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Research article

Systematic wood anatomical study in some species of Sapindaceae Juss. in South-Western Nigeria

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Abstract: Comparative wood anatomical studies was carried out on ten species in the family Sapindaceae. The species were relatively uniform in the features of their vessels, in which diffuse porous was observed with solitary vessels to pore multiples in transverse section and ray cells were predominantly heterogeneous in radial section. Fibres were long and extensive. The longest fibre was observed in *Blighia sapida* (1025±28.5 µm), while the shortest fibre was observed in *Cardiospermum halicacabum* (139±6.5 µm). The longest vessel was observed in *Deinbolia pinnata* (509±34.9 µm) and the shortest vessel was observed in *Cardiospermum halicacabum* (85.36±4.9 µm). The implication of these features in the taxonomy of the family was discussed. The Dendrogram based on the quantitative wood characters confirmed *Allophylus africanus* and *Allophylus spicatus* belong to the same genus as classified, likewise *Blighia unijugata*, *Blighia sapida* but *Cardiospermum halicacabum* is closely related to *Paullinia pinnata* while others exhibited distinct generic characters.

Keywords: Photomicrography, Maceration, Fibre, Anatomy, Microtome, Sapindaceae.

INTRODUCTION

Contributions of wood anatomy is vital among other several approaches used in taxonomic investigations of taxa. Wood anatomical features have been proven to have classificatory and diagnostic values, this is evident in the works of Akinloye *et al.* (2012) who have recommended the aspects of variation in wood structure to be of practical importance in wood industry. Jayeola *et al.* (2009) stated that wood gross structure can provide useful characters that could be employed to identify the Nigerian trees, whether fresh or dry samples. Wood anatomical characters such as simple perforation plate with oblique end wall, paratracheal vasicentric axial parenchyma, alternate intervascular pitting, septate fibres, upright ray cells, and presence or absence of starch grains and crystal in the ray cells in some species of *Jatropa* L. have been used by Oladipo & Illoh (2012) and their importance in the identification of woods of some *Cola* species were documented (Akinloye *et al.*, 2012). A comprehensive study of wood anatomy of the family Sapindaceae Juss. including Dodonaeoideae and Sapindoideae was published by Klassen (1999) and he reported that the vessel segments of members of Sapindaceae usually have simple perforation; scalariform perforation is rarely seen in Sapindoideae, and more often in Hippocastaneae. Regional literature on wood anatomy of the Sapindaceae can be found in Prior & Gasson (1990); Ilic (1991). However, reports on wood anatomical features of Nigerian Sapindaceae were not covered. Therefore the aim of this study is to describe anatomical features of some species in the family in Nigeria and elucidate their taxonomic relationships on the basis of the characters employed.

MATERIALS AND METHODS

Wood sample preparation

The wood blocks of approximately (10 × 10 × 10) cm^3 were collected from tension free mature branches of *Allophylus africanus* P. Beauv., *Allophylus spicatus* (Poir) Radlk, *Blighia sapida* K.D. Koenig, *Blighia unijugata* Baker, *Cardiospermum grandiflorum* Swartz, *Cardiospermum halicacabum* L., *Deinbolia pinnata* Schumach. & Thonn., *Lecaniodiscus cupanioides* Planch ex Benth., *Paullinia pinnata* L. and *Zanha golungensis* Hiern (collected randomly from Ibadan, Oyo state, and Moro, Osun state, Nigeria), small blocks of 5 cm^3 were cut out and preserved in 50% ethanol. The blocks were boiled in 5% Sodium hydroxide (NaOH) to soften them.

Sectioning and staining

Transverse section (TS); tangential longitudinal section (TLS) and radial longitudinal section (RLS) of each wood were made at 20 micron using Reichert (Austria) sliding Microtome. The wood sections were preserved in 50% ethanol

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prior to staining. Each section was stained for 5 minutes in Safranin O and counter stained in Alcian blue for 5 minutes. The stained sections were rinsed in water before serial treatment in ethanol solution (50%, 70%, 80%, 90% and 100%) to remove water molecules (dehydration process) and excess stain (differentiation process). The dehydrated and differentiated sections were mounted in 25% glycerol on microscopic glass slide covered carefully with cover slip with the edges of the cover slip well sealed with nail vanish to prevent dehydration.

Wood maceration and staining of the macerates

Wood samples from each species considered were sliced into small pieces using pen knife and macerated using Schultz's fluid obtained by mixing equal volume of 10% chromic acid (dissolved 5 gm of Potassium Nitrate, KNO_3) in 250 ml concentrated Nitric acid and 250 ml of 10 % Ntric acid. The maceration was carried out in a beaker kept in the oven at 90°C for 30 minutes. The macerated wood samples were rinsed in several changes of water and was stained for 5 minutes in Safranin O. Fibre anatomical characters such as fibre length (FL), fibre diameter (FD), fibre wall thickness (FWT) and fibre lumen (FL) and vessel anatomical characters such as vessel length (VL), vessel diameter (VD), perforation plate type and type of pitting were examined.

Descriptive terms

Descriptive terminologies and measurements were in accordance with that of the International Association of Wood Anatomists (IAWA) List of Microscopic Features for Hardwood and Softwood Identification (IAWA Committee, 1989; 2004). Microscopic observation of each prepared slide were made and recorded.

Photomicrography

Photomicrographs of the slides were made using Accu-scope microscope equipped with 3.2 MP CMOS digital camera. Tissues and cells identification was done following the works of Metcalfe & Chalk (1979).

Phenetic analyses

To examine the relationships of the taxa, data obtained were subjected to phenetic analysis using PAST (PAleontological STatistics) statistical software package version 1.94b (Hammer *et al.*, 2001) following the steps below.

