The Bioscientist Journal Vol. 14 (2): 13 – 20, May 2026
Journal of the Faculty of Biosciences, Nnamdi Azikiwe University, Awka, Nigeria
Available online at http://www.bioscientistjournal.com
DOI 10.54117/the_bioscientist.v14i2.213



Full Length Research Article

Anatomical Characterization of Vessels in Selected Nigerian Wood Species of Verbenaceae Family

Adeniyi, I. M.

Forestry Research Institute of Nigeria P.M.B 5054, Forest Hill, Jericho Estate, Ibadan, Oyo-State
micifad@gmail.com; +2348060255041
***Article History**: Received: 27th February, 2026, Accepted: 1st May, 2026*

ABSTRACT
Nature of vessels in selected Nigerian trees of Verbenaceae family was investigated for variations and similarities in this study. Wood samples were collected from the stems of *Tectona grandis*, *Gmelina arborea*, *Vitex cienkowskii*, *Vitex doniana*, *Gmelina leichhardtii* and *Avicennia nitida* at Forestry Research Institute of Nigeria, Ibadan. Wood samples were cut into about 20 µm sections using a Ritchet sliding microtome machine. Measurements of wood vessels were performed on an Olympus light microscope (CH Series) at 80 × magnification, Pore tangential diameter (PTD) was measured in the direction perpendicular to the rays at the transverse section, while pore radial diameter (PRD) was measured in the direction parallel to the rays at the transverse section. Results showed that values of pore radial diameter (PRD) ranged from 53.6 µm in *Avicennia nitida* to 294 µm in *Vitex doniana*; pore tangential diameter (PTD) ranged from 53.6 µm in *A. nitida* to 245 µm in *V. doniana*; *A. nitida* had the least solitary pores of 5.27 % as most pores were in clusters, while *T. grandis* had the highest solitary pores of 73.78 %. Generally, PRD was higher than PTD among the wood species, this might be due to procumbent rays in which pores were sandwiched forcing vessels to assume an oval shape. All the wood species possessed pore pairs; and there were inclusions in vessels in form of either gum or tyloses. Whereas few differentiating characters include the number of solitary pores which were few in *A. nitida* and *G. leichhardtii* but high in *T. grandis* and *V. doniana*. These findings may enhance wood identification and utilization of the members of the family.

Keywords: Rays, Vessels, Pattern, identification, Verbenaceae, Group

Introduction

Vessels (pores) are specialized cells for conduction in trees, their size is not the same in all wood species (Adeniyi *et al*., 2013). In a cross section, Pores can be described by their position relative to one another within the xylem. Hence different wood species uniquely differ in vessel diameter, arrangements, vessel number and spacing that can consequently influence wood density; this is because wood density is dependent not only on fiber wall thickness, but also on the amount of void space occupied by vessels and parenchyma (Wiedenhoeft, 2010).

The Nigerian family Verbenaceae was represented in this study by *Tectona grandis*, *Gmelina arborea*, *Vitex cienkowskii, Vitex doniana*, *Gmelina leichhardtii* and *Avicennia nitida*. Most botanists classified these species in Verbenaceae family, but most of the genera in this family have alternatively been placed in the Lamiaceae family. As a matter of fact, several important timber plants in this family like Teak, *Gmelina* and *Vitex* for instance, have been reassigned to Lamiaceae (Cantino, 1998; Paul, 2009). *V. doniana* is a deciduous species with a medium growth rate (Orwa *et al*., 2009) and geographically abundant in savannah regions. Timber from the wood species can readily be impregnated with little or no resistance under both non-pressure and pressure methods (Makonda *et al*., 2016). *Vitex* species produce wood used for shingles and bark for tanning, also hardy ornamental in warm temperate regions. It dries slowly, but once seasoned, the wood species is used in constructions, furniture, carriages, sports, musical instruments and joinery. *Gmelina arborea* is fast growing and deciduous species, occurring in most part of the country as a plantation species, with pulping properties superior to most hardwood pulps. While Olaniran *et al* (2022) stated that impregnation of chemicals into microstructure of *G. arborea* is next to impossible, the wood species has been found as an excellent substitute to *C. milleni* for making talking drums and other types of drums (Aiyejola *et al*., 2015). *Tectona grandis* has become one of the most important wood species for tropical plantation under intensive short rotation management with 20–30-year rotations (Bhat, and Ok Ma, 2004). Coupled with its characteristic fragrance and an oily feel, its features have made the wood one of the most important wood species in the market and one of the most planted and marketable (Goh and Monteuuis, 2005). *Avicennia nitida* which is widely referred to as *A. germinans* is a mangrove tree. Avicennia species have been traditionally used as a medicine for a wide range of diseases (Das *et al*., 2016). The wood (*A. nitida*) is also used for marine construction, boat construction, furniture, implements and heavy flooring. Effect of pores during wood utilization cannot be underestimated; for instance, timber with large pores or wood species with large pores are light, and coarse-textured. Such wood species can easily be impregnated with chemical preservatives during non-pressure or pressure methods (Makonda *et al*.,2016). Hence, this study intends to investigate characteristic features of pores in some tree members of Verbenaceae family with a view to ascertaining the nature of vessels within the wood species.

