

The Intrafamilial Taxonomy of African Sapindaceae[†]

Temitope O. Onuminya,* Oluwatoyin T. Ogundipe and James D. Olowokudejo

Department of Botany, University of Lagos, Akoka-Yaba, Lagos, Nigeria

*tadeyemi@unilag.edu.ng

Abstract

A brief historical taxonomic sketch as well as distribution of Sapindaceae in West Africa, Cameroon and Madagascar is presented based on extensive study of herbaria and field collections. The infrafamilial taxonomy of the family Sapindaceae was re-examined using both qualitative and quantitative morphological characters. A total of 17 vegetative and 24 reproductive characters were used in the description of the family. 2 subfamilies were recognised; a strongly predominant subfamily – Sapindoideae – with 8 tribes and subfamily – Dodonaeoideae – comprising 3 tribes. A total of 28 genera and 118 species were recorded in the study area. The most diverse genera are *Allophylus* with 20 species followed by *Placodiscus* with 17 species and *Chytranthus* with 14 species. Members of the family are characterised by compound leaves (paripinnate, imparipinnate or trifoliate); flowers are in spirals, fruits occur as berry, drupe or capsule and contain seed with white or orange aril. A descriptive key for the identification of each genus is given.

Keywords: Africa, life-forms, morphology, sapindaceae, systematic diversity, tribes

Introduction

The African mainland has between 40,000 and 60,000 plant species, of which approximately 35,000 are endemic (Programme, 2011). In West Africa, an estimated 9,000 plant species are present with about 2,250 endemic to the region (Myers *et al.*, 2000). The family Sapindaceae consists of about 140 genera with 1500 species worldwide; of these, about 49 genera and 307 taxa are found in Africa (WCMC, 2012). According to Hutchinson and Dalziel (1958), 25 genera are represented in East Africa while 18 genera are represented in West Africa.

Sapindaceae was first proposed by Jussieu (1789) in his *Genera Plantarum* as a family distinct from Aceraceae based on morphology. This family concept has been followed by numerous workers including Cambessedes (1828). Later works such as that of Bentham and Hooker (1862) included Aceraceae, Hippocastanaceae and various genera currently recognised in other families as Staphyleaceae, Sabiaceae and Melianthaceae with Sapindaceae.

Radlkofer (1890, 1933) provided the first worldwide system of classification for the family, recognising 2 subfamilies and 14 tribes. Scholz (1964) provided modern names for the two recognised subfamilies (i.e., Dodonaeoideae Burnett and Sapindoideae Burnett); this rearrangement was followed by Capuron (1969), who, in addition, modified some of the generic concepts. Muller and Leenhouts (1976) proposed a rearrangement to Radlkofer's system that agreed with Scholz's general rearrangement but

[†] Supplementary data available

proposed more substantial changes. They reduced the tribe Aphanieae into Lepisantheae Radlk and suggested the inclusion of the families Aceraceae and Hippocastanaceae into the subfamily Dodonaeoideae, with Hippocastanaceae as part of tribe Harpullieae and Aceraceae in its own tribe. A comparison of different infrafamilial classification systems within Sapindaceae is shown in Table 1.

Several workers have maintained Aceraceae and Hippocastanaceae as separate from Sapindaceae including Takhtajan (1987), Cronquist (1988) and Dahlgren (1989), however, others including Umadevi and Daniel (1991), Judd *et al.* (1994), Gadek *et al.* (1996), Savolainen *et al.* (2000), Thorne (2000), APG II (2003), Harrington *et al.* (2005), Thorne (2007), APG III (2009) and Buerki *et al.* (2009) have adopted a broader concept of the family.

Based on the new assessment of the Sapindaceae s.l. proposed by Thorne (2007) and a broad review of currently described taxa by Buerki *et al.* (2009, 2010), it is now widely accepted that the 1900 species in the family belong to 141 genera divided among 4 subfamilies, viz: Dodonaeoideae Burnett, Hippocastanoideae Burnett, Sapindoideae Burnett and Xanthoceroideae Thorne and Reveal.

