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Variations in the anatomical characteristics of plantation grown *Tectona grandis* wood in Edo State, Nigeria.

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ABSTRACT

The variations in anatomical characteristics namely fibre length, fibre diameter, fibre lumen width and cell wall thickness of Tectona grandis wood age 15, 20 and 25-year old respectively were investigated. Six trees from each even aged stand and similar class diameter selected from Edo State Forestry plantations were used for the study. Wood samples were systematically collected from the outer, middle and inner wood sections of the radial and longitudinal positions at 10, 50 and 90% of the tree height. The mean values of fibre length were 1.45, 1.73 and 1.96 mm; fibre diameter were 26.79, 29.47 and 32.83 µm; fibre lumen width were 18.17, 15.60 and 14.17 µm while the mean values for fibre wall thickness were 5.87, 7.89 and 9.80 µm for 15, 20 and 25-year old Tectona grandis wood respectively. Fibre length, fibre diameter and cell wall thickness increased with increase in age while fibre lumen width decreased with increase in age. However all the anatomical characteristics examined in this study increased from innerwood to outerwood but decreases from the base to top. Analyses of variance used for mean separation were significant ($p < 0.05$).

Key words: *Tectona grandis* wood, Fibre Length, Fibre Diameter, Fibre Lumen Width, Cell Wall Thickness, longitudinal and radial positions.

INTRODUCTION

Wood consists of matrix of fibre walls and air spaces. Its structural properties vary from pith to bark, from the tree base to the top and from the stem to the branches and roots [1]. The primary structural block of wood is the tracheids or fibre cells. These cells vary from 16 - 42 micrometers in diameter and from 870 - 4000 micrometer long [2]. The variations in wood properties are attributable to the different distribution patterns of its micro structures, its arrangement, size and dimension of components cells. In hard wood, the cells that make up the anatomical organization are the vessels, fibres, parenchyma cells and the wood rays. Fibres are the principal element that is responsible for the strength of the wood [2,3]. Ocloo and Laing [4] reported on the major contributors to the strength of *Celtis adolfi-friderici, Celtis mildbraedii and Celtis zenkeri* to include wall thickness of the vessels and fibres, the fractional wall volumes of the vessels and fibres and the length of the fibres. These anatomical properties according to [4] have a positive correlation on the strength characteristics of wood. Onilude [5] discovered a positive correlation in fibre length with the age of the tree from the pith to the bark for plantation grown *Terminalia superb* in his work.

Fibre length is one of the quality parameters for pulpwood [6]. It has been extensively studied in relation to tree age and within tree position [7, 8]. Fibre dimension are determined by the dimensions of the cambial fusiform cells from which they are derived and by the process that occurs during cell differentiation [9,10]. Fibre length and cell wall thickness have been reported to show gradual increase from pith to bark [11,5]. The increases in fibre length from pith to bark according to [5] are due to the increasing age of the tree with a resulting effect on cell wall development. Rulliaty and America [12] reported a decreasing trend in wood fibre length from the tree base to the top. This decreasing trend on wood fibre length is attributable to the influence of the growth promotion substances which are close to the growing tip. These growth promoting substances initiate rapid production of cells at this point with decreasing maturation time thereby resulting in the production of short cells at the tree top.

The main objective of the study was to examine the variations in anatomical characteristics of plantation grown *Tectona grandis* wood in Edo State, Nigeria. The specific objectives were to investigate the variations in fibre length, fibre diameter, fibre lumen width and fibre wall thickness within and between trees of the same and different age classes of *Tectona grandis* wood in both radial and longitudinal positions.

Study Area

Wood samples of *Tectona grandis* were collected from Edo State Forestry plantation. The forest plantation lies between latitude 5^0 45' and 7^0 8' north and longitude 5^0 4' and 6^0 52' east. The climate of the area is tropical with distinct wet and dry season characterized by humid conditions in the south and sub-humid conditions in the north. The rain fall pattern is bimodal and varies from 2000 mm a year in the humid southern part to 1150 mm a year in the sub-humid northern parts. The mean monthly temperature is about 27^0C with a range of 22-35^0C while the relative humidity range is from 79-90% [13]. The topography of the area is generally flat with pocket of gentle undulation.

