ACTA BIOLOGICA SLOVENICA
LJUBLJANA 2020 Vol. 63, Št. 1: 25–43

On the systematic implication of foliar epidermal micro-morphological and venational characters: diversities in some selected Nigerian species of Combretaceae

Mikromorfološke značilnosti listne povrhnjice in žilnatost listov ter implikacije za sistematiko: raznolikost izbranih nigerijskih vrst iz družine Combretaceae

Opeyemi Philips Akinsulire[a*], Olaniran Temitope Oladipo[a], Oluwabunmi Christy Akinkunmi[b], Oladipo Ebenezer Adeleye[a], Akinwumi Johnson Akinloye[a]

[a]Department of Botany, Obafemi Awolowo University, Ile-Ife, Nigeria
[b]Department of Microbiology, Federal University of Technology, Akure, Nigeria
*correspondence: opeyemibotanist@gmail.com, opeyemiakinsulire@gmail.com

Abstract: Foliar epidermal micro-morphology and venation patterns of eleven species representing four genera in the family Combretaceae revealed stable foliar anatomical characters that are diagnostic and are important in separating the taxa. Distinguishing characters of taxonomic significance in the cells and tissues structures of the species include epidermal cell shape, stomata type, stomata frequency, stomata index, trichome micro-morphology and frequency, areolation shape, vein micro-morphology as well as distribution of druses within areoles. Numerous epidermal striations on the abaxial surface of lamina are diagnostic for *Combretum zenkeri* while *C. platypterum* is distinctly separated from other taxa by the possession of staurocytic stomata in addition to the prominent anomocytic and/or anisocytic stomata. The simple unicellular non-glandular trichomes in the genus *Combretum* indicate a generic attribute classificatory for members of the genus. Druses within the areoles classify *C. platypterum, Terminalia catappa, T. superba* and *Quisqualis indica* within and across the genera studied. This study which is in line with most previous studies revealed that characters of epidermal micromorphology and venation patterns are important in the identification and separation of the taxa discussed, and that the placement of the species in each of their respective genus should be maintained.

Keywords: classification, Combretaceae, diagnostic, epidermal micromorphology, spot character, systematic, venation pattern

Izvleček: Mikromorfologija listne povrhnjice in vzorec žilnatosti listov pri enajstih vrstah iz štirih rodov družine Combretaceae je pokazala, da anatomske lastnosti listov stabilne in pomembne za ločevanje taksonov. Taksonomsko pomembni razlikovalni znaki so oblika epidermalnih celic, tip in pogostost listnih rež, stomatalni indeks, mikromorfologija in pogostost trihomov, oblika areol, mikromorfologija žil, razporeditev drusov v areolah. Za vrsto *Combretum zenkeri* so značilne številne epidermalne

proge na abaksialno stran listne ploskve. Vrsta *C. platypterum* ima poleg anomocitnega in/ali anizocitnega tipa še staurocitni tip rež in se jasno loči od ostalih taksonov. Za rod *Combretum* so značilni enocelični nežlezni trihomi. Druse v areolah imajo *C. platypterum, Terminalia catappa, T. superba* and *Quisqualis indica.* Raziskava prikazuje pomen mikromorfologije povrhnjice in žilnatosti za identifikacijo in ločevanje preučevanih taksonov in podpira uvrstitev v ustrezne rodove.

Ključne besede: Combretaceae, diagnostika, klasifikacija, mikromorfologija povrhnjice, pegavost, sistematika, žilnatost

Introduction

The family Combretaceae belongs to the angiosperm order Myrtales. Gill (1988) reported that the genus consists of 20 genera and 600 species. Stace (2007) put the number of genera in the family at 23. Mabberley (2008) described the family as comprising trees, shrubs, lianas and mangroves largely distributed in tropical and subtropical Africa. The family is also wide spread in **c**entral and south America, southern Asia and northern Australia (Thiombiano et al. 2006). However, Gere et al. (2015) reported that Old world has the bulk of the species richness of the family. Gere (2013) also reported that the genus *Combretum* Loefl. is the only infrageneric taxon. In West Africa, the family is represented by 9 genera with 72 species with the genus *Combretum* being the largest with 49 species (Gill 1988). Keay (1989) reported 25 species in the genus *Combretum* which are mainly straggling shrubs or lianas in Nigeria. Hutchinson and Dalziel (1958) showed that a number of species are indeterminate and occur in the south-eastern Nigeria. The family stands out economically for its ornamental value, with some species commercialized by florists worldwide. Others are cited in the literature as having pharmacological potential and being widely used as popular diuretics or antipyretics. A number of species exhibit antimicrobial, anti-haemorrhagic and antiulcer activities. The ethno-pharmacological importance of Combretaceae which include anti-inflammatory, anthelmintic, anti-bilharzias (anti-schistosomal), treatment of malaria, pain, dermatitis, diarrhea, Pneumonia, gonorrhoea, syphilis, hypertension and cancer have been reported (Baba-Moussa et al. 1999, Fyhrquist et al. 2002, Simon et al. 2003, Martini et al. 2004, Batawila et al. 2005, Coulidiati et al. 2009). Some members of this family produce useful construction timber, such as *idigbo* from *Terminalia ivorensis* A. Chev. A comprehensive vegetative and reproductive morphological description of the eleven species considered in this study has previously been documented by Akinsulire et al. (2018a), while the wood anatomy of the eleven taxa has also been investigated by Oladipo et al. (2016). Other researchers (Carlquist 1988, Kishore et al. 1999, Tilney 2002, Jayeola et al. 2009, Jordaan et al. 2011, Ekeke et al. 2014, Akinsulire et al. 2018b) had also investigated the family but the family Combretaceae is a rather complex one. According to Jayeola et al. (2009), scientific diagnosis calls for a very sound knowledge of anatomical structures. There has been a call for the review of the present taxonomic status of the family Combretaceae. Though Oladipo et al. (2016) and Akinsulire et al. (2018a) reported on the wood anatomy and the vegetative and reproductive morphology respectively of the eleven species in this family, as well as Akinsulire et al. (2018b) on the leaf and petiole anatomy of the genus *Terminalia* L., one of the genera investigated in this paper, there are still gaps to be filled in our knowledge of the family. The taxonomy of the family Combretaceae is unresolved (Ekeke et al. 2015). A lot of conflicting identities exists in the Nigerian species with great morphological signs of introgression (Oladipo et al. 2016). The objective of this study therefore serves to increase our knowledge of the family Combretaceae, identify patterns of variation in the foliar epidermal characteristics and venation patterns of the species and assess their taxonomic value in delimiting members of the family, as well as serving as a follow-up research to those investigations of Oladipo et al. (2016) and Akinsulire et al. (2018a, b).

Materials and methods

Foliar epidermal micro-morphology and venation patterns of 11 species representing four genera in the family Combretaceae in Nigeria were investigated using light microscopy since paucity of information exists on the topological properties of the leaf venation patterns and epidermal micro-morphology of the species and in relation to their taxonomy, thus these traits were far from being well understood. Similarly, the species were selected based on their complexities and their mistaken identities in their respective genus and based their unresolved taxonomy (Akinsulire et al. 2018), their large ecological distributions and on their usefulness in pharmacopeia and other great economic importance (Thiombiano 2005). The species are: *Combretum platypterum* Hutch. and Dals., *Combretum racemosum* P. Beauv, *Combretum zenkeri* Engl. and Diels., *Combretum dolichopetalum* Engl. and Diels., *Terminalia catappa* L, *Terminalia superba* Engl. and Diels., *Terminalia ivorensis* A. Chev., *Terminalia mantaly* H. Perr., *Terminalia avicennioides* Guill. and Perr., *Anogeissus leiocarpus* (DC.) Guill. and Perr. and *Quisqualis indica* Linn.

In addition to these, *A. leiocarpus* and *Q. indica* were selected because the two taxa represent the only West African monotypic genera in the family Combretaceae with their epidermal micro-morphology and venation patterns yet unstudied. Three to five matured and healthy accessions were collected for each of the 11 species while eight to 10 matured leaves were investigated in each of the accessions. All plants collected were in sunlit environments and collections were done during regular field trips to various parts of south-western Nigeria (Fig. 1) and between April and June. The fresh leaf materials were preserved in formalin acetic-alcohol (FAA) (Formaldehyde 10%; Alcohol: 50%; Acetic acid: 5%; Water: 35%) solution. Sizeable portions from the leaves of the species were taken from standard median portion from each species and portions were put into nitric acid, in glass Petri-dishes, and kept in an oven at 60ºC for 20 minutes. Each sample was then washed thoroughly in 4-5 changes of water. The adaxial and the abaxial epidermises were separated by means of fine forceps and dissecting needle. The epidermides were then stained in safranin O solution, and counter stained in Toluidine blue for five minutes, washed with 4-5 changes of water to remove excess stain and then mounted in 25 % glycerol (containing thymol crystals to prevent fungal attack) on a clean glass slide for examination under a light microscope as previously documented (Akinsulire et al. 2018b, Jainab and Kensa 2018, Priya and Hari 2018, Shirsagar and Vaikos 2013, Sonibare et al. 2014). Both qualitative and quantitative characters of the epidermis (including spot characters), which could enhance the identification of the taxa were observed and documented. Stomata index was estimated for the two leaf surfaces using the formula below as proposed by Wilkinson (1979):

$$\text{Stomata index (I)} = S / (S + E) * 100$$

where S = number of stomata per unit area and E = number of ordinary epidermal cell in the same area.

