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Axial and Radial Variations in the Physical Properties of Plantation Grown *Tectona grandis* Wood

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ABSTRACT: The variations in density, percentage shrinkage and thickness swelling of plantation grown *Tectona grandis* wood aged 15, 20 and 25 years were examined. Six trees from each even aged class were selected at the Edo State Forestry plantation sites. Wood samples were collected from innerwood, middle wood and outerwood at 10, 50 and 90% of the tree merchantable height. The density, percentage shrinkage and thickness swelling increased with increase in age of the tree. The mean values of density for the three age classes on oven-dry weight and volume basis were 479, 555, 649kg m^{-3}. Mean percentage shrinkage values in the radial directions were 3.702, 2.717 and 1.460% while the mean values obtained in the tangential directions were 7.602, 5.519 and 5.040%. Similarly, the mean values for thickness swelling in the radial directions were 5.456, 4.081 and 2.404% while the mean values obtained in the tangential directions were 9.909, 7.559 and 5.133% for 15, 20 and 25 years old *Tectona grandis* wood respectively Wood density increased from pith to bark and decrease from base to top. Also percentage shrinkage and thickness swelling increase from pith to bark while it decreased from base to top. The correlation between density, percentage shrinkage and thickness swelling were significant at 0.05 level of probability.

Key words: *Tectona grandis*, Plantation, Density, Percentage shrinkage, Thickness swelling.

Introduction

In Nigeria, the increased in population has brought increased pressure on timber resources as a result of high demand for wood products as raw materials for construction and building purposes, fuel wood and agricultural tools. Over the years, much exploitation of the forest has been done in order to meet the increasing demand for wood and its products for the teaming population. This situation has resulted in serious depletion of the resource base to such an extent that some favour timber species has become scarce while others have become extinct in certain ecological zones (Fuwape, 2000). The Nigeria tropical forest is decreasing at an alarming rate due to increased demand for wood and wood product as a result of increasing population growth, deforestation for agriculture and other infrastructural development (Izekor and Okoro, 2004). The over exploitation of the existing forest resources and the disappearance of economic hard wood species are of great concern to the wood scientists, technologists and users as well. The supply of quality timber from the natural forests in Nigeria to wood based industries which took place up to the 1970s is no more available in the quantities that can sustain the usual large diameter class logs required by these industries. The natural forest has shrunken considerably to less than 5% of Nigeria total land area of 913,000km^2 (Okojie and Akande, 1995). The annual consumption of wood in Nigeria has exceeded the allowable cut by about 3 million m^3 for industrial wood and about 10 million m^3 for fuel wood.

Teak is one of the fastest growing exotic tree species grown widely in Nigeria. It belong to the family Verbenaceae and is indigenous to continental Asia and is confined to the moist deciduous forest below 1000 m altitude in India, Myammar, Thailand and Lao (F.A.O. 1995). Akinsanmi (1985) has attributed the choice of teak for large scale industrial forest plantation in Nigeria to its ease of establishment, fast growth rate, fire resistance trait and excellent wood properties. Today, more attention is being devoted to plantation forestry in order to meet the country's requirement for wood products on a sustainable basis. Hence the Federal Government of Nigeria resorted to establishment of plantation forestry in several parts of the country (Onyekwelu and Akindele, 1995). The demand for wood and wood products will continue to increase due to Nigeria's fast growing population and rising standard of living of the people. In view of the on-going therefore, evaluation of wood qualities of *Tectona grandis* from a relatively young plantation is necessary in order to provide relevant information on the utilization of the wood resources base of the country.

The main objective of this study was to investigate variation in the physical properties of different age classes of plantation grown *Tectona grandis* wood in Edo State, with a view to make appropriate recommendation as well as provide some technical information which will be relevant for its utilization. The specific objective was to determine the variations in wood density, percentage shrinkage and thickness swelling of the same and different age classes viz; 15, 20 and 25 years in both axial and radial direction of plantation grown *Tectona grandis.*

Materials and Methods

Wood samples of *Tectona grandis* were collected from Edo State Forestry plantation sites in Ologbo, Irrua and ohrionmwon forest reserves. The total land area covered by *Tectona grandis* plantation in Edo State is 6,057 hectares with a volume of 1,856,848 m^3 (FORMECU, 1998). 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% (FORMECU, 1999). The topography of the area is generally flat with pocket of gentle undulation. Its soils are reported to be of very recent deposits and are derived from sand stones and shales. These soils are very susceptible to leaching; hence they lose their fertility very fast (Egbe, 1989).