MATERIALS AND METHODS

Six trees were randomly selected from each even aged stand of *Tectona grandis* plantation in accordance with the procedure of ASTM D143-83 standard [14]. Sample trees with very close diameter classes, relatively straight stem and clear wood were selected. Wood samples for the test were systematically collected from the inner wood section (near the pith) and outer wood section (close to the bark) while the middle wood section was collected from midpoint between the inner and the outer wood sections of the trees. The test samples were conditioned to 12 % moisture content in a controlled laboratory during the test.

Wood samples used for anatomical properties evaluation were collected from the radial and longitudinal positions of the trees among the three age classes of 15, 20 and 25- year old *Tectona grandis* wood respectively. Wood samples measuring 20mm x 20mm x 30mm were collected and softened by boiling for 24 hours in a beaker of water over a hot plate. Thin sections of 20 microns were prepared from the three well oriented planes vis-à-vis cross sectional, transverse radial longitudinal sections (R.L.S.) and tangential longitudinal sections (T.L.S.) respectively, using a microtone slicing machine according to the procedure used by [15]. The microtoned wood sections were placed into petridishes containing methylated spirit for moistening. Methylated spirit was used in order to prevent rolling and flaking characteristics of wood sections. Staining was immediately done by adding drops of safranin solution to the sections in the petridish and left for ten minutes. The stained wood sections were dehydrated with 95% ethyl alcohol (ethanol) for about 60 seconds and were cleaned using cedar wood oil as a cleaning agent. This facilitated easy lifting of section during mounting.

Dimensions of cells from each representative samples were on the average of 25 measurements according to [6]. One section each was lifted from the petridish with the aid of a forceps into a slide and trimmed to sizes for coverage with a slide cover of 2 cm square. Filter paper was used to mop up excess oil. Canada balsam was added to the slide and covered with cover slid. The prepared slides were placed over a hot plate to expel air bubbles and also effect even spread of Canada balsam on the slide. The slides were observed under a photomicrograph electronic microscope with tracer reflector and this brought out the different anatomical features of the wood.

All the projected fibres were measured for anatomical characteristics evaluation such as fibre length, fibre diameter,fibre lumen width and cell wall thickness.

RESULTS AND DISCUSSION

Fibre Length

The mean fibre length values obtained were 1.45, 1.73 and 1.96 mm for 15, 20 and 25- year old *Tectona grandis* wood respectively (Table 1).

The mean values of fibre length obtained in the longitudinal positions ranged from 1.55 to 1.32, 1.85 to 1.58 and 2.11 to 1.80 mm while in the radial position the mean values obtained ranged from 1.37 to 1.51, 1.63 to 1.82 and 1.80 to 2.15 mm for ages 15, 20 and 25- year old *Tectona grandis* wood respectively (Table 1). Therefore wood fibre length increased with increase in age. Generally, there was decrease in fibre length from the base to the top and an increase from inner wood to outer wood (Table 1).

Analysis of variance carried out at 5% probability level showed that the variations in wood fibre length for different ages, sample trees, longitudinal and radial positions were significant (Table 5). This is an indication that age, sample trees, longitudinal and radial positions from where the wood samples were collected contributed to the variations in fibre length.

The general decrease in fibre length from the base to the top and its corresponding increase from innerwood to outerwood sections observed in this study had earlier been reported in the wood of *Eucalyptus globules* [6]. The authors attributed the increase in fibre length to increase in the length of cambial initial with increasing cambial age.

The differences in fibre length associated with increase in height is mainly due to the differences in the juvenile and mature wood proportion in the tree, since the proportion of juvenile wood increases with an increase in height [16]. Generally there was a decrease in fibre length with increasing height of the tree [17, 18, 19, and 20].

