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DENSITY VARIATIONS IN RED MANGROVE (*Rhizophora racemosa GFW Meyer*) IN ONNE, RIVER STATE, NIGERIA

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ABSTRACT
Wood density is a key indicator of the mechanical properties playing important role in wood history and utilization. Variation in wood density from the base to the top of tree and from pith to bark was investigated for *Rhizophora racemosa GFW Meyer* in Onne, Port Harcourt, Nigeria. Wood samples were taken as disks (50cm length bolts) from ten selected trees at three sampling positions (base 10%, middle 50% and top 90%) of total trees height. The trees were selected from Forestry Research Institute of Nigeria (FRIN) Nature Reserve located at Onne, Port Harcourt. Air-dry density of 12% (ADD) (apparent density) was determined as ratio of mass to volume using an electric beam balance and digital venier calliper. The results showed an average value of 896kg/m^3 with an increase in density from pith and slightly declined to bark. Changes in density from pith to bark were greater at the base than the top of the trees. It was also evident that density decreased from the base of the tree to half (50%) of the total height, then increased towards the top of the tree. These difference were not significantly different at $\alpha = 0.05$. Coefficient of variation along the bole ranged from 35.54% to 44.59% and across the bole ranged from 28.63% to 46.60%. The correlations showed that density was negatively correlated with the length of the wood but positively correlated with volume, breadth, and height of the wood. *Rhaziphora racemosa* wood demonstrated consistency among the sampling positions.

KEYWORDS: Air-dry method; Nigeria; *Phizophora racemosa*; sampling positions; wood density

INTRODUCTION

Wood density is a measure of the amount of cell wall substance per unit volume of wood. It is expressed in terms of mass over volume units (gcm^{-3}, kgm^{-3}). It is an important index for estimating the strength and mechanical properties of wood to determine its suitability for various uses (Tamolang *et al*., 1995). Wood density is a complex physical property, depending on the tree species and its interaction with the environment (Ilic *et al*. 2000) as well as silvicultural measures (Tsoumis, 1991). Understanding and documenting the great degree of variation in wood density is thus an important challenge in determining the heterogeneity of wood to suit various utilisation purposes.

Variation in wood density occurs at multiple scales in forest ecosystem, ranging from within trees, to regional changes in mean wood density among forest communities (Hermandez and Restrepo, 1995; Muller-Landua, 2004; Chave *et al*., 2006; Grabner and Wimmer, 2006; Swenson and Enquist, 2007). Within individual trees, wood density differs among branches, trunk and roots and can also vary radially within the trunk as wood is added at the periphery during growth. The difference in wood density and its radial trends reflect growth strategy and biomechanical considerations. A direct relationship between wood density and tree growth is expected because the volume of wood produced for a given unit biomass is inversely proportional to its density (King *et al*., 2005). Variations in wood density values within and between tree species and sites exist as a result of the varying needs of trees for structural support under different circumstances (Fearnside, 1997). Density varies in trees from pith to bark (lateral variation) and from base to apex (vertical variation) depending on the species and its locality of growth. Pith-to-bark gradients in wood density values occur because of varying growth rates as trees mature. Studies conducted in Australia by Ilic *et al*., (2000) showed a reduction in density with height for softwoods and a gradual increase with height for hardwoods. Tsoumis (1991) reported that a reduction in density with increasing height is common in softwoods, although not in all cases.

