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Variations in the Wood Properties of *Terminalia mantaly* (H. Perrier) Grown as Municipal Tree in a Nigerian University

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Abstract

A study was carried out to investigate wood properties of Terminalia mantaly (H. perrier), one of the municipal tree species in University of Ibadan, Ibadan. Materials for the study were obtained from four of the urban trees in the University campus. Test samples were collected at four different levels along the height and radial positions with the test specimen prepared in accordance with standard test procedures. Prepared samples were subjected to some physical and mechanical property tests. The selected physical properties were Moisture Content (MC), Specific Gravity (SG) and Volumetric Shrinkage (VS). The mechanical properties (Modulus of Rupture, MOR; Modulus of Elasticity, MOE and Impact Bending, IB) were determined in accordance with the British Standard BS373 (1989). Data generated were subjected to statistical analysis. The overall mean SG, MC and VS for the species were 0.797, 39.82% and 46.52%, respectively while the mean MOR, MOE and IMB were 62.94N/mm2, 5056N/mm2 and 404.81, respectively. It was evident that variations exist in both the radial directions and sampling heights for all the selected trees. Findings revealed that Terminalia mantaly is a strong wood with good quality, making it a potential material for load bearing and other construction works.

Keywords: Wood properties, Terminalia mantaly, municipal trees, Property variations

Introduction

The special interest by wood science researchers for increased utilization of urban wood for structural applications are a key step towards the conservation and better management of our fast disappearing lean natural forests. Comprehensive knowledge and understanding of the qualities or properties of wood from municipal trees are the necessary ingredients required for harnessing the utilization potentials of this category of wood. This category of wood can be utilized with intelligence if we understand the properties (Bratkovich 2001). Wood resource managers and foresters, who wish to maximize forest produce, need to understand not only the principles of tree growth but also the physical and mechanical properties of the wood in order to determine the quality of such wood and its utility.

Although there are catalogues of reasons against the utilization of urban wood one of which is the fact that urban trees have shorter trunks and more branches than trees in the natural stands or plantation due to low competition among the growing stock. There is also the possibility of imbedded foreign materials (like metals, concrete, cables etc.) in the wood of such trees(Steve *et al.*,2008;Omole, 2008), however, urban trees represent a major source of of timber for construction and other purpose especially in the developed Countries.

The University of Ibadan in Nigeria is specially endowed with a lot of diversities in terms of trees that can be found all over its landscape.. Apart from known native timber species that dotted the campus, there are some ornamental trees, which have also grown to timber size with good form. One of such trees is *Terminalia mantaly*(Madagascar almond). As an exotic tree species, *Terminalia mantaly* serves as shade and avenue tree in many parts of the University landscape. This study was initiated to investigate the

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quality of the wood of this species in terms of physical and mechanical properties. Several works have been done on variation in wood properties along and across the bole of some tropical trees species (Akachukwu, 1980; Panshin and Dezeeuw, 1980; Onilude, 1987; Bada, 1990; Ogunsanwo, 2000). The knowledge of variation in the properties of *Terminalia mantaly* wood grown as urban tree in this study is aimed at providing reliable baseline data for assessing the utilization of the species by wood processing industries and other users when cropped as the need arises.

Materials and Methods

Four mature trees of *Terminalia mantaly* (aged 20 years) with an average height of about10 meters were felled from a live fence at the University of Ibadan, Nigeria. The University is situated at latitude 7°26'N and longitude 3°54'E in Ibadan, Nigeria. The felled trees were crosscut into billets and four (4) billets of 50 cm were removed from each tree, representing the different height levels at which the experimental samples were collected. Test samples of different dimensions were then prepared from each billet in accordance with the properties tested.

The test sample size of 20 x 20 x 20 mm was prepared for physical properties and 20 x 20 x 300mm for mechanical properties in accordance with BS 373 (1989). For each of the tests, ten (10) specimens per sampling position (axial and radial) were taken from the lots produced from each billet so as to have a good representation and remove bias. The parameters tested were: moisture response and specific gravity.