Table 1: Mean Fibre Length (mm) of *Tectona grandis* wood in Relation to Age, Heights and Positions in the Tree

		Sampling	Height (%)		
Age (Years)	Radial Position	Base (10%) Mean±SD	Middle (50%) Mean±SD	Top (90%) Mean±SD	Mean Pooled Mean
15	Outerwood	$1.61±0.18^{a}$	$1.56±0.18^{ab}$	$1.35±0.07^{c}$	1.51±0.14
	Middlewood	$1.57±0.15^{ab}$	$1.50±0.12^{ab}$	$1.33±0.09^{cd}$	1.47±0.13
	Innerwood	$1.45±0.16^{e}$	$1.38±0.09^{ef}$	$1.28±0.06^{cg}$	1.37±0.09
	Pooled mean	1.55±0.08	1.48±0.09	1.32±0.04	1.45±0.07
20	Outerwood	$1.95±0.18^{a}$	$1.84±0.15^{b}$	$1.67±0.16^{c}$	1.82±0.14
	Middlewood	$1.86±0.14^{d}$	$1.76±0.12^{e}$	$1.58±0.08^{f}$	1.73±0.14
	Innerwood	$1.75±0.13^{eg}$	$1.63±0.12^{ch}$	$1.50±0.08^{fi}$	1.63±0.13
	Pooled mean	1.85±0.10	1.74±0.11	1.58±0.09	1.73±0.10
25	Outerwood	$2.33±0.18^{a}$	$2.17±0.15^{b}$	$1.96±0.18^{c}$	2.15±0.19
	Middlewood	$2.07±0.10^{d}$	$1.92±0.12^{ce}$	$1.78±0.14^{ef}$	1.92±0.15
	Innerwood	$1.93±0.17^{eg}$	$1.82±0.14^{eh}$	$1.65±0.13^{i}$	1.80±0.14
	Poole mean	2.11±0.20	1.97±0.18	1.80±0.16	1.96±0.18

Each value is the mean and standard deviation of 6 replicates sampled trees of Teak
Mean of the same age with different superscript are significantly different ($p < 0.05$)

Fibre Diameter

The mean fibre diameter values were 26.64, 29.47 and 32.83 µm for ages 15, 20 and 25- year old *Tectona grandis* wood respectively (Table 2).

The mean values of fibre diameter obtained in the longitudinal positions ranged from 29.20 to 24.52, 31.89 to 26.92 and 35.47 to 30.19 µm. In the radial positions, the mean values obtained ranged from 24.65 to 28.36, 27.42 to 31.71 and 30.25 to 34.70 µm for ages 15, 20 and 25-year old *Tectona grandis* wood respectively (Table 2). Fibre diameter increased with age, from 15-year through 20- year to 25- year old *Tectona grandis* wood. Fibre diameter generally decreased from base to top and increase from innerwood to outerwood at any particular height level (Table 2). The observed increase in fibre diameter associated with the increasing age of the tree may be due to the many molecular and physiological changes that occur in the vascular cambium as well as the increase in the wood cell wall thickness during the tree aging process [21, 22].

Analysis of variance for fibre diameter showed that age, tree sample longitudinal and radial positions from where the wood samples were collected contributed significantly to its variations at 5% probability level (Table 5).

Table 2: Mean Fibre Diameter (µm) of *Tectona grandis* wood in Relation to Age, Heights and Positions in the Tree

		Sampling	Height (%)		
Age (Years)	Radial Position	Base (10%) Mean±SD	Middle (50%) Mean±SD	Top (90%) Mean±SD	Mean (%) Mean±SD
15	Outerwood	30.39±2.33[a]	28.42±3.89[be]	26.27±2.93[c]	28.36±2.06
	Middlewood	29.83±2.58[d]	26.35±3.12[c]	24.54±2.41[eh]	26.91±2.69
	Innerwood	27.37±3.03[cf]	23.84±2.88[g]	22.75±2.21[fh]	24.65±2.42
	Pooled mean	29.20±1.61	26.20±2.29	24.52±1.76	26.64±2.37
20	Outerwood	34.36±2.38[a]	32.07±3.57[ab]	28.70±2.95[ce]	31.71±2.85
	Middlewood	31.85±2.71[bd]	29.18±3.08[e]	26.82±3.08[fi]	29.28±2.52
	Innerwood	29.46±3.06[e]	27.58±2.44[gf]	25.23±2.13[h]	27.42±2.12
	Pooled mean	31.89±2.45	29.61±2.28	26.92±1.74	29.47±2.49
25	Outerwood	36.54±2.19[ab]	35.09±4.15[b]	32.47±3.24[c]	34.70±2.06
	Middlewood	36.41±2.41[d]	33.52±3.25[ce]	30.65±2.82[f]	33.53±2.88
	Innerwood	33.45±3.36[ce]	29.85±2.38[fg]	27.46±2.14[h]	30.25±3.02
	Pooled mean	35.47±1.75	32.82±2.69	30.19±2.54	32.83±2.64