Rhizophora racemosa is an endemic Nigerian mangrove species. It is known as red mangrove (English name, Nigeria). It is locally known as "Angala" among Okrika, Kalabari, Opobo, and Bonny communities (Nigeria) while among Onne, Ogoni and Eleme communities, it is called "Ngala" which means strength. This species is widespread, but very patchily distributed and threatened by a coastal development, pollution, siltation, and more recently extraction for fuelwood in many parts of its range. The red mangroves – *Rhizophora racemosa* make up about 90% of the vegetation of the mangrove ecosystem. Other species are R. *harrisonii*, *R. mangle* and the white mangrove *Avicennia Africana* (Adegbehin, *et al*., 1991). One important factor in the use of *R. racemosa* being the pioneer is the indigenous knowledge of its wood strength. Its wood is widely used for carving purposes, electric poles and columns, axe-handles, sawn timber for building construction purposes, shuttles, paddles for water transportation and fuelwood. *R. racemosa* also finds application in the production of dyes and has many medicinal values from all its parts. In spite of this wider application and relevance of wood density not only to determining wood strength but also useful in estimating forest biomass and carbon stock potentials of trees needed for mitigation of current climate change. There is no available report of wood density variations within tree of *R. racemosa* in the natural forest of Nigeria although the wood density of this species native to Tanzania and its congeners *R. mangle* in Brazil have been reported in the past four decades (Balza and Keating, 1972; and Chudnoff, 1980). However, few studies reported on *R. racemosa* species native to Nigeria have focused on their distribution, morphology and floristic nature. *Rhizophora racemosa* wood is well known in the regions of their origin and users rely on experience and traditional specifications to determine the dimensions of timber for construction without considering the timber strength properties. Reported studies on the fibre characteristics of this species for pulp and paper production are a misplaced priority/justification when attention has been shifted to the exploration of non-woody plants in order to conserve woody plants for more pressing global needs. To date, no study has been reported on wood density of *R. racemosa* in Nigeria. This shortcoming prompted us to investigate the variations in wood density of *R. racemosa* with a view to providing database information for appropriate conservation of the species.

MATERIALS AND METHODS

Sample trees were obtained from FRIN nature forest reserve, Onne station, Port Harcourt, Rivers State. Onne is situated within longitudes 7^0 9^1 and 7^0 15^1 East of the Greenwich Meridian and latitudes 4^0 43^1 and 4^0 73^1 North of the equator. A total number of ten trees with diameter range from 26-31cm were randomly selected. All the tree stems were selected for their straightness with no blemish and showed good adaptability to the mangrove/swampy climatic conditions with satisfactory foliage production and bole length ranged from 380cm to 470cm above the prop roots level. In order to obtain more representative results tree samples (bolt of 50cm) from each stem were taken at 10% (base), 50% (middle) and 90% (top) of its height totalling 30 samples (bolts). The bolts were labelled, cleaned and immediately transported for processing.

Preparation of wood test block

Stem cross-sectional samples (disks) of thickness 20mm centrally were taken from each bolt. Centre diameter wood samples of 20mm width were boxed out for production of rectangular sub-samples (test blocks) of 20 x 20 x 60mm at interval of 2mm from pith to the periphery. Six (6) test blocks were taken radially, three blocks each towards opposite direction from pith (north and south) totaling 180 test blocks. All the test blocks were appropriately labeled, air-dried and conditioned to 12% moisture content (MC) under room temperature of 27±2^{o}C and 70±5% for 10 weeks and the air-dry mass determined with an electronic balance. For accuracy, the rectangular wood blocks were re-measured with a digital venier calliper at three points along the length for the width and breadth and at two points for the length. The volume and the dry mass measurements were used to determine the density.

Wood density determination

Wood density was determined at a moisture content of 12%. All the air-dried test blocks volume were measured using digital venier calliper at three points along the length for the width and breadth and at two points for the length and the air-dry mass determined with an electronic balance. The density was evaluated as the ratio of volume to air-dry mass measurements in g/cm^3 and converted to kg/m^3.

Data Analysis

Analysis of variance in Split plot design was used to test variations among sampling positions along the height and across the height of the trees and correlation analysis was performed to determine the relationship between density and other variables such as length, volume, breadth and height of the species. Descriptive statistics were also used to illustrate coefficients of variation patterns among the sampling positions. Top, middle and base were used as main-plot while inner, middle and outer were used as sub-plot.