The venation patterns of the species studied were obtained from the median portion of the leaf. The materials were decolourised by boiling in 90 % ethyl alcohol at 20 °C for about 10 - 15 minutes, then washed in 3-4 changes of water to remove all traces of alcohol. The portions were then transferred into 5 % Sodium Hydroxide and boiled for 20 minutes for further decolourization. The partially cleared leaves were further cleared in 5 % domestic bleach (sodium hypochlorate) for 20 - 30 minutes under the sunlight. The portions were again washed in 3-4 changes of water, stained in Safranin O solution and counter stained in Alcian blue (to enhance contrast), rinsed with water (to remove excess stain) before being mounted in 25 % glycerol containing thymol crystals to prevent fungal attack on a clean glass slide for examination under a light microscope (Akinsulire et al. 2018b, Jainab and Kensa 2018 Priya and Hari 2018, Sonibare et al. 2014). Qualitative assessments and terminologies were documented following Metcalfe and Chalk (1979) as well as Manual of Leaf Architecture by the Leaf Architecture Working Group (1999). All quantitative parameters were measured (per field of view with Leica Galen III microscope) using ocular micrometre while the measurements were converted to microns using the stage micrometre with respect to ocular constant and the objective with which the measurements

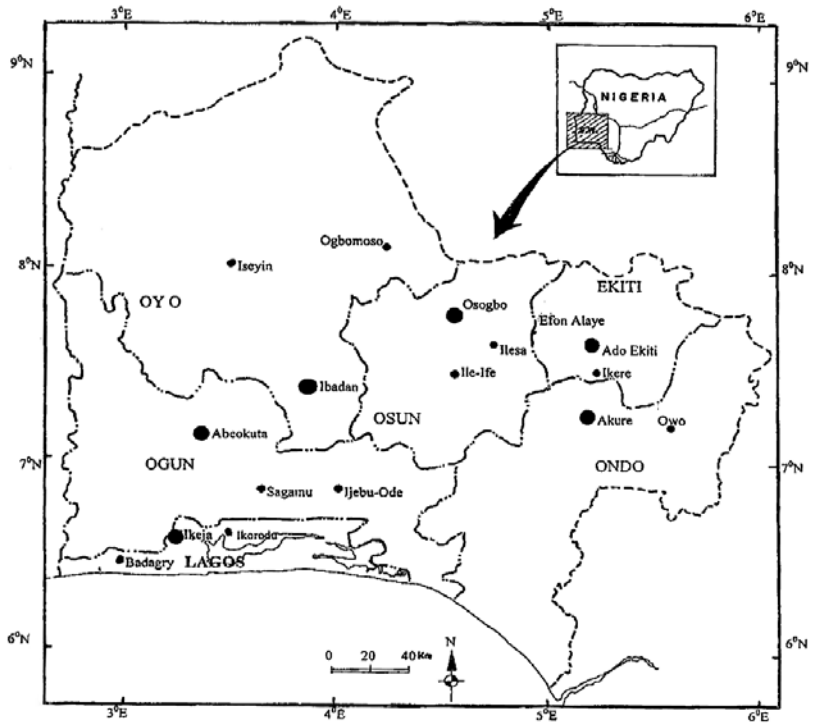

Figure 1: Map of Nigeria showing the sites of collection of plant specimens in southwest (Oladipo et al. 2016)
Slika 1: Zemljevid Nigerije z označenimi mesti vzorčenja na jugovzhodu (Oladipo et al. 2016)

(readings) were taken. Quantitative data were further subjected to One Way Analysis of Variance while means were separated using Duncan Multiple Range Test to show the significant differences within each groups or genera as well as among members of the family.

Results

Overall result of the qualitative and quantitative leaf epidermal micro-morphological and venational characters of the eleven species showed that the characters examined vary significantly ($p < 0.05$) among the taxa while great affinities were also revealed (Tables 1 to 4). A list of the qualitative features are given in Tables 1 and 3 while Tables 2 and 4 shows the dimensions of leaf epidermis and venation in the eleven species as Figs. 2-4 provide photomicrographs of characteristic cells and tissues structures of the species. Spot characters, diagnostic characters as well as other anatomical characters useful in the classification and identification of the taxa and which are good tools in the systematic assessment of members of the family Combretaceae investigated were all presented. Stomata in the family vary from anomocytic to anisocytic or staurocytic. There are variations in the sizes of stomata as well as lengths and widths of epidermal cells. The groupings and delimitation of members of the family agrees with most previous researches.

Combretum platypterum

Adaxial and abaxial leaf surfaces: On the adaxial leaf surface, epidermal cells are polygonal with straight anticlinal walls, size vary between 15.0-27.5 µm long and 7.5-17.5 µm wide, 180-221 cells per field of view, periclinal walls striated, stomata absent. The leaf indumentum shows the pres-

ence of simple unicellular uniseriate non-glandular trichomes, sparsely distributed, frequency 0-4 per field of view (Fig. 2A) while on the abaxial leaf surface, epidermal cells are also polygonal but anticlinal walls ranges between straight to sinuous, size ranging between 12.50-30.00 µm long and 7.50-20.00 µm wide, 100-128 cells per field of view, periclinal walls striated, stomata anomocytic, sometimes staurocytic. Stomatal frequency about 14-43 per field of view, mean stomatal size up to 20.75±0.34 µm long and 14.50 ± 0.29 µm wide, mean stomatal index 19.98%, simple unicellular uniseriate non-glandular trichomes are present, sparsely distributed, frequency 0-1 per field of view (Figs. 3A and A_2).

Venation pattern: Venation is regular polygonal reticulate with well-developed areoles enclosing the veinlets. Areolar shape is triangular to hexagonal (3 to 6 - sided); size ranges between 250.00-580.00 µm long and 180.00-400.00 µm wide, veinlet endings are simple linear, branched or occasionally furcate, 0 - 2 per areole, druses are present in the areoles (Fig. 4A).

Combretum zenkeri

Adaxial and abaxial leaf surfaces: Epidermal cells are largely polygonal, anticlinal walls straight to undulating on the adaxial leaf surface while on the abaxial surface; the cells are irregular and largely covered with epidermal striations with undulating anticlinal walls. Cell size ranges between 10-30 µm long and 7.5-17.5 µm wide, 218-236 cells per field of view on the adaxial leaf surface but 89-118 cells per field of view, 12.50-30.00 µm long and 10.00-20.00 µm wide on the abaxial leaf surface. On the adaxial surface, periclinal walls are not striated, stomata are absent, simple unicellular non-glandular trichomes are present and trichomes frequency about 0-5 per field of view (Fig. 2B). However, on the abaxial leaf surface, periclinal walls are striated, stomata are anomocytic, stomatal frequency 19-36 per field of view, mean stomatal size up to 14.25±0.26 µm long and 7.00±0.23 µm wide, mean stomatal index is 21.83%, simple unicellular non-glandular trichomes are present, frequency 0-6 per field of view (Fig. 3B).

Venation pattern: Venation is regular polygonal reticulate, areoles are moderately developed and enclosing the veinlets, size ranging from 140.00-360.00 µm long to 120.00-280.00 µm wide, areolar shape triangular to hexagonal (3 to 6-sided), veinlet endings mostly simple linear, unbranched, 0 to 1 per areole, druses absent (Fig. 4B).

Combretum racemosum

Adaxial and abaxial leaf surfaces: The epidermal cells on adaxial surface are generally polygonal-with straight to slightly undulating anticlinal walls, size ranges between 12.5-35.0 µm long and 10.0-22.5 µm wide, cell number about 168-204 cells per field of view, periclinal walls not striated, stomata are absent, simple unicellular non-glandular trichomes present, frequency 0-1 per field of view (Fig. 2C), whereas on the abaxial leaf surface, epidermal cells are polygonal, anticlinal walls straight to slightly undulating, size ranging between 10.00-32.50 µm long and 7.50-20.00 µm wide, 115-161 cells per field of view, periclinal walls not striated, stomata anomocytic, stomata frequency 18-31 per field of view, mean stomata size up to 16.50±0.28 µM long and 9.38±0.25 µm wide, mean stomata index 16.57%, simple unicellular non-glandular trichomes are present, trichome frequency 0-4 cells (Fig. 3C).

Venation pattern: Venation is regular polygonal reticulate, areoles moderately developed, shape triangular to hexagonal (3 to 6-sided), and size varies from 450.00-840.00 µm long and 150.00-630.0 0 µm wide. Veinlet endings mostly linear occasionally branched or forked; number range from 1-3 per areole, druses absent (Fig. 4C).

