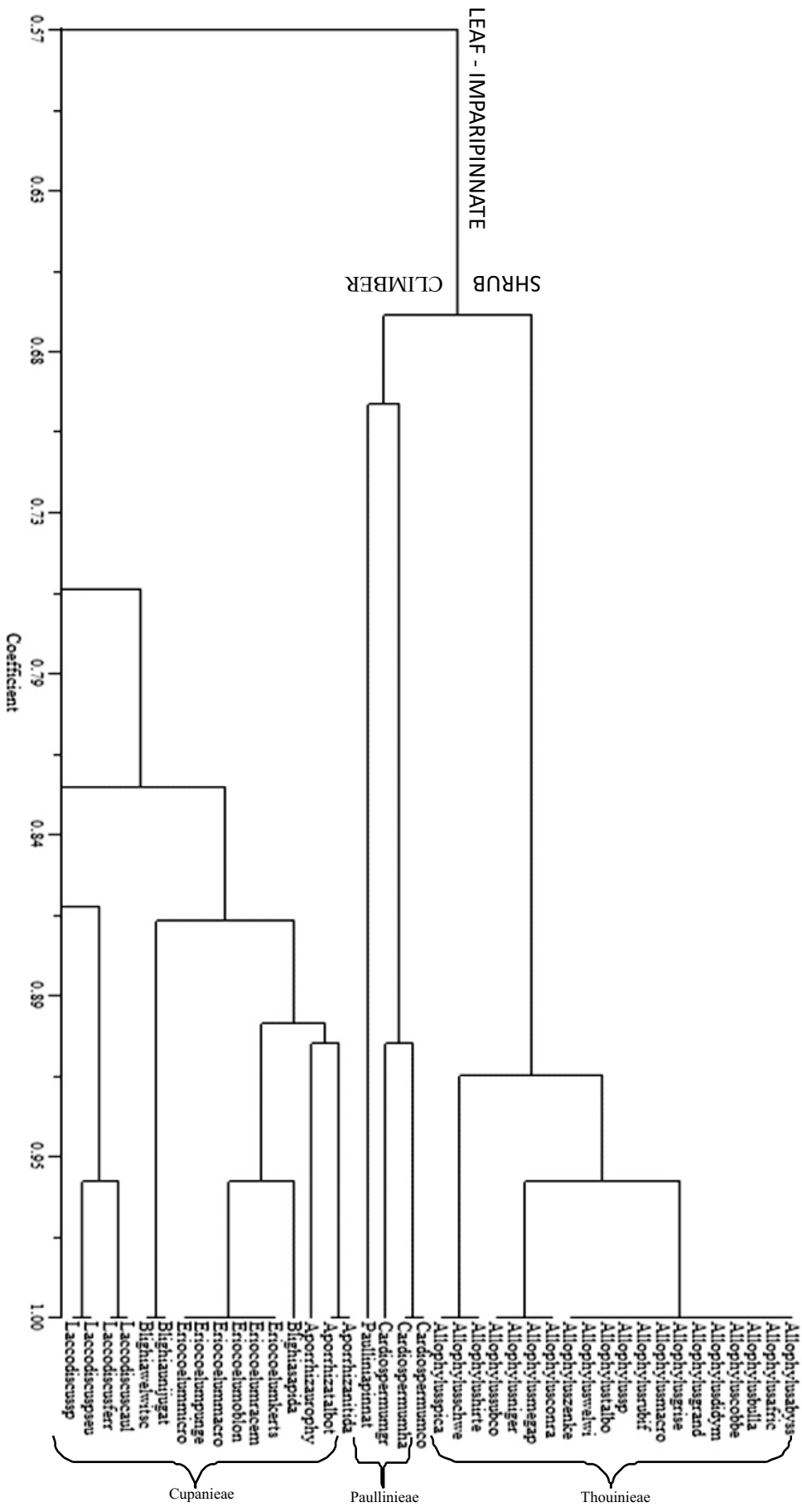

Figure 1: Pair-wise (Similarity) Analysis showing Relationships within Sapindaceae based on Morphological Data.

