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DENSITY VARIATION IN AXIAL AND RADIAL POSITIONS OF CARIBBEAN PINE (Pinus caribaea Morelet) GROWN IN AFAKA, NIGERIA

J.T.B. Riki, S.M. Adeyemo, A.R. Majekobaje, A.T. Oyelere and A.O. Oluwadare

Department of Forest Production and Products, Faculty of Renewable Natural Resources, University of Ibadan, Ibadan, Nigeria

ABSTRACT

The study was undertaken in Plantation grown Caribbean Pine (*Pinus caribaea* Morelet) in Afaka plantation, Kaduna State, Nigeria on variability (radial and axial) of basic wood density. In order to ensure efficient and sustainable utilization of this species apart from local supply of long fibre for pulp and paper making, it is important to look into the pattern of variation in its properties, hence the justification for this study. The trees selected were 5, 7, 15, 20 and 25 years old respectively. In each age group three trees were harvested with their total tree height and diameter at breast height measured. Discs of 5 cm in thickness were obtained at breast height. Additional bolts of 20 cm for pulping materials were obtained at base, middle and top of trees sampled in 15, 20 and 25 age series while the entire logs from 5 and 7 age series was used. Each disc was cut at the pith, smoothened and the number of rings was counted. Each disc was then divided into sections based on the ring numbers. The sections were soaked in distilled water for 36 hours to attain green volume and density was estimated by water displacement method. The results showed significant variation in wood density of *P. caribaea* from the pith to the bark as well as from the base to the top. Ring number 11-15 from disc at Diameter at Breast Height (DBH) showed the highest density value of 0.6489 kg/m^3 while ring number 1-6 from disc at 50% total tree height had the lowest density value of 0.3811 kg/m^3. Axially, density decreases with increasing height along the log, but there is no significant difference in their values ($p>0.05$). From the findings, the radial variation in wood density of *P. carribaea* grown in Afaka is significantly different from the pith to the bark but no significant difference along the sampling height.

Keywords: Axial variation; radial variation; basic density; ring number; *Pinus caribaea*

INTRODUCTION

Wood density is an important wood quality parameter in carbon cycle research and offers resistance in the trees against wind, storms, cavitation of xylem vessels, and other environmental stresses (Maiti *et al.,* 2016). It is the simplest and most useful single index to the suitability of wood for various uses (Oluwadare and Ogunleye, 2011). Wood properties such as wood density and extractive content may change as the plantation gets older and the magnitude of such change is worthy of investigation. Inter- and intraspecific variation in these properties in radial and axial axes has been studied in many species (Ivkovic and Rozenberg, 2004; Osunkoya *et al.,* 2007; Roque and Fo, 2007; Knapic *et al.*, 2008; Nock *et al.*, 2009). The inferences drawn from these studies showed that significant differences exist both in radial and axial axes of trees whether between or within trees and in different patterns. Also, variation in wood properties could be studied in annual rings numbered from pith to bark along stem axis in either vertical or oblique sequence (Oluwadare and Ogunleye, 2011).

Wood density as defined by Zobel and Van Buijtenen (1988), Haygreen and Bowyer (1996) and Hoadley (2000) is the mass or weight of wood per unit volume of water (such as pounds per cubic foot, grams per cubic centimeter or kilograms per cubic meter). Zobel and Buijtenen (1988) pointed out that wood density is, in fact, not a single wood property but a combination of wood properties (latewood percent, wall thickness, cell size and others). However, despite its complexities, wood density reacts generally as though it were a single, simple characteristic. Desch (1988) explained that density of wood is a function of cell wall thickness and also depends on the level of cell wall development. Chaffe (1991) reported that high cellulose content in wood is a good indication of high density and low lignin content. Density varies greatly depending on the anatomical structure of the wood. Variation in density occurs within as well as between species. The variability in density within species may be due to effects of tree age (age of cambium), the between trees, as a result of environment, genetic and silvicultural effects (Evans, 1991). Adequate explanation of density pattern must take into consideration, the difference between juvenile and mature wood. The presence of heartwood is slightly denser than sapwood. However, deposition of extractives rarely adds more than a few percent to the density of wood and some species do not produce heartwood (Panshin and De Zeeuw, 1980).

Wood density predicts life-history strategies of tree species, owing to the fact that it is closely related to tree growth rates (Maiti *et al.,* 2016). On the other hand, wood density is positively related to drought resistance in tropical trees (Hacke *et al.*, 2001; Meinzer, 2003). High wood density is positively correlated with xylem wall enforcement, which in turn reduces cavitation risk due to strong tensions during periods of drought (Slik, 2004: Maiti and Rodriguez, 2015).

