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SPATIAL AND VOLUMETRIC SHRINKAGE OF TERMINALIA CATAPPA (LINN) WOOD IN BUNU TAI, RIVERS STATE, NIGERIA

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Abstract

The study aimed at spatial and volumetric shrinkage of Terminalia catappa wood in Bunu Tai, Rivers State. The experimental design was Completely Randomized Design at 0.05 probability level, replicated and the data obtained were analysed using Analysis of Variance (ANOVA). Three tree groups of merchantable sizes of T. catapppa were sawn and wood samples of (1-2m) in length at the tree top, middle (4.7m) and at 1.3m height from the ground level (base). The bolts were then processed into 20x20x60mm. The result showed a gradual decrease of the radial shrinkage from base to top along the axial axis: radial shrinkage of individual trees had mean values ranging from 1.09% to 1.82%, while an inconsistent variation in the tangential shrinkage from base to top as it decreased from base to middle and then increased to the top: tangential shrinkage of individual trees had mean values ranging from 3.78% to 4.63%. Longitudinal shrinkage of T. catappa shows also an inconsistent variation as it decreased from base to middle and then increased a little towards the top: 0.48%, 0.41%, and 0.44% respectively. However, the longitudinal shrinkage of individual trees had mean values ranging from 0.37% to 0.49%. Volumetric shrinkage decreased from base to top along the axial axis and volumetric shrinkage of individual trees had mean values ranging from 5.38% to 7.37%. The wood would be suitable for joinery and high pressured services.

INTRODUCTION

The drying of wood is an area for research and development, which concern many researchers and timber companies around the world because wood is an amenable material with great deal of variability in the mechanical and physical properties essential to its best processing (Teixeira, *et al.,* 2011), providing a wide range of use, whether in industry or in civil construction (Calil-Junior *et al.,* 2010).

Terminalia catappa is a large tropical tree in Combreataceae family that grows mainly in the tropical regions of Asia, Africa, Australia (Pankajoudhia and Robert, 2008). It is known by English common names; country –almond, Indian almond (United State Development Agency-USDA, 2016).

There is an increasing demand for this hard wood for building and construction purposes due to the increasing population and decrease in known conventional wood species. The moisture content of the wood influenced the average values of mechanical and physical properties (Calil-Junior *et al.,* 2003). Consequently, water in wood is classified in three (3) forms; free water above to fiber saturation point (FSP) which is more easily removed during drying; hygroscopic water which is below FSP and 0% of moisture content bound within the cellulose molecules if removed causes shrinkage of the wood; constitution water from the elimination of hydroxyl groups of cellulose molecules and their elimination causes degradation of the wood (Martins and Secagem de Maderia Senrada, 2000).

Wood's hygroscopic nature-ability to absorb and release moisture has the potential to change dimensionally as its moisture content varies. During the seasoning of green or freshly sawn lumber, there is a decrease in dimension. Seasoned wood in service has its dimension decreased or increased depending on whether it losses or gains moisture thus dimensional change in the wood are brought about the shrinkage or swelling of the cells or fibers of which the wood is composed (Keey *et al.*, 2000).

The dimensional changes that accompany the shrinkage of wood are major sources of both visual and structural problem in Timber in use for example furniture, tool handles, wooden roofs, etc. Shrinkage occurs as the wood changes moisture content in response to daily as well as seasonal change in accordance with the relative humidity of the atmosphere, i.e. when the air is dry wood losses moisture and shrinks and when the air is humid wood absorbs moisture. Thus, wood that is kiln dried to 6 percent moisture content and store in a dry shed outdoor in a temperate such as that found in temperate zones will regain moisture content under the same; in tropical climate, the moisture content of the wood would be about 16 percent (Carl, 2002).

Wood shrinkage occurs perpendicular to grain, meaning that a solid sawn wood study or floor joist will shrink in its cross section dimension (width and depth). Longitudinal shrinkage is negligible, meaning the length of a wood or floor will essentially remain unchanged. In multi-storey building, wood shrinkage is therefore concentrated at the wall plates, floor and roof joists and rim boards, depending on the materials and details used at floor to wall and roof to wall intersection, shrinkage in light frame wood construction can range from 0.05 inches to 0.5 inches per level (Richard, 2001).