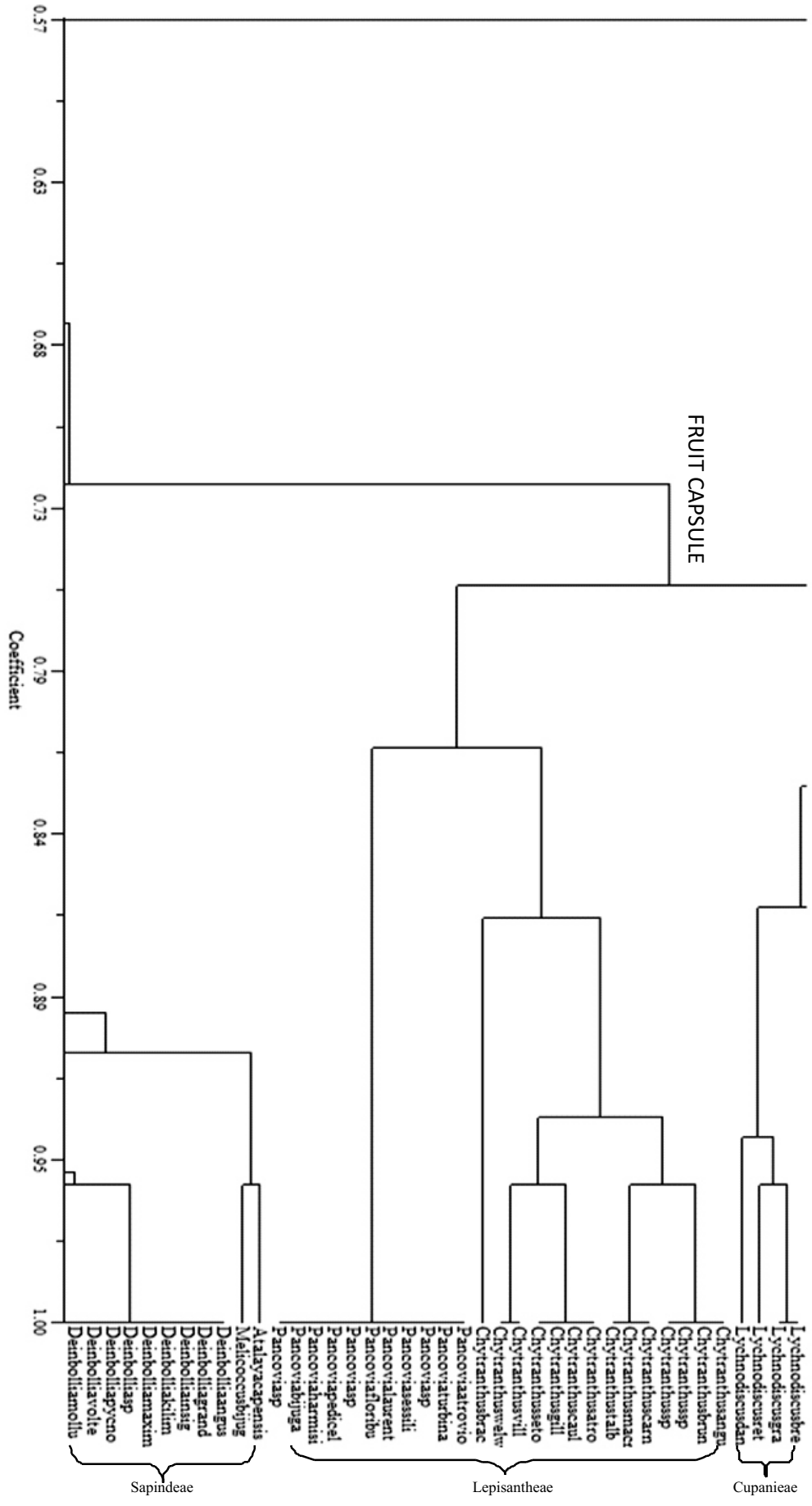

Figure 1: Pair-wise (Similarity) Analysis showing Relationships within Sapindaceae based on Morphological Data (cont'd).