Pinus caribaea (Carribean Pine) was primarily introduced to Nigeria for the production of long fibre pulp (Oluwadare, 2007). In the past, *Pinus caribaea* selection was based purely on the tree's vigour, stem quality, branch habit and crown features. Presently, interest in its improvement is not only centered on over-all form and growth rate but also on wood properties particularly density. Characterizations of the various wood properties of *P. caribaea* had been dealt with in a number of investigations (Wangaard *et el.*, 1955; Harris, 1973). These studies suggest that there is a wide range of variability present in the wood properties of *P. caribaea*. Many researchers have also dealt with the identification and quantification of the different sources of variation in the wood properties of this species (Lantican, 2012). There is a general agreement that, although site may be an important source of variation, the tree-to-tree differences in wood properties are considerable, and it is hoped that an appreciable proportion of these may be genetic in nature. In pines, the negative genetic correlations obtained between density and diameter in some studies is extremely discouraging (Zobel and Van-Buijtenen, 1989; Nicholls *et al.,* 1964; Jourez *et al.,* 2001) Nevertheless, there are also studies suggesting that there is independence between density and growth rate (Hoadley, 2000). For *P. caribaea*, negative correlations (phenotypic) have already been obtained between ring width and density (Desch, 1988).

In order to contribute to the existing knowledge on the variation in *P. caribaea* wood, this study aims to quantify radial and axial variation in basic wood density of *P. caribaea* with a view to advancing further knowledge on the specie for efficient utilization.

MATERIALS AND METHODS

Study Area

The study was conducted at Afaka Forest Reserve, situated at some 30km N-W of Kaduna township, along Kaduna – Lagos Express Highway road, and is about 12,243.760 hectares in a real extent (Nwadialor, 2001). Afaka Forest Reserve was established in 1954 as an experimental plantation site to increase the productivity and arrest the deterioration and desertification of the semi-arid zone of the Northern Guinea Savannah of Nigeria (Nwadialor, 2001). The Afaka Forest Reserve is geographically located between latitudes 10.0 33'N and 10.0 42'N; Longitudes 7.0 13'E and 7.0 24'E on 600 m above sea level. Mean annual rainfall is about 1300 mm with daily minimum and maximum temperatures of 18°C and 24°C respectively.

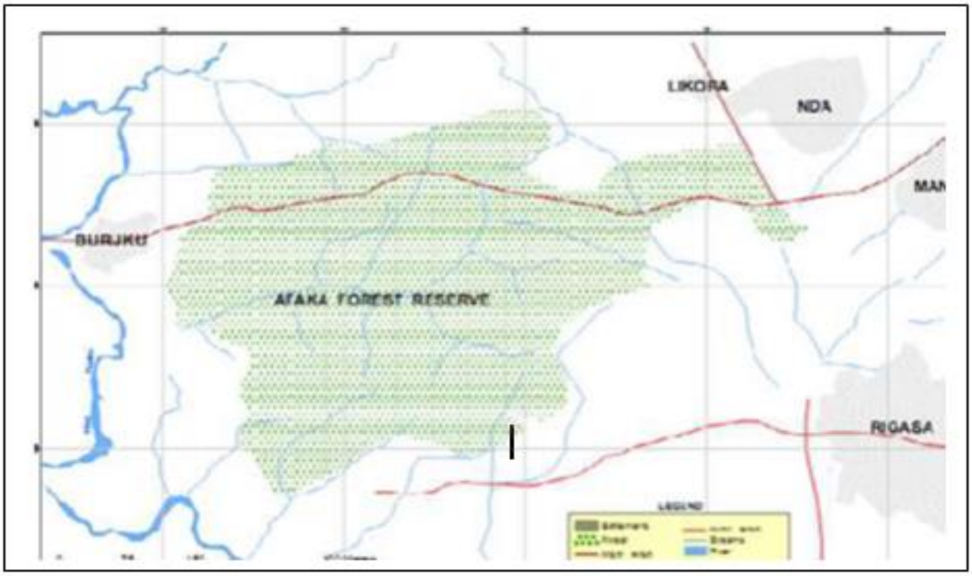

Fig. 1: Map of Afaka Forest Reserve
Source: *Department of Geography, NDA Kaduna*

Sampling Technique and Data Collection

A reconnaissance survey of the plantation was carried out to know the different age series available. The trees selected were 5, 7, 15, 20 and 25 years old respectively. In each age group three trees were harvested with their total tree height and diameter at breast height measured. Discs of 5 cm in the thickness were obtained at breast height. Additional bolts of 20 cm for pulping materials were obtained at base, middle and top of trees sampled in 15, 20 and 25 age series while the entire logs from 5 and 7 age series was used. Based on the experimental design used, each age group was considered a treatment and each tree a replicate meaning five treatments with three replicates making a total sample of 15 trees in accordance to the method adopted by Oyelere *et al.* (2019).