In Nigeria presently, few construction workers make use of *T. catappa* (almond wood) due to the limited information of the efficiency and good strength properties of the wood. This maybe because the tree is mainly grown for its shade and been neglected for its construction applications. Furthermore, as a result of high rate of demand for timber species, it has become important to study the dynamism of volumetric shrinkage of *Terminalia catappa*.

Shrinkage and swelling may occur in wood when the moisture content is changed (Stamm, 1964). The duet of shrinkage and swelling tilts either way based on negative and positive axis of anisotropic scale of a wood species and is due to irregular push and pull of intracellular hydroxyl ions within water molecules and wood cells (David, 2013): shrinkage occurs as moisture content decreases, while swelling takes place when it increases. Volume change is not equal in all directions. The greatest dimensional change occurs in a direction tangential to the growth rings. Shrinkage from the pith outwards, or radially, is usually considerably less than tangential shrinkage, while longitudinal (along the grain) shrinkage is so slight as to be usually neglected. The longitudinal shrinkage is 0.1% to 0.3%, in contrast to transverse shrinkages, which is 2% to 10%. Tangential shrinkage is often about twice as great as in the radial direction, although in some species it is as much as five times as great. The shrinkage is about 5% to 10% in the tangential direction and about 2% to 6% in the radial direction (Walker *et al.,* 1993).

It is probably impossible to completely eliminate dimensional change in wood, but elimination of change in size may be approximated by chemical modification. For example, wood can be treated with chemicals to replace the hydroxyl groups with other hydrophobic functional groups of modifying agents (Stamm, 1964). Drying enables substantial long-term economy by rationalizing the use of timber resources. Studies with Paricá species (*Schizolobiu mamazonicum* Herb.) and Cumaru species (Dipterixodorata) present different values for mechanical and physical properties, classifying it according to Brazilian standard ABNT NBR 7190:1997 (Associacao Brasileria de Normas Techicas (1997) as belonging to strength classes C20 and C60 of the dicotyledons respectively (Almeida, 2013). Researches with different positions, sizes and grain directions of the specimens were realized to determine more information on mechanical and physical properties of wood (Ferro, 2013). The anisotropic property of the wood is very important to studies on the characteristics related with their moisture content. The dimensions of the wood undergo variations according to the increase or decrease in moisture content. The fibers saturation point determines the swelling and shrinkage of wood increasing or decreasing moisture (Logsdon, 2002).

It is reported that the ratio of the longitudinal to the transverse (radial and tangential) diffusion rates for wood ranges from about 100 at a moisture content of 5%, to 2 - 4 at a moisture content of 25% (Langrish and Walker, 1993). Radial diffusion is somewhat faster than tangential diffusion, although longitudinal diffusion is most rapid, it is of practical importance only when short pieces are dried. Generally, the timber boards are much longer than in width or thickness. Efficient uses of commercial timber require information on its basic characteristics and processing. Drying is among the most important and fundamental processing step to produce high quality timber product. Drying can prolong the service life of wood, along with the reduction of processing wastes, and prolonging service life of wood can be considered as increasing the efficiency of resources utilization.

The information about the durability and efficiency of wood will attract construction workers, and reduce over dependence on other timber species.

The study investigated the variation of volumetric shrinkage of *T. catappa* along the axial and radial directions of the wood.

MATERIALS AND METHODS

Wood specimens were collected from Bunu Tai in Tai Local Government Area (TALGA) on latitude $4^{o}46'N$ and longitude $7^{o}13'E$ East of Port Harcourt (David-Sarogoro & Emerhi, 2016) and 15.4 miles (18.48km) away from Port Harcourt (State capital) [Plate 1]. It is occupied by rainforest and mangrove ecosystem.