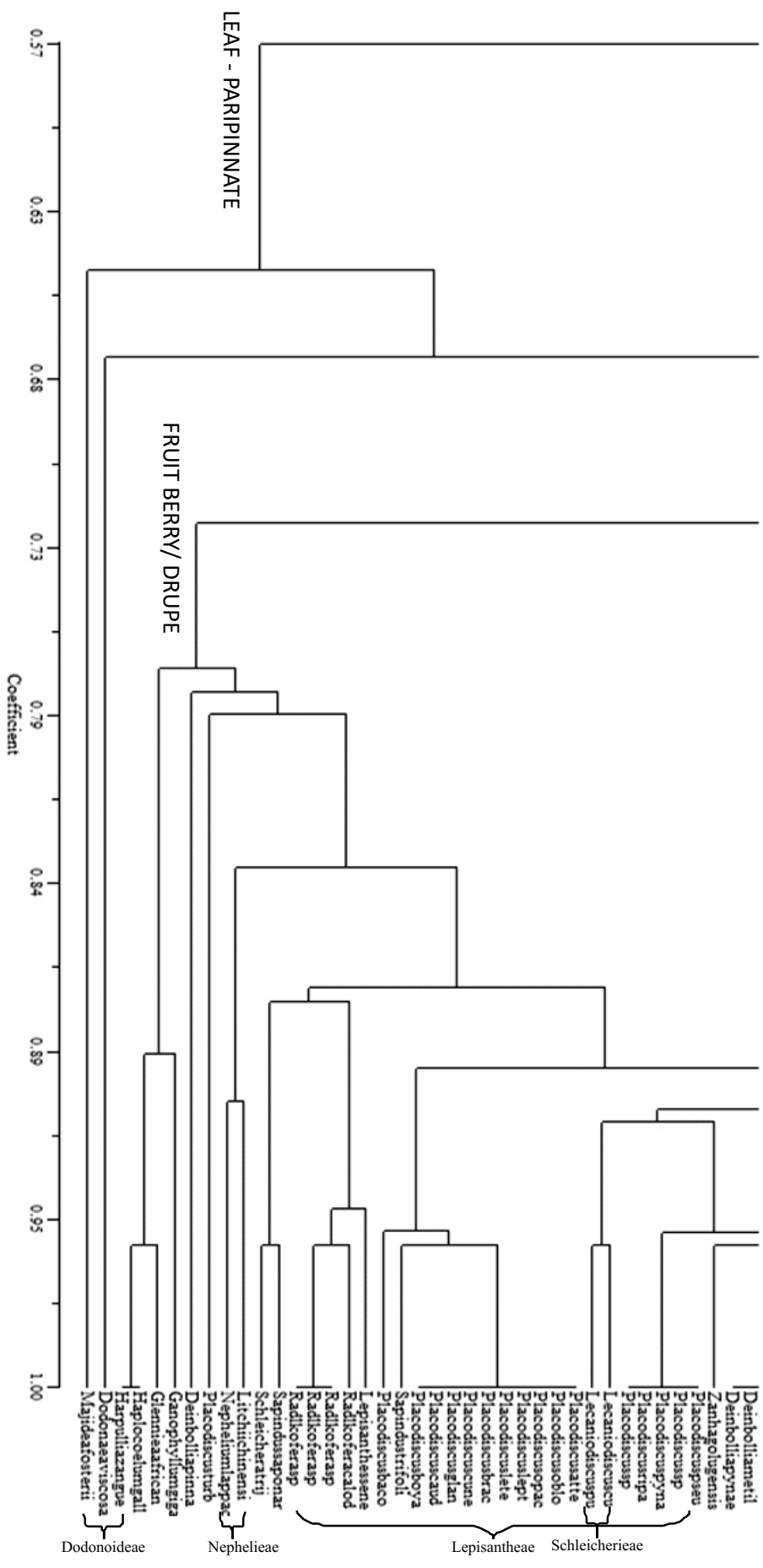

Figure 1: Pair-wise (Similarity) Analysis showing Relationships within Sapindaceae based on Morphological Data (cont'd).