Six trees were randomly selected from each even aged stand of *Tectona grandis* according to the provision of ASTM D 143-148 (ASTM, 1987). Sample trees with very close diameter classes, relatively straight stem and clear wood were selected. Billets measuring 750 mm were cut from felled trees at 10, 50 and 90% of the merchantable length of each stem. The billets were then sawn through the pith into four parts. A board of 20 mm thick was sawn from each of the four parts through the pith to the bark using a circular bench saw. Wood samples from the test were systematically collected from the innerwood (near the pith), and outerwood (close to the bark) while the middle wood was selected from the midpoint between the innerwood and the outerwood. The samples were conditioned to 12 % moisture content in a controlled laboratory at the time of the test. The experiment was carried out using a completely randomized design. Factor A was the age class, viz 15, 20 and 25 years. Factor B was the six trees selected from each even aged stand. Factor C was the longitudinal position of 10, 50 and 90 %. While factor D was the radial position viz, innerwood, middlewood and outerwood. Four replicates of wood samples were selected for test from the innerwood, the middlewood and the outerwood.

Wood density determination was carried out using sample sizes of 20 x 20 x 60 mm according to (BS, 1989). A total of 648 wood samples were used for the test after drying the samples to a constant weight at 103 ± 2^0c. Test samples used for wood density determination were also used for the determination of percentage shrinkage and thickness swelling as suggested by BS 373 [11]. Shrinkage values in each structural direction were calculated from the ratio of change in dimension from the air-dry condition to oven-dry dimension expressed as a percentage. Thickness swelling values in each anisotropy direction were calculated from the ratio of change in dimension from the oven-dry condition to swollen dimension also expressed as a percentage.

The values obtained were subjected to analysis of variance to evaluate the variance component and determine if there are significant differences in the physical properties of plantation grown *Tectona grandis* in its axial and radial direction. The main effect considered were those due to differences between age classes, sample trees, longitudinal position and radial position. The interaction effects between the main components were also considered. Correlation and regression analysis were conducted to establish the relationship that exist between density, percentage shrinkage and thickness swelling.

Results and Discussion

Wood Density

The mean density values of plantation grown *Tectona grandis* based on oven-dry weight and volume increased progressively with increase in age. The mean density values for the three age classes were 479, 555 and 649 kg m^{-3} for 15, 20 and 25 years old plantation grown *Tectona grandis* (Table 1). In the tree longitudinal position the mean density values ranged from 442-514, 512-601 and 605-689kg m^{-3} while in the radial position the mean density values ranged were 441-520, 521-592 and 607-695 kg m^{-3} for 15, 20 and 25 years old *Tectona grandis* respectively (Table 1). The differences in wood density among the three age classes observed in this study were quite obvious. The general trend was an increase in density values from 15 years through 20 years to 25 years respectively. These differences in density values may be due to changes brought about by increase in cell size and physiological development of the wood as a result of increment of the wood annual growth rings as well as the addition of more wood which result from the formation of new tissues as the tree grow in girth.

These findings are in accordance with the earlier report by (Fuwape and Fabiyi, 2003) on the variation of wood density of plantation grown *Nauclea diderrichii*. This similar observation was made by (Akachuku, 1982) for wood density of Nigerian grown *Gmelina arborea*. He reported that variations in density within trees do occur as a result of changes in cell size and cell wall thickness that are associated with annual and periodic growth cycles and the increasing age of the cambium. A general decrease in wood density values was observed in this study from the tree base through the mid log to the top log with a progressive increase in density values from the pith outwards to the bark (Table 1). This finding agrees with the report of (Bendtsen, 1978). The vertical variations in wood density as observed in this study have also been reported by (Jugo *et al*, 2000; Rupert *et al*, 2002).

Analysis of variance carried out showed that variations in density for different ages, sample trees, longitudinal and radial position were significant at 0.05 probability level (Table 4). Also the interaction between age and height, age and radial position were significant at 0.05 % probability level. This is an indication that tree ages as well as the longitudinal and radial position from where the wood samples were collected contributed to the variations in density.

