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Wood micro-morphological characteristics of the Tribe Dalbergieae in Nigeria

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Abstract. The present study examined the wood micro-characters of 18 species of the tribe Dalbergieae across 4 genera in Nigeria, following previously described methods by other authors. The species are distributed across all geo-ecological zones of the country but more abundant in the southern area which is characterized by higher precipitation. Findings clearly showed that members of the tribe Dalbergieae have more generic/tribal characteristics than delimiting characters. The species have certain unifying characters such as diffuse pore porosity, simple perforation plates, oblique to orthogonal vessel transverse wall inclination, prismatic/styloid crystals, and non-septate fibres. Vessels were longest and widest in *D. saxatilis*, about 197.89x104.23µm. On the contrary, the shortest was observed in *D. hostilis* - 67.62 µm while the narrowest was in *D. oligophylla* (28.4 µm). While fibre length was highest in *P. mildbraedii* (331.22 µm±7.5) and smallest in *D. saxatilis* (0.69 µm±0.0), the ray cells were longest in *D. saxatilis* (185µm) and shortest in *P. santalinoides* (41.82µm) respectively. We confirm here that anatomical studies should not be neglected in plant systematics, even though molecular approaches have been the focus in recent times.

Keywords: Dalbergieae, ecology, taxonomy, Nigeria, wood anatomy.

INTRODUCTION

The family Papilionaceae comprises 470 genera and about 14,000 diverse species; and includes small herbs from temperate regions as well as large tropical rainforest trees (Wojciechowski 2003). Together with Caesalpinaceae and Mimosaceae, they form the legume family (Leguminosae), and constitute the third-largest land plant family after Orchidaceae and Asteraceae (Mabberley 1997; Lewis et al. 2005). The Legume Phylogeny Working Group - LPWG (2013) reported some early taxonomists like De Candolle (1825) and Bentham (1865) who had worked on this family as a result of its ecological and economical importance. To date, taxonomists have continued to work on this family and in a more recent work by LPWG (2017), six subfamilies were recognized namely: Caesalpinioideae, Cercidoideae, Detarioideae, Dialioideae, Duparquetioideae, and Papilionoideae (with 503 genera and approximately 14,000 species). Evidence from molecular studies confirms the monophyly of legumes and their closeness to the other members of Fabales, which include Polygalaceae, Surianaceae, and Quillajaceae (Lewis et al. 2005).

The tribe Dalbergieae is not a monophyletic clade and comprises 19 tropical woody genera (Polhill 1981; Lavin et al. 2001). It comprises trees, shrubs, and lianas (Gillett et al. 1971). According to Corby (1981) who was the first researcher to consider nodule morphology as a useful character in legume taxonomy, members of Dalbergieae tribe have unique root nodule morphology often referred to as an "Aeschynomenoid" or "Dalbergioid" nodule (Doyle et al. 2000; Kajita et al. 2001; Cardoso et al. 2013).Sprent and James (2007) had ealier noted that approximately 25% of legume species adapts to crack-entry; a characteristic feature for certain legumes from sub-tropical regions whuch belong to Dalbergioid/Genistoid clades like species of *Aeschynomene, Arachis,* and *Stylosanthes*. As a result of direct access of rhizobia to the cells in the cortex, nodule primordial are developed and repeated cell division of infected cells forms aeschynomenoid nodules. Nevertheless, there are usually no uninfected cells present in the infected zone. Thus, in Aeschynomenoid nodules, the infected regions are always separated from uninfected cells (Fabre et al. 2015; Sharma et al. 2020).

In the work of Lavin et al. (2001), it was reported that within the Dalbergioid clade, there are three well-supported subclades marked as the *Adesmia*, *Dalbergia*, and *Pterocarpus* clades. Polhill (1981) noted that there appear to be two centres within the Dalbergieae: one around *Andira* with *Hymenolobium*, *Vatairea*, *Vataireopsis*, *Dalbergia*, and *Machaerium*; and another one around *Pterocarpus*. He highlighted evidence from wood anatomy (Baretta-Kuipers, 1981) which showed that *Andira*, *Hymenolobium*, *Vatairea*, and *Vataireopsis* have coarser wood structures more typical of members of the Sophoreae than the remaining members of the Dalbergieae. The study of fruit and seedling morphology by Lima (1990) further supported these two centres within the Dalbergieae: one including *Andira*, *Hymenolobium*, *Vatairea*, and *Vataireopsis*, and the second the remaining genera. Several recent molecular and morphological studies (Lavin et al. 2001; Pennington et al. 2001; Wojciechowski et al. 2004) confirm that these four genera do not belong in the Dalbergioid clade. In Nigeria, the tribe is represented by four genera viz: *Andira* Lam., *Dalbergia* L. f, *Machaerium* Pers. and *Pterocarpus* Jacq. (Soladoye and Lewis 2003). Generally, all the genera comprise species of great economic importance such as food, oils, fibre, fuel, timber, medicinal uses, amongst others (Wojciechowski 2003).

Herendeen and Miller (2000) had earlier emphasized the importance of wood taxonomy in the identification and classification of flowering plants. LPWG (2013) also reported that morphology can be incorporated into legume phylogeny to address issues in comparative biology and classification. This was reiterated by Maiti et al. (2016) who noted that in phylogenetic studies, the importance of the anatomical features of wood cannot be overemphasized. Given these submissions, only a few documented descriptions are available on the wood anatomical characteristics of African species including those of Leguminosae. Consequently, this study aimed at investigating the wood anatomy of members of the tribe Dalbegieae in Nigeria, in an attempt to identify additional diagnostic characters that could be used for their identification; as well as determining whether the variations in the wood anatomical characters of the members reflect the current circumscription of the tribe. Results obtained may also provide more information on the delimitation of members of this group.

MATERIALS AND METHODS

Species distribution

Preliminary species examination was done using previously deposited herbarium specimens at the Forest Herbarium Ibadan (FHI) and University of Ibadan Herbarium (UIH), both listed in Holmgren et al. (1990) from which useful ecological data were obtained and carefully recorded. Additional information was obtained from the Global Biodiversity Information Facility portal (GBIF.org). These were combined, carefully checked for duplicates using the Remove Duplicate tool implemented in Microsoft Excel© and thereafter used to generate a generic distributional map of the tribe Dalbergieae in Nigeria (Figure 1) using ArcMap version 10.3.1 (ESRI, Redlands, CA, USA).