Flowers are arranged in groups, usually creamy white but sometimes pinkish white as in *Dodonaea*. Inflorescence is usually in form of raceme or cyme. Fruits are green in colour turning orange or red as they become ripe however they are brown in *Dodonaea* species. They occur in form of berry, drupe or capsule (3 or 5-lobed) with black colour seed usually with ovoid or sub-globose shape. (Plate 2)

Pair-wise similarity analysis of the data support most of the taxonomic groups arrived at by various orthodox methods. UPGMA dendogram generated showed relationships amongst taxa assessed (Fig. 1). The dendograms consist of a single cluster from 0 - 57 % similarity coefficient suggesting the monophyletic nature of the family. It also revealed that the family can be separated into eleven (11) groups based on qualitative morphological data.

DISCUSSION AND CONCLUSION

In the recent past, several attempts have been made at describing and conserving members of the family Sapindaceae worldwide. However, factors such as high rate of deforestation and agricultural practices continue to pose threats to the continued survival of constituent species especially in Africa (Adeyemi *et al.,* 2012). Also, a large representative of the family is seen to be under some form of threat in the IUCN R.L. (2008).

In this study, a total of twenty eight genera were encountered and identified as members of Sapindaceae. They were found largely in the lowland forest region with a few taxa located in the highlands and mountains (*Allophylus bullatus* L., *Schleichera trijuga* Willd. and *Sapindus saponaria* L.). All the observations made in this study are consistent with earlier description of the family given by Heywood (1978), Singh (2004) and Acevedo-Rodríguez *et al.* (2011).

The vegetative and reproductive morphology of Sapindaceae shows similarities and differences among the various genera constituting the family. Pair-wise analysis of qualitative data generated a dendogram. A common feature in the dendogram is the clear separation of the family into two major clusters equivalent to the two subfamilies recognised within the family Sapindaceae i.e. Sapindoideae and Dodonaeoideae. However, within the 1st cluster (representing Sapindoideae) the genera were separated first based on the type of leaves they bear then by the type of fruits produced. Hence *Allophylus, Cardiospermum and Paullinia* were grouped in the same cluster and separated from all the other genera in the subfamily Sapindoideae due to their imparipinnate leaf type. Furthermore, *Allophylus* was separated from the other two genera based on its nonclimbing habit at 67 % similarity coefficient. *Allophylus* species were separated into two clusters at 91 % while *Allophylus spicatus, Allophylus hirtellus* and *Allophylus schweinfurthii* were delimited from all the other *Allophylus* species due to the presence of hairs on their leaves. *Paullinia pinnata* was separated from the other climbing forms at 67 % similarity coefficient.

Furthermore, members of the Sapindaceae bearing paripinnate leaves were delimited using reproductive morphology, especially the fruits, thereby forming two major sub-clusters: one consisting of capsule-bearing genera (including *Aporrhiza, Blighia, Chytranthus, Eriocoelum, Laccodiscus, Lychnodiscus* and *Pancovia*) and the other comprising berry - or drupe-bearing genera (including *Atalaya, Deinbollia, Glenniea, Harpullia, Haplocoelum, Lecaniodiscus, Lepisanthes, Litchi, Melicoccus, Nephelium, Placodiscus, Radlkofera, Sapindus* and *Schleichera*). At 65 % two clusters were discerned with *Majidea fosterii* being separated from the cluster.

In conclusion, this work has been able to give concise information on the macro-morphology of the various life forms represented within the family Sapindaceae in Africa hence it would serve as an essential identification tool for field researchers and a basis for further taxonomic work on African Sapindaceae.

Key to Genera:

A tropical family comprising trees, shrubs or climbers with simple, imparipinnate or paripinnate leaves and fruits in form of drupe, berry or capsule.