As a result of the foregoing, this work attempts to produce the infrafamilial taxonomy of the family Sapindaceae with reference to taxa represented in West Africa, Cameroon and Madagascar.

Table 1: Comparison of Different Intrafamilial Classification Systems within Sapindaceae

Bentham & Hooker (1862)	Radlkofer (1933)	Muller & Leenhouts (1976)	Umadevi & Daniel (1991)	Thorne (2000)
<i>Sub ordo:</i> Sapindeae Acerineae Dodonaeae Meliantheae Staphyleae	Subfamily I: Eusapindaceae nomophyllae 1. Paullinieae 2. Thouinieae Eusapindaceae anomophyllae 3. Sapindeae 4. Aphanieae 5. Lepisantheae 6. Meliococcaeae 7. Schleichereae 8. Nephelaeae 9. Cupanieae	Subfamily II: Sapindoideae Group C 1. Paullinieae 2. Thouinieae Group A 3. Sapindeae, 4. Lepisantheae (incl. Aphanieae) 6. Meliococcaeae; Group B 7. Schleichereae, 8. Nephelieae 9. Cupanieae	Sapindoideae (incl. Hippocastanaceae)	Sapindoideae (incl. Hippocastanaceae)
	Subfamily II: Dyssapindaceae nomophyllae 10. Koelreuterieae 11. Cossignieae 12. Dodonaeae Dyssapindaceae anomophyllae 13. Doratoxyleae 14. Harpullieae (Aceraceae) (Hippocastanaceae)	Subfamily I: Dodonaeoideae 10. Koelreuterieae 11. Cossinieae 12. Dodonaeae 13. Doratoxyleae 14. Harpullieae (including Hippocastanaceae) (Aceraceae)	Koelreuterioideae Dodonaeoideae Aceroideae	Koelreuterioideae Dodonaeoideae Aceroideae Hippocastanoideae

Source: Adapted from Harrington *et al.*, 2005.

Materials and Methods

Taxonomic Concepts

The systematics used in this study is hinged on morphological characteristics of the plants collected, which were obtained from herbaria and field studies.

Sources of Plant Materials

Herbarium (74 spp) and fresh (44 spp) specimens were used. The fresh samples were obtained from the field, botanical gardens and forest reserves in Cameroon (25 spp), Ghana (2 spp), Nigeria (13 spp), Madagascar (1 sp) and Togo (3 spp); complemented with herbarium samples from Forestry Herbarium Ibadan (FHI), Ahmadu Bello University (ABU) Herbarium, University of Ghana Herbarium (GCH), National Herbarium of Cameroon (HNC) and Lagos University Herbarium (LUH), amongst others. Voucher specimens of field collections were prepared and authenticated at the FHI and deposited at the University of Lagos Herbarium (for reference). The identification of samples was achieved using manuals and Floras (Hutchinson and Daziel, 1958; Fouilloy and Halle, 1973; Cheek *et al.*, 2000). Nomenclature, generic delimitation and total species numbers for the genera follow the International Plant Names Index.

Morphological Characterisation

17 vegetative and 24 reproductive characters were used in the description of the family. All qualitative features were visually assessed or by x10 magnifying hand lens. Quantitative characters were determined using thread, metre rule or by direct counting.

Results

Our studies revealed that the West Africa region harbours 28 genera (*Allophylus*, *Aporrhiza*, *Atalaya*, *Blighia*, *Cardiospermum*, *Chytranthus*, *Deinbollia*, *Dodonaea*, *Eriocoelum*, *Ganophyllum*, *Glenniea*, *Haplocoelum*, *Harpullia*, *Laccodiscus*, *Lecaniodiscus*, *Lepisanthes*, *Litchi*, *Lychnodiscus*, *Majidea*, *Melicoccus*, *Nephelium*, *Pancovia*, *Paullinia*, *Placodiscus*, *Radlkofera*, *Sapindus*, *Schleichera* and *Zanha*) and 118 species of Sapindaceae, which represents 1.31% of the total angiosperm flora of the region. Among the 2 subfamilies of Sapindaceae represented in West Africa and Cameroon, Sapindoideae is the most diverse. At the generic level, *Allophylus* is the most diverse group with 20 species representing 16.95% of total Sapindaceae recorded. Second in species' richness is *Placodiscus* (17 species) followed by *Chytranthus* (14 species), *Deinbollia* (12 species) and *Pancovia* (11 species). Members of the family are largely found in the lowland forest region with a few taxa located in the highlands and mountains (*Allophylus bullatus*, *Schleichera trijuga*, *Sapindus saponaria*). The most species-rich regions are Nigeria, western Cameroon and Ghana with 47, 45 and 25 taxa, respectively. A descriptive key for the identification of each genus is given (see e-material).[†]