Wood microscopic studies

Fresh wood samples used for this study were collected from the wild. It comprises 18 species as detailed in Table 1. Upon collection, specimens were carefully identified at the Forest Herbarium Ibadan (FHI). Small blocks of about 1cm^3 were obtained from the mature stem of each species; and boiled in water for about two hours to enhance softening of tissues. Three types of sections - transverse section (TS), tangential longitudinal section (TLS), and radial longitudinal section (RLS);

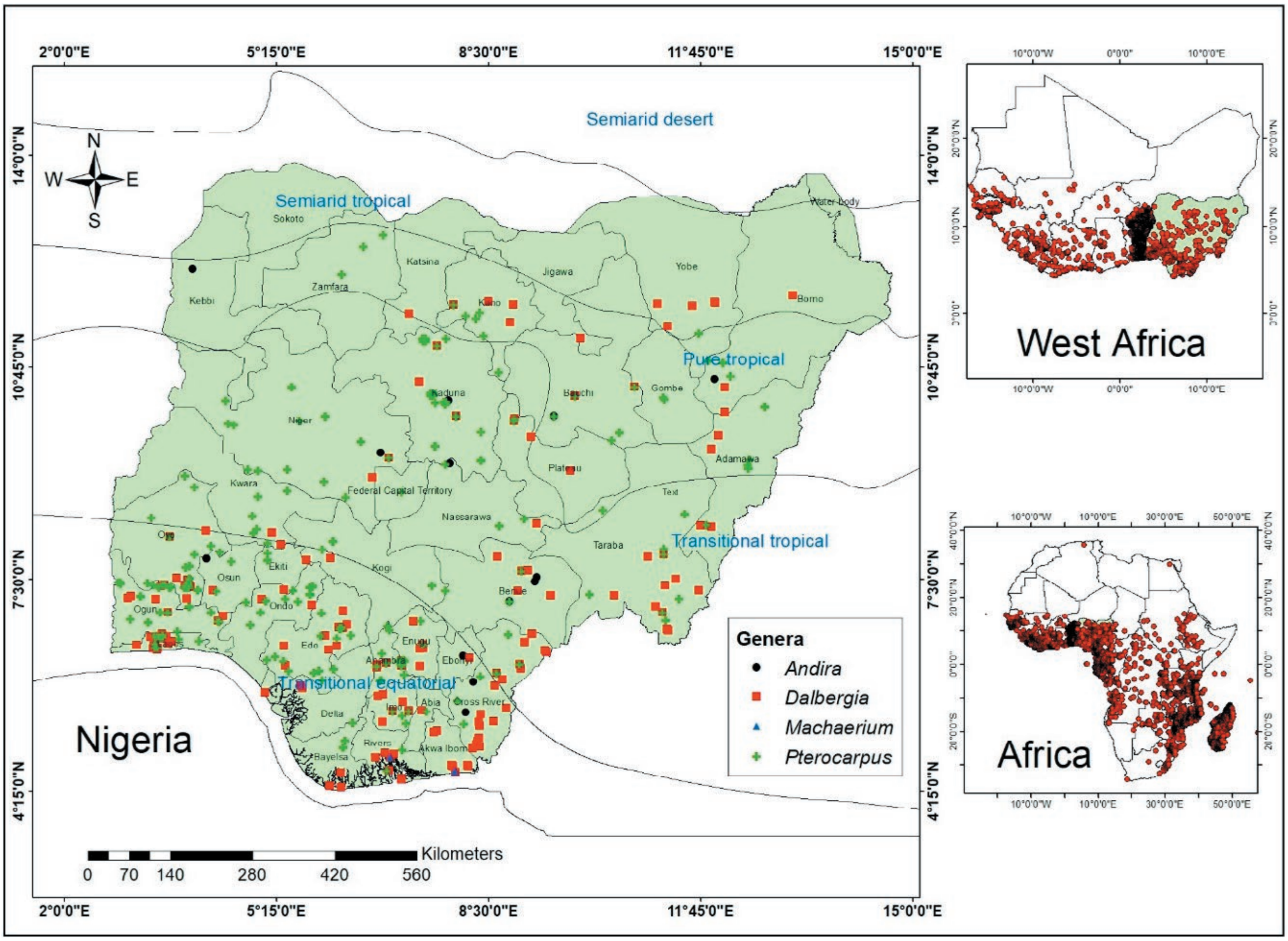

Figure 1. Distribution of Dalbergieae species in Nigeria.

all 10 μm thick were obtained with the aid of a sledge microtome, and thereafter preserved in 50% ethanol. The sections were stained with Safranin O and left for about three minutes, rinsed in clear water and counter-stained with Alcian blue, and also left for about three minutes before they were rinsed again in water. For dehydration and differentiation, the counter-stained sections were treated with series of ethanol - 50%, 70%, 80%, 90%, and 100% (absolute ethanol) respectively. For the removal of traces of water and ethanol, the differentiated sections passed through two series of absolute xylene.

For maceration of tissues, slices of each wood sample were put in a beaker containing Schulz's fluid (obtained by mixing equal volume of 10% chromic acid and 10% nitric acid as described by Ogbonnaya et al. (1997), Akinloye et al. (2012), and Oladipo and Oyaniran (2013). The macerated specimens were rinsed in water about five times and later preserved in 50% ethanol. They were then stained first with Safranin O, left for about three minutes; rinsed in water, and then counter-stained with Alcian blue, left for another three minutes, and then rinsed. They were also subjected to series of treatments in ethanol (50%, 70%, 80%, 90%, and 100%) for dehydration and differentiation.

All mounted slides were carefully studied under an Olympus© light microscope, while quantitative and qualitative data were observed and recorded accordingly. Some of the quantitative data include pore diameter, pore per square, ray height, ray width, fibre length, fibre width, fibre lumen, fibre wall thickness, vessel length, and vessel width. All microscopic measurements were taken with the aid of ocular and stage micrometers. Qualitative data include pore shape, dominant vessel type, inclination, type of axial parenchyma amongst others. Photomicrographs of all slides were also taken using a Sony digital camera mounted on the microscope. All terminologies used for the description of microscopic features follow the International Association of Wood Anatomists' list of microscopic features for hardwood identification (IAWA Committee 1989).

Table 1. List of Dalbergieae species studied.