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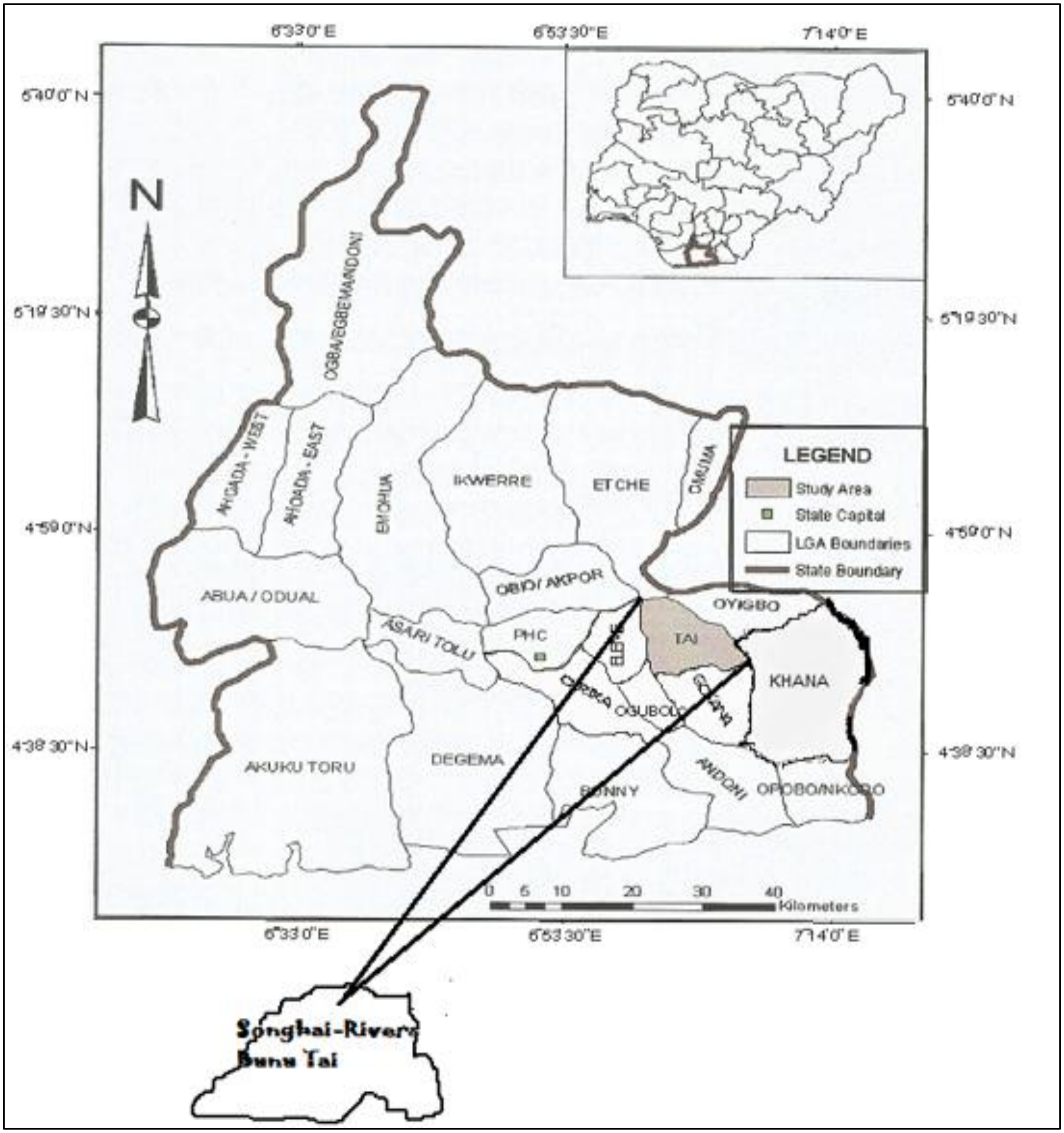

Plate 1: Map of Rivers State indicating the study areas
Source: Rivers State Ministry of Environment

Sample Collection

Three trees of merchantable sizes of *Termnalia catapppa* were harvested with the use of power chain saw and wood samples of 1-2m in length knot-free and free of decay were taken immediately after felling at the tree top (second internode), middle and at 1.3m height from the ground level (base). The bolts were taken to sawmill and processed into 20x20x60mm for all the samples used for the study. The test specimens were wrapped in polyethylene sheet to minimize changes in their moisture content and stored in a cool, dry place until the test.