Sample exploration revealed that members of the family generally occur as small trees (shrubs; Figure 1i) or climbers (*Paullinia*, *Cardiospermum*; Figure 1e).

Key to Genera of African Sapindaceae

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 trifoliolate 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 diameter 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 *Sapindus*
 - 16b. Leaflets more than 12 cm long, blade up to 42 cm *Schleichera*
 - 14b. Fruit drupe, up to 10 cm in diameter 17
 - 17a. Leaflets 3–9 pairs, inflorescence raceme 18
 - 18a. Leaves oblong, leaflets 5–9 pairs, seed 1 *Deinbollia*
 - 18b. Leaves obovate, leaflets 4 pairs, seed 2 *Radlkofera*
 - 17b. Leaflets 5 pairs, inflorescence cyme 19
 - 19a. Leaves oblong, inflorescence 10–25 cm long, seed 1 *Zanha*
 - 19b. Leaves 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 *Glennia*
 - 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*

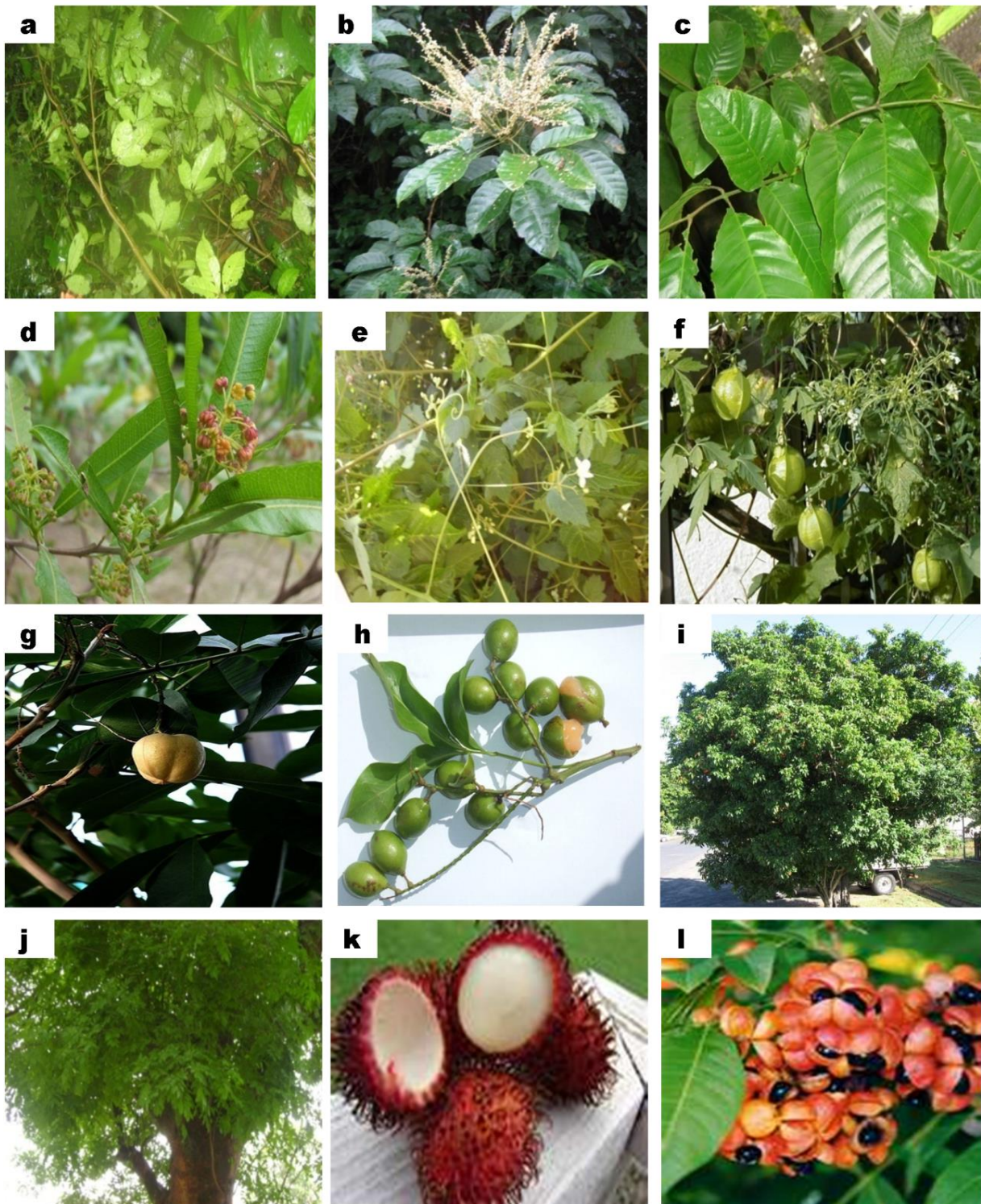


Figure 1: Photographs of characteristic features of Sapindaceae

(a) *Allophylus* spp showing trifoliate leaves; (b) *Allophylus africanus* showing flower; (c) *Eriocoelum macrocarpum* showing compound paripinnate leaves; (d) *Dodonea viscosa* showing simple leaves & inflorescence; (e) *Cardiospermum grandiflorum* showing inflated fruit; (f) *Cardiospermum halicacabum* showing inflated fruit; (g) *Blighia sapida* showing leaves and fruits; (h) *Melicoccus bijugatus* showing berry fruit; (i) *Harpullia pendula* showing shrub plant habit; (j) *Zanha golugensis* showing tree habit; (k) *Nephelium lappaceum* showing ripe hairy drupe with seeds containing aril and (l) *Harpullia pendula* showing drupe.