Combretum dolichopetalum

Adaxial and abaxial leaf surfaces: On the adaxial lamina, epidermal cells are generally polygonal, anticlinal walls wavy to sinuous, size ranging between 20.0 – 35.0 µm long and 10.0 – 22.5 µm wide, 208 - 281 cells per field of view, periclinal walls not striated, stomata present, stomata anomocytic, stomata frequency

0 – 2, mean stomatal size 12.88±2.42 µm long and 7.75±1.48 µm wide, mean stomata index is 0.38%, simple unicellular non-glandular trichomes present, few or sparsely distributed, frequency 0 – 6 per field of view (Fig. 2D). Whereas on the abaxial lamina, epidermal cells are generally polygonal with sinuous anticlinal walls (sometimes straight), size ranging between 10.00 – 32.50 µm long and7.50 – 15.00 µm wide, 206 – 245 cells per field of view, periclinal walls striated, stomata anomocytic, stomata frequency 7 – 66 per field of view, mean stomatal size is 18.64±0.29 µm long and 11.00±0.28 µm wide, mean stomata index is 13.01 %, simple unicellular non-glandular trichomes present and are uniformly distributed, frequency 4 – 28 per field of view (Fig. 3D).

Venation pattern: Venation is regular polygonal reticulate, areoles moderately developed or fairly pixilate and random in arrangement, triangular to pentagonal in shape (3 to 5-sided), size ranges between 180.00 – 410.00 µm long and 120.00 – 310.00 µm wide, veinlet endings are mostly linear, occasionally branched, 0 to 3 per areole (Fig. 4D).

Terminalia catappa

Adaxial and abaxial leaf surfaces: On the adaxial lamina surface, epidermal cells are polygonal (triangular to pentagonal), sometimes irregular, anticlinal walls are straight to wavy, periclinal walls not striated, size ranges between 17.50-30.00 µm long and 12.50-20.00 µm wide, 186-226 cells per field of view, periclinal walls not striated, stomata anisocytic, stomata frequency 0–62 per field of view, mean stomata size up to10.25±2.15 µm long and 6.25±1.31 µm wide, mean stomata index is 3.54% (Fig. 2E). On the abaxial leaf surface, epidermal cells are polygonal to irregular, size variable, ranging from 10.00–30.00 µm long and 7.50–12.50 µm wide, 196–305 cells per field of view, anticlinal walls largely wavy, sometimes sinuous, stomata anisocytic, 18–66 cells per field of view, mean stomatal size is 17.50±0.48 µm long and 8.50±0.28 µm wide, mean stomatal index is 11.06 % (Fig. 3E).

Venation pattern: Venation in this taxa is dichotomous, areoles well developed and oriented in arrangement, size variable, ranging from 240.00–730.00 µm long and 150.00–370.00 µm wide, areolation shape triangular to pentagonal (3 to 3-sided). Veinlet endings are simple linear and branched or forked; 0-5 per areole, druses present in the areolar region, sparsely distributed (Fig. 4E).

Terminalia superba

Adaxial and abaxial leaf surfaces: On the adaxial, epidermal cells are irregular on with variable sizes ranging between 15.00–25.00 µm long and 5.00 - 17.50 µm wide, 116-248 cells per field of view, anticlinal walls straight to undulating, periclinal walls not striated stomata absent (Fig. 2F). On the abaxial, epidermal cells are irregular, anticlinal walls wavy to sinuous, cells variable in size, ranging from 12.50–32.50 µm long and 7.50–15.00 µm wide, 110-228 cells per field of view, stomata anomocytic, stomata frequency 18-52 per field of view, mean stomatal size 17.88±0.42 µm long and 9.63±0.38 µm wide, mean stomata index is 16.61% (Fig. 3F).

Venation pattern: Venation is regular polygonal reticulate, areoles well developed with occasional incompletely closed meshes, areole size variable, ranging from 240.00–600.00 µm long and 200.00–290.00 µm wide, triangular to hexagonal areolation shape. Veinlet endings largely linear or simple, occasionally branched or forked, 1 to 3 per areole, druses present in the areole but scanty (Fig. 4F).

Terminalia ivorensis

Adaxial and abaxial leaf surfaces: Epidermal cells are largely irregular on the adaxial surface, anticlinal walls sinuous, periclinal walls not striated, size ranges between 10.00–25.00 µm long and 7.50–15.00 µm wide, 206–292 cells per field of view, stomata absent (Fig. 2G). On the abaxial surface, the epidermal cells largely irregular, size ranges between 10.00–30.00 µm long and 7.50–20.0 µm wide, 201–289 cells per

field of view, anticlinal walls sinuous, periclinal walls not striated, stomata anomocytic, stomatal frequency 34–56 per field of view, mean stomatal size up to 17.75±0.31 µm long and 10.25±0.48 µm wide, mean stomatal index is 16.37%, simple unicellular non-glandular trichomes present, trichomes few or sparsely distributed, frequency 0–1 cell per field of view, trichomes occur only on the main vein epidermis (Fig. 3G)

Venation pattern: Venation in *T. ivorensis* is regular polygonal reticulate, areoles moderately developed and variable in size; ranges between 130.00–420.00 µm long and 100.00–350.00 µm wide, pentagonal to hexagonal in shape (4 to 6-sided), veinlet endings simple, linear, or occasionally branched, 0 to 2 per areole, druses absent (Fig. 4G).

Terminalia mantaly

Adaxial and abaxial leaf surfaces: The adaxial surface has epidermal cells that are largely polygonal with variable size, ranging between 20.00–40.00 µm long and 10.00–22.50 µm wide, 202–228 cells per field of view, anticlinal walls straight to undulating, periclinal walls not striated. Stomata anisocytic, stomata frequency 4 -9 cells per field of view with more or less isodiamtric, 18.75±0.29 µm long and 13.25±0.26 µm wide, mean stomatal index up to 2.92% (Fig. 2H). On the abaxial leaf surface, epidermal cells are mostly polygonal with straight to undulating anticlinal walls, size ranges between 15.00–37.50 µm long and 7.50–17.50 µm wide, 201–260 cells per field of view, periclinal walls not striated. Stomata anisocytic, 2–10 cells per field of view, size range ranges between 20.25±0.44 µm long and 12.88±0.42 µm wide, mean stomatal index up to 2.41% (Fig. 3H)

Venation pattern: Venation is dichotomous, areoles well developed, size ranges between 300.00–580.00 µm long to 160.00–360.00 µm wide, triangular to hexagonal (3 to 6-sided), veinlet endings linear, branched or occasionally furcated, 1 to 3 per areole, druses absent (Fig. 4H).

Terminalia avicennioides

Adaxial and abaxial leaf surface: Epidermal cells largely irregular to polygonal with varying sizes ranging from 10.00–30.00 µm long and 7.50–20.00 µm wide, 125–225 cells per field of view on the adaxial surface. Anticlinal walls are wavy, sometimes undulating, periclinal walls not striated. Stomata and trichomes are absent (Fig. 2I). Whereas, on the abaxial surface, epidermal cells are mostly polygonal with wavy anticlinal walls, size ranges between 12.50–30.00 µm long and 7.50–20.00 µm wide, 90-112 cells per field of view, periclinal walls not striated. Stomata anomocytic, stomatal frequency 51-69 cells per field of view, size ranges between 16.75±0.26 µm long and 8.00±0.23 µm wide, mean stomatal index is 37.86%. Simple, unicellular non-glandular trichomes present, sparsely distributed; trichome frequency 0-8 cells per field of view (Fig. 3I).

Venation pattern: Venation is regular polygonal reticulate, areoles well developed, triangular to haxagonal in shape (3 to 6-sided), and size ranges between 190.00 – 430.00 µm long and110.00 – 350.00 µm wide. Veinlet endings mostly simple and linear, sometimes branched, 0 to 3 per areole, druses absent (Fig. 4I).

Anogeissus leiocarpus

Adaxial and abaxial leaf surfaces: Epidermal cells on the adaxial surface are largely polygonal, anticlinal walls undulating or wavy, size ranging between 10.00–25.00 µm long and 5.00–12.50 µm wide, 228–341 cells per field of view, periclinal walls not striated. Stomata generally absent, simple unicellular non-glandular trichomes present, abundant and uniformly distributed, trichomes frequency 7–20 per field of view (Fig. 2J), meanwhile **o**n the abaxial surface, epidermal cells are generally polygonal, mostly hexagonal, anticlinal walls sinuous, cells vary in size, from 20.00–30.00 µm long to 10.00-15.00 µm wide, 124–158 cells per field of view, periclinal walls not striated, stomata anomocytic, stomatal frequency 36–51 per field of view of view, mean stomatal size 14.13±0.27 µm long and 7.50±0.00 µm wide, mean stomatal index is 22.84%, long simple unicellular

non-glandular trichomes present, frequency 1-7 per field of view (Fig. 3J).

Venation pattern: Venation is alternate percurrent or regular polygonal reticulate, areole imperfectly formed, shape rectangular to hexagonal (4 to 6-sided), size ranges between 270.00-650.00 µm long and 150.00–350.00 µm wide. Veinlet endings mostly simple and linear, occassionally branched, 0 to 2 per areole, druses absent (Fig. 4J).