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Wood Density Determination (Kgm^{-3})

Each disc was cut at the pith, smoothened and the number of rings was counted. The discs at DBH were partitioned into rings 1-5, 6-10, 11-15, 16-20 and 21-16 from the pith to the bark. The discs at 25% total tree height were portioned into rings 1-6, 7-12, 13-18 and 19-22 from the pith to the bark. The discs at 50% total tree height were partitioned into rings 1-6, 7-12 and 13-18 from the pith to the bark. The sections were then soaked in distilled water for at least 36 hours to attain green volume. Green volumes of the sections were then measured by water displacement. After measuring the green volumes, the sections were dried in an oven at 103 + 2° C to constant weight. The oven dry sections were cooled in a desiccator over silica gel before their weights were recorded. Basic density was calculated using the mathematical expression in Eqn. 1;

$$\text{Basic density } (\text{kgm}^{-3}) = \frac{\text{Section green volume}}{\text{Section oven dry weight}} \quad (1)$$

Data Analysis

The experimental design adopted for the study is a 5 x 3 factorial experiment in a Completely Randomized Design (CRD) and data obtained were subjected to Analysis of Variance at 0.05 probability level. Statistical Package for the Social Sciences (SPSS) version 20 was used for the analysis.

RESULTS

Radial Variation of Basic Density

Table 1 shows that ring number 21-26 has the highest mean radial basic density at the diameter at breast height (0.5787kg/m^3), but it's not significantly different from means of ring numbers 6-10, 11-15 and 16-20, while the lowest mean radial basic density (0.4454 kg/m^3) was shown by ring number 1-5 which significantly differ ($p < 0.05$) with other ring numbers.

At 25% of the total tree height, ring number 1-6 showed the least mean radial basic density of 0.4383 kg/m^3 and this is significantly different from the means of other ring numbers ($p < 0.05$), while ring number 13-18 has the highest mean radial basic density of 0.5478 kg/m^3, which is not significantly different from means of ring numbers 7-12 and 19-22.

At 50% of the total tree height, ring number 7-12 has the highest mean radial basic density of 0.5471 kg/m^3, and this is significantly different from the mean radial basic density of ring number 1-6 (0.4411 kg/m^3) which is the lowest and that of ring number 13-18 (0.5354 kg/m^3) ($P < 0.05$).

Table 1: Descriptive and ANOVA for variation in mean radial basic density (kgm^{-3}) of *Pinus caribaea* (Afaka) at various levels

Position	Ring Number (Pith – Bark)	Minimum Density	Maximum Density	Mean ± SE
	1-5	0.3985	0.4840	0.4454±0.0138^a
	6-10	0.4680	0.5634	0.5145±0.0359^b
DBH	11-15	0.4977	0.6489	0.5705±0.0668^b
	16-20	0.5092	0.6285	0.5616±0.0540^b
	21-26	0.5117	0.6354	0.5787±0.0525^b
	1-6	0.4155	0.4745	0.4383±0.0101^a
	7-12	0.4810	0.6322	0.5309±0.0274^b
25%THT	13-18	0.4937	0.6056	0.5478±0.0205^b
	19-22	0.4764	0.6441	0.5445±0.0286^b
	1-6	0.3811	0.5100	0.4411±0.0204^a
50%THT	7-12	0.4281	0.5883	0.5471±0.0628^b
	13-18	0.4585	0.5916	0.5354±0.0498^b

Means with the same alphabet are not significantly different using Duncan's Multiple Range Test ($p<0.05$)

Axial Variation of Basic Density

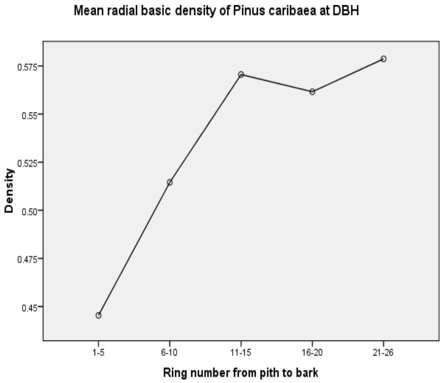
Results in Table 2 shows the axial variation in basic density along different position from top to the base of the tree (i.e. at diameter at breast height, at 25% total tree height and 50% total tree height). The basic density at the DBH was seen to be the highest with a mean value of 0.5342 kgm^{-3}, while the density at 25% of total height of the tree and 50% of total height of the tree were 0.5154 kgm^{-3} and 0.4980 kgm^{-3} respectively.