They have compound leaves; which are trifoliate with serrated margin i.e., *Allophylus* (Figure 1a) and *Cardiospermum* or paripinnate (Figure 1c) with entire margins, however, *Dodonaea* has simple leaves with entire margins (Figure 1d). The leaf arrangement is either sub-opposite or alternate; petiole is present, pubescent in some members and bulbous in nature. Some members possess leaves with glabrous/glossy surfaces as in *Litchi chinensis* while others have pubescent papery surface e.g., *Laccodiscus ferrugineus* and *Allophylus hirtellus*. Flowers are arranged in groups (Figure 1b), usually creamy white but sometimes pinkish white as in *Dodonaea* (Figure 1d). Inflorescence is usually in form of raceme. Fruits are green in colour (Figure 1h) turning orange or red as they become ripe however they are brown in *Dodonaea* species. They occur in form of berry, drupe (Figure 1l), inflated (Figure 1f) or capsule (Figure 1g) with black colour seeds usually with ovoid or sub-globose shape (Figure 1k).

From the herbarium studies, a number of samples which were treated as different species were found to be identical and are treated as cases of synonyms. These are as follows:

- *Crossonephelis africanus* (Radlk.) Leenhouts, *Melanodiscus africanus* Radlk. and *Glenniea africanus* Radlk. are all the same species and the accepted name is *Glenniea africanus* Radlk.
- *Cardiospermum halicacabum* L. and *Cardiospermum corindum* L. are both the same species and the accepted name is *Cardiospermum halicacabum* L.
- *Chytranthus cauliflorus* (Hutch. and Dalzi.) Wickens and *Laccodiscus cauliflorus* Hutch. and Dalzi. are synonyms and the accepted name is *Laccodiscus cauliflorus* Hutch. and Dalzi.
- *Chytranthus bracteosus* Radlk. and *Chytranthus verecundus* N. Halle and ke Assi. are synonyms and the accepted name is *Chytranthus bracteosus* Radlk.
- *Nephelium litchi* L. and *Litchi chinensis* Sonn. are synonyms and the accepted name is *Litchi chinensis* Sonn.
- *Aphania senegalensis* (Juss.) Radlk. and *Lepisanthes senegalensis* Blume are synonyms and the accepted name is *Lepisanthes senegalensis* Blume.