Quisqualis indica

Adaxial and adaxial leaf surfaces: On the adaxial surface, the epidermal cells are polygonal, largely rectangular, anticlinal walls straight, rarely undulating, size ranges between 20.00–32.50 µm long and 12.50–22.50 µm wide, 126-150 cells per field of view, periclinal walls not striated. Stomata absent, simple unicellular non-glandular trichomes present, few or sparsely distributed and occur only on the main veins, trichome frequency 0–2 per field of view (Fig. 2K) whereas epidermal cells on the abaxial surface are largely polygonal, anticlinal walls slightly sinuous or straight, size ranges between 15.00–30.00 µm long and 12.50–20.00 µm wide, 128–164 cells per field of view, periclinal walls not striated. Stomata anomocytic, stomatal frequency 40–48, mean stomatal size is 15.63±0.25 µm long and 8.25±0.26 µm wide, mean stomatal index up to 23.07%, simple unicellular non-glandular trichomes present, frequency 0 – 2 cells field. (Fig. 3K)

Venation pattern: Venation is regular polygonal reticulate, areoles imperfectly formed, variable in shape, generally triangular to pentagonal (3 to 6-sided), size ranges between 200.00–550.00 µm long and 130.00–370.00 µm wide. Veinlet endings are simple and linear, sometimes branched, 0 to 3 per areole, druses present within the areoles but scanty (Fig. 4K)

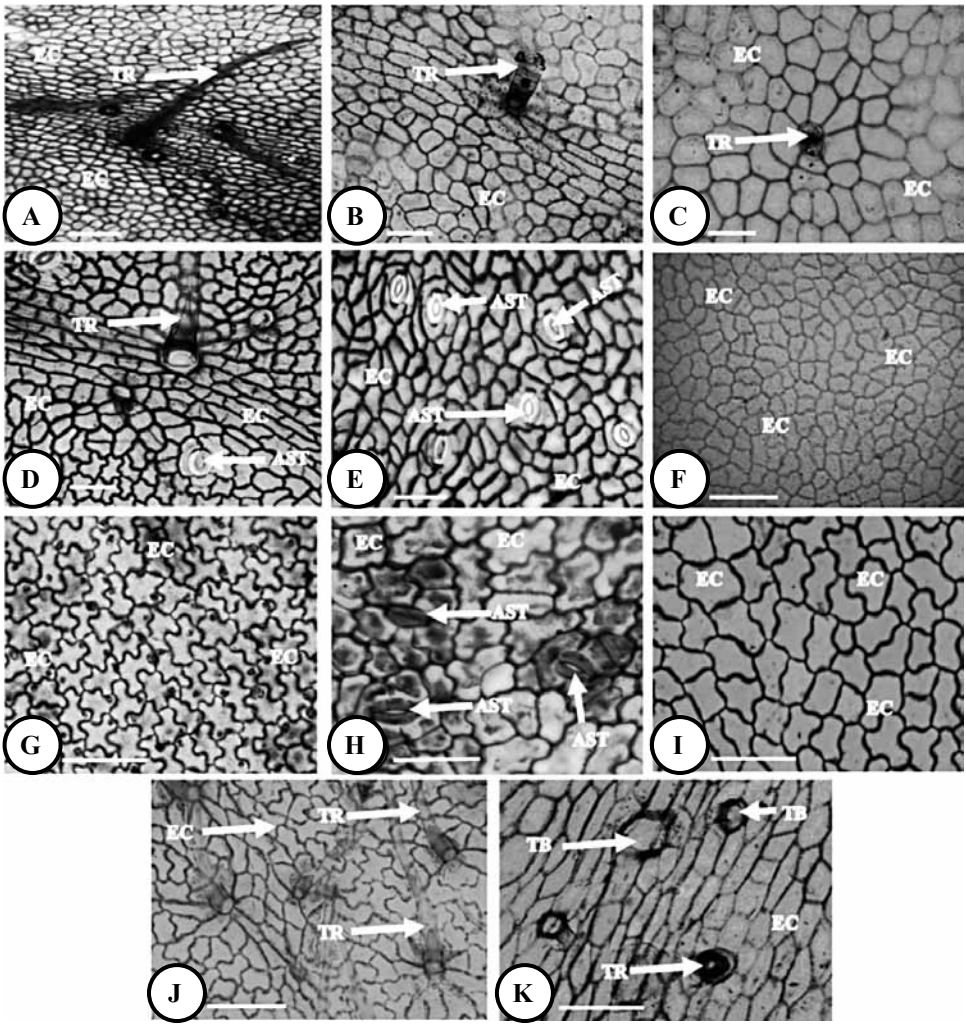

Figure 2: Leaf epidermal micro-morphology of the adaxial leaf surface of eleven species of Combretaceae. (A) *Combretum platypterum,* (B) *C. zenkeri,* (C) *C. racemosum,* (D) *C. dolichopetalum,* (E) *Terminalia catappa,* (F) *T. superba,* (G) *T. ivorensis,* (H) *T. mantaly* (I) *T. avicennioides,* (J) *Anogeissus leiocarpus,* (K) *Quisqualis indica.* Abbreviations: ST – stomata, TB - trichome base, AST - anomocytic stomata; EC - epidermal cell, TR – trichome, DR - druse.

Slika 2: Mikromorfologija adaksialne listne povrhnjice pri enajstih vrstah iz družine Combretaceae. (A) *Combretum platypterum,* (B) *C. zenkeri,* (C) *C. racemosum,* (D) *C. dolichopetalum,* (E) *Terminalia catappa,* (F) *T. superba,* (G) *T. ivorensis,* (H) *T. mantaly* (I) *T. avicennioides,* (J) *Anogeissus leiocarpus,* (K) *Quisqualis indica.* Okrajšave: ST – listna reža, TB – baza trihoma, AST – anomocitna reža; EC – celica povrhnjice, TR – trihom, DR - drus.

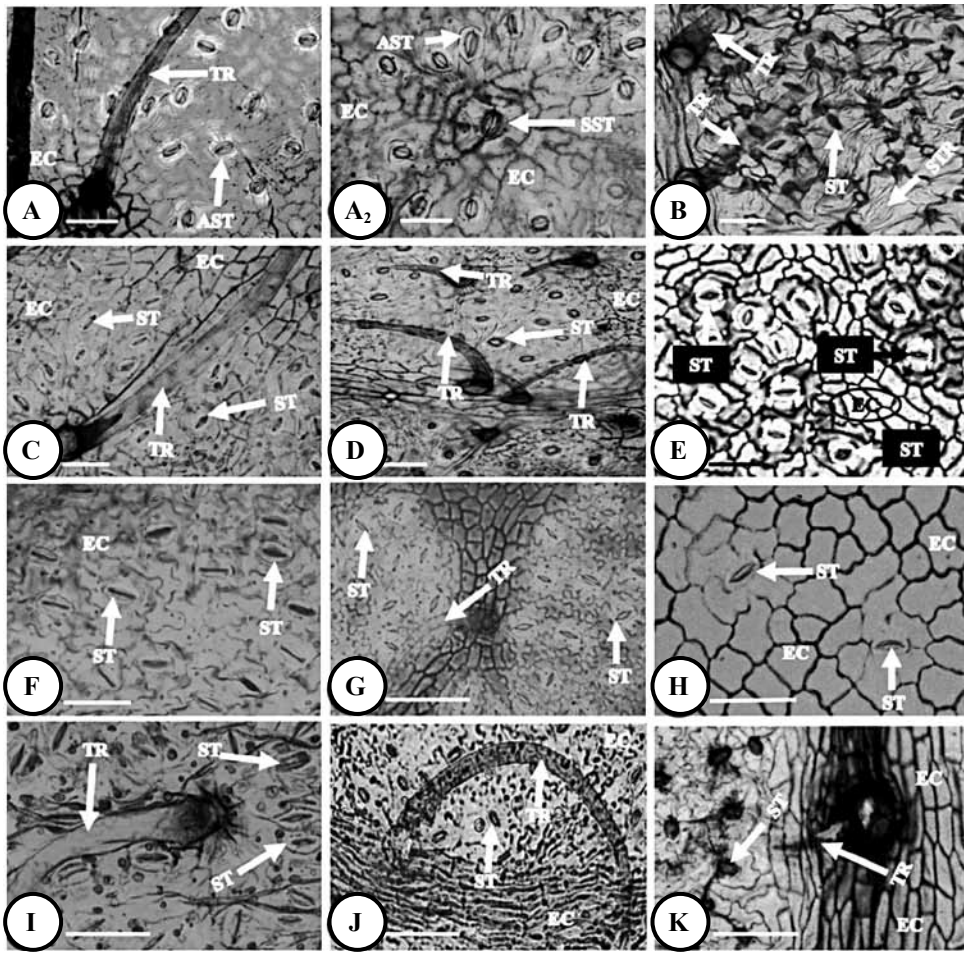

Figure 3: Leaf epidermal micro-morphology of the abaxial leaf surface of eleven species of Combretaceae. (A and A_2) *Combretum platypterum,* (B) *C. zenkeri,* (C) *C. racemosum,* (D) *C. dolichopetalum,* (E) *Terminalia catappa,* (F) *T. superba,* (G) *T. ivorensis,* (H) *T. mantaly* (I) *T. avicennioides,* (J) *Anogeissus leiocarpus,* (K) *Quisqualis indica.* Abbreviations: ST – stomata, TB - trichome base, AST - anomocytic stomata; EC - epidermal cell, TR – trichome, DR - druse.