Materials and Methods

Study Area

This study was carried out in Forestry Research Institute of Nigeria (FRIN) Ibadan. The institute lies within latitude 7° 23′ 15" to 7° 24′ 00" N and longitude 3°51' 00" to 3° 52′ 15″ E, with an annual rainfall ranging from 1400mm – 1500mm. The mean annual temperature ranges between 18.7°C and 34.4°C; the average relative humidity is about 80-85% (FRIN 2015).

Sample Collection

Wood samples (Four for each species) were collected from mature trees of *Tectona grandis* (FHI NO. 44304), *Gmelina arborea* (FHI NO. 34044), *Vitex cienkowskii* (FHI NO. 76755), *Vitex doniana* (FHI NO. 44335), *Gmelina leichhardtii* (FHI NO. 42) and *Avicennia nitida* (FHI NO. 21214), at the Forestry Research Institute of Nigeria, Ibadan. Identification of wood samples was done at the Wood Anatomy Section of the Institute through authenticated wood samples and microscopic slides in the Wood Library. Only the sapwood portion (the part containing active cells) was collected at the breast height (Prasad and Nageeb, 2012,) using an increment borer (Rahman, *et al*, 2004; Marcati *et al*, 2014) of diameter 12 mm.

Slide Preparation and examination

Sectioning of sample materials was performed in accordance with standard procedures for the study of wood structure employed to prepare sections for light microscopic studies (ASTM, 2018) using a sliding microtome machine. Sections (about 20 µm thick) from wood samples were stained using Safranin stain and dehydrated by passing wood sections through a series of bath of increasing concentrations (30%, 50%, 70% and 90%) of ethanol to replace water, cleared in a coconut oil (Adeniyi *et al*. 2016) and later mounted on a microscopic slide using Canada balsam and covered with a cover glass slip. Measurements of wood vessels were performed under an Olympus light microscope (CH Series), at 80 × magnification using a stage micrometer and eye piece graticules. Pore tangential diameter (PTD) was measured as the diameter of vessels in the direction perpendicular to the rays at the transverse section, while pore radial diameter (PRD) was measured the diameter of vessels in the direction parallel to the rays at the transverse section.

Data Analysis

The study was designed in a single-factor (tree species) CRD and analyzed using Analysis of Variance (ANOVA) in R statistical software (R Core Team 2016).

Result and Discussion

Vessels (pores) were mostly ring porous in all the species investigated except *G. Arborea* in which pores were diffuse (Plates 1 to 6). Percentages of solitary pores in *Avicennia nitida, Vitex doniana, Gmelina arborea, Gmelina leichhardtii*, *Vitex cienkowskii* and *Tectona grandis* were 5.2 %, 71.15 %, 50.07%, 38.33 %, 41.45 % and 73.78 % respectively (Figure 2). Hence, pores were mostly solitary in *V. doniana* (almost in tangential arrangement) and *T. grandis*, but pores in *A. nitida* were exclusively in groups (mostly in clusters), and this confirms the least solitary pores of 5.2 % recorded for *A. nitida*. Pores were in radial multiples in *G. leichhardtii* (about 3 to 4) and *A. nitid*a (about 4 to 9). Inter-vessel pits were small in *G. leichhardtii*, minute in *A. nitida*, and slit-like in *V. doniana*, while they were alternate and vestured in *V. cienkowskii, T. grandis* and *G. arborea*. Perforations were simple in all the species. Gum or deposits were present in *T. grandis* and *A. nitida*, while tyloses were present in *G. arborea*, *G. leichhardtii*, and *T. grandis.* Results of anatomical features of *V. doniana* are similar to the previous findings of Makonda *et al*., 2016). Included phloem and parenchyma containing a band of stone cells were observed in *A. nitida*.