For the determination of specific gravity, 10 test samples of 20 x 20 x 20 mm dimension, produced from billets were randomly selected from the lots per each sampling height to give a total of 40 test samples per tree and 160 samples for the study. The samples collected were oven-dried to a constant weight (Wo). The oven-dried samples were then coated with paraffin wax against water absorption. Each test sample was later immersed in Eureka can filled with water while the displaced water (Ww) was measured. Specific gravity was determined in accordance with the model used by Panshin and Dezeeuw (1980) for density gradient across the bole using the relation

$$SG = \frac{Wo}{Ww} \quad \text{.................................} \quad (1)$$

where, *Wo = ovendried weight of sample, and Ww = displaced water*

Ten test specimens, each of 20 x 20 x 20mm, were removed from the specimen prepared for the physical property tests. The specimens were soaked in water for 48hrs to get them saturated and later oven dried. The percentage shrinkage along the two planes was determined in accordance with the method used by Dinwoodie (1989):

$$S = \frac{D^s - D0}{Ds} \; x\,100 \quad \text{..........................} \quad (2)$$

where, S = Shrinkage % ,Ds = Dimension at saturated condition , Do = Dimension of oven dry condition,

Ten test samples of 20 x20 x300mm were prepared from each height level per tree. The impact bending was determined in accordance with BS 373 (BS 1989). Ten test specimens of the dimension of 20 x20 x300mm per radius per height were prepared for the static bending on a Hounsfield Tensometer in accordance with BS 373 (BS 1989). The results obtained were then used to compute the Modulus of Rupture and Modulus of Elasticity of the test specimens.

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The Modulus of Rupture was calculated using the equation: MOR = $\frac{3PL}{2bh^2}$

where, P =Maximum load (N), L = Span in centimeter, B = Breath in centimeter , H = Depth in centimeter

while, the Modulus of Elasticity was determined by:

MOE = $\frac{P_1 L_3}{4\Delta 1 b h^3}$

Where, P_1 *= Load(N),* Δ_1 *= Deflection of midpoint corresponding to the load pi. ,L = Span in mm, B = Breath in mm, H = Depth in mm*

Data analysis

The data generated were subjected to statistical Analysis of Variance (ANOVA). This was conducted to determine the statistical significance of various sources of variation in assessed wood properties. The main effects considered were differences along sampling heights (*4 levels*) and across the radial positions (*4 zones*). Follow-up tests were conducted using Fischer's Least Significant Difference (LSD) to know the differences between the means.

Results and Discussion

Specific gravity

The pooled mean of Specific Gravity (SG) as shown in Table 1 ranged from 0.76 to 0.84 across the vertical and radial positions with the overall mean of 0.80. For sampling height, the results show a decrease in mean from butt to top. The trend of values recorded for the SG followed the same trend with the previous studies of Panshin and Dezeeuw, (1980) and Bada (1990), who reported decreasing SG from base to top in a non-uniform pattern. ANOVA results in Table 3 revealed that the radial and height positions had significant influence on the SG of wood. Panshin and Dezeenw, (1980); Dinwoodie (1981) as well as Desch, (1980), explained that SG of wood is a function of the cell wall thickness and also depends on the level of cell wall development. This can be taken to be valid as the wood towards the upper region of the trees are usually newer and still under the influence of the meristematic cells unlike those close to the butt that are more mature.

Moisture content

Moisture Content (MC) ranged from 29.5 to 47.9% for the radial direction and sampling height (Table 1). Results also showed that there were decreases in MC from butt to top. The variations observed in the MC at the different height levels were supposed to be manifested in the strength properties of the wood. ANOVA results on Table 4 reveal that sampling positions exhibited significant influence on the amount of moisture in the green wood of the studied species.

Shrinkage characteristics

The pooled mean percentage volumetric shrinkage ranged from 44.67 - 48.58% across the sampling positions, with overall mean of 46.52%. The result obtained at sampling heights showed a decrease from butt to top. The values recorded for percentage shrinkage in relation to sampling height can be said to be in order as it followed the same trend with the previous work of Ogunsanwo (2000) and Ojelade (2009). The Analysis of Variance conducted indicated that the effects of the sampling positions were statistically significant at 5% level probability.

Impact Bending

The results of the impact bending test showed decreases from butt to top. The

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overall mean values of the impact bending strength as presented in Table 2 ranged from 370.20 to 459.10. The anatomical effects of cell length, micro-fibril angle, ring width as well as early wood: latewood ratio could account for the differences (Eaton and Hale, 1993). Dinwoodie (2000) also noted that knots can also contribute considerably to a reduction in strength dependent on their size, number and distribution in relation to beam edges and clustering as the top region contains more knots than the butt region. All these could be responsible for the results obtained in the present study. The variation in the strength properties at different height levels observed in this study is in consonance with the research of Shukla *et al.* (1989). Analysis of variance in Table 6 shows that both the parameter and the interaction between them significantly affected the impact bending strength. This indicates that the strength properties decreased from butt to the top of the tree.