Table 1: Mean values of Density (kg m^{-3}) of Plantation grown *Tectona grandis*.

		Sampling	Height (%)		
Age (Years)	Radial Position	Base (10%)	Middle (50%)	Top (90%)	Mean (%)
15	Outerwood	558 ± 4.75	520 ± 5.31	481 ± 5.45	520 ± 38.5
	Middlewood	512 ± 4.86	473 ± 5.92	443 ± 5.66	476 ± 34.6
	Innerwood	473 ± 5.17	447 ± 6.34	403 ± 6.13	441 ± 35.4
	Mean	514 ± 42.5	480 ± 37.0	442 ± 39.0	479 ± 36.0
20	Outerwood	637 ± 4.29	590 ± 4.60	550 ± 4.81	592 ± 43.5
	Middlewood	602 ± 5.47	548 ± 3.66	508 ± 4.64	553 ± 47.2
	Innerwood	565 ± 5.26	520 ± 4.77	479 ± 5.26	521 ± 43.0
	Mean	601 ± 36.0	553 ±35.2	512 ± 35.7	555 ± 44.5
25	Outerwood	732 ± 6.42	701 ± 4.70	652 ± 5.60	695 ± 40.3
	Middlewood	687 ± 4.77	644 ± 5.51	602 ± 5.96	644 ± 42.5
	Innerwood	648 ± 5.35	612 ± 4.69	561 ± 5.26	607 ± 43.7
	Mean	689 ± 42.0	652 ± 45.1	605 ± 45.6	649 ± 42.1

Percentage Shrinkage

The result of the oven-dry weight of percentage shrinkage of the study samples are presented in (Table 2). The mean values obtained for percentage shrinkage in the radial direction were 3.702, 2.717 and 1.460% while in the tangential directions, the mean values were 7.248, 5.040 and 2.888% for 15, 20 and 25 years plantation grown *Tectona grandis* respectively. The mean values of percentage shrinkage in the radial direction ranged from 3.491-3.894, 2.481-2.964 and 1.223-1.708% while in the tangential direction, the mean values ranged from 6.948-7.529, 4.904-5.180 and 2.526-3.923% along the tree merchantable height for 15, 20 and 25 years respectively of plantation grown *Tectona grandis* (Table 2). The same table also show the ranged of the mean values of percentage shrinkage of *Tectona grandis* across the tree bole from 3.436-3.931, 2.461-2.976 and 1.244-1.688% in the radial direction as well as 6.912-7.602, 4.324-5.519 and 2.512-3.393% in the tangential direction for 15,20 and 25 years plantation grown *Tectona grandis.*

A progressive decrease in the mean values of percentage shrinkage with increase in tree age were observed in this study. The observed differences may be due to the presence of more mature wood resulting from the increasing age of the cambium. The pattern of variations observed in this study showed that radial and tangential shrinkages decreased along the tree bole from the butt log through the mid log to the top log. These observation are in accordance with the earlier findings of (Mottonen and Loustarinen, 2006; Seralde, 2006). Also (Ogunsanwo and Onilude, 2000) reported that radial shrinkage of *Triplochiton scleroxylon* decreases drastically from the butt log to the crown point and this subsequently have a linear relationship with specific gravity. The increased in shrinkage percentage from the pith to the bark as observed in this study is similar to the published work of (Shupe *et al*, 1995) as observed for yellow Poplar tree.

Koubaa *et al* (1998), working on 9 years old Poplar clones also observed increased tangential shrinkage from the pith to the bark. They concluded that the inner wood shrink less than the outer wood in both radial and tangential directions due to the greater amount of extractives in the inner wood as well as the increase specific gravity from the inner wood to the outer wood. The mean percentage shrinkage values obtained in the tangential direction almost double that in the radial direction. These differences according to (Desch and Dinwoodie, 1991) is as a result of the restricting effect of the rays on the radial plane; the differences in the degree of lignifications between the radial and the tangential walls; the differences in microfibrillar angle between the two walls and the increased thickness of the middle lamella in the tangential direction in relation with that in the radial direction.