Values of pore radial diameter (PRD) ranged from 53.6 µm in *Avicennia nitida* to 294 µm in *Vitex doniana*; pore tangential diameter (PTD) ranged from 53.6 µm in *A. nitida* to 245 µm in *V. doniana*. Table 1 shows that *A. nitida* had the smallest values of PTD (64.85 ±7.66 µm) and PRD (67.40 ± 13.3 µm), while *V. doniana* had the highest values of PTD (182.91 ±36.04 µm) and PRD (229.54 ±39.98 µm) as shown in Figure 2. *A. nitida* is a mangrove wood, small vessel diameter in mangrove trees is to produce

high increase in water flow resistance (Li *et al*. 2009).

Generally, PRD was higher than PTD among the wood species as seen in Table 1. This might be due to procumbent rays that force some vessels to assume oval shape, although Figure shows that vessel parameters (PTD and PRD) were almost the same in *G. leichhardtii* indicating that vessels in the *G. leichhardtii* were almost round. Meanwhile, Table 2 shows that variations in vessel parameters (dimensions) among the members of the family studied were highly significant at $P < 0.001$. The values recorded for *V. doniana* was similar to the previous work of Richter and Dallwitz (2000) on the same species, but different from the previous work of Makonda *et al*., (2016) in which 20 µm to 100 µm were recorded for *V. doniana.* This discrepancy might be due to variances in locations of the species. Generally, among the wood species, PRD (pore radial diameter) values were higher than PTD (pore tangential diameter), this is in line with the work of Dodd (1984) on *Acer pseudoplatanus*. PRD and PTD values were almost the same in *A. nitida*, and this is an indication that vessels or pores in *A. nitida* were almost round. However, PRD (pore diameter along ray direction) values were generally larger than PTD (pore diameter perpendicular to ray direction) in all the species. This difference between PTD and PRD might be due to the procumbent rays in which the vessels are sandwiched thereby resulting in oval shape of pores. Vessel length ranged from 0.11mm in *Gmelina arborea* to 0.46 mm in *Gmelina leichhardtii*, while vessel frequency ranged from 4 N/mm^2 in *V. doniana* to 40 N/mm^2 in *A. nitida*. Table 3 indicates a significant negative correlation ($R= 0.71$, $P<0.001$) between vessel diameter and vessel frequency (VF). This implies that wood species with larger pores (*V. doniana*) will show a lower vessel density or vessel frequency (Bessa *et al*., 2022) as seen in Figure 1: species with smaller pores (*A. nitida*) possessed higher VF (Figure 2).

Using similarities and differences as a method to show phenetic relationships, it is glaring from the anatomical data presented here that the members of Verbenaceae have many characters in common. All the wood species possessed pore pairs; and there were inclusions in vessels in form of either gum or tyloses. Whereas few differentiating characters include the number of solitary pores which were few in *A. nitida* and *G. leichhardtii* but high in *T. grandis* and *V. doniana* as shown in Table 1. Since tyloses act as plugs within hardwood species making wood less permeable and harder to treat with preservatives (Hillis, 1972; Mirand *et al*, 2009), tyloses in *G. arborea*, *G. leichhardtii*, and *T. grandis* will create extreme resistance to penetration of chemical preservatives (Olaniran *et al* 2022; Olorunnisola, 2023). Meanwhile, depending on the end use, the presence of tyloses and gum deposits may also be advantageous as they increase the durability of the wood, hence gum or deposits observed in *T. grandis* and *A. nitida* can repel the attack of insects of all kind. Tyloses make woods particularly useful for liquid containers especially the wood of *Sorindeia trimeris* in which tyloses are sclerotic (Meyer, 1967; Dickison, 2000). During seasoning too, permeability can be low as a result of blockage by tyloses.