1a. Leaves imparipinnate, simple, biternate or trifoliate..... 2
2a. Tree or Shrub, tendril absent..... 3
3a. Leaves simple, fruit dehiscent capsule..... *Dodonaea*
3b. Leaves trifoliolate, fruit indehiscent berry..... *Allophylus*
2b. Climbing plant, tendril present..... 4
4a. Woody, leaves imparipinnate, margin dentate, fruit not inflated……. *Paullinia*
4b. Herbaceous, leaves biternate, margin serrate, fruit inflated……..…..... *Cardiospermum*
1b. Leaves paripinnate, leaflets 3 10 pairs..... 5
5a. Fruit dehiscent, ovary 2 or 3 lobed..... 6
6a. Inflorescence cymose, not less than 10 cm long..... 7
7a. Shrub, leaf elliptic 8 - 12 cm long..... *Laccodiscus*
7b. Small tree, leaf oblong 10 - 25 cm long..... *Lychnodiscus*
6b. Inflorescence raceme, less than 10 cm long..... 8
8a. Fruit 2-lobed, leaf not more than 15 cm long..... *Aporrhiza*
8b. Fruit 3-lobed, leaf up to 30 cm long..... 9
9a. Inflorescence up to 20 cm long, seed without aril..... *Pancovia*
9b. Inflorescence less than 20 cm long, seed with orange aril…….. 10
10a. Leaflets 5 pairs, base acute……..….....…… *Blighia*
10b. Leaflets more than 5 pairs, base cuneate..... *Eriocoelum*
5b. Fruit indehiscent, ovary 1 3-lobed..... 11
11a. Tree, seeds without aril..... 12
12a. Petiole less than 5 cm long, ovary 3-lobed.....13
13a. Leaf apex cuspidate, leaflets less than 30 cm long, stamen 7-15……..……..….. *Chytranthus*
13b. Leaf apex acuminate, leaflets less than 45 cm long, stamen 8...……..…….…….... *Placodiscus*
12b. Petiole up to 10 cm long, ovary 1-lobed……..... 14
14a. Fruit berry, 3 - 8 cm in diam ...….... 15
15a. Leaf venation pinnate, petiole pubescent ……..... *Lecaniodiscus*
15b Leaf venation reticulate, petiole glabrous…..…... 16
16a. Leaflet less than 12 cm long, blade up to 34 cm long……..…….... *Sapindus*
16b. Leaflets more than 12 cm long, blade up to 42 cm long..... *Schleichera*
14b. Fruit drupe, up to 10cm in diam…….……...……... 17
17a. Leaflets 3 - 9 pairs, inflorescence raceme……...…… 18
18a. Leaf shape oblong, leaflets 5 - 9 pairs, seed 1..... *Deinbollia*
18b. Leaf shape obovate, leaflets 4 pairs, seed 2..... *Radlkofera*
17b. Leaflets 5 pairs, inflorescence cyme..…... 19
19a. Leaf shape oblong, inflorescence 10 - 25 cm long, seed 1..... *Zanha*
19b. Leaf shape obovate, inflorescence 8 - 15 cm long, seed 2..... *Lepisanthes*
11b. Shrub or tree, seeds with aril..... 20
20a. Shrub, fruit 2-lobed……..... 21
21a. Leaflets 3 pairs, more than 7 cm long..... *Glenniea*
21b. Leaflets 10 pairs, less than 7 cm long..... 22

22a. Inflorescence 10 cm long, leaflets up to 5 cm long…….....*Harpullia*
22b. Inflorescence 10 - 15 cm long, leaflets less than 3 cm long.....*Haplocoelum*
20b. Tree, fruit 1 3-lobed…….. 23
23a. Fruit bladder-like, 3-lobed, inflorescence cyme...*Majidea*
23b. Fruit drupe, 1 2-lobed, inflorescence raceme..... 24
24a. Leaflets 3 - 7 cm wide, seed with white aril…..... 25
25a. Fruit 3 - 6 cm long, seed 3…….*Litchi*
25b. Fruit 5 - 10 cm long, seed 1….....*Nephelium*
24b. Leaflets 2 - 6 cm wide, seed with orange aril..... 26
26a. Leaflets elliptic, 8 - 12 cm long ….....*Ganophyllum*
26b. Leaflets oblong, 4 - 8 cm long...…..... 27
27a. Petiole glabrous, seed 1, inflorescence up to 15 cm...*Atalaya*
27b. Petiole sessile, seed 2, inflorescence less than 10 cm ….. .*Melicoccus*

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