Each value is the mean and standard deviation of replicates sampled trees of Teak
Mean of the same age with different superscript are significantly different ($p < 0.05$)

Table 4: Mean Lumen Width (µm) of *Tectona grandis* wood in Relation to Age, Heights and Positions

		Sampling	Height (%)		
Age (Years)	Radial Position	Base (10%) Mean±SD	Middle (50%) Mean±SD	Top (90%) Mean±SD	Pooled Mean Mean±SD
15	Outerwood	22.10±1.42[a]	19.48±1.86[b]	17.69±1.31[c]	19.76±2.22
	Middlewood	20.65±1.63[d]	18.33±1.63[ce]	16.71±1.29[f]	18.56±1.98
	Innerwood	18.47±1.65[ce]	15.60±2.07[g]	14.53±1.29[h]	16.20±2.04
	Pooled Mean	20.41±1.83	17.80±1.99	16.31±1.62	18.17±2.08
20	Outerwood	18.79±1.36[a]	16.43±1.92[b]	14.89±1.35[c]	16.70±1.96
	Middlewood	17.50±1.51[d]	15.53±1.71[ce]	13.89±1.46[f]	15.64±1.81
	Innerwood	15.90±1.47[ce]	14.59±1.40[c]	12.82±1.25[g]	14.44±1.55
	Pooled Mean	17.40±1.45	15.52±0.92	13.87±1.04	15.60±1.77
25	Outerwood	16.51±1.50[a]	15.18±1.53[b]	13.64±1.18[c]	15.11±1.44
	Middlewood	15.32±1.10[b]	14.31±1.64[cd]	12.51±1.10[f]	14.05±1.42
	Innerwood	14.52±1.34[cd]	13.76±1.52[c]	10.75±1.11[h]	13.01±1.99
	Pooled Mean	15.45±1.00	14.42±0.72	12.30±1.46	14.06±1.05

Each value is the mean and standard deviation of 6 replicates sampled trees of Teak
Mean of the same age with different superscript are significantly different ($p < 0.05$)

Fibre Lumen Width

The mean values obtained for fibre lumen width at 15, 20 and 25 year-old *Tectona grandis* wood were 18.17, 15.60 and 14.17 µm respectively (Table 3). The mean values obtained in the longitudinal positions ranged from 20.41 to 16.31, 17.40 to 13.87 and 15.45 to 12.30 µm while the mean values obtained in the radial positions ranged from 16.20 to 19.76, 14.44 to 16.70 and 13.01 to 15.11 µm for ages 15, 20 and 25 year- old *Tectona grandis* wood respectively (Table 3). This showed that fibre lumen width decreases with age, which may be attributed to the increase in the length of fibre initial associated with increasing age of the cambium (Jorge *et al*., 2000). The observed differences in lumen width with increasing age of the tree may also be due to increase in cell size and physiological development of the wood as the tree grows in girth. Frmpong-Mensah [23,22] reported positive relationship between variations in lumen width and age of the cambium. Fibre lumen width increased from innerwood to the outerwood at any particular height (Table 3). Generally, the trend of variations in fibre lumen width showed a decrease from base to top and an increase from innerwood to outerwood.

Analysis of variance carried out at 5% probability level showed that, the effects of the different age classes, sample trees, longitudinal and radial positions on fibre lumen width were significant (Table 5).

Cell Wall Thickness

The mean values for cell wall thickness were 5.87, 7.89 and 9.80 µm for age 15, 20 and 25 year-old *Tectona grandis* wood respectively (Table 4). The mean cell wall thickness obtained in the longitudinal positions ranged from 6.65 to 4.97, 9.41 to 6.63 and 11.46 to 8.53 µm while in the radial positions, the mean values obtained ranged from 5.08 to 6.70, 6.80 to 8.89 and 8.87 to 10.78 µm for ages 15, 20 and 25-year old *Tectona grandis* wood respectively (Table 4). This showed that cell wall thickness increases with age. It also increases from innerwood to outerwood and decreases from the base to the top (Table 4).

Analysis of variance used to test for significant differences among the different age classes, sample trees, longitudinal and radial positions are presented (Table 5). The results showed that, the effects of the different age classes, sampled trees, longitudinal and radial positions from where the samples were collected contributed significantly ($p < 0.05$) to variations in cell wall thickness.