On the other hand, timber with large pores can readily be impregnated with little or no resistance during non-pressure or pressure methods (Makonda *et al*., 2016), therefore timber from *V. doniana* species may not resist chemical impregnation owing to the size of pores as seen in Table 1. However, such wood species with large pores also require some fillers before it is finished to a smooth surface (Karl, 1984; Adeniyi *et al*, 2013); moreover, species with large pores (e.g. Ceiba pentandra) are usually easily attacked by beetles because their eggs are usually laid in the pores after feeding on the starchy contents of the sapwood. Generally, wood species with large pores are

light, and coarse-textured e.g. *Triplochyton scleroxylon*, *Ceiba pentandra*, *Bombax bounopozense* and *Ricinodendron heudelotii*. This could explain the reason they are used for light construction purposes (Adeniyi *et al*, 2013).

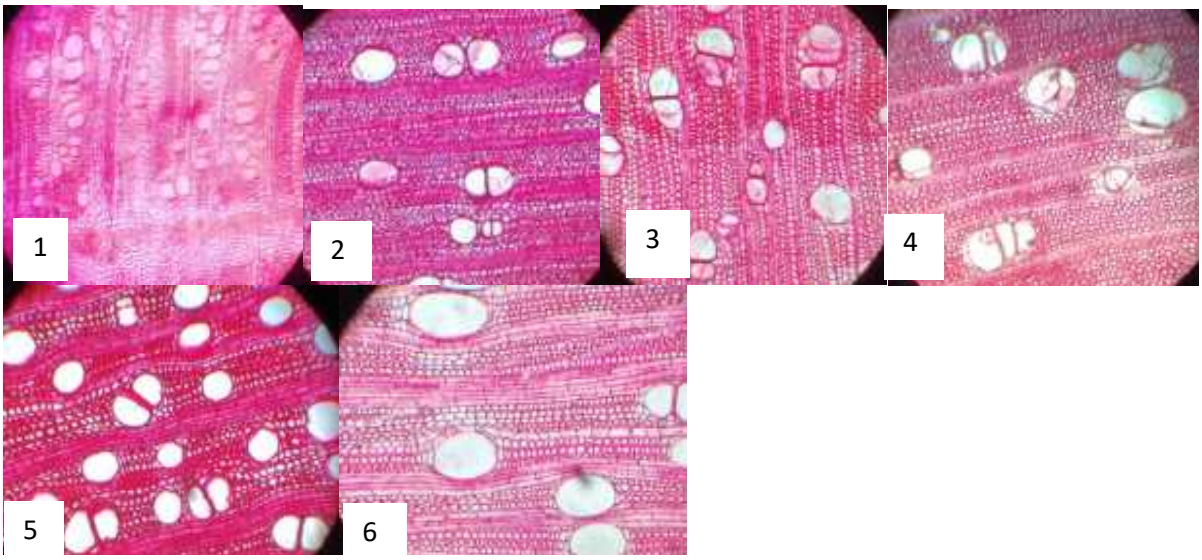


Plate 1. Small vessels, *A. nitida,* 80 ×. _Plate 2. *G. arborea* 80 ×. _Plate 3. *G. leichhardtii* 80 ×. _Plate 4. *T. grandis* 80 ×. _Plate 5. *V. clenkowks* 80 ×. _Plate 6. Big vessels, *V. doniana* 80 ×.