S/n	Species	Habit	**Location**
1.	*Andira inermis* (W.Wright.) Kunth ex DC	Tree	Ago-Are, Oyo State
2.	*Dalbergia albiflora* A. Chev. ex Hutch. & Dalziel	Shrub	Calabar, Cross River State
3.	*Dalbergia ecastaphyllum* (L.) Taub.	Shrub	Lagoon Front, UNILAG
4.	*Dalbergia hostilis* Benth.	Shrub/small tree	Obudu, Cross River State
5.	*Dalbergia lactea* Vatke	Shrub	New Bussa, Niger State
6.	*Dalbergia latifolia* Roxb.	Tree	Ibadan, Oyo State
7.	*Dalbergia melanoxylon* Guill. & Perr.	Tree	Bauchi
8.	*Dalbergia oligophylla* Bak. ex Hutch. & Dalz.	Shrub	Obudu Cattle Ranch, Cross River State
9.	*Dalbergia rufa* G. Don	Shrub/liana	Ibadan
10.	*Dalbergia saxatilis* Benth.	Shrub	Efon-Alaye, Ekiti State
11.	*Dalbergia sissoo* Roxb. ex DC.	Tree	Ibadan, Oyo State
12.	*Machaerium lunatum* (L.f.) Ducke	Shrub/small tree	Okitipupa, Ondo State
13.	*Pterocarpus erinaceus* Poir.	Tree	Olokemeji, Ogun state
14.	*Pterocarpus lucens* Lepr. ex Guill. et Perrott.	Shrub	Mokwa road, Niger State
15.	*Pterocarpus mildbraedii* Harms	Tree	FRIN Premises, Ibadan
16.	*Pterocarpus osun* Craib	Tree	Ibadan, Oyo State
17.	*Pterocarpus santalinoides* L'Hérit. ex DC	Tree	Olokemeji, Ogun state
18.	*Pterocarpus soyauxii* Taub.	Tree	Umuahia, Abia State

Data analysis

All quantitative data were subjected to multivariate analyses using PAlaeontological STatistics version 4.02 (PAST; Hammer et al. 2001).

RESULTS

The preliminary diversity studies showed that members of the tribe Dalbergieae are distributed across all the geo-ecological zones of Nigeria (Figure 1). Specifically, the transitional equatorial climatic zone of Nigeria appears to be the region of the widest distribution.

Qualitative and quantitative wood characteristics of the studied Dalbargieae species are presented in tables 2 and 3 respectively, while illustrations are presented in figures 2-5. Diffuse porosity, oblique to transverse vessel inclination, and simple perforation plates were observed in all the species, while the vessel pore was generally circular, oval, and short cylindrical in all but *P. mildbraedii* and *P. santalinoides*. Other variations in vessel pore observed were short rectangular, arc, polygonal and triangular types. The pitting of the vessel was commonly simple in all the species but also alternate in most of the species including *P. mildbraedii, P. santalinoides, P. erinaceus*, *D. albiflora, D. oligophylla, D. sissoo, Dalbergia lactea*, *D. ecastaphyllum*, *D. hostilis*, *D. lunatum*, *P. osun* and *D. latifolia;* and in addition, spiral in *D. latifolia* and *A. inermis*. Tyloses, which are outgrowths from adjacent ray or axial parenchyma cell through a pit in a vessel wall, were also seen in 13 of the species but absent in *P. santalinoides, D. melanoxylon*, *D. rufa*, *D. latifolia* and *M. lunatum*. Only *P. osun* had secretory ducts present; while ray type was mainly uniseriate, non-storied and heterogeneous (Table 2; Figures 2-4).

Fibres were generally non-septate and non-storied (Figure 5), with narrow walls about 1.0μm thick except in *D. saxatilis* (2.75 μm± 0.2); and large lumen with no pitting. Fibre length ranged between 0.69 μm±0.0 (*D. saxatilis*) and 331.22 μm±7.5 (*P. mildbraedii*) while lumen diameter was between 3.69 μm±0.1 (*D. oligophylla*) and 6.53 μm±0.1 (*P. soyauxii*) as shown in Table 3.

Pore diameter was generally small in all the species studied ranging from 0.04μm (in *M. lunatum* and *D. malanoxylon*) to 0.09μm (in *P. osun* and *P. souyauxii*). Ray cells observed were longer than wide, ray height measurements were between 41.82μm in *P. santalinoides* and 185μm in D*albergia saxatilis* while ray width measured between 4.33μm in *D. rufa* and 26.93μm in *D. saxatilis*. Vessel length measured after maceration was between 67.2μm in *D. hostilis* and 197.89 μm in D*albergia saxatilis*. However, the widest vessel was observed in *D. saxatilis* (104.23μm) while the least was seen in *D. oligophylla* (28.4μm), as noted in Table 3. Correlation coefficients of the examined wood characters are also presented in Table 4.

Further results as revealed through the dendrogram and scatter plot of species showed that there are three (3)

Table 2. Qualitative Wood Anatomical Characters of Some Members of the Tribe Dalbergieae.