Table 1:Pooled mean values for the selected physical properties of the wood of *Terminalia mantaly.*

Tree No	Physical Properties Tested								
	Specific Gravity			Moisture Content %			Percentage Shrinkage		
	Mean	SD	Number	Mean	SD	Number	Mean	SD	Number
1	0.78	64.4	40	29.54	9.09	40	44.92	5.09	40
2	0.81	74.8	40	45.91	15.34	40	48.59	2.99	40
3	0.84	85.95	40	47.88	13.06	40	47.88	3.30	40
4	0.76	91.27	40	35.95	16.00	40	44.68	4.65	40
Overall Mean	0.80	85.43	40	39.83	15.45	40	46.52	4.42	40

Table 2: Pooled mean values for the selected mechanical properties of the wood of *Terminalia manta*

Tree No	Mechanical Properties Tested								
	Modulus of rupture (Nmm^{-2})			Modulus of elasticity (Nmm^{-2})			Impact bending (Nmm^{-2})		
	Mean	SD	Number	Mean	SD	No	Mean	SD	Number
1	69.61	16.25	40	5818.14	2403.34	40	325.12	126.83	40
2	54.56	17.80	40	4490.42	1839.88	40	415.93	93.40	40
3	67.67	14.60	40	5416.75	1569.10	40	440.06	78.53	40
4	59.91	24.52	40	4535.07	1642.03	40	438.15	178.10	40
Overall Mean	62.94	17.47	40	5065.10	1959.56	40	404.81	132.66	40

Note: SD = Standard deviation, and No = number of samples per sampling positions'

Table 3: ANOVA for comparing specific gravity at radial positions and sampling heights

Source Variation	Degree of freedom	Sum of Squares	Mean Square
Rp	3	167526.367	55842.122*
Sh	3	131565.430	43855.143*
Rp*Sh	9	226727.539	25191.949*
Error	144	634703.125	4407.661
Total	159	1160522.461	

*Rp = radial position, Sh = sampling height, *= significant at 5% level*

Table 4: ANOVA for comparing moisture content at the radial positions and sampling heights.

Source Variation	Degree of freedom	Sum of Squares	Mean Square
Rp	3	19207.911	1280.527*
Sh	3	3595.435	1198.478*
Rp*Sh	9	6707.262	745.251*
Error	144	18744.585	130.171
Total	159	37952.496	

*Rp = radial position, Sh = sampling height, *= significant at 5% level*

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Table 5: ANOVA for comparing the effect of sampling position on volumetric shrinkage

Source Variation	Degree of freedom	Sum of Squares	Mean Square
Rp	3	483.266	161.089*
Sh	3	133.419	44.473*
Rp*Sh	9	589.317	65.480*
Error	144	1904.692	13.227
Total	159	3110.694	

*Rp = radial position, Sh = sampling height, *= significant at 5% level*

Table 6: ANOVA for comparing the effect of sampling positions on IB

Source Variation	Degree of freedom	Sum of Squares	Mean Square
Rp	3	353112.197	117704.066*
Sh	3	174080.297	58026.766*
Rp*Sh	9	1130336.449	125592.939*
Error	144	1140771.912	7922.027
Total	159	2798300.855	

*Rp = radial position, Sh = sampling height, *= significant at 5% level*

Modulus of Rupture (MOR)

The mean values of MOR ranged from 55.40 to 75.23 Nmm^{-2}. The decrease of MOR from butt to top as observed in this study is in consonance with the works of Shukla *et al.* (1989) who equally observed that as sampling position of tree moves from butt to top, the MOR decreases. Moreover, the fibre morphological characteristics as well as defects such as knots found in the upper region of a tree would determine its bending properties. The ANOVA results as presented in Table 7, revealed significant relationship between the parameters and the property tested.

MOE also showed similar trend as those of IB and MOR, with the mean values decreasing from butt to top. The mean values of the modulus of elasticity ranged between 4490 and 5818Nmm^{-2}, with the overall mean of 5065.09Nmm^{-2}.The explanation for the observed trend is as given for IB and MOR. The reduction in MOE at the top, which is in the crown region, is due to the presence of knots, which in general, have a greater effect on strength (Shukla*et al.*, 1989; Shupe*et al.*, 1997). The decrease in wood quality of crown region can be attributed to the influence of the growth promotion hormones of the meristematic cells at the apical region of the tree. ANOVA showed significant relationships between sampling positions and MOE.

Further tests using LSD for all the significant relationship as revealed in tables 9 and 10 indicated that mean values wood at both the radial direction and sampling height were significantly different in terms of specific gravity, moisture content and volumetric shrinkage. This trend was also observed for impact bending and static bending (MOR and MOE).

It is obvious from the results obtained from this study and those of previous work done on other wood species that *Terminalia mantaly,* though a fast growing tree, has good strength properties required by wood industry for furniture making, sheeting and lining, heavy and light construction, industrial flooring and handle of tools due to high density of the wood.