Methods

For the determination of density, test samples of dimension 20x20x60mm produced from the central planks obtained at each sampling height (that is, from the base, middle and top) for each of the three tree specimens. 9 test samples were obtained for each replicate to make 15 test samples for each species and 45 test samples for the three tree specimens. The test samples were oven-dried to a constant weight, density gradient across and along the bole was thus determined as given below.

Determination of Percentage Shrinkage

This experiment was conducted in Forestry Research Institute of Nigeria (FRIN), Oyo State.

Test specimens of 20mm x 20mm x 60mm were prepared for this test; they were properly aligned and denoted 'T' and 'R' for Tangential and Radial planes respectively. They were soaked in water for 48 hours in order to get them conditioned to moisture content (12%) above Fibre Saturation Point (FSP). Specimens were removed one after the other; their dimensions in wet condition were measured to the nearest millimetre. Percentage shrinkages along the two planes were measured after specimens had been oven-dried as

$$\% \text{ Shrinkage} = \frac{V_{fsp} - V_0}{V_{fsp}} \times 100$$ Desch and Dinwoodie, (1989).

Where: V_{fsp} = Volumetric dimension at saturated condition

V_0= Volumetric dimension of oven dry condition

Volumetric shrinkage was calculated using the formula

VS=SR+ST (Ogunsanwo and Omole, 2010)

Where: VS=Volumetric Shrinkage, SR=Radial Shrinkage, ST=Tangential Shrinkage

Volumetric shrinkage

Where: = Volumetric shrinkage

= Radial shrinkage

= Tangential shrinkage

Experimental Design and Data Analysis

The experimental design was Completely Randomized Design at 0.05 probability level, replicated thrice and the data obtained were analysed using One-Way Analysis of Variance (ANOVA). Duncan Multiple Test Range used in separation of means.

Results

Radial Shrinkage of *Terminalia catappa*

The result of Analysis of variance shows that there was no significant difference (P>0.05) in the radial shrinkage of individual trees and sampling height of *T. catappa* wood sampled as well as the interaction between trees and sampling position. Radial shrinkage of *T. catappa* wood shows that the mean radial shrinkage was 1.51% shown in the table, with a mean value of 1.76% at the base, 1.39% at the middle and 1.36% at the top as shown (Table 1). There was a gradual decrease of the radial shrinkage from base to top along the axial axis.

Table 1: Mean values of Radial Shrinkage of *T. catappa*

	Top	Middle	Base	Mean
T1	0.75±0.17[a]	2.24±0.82[a]	1.82±0.51[a]	**1.6±0.35**
T2	2.13±0.77[a]	1.11±0.16[a]	2.22±1.04[a]	**1.82±0.43**
T3	1.21±0.13[a]	0.82±0.23[a]	1.25±0.26[a]	**1.09±0.12**
Mean	**1.36±0.29**	**1.39±0.31**	**1.76±0.38**	**1.51±0.19**

Mean values with the same alphabets in the column (Sampling height) and row (Individual tree) are not significantly different (P>0.05) from one another.

Tangential shrinkage of *Terminalia catappa*

The tangential shrinkage of *T. catappa* wood shows no significant difference in the tangential shrinkage of individual trees and sampling height of *Terminalia catappa* wood sampled as well as the interaction between trees and sampling position. The mean tangential shrinkage was 4.32% with a mean value of 3.76% at the base,

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5.06% at the middle and 4.14% at the top. There was an inconsistent variation in the tangential shrinkage from base to top as it decreased from base to middle and then increased to the top. However, the tangential shrinkage of individual trees have mean values ranging from 3.78% to 4.63% (Table 2).

Table 2: Mean values of Tangential shrinkage of *T. catappa*

	Top	**Middle**	**Base**	**Mean**
T1	2.61±0.54[a]	5.33±1.96[a]	3.40±0.63[a]	**3.78±0.73**
T2	4.04±1.21[a]	5.98±1.41[a]	3.87±1.11[a]	**4.63±0.72**
T3	5.77±1.41[a]	3.88±0.83[a]	4.01±0.95[a]	**4.55±0.63**
Mean	**4.14±0.69**	**5.06±0.82**	**3.76±0.50**	**4.32±0.39**

Mean with the same alphabets in the column (Sampling height) and row (Individual tree) are not significantly different (P>0.05) from one another.