Analysis of variance carried out at 0.05 probability level showed that variations in percentage shrinkage among the three age series of the sampled trees in the longitudinal and radial positions were significant (Table 4). This means that the tree age, longitudinal and radial positions from where the wood samples were collected have effect on the differences in the percentage shrinkage of plantation grown *Tectona grandis.*

Thickness Swelling

The result of the thickness swelling of plantation grown *Tectona grandis* obtained in this study after complete immersion in water for five days are presented in (Table 3). The mean values obtained for thickness swelling in the radial direction were 5.456, 4.081 and 2.404% while the mean values obtained in the tangential direction were 9.909, 7.559 and 5.133% for 15, 20 and 25 years respectively. The mean values of thickness swelling along the tree merchantable height ranged from 5.267-5.535, 3.864-4.308 and 2.153-2.657% while the values obtained in the tangential direction ranged from 9.654-10.148, 7.435-7.676 and 4.838-5.542% (Table 3). Also the mean values of thickness swelling across the tree bole in the radial direction ranged from 5.215-5.659, 3.837-4.324 and 2.181-2.626% while in the tangential direction, the mean values ranged from 9.560-10.204, 6.935-7.971 and 4.729-5.616% for 15, 20 and 25 years respectively (Table 3).

A general increase in mean thickness swelling was observed from the tree base through the mid log to the top log and also from the pith outward to the bark. These observations agree with the previous findings of (Kollmann and Cote, 1968; Desch and Dinwoodie, 1991). According to (Kollmann and Cote,1968) these differences in thickness swelling between the radial and the tangential directions could be due to the restraining influence of the wood rays in the radial direction and by the different helical arrangement of fibre in the radial and tangential cell walls

Analysis of variance carried out, showed that thickness swelling among the tree age classes in the longitudinal and radial directions were significant at 0.05 probability level (Table 4). The implication of this is that, tree age, longitudinal and radial positions from where the wood samples were collected has effect on the differences in thickness swelling of plantation grown *Tectona grandis.*

Table 2: Mean values of Percentage shrinkage of plantation grown *Tectona grandis* in the radial and tangential direction.

			Sampling	Height (%)		
Age (Years)	Wood Properties	Radial Position	Base (10 %)	Middle (50 %)	Top (90 %)	Mean (%)
15	Radial Shrinkage (%)	Outerwood	3.744±0.303	3.915±0.279	4.104±0.251	3.931±0.166
		Middlewood	3.529±0.276	3.762±0.270	3.924±0.299	3.738±0.199
		Innerwood	3.200±0.323	3.452±0.289	3.655±0.282	3.436±0.228
		Mean	3.491±0.274	3.710±0.236	3.894±0.226	3.702±0.249
20		Outerwood	2.776±0.326	2.952±0.330	3.200±0.361	2.976±0.213
		Middlewood	2.504±0.322	2.706±0.330	2.943±0.364	2.718±0.220
		Innerwood	2.172±0.302	2.460±0.332	2.750±0.383	2.461±0.289
		Mean	2.481±0.302	2.706±0.246	2.964±0.226	2.717±0.242
25		Outerwood	1.455±0.333	1.705±0.387	1.903±0.295	1.688±0.225
		Middlewood	1.163±0.302	1.472±0.384	1.713±0.338	1.449±0.276
		Innerwood	1.050±0.341	1.173±0.366	1.508±0.336	1.244±0.237
		Mean	1.223±0.209	1.450±0.267	1.708±0.198	1.460±0.222
15	Tangential Shrinkage (%)	Outerwood	7.346±0.148	7.595±0.139	7.866±0.200	7.602±0.260
		Middlewood	7.086±0.194	7.287±0.254	7.547±0.299	7.307±0.231
		Innerwood	6.412±0.205	6.915±0.403	7.713±0.432	6.912±0.262
		Mean	6.948±0.482	7.266±0.341	7.529±0.347	7.248±0.291
20		Outerwood	5.374±0.214	5.513±0.198	5.671±0.211	5.519±0.149
		Middlewood	5.153±0.204	5.272±0.220	5.402±0.210	5.276±0.125
		Innerwood	4.185±0.265	4.321±0.261	4.466±0.248	4.324±0.141
		Mean	4.904±0.632	5.035±0.630	5.180±0.633	5.040±0.632
25		Outerwood	3.138±0.272	3.413±0.277	3.627±0.215	3.393±0.245
		Middlewood	2.381±0.318	2.556±0.324	3.345±0.295	2.761±0.514
		Innerwood	2.060±0.415	2.568±0.357	2.908±0.243	2.512±0.428
		Mean	2.526±0.554	2.846±0.491	3.293±0.362	2.888±0.385

Table 3: Mean values of thickness swelling of plantation grown *Tectona grandis* in the radial and tangential directions.