Choice of operational taxonomic units (OTUs)

Each taxon was considered as an operational taxonomic unit (OTU) as presented below,

Allophylus africanus P. Beauv.	OTU1
Allophylus spicatus (Poir) Radlk	OTU2
Blighia sapida K.D. Koenig	OTU3
Blighia unijugata Baker	OTU4
Cardiospermum grandiflorum Swartz	OTU5
Cardiospermum halicacabum L.	OTU6
Deinbolia pinnata Schumach. & Thonn.	OTU7
Lecaniodiscus cupanioides Planch ex Benth.	OTU8
Paullinia pinnata L.	OTU9
Zanha golungensis Hiern	OTU10

Selection and coding of characters

Selection and coding of characters were made following the methods of Adeyemi *et al.* (2013) and Herendeen & Miller (2000). A total of fourteen (14) characters were selected for the analysis. This comprised of eight (8) qualitative and six (6) quantitative characters and subsequently used to generate 10 × 14 data matrix.

Principal components analysis (PCA) and cluster analysis (CA)

The data matrix was then subjected to multivariate techniques of Principal Components Analysis (PCA) and Cluster analysis (CA) using unweighted pair group method with arithmetic averages (UPGMA) to generate scatter diagram and phenogram (dendrogram) respectively.

RESULTS

Description wood anatomical features

Allophylus africanus P. Beauv.

Porosity: Diffuse porous

Vessels: Predominantly solitary with radial multiples of 2-3 and few pore clusters of three (3) pores that were mostly circular with few oval outlines. Mean vessel member length 353.5±18.4 µm and diameter 81.6±4.4 µm. Vessels with simple perforation plate, long and short tail. Simple pitting that were alternate in orientation.

Axial parenchyma: Absent or very rare, if present paratracheal.

Ray cells: Uniseriate and non-storied. Composed mainly of procumbent cells with no secretory ducts within but ergastic substances in form of prismatic crystals.

Crystals: prismatic crystals present in ray cells

Fibre: Fibres non storied, thin, to thick-walled with mean fibre length, fibre diameter, fibre lumen and fibre wall thickness of 561.9±28.8 µm, 15.4±0.6 µm, 9.0±0.6 µm and 3.2±0.2 µm respectively.

Allophylus spicatus (Poir) Radlk

Porosity: Diffuse porous

Vessels: Predominantly solitary pores with few pore multiples of two (2). Vessels had circular solitary vessel outlines with mean vessel length and diameter 423.7±22.9 µm and 56.4±2.4 µm respectively. Simple perforation plate, vessels had both long and short tails, pitting simple and alternate. Tannins were observed in the vessel lumina.

Axial parenchyma: present and associated with vessels *i.e.* paratracheal banded and continuous in three (3) cell wide bands.

Ray cells: Uniseriate, long, non-storied, homocellular procumbent rays.

Fibre: Fibres non storied, thin, to thick-walled. Mean fibre length, fibre diameter, fibre lumen and fibre wall thickness of 601.8±22.1 µm, 15.1±0.5 µm, 8.3±0.6 µm and 3.8±0.2 µm respectively.

Blighia sapida K.D. Koenig

Porosity: Diffuse porous

Vessel: Solitary vessels predominant. Pore multiple of 2-7 and pore clusters of seven (7). Pore shapes varied from circular or arc to oval. Perforation plates simple with alternate pitting. Vessel elements were short and long with tail(s) at one end or at both ends. Mean vessel length up to 474.5±29.4 µm and vessel diameter of 129.3±7.9 µm.

Axial parenchyma: Apotracheal

Ray cells: Uniseriate, homogenous procumbent with few upright cells. Ray cells oval, circular, cylindrical and short rectangular shaped.

Fibre: Fibres were long and extensive, non-septate, non-storeyed and thin, to thick-walled. Mean fibre length, fibre diameter, fibre lumen and fiber wall thickness of 1025±28.5 µm, 20.4±0.7 µm, 14.1±0.7 µm, 3.9±0.3 µm respectively.

Blighia unijugata Baker

Porosity: Diffuse porous.

Vessels: Solitary vessels. Radial multiples of 2-9. Pores oval, circular, and arc. Mean vessel length 394±18.1 µm and diameter 87.4±6.6 µm. Soft vessel with simple perforation plates, with short or no tail, pitting simple and alternate.

Axial parenchyma: Apotracheal

Ray cells: Uniseriate and non-storied heterogenous rays (comprising of procumbent and upright cells). Ray cells were short rectangular, circular and cylindrical shaped at radial and tangential planes.

Crystals: Styloid crystals and tannins were present in ray cells.

Fibre: Extensive and prominent fibres, thin-walled with large lumen. Mean fibre length 780±22.9 µm, fibre diameter 21.4±0.9 µm; fibre lumen diameter 16.1±0.9 µm and fibre wall thickness 2.7±0.1 µm were recorded.

Cardiospermum grandiforum Swartz

Porosity: Diffuse porous

Vessels: Solitary vessel dominant with few radial pore multiple of 2-4 but rarely in clusters. Mostly short with wide lumina and distinct wall pitting. Mean vessel length 315±16.1 µm and diameter 126.1±20.2 µm. Perforation plate simple. Most of the vessel had no tail, pitting simple and alternate.

Axial parenchyma: Scanty paratracheal axial parenchyma.

Ray cells: Uniseriate, occassionally multiseriate with heterocellular composition, prismatic crystals sighted enclosed in the ray cells. Ray cells square and upright.

Crystals: Prismatic crystals observed enclosed within ray cells and vessel lumina.

Fibre: Fibres non-storied, thin- to thick-walled. Mean fibre length, fibre diameter, fibre lumen and fibre wall thickness of 504.8±40.3 µm, 19.9±1.0 µm, 10.3±1.3 µm and 5.8±0.9 µm respectively.

Cardiospermum helicacabum L.

Porosity: Diffuse porous.

Vessels: Predominantly solitary with few pore multiples 2-4 and occasional clusters of 2-4. Very short and narrow

vessels of mean vessel length 213.4±12.1 µm and diameter 53.4±6.8 µm respectively. Vessels with simple perforation plate, no tail, when present very short, pitting simple and alternate.

Axial parenchyma: Absent or extremely rare.

Ray cells: Uniseriate with few biseriate cells upright or occasionally procumbent.

Crystal: Enclosed in vessel.