Slika 3: Mikromorfologija abaksialne listne povrhnjice pri enajstih vrstah iz družine Combretaceae. (A in A_2) *Combretum platypterum,* (B) *C. zenkeri,* (C) *C. racemosum,* (D) *C. dolichopetalum,* (E) *Terminalia catappa,* (F) *T. superba,* (G) *T. ivorensis,* (H) *T. mantaly* (I) *T. avicennioides,* (J) *Anogeissus leiocarpus,* (K) *Quisqualis indica.* Okrajšave: ST – listna reža, TB – baza trihoma, AST – anomocitna reža; EC – celica povrhnjice, TR – trihom, DR - drus.

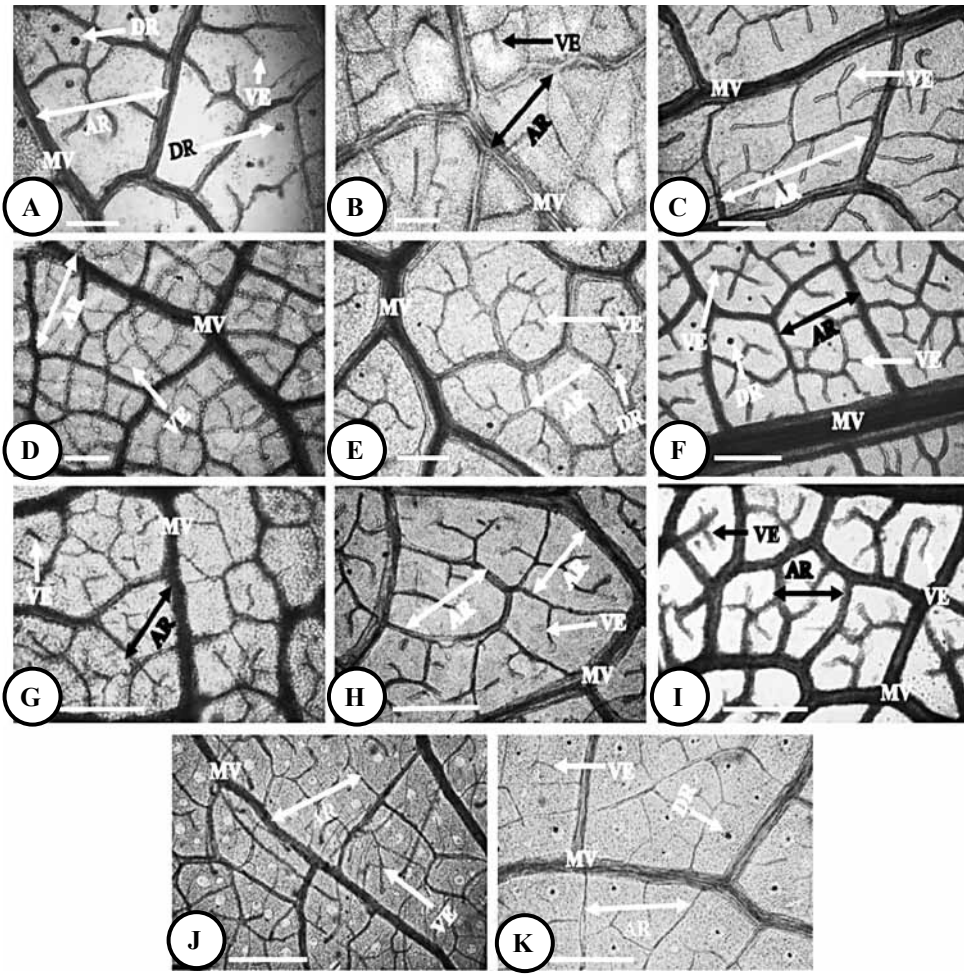

Figure 4: Venation patterns of eleven species of Combretaceae. (A) *Combretum platypterum,* (B) *C. zenkeri,* (C) *C. racemosum,* (D) *C. dolichopetalum,* (E) *Terminalia catappa,* (F) *T. superba,* (G) *T. ivorensis,* (H) *T. mantaly* (I) *T. avicennioides,* (J) *Anogeissus leiocarpus,* (K) *Quisqualis indica.* Abbreviations: MV - main vein, VE - veinlet ending, AR – areole.

Slika 4: Žilnatost listov pri enajstih vrstah iz družine Combretaceae. (A) *Combretum platypterum,* (B) *C. zenkeri,* (C) *C. racemosum,* (D) *C. dolichopetalum,* (E) *Terminalia catappa,* (F) *T. superba,* (G) *T. ivorensis,* (H) *T. mantaly* (I) *T. avicennioides,* (J) *Anogeissus leiocarpus,* (K) *Quisqualis indica.* Okrajšave: MV – glavna žila, VE – konec žile, AR - areola.

Discussion

Carlquist (1961) cited in Illoh (1995) has stated that leaf provides variety of anatomical features that are of taxonomic importance. Metcalfe (1968) pointed out that certain characters of the epidermis such as shape of subsidiary cells of the stomata, micro hairs, trichomes and prickles are of systematic importance. Akinsulire et al. (2018b) also stated that data recorded in leaf and petiole studies are sufficient for the taxa to be distinguished from one another taxonomically. In this study, the shapes of epidermal cells are generally polygonal, ranging from rectangular to octagonal except on the abaxial leaf surface of *C. zenkeri* which has irregular epidermal cells and possesses numerous epidermal striations (Fig. 3B). This easily separates the species from other taxa investigated in the family. In the genus *Combretum, C. dolichopetalum* is demarcated from other species of the genus by the possession of straight, undulating, wavy or sinuous anticlinal walls on the adaxial leaf surface (Fig. 2D). However, anticlinal walls on the abaxial leaf surfaces were found to be wavy or occasionally sinuous in *C. platypterum* (Figs. 3A and $3A_2$), straight or occasionally undulating in *C. racemosum* (Fig. 3C), sinuous in *C. dolichopetalum* (Fig. 3D), while *C. racemosum* is quite distinct on the abaxial lamina surface view being a taxon without epidermal striations (Fig. 3C). Sinuous anticlinal walls on both surfaces of *C. dolichopetalum* and *T. ivorensis* (Figs. 2D and 3D; 2G and 3G) separate the two species from others in their respective genera and among other members of the family Combretaceae studied.

Other taxonomically useful characters recorded in this study include the stomatal distribution which is largely hypostomatous though sometimes amphistomatous as documented in *C. dolichopetalum, T. catappa* and *T. mantaly* (Plate 2 and 3). Anomocytic stomata are largely prevalent in the family but anisocytic stomata also occur on the adaxial lamina surface of *T. catappa* and *T. mantaly.* The presence of epidermal striations is also a good taxonomic tool in classifying members of the genus *Combretum* and other genera studied. This was prominently observed on the abaxial leaf surface of *C. platypterum, C. zenkeri* and *C. dolichopetalum* but absent in other genera studied within the family and as such a good character of systematic importance that delimits the genus from other genera of the family Combretaceae investigated. There are also marked differences in the stomatal frequency in all the species studied, although only three of the species possess stomata on the adaxial leaf surface. Stomatal frequency of 0 – 2 was reported for *C. dolichopetalum,* 4 – 9 for *T. mantaly* while the highest stomata frequency on the adaxial leaf surface was found in *T. catappa*. However, it was observed that the occurrence of several stomatal number or frequency even in the same taxon has been a subject of controversy and has subsequently made the use of stomatal number a less reliable character in taxonomic work (Esau 1962, Raju and Rao 1977). Anisocytic stomata are restricted to members of the genus *Terminalia* (*T. catappa* and *T. mantaly* are characterised by anisocytic stomata on both surfaces of the leaf). The rest of the species have anomocytic stomata. This implies that members of the genus *Terminalia* (except *T. superba, T. ivorensis* and *T. avicennioides*) can be separated from other genera in the family on account of the presence of anisocytic stomata. This corroborates the classification and grouping earlier documented by Akinsulire et al. (2018b) in the genus *Terminalia*, as well as Akinsulire et al. (2018a) in the family Combretaceae. The presence of two types of stomata on the epidermal surface can as well be useful in the delimitation of the taxa studied. Among all the species, *C. platypterum* is quite distinct owing to the presence of staurocytic stomata in addition to the prevalent anomocytic or anisocytic stomata found in all the species (Table 1). This is a spot character for the species and according to Illoh (1998) cited in Chappet (1969), the trend of possessing more than one stomata type has been shown in *Vicia faba*. Patet and Inamdar (1971) also reported such taxonomic character in some Polemoniales as well as Akinsulire et al. (2018c) in their investigation into some species of *Diospyros* L. in Nigeria.

Table 1: Qualitative and quantitative foliar micro-morphological features of eleven species of Combretaceae (n=30). Adaxial leaf surface – upper line, adaxial leaf surface – lower line.

Tabela 1: Kvalitativni in kvantitativni mikromorfološki znaki listov (adaksialna in abaksialna površina) pri enajstih vrstah iz družine Combretaceae (n=30). Adaksialna površina lista – zgornja vrstica, abaksialna površina lista – spodnja vrstica.