Species	Porosity	Vessel pore shape	Perforation plate	Vessel inclination	Vessel pitting	Tylose	Secretory ducts	Axial parenchyma	Ray type	Crystal	Fibre
A. inermis	Diffuse	Circular, oval, short rectangular, short cylindrical to arc	Simple	Oblique to transverse	Simple, alternate and spiral	Present	Absent	Winged aliform, confluent, diffuse	Mainly multiseriate and biseriate, few uniseriate	Prismatic and styloid	Non-septate
D. albiflora	Diffuse	Circular, oval, short cylindrical to arc	Simple	Oblique to transverse	Simple and alternate	Present	Absent	Diffuse	Mainly uniseriate, non-storied and heterogeneous	Prismatic and styloid	Non-septate
D. ecastaphyllum	Diffuse	Circular, oval, short rectangular, short cylindrical to arc	Simple	Oblique to transverse	Simple and alternate	Absent	Absent	Diffuse in aggregate	Uniseriate, biseriate, multiseriate, non-storied and heterogeneous	Prismatic and styloid	Non-septate
D. hostilis	Diffuse	Circular, oval, short rectangular, short cylindrical to arc	Simple	Oblique to transverse	Simple and alternate	Present	Absent	Diffuse in aggregate	Mainly uniseriate, non-storied and heterogeneous	Prismatic and styloid	Non-septate
D. lactea	Diffuse	Circular, oval, short cylindrical to arc	Simple	Oblique to transverse	Simple and alternate	Present	Absent	Absent	Mainly uniseriate, non-storied and heterogeneous	Prismatic and styloid	Non-septate
D. latifolia	Diffuse	Circular, oval, short cylindrical to arc	Simple	Oblique to transverse	Simple, alternate and spiral	Absent	Absent	Winged aliform confluent, diffuse	Mainly uniseriate, non-storied and heterogeneous	Prismatic and styloid	Non-septate
D. melanoxylon	Diffuse	Circular, oval, short cylindrical to arc	Simple	Oblique to transverse		Absent	Absent	Diffuse in aggregate	Mainly uniseriate, non-storied and heterogeneous	Prismatic and styloid	Non-septate
D. oligophylla	Diffuse	Circular, oval, short cylindrical, short rectangular to arc	Simple	Oblique to transverse	Simple and alternate	Present	Absent	Diffuse in aggregate	Mainly uniseriate, non-storied and heterogeneous	Prismatic and styloid	Non-septate
D. rufa	Diffuse	Circular, oval, short cylindrical to arc	Simple	Oblique to transverse	Simple	Absent	Absent	Absent	Mainly uniseriate, non-storied and heterogeneous	Prismatic and styloid	Non-septate
D. saxatilis	Diffuse	Circular, oval, short cylindrical to arc	Simple	Oblique to transverse	Simple	Present	Absent	Diffuse	Mainly uniseriate, non-storied and heterogeneous	Prismatic and styloid	Non-septate
D. sissoo	Diffuse	Circular, oval, short cylindrical, triangular to arc	Simple	Oblique to transverse	Simple and alternate	Present	Absent	Diffuse in aggregate	Mainly uniseriate, non-storied and heterogeneous	Prismatic and styloid	Non-septate
M. lunatum	Diffuse	Circular, oval, short rectangular, short cylindrical to arc	Simple	Oblique to transverse	Simple and alternate	Absent	Absent	Diffuse in aggregate	Mainly uniseriate, non-storied and heterogeneous	Prismatic and styloid	Non-septate
P. erinaceus	Diffuse	Circular, oval, short cylindrical to arc	Simple	Oblique to transverse	Simple and alternate	Present	Absent	Diffuse in aggregate	Mainly uniseriate, non-storied and heterogeneous	Prismatic and styloid	Non-septate
P. lucens	Diffuse	Circular, oval, short cylindrical to arc	Simple	Oblique to transverse		Present	Absent	Diffuse in aggregate	Mainly uniseriate, non-storied and heterogeneous	Prismatic and styloid	Non-septate
P. mildbraedii	Diffuse	Circular, oval to arc	Simple	Oblique to transverse	Simple and alternate	Present	Absent	Diffuse in aggregates	Mainly uniseriate, non-storied and heterogeneous	Prismatic	Non-septate
P. osun	Diffuse	Circular, oval, short cylindrical to arc	Simple	Oblique to transverse	Simple and alternate	Present	Present	Diffuse in aggregate	Heterogeneous	Prismatic and styloid	Non-septate
P. santalinoides	Diffuse	Circular, oval, short rectangular, arc to polygonal	Simple	Oblique to transverse	Simple and alternate	Absent	Absent	Paratracheal aliform confluent, diffuse	Mainly uniseriate, non-storied and heterogeneous	Styloid	Non-septate
P. soyauxii	Diffuse	Circular, oval, short cylindrical to arc	Simple	Oblique to transverse		Present	Absent	Aliform confluent,	Mainly uniseriate, non-storied and heterogeneous	Prismatic and styloid	Non-septate

Table 3. Quantitative wood anatomical characters of some members of the tribe Dalbergieae (Mean±S.E).

Species	PD	PPS	RH	RW	FL	FW	FLU	FWT	VL	VW
A. inermis	0.08±0.8	2.47±0.1	99.03±4.8	13.58±1.2	185.08±5.4	6.43±0.2	4.45±0.2	1±0	76.23±2.4	31.14±0.9
D. albiflora	0.06±0.6	3.57±0.2	55.75±2.1	5.47±0.2	165.8±3.5	6.33±0.1	5.07±0.7	0.99±0	77.24±2.7	29.64±1.0
D. ecastaphyllum	0.08±0.8	2.00±0.1	61.47±2.3	7.53±0.2	206.01±4.2	7.21±0.1	5.23±0.1	1±0	82.64±2.4	36.85±1.1
D. hostilis	0.06±0.6	2.4±0.1	58.9±2.3	5.08±0.1	231.7±4.5	6.69±0.1	4.69±0.1	1±0	67.62±1.8	30.67±0.8
D. lactea	0.07±0.9	1.78±0.1	67.03±2.3	5.7±0.2	199.59±6.6	7.51±0.2	5.44±0.2	1±0	84.11±3.1	35.84±1.2
D. latifolia	0.08±0.7	1.71±0.1	0	0	271.79±7.1	6.57±0.1	4.6±0.1	1±0	78.12±2.0	47.92±1.9
D. melanoxylon	0.04±0.4	9.42±0.5	43.88±1.8	5.21±0.2	183.64±3.7	6.44±0.1	4.42±0.1	1±0	76.17±2.9	35.32±1.0
D. oligophylla	0.06±0.6	2.64±0.1	104.74±5.3	7.7±0.3	150.98±4.1	5.67±0.1	3.69±0.1	1±0	73.53±2.2	28.4±0.7
D. rufa	0.06±0.5	3.35±0.2	49.29±2.1	4.33±0.1	166.41±4.7	6.63±0.1	4.55±0.1	1±0	105.42±4.8	31.83±0.9
D. saxatilis	0.06±3.7	3.2±0.2	185.13±12.6	26.93±8.8	0.69±0.0	10.2±0.2	4.69±0.4	2.75±0.2	197.89±8.1	104.23±3.7
D. sissoo	0.07±0.6	3.16±0.2	56.97±2.7	6.7±0.2	220.52±4.3	6.12±0.1	4.19±0.1	1±0	59.57±1.3	31.15±0.8
M. lunatum	0.04±0.3	3.23±0.1	57.7±1.9	4.56±0.1	247.33±8.6	7.34±0.2	5.21±0.2	1±0	91.65±3.2	39.15±1.5
P. erinaceus	0.08±1.2	3.66±0.2	59.56±2.7	4.6±0.1	297.64±7.1	6.83±0.1	4.84±0.1	1±0	86.2±1.2	56.74±1.6
P. lucens	0.07±0.6	5.22±0.2	46.92±2.3	5.46±0.2	213.31±4.5	7.65±0.1	5.66±0.1	1±0	72.37±1.9	30.07±1.0
P. mildbraedii	0.07±0.8	2.22±0.1	55.86±3.1	7.33±0.3	331.22±7.5	7.05±0.1	5.06±0.1	1.01±0	75.47±1.8	37.27±1.5
P. osun	0.09±0.9	2.02±0.1	0	0	274.95±9.5	6.4±0.1	4.4±0.1	1±0	82.84±2.6	37.95±1.1
P. santalinoides	0.08±1.1	3.58±0.2	41.82±1.6	4.78±0.1	262.84±5.5	7.29±0.1	5.6±0.1	1±0	83.04±1.7	47.29±1.1
P. soyauxii	0.09±0.9	2.88±0.1	48.77±2.3	6.9±0.2	259.86±5.3	8.56±0.1	6.53±0.1	1±0	90.76±2.5	54.15±2.7

Key: PD: Pore diameter; PPS – Pore per square; RH – Ray height; RW – Ray width; FL- Fibre length; FW – Fibre width; FLU – Fibre lumen; FWT – Fibre wall thickness; VL- Vessel length; VW – Vessel width. All measurements in μm.