Fibre: non storied, thin-thick walled. Mean fibre length, fibre diameter, fibre lumen and fibre wall thickness of 348.6±16.2 µm, 14.4±0.6 µm, 9.9±0.7 µm and 2.5±0.0 µm respectively.

Deinbolia pinnata Schumach. & Thonn.

Porosity: Diffuse porous

Vessel: Both solitary and pore multiple were present but solitary vessels were more than pore clusters. Pore multiple of 2-5 and pore clusters ranged from 3-4 with either circular or oval shaped. Vessel elements were long and extensive, tail(s) at one or both ends with simple perforation plate. Mean vessel length and diameter were 509.9±9.0 µm and 101.7±4.0 µm respectively.

Axial parenchyma: Unilateral-paratracheal, winged-paratracheal with aliform and few apotracheal.

Ray cells: Non-storeyed uniseriate ray. Heterogenous rays, comprising of upright and procumbent rays. Ray cells circular, oval, and rectangular in shape.

Crystals: Prismatic crystal sands and tannin were observed in some member vessel at radial longitudinal plane.

Fibre: Non-storied fibres with large lumen 11.8±0.5µm and relatively thin wall 2.85±0.2 µm were observed, fibre length 900.6±31.9 µm and diameter 17.3±0.6 µm were recorded.

Lecaniodiscus cupanioides Planch ex Benth.

Porosity: Diffuse porous.

Vessels: Solitary vessels dominant with few pore multiple. Pore multiple of 2-5, pore clusters 3-4. Pore oval, circular and arc. Vessel elements were relatively shorter with tail(s) at one or both ends. Perforation plate simple, mean vessel diameter of 104±5.3 µm while vessel length up to 428.1±18.4 µm were recorded.

Axial parenchyma: Apotracheal

Ray cells: Rays predominantly uniseriate with few biseriate cells, non-storied. Procumbent and upright rays present. Ray cells were short rectangular, cylindrical and circular shaped.

Crystals: Crystal druses and tannin in ray cells

Fibre: Fibres are non-storied, non-septate, large lumen and narrow wall. Mean fibre length 762±21.8 µm, fibre diameter 18±0.5 µm, and fibre lumen diameter 12.9±0.4 µm, and fibre wall thickness 1.0±0 µm were recorded.

Paullinia pinnata L.

Porosity: Diffuse porous.

Vessels: Most of the vessels were solitary while others were in radial multiples of 2-4 and few pore clusters. Tyloses were observed in some vessel at transverse plan. Solitary vessel outline circular. Mean vessel length 260.1±11.5 µm and diameter 85.4±12.0 µm. Vessel had simple perforation plate, with short or no tail, pitting simple and alternate.

Axial parenchyma: Apotrachial and Paratrachial (few).

Ray cells: Range from few uniseriate to predominantly biseriate to multiseriate (2-4 seriates). Non-storied. Aggregate rays absent. Ray cells were heterogeneous with upright, square and procumbent.

Ergastic substance: Tannin was observed in the vessels

Fibre: Fibres non storied, thin-thick walled. Mean fibre length, fibre diameter, fibre lumen and fibre wall thickness recorded 375.9±17.5 µm, 16.4±0.8 µm, 11.0±0.9 µm and 2.8±0.1 µm respectively.

Zanha golungensis Hiern

Porosity: Diffuse porous.

Vessels: Solitary vessels predominant with few pore multiple. Pore multiple of 2-4 and pore cluster of 2-3 in transverse plane Pore shape circular, oval. Vessel members had one short tail or two long tails and some with no tail, pitting alternate. Perforation plate simple, mean vessel diameter of 75.5±4.6 µm, while vessel lengths up to 358.4±14.7 µm, were recorded.

Axial parenchyma: Paratracheal confluence

Ray cells: Uniseriate with few biseriate and non-storied. Upright with few procumbent ray cells present at radial plane.

Crystals: Styloid crystals, prismatic crystals and tannin in ray cells.

Fibre: Fibre extensive and prominent, non-storied, thick walled with large lumen. Mean fibre length 975.4±29.6 µm, fibre diameter 14.6±0.5 µm and fibre lumen diameter 6.1±0.5 µm and fiber wall thickness 4.1±0.3 µm.

DISCUSSION

The woods of all the taxa examined were diffuse porous (Fig. 1) with simple perforation plates, alternate inter vessel pitting (Fig. 2) and non-storeyed ray cells. These features can be regarded as characteristic of the family Sapindaceae. Only a few genera in the species of Sapindaceae are known to have ring-porous to semi ring-porous woods (Record and Hess 1943; Metcalfe & Chalk, 1950). Ring porous woods was reported to be present mostly in some temperate species of Sapindaceae (Wheeler & Baas, 1998). In addition to the alternate inter vessel pitting, Klassen (1999) reported opposite and scalariform pitting in some lianas of Sapindaceae. However, variation in vessel grouping has been observed; radial pore multiples of four or more were present in all taxa except in species of *Allophylus* and pore clusters were commonly found in *Blighia sapida*. The former separate the genus *Allophylus* from the other genera while the latter clearly distinguished the two species of *Blighia*. It was also observed that each species had a particular pattern of axial parenchyma, which was more or less consistent from species to species and these cell patterns were important in identification of woods of the examined taxa. Distribution of the axial parenchyma was so variable and easy to detect in the examined species and therefore, a very important diagnostic feature. Paratracheal and apotracheal types occur more or less regularly. The Solitary paratracheal axial parenchyma were observed in the species *Allophylus* and