Discussion

Although members of the family Sapindaceae have been recorded to be widely distributed in Africa, their occurrence is being threatened by the high rate of deforestation and agricultural practices, leading to loss of forest and threatened status of the family as

recorded in the IUCN R.L. (2008). However, our sampling revealed that there are twenty eight (28) genera and a hundred and six (106) species in Africa in contrast to the twenty two (22) genera recorded by Burkill (2000). The other six genera include *Aphania*, *Atalaya*, *Ganophyllum*, *Haplocoelum*, *Laccodiscus* and *Litchi*.

Members of the family can be largely grouped into trees, shrubs and climbers with compound paripinnate or trifoliate leaves with exception to *Dodonaea*; petiole is usually bulbous and short with tendrils in the climbing forms. Flowers are usually in form of raceme or cyme while fruits are in form of berry, drupe or capsule (3 or 5 lobed). These observations are consistent with the earlier descriptions of the family given by Heywood (1978) and Singh (2004). Endemism and number of taxa shared are highest between Nigeria and Ghana with nine (9) species endemic to the mountains and the coasts, respectively.

Furthermore, from our assessment, two subfamilies (Sapindoideae and Dodonaeoideae) were recognised. This is consistent with the earlier classifications made by Muller and Leenhouts (1976), Umadevi and Daniel (1991) as well as Thorne (2000). Also, a total of 11 tribes were recognised. This is in contrast to Radlkofer's (1933) as well as Muller and Leenhouts' (1976) reports.

Conclusion

The classification produced here is a result of a detailed taxonomic investigation carried out by the authors and it has formed a basis for a taxonomic revision that recognises 2 subfamilies, 11 tribes and 28 genera.

Acknowledgement

We are grateful to the curators of all the herbaria visited (ABU, BUK, FHI, GCH, HNC, LUH, UIH, SFRK) for granting access to their collections. Also, we appreciate Mr. B. O. Daramola and Mr. T. K. Odewo for their expertise in the identification of the samples.

References

- Angiosperm Phylogeny Group (APG II) (2003). An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. *Botanical Journal of the Linnean Society* **141**: 399–436.
- Bentham, G. and Hooker J. D. (1862). *Genera Plantarum: Ad Exemplaria Imprimis In Herbario Kewensibus Servata*. Voluminis Primi, Pars 1. London: Black A, Hookerian Herbarium, Kew. 454pp.