Species	Epidermal cell shape	Anticlinal wall	Periclinal wall	ECL (µm)	ECW (µm)	Stomata type	Stomata frequency	Trichome	Trichome type	Trichome frequency
C. platypterum	Polygonal	Straight	Not striated	12.50 - 27.50	7.50 - 17.50	-	-	+	SUNT	0 - 4
	Polygonal	Wavy/ Sinuous	Striated	12.50 - 30.00	7.50 - 20.00	Anom & Staur	14 - 43	+	SUNT	0 - 1
C. zenkeri	Polygonal	Wavy	Not striated	10.00 - 30.00	7.50 - 17.50	-	-	+	SUNT	0 - 5
	Irregular	Wavy	Striated	12.50 - 30.00	10.00 - 20.00	Anomocytic	19 - 36	+	SUNT	0 - 6
C. racemosum	Polygonal	Straight/ Undul.	Not striated	12.50 - 35.00	10.00 - 22.50	-	-	+	SUNT	0 - 1
	Polygonal	Straight/ Undul.	Not striated	10.00 - 32.50	7.50 - 20.00	Anomocytic	18 - 31	+	SUNT	0 - 4
C. dolichopetalum	Polygonal	Wavy/ Sinuous	Not striated	20.00 - 35.00	10.00 - 22.50	Anomocytic	0 – 2	+	SUNT	0 - 6
	Polygonal	Sinuous	Striated	10.00 - 32.50	7.50 - 12.50	Anomocytic	7 - 66	+	SUNT	4 - 28
T. catappa	Polygonal	Straight/ Undul.	Not striated	7.50 - 30.00	12.50 - 20.00	Anisocytic	0 – 62	-	-	-
	Polygonal	Wavy/ Sinuous	Not striated	10.00 - 30.00	7.50 - 12.50	Anisocytic	18 - 66	-	-	-
T. superba	Polygonal	Straight/ Undul.	Not striated	15.00 - 25.00	5.00 - 17.50	-	-	-	-	-
	Polygonal	Wavy/ Sinuous	Not striated	12.50 - 32.50	7.00 - 15.00	Anomocytic	18 - 52	-	-	-
T. ivorensis	Polygonal	Sinuous	Not striated	10.00 - 25.00	7.50 - 15.00	-	-	-	-	-
	Polygonal	Sinuous	Not striated	10.00 - 30.00	7.50 - 20.00	Anomocytic	34 - 56	+	SUNT	0 - 1
T. mantaly	Polygonal	Undul./ Wavy	Not striated	20.00 - 40.00	10.00 - 22.50	Anisocytic	4 – 9	-	-	-
	Polygonal	Straight/ Undul.	Not striated	15.00 - 37.50	7.50 - 17.50	Anisocytic	3 - 14	-	-	-
T. avicennioides	Polygonal	Wavy/ Undul.	Not striated	10.00 - 30.00	7.50 - 20.00	-	-	-	-	-
	Polygonal	Wavy	Striated	12.50 - 30.00	7.50 - 20.00	Anomocytic	51 - 69	+	SUNT	0 - 8
A. leiocarpus	Polygonal	Undul./ Wavy	Not striated	10.00 - 25.00	5.00 - 12.50	-	-	+	SUNT	7 - 20
	Polygonal	Sinuous	Not striated	20.00 - 30.00	10.00 - 15.00	Anomocytic	36 - 51	+	SUNT	0 - 2
Q. indica	Polygonal	Straight	Not striated	20.00 - 32.50	12.50 - 22.50	-	-	+	SUNT	0 - 2
	Polygonal	Straight/ Sinuous	Not striated	15.00 - 30.00	12.50 - 20.00	Anomocytic	40 - 48	+	SUNT	0 - 1

Abbreviations: - absent, + present, SUNT - simple unicellular non-glandular trichome, NEC - number of epidermal cells, ECL - epidermal cell length, ECW - epidermal cell width, NTR - number of trichomes, Undul. – undulating, Anom. – anomocytic, Staur – staurocytic.

Table 2: Quantitative foliar micro-morphological features of eleven species of Combretaceae (Duncan's Multiple Mean Separation analysis - DMMS). Adaxial leaf surface – upper line, adaxial leaf surface – lower line. Values are expressed as mean ± standard error (n = 30). Values in each column with different superscripts are significantly different ($p < 0.05$).

Tabela 2: Kvantitativni mikromorfološki znaki listov pri enajstih vrstah iz družine Combretaceae (analiza DMMS). Adaksialna površina lista – zgornja vrstica, abaksialna površina lista – spodnja vrstica. Prikazane so povprečne vrednosti ± standardna napaka (n = 30). Vrednosti v vsaki koloni z različnimi črkami v nadpisu so signifikantno različne ($p < 0,05$).

Species	Stomata density	Stomata length (µm)	Stomata width (µm)	Stomata index (%)	NEC	ECL (µm)	ECW (µm)	NTR
C. platypterum	-	-	-	-	199 ± 2.91^{bc}	20.88 ± 0.88^{b}	13.50 ± 0.69^{cde}	0.85 ± 0.27^{ab}
	28.75 ± 1.79^{bc}	20.75 ± 0.37^{g}	14.50 ± 0.29^{g}	19.98	115 ± 1.89^{a}	21.50 ± 1.35^{ab}	14.63 ± 0.98^{def}	0.35 ± 0.11^{a}
C. zenkeri	-	-	-	-	225 ± 1.29^{ef}	20.75 ± 1.28^{b}	12.63 ± 0.69^{bcd}	1.30 ± 0.31^{b}
	28.30 ± 1.03^{bc}	14.25 ± 0.26^{a}	7.00 ± 0.23^{a}	21.83	101 ± 1.89^{a}	22.88 ± 1.17^{ab}	13.63 ± 0.59^{cde}	2.40 ± 0.41^{bc}
C. racemosum	-	-	-	-	189 ± 2.42^{ab}	24.75 ± 1.51^{c}	14.50 ± 0.69^{def}	0.25 ± 0.10^{a}
	26.20 ± 0.81^{b}	16.50 ± 0.28^{bc}	9.38 ± 0.25^{d}	16.57	131 ± 2.73^{b}	23.63 ± 1.24^{ab}	15.25 ± 0.83^{ef}	1.55 ± 0.32^{ab}
C. dolichopetalum	0.90 ± 0.20^{a}	12.88 ± 2.42^{a}	7.75 ± 1.48^{a}	0.38	238 ± 4.78^{f}	27.50 ± 0.99^{c}	17.13 ± 0.73^{g}	0.95 ± 0.15^{ab}
	33.80 ± 3.38^{cd}	18.63 ± 0.29^{f}	11.00 ± 0.28^{e}	13.01	221 ± 2.03^{de}	22.00 ± 1.35^{ab}	10.50 ± 0.53^{ab}	10.40 ± 1.47^{d}
T. catappa	7.50 ± 3.38^{b}	10.25 ± 2.1^{a}	6.25 ± 1.31^{a}	3.54	204 ± 3.08^{cd}	24.63 ± 0.98^{c}	16.13 ± 0.59^{fg}	-
	31.80 ± 3.06^{cd}	17.50 ± 0.48^{de}	8.50 ± 0.28^{c}	11.06	255 ± 9.66^{f}	20.00 ± 1.20^{a}	9.63 ± 0.42^{a}	
T. superba	-	-	-	-	182 ± 8.72^{a}	21.00 ± 0.66^{b}	12.00 ± 0.72^{bc}	-
	39.95 ± 2.28^{d}	17.88 ± 0.42^{ef}	9.63 ± 0.38^{d}	16.61	180 ± 10.87^{c}	21.75 ± 1.38^{ab}	11.75 ± 0.48^{bc}	-
T. ivorensis	-	-	-	-	233 ± 4.87^{f}	16.75 ± 0.01^{a}	11.13 ± 0.67^{b}	-
	45.80 ± 1.68^{e}	17.75 ± 0.31^{ef}	10.25 ± 0.48^{de}	16.37	233 ± 6.86^{e}	21.13 ± 1.31^{ab}	10.50 ± 0.74^{ab}	0.45 ± 0.11^{a}
T. mantaly	6.50 ± 0.30^{b}	18.75 ± 0.29^{b}	13.25 ± 0.26^{b}	2.92	215 ± 1.84^{de}	27.75 ± 1.40^{c}	14.88 ± 0.86^{ef}	-
	5.30 ± 0.73^{a}	20.25 ± 0.44^{g}	12.87 ± 0.42^{f}	2.41	215 ± 3.10^{d}	22.88 ± 1.23^{ab}	12.88 ± 0.61^{cd}	
T. avicennioides	-	-	-	-	185 ± 8.03^{ab}	21.38 ± 1.17^{b}	12.00 ± 0.74^{bc}	-
	60.80 ± 1.19^{f}	16.75 ± 0.26^{cd}	8.00 ± 0.23^{bc}	37.86	99 ± 1.45^{a}	23.25 ± 1.22^{ab}	15.00 ± 0.81^{ef}	2.35 ± 0.50^{bc}
A. leiocarpus	-	-	-	-	273 ± 7.26^{g}	16.75 ± 0.89^{a}	9.00 ± 0.53^{a}	12.55 ± 0.88^{e}
	41.45 ± 0.89^{e}	14.13 ± 0.27^{a}	7.50 ± 0.00^{ab}	22.84	140.00 ± 2.38^{b}	24.13 ± 0.82^{b}	12.63 ± 0.42^{cd}	3.15 ± 0.37^{c}
Q. indica	-	-	-	-	174 ± 2.73^{a}	26.38 ± 1.11^{c}	$16.50 \pm 0.0.73^{fg}$	0.65 ± 0.13^{ab}
	43.00 ± 0.63^{e}	15.63 ± 0.25^{b}	8.25 ± 0.26^{bc}	23.87	143 ± 2.93^{b}	21.75 ± 1.12^{ab}	15.88 ± 0.64^{f}	0.70 ± 0.16^{a}

The values of stomatal index are also important in separating members of this family. Another character of identification and systematic significance was found to be present on the abaxial leaf surfaces of the eleven taxa where stomatal occurrence and indices were general. *T. avicennioides* has the highest stomata index (37.86%) while the least was observed in *T. mantaly* (2.41%) (Tab. 2). The fact that stomatal index is constant for any taxon delimits the taxa. The variability observed in the stomatal index of members of this family aligns with the work of Olatunji (1983) who posited that stomatal index is constant for a given species and as such, it is useful in delimiting species.