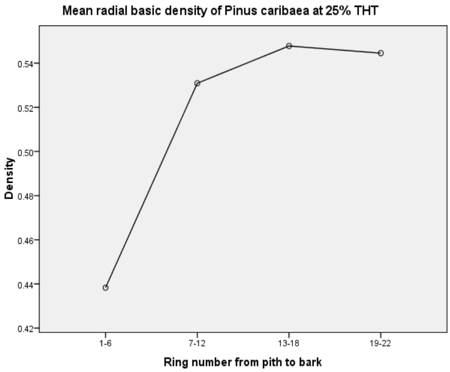
From the result, there is no significant difference in the basic density from base to top of the tree ($p > 0.05$) which implies that there is no variation in the ring width of *P. caribeae* from base to top.

Table 2: Descriptive and ANOVA for mean axial variation in Ring width (mm) of *Pinus caribaea* (Afaka) at various levels.

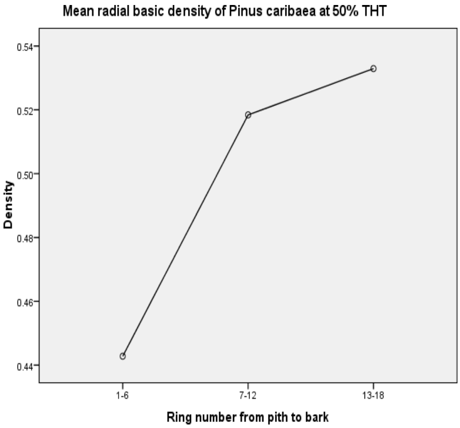
Position	Minimum	Maximum	Mean ± SE	Significance
DBH	0.4798	0.5885	0.5342±0.0196^a	0.481^{ns}
25%	0.4586	0.5721	0.5154±0.0204^a	
50%	0.4387	0.5574	0.4980±0.0214^a	

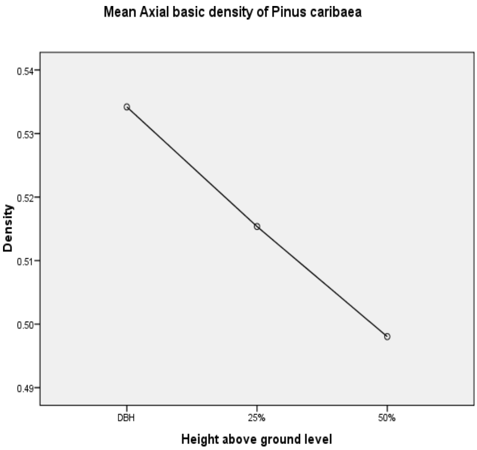
The trends of the variation in radial and axial directions are shown in Figure 1 below which further supports the claims of the result discussed in Table 1 and 2 above.





(A) **(B)**





(C) **(D)**

Figure 1: Trend showing the mean radial, (A-C), and axial, (D), variation in basic density (kgm^{-3}) of *Pinus caribeae.*

DISCUSSION

The present study shows variation in wood density (Figure 1) as it increases from the pith to the bark and falls just before the bark. This relationship does not follow a pattern described by Akachukwu (1982) and Evans (1991) who reported that wood density decreases from pith to bark. Though, the pattern of variation in the study is in consonance with that of Ogunsanwo and Onilude (2000) and Veenin *et al.* (2005). The observed variation in the mean value of basic density in this study may be due to environmental factor, genetic composition or silvilcultural effects.

Wood density is widely regarded as one of the most influential properties affecting the strength and several wood characteristics. Savidge (2003) opined that basic wood density is the prime wood quality consideration for industry as higher wood values yield stronger and more pulp wood density has been the focus of many researchers in the past and has traditionally been the factor on which the utilization potential of timber species are based (Oyagade and Fabiyi, 2002; Akpan *et al.,* 2006; Poku *et al.,* 2001; Oluwadare and Somorin, 2007). This could be attributed to the fact that density has been very good indication of wood strength, stiffness and stability (Josue, 2004).