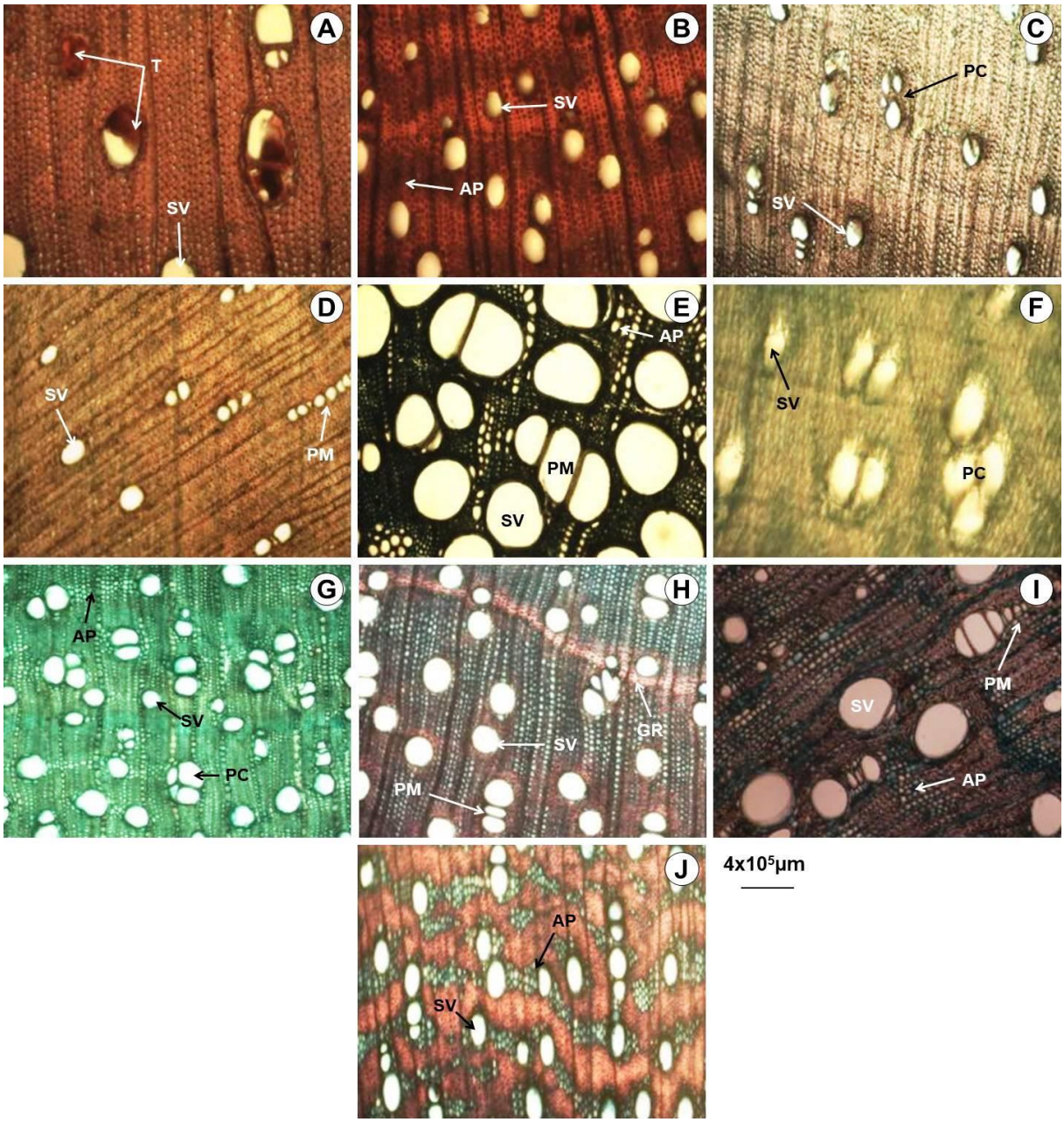

Figure 1. Transverse Sections (TS) of the Woods showing diffuse porous wood type: **A**, *Allophylus africanus* P. Beauv.; **B**, *Allophylus spicatus* (Poir) Radlk; **C**, *Blighia sapida* K.D. Koenig; **D**, *Blighia unijugata* Baker; **E**, *Cardiospermum grandiflorum* Swartz; **F**, *Cardiospermum halicacabum* L.; **G**, *Deinbolia pinnata* Schumach. & Thonn.; **H**, *Lecaniodiscus cupanioides* Planch ex Benth.; **I**, *Paullinia pinnata* L.; **J**, *Zanha golungensis* Hiern [AP- Axial Parenchyma, GR- Growth Ring, PC- Pore Cluster, PM- Pore Multiple, SV- Solitary Vessel, T- Tannin]