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Table 7: ANOVA for comparing the effect of sampling positions on MOR

Source Variation	Degree of freedom	Sum of Squares	Mean Square
Rp	3	5849.110	1949.703*
Sh	3	9496.641	3165.547*
Rp*Sh	9	19902.657	2211.406*
Error	144	25006.092	173.653
Total	159	3110.694	

*Rp = radial position, Sh = sampling height, *= significant at 5% level*

Table 8: ANOVA for comparing the effect of sampling positions on MOE.

Source Variation	Degree of freedom	Sum of Squares	Mean Square
Rp	3	52076484.083	17358828.028*
Sh	3	25015145.615	8338381.873*
Rp*Sh	9	67499575.882	7499952.876*
Error	144	4.659E8	3235754.980
Total	159	6.105E8	

*Rp = radial position, Sh = sampling height, *= significant at 5% level*

Table 9: LSD follow-up test for Specific Gravity, Moisture Content and Shrinkage

		Specific Gravity (M. d)			Moisture Content (M. d)			Percentage Shrinkage (M. d)		
		Rp	Sh	S.E	Rp	Sh	S.E	Rp	Sh	S.E
Tree1	Tree2	-31.88*	68.76*	14.85	-16.36*	7.02*	2.551	-4.28*	.781	.776
	Tree3	-65.00*	70.00*	14.85	-18.34*	12.25*	2.551	-3.58*	.229	.776
	Tree4	20.31	35.94*	14.85	-6.41*	10.80*	2.551	-.37	2.232*	.776
Tree2	Tree1	31.88*	-68.75*	14.85	16.36*	-7.02*	2.551	4.28*	-.782	.776
	Tree3	-33.13*	1.250	14.85	-1.98	5.22*	2.551	.706	-.552	.776
	Tree4	52.19*	-32.81*	14.85	9.95*	3.78	2.551	3.91*	1.450	.776
Tree3	Tree1	65.00*	-70.00*	14.85	18.34*	-12.25*	2.551	3.57*	-.229	.776
	Tree2	33.13*	-1.25	14.85	1.977	-5.22*	2.551	-.706	.552	.776
	Tree4	85.31*	-34.06*	14.85	11.93*	-1.45	2.551	3.21*	2.002*	.776
Tree4	Tree1	-20.31	-35.94*	14.85	6.41*	-10.80*	2.551	.372	-2.231*	.776
	Tree2	-52.19*	32.81*	14.85	-9.95*	-3.79	2.551	-3.91*	-1.450	.776
	Tree3	-85.31*	34.06*	14.85	-11.93*	1.45	2.551	-3.21*	-2.00*	.776

M.d = mean difference,

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Table 10: LSD follow-up test for Impact bending, MOR and MOE

		Impact bending (M. d)			MOR (M. d)			MOE (M. d)		
		Rp	Sh	S.E	Rp	Sh	S.E	Rp	Sh	S.E
Tree1	Tree2	-90.81*	-61.60*	19.90	15.05*	6.012*	2.947	1327.72*	-308.27	402.23
	Tree3	-114.94*	27.31	19.90	1.94	8.16*	2.947	401.39	772.92	402.23
	Tree4	-113.03*	5.08	19.90	9.70*	-11.67*	2.947	1283.07*	235.82	402.23
Tree2	Tree1	90.80*	61.59*	19.90	-15.05*	-6.02*	2.947	-1327.72*	308.27	402.23
	Tree3	-24.13	88.90*	19.90	-13.11*	2.14	2.947	-926.33*	1081.19*	402.23
	Tree4	-22.23	66.68*	19.90	-5.34	-17.69*	2.947	-44.65	544.08	402.23
Tree3	Tree1	114.93*	-27.31	19.90	-1.94	-8.16*	2.947	-401.39	-772.92	402.23
	Tree2	24.13	-88.90*	19.90	13.11*	-2.14	2.947	926.33*	1081.18*	402.23
	Tree4	1.91	-22.23	19.90	7.76*	-19.83*	2.947	881.68*	-537.10	402.23
Tree4	Tree1	113.03*	-5.08	19.90	-9.70*	11.67*	2.947	-1283.07*	-235.82	402.23
	Tree2	22.22	-66.68*	19.90	5.34	17.69*	2.947	44.65	-544.09	402.23
	Tree3	-1.90	22.23	19.90	-7.76*	19.83*	2.947	-881.68*	537.10	402.23

Conclusions

Within the scope of this study and statistical analysis carried out, the following conclusions have been drawn:

1. The specific gravity of the wood varied consistently from butt to top and significantly different at á$_{0.05}$.
2. The moisture content and percentage shrinkage followed the same trend with specific gravity both at the radial position and sampling height.
3. The modulus of rupture and modulus of elasticity were significant but varied inconsistently from butt to top of the wood.
4. Both the sampling height and radial position exhibited significant influence on the properties tested.

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