Results from this study also, shows that wood density decreased from the base to the top. The same pattern of variation was reported by Sotannde and Riki (2019) and many researchers on different wood species. The observed variation in the mean value of basic density of *P. carribaea* from base to top of the sampling height may be due to the effect of tree age (age of cambium), environmental factor, genetic composition or silvilcultural effects (Evans, 1991).

CONCLUSION

It can be concluded from the study that the radial variation in wood density of *P. carribaea* grown in Afaka is significantly different from the pith to the bark and also wood density increases from the base to the top but the values are not significantly different. The range of density values obtained from this study falls within the range of 0.3811kgm^{-3} to 0.6489kgm^{-3}.

Based on the study, mature wood should be selected for density study and more sampling positions should be carried out along and across the wood to understand the uniformity of the wood density and other strength properties on *P. caribeae.*

REFERENCES

Akachukwu, A.E. (1982). Variation in wood density of dicotyledon as a guide for forest plantation management. *Agricultural Resources Bulletin* 3(1): 1- 18.

Akpan, M., Olufemi, B. and Apagu, V. V. (2006). Qualitative Studies on Density of Neem (*Azadirachta indica* A. Juss) Wood for Utilization as timber in North Eastern Nigeria. *Nigeria Journal of Construction Technology and Management*.7:6-12.

Chaffe, S.C. (1991). A relationship between equilibrium moisture content and specific gravity in wood. *Journal of Institute of Wood Science* 12930: 119-122pp.

Desch, H. E. (1988). Timber: Its structures, properties and utilization, 6th edition, Macmillan education, U.S.A, pp 12-18

Evans, P. D. (1991). The strength properties of clear wood materials forum 15:231-244.

Hacke, U.G., Sperry, J.S., Pockman, W.T., Davis, S.D. and Mcculloh, K.A. (2001). Trends in wood density and structure are linked to prevention of xylem implosion by negative pressure. *Oecologia* 126:457–461.

Harris, J.M. (1973). The use of beta-rays to examine wood density of tropical pines grown in Malaya. In: Burley J, and Nikles D.G. (eds). Selection and Breeding to Improve Some Tropical Conifers. CFI, Oxford and Department of Forestry, Queensland. 2: 86-94.

Haygreen, J.G. and Bowyer, J.L. (1996). *Forest Products and Wood Science: An Introduction.* 3rd ed. Ames: Iowa State University Press, pp 93-112.

Hoadley, R.B. (2000). *Understanding Wood. A craftsman's Guide to Wood Technology*. The Taunton Press, U.S.A, 132pp.

Ivkovic, M. and Rozenberg, P. (2004). A method for describing and modeling of within-ring wood density distribution in clones of three coniferous species. *Annals of Forest Science*. 61 (2004) 759-769.

Josue, J. (2004). Some wood properties of *Xylia xylocarpa* planted in Sabah. *Sepilok Bulletin* 1: 1-15.

Jourez, B., Ribox, A. and Leclercq, E. (2001). Comparison of basic density and longitudinal shrinkage in tension wood and opposite wood in young stem of *Populus euramericana* Ghoy when subjected to a gravitation stimulus. *Forest Resources Journal*, 31: 1676-1683.

Knapic, S., Louzada, J.L., Leal, S. and Pereira, H. (2008). Within-tree and between-tree variation of wood density components in cork oak trees in two sites in Portugal. *Forestry*, (814): 465-473.

Lantican, C. B. (1972). Variations in some structural features and wood properties of *P. caribeae* Mor. from British Honduras. D.Phil. Thesis. CFI, Oxford University, 65p

Maiti, R., Rodriguez, H.G. and Kumari, A. (2016). Wood Density of Ten Native Trees and Shrubs and Its Possible Relation with a Few Wood Chemical Compositions. *American Journal of Plant Sciences* 7:1192-1197. http://dx.doi.org/10.4236/ajps.2016.78114

Maiti, R.K and Rodriguez, H.G. (2015). Wood Anatomy Could Predict the Adaption of Woody Plants to Environmental Stresses and Quality of Timbers. Forest Research, 4, 4. http://dx.doi.org/10.4172/2168-9776.1000e121

Meinzer, F.C. (2003). Functional Convergence in Plant Responses to the Environment. *Oecologia*, 134:1-11. http://dx.doi.org/10.1007/s00442-002-1088-0

Nicholls, J. W. P., Dadswell, H. E. and Fielding, J. M. (1964). The heritability of wood characteristics of *Pinus radiata* Silvae. *Genetica*, 13(3): 68-71.