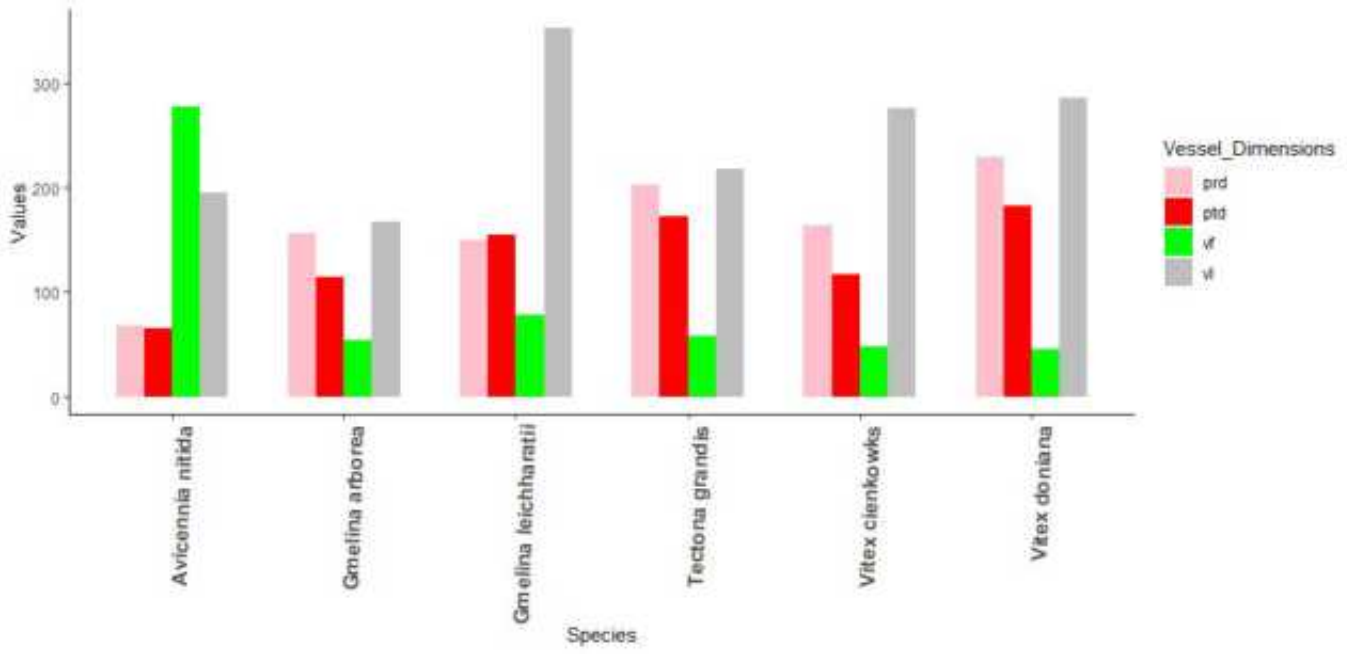


Figure 1: Vessel dimensions among Verbenaceae wood species.