Table 4. Pearson's correlation coefficients of the examined wood anatomical characters.

	PD	PPS	RH	RW	FL	FW	FLU	FWT	VL	VW
PD	1.00									
PPS	-0.515	1.00								
RH	-0.306	-0.028	1.00							
RW	-0.157	-0.006	**0.943***	1.00						
FL	0.461	-0.171	-0.779	-0.756	1.00					
FW	0.066	-0.039	0.527	0.665	-0.401	1.00				
FLU	0.330	-0.041	-0.168	-0.064	0.276	0.553	1.00			
FWT	-0.172	-0.008	0.772	**0.865***	-0.732	0.765	-0.082	1.00		
VL	-0.162	-0.034	0.694	0.778	-0.687	**0.805***	0.038	**0.940***	1.00	
VW	0.080	-0.048	0.563	0.685	-0.429	**0.826***	0.153	**0.880***	**0.890***	1.00

Key: PD: Pore diameter; PPS – Pore per square; RH – Ray height; RW – Ray width; FL- Fibre length; FW – Fibre width; FLU – Fibre lumen; FWT – Fibre wall thickness; VL- Vessel length; VW – Vessel width.

main clusters (Figure 6, 7). 7 species formed cluster 1, 10 species formed cluster 2, while *D. saxatilis* occupied an isolated position, thereby representing an outlier.

Similarity indices (euclidean distance) for the species of the tribe Dalbergiae based on the wood anatomical characters is shown in Table 5. The least coefficient was observed between *D. lactea* & *D. ecastaphyllum* (8.88), followed by *P. osun* & *D. latifolia* (11.48), and then *P. souyauxii* & *P. santalinoides* (13.09); while the highest was observed between *P. mildbraedii* & *D. saxatilis* (381.89). This was closely followed by *P. osun* & *D. saxatilis* (357.59), and *D. saxatilis* & *D. latifolia* (355.01) respectively. Interestingly, the dissimilarity coefficients between *D. saxatilis* and the remaining species were very high compared to other taxa when compared; and this observation is also in support of the illustrations on the dendrogram and scatter-plot of the species where it occupied isolated positions.

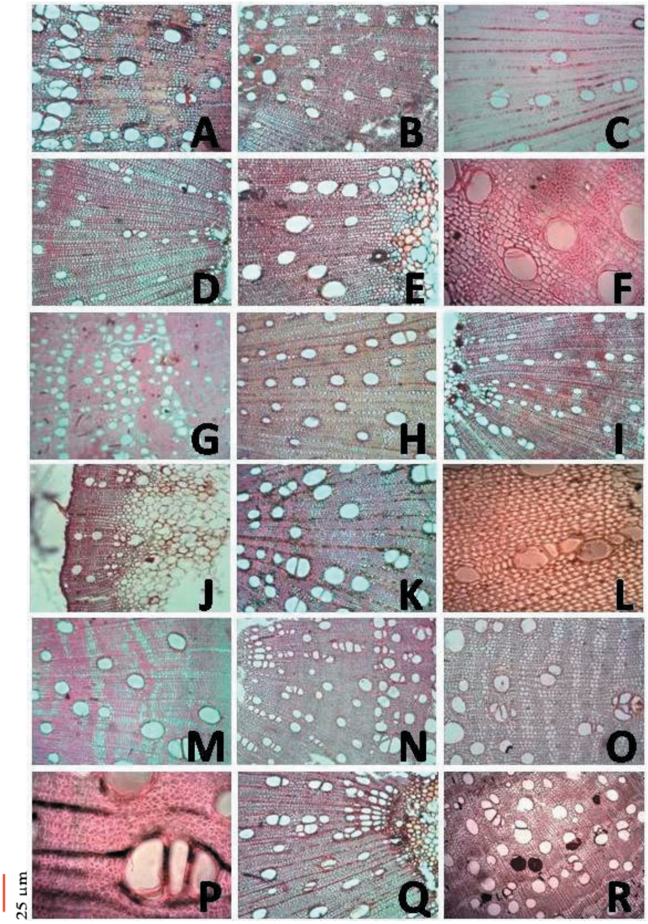

Figure 2. Transverse Sections (TS) of Dalbergieae species in Nigeria. Mg.*x400*. **A**- *Andira inermis;* **B**- *Dalbergia albiflora*; **C**- *Dalbergia ecastaphyllum*; **D**- *Dalbergia hostilis*; **E**-*Dalbergia lactea*; **F**-*Dalbergia latifolia*; **G**-*Dalbergia melanoxylon*; **H**-*Dalbergia oligophylla*; **I**-*Dalbergia rufa*; **J**-*Dalbergia saxatilis*; **K**-*Dalbergia sissoo*; **L**-*Machaerium lunatum*; **M**-*Pterocarpus erinaceus*; **N**-*Pterocarpus lucens*; **O**-*Pterocarpus mildbraedii;* ***P***-*Pterocarpus osun*; **Q**-*Pterocarpus santalinoides*; **R**-*Pterocarpus soyauxii*