Longitudinal shrinkage of *T. catappa*

The longitudinal shrinkage of *T. catappa* wood shows that the mean longitudinal shrinkage ranged from 0.37% to 0.49%: 0.48% at the base, 0.41% at the middle and 0.44% at the top. This indicates an inconsistent variation as it decreased from base to middle and then increased a little towards the top (Table 3). There was no significant difference (P>0.05) between longitudinal shrinkage of individual trees and sampling height of wood sampled.

Table 3: Mean values of longitudinal shrinkage of *Terminalia catappa*

		Sampling height		
Top	**Middle**	**Base**	**Mean**	
T1	0.38±0.15[a]	0.33±0.08[a]	0.40±0.16[a]	**0.37±0.07**
T2	0.44±0.08[a]	0.64±0.20[a]	0.39±0.15[a]	**0.49±0.09**
T3	0.50±0.18[a]	0.26±0.10[a]	0.66±0.19[a]	**0.47±0.10**
Mean	**0.44±0.08**	**0.41±0.09**	**0.48±0.10**	**0.44±0.04**

Mean with the same alphabets in the column (Sampling height) and row (Individual tree) are not significantly different from one another (P>0.05).

Volumetric shrinkage of *Terminalia catappa*

The result showed that no difference (P>0.05) in volumetric shrinkage but ranged from 5.38% to 7.37% and had mean volumetric shrinkage is 5.83%,5.52% at base, 6.45% at middle and 5.51% at top decreased from base to top along the axial axis (Table 4).

Table 4: Mean values of volumetric shrinkage of *Terminalia catappa*

	Top	Middle	Base	Mean
T1	3.36±0.57[a]	7.57±2.69[a]	5.22±1.06[a]	**5.38±1.02**
T2	6.18±1.84[a]	7.09±1.48[a]	6.09±2.11[a]	**6.45±1.00**
T3	6.98±1.44[a]	4.70±0.87[a]	5.26±1.04[a]	**5.65±0.66**
Mean	**5.51±0.85**	**6.45±1.04**	**5.52±0.81**	**5.83±0.51**

Mean with the same alphabets in the column (Sampling height) and row (Individual tree) are not significantly different (P>0.05).

DISCUSSION

Radial Shrinkage of *T. catappa*

The increasing trend for radial shrinkage from base to top is in consonance with the report of Effah (2012) who observed similar trend in *Cola nitida* wood. According to the classification of Bolza and Keating (1972), TEDB (1994) and Upton and Attah (2003), the total radial shrinkage values obtained indicated that shrinkage is small in *T. catappa.* Ogunsanwo and Ojo (2011), observed 3.66% for *Borassus species.*

The value obtained from this study is lower compared to reports of Ofori and Brentuo (2010), Sadegh *et al*., (2011), and Effah (2012) on other lesser known species. The observed values were lower than that reported by Poku, *et al*, (2001) for other lesser known species mean value of 2.51% for *Alstonia boonei*, 4.01% for *Petersantthus macrocarpus* and 2.23% for *Ricinodendron hendelotti.*

According to Oriowo *et al*., (2015) who carried out an investigation on *T. catappa* timber, the mechanical properties such as density, compression, modulus of rupture, impact bending strength and modulus of elasticity where evaluated in accordance with the British standard (D373) the result proves that *T. catappa* is a strong wood that is suitable for building and construction purposes.

Tangential shrinkage of *T. catappa*

There was an inconsistent variation in the tangential shrinkage from base to top as it decreased from base to middle and then increased to the top

According to the classification of Bolza and Keating (1972), TEDB (1994) and Upton and Attah (2003), the mean total tangential shrinkage values obtained indicate that shrinkage is small for *Terminalia catappa.* The low tangential shrinkage values show potential for exterior joinery (Ofori and Brentuo, 2005).

The trend of variation observed in this study is similar to that of Poku, *et al*, (2001). They observed that the values decreased from the base to the middle and increased slightly to the top in *Peterslanthus macrocarpus* and *Ricinodendron* *heudelotti* from Ghana. Herritesch (2007) also observed a higher tangential shrinkage at the breast height and lower value at the top.