In this study, leaf indumentum on the adaxial leaf surface reveal the preponderance of simple unicellular non-glandular trichome in all the genera studied except in the genus *Terminalia* (Table 1 and 2). This indicates that the absence of simple unicellular trichome on the adaxial leaf surface is a generic feature for members of the genus *Terminalia* and also delimits the genus, thereby serving as a character of identification useful in the taxonomy of the genus. However, *T. ivorensis* and *T. avicennioides* are separated from other species in the genus *Terminalia* and among other genera studied by the possession of simple unicellular non-glandular trichomes on their abaxial leaf surfaces (Table 1and 2). This grouping greatly agrees with recent investigations into the genus *Terminalia* by Akinsulire et al. (2018b) who grouped *T. avicennioides* and *T. ivorensis* based on a number of leaf and petiole anatomical parameters. These findings also corroborate Akinsulire et al. (2018a) who classified the species using their vegetative and reproductive morphological attributes. Meanwhile, Adedeji et al. (2007) has earlier reported the importance of trichome types in different organs of plant body in the delimitation of genera and species within the family Solanaceae. Rammaya and Rao (1976) as well as Rao and Rammaya (1977) also emphasised the taxonomic importance of trichomes. Therefore, the result of this study aligns with that of Stace (1981) who reported a significant influence of trichomes in the classification of genera in the family Combretaceae.

Foliar venation, though an underutilised and neglected character, has proven to be useful in delimitation of species of Combretaceae investigated. Studies such as of Levin (1986), Provance and Sanders (2006), Akinsulire et al. (2018c) have revealed the significance of foliar venation characters in the delimitation of several plant taxa. Regular polygonal reticulate venation and triangular to pentagonal (3 to 5-sided, or 6-sided) areolation seem to be generic for members of the genus *Combretum*. This generic classification also is in conformity with previous studies (Oladipo et al. 2016*;* Akinsulire et al. 2018a, b) for which this paper serves to be a follow-up and probably a conclusion. Dichotomous venation groups *T. catappa* and *T mantaly* while alternate percurrent/regular polygonal reticulate venation as well as imperfect areolation (Table 3 and Figs. 4J and 4K) can be used to classify *A. leiocarpus* and *Q. indica* - the two West African monotypic genera in the family Combretaceae investigated. Simple linear or forked/branched veinlets dominate the family except in *C. zenkeri* (Fig. 4B), which is a spot character for the taxa. However, this study has greatly supported the placement of each of the species in their respective genera (Hutchinson and Dalziel, 1958). Meanwhile, the general absence of druses within the areoles except in *C. platypterum*, *T. catappa*, *T. superba* and *Q. indica* (Figs. 4A, 4E, 4F and 4K, respectively) placed the eleven species into two groups. This is a spot character that delimits each of the four species from others in their respective genera and from all other species studied within the family.

Critical examination of quantitative attributes of venation pattern reveals significant intra- and intergeneric differences among all the species studied. In the genus *Combretum, C. racemosum* has a significantly longer areole length, width and more veinlet endings than other species within the genus (Tab. 4), this also delimits the species. Furthermore, the similarity observed in the number of veinlet endings can be used in grouping *C. zenkeri*, *C. platypterum* and *C. dolichopetalum* (Tab. 3). Longer areole and higher number of veinlet endings were found in *T. mantaly* while *T. catappa* had a wider areole (Tab. 2). However, the occurrence of highest number of veinlet endings separates *T. mantaly* from all other species of the family Combretacae studied (Tab. 3).

Table 3: Micro-morphological characters of veins of eleven species of Combretaceae.
Tabela 3: Mikromorfološki znaki žilnatosti listov pri enajstih vrstah iz družine Combretaceae.

Species	Venation	Areole development	Shape/side	Vein ending	Vein density	Druses
C. platypterum	RPR	Well	3 - 6 sided	Linear/forcated	0 – 2	+
C. zenkeri	RPR	Moderate	3 - 6 sided	Linear/unbranched	0 – 1	-
C. racemosum	RPR	Moderate	3 - 6 sided	Linear/forcated	1 – 3	-
C. dolichopetalum	RPR	Moderate FP	3 - 5 sided	Linear/branched	0 – 3	-
T. catappa	D	Well dev.	3 - 5 sided	Linear/forcated	0 – 3	+
T. superba	RPR	Well dev.	3 - 5 sided	Linear/forcated	1 – 3	+
T. ivorensis	RPR	Moderate	4 - 6 sided	Linear/branched	0 – 2	-
T. mantaly	D	Well	3 - 6 sided	Linear/branched	1 – 3	-
T. avicennioides	RPR	Well	3 - 6 sided	Linear/forcated	0 – 3	-
A. leiocarpus	AP/RPR	Imperfect	4 - 6 sided	Linear/forcated	0 – 2	-
Q. indica	PRP/AP	Imperfect	3 - 6 sided	Linear/branched	0 – 3	+

Abbreviations: RPR - regular polygonal reticulate, D – dichotomizing, AP - alternate percurrent, FP - fairly paxillate.

Table 4: Analysis of quantitative features of the veins with Duncan's multiple range test. Values are expressed as mean ± standard error (n = 30). Values in each column with different superscripts are significantly different ($p < 0.05$).
Tabela 4: Analiza kvantitativnih znakov žilnatosti listov (Duncanov test rangov). Prikazane so povprečne vrednosti ± standardna napaka (n = 30). Vrednosti v vsaki koloni z različnimi črkami v nadpisu so signifikantno različne ($p < 0,05$).

Species	Areole length (µm)	Areole width (µm)	Number of veinlet endings
C. platypterum	417.00 ± 21.52^{d}	282.50 ± 14.76^{f}	0.60 ± 0.15^{a}
C. zenkeri	241.00 ± 12.71^{a}	175.00 ± 9.61^{a}	0.55 ± 0.11^{a}
C. racemosum	658.50 ± 23.94^{e}	394.00 ± 25.07^{g}	1.50 ± 0.20^{cd}
C. dolichopetalum	278.50 ± 14.75^{ab}	202.50 ± 10.68^{ab}	0.55 ± 0.11^{a}
T. catappa	411.00 ± 26.34^{d}	276.00 ± 13.56^{ef}	1.65 ± 0.17^{d}
T. superba	369.00 ± 23.12^{cd}	247.50 ± 5.61^{cdef}	1.35 ± 0.17^{cd}
T. ivorensis	321.50 ± 16.36^{bc}	224.00 ± 15.40^{bc}	1.15 ± 0.17^{bc}
T. mantaly	429.50 ± 18.01^{d}	272.50 ± 11.14^{def}	2.10 ± 0.12^{e}
T. avicennioides	328.00 ± 15.90^{bc}	236.00 ± 17.13^{bcde}	1.25 ± 0.16^{bcd}
A. leiocarpus	393.50 ± 23.26^{d}	264.50 ± 9.42^{cdef}	0.80 ± 0.12^{ab}
Q. indica	329.50 ± 21.26^{bc}	229.00 ± 13.59^{bcd}	1.30 ± 0.22^{cd}

Conclusions

Investigations of leaf epidermal micromorphology and venation characters of members of the family Combretaceae as carried out in this study can successfully be employed in the identification, classification and delimitation of members of the family Combretaceae while the evidences should be used as basis for taxonomy. This research and previous investigations (Oladipo et al. 2016, Akinsulire et al. 2018a, b) for which this study serves as a follow-up, has revealed several micro-morphological characters of taxonomic delimitations and great affinities in the selected members of the family. It is therefore concluded that the placement of the 11 species in their respective genera (Hutchinson and Dalziel 1958) should be maintained.

Acknowledgement

We acknowledge Obafemi Awolowo University (OAU) for providing facilities and equipments for the research. Thanks to Mr Bernard Omomoh (Department of Forestry and Wood Technology, FUTA) for his efforts in plant collection. We appreciate Dr K. F Adelalu (CAS, Wuhan Botanical Garden, China) for his efforts towards a successful foliar epidermal investigation as well as Mr Abiodun Omole (Department of Botany, OAU) for the technical supports in slide preparation and photomicrography. Anonymous reviewers are also greatly appreciated for providing valuable and constructive comments on the manuscript.