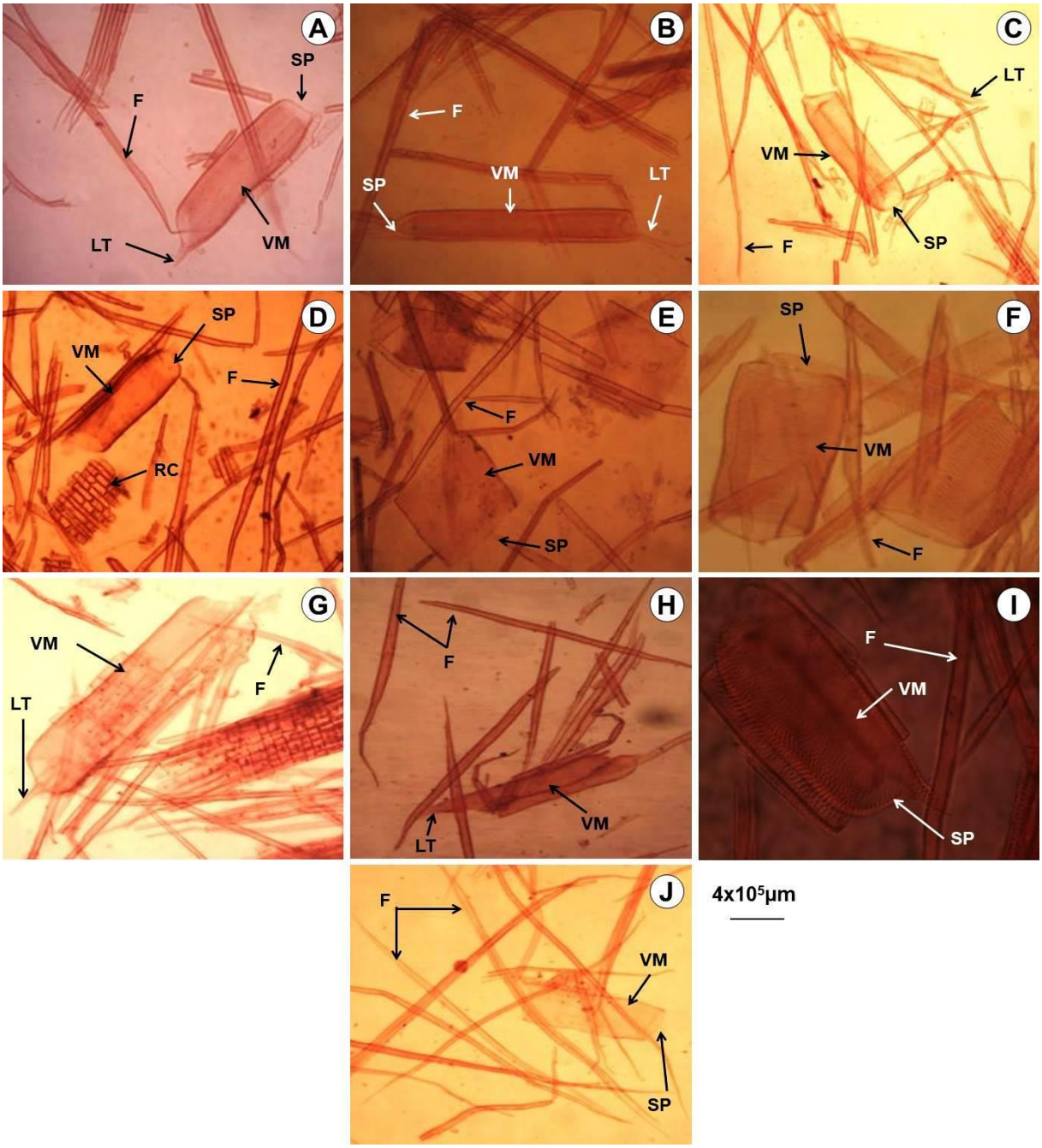

Figure 2. A, Wood macerates: *Allophylus africanus* P. Beauv.; **B**, *Allophylus spicatus* (Poir) Radlk; **C**, *Blighia sapida* K.D. Koenig; **D**, *Blighia unijugata* Baker; **E**, *Cardiospermum grandiflorum* Swartz; **F**, *Cardiospermum halicacabum* L.; **G**, *Deinbolia pinnata* Schumach. & Thonn.; **H**, *Lecaniodiscus cupanioides* Planch ex Benth.; **I**, *Paullinia pinnata* L.; **J**, *Zanha golungensis* Hiern [F- Fibre, LT- Long Tail, RC- Ray Cells, SP- Simple Perforation, ST- Short Tail, VM- Vessel Member]

Cardiospermum, combinations of unilateral, winged and aliform paratracheal distinguished *Deinbolia pinnata* from the other taxa and confluence paratracheal parenchyma observed in *Zanha golungensis* had a great diagnostic value. Klassen (1999) also reported banded paratracheal in *Zanha golungensis*, which is the only species with banding observed in this (Fig. 1).

Wood in *Blighia sapida*, *Blighia unijugata*, *Lecaniodiscus cupanioides* and *Paullinia pinnata* were Apotracheal. All the taxa had indistinct growth rings except *Lecaniodiscus cupanioides.* The growth ring is therefore important as generic delimiting feature for *Lecaniodiscus cupanioides* (Fig. 1). Use of growth ring as diagnostic feature is limited because it is likely that the flattened latewood fibres reflected by the change in cambial activity was induced by environmental conditions such as drought (Eckstein *et al.*, 1995). However, it was considered reliable indicator in this study because it correlated with heterocellular ray cell composition as suggested by Klassen (1999). Crystal were present in chambered axial parenchyma and rays of some species examined. Prismatic crystals were found in *Allophylus africanus*, *Deinbolia pinnata* and *Zanha golungensis* while styloid crystals were found in *Blighia unijugata*, *Cardiospermum grandiflorum* and *Zanha golungensis* (Table 1). These prismatic crystals were confined to the diffuse