The value obtained from this study is low compared to reports of Ofori and Brentuo (2010) Sadegh *et al*., (2011) and Effah (2012) on other lesser known species. Chudnoff, (1976), recorded a mean value of 7.0% for *Aningeria robusta*, Ajala, (2005), recorded 1.35% for the same species, Ofori and Brentuo (2005) recorded 4.48% for *Cedrela odorata* while Poku, *et al*, (2001), recorded mean values of 4.4%, 6.8% and 4.0% for *Alstonia boonei*, *Petersianthus macrocarpus* and *Ricinodendrron heudelotti* respectively being lesser-used hardwood species from Ghana.

Longitudinal shrinkage of *T. catappa*

The value obtained from this study is higher than the reports of Ofori and Brentuo (2005), and Effah (2012) on other lesser known species and lower than the report of Sadegh *et al.,* (2011).

Typically, total longitudinal shrinkage is only 0.1-0.2% for most species and rarely exceeds 0.4% (Wengert, 2006). The shrinkage longitudinally is so small and it is mostly ignored. The value obtained for *Terminalia catappa* was a little greater than the maximum accepted range.

Volumetric shrinkage of *T, catappa*

The value obtained from this study is low compared to reports of Ofori and Brentuo (2010), Sadegh *et al* (2011) and Effah (2012) on other lesser known species. Poku, *et al*, (2001), recorded 7.51%, 11.51% and 6.21% for *A. boonei. P. macrocarpus* and *R. hendelotti* respectively. The wide disparity could have been attributed to the nature of the wood of trees and probably presence of more biomass in latewood cells as noted by Chudnoff, (1976).

Conclusion

The mean tangential shrinkage of *T. catappa* is 4.32% indicating that the shrinkage is small. Mean radial shrinkage has 1.51% indicating that the radial shrinkage to be small, longitudinal shrinkage has a value of 0.44% which is a little higher than the preferred range while the volumetric shrinkage is 5.83%. These results suggests that the timber of *T. catappa* shrinks less. The low shrinkage values of *T. catappa* show potential for exterior joinery.

Based on the research findings, the species show potentials stability in radial but negligible inconsistence in tangential and longitudinal shrinkage which implies slight uniformity in respect to direction and utilization reliability. Further studies on the chemical components, anatomical features and mechanical properties of this species is necessary for revealing its potential for other uses of interest. The wood may be suitable for joinery and high pressured services.

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Appendice

Table 2: AVOVA table for radial shrinkage of *Terminalia catappa*

	DF	Sum of Square	Mean Square	F	*p-value*
Tree	2	4.2070	2.1035	1.34870	0.272380
Sampling height	2	1.5194	0.7597	0.48709	0.618405
Tree*Sampling Height	4	8.7100	2.1775	1.39615	0.254886
Error	36	56.1476	1.5597		
Total	44	70.5840			

Table 4: AVOVA table for tangential shrinkage of *Terminalia catappa*

DF Sum of Mean		**F Square**	**P Square**		
Tree	2	6.6167	3.3083	0.4641	0.632395
Sampling Height	2	13.5164	6.7582	0.9481	0.396935
Tree*Sampling Height	4	31.0104	7.7526	1.0876	0.377248
Error	36	256.6121	7.1281		
Total	44	307.7556			

Table 6: AVOVA table for longitudinal shrinkage of *Terminalia catappa*

DF Sum of Mean		**F Square**	**p Square**		
Tree	2	0.137173	0.068587	0.59597	0.556374
Sampling Height	2	0.038093	0.019047	0.16550	0.848110
Tree*Sampling Height	4	0.557093	0.139273	1.21018	0.323437
Error	36	4.143040	0.115084		
Total	44	4.875400			

Table 8: AVOVA table for volumetric shrinkage of *Terminalia catappa*

	Df	Sum of Square	Mean Square	F	p
Tree	2	9.320	4.660	0.3698	0.693434
Sampling Height	2	8.844	4.422	0.3510	0.706373
Tree*Sampling Height	4	52.753	13.188	1.0468	0.396821
Error	36	453.570	12.599		
Total	44	524.487			