References

Adedeji, O.A., Ajuwon, O.Y., Babawale, O., 2007. Foliar epidermal studies, organographic distribution and taxonomic importance of trichomes in the family Solanaceae. International Journal of Botany, 3(3), 276-282.

Akinsulire, O.P., Oladipo, O.T., Illoh, H.C., Mudasiru, O.M., 2018a. Vegetative and reproductive morphological study of some species in the family Combretaceae in Nigeria. Ife Journal of Science, 20(2), 371-389. https://dx.doi.org/10.4314/ijs.v20i2.18

Akinsulire, O.P., Oladipo, O.T., Illoh, H.C., Akinloye, A.J., 2018b. Structure, distribution and taxonomic significance of leaf and petiole anatomical characters in five species of *Terminalia* (L.) (Combetaceae: Magnoliopsida). Brazilian Journal of Biological Sciences, 5(10), 515-528. https://doi.org/10.21472/bjbs.051027

Akinsulire, O.P., Oladipo, O.T., Abdulraheem, O.A., Akinloye, A.J., Illoh, H.C., 2018c. Taxonomic significance of epidermal and venation characters in the genus *Diospyros* L. (Ebenaceae) in Nigeria. Brazilian Journal of Biological Sciences, 5(10), 499-514. https://doi.org/10.21472/bjbs.051026

Baba-Moussa, F., Akpagana, K., Bouchet, P., 1996. Antifungal activities of seven West African Combretaceae used in traditional medicine. Journal of Ethnopharmacology, 66*,* 335-338.

Batawila, K., Kokou, K., Koumaglo, K., et al., 2005. Antifungal activities of five Combretaceae used in Togolese traditional medicine. Fitoterapia*,* 76, 264-268.

Carlquist, S., 1961. Comparative plant anatomy. Holt, Rinehart and Winston. New York.

Carlquist S., 1988. Comparative wood anatomy: Systematic, ecological and evolutionary aspects of dicotyledon wood. Springer Verlag, Berlin.

Chappet A., 1969. The biology and systematics*.* Edited by D'Arcy W. G. Columbia University Press, New York.

Coulidiati, T.H., Millogo-Kone, H., Lamien-Meda, A., Lamien, C., Lompo, M., 2009. Antioxidant and antibacterial activities of *Combretum nioroense* Aubrev. ex Keay (Combretaceae). Pakistan Journal of Biological Sciences, 12, 264-269.

Ekeke, C., Agbawa, I. O., Okoli, B.E., 2014. Numerical taxonomy of *Combretum* Loefl. from Southeastern Nigeria. Journal of Plant Sciences, 9, 25–31.

Esau, K., 1962. Anatomy of seed plants. John Wiley and sons Inc., New York.

Fyhrquist, P., Mwasumbi, L., Haeggstrom, C.A., Vuorela, H., Hiltunen, R., Vuorela, P., 2002. Ethnobotanical and antimicrobial investigation on some species of *Terminalia* and *Combretum* (Combretaceae) growing in Tanzania. Journal of Ethnopharmacology, 79, 169-177.

Gill, L.S., 1988. Taxonomy of flowering plants. Africana-FEP Publishers Ltd., Ibadan, Nigeria.

Hutchinson, J., Dalziel, J.M., 1958. Flora of west tropical Africa. Crown Agents for Overseas Government and Administration Nill Bank London Vol. 1.

Illoh, H.C., Inyang, U.E., 1998. Foliar epidermis and petiole anatomy in some Nigerian *Solanum* Linn. species in the sub-genus *Leptostemon* (Bitt) Dun. Glimpses in Plant Research, 12, 73–86.

Illoh, H.C., 1995. Foliar epidermis and petiole anatomy of four species of *Celosia* L. in Nigeria. Feddes Repertorium, 106, 1-2, 15 - 23.

Jainab, S.I., Kensa, M.V. 2018. Morpho-anatomical studies on *Vitex negunlo* L. International Journal of Botany Studies, 3(2), 1-7.

Jayeola, A.A., Aworinde, D.O., Folorunso, A.E., 2009. Use of wood characters in the identification of selected timber species in Nigeria. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 37(2), 28-32.

Jordaan, M., Van Wyk, A.E., Maurin, O., 2001. Generic status of *Quisqualis* (Combretaceae), with notes on the taxonomy and distribution of *Q. parviflora.* Bothalia, 41(1), 161-169.

Keay, R.W.J., 1989. Trees of Nigerian. Clarendon Press, Oxford, UK.

Kishore, S.R., Rao, K.S., 1999. Nucleated wood fibres in some members of Combretaceae. International Association of Wood Anatomy (IAWA) Journal, 20(1), 79-83.

Leaf Architecture Working Group (LAWG), 1999. Manual of leaf architecture: morphological and categorization of dicotyledonous and net-veined monocotyledonous angiosperm, p. 65.

Levin, G.A., 1986. Systematic foliar morphology of Phyllanthoideae (Euphorbiaceae). 1. *Conspectus* Saint. Ann. Missouri Botanical Garden, 73, 86-98

Mabberley, D.J., 2008. The Plant Book: A portable dictionary of the vascular plants, 3rd edn. Cambridge University Press.

Martini, N., Katerere, D.R.P., Eloff, J.N., 2004. Seven flavonoids with antibacterial activity isolated from *Combretum erythrophyllum* (Burch) Sond (Combretaceae). South African Journal of Botany, 70, 310-312.

Metcalfe, C.R., 1968. Current development in systematic plant anatomy. In: Heywood, V.H. (ed.): Modern methods in plant taxonomy. Academy Press, London, New York, pp. 45-57.

Metcalfe, C.R., 1979. The leaf: General topography and ontogeny of the tissues. In: Metcalfe, C.R. and Chalk, L.: Anatomy of the dicotyledons, Vol. I. Clarendon Press, Oxford, England, p. 63.

Oladipo, O.T., Akinsulire, O.P., Illoh, H.C., 2016. Comparative systematic wood anatomical study of eleven species in four genera of the family Combretaceae in Nigeria. Nigerian Journal of Botany, 29(1), 43-57.

Olatunji, O.A., 1983. Practical manual for plant anatomy. Obafemi Awolowo University, Ile-Ife, Nigeria (unpubl.), pp. 14-19.

Patet, R.C., Inamdar, C., 1971. Structure and ontogeny of stomata in some Polemiales. Annals of Botany, 35, 389-409.

Priya, C., Hari, N., 2018. A study on leaf and petiole anatomy of endemic and vulnerable species of *Garcinia*. Journal of Emerging Technologies and Innovative Research, 5(12), 509-512.

Provance, M.C., Sanders, A.C., 2006. More American black sapotes: New *Diospyros* (Ebenaceae) for Mexico and Central America. Sida, 22, 277-304.

Raju, V.S., Rao, P.N., 1977. Variation in the structure and development of foliar stomata in the Euphorbiaceae. Botanical Journal of the Linnaean Society, 75, 69-97.

Rammaya, N., Rao, R.S., 1976. Morphology phylesis and biology of the peltate scale, stellate and tufted hairs in some Malvaceae. Journal of Indian Botanical Society, 55, 75-79.

Rao, R.S., Rammaya, N., 1977. Structure, distribution and taxonomic importance of trichomes in the Indian species of *Malvastrum*. Phytomorphology, 27, 40-44.

Shirsagar, A.A., Vaikos, M.P., 2013. Foliar epidermal features and their taxonomic significance in *Rotala* L. (Lythraceae). Asian Journal of Plant Science and Research, 3(3), 117-120.

Simon, G., Dewelle, J., Nacoulma, O., et al., 2003. Cytotoxic pentacyclic triterpenes from *Combretum nigricans.* Fitoterapia, 74, 339-34.

Sonibare, M.A., Oke, T.A., Soladoye, M.O., 2014. A pharmacobotanical study of two medicinal species of Fabaceae. Asian Pacific Journal of Tropical Biomedicine, 4(2), 131-136.

Stace, C.A., 1981. The significance of the leaf epidermis in the taxonomy of the Combretaceae: conclusions. Botanical Journal of the Linnaean Society, 81, 327-339.

Stace, C.A., 2007. Combretaceae. In: Kubitzki, K. (ed.): The families and genera of vascular Plants 9. Springer Verlag, Berlin, pp. 67-82.

Thiombiano, A., Schmidt, M., Kreft, H., Guinko, S., 2006. Influence of the climatic gradient on the distribution of Combretaceae species in Burkina Faso (West Africa). Candollea, 61, 189-213.

Thiombiano, A., 2005. Les Combretaceae du Burkina Faso: Taxonomie ecologie et regeneration des especes. These d'Etat, Universite de Ouagadougou, pp. 290.

Tilney, M.P., 2002. A contribution to the leaf and young stem anatomy of the Combretaceae. Botanical Journal of the Linnaean Society, 138, 163-196.

Wilkinson, H.P., 1979. The Plant Surface (mainly leaf) Part 1: Stomata In: Metcalfe, C.R and L. Chalk (eds): Anatomy of the dicotyledons, Vol. 1, 2nd ed. Clarendon Press, Oxford, pp. 113.