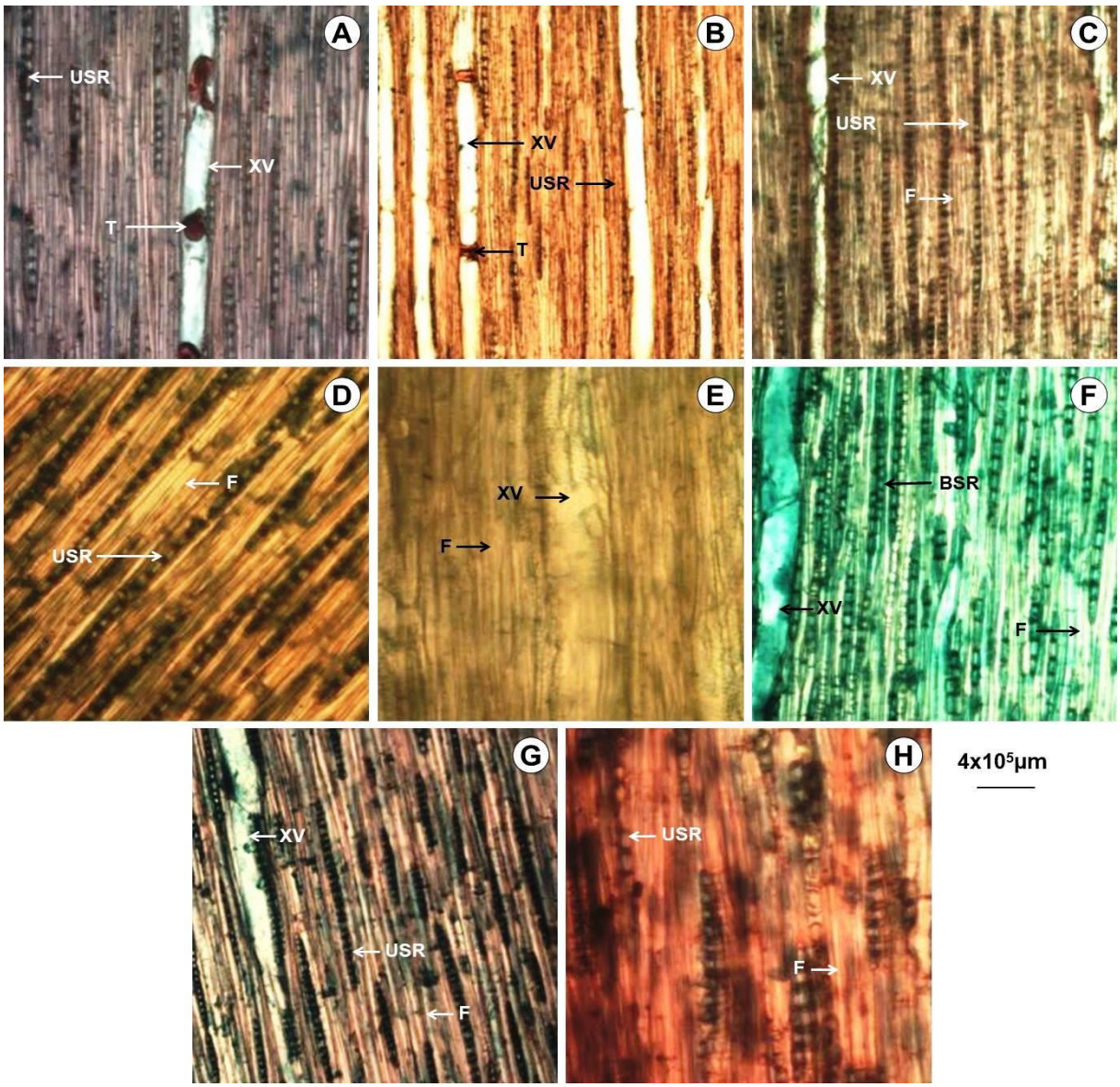

Figure 3. Tangential Longitudinal Sections (TLS) of the Woods showing diffuse porous wood type: **A**, *Allophylus africanus* P. Beauv.; **B**, *Allophylus spicatus* (Poir) Radlk; **C**, *Blighia sapida* K.D. Koenig; **D**, *Blighia unijugata* Baker; **E**, *Cardiospermum grandiflorum* Swartz; **F**, *Cardiospermum halicacabum* L.; **G**, *Deinbolia pinnata* Schumach. & Thonn.; **H**, *Lecaniodiscus cupanioides* Planch ex Benth. [F- Fibre, BSR- Biseriate Ray, MSR- Multiseriate Ray, T- Tannin, USR- Uniseriate Ray, XV- Xylem Vessel]

parenchyma rays. Consequently, crystals and tannins were unifying characters for all examined species. The results obtained from this study were in line with previous work done by Illoh & Inyang (1998) which showed that ergastic substances such as crystals and tannins are of diagnostic usefulness in plant classification. This study indicated that all species exhibited distinctive ray patterns by having a very high degree of uniseriate rays and low degree of biseriate and multiseriate rays (Figs. 3 & 4). This is in agreement with the report of Klassen (1999). In spite of the uniformity of the qualitative wood anatomical characters of the examined species, there were interspecific variations in wood quantitative (Table 2) characters indicating that the species could be delimited by their quantitative wood characters. This could then be used in resolving their taxonomic problems. *Blighia sapida* had the longest fibre length 1025±28.5 µm and *Cardiospermum halicacabum* had the shortest fibre length 348.6±16.2 µm among the examined species.

On the other hand, *Blighia unijugata* had the largest fibre diameter 21.4±0.85 µm. *Cardiospermum halicacabum* had the shortest vessel length and diameter with mean value of 213.4±12.1 µm and 53.4±6.8 µm respectively. *Deinbolia pinnata* had the longest vessel 509±30.5 µm, while *Blighia sapida* had the widest vessel diameter 129.3±7.9 µm. Elongated or narrow vessels were regarded as primitive character while short or wide vessels is an advanced character (Metcalfe & Chalk, 1950). It can therefore be inferred from this study that *Cardiospermum halicacabum* was the most advanced with the shortest vessel length and *Deinbolia pinnata* was derived with longest vessel length. Because of its wide variation and well known correlation with habit and age, Zhang *et al.* (1992) opined that vessel diameter is of very limited diagnostic and taxonomic significance.