Nock, C.A., Geihofer, D., Grabner, M., Baker, P.J., Bunyavejchewin, S. and Hietz, P. (2009). Wood density and its radial variation in six canopy tree species differing in shade tolerance in Western Thailand, Annals of Botany (104) 297-306.

Nwadialor, I.J. (2001). An assessment of spatiotemporal variabilities of deforestation for sustainable forestry development: A case study of Afaka forest reserve. *International Conference on Spatial Information for Sustainable Development*, Nairobi, Kenya. 2–5

Ogunsanwo, O.Y. and Onilude, M.A. (2001). Radial and axial variations in Fibre Characteristics of plantation grown Obeche in Omo forest Reserve. *Nigeria Journal of Forestry*, 30(1): 33-37.

Oluwadare, A.O. (2007). Wood Properties and selection for rotation length in Caribbean pine (*Pinus caribaea* Morelet) grown in Afaka, Nigeria. *American-Eurasian Journal of Agriculture and Environmental Science,* 2 (4): 359-363.

Oluwadare, A.O. and Somorin O.A. (2007). Preliminary report on utilization of *Gliricidia sepium* (Jacq.) Steud. for timber. *Research Journal of Forestry,* 1(2): 80-87.

Oluwadare, A. O. and Ogunleye, M. B. (2011). Between-Tree and Within-Tree Variation in Specific Gravity and Extractive Content in the Wood of *Sterculia setigera* Del. Grown in Nigeria. *Journal of Agricultural Science and Technology* B 1 1075-1085.

Osunkoya, O.O., Sheng, T.K., Mahmud, N. and Damit, N. (2007). Variation in wood density, water content, stem growth and mortality among twenty-seven tree species in a tropical rainforest on Borneo Island, Austral Ecology 32 (2007) 191-201.

Oyagade, A.O. and Fabiyi, J.S. (2002). Density variation in plantation grown *Nauclea diderrichii*. *J. Trop. For. Resources*, 18(1): 26-34.

Oyelere, A.T., Riki, J.T.B., Adeyemo, S. M., Majekobaje, A. R. and Oluwadare, A.O. (2019). Radial and Axial Variation in Ring Width of Caribbean Pine (*Pinus caribaea* Morelet) in Afaka Plantation, Kaduna State, Nigeria. *Journal of Research in Forestry, Wildlife & Environment*, 11(3):81-89

Panshin, A.J. and De Zeeuw, C. (1980). *Textbook of Wood Technology*. Vol 1, 4th edition. Mc Graw-Hill Book Company, 704pp.

Poku, K., Qinglin, W. and Vlosky, R. (2001). Wood properties and their variations within the tree stem of lesser-used species of tropical hardwood from Ghana. *Wood Fiber Sci*ence. 33: 284-291.

Roque, R.M. and Fo, M.T. (2007). Wood density and fibre dimensions of *Gmelina arborea* in fast growth trees in Costa Rica: relation to the growth rate, *Investigación agraria. Sistemas y Recursos Forestales* (16) 267-276.

Savidge, R.A. (2003). Tree Growth and Wood Quality. *Wood Quality and its Biological Basis*. Authors: Jeronimidis JR and Barnett G. Blackwell Publishing, CRC Press. Pp 226.

Slik, J.W.F. (2004). El Nino Droughts and Their Effects on Tree Species Composition and Diversity in Tropical Rainforests. *Oecologia*, 141:114-120. http://dx.doi.org/10.1007/s00442-0

Sotannde, O.A. and Riki, J.T.B. (2019). Wood quality studies of some wood species in Sudano-Sahelian environment of Borno State, Nigeria. *Journal of Research in Forestry, Wildlife & Environment,* 11(3):8-19

Veenin, T., Fujita, M., Nobuchi, T. and Siripatanadilok, S. (2005). Radial Variations of Anatomical Characteristics and Specific Gravity in *Eucalyptus camaldulensis* Clones. *IAWA Journal* 26:353–361.

Wangaard, F. F., Stern, W. L. and Goodrich, S. I. (1955). Properties and uses of tropical woods. *Journal Tropical Woods* 103:1-139.

Zobel, B.J. and Van Buijtenen, J.P. (1989). *Wood Variation, Its Causes and Control*. Spring-Verlag, Berlin, Heidelberg, New York, pp 43-5.