Age (Years)	Wood Properties	Radial Position	Sampling Height (%) Base (10 %)	Middle (50 %)	Top (90 %)	Mean (%)
15	Radial Swelling (%)	Outerwood	5.498±0.276	5.653±0.253	5.825±0.226	5.659±0.163
		Middlewood	5.302±0.253	5.515±0.245	5.662±0.271	5.493±0.181
		Innerwood	5.000±0.297	5.229±0.266	5.417±0.257	5.215±0.209
		Mean	5.267±0.251	5.466±0.216	5.635±0.205	5.456±0.184
20		Outerwood	4.138±0.304	4.301±0.305	4.532±0.334	4.324±0.198
		Middlewood	3.883±0.301	4.072±0.308	4.294±0.337	4.083±0.206
		Innerwood	3.571±0.285	3.843±0.312	4.097±0.336	3.837±0.263
		Mean	3.864±0.284	4.072±0.229	4.308±0.218	4.081±0.222
25		Outerwood	2.393±0.312	2.647±0.372	2.838±0.281	2.626±0.223
		Middlewood	2.136±0.298	2.426±0.369	2.657±0.323	2.406±0.261
		Innerwood	1.931±0.331	2.137±0.353	2.475±0.327	2.181±0.275
		Mean	2.153±0.231	2.403±0.256	2.657±0.182	2.404±0.252
15	Tangential Swelling (%)	Outerwood	9.984±0.125	10.201±0.116	10.427±0.166	10.204±0.222
		Middlewood	9.775±0.164	9.944±0.213	10.169±0.257	9.963±0.198
		Innerwood	9.203±0.175	9.630±0.340	9.847±0.363	9.560±0.328
		Mean	9.654±0.404	9.925±0.286	10.148±0.291	9.909±0.247
20		Outerwood	7.839±0.165	7.985±0.173	8.090±0.231	7.971±0.126
		Middlewood	7.654±0.189	7.775±0.193	7.881±0.183	7.770±0.114
		Innerwood	6.812±0.237	6.934±0.233	7.058±0.231	6.935±0.123
		Mean	7.435±0.547	7.565±0.556	7.676±0.546	7.559±0.121
25		Outerwood	5.407±0.250	5.586±0.248	5.854±0.195	5.616±0.225
		Middlewood	4.701±0.302	4.870±0.300	5.594±0.267	5.055±0.474
		Innerwood	4.406±0.389	4.602±0.333	5.178±0.242	4.729±0.401
		Mean	4.838±0.514	5.019±0.509	5.542±0.341	5.133±0.366

Table 4: Result of Analysis of Variance for physical properties of plantation grown *Tectona grandis*.

Source of variation	Degree of freedom	Wood density	Percentage shrinkage	Thickness swelling
Age	2	5203.94*	663.86*	1367.15*
Height	2	1271.74*	27.41*	28.30*
Radial Position	2	1108.79*	32.09*	31.07*
Age*Height	4	9.02*	0.13^{ns}	0.24^{ns}
Age*Radial Position	4	2.34*	0.12^{ns}	0.10^{ns}
Radial Position*Height	4	2.81^{ns}	0.14^{ns}	0.16^{ns}
Age*Radial Position*Height	8	1.24^{ns}	0.04^{ns}	0.05^{ns}
Error	135			
Total	161			

*Significant at 0.05 probability level
Ns = Not significant at 0.05 probability level

Conclusion

The data obtained in this study showed a general trend in the variations of wood density, percentage shrinkage and thickness swelling of 15, 20 and 25 years plantation grown *Tectona grandis* evaluated in the axial and radial positions. There were significant differences in wood density, percentage shrinkage and thickness swelling within and between trees of the same as well as different age classes in both vertical and axial positions. Generally, wood density increased with the age of the tree, whereas it decreases from the tree base to the top, it however show an increase from the pith outward to the bark.

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