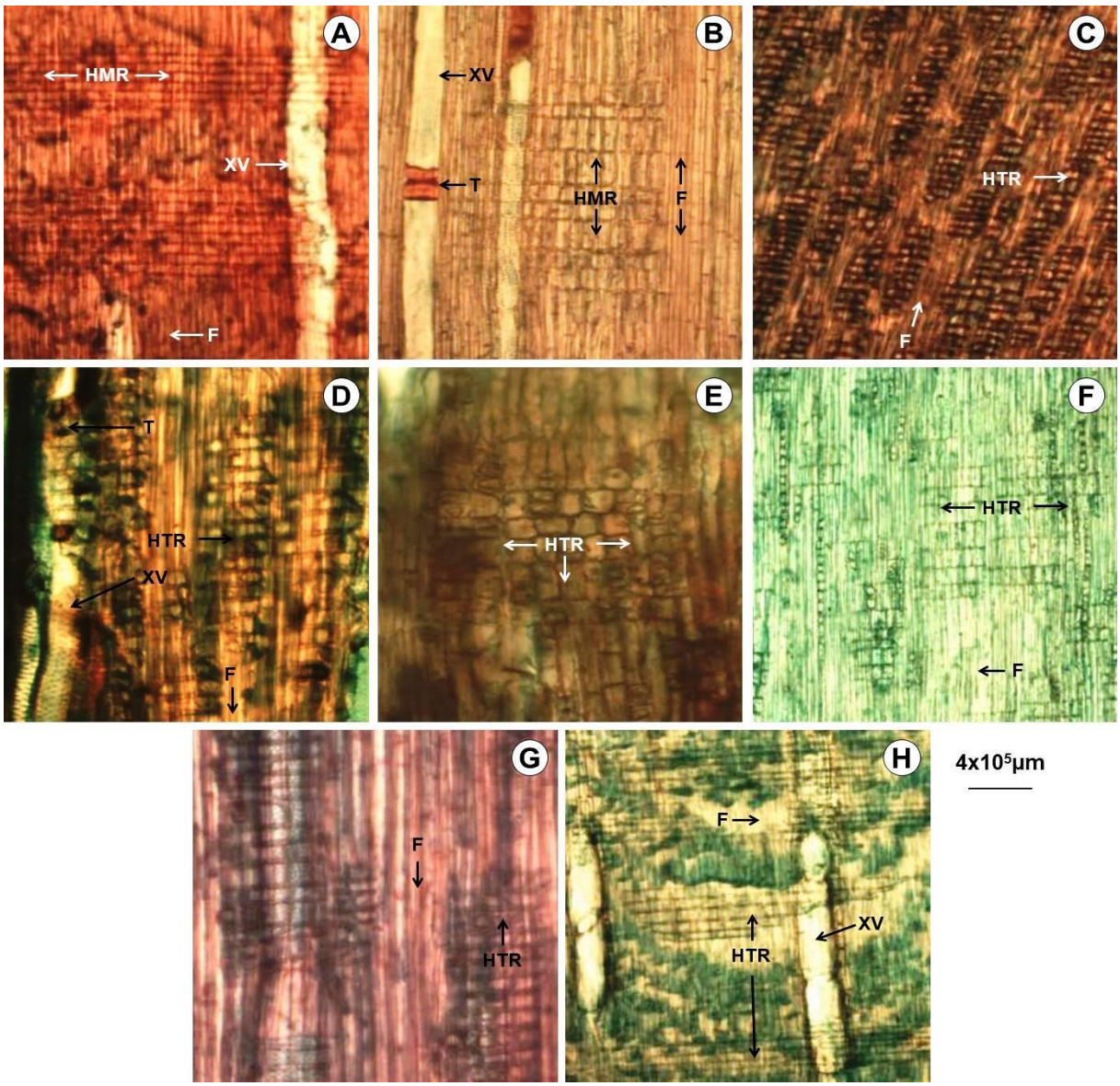

Figure 4. Radial Longitudinal Sections (RLS) of the Woods showing diffuse porous wood type: **A**, *Allophylus africanus* P. Beauv.; **B**, *Allophylus spicatus* (Poir) Radlk; **C**, *Blighia sapida* K.D. Koenig; **D**, *Blighia unijugata* Baker; **E**, *Cardiospermum grandiflorum* Swartz; **F**, *Cardiospermum halicacabum* L.; **G**, *Deinbolia pinnata* Schumach. & Thonn.; **H**, *Lecaniodiscus cupanioides* Planch ex Benth. [F- Fibre, HMR- Homogenous Ray, HTR- Heterogenous Ray, T- Tannin, XV- Xylem Vessel]

Table 1. Qualitative wood anatomical features of species of Sapindaceae.

Taxa	Growth ring	Vessel Grouping			Axial Parenchyma	Seriation	Composition
		ES	RM	CC			
Al_af	Indistinct	Present	Absent	Absent	Solitary	Uniseriate	Homocellular
Al_sp	Indistinct	Present	Absent	Absent	Solitory	Uniseriate	Homocellular
Bl_sa	Indistinct	Present	Present	Present	Apotracheal	Uniseriate	Heterocellular
Bl_un	Indistinct	Present	Present	Absent	Apotracheal	Uniseriate	Heterocellular
Ca_gr	Indistinct	Present	Present	Absent	Solitary Paratracheal	Uniseriate	Heterocellular
Ca_ha	Indistinct	Present	Present	Absent	Solitary Paratracheal	Uniseriate	Heterocellular
De_pi	Indistinct	Present	Present	Absent	Unilateral Paratracheal,	Uniseriate	Heterocellular
Le_cu	Distinct	Present	Present	Absent	Apotracheal	Multiseriate	Heterocellular
Pa_pi	Absent	Present	Present	Absent	Banded Apotracheal	Biseriate to multiseriate	Heterocellular
Za_go	Indistinct	Present	Present	Absent	Paratracheal Confluence	Multiseriate	Heterocellular

Note: Al_af- *Allophylus africanus* P. Beauv.; Al_sp- *Allophylus spicatus* (Poir) Radlk; Bl_sa- *Blighia sapida* K.D. Koenig; Bl_un- *Blighia unijugata* Baker; Ca_gr- *Cardiospermum grandiflorum* Swartz; Ca_ha- *Cardiospermum halicacabum* L.; De_pi- *Deinbolia pinnata* Schumach. & Thonn.; Le_cu- *Lecaniodiscus cupanioides* Planch ex Benth.; Pa_pi- *Paullinia pinnata* L.; Za_go- *Zanha golungensis* Hiern.
ES- Vessels exclusively solitary; RM- Vessels Commonly in Radial Multiples of 4 or more; CC- Vessel Clusters Common.

Table 2. Quantitative wood anatomical features of species of Sapindaceae.