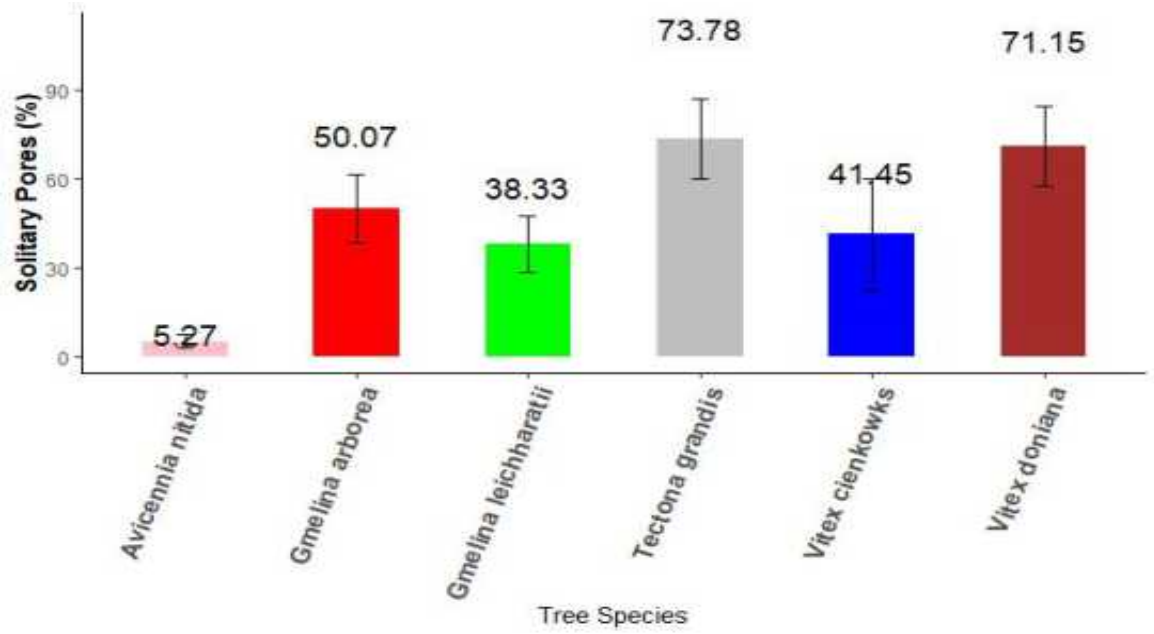


Figure 2: Percentage of solitary pores among the wood species

Table 1: Average values of vessel parameters in Verbenaceae wood species

	Solitary Pores (%)	PRD (µm)	PTD (µm)	VL (mm)	VF (v/mm^2)
Avicennia nitida	5.27^{d}	67.40 ± 13.37^{c}	64.85 ±7.66^{d}	0.196 ±0.05^{cd}	27.8 ±7.51^{a}
Vitex doniana	71.15^{a}	229.54 ±39.98^{a}	182.91 ±36.04^{a}	0.29 ±0.05^{b}	4.5 ±0.85^{d}
Gmelina arborea	50.07^{b}	156.38 ±27.16^{b}	114.57 ±15.32^{c}	0.17 ±0.04^{d}	5.4 ±0.7^{cd}
Gmelina leichhardtii	38.33^{c}	150.35 ±22.57^{b}	154.56 ±24^{b}	0.35 ±0.06^{a}	7.8 ±2.35^{bc}
Vitex cienkowskii	41.45b^{c}	164.24 ±32.64^{b}	117.25 ±29.93^{c}	0.28 ±0.06^{b}	9.6 ±2.68^{b}
Tectona grandis	73.78^{a}	202.47 ±38.29^{a}	172.86 ±51.37^{ab}	0.22 ±0.03^{c}	5.8 ±0.92^{cd}

PRD = pore radial diameter, PTD = pore tangential diameter, VF = vessel frequency, VL = vessel length

Means with different superscripts are significantly different ($p<0.05$)

Table 2: ANOVA table for vessel parameters in Verbenaceae wood species

Vessel Dimensions	DF	F value	Pr(>F)
Prd	5	33.09	< 0.001
Ptd	5	20.541	< 0.001
Vl	5	17.34	< 0.001
Vf	5	65.93	< 0.001
Solitary Pore	5	40.08	< 0.001
Residuals	54		
Total	59		

*** PRD = pore radial diameter, PTD = pore tangential diameter, VF = vessel frequency, VL = vessel length**

Table 3: Correlation among the vessel parameters

Solitary Pores	Prd	Ptd	Vl	Vf
Prd	1.00	0.87	0.20	-0.72
Ptd	0.87	1.00	0.35	-0.65
Vl	0.20	0.35	1.00	-0.19
Vf	-0.72	-0.65	-0.19	1.00

PRD = pore radial diameter, PTD = pore tangential diameter, VF = vessel frequency, VL = vessel length

Conclusion

Members of Verbenaceae have many characters in common which include pore pairs, inclusions (either gum or tyloses) in vessels (which are also ring porous vessels). Yet they can be separated by the number of solitary pores which vary among the wood species of the Verbenaceae family. This characterization definitely has a great influence during wood utilization of the members of the family.

Significance Statement

This study discovers features that bring about variability and similarity of wood species in Vebenaceae family. These anatomical structures also influence the behavior of the resultant timbers of the wood species in service. The study will certainly assist researchers and wood end users to identify which features are common to members of the family investigated in this study.

Acknowledgement

Xylarium section of the Forestry Research Institute of Nigeria, Ibadan is hereby acknowledged for proper identification of wood samples and slides used in this study.

Authors Contribution

Conceptualization, material preparation, data collection and analysis were all performed by the author Adeniyi Ifedayo Michael.

Conflict Of Interest

This research was not funded by anybody of organization. It is solely a self-sponsored study. Therefore, it is paramount to highlight that there is no conflict of interest on this study.

References

Adeniyi, I.M., Adebagbo, C.A., Oladapo, F.M. and Ayetan, G. (2013). Utilization of Some Selected Wood Species in Relation to their Anatomical Features. Global Journal of Science Frontier Research Agriculture and Veterinary Volume 13 Issue 9. Pp20-27.