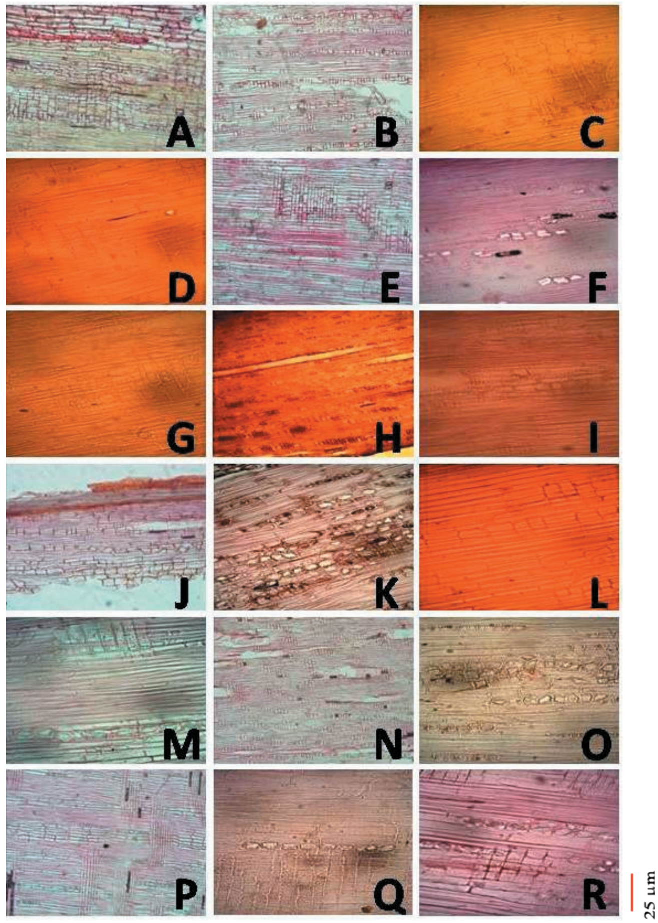

Figure 3. Radial Longitudinal Sections (RLS) of Dalbergieae species in Nigeria. Mg.*x400*. **A**- *Andira inermis;* **B**- *Dalbergia albiflora*; **C**- *Dalbergia ecastaphyllum*; **D**- *Dalbergia hostilis*; **E**-*Dalbergia lactea*; **F**-*Dalbergia latifolia*; **G**-*Dalbergia melanoxylon*; **H**-*Dalbergia oligophylla*; **I**-*Dalbergia rufa*; **J**-*Dalbergia saxatilis*; **K**-*Dalbergia sissoo*; **L**-*Machaerium lunatum*; **M**-*Pterocarpus erinaceus*; **N**-*Pterocarpus lucens*; **O**-*Pterocarpus mildbraedii;* ***P***-*Pterocarpus osun*; **Q**-*Pterocarpus santalinoides*; **R**-*Pterocarpus soyauxii*

DISCUSSION

Shreds of evidence from anatomical studies have been used for the delimitation of taxa as reported by Metcalfe and Chalk (1979); Aguoru and Okoli (2008), Arogundade and Adedeji (2019). Carlquist in 1961 had earlier submitted that wood anatomical characters are of taxonomic and phylogenetic importance, while more recently, Liu et al. (2020) noted that anatomical properties of wood relate closely to several factors amongst which is their genetic origin. In the current study, the wood anatomy of the 18 species of the tribe Dalbergieae studied provided more information on their taxonomic placement rather than characters that can be used for their delimitation. Generally, porosity is diffuse; perforation plate simple; tyloses present in all except *P. santalinoides, D. melanoxylon, D. rufa, D. ecastaphyllum, M. lunatum*, and *D. latifolia*; secretory ducts absent in all except *P. osun,* while fibre is non-septate in all the examined species. In furtherance, crystal is prismatic in *P. mildbraedii*, styloid in *P. santalinoides*, but a combination of both in the remaining 16 species studied. Vessel inclination is oblique to transverse while pitting is simple and alternately positioned. The presence of solitary vessels as also observed in this work is an indication of species primitiveness earlier reported by Oladipo and Oyaniran (2013).

Certain wood characters have more importance than others in the taxonomic understanding of the taxa stud-

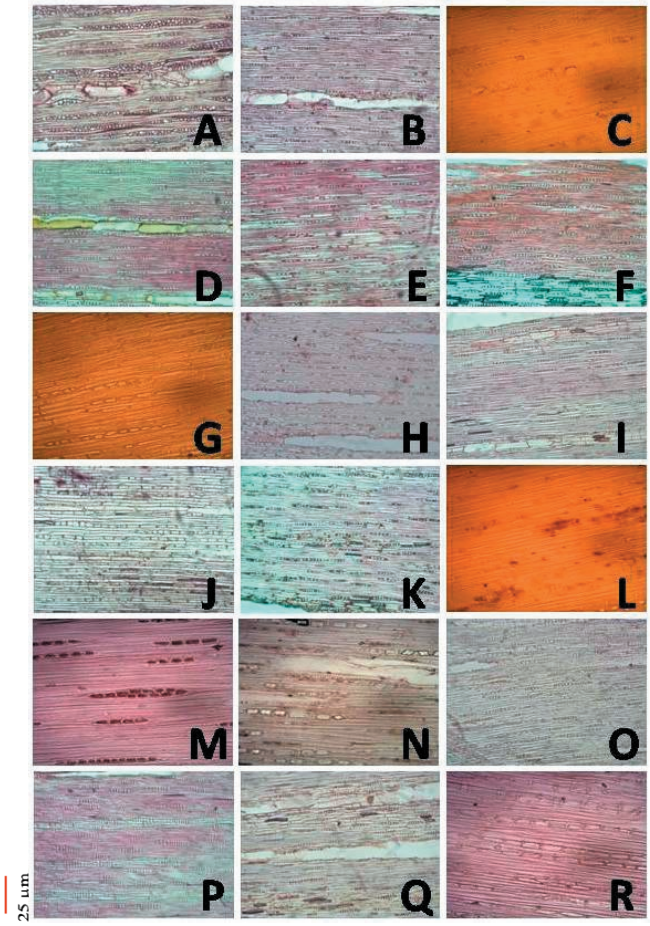

Figure 4. Tangential Longitudinal Sections (TLS) of Dalbergieae species in Nigeria. Mg.*x400*. **A-** *Andira inermis;* **B-** *Dalbergia albiflora*; **C-** *Dalbergia ecastaphyllum*; **D-** *Dalbergia hostilis*; **E**-*Dalbergia lactea*; **F**-*Dalbergia latifolia*; **G**-*Dalbergia melanoxylon*; **H**-*Dalbergia oligophylla*; **I**-*Dalbergia rufa*; **J**-*Dalbergia saxatilis*; **K**-*Dalbergia sissoo*; **L**-*Machaerium lunatum*; **M**-*Pterocarpus erinaceus*; **N**-*Pterocarpus lucens*; **O**-*Pterocarpus mildbraedii; **P**-Pterocarpus osun*; **Q**-*Pterocarpus santalinoides*; **R**-*Pterocarpus soyauxii*.