Taxa	Fibre Length (µm)	Fibre Diameter (µm)	Fibre Lumen (µm)	Fibre Wall Thickness (µm)	Vessel Length (µm)	Vessel Diameter (µm)
Al_af	561.9±28.8 (330 to 850)	15.4±0.6 (7.5 to 20.0)	9.0±0.6 (2.5 to 12.5)	3.2±0.2 (2.5 to 5.0)	353.5±18.4 (162.5 to 575.0)	81.6±4.4 (37.5 to 135.0)
Al_sp	601.8±22.1 (330 to 745)	15.1±0.5 (12.5 to 20.0)	8.3±0.6 (5 to 15)	3.8±0.2 (2.5 to 5.0)	423.7±22.9 (260.0 to 667.5)	56.4±2.4 (35 to 80)
Bl_sa	1025±28.5 (788 to 1325)	20.4±0.68 (15 to 30)	14.1±0.70 (10 to 20)	3.9±0.3 (2.5 to 5.0)	474.5±29.4 (200 to 750)	129.3±7.85 (75 to 200)
Bl_un	780±22.9 (575 to 990)	21.4±0.85 (12.5 to 32.5)	16.1±0.86 (10.0 to 27.5)	2.7±01 (2.5 to 5.0)	394±18.13 (225 to 538)	87.4±6.58 (37.5 to 305)
Ca_gr	504.8±40.3 (235 to 975)	19.9±1.0 (10.0 to 27.5)	10.3±1.3 (2.5 to 20.0)	5.8±0.9 (2.5 to 17.5)	315±16.1 (95 to 490)	126.1±20.2 (23.5 to 330.0)
Ca_ha	348.6±16.2 (185 to 480)	14.4±0.6 (7.5 to 25.0)	9.9±0.7 (5 to 20)	2.5±0.0 (2.5 to 2.5)	213.4±12.1 (105.0 to 312.5)	53.4±6.8 (17.5 to 130.0)
De_pi	900.6±93 (563 to 1183)	17.3±0.63 (12.5 to 25.0)	11.8±0.48 (7.5 to 15.0)	2.9±0.2 (2.5 to 5.0)	509±30.48 (200 to 725)	101.7±4.03 (57.5 to 137.5)
Le_cu	762±21.8 (580 to 1000)	18±0.45 (15.0 to 22.5)	12.9±0.43 (10.0 to 17.5)	1±0 (0.0 to 2.5)	428±18.43 (212.5 to 570.0)	104±5.33 (42.5 to 150.0)
Pa_pi	375.9±17.5 (247 to 573)	16.4±0.8 (7.5 to 25.0)	11.0±0.9 (2.5 to 20.0)	2.8±0.1 (2.5 to 5.0)	260.1±11.5 (145 to 350)	85.4±12.0 (32.1 to 207.5)
Za_go	975±29.55 (700 to 1280)	14.6±0.45 (10 to 20)	6.1±0.48 (2.5 to 10.0)	1.6±0.1 (2.5 to 7.5)	358±14.78 (235 to 485)	75.5±4.63 (35 to 120)

Note: Al_af- *Allophylus africanus* P. Beauv.; Al_sp- *Allophylus spicatus* (Poir) Radlk; Bl_sa- *Blighia sapida* K.D. Koenig; Bl_un- *Blighia unijugata* Baker; Ca_gr- *Cardiospermum grandiflorum* Swartz; Ca_ha- *Cardiospermum halicacabum* L.; De_pi- *Deinbolia pinnata* Schumach. & Thonn.; Le_cu- *Lecaniodiscus cupanioides* Planch ex Benth.; Pa_pi- *Paullinia pinnata* L.; Za_go- *Zanha golungensis* Hiern.
Quantitative data were expressed as Mean±Standard Error (Minimum to Maximum).

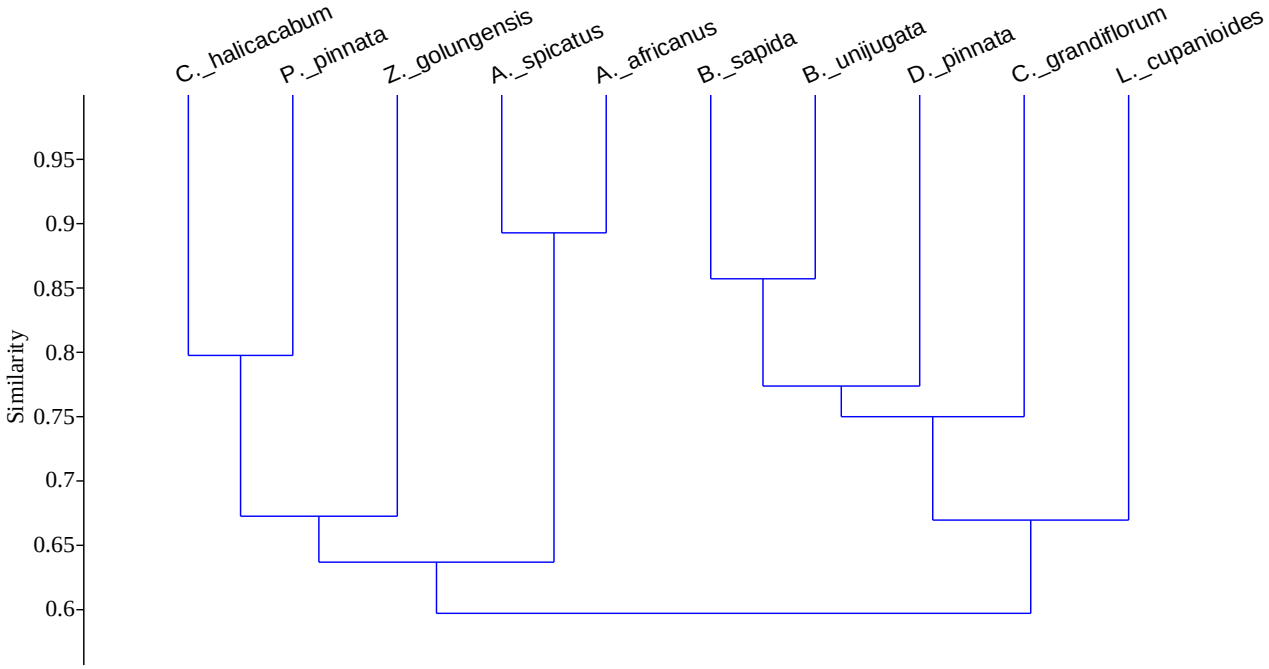

Figure 5. Dendrogram of *Sapindaceae* species studied based on the quantitative wood characters.

The dendrogram of Sapindaceae species based on the quantitative wood characters (Fig. 5) confirmed *Allophylus africanus* and *Allophylus spicatus* belong to the same genus as classified, likewise *Blighia unijugata*, *Blighia sapida* but *Cardiospermum halicacabum* is closely related to *Paullinia pinnata* while others exhibited distinct generic characters.

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