ASTM (2018). American Society for Testing and Materials. ASTM D 1030-95 – "Standard test method for microscopic measurement of dry film thickness of coatings on wood products". West Conshohocken, PA. 2018.

Bessa, F., Sousa, V., Quilhó, T., and Pereira, H. (2022). An Integrated Similarity Analysis of Anatomical and Physical Wood Properties of Tropical Species from India, Mozambique, and East Timor. *Forests* 2022, 13, 1675. https://doi.org/10.3390/f13101675

Cantino P.D., Wagstaff, S.J. Olmstead, R.G. (1998). *Caryopteris* (Lamiaceae) and the conflict between phylogenetic and pragmatic considerations in botanical nomenclature Syst. Bot. (1998), pp. 369-386

Das, S.K., Samantaray, D., Patra, J.K., Samanta, L, and Thatoi, H. (2016) Antidiabetic potential of mangrove plants; a review. *Front Life Sci*. 9:75-88.

Dickison, W. C. (2000). Integrative plant anatomy. New York, NY: Academic Press. Pp 533 -546.

Dodd, R.S. (1984). Radial and tangential diameter variation of wood cells within trees of Acer pseudoplatanus. IAWA Bulletin, n.s., Vol. 5 (3), 253-257

Goh, D. K. S. and Monteuusis, O. (2005). Rationale for developing intensive teak clonal plantations, with special reference to Sabah. Bois et Forêt des Trop 285:5–16.

Ky, K.J.M., (2008). *Vitex doniana* Sweet. [Internet] Record from PROTA4U. Louppe, D., Oteng-Amoako, A.A. & Brink, M. (Editors). PROTA (Plant Resources of Tropical Africa / Ressources végétales de l'Afrique tropicale), Wageningen, Netherlands. <http://www.prota4u.org/search.asp>. Accessed 24 January 2026.

Karl, F. W. (1984): Forestry Handbook, Society of American Foresters, Pp 616-623.

Keay, R.W.J., Onochie, C.F.A. and Stanfiled, D.P. (1964): Nigeria trees. Federal Department of Forest Research, Ibadan Nigeria. Voloume II, Pp 430-436.

Li, Y.,Li, Z., and Lin, P. (2009).The study on the leaf anatomy of some mangrove species of China. In: International conference on environmental science and information application technology, 2009. *ESIAT* 2009, Wuhan, China, 11-14.

Makonda, F.B.S.1, Kitojo, D.H., Augustino, S., Ruffo, C., Ishengoma, R.C., Gillah, P.R.,

Eriksen, S., and Msanga, H.P. (2016). *Vitex doniana* sweet: a potential lesser-known and lesser utilized agro-forestry timber species in Kilosa district, Morogoro Tanzania**.** International Journal of Contemporary Applied Sciences Vol. 3, No. 1. 100-113.

Moya, R. and Tomazello F.M. (2008): Variation in the wood anatomical structure of Gmelina arborea (Verbenaceae) trees at different ecological conditions in Costa Rica. PubMed Journals, NCBI Resources, US National Library of medicine. Rev Biol Trop. 2008 Jun;56(2):689-704.

Olaniran, S.O., Loning, S., and Buschalsky, A., and Militz, H. (2022). Impregnation properties of Nigerian-grown Gmelina arborea Roxb. Wood. Forests 13 (12), 2036,2022.

Olorunnisola, A.O. (2023). The Past, Present and Future Outlook of the Wood Industry in Nigeria. IntechOpen. doi: 10.5772/intechopen.105794.

Paul, E. B. "Lamiaceae". Encyclopedia Britannica, 12 Mar. 2025, https://www.britannica.com/plant/Lamiaceae. Accessed 30 August 2025.

Rahman, M.M., Fujiwara, S., and Kanagawa, Y. (2004). Variation in volume and dimensions of rays and their effect on wood properties of Teak. *Wood and Fiber Science*, 37 (3), 497 – 504.

Richter, H.G., and Dallwitz, M.J. (2000). Onwards. Commercial timbers: descriptions, illustrations, identification, and information retrieval. In English, French, German, Portuguese, and Spanish. Version: 25th June 2009. http://delta-intkey.com

Wiedenhoeft, A. (2010). Structure of wood. Forest Products Laboratory General Technical Report . FPL-GTR-190. Chapter 3. Pp 3-12.