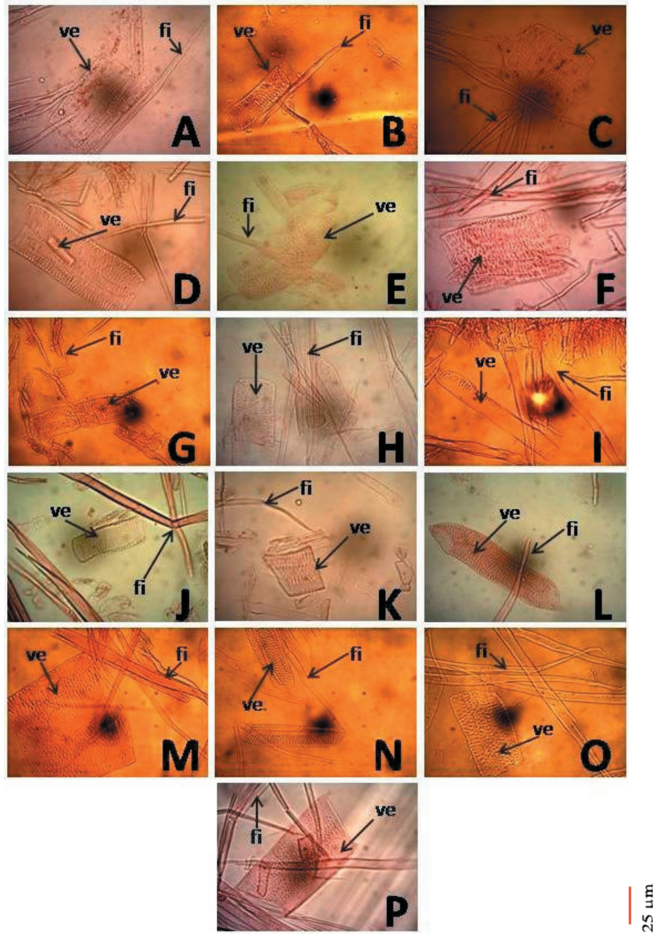

Figure 5. Wood macerates of Dalbergieae species in Nigeria. Mg.*x400*. **A-** *Andira inermis;* **B-** *Dalbergia albiflora*; **C-** *Dalbergia ecastaphyllum*; **D-** *Dalbergia hostilis*; **E**-*Dalbergia lactea*; **F**-*Dalbergia latifolia*; **G**-*Dalbergia melanoxylon*; **H**-*Dalbergia oligophylla*; **I**-*Dalbergia rufa*; **J**-*Dalbergia saxatilis*; **K**-*Dalbergia sissoo*; **L**-*Machaerium lunatum*; **M**-*Pterocarpus erinaceus*; **N**-*Pterocarpus lucens*; **O**-*Pterocarpus mildbraedii; **P**-Pterocarpus osun*. **fi**- fibre; **ve**- vessel elements.

ied. Pearson's correlation of the wood characters in Dalbergieae showed that ray height is highly correlated with ray width, ray width is highly correlated with fibre wall thickness, fibre width is highly correlated with vessel length and vessel width. Further, fibre wall thickness is very highly correlated with vessel length and vessel width, while vessel length and vessel width are also highly correlated. These combinations could be used to distinguish the taxa. It was also observed that all species studied have similar vessel shapes at a transverse plane, from circular, oval, short cylindrical, short rectangular, arc to polygonal. Kribs (1937) in Metcalf and Chalk (1989) considered the lack of axial parenchyma in the wood of plants as a primitive character, on the contrary, the species studied have axial parenchyma except for *D. rufa* and *D. lactea*. In *P. mildbraedii, P. erinaceus, P. lucens, P. osun, D. melanoxylon, D. oligophylla, D. sissoo, D. ecastaphyllum, D. hostilis,* and *M. lunatum*, it is diffuse in aggregate while in others it was either winged or paratrecheal aliform, confluent and diffuse. According to Wickremasinghe and Herat (2006), features of wood ray tissues are important in deducing evolutionary sequences within angiosperm groups. In the present study, ray type varied from heterogenous in *P. osun* to a combination of uniseriate, biseriate, multiseriate, non-storied, and heterogeneous in other species. Simply put, the presence of uniseriate ray cells observed in almost all the species except *D. ecastaphyllum* and *A. inermis*, is a diagnostic feature of phylogenetically

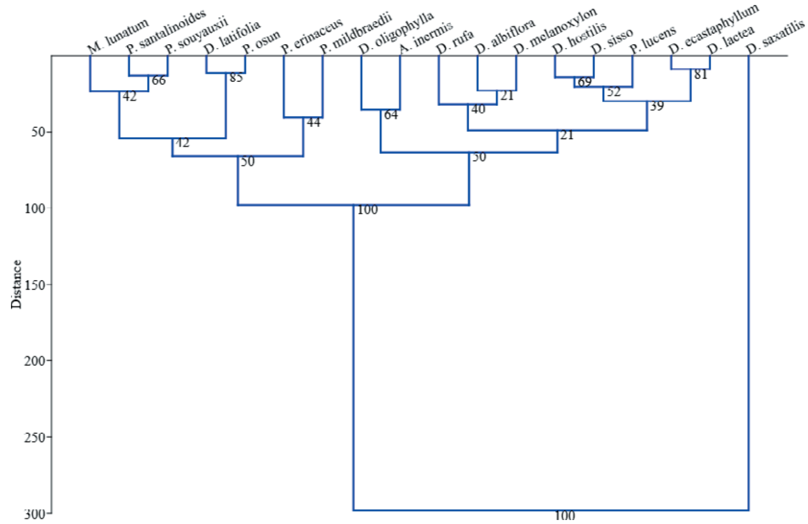

Figure 6. Dendrogram (UPGMA) of Dalbergieae species based on euclidean distance.