RESULTS & DISCUSSION

Density of *Rhizophora racemosa* wood

TABLE 1: Descriptive statistics of wood density variation along bole

	Top	Middle	Base
Mean (kg/m^3)	911.935	829.766	946.378
SD(kg/m^3)	324.077	369.999	385.655
CV (%)	35.54	44.59	40.75

TABLE 2: Descriptive statistics of wood density variation across bole

	Inner	Centre	Outer	Average
Mean(kg/m^3)	825.458	961.189	901.431	896.026
SD(kg/m^3)	236.330	423.310	420.091	
CV (%)	28.63	44.04	46.60	

The results, presented in table 1 and 2 with an overall average density of 896kg/m^3 placed the wood in the heavy construction timber category. These results attest to the local name of the wood "Ngala" which means strength. The value is in conformity with value obtained by Chudnoff (1980) on the density of *Rhizophora mangle* L. as 890kg/m^3 in Brazil and the range of mean densities across the pith 825-961kg/m^3 is relatively close to range figures (102-114 kg/m^3) reported by Bolza and Keating (1972) on native Tanzanian *Rhizophora racemosa* wood density as cited on African Wood Density Database. Coefficient of variations along the bole ranged from

35.54-44.59% and across ranged from 28.63-46.60%. These values indicated wood consistency and moderate compactness among the sampling positions both along and across the bole. The results showed an increase in wood density from pith (inner) to centre and then a decrease towards the bark (outer), a decrease from the base to half (middle) of the total tree height and then an increase towards the top of the stem. The trend of variation in density from base to top is in agreement with the trend reported by Espinoza (2004) for *Gmelina arborea* wood density in the tropical forest plantation in Venezuela but not in agreement with the trend of variation from pith to bark. The highest mean value density of 946.378 kg/m^3 at the base along the bole could be as a result of the aggregation of matured wood cells while highest mean value density of 946.378 kg/m^3 at the centre across the bole could be attributed to the mixture combination of heartwood and sapwood cells (diversification of reactions) that usually characterized the transitional zone in the course of heartwood formation.

TABLE 3: Analysis of Variance between the main plots (Along bole) for wood density

Source of variation	Sum of squares	Degree of freedom	Mean square	F	P level
Along	1958626.377	2	979313.188	1.650	.211
Error	1.603E7	27	593648.452		

TABLE 4: Analysis of variance between the sub plots for wood density

Source of variation	Sum of square	Degree of freedom	Mean square	F	P level
Across	139683.441	1	139683.441	.213	.648
Along*Across	539194.271	2	269597.135	.411	.667
Error (Across)	1.769E7	27	655312.217		
Position	555322.727	2	277661.364	.672	.420
Position*Along	2037658.144	4	509414.536	.414	.665
Error (Position)	6957593.456	27	257688.647		
Across*Position	2090542.485	2	1045271.243	1.343	.257
Across*position*along	2852399.615	4	713099.904.699	.069	.934
Error(Across*Position)	5469683.973	27	202580.888		

TABLE 5: Correlation matrix between wood density and measurable wood parameters

	DENSITY	*Volume*	*Breadth*	*Height*	*Length*	*Along*	*Across*	*Position*
Density	1	-.124	-.117	-.099	-.194**	.085	.035	.038
Volume		1	.908**	.780**	.854**	-.703**	-.035	.072
Breadth			1	.774**	.841**	-.824**	-.017	.086
Height				1	.764**	-.765**	-.026	-.007
Length					1	-.800**	-.022	-.010
Along						1	.000	.000
Across							1	.000
Position								1

Statistical evaluation revealed statistically no significant differences in density both along and across the studied wood as shown in Tables 3 and 4 though appreciable variations exist in the density mean values from top to base and pith to bark in tables 1 and 2. From Table 5, the correlations showed that density was negatively correlated with the length of the wood but positively correlated with volume, breadth, and height of the wood. The small density variability that showed no statistical difference in this study could be as result genetics make up or and climatic conditions. *Rhaziphora racemosa* wood demonstrated consistency among the sampling positions.

CONCLUSION

Every stem of *Rhizophora racemosa* exhibits no significant degree of variation in wood density both the radial and vertical position. However, appreciable amount of variation exist. The middle stem contains a lowest density with the highest density located around the centre portion of the base stem. Wood heterogeneity in solid wood is a major defect. It is of general viewpoint that juvenile wood has a lower quality than matured wood. This result counters the view and presents a relief for heterogeneity defect in wood of *Rhizophora racemosa.* The average mean value of 896kg/m^3 obtained from this study places the wood in the heavy construction utility timber category.

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