Table 4.40: Mean Cell Wall Thickness (µm) of *Tectona grandis* in Relation to Age, Heights and Positions in the Tree

		Sampling	Height (%)		
Age (Years)	Radial Position	Base (10%) Mean±SD	Middle (50%) Mean±SD	Top (90%) Mean±SD	Pooled Mean Mean±SD
15	Outerwood	7.52±0.95^{a}	6.73±0.63^{b}	5.84±0.81^{c}	6.70±0.84
	Middlewood	6.68±1.10^{b}	5.92±0.84^{c}	4.86±0.52^{d}	5.82±0.91
	Innerwood	5.75±0.62^{c}	5.27±0.66^{cd}	4.21±0.65^{e}	5.08±0.79
	Pooled mean	6.65±0.89	5.97±0.73	4.97±0.82	5.86±0.85
20	Outerwood	10.62±1.04^{a}	8.66±0.95^{b}	7.40±0.93^{c}	8.89±1.63
	Middlewood	9.37±1.24^{d}	7.85±0.73^{c}	6.73±0.45^{e}	7.98±1.33
	Innerwood	8.23±0.78^{f}	6.40±0.65^{e}	5.76±0.44^{g}	6.80±1.28
	Pooled mean	9.41±1.20	7.64±1.15	6.63±0.82	7.89±1.05
25	Outerwood	12.57±0.84^{a}	10.23±1.11^{b}	9.55±0.80^{c}	10.78±1.58
	Middlewood	11.33±0.75^{d}	9.39±0.84^{c}	8.48±0.79^{e}	9.73±1.46
	Innerwood	10.47±1.27^{b}	8.58±0.77^{e}	7.56±0.84^{f}	8.87±1.48
	Pooled mean	11.46±1.06	9.40±0.83	8.53±1.00	9.80±0.96

Each value is the mean and standard deviation of 6 replicates of sampled trees of Teak
Means of the same age with different superscript are significantly different ($p < 0.05$)

The variations in cell wall thickness among age classes and within tree positions observed in this study are similar to those reported in literature [24, 22]. The increase in cell wall thickness among the study samples could be attributed to the increasing age of the cambium as the tree grows in girth [23, 22]. The authors reported significant correlations with cell wall thickness and cambial age. Akachuku [25] also attributed the increase in cell wall thickness of *Gmelina arborea* to changes in cell size that are associated with annual and periodic growth cycles and the increasing age of the cambium. Age, longitudinal and radial positions contributed significantly to variations in cell wall thickness among the study samples.

Table 5: Analysis of Variance for Anatomical characteristics of *Tectona grandis* wood

Source of variation	df	Fibre Length (mm)	Fibre Diameter (µm)	Lumen Width (µm)	Cell Wall Thickness (µm)
Age	2	763.60*	255.59*	427.00*	101.46*
Height	2	214.88*	169.52*	325.09*	26.40*
Radial Position	2	148.83*	128.97*	189.62*	27.66*
Age*Height	4	2.11^{ns}	2.04^{ns}	4.36*	1.65^{ns}
Age*Radial Position	4	14.55*	2.13^{ns}	5.55*	1.27^{ns}
Radial Position*Height	4	1.69^{ns}	0.73^{ns}	0.88^{ns}	0.80^{ns}
Age*Radial Position*Height	8	0.43^{ns}	0.46^{ns}	1.56^{ns}	1.16^{ns}
Error	648				
Total	674				

**significant at ($p < 0.05$) probability level; ns = not significant at ($p < 0.05$) probability level*

CONCLUSION

The differences in anatomical characteristics, fibre length, fibre diameter, fibre lumen width and fibre wall thickness of 15, 20 and 25-year-old *Tectona grandis* wood were discovered significant ($p < 0.05$). There were also significant differences within and between trees of the same and different age classes. Anatomical characteristics such as fibre length, fibre diameter, cell wall thickness increases with age, however fibre lumen width decreases with age. Generally anatomical characteristics decrease from base to top and increased from innerwood to outerwood from where the wood samples were collected. The effects of age, samples trees, longitudinal and radial positions contributed significantly to variations in anatomical characteristics of *Tectona grandis* wood.

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