- Buerki, S., Forest, F., Acevedo-Rodríguez, P., Callmander, M. W., Nylander, J. A. A., Harrington, M., Sanmartín, I., Küpfer, P., and Alvarez, N. (2009). Plastid and nuclear DNA markers reveal intricate relationships at subfamilial and tribal levels in the soapberry family (Sapindaceae). *Molecular Phylogenetics and Evolution* **51**: 238–258.
- Buerki, S., Phillipson, P. B., Lowry II, P. P. and Callmander, M. W. (2010). Molecular phylogenetics and morphological evidence support recognition of *Gereaua*, a new endemic genus of Sapindaceae from Madagascar. *Systematic Botany* **35**: 172–180.
- Burkhill, H. M. (2000). *The Useful Plants of West Tropical Africa*. Volume 5, Edition 2. Royal Botanic Gardens Kew, London. 686pp.
- Cambessedes, A. (1828). *Myrtus grumixama* Vell. *Florae Fluminensis* **5**: 2163
- Capuron, R. (1969). Révision des Sapindacées de Madagascar et des Comores. *Memoirs du Museum National d'Histoire Naturelle Serie B. Botanique* **19**: 1–189.
- Cheek, M., Onana, J. M. and Pollard, B. J. (2000). *The Plants of mount Oku and the Ijim ridge, Cameroon: A Conservation Checklist*. Royal Botanic Gardens, Kew, London. 211pp.
- Cronquist, A. (1988). *The Evolution and Classification of Flowering Plants*. Second edition. New York: New York Botanic Gardens. 555pp.
- Dahlgren, G. (1989). An updated system of classification. *Botanical Journal of the Linnean Society* **100**: 197–203.
- Fouilloy, R. and Hallé, N. (1973). *Flora of Cameroon: Sapindaceae*. Volume 16. National Museum of Natural History, Paris. 202pp.
- Gadek, P. A., Fernando, E. S., Quinn, C. J., Hoot, S. B., Terrazas, T., Sheahan, M. C., Chase, M. W. (1996). Sapindales: molecular delimitation and infraordinal groups. *American Journal of Botany* **83**: 802–811.
- Harrington, M. G., Edwards, K. J., Johnson, S. A., Chase, M. W., Gadek, P. A. (2005). Phylogenetic inference in Sapindaceae sensu lato using plastid matK and rbcL DNA sequences. *Systematic Botany* **30**: 366–382.
- Hutchinson, J. and Daziell, J. M. (1958). *Flora of West Tropical Africa*. Volume 1, Part 2. Crown Agents for Oversea Government and Administrations, Millbank, London. 828pp.
- International Plant Names Index (IPNI) (2011). Available: www.gbif.org/species/ (Accessed on 1st December 2015)
- International Union for Conservation of Nature and Natural Resources (IUCN R.L.) (2008). The IUCN red list of threatened species. International Union for Conservation of Nature and Natural Resources. <http://www.iucnredlist.org/>
- Judd, W. S., Sanders, R. W. and Donoghue, M. J. (1994). Angiosperm family pairs: preliminary phylogenetic analyses. *Harvard Papers in Botany* **5**: 1–51.
- Jussieu, A. L. (1789). *Genera Plantarum Secundum Ordines Naturales Disposita, Juxta Methodum in Horto Regio Parisiensi Exaratam, Anno 1774*. Paris: Herissant and Barrois. 453pp.
- Müller, J. and Leenhouts, P. W. (1976). A general survey of pollen types in Sapindaceae in relation to taxonomy. In: *The Evolutionary Significance of the Exine*. Ferguson, I. K. and Müller, J. (Eds.). London: Academic Press. p. 407–445.
- Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B. and Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature* **403**: 853–858.
- Programme, U. (2011). Biodiversity in Africa. Retrieved from <http://www.eoearth.org/view/article/15050>
- Radlkofer, L. (1890). Ueber die Gliederung der Familie der Sapindaceen. *Sitzungsberichte der Königl. Bayerischen Akademie der Wissenschaften zu München* **20**: 105–379.
- Radlkofer, L. (1933). Sapindaceae. In: Engler, A. (Ed.) *Das Pflanzenreich: Regni Vegetabilis Conspectus (IV) 165 (Heft 98ah)*. Leipzig, Verlag von Wilhelm, Engelmann. p. 983–1002.
- Savolainen, V., Fay, M. F., Albach, D. C., Backlund, M., Van der Bank, M., Cameron, K. M., Johnson, S. A., Lledó, L., Pintaud, J. C., Powell, M., Sheenan, M. C., Soltis, D. E., Soltis, P. S., Weston, P., Whitten, W. M., Wurdack, K. J. and Chase, M. W. (2000). Phylogeny of the eudicots: A nearly complete familial analysis of the rbcL gene sequences. *Kew Bulletin* **55**: 257–309.
- Takhtajan, A. (1987). *Systema Magnoliophytorum*. Russia: Soviet Sciences Press, Leningrad. 437pp.
- Thorne, R. F. (2000). The classification and geography of the flowering plants: dicotyledons of the class Angiospermae. *Botanical Reviews* **66**: 441–647.
- Thorne, R. F. (2007). An update classification of the class Magnoliopsida (“Angiospermae”). *Botanical Reviews* **73**: 67–182.
- Umadevi, I. and Daniel, M. (1991). Chemosystematics of the Sapindaceae. *Feddes Repertorium* **102**: 607–612.
- World Conservation Monitoring Centre (WCMC) (2012). *Global Biodiversity: Status of the Earth's Living Resources*. Springer Science and Business Media, Netherlands. 585pp.