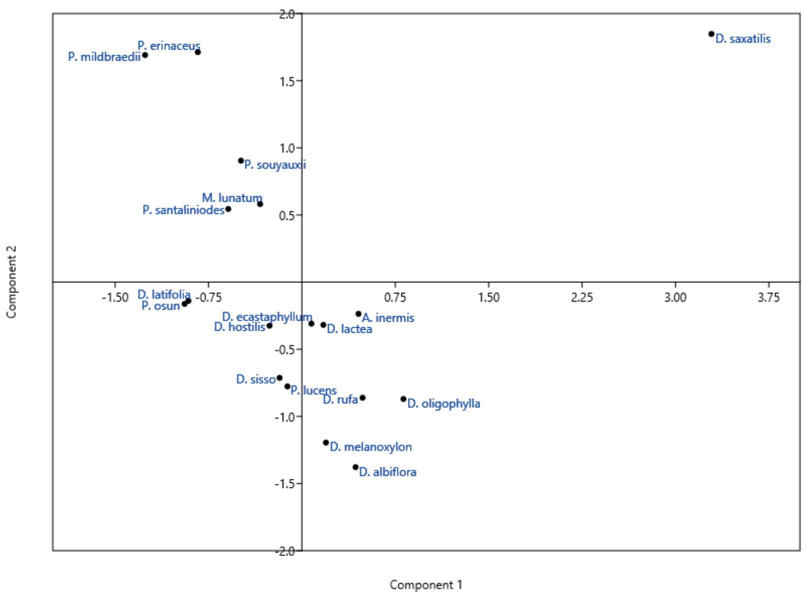

Figure 7. Scatter plot of species of Dalbergieae studied based on the wood anatomical characters.

advanced taxa (Metcalfe and Chalk, 1989), and important in depicting the evolutionary sequence of specialization within angiosperms (Kribs, 1935). However, the rays are non-storied which is quite different from the observations of Lavin et al. (2001), who earlier recorded storied rays and axial parenchyma in legumes; but conforms to their report of heterogeneous rays in juvenile wood samples as used in this study.

All studied species have crystals that were either prismatic or styloid or both and this may not be a diagnostic feature. It was also observed that most of the studied species have tylose except *P. santalinoides, P. erinaceus, D. melanoxylon, D. rufa, D. ecastaphyllum, D. latifoila, M. lunatum*. This character is also considered an indication of evolutionary primitiveness (Bonsen and Kucera, 1990 in: Wickremasinghe and Herat, 2006). The presence of non-septate, non-storied fibres observed in all of them is of no taxonomic importance, unlike septate fibres which are important taxonomic tools (Metcalfe and Chalk, 1989).

Quantitative features as observed in this study revealed that the average number of vessels per square millimeter may not be taxonomically important as a classificatory and diagnostic character for this taxon;

Table 5. Similarity indices (Euclidean) for the examined species of Dalbergieae based on wood anatomical characters.

Species	*A. inermis*	*D. albiflora*	*D. ecastaphyllum*	*D. hostilis*	*D. lactea*	*D. latifolia*	*D. melanoxylon*	*D. oligophylla*	*D. rufa*	*D. saxatilis*	*D. sisso*	*M. lunatum*	*P. erinaceus*	*P. lucens*	*P. mildbraedii*	*P. osun*	*P. santalinoides*	*P. souyauxii*
A. inermis	0																	
D. albiflora	48.12	0																
D. ecastaphyllum	44.28	41.69	0															
D. hostilis	62.69	66.69	30.61	0														
D. lactea	37.19	36.87	**8.88**	37.39	0													
D. latifolia	133.40	121.29	91.14	74.23	99.61	0												
D. melanoxylon	56.39	22.96	30.26	51.76	30.24	99.73	0											
D. oligophylla	35.30	51.41	71.13	93.09	62.96	161.34	69.85	0										
D. rufa	61.33	29.03	47.68	76.07	43.49	120.67	35.09	65.99	0									
D. saxatilis	248.52	254.18	275.08	303.62	267.59	**355.01**	271.15	225.10	245.44	0								
D. sisso	57.88	57.56	28.28	14.05	34.20	80.91	43.20	85.57	71.38	299.43	0							
M. lunatum	77.26	83.37	42.64	29.95	49.37	64.90	67.39	109.34	82.84	305.14	42.66	0						
P. erinaceus	122.74	134.95	93.91	73.32	100.58	66.21	117.62	156.61	135.34	345.25	85.58	53.61	0					
P. lucens	60.04	48.62	20.77	22.68	27.85	77.57	30.86	85.16	57.51	293.34	18.12	41.63	90.43	0				
P. mildbraedii	152.64	165.62	125.54	100.12	132.41	82.63	148.27	186.98	167.76	**381.89**	112.02	85.53	40.56	118.56	0			
P. osun	134.75	123.11	92.69	75.17	101.06	**11.48**	101.96	163.03	121.57	**357.59**	82.72	64.77	66.71	78.84	79.98	0		
P. santalinoides	98.53	99.79	61.12	42.17	69.08	43.38	80.65	130.13	100.48	**325.89**	53.28	25.17	40.32	53.79	70.99	44.84	0	
P. souyauxii	94.40	98.43	58.57	44.64	65.96	52.69	80.35	126.35	97.27	316.49	55.93	21.71	39.79	55.66	75.27	54.67	**13.09**	0

as neither very low nor very high measurements were obtained, the range is between 1.71 µm ± 0.1 (*D. latifolia*) and 9.42 µm ±0.5 (*D. melanoxylon*) (Metcalfe and Chalk (1989). Mean pore diameter ranges between 0.04 µm±0.3 in *M. lunatum* and 0.09 µm±0.9 in *P. soyauxii* and *P. osun*. On average, the longest fibre was observed in *P. midbraedii* (331.22 µm±7.5) while the shortest fibre was seen in the macerated wood of *D. oligophylla* (150.98 µm±4.1). According to Maiti et al. (2016), the presence of big vessels in plants makes them susceptible to drought and therefore may possess a deep root system to adapt to this condition. However, all studied species have relatively small vessels because they are not found in arid habitats. As evidenced in this study, the woods of members of the tribe Dalbergieae have more generic/tribal characteristics than delimiting characters. Distributional information also clearly showed that members of the tribe occur in all the geo-ecological zones of Nigeria but are most widely distributed around the Southern region. This could be attributed to the high rainfall or precipitation characterized by this area which also enhances species growth and development compared to species in the Northern area. Given the continuous habitat degradation in the south however, the distribution of the species may decline further. Hence, it is imperative to consider the sustainable collection and use of plant genetic resources on one hand, and the conservation of our remaining forest estates on the second hand, else we loose our biodiversity to climate change.

CONCLUSION

The present study examined the wood anatomical features of some species of the tribe Dalbergieae in Nigeria. Results have shown that the porosity of the wood of all species studied was diffuse and the vessels have simple perforation plate. All except *P. osun* lacked secretory ducts; and possess non-septate fibres. However, few of the species lacked tylose. Crystals were either prismatic, styloid or a combination of both. Generally, wood micro- characteristics across all the species overlapped, yet, certain characters can be utilized in distinguishing the taxa. While we recognize the importance of molecular data in recent studies, we advocate that other aspects such as macro and micro-morphology should not be ignored, as they provide supplementary information to aid the taxonomic understanding of species.

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