RELIABILITY OF ANNUAL GROWTH RINGS IN AGE DETERMINATION OF ROSEWOOD (*PTEROCARPUS ERINACEUS*) FROM BALI LOCAL GOVERNMENT AREA OF TARABA STATE, NIGERIA

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ABSTRACT

A study was undertaken to determine if Rosewood (Pterocarpus erinaceus) produce distinct growth rings and to determine the reliability of the annual growth rings in tree age determination and finally the relationship between the number of growth rings and age of the tree and stem diameter. Thirty-two (32) stem sections were used for the study; sixteen (16) each from Medium (M) and Large (L) sample trees. Macroscopic and Microscopic investigation of annual growth rings in stem sections shows that growth rings were visible and growth ring boundaries were reasonably distinct in all the selected sample stems. The result showed a significant difference between girth, DBH and age (0.00) (P > 0.05). The pattern of ring development provides a basis for the use of ring counts in determining the age of P. erinaceus. The results can therefore be used in forest management studies in the woodlands of Bali local government area of Taraba State, Nigeria as tree-ring analysis gives information on the real age of a tree and the lifetime growth rates. However, the phenomenon of missing growth rings suggests that the influence of environment in the use of growth rings in age determination needs to be considered in areas that experience droughts.

Keywords: *Pterocarpus erinaceus, Growth rings, Reliability, DBH and Bali L. G.*

INTRODUCTION

The occurrence of annual growth rings in the tropics has been denied for a long time until it has become clear that annual rings are formed when tropical trees experience cambial dormancy in one period of the year due to unfavorable environmental conditions. Such a period can be the dry season in areas with distinct seasonality and flooding periods in floodplain forests (Schöngart *et al.*, 2002) and fluctuations in salinity in mangrove forests due to seasonality in precipitation and temperature (Chowdhury *et al.*, 2008). As seasonally dry forests, floodplain forests, and mangroves cover large part of the total tropical forest areas; there is a large potential for the application of tree-ring analysis in the tropics.

Even in evergreen forests, successful tree-ring studies have been conducted in areas where a short- dry period triggers annual ring formation (Dünisch *et al.*, 2003; Fichtler *et al.*, 2003).

Tree-ring analysis has a lot of advantages for forest management studies (Brienen, 2005). First, tree-ring analysis gives information on the real age of a tree and the lifetime growth rates and is therefore more effective in tree age determination. It can be used to reconstruct past disturbance (Brienen *et al.*, 2007), such as fire history from fire scars (Welsberg and Swanson, 2001; Guyette and Stambaught, 2004; Van Horne and Fule, 2006; Hall, 2008). Another advantage of the ring analysis is the possibility it offers to quantify variation in growth among individuals over long periods of time (Desta *et al.*, 2003).

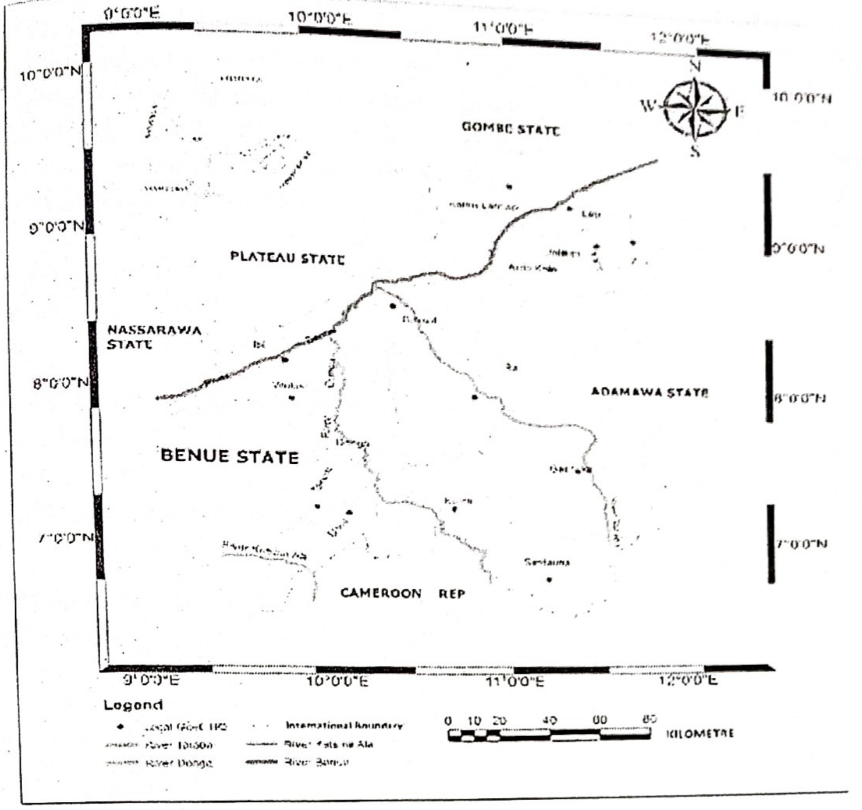

Figure 1: Nigeria Showing Taraba

The identification of annual growth rings in *Pterocarpus angolensis* from western Zimbabwe by Stephen *et al.* (2010) has important implications for the forest ecology and management of this valuable timber species, and for the reconstruction of past climate and stream-flow. The study shows that annual growth rings provide a solid basis for age determination of *P. angolensis* growing under different ecological conditions, or under different management prescriptions. Studies carried out by Stephen *et al.* (2010) on Miombo woodland species in charcoal and, slash and burn regrowth stands in Zambia showed that growth ring boundaries were reasonably distinct in all three species from both the charcoal and slash and burn regrowth stands. The number of growth rings showed a strong positive linear relationship with stand age in both slash and burn. All the three selected species for the study showed that the number of growth rings can be used as a good estimate of stand age in both charcoal and slash and burn regrowth stands.

Similarly, study carried out by Laurence *et al.* (2012) showed that tree-ring counting in large trees was usually straightforward and ring boundaries were easy to distinguish. This was not the case for small trees, in which very narrow and compact rings (<0.2 mm) were found, often reduced to one single row of vessels with intermitting tracheid, fibers and parenchyma cells.

Esther and Deborah (2003) also demonstrated the existence of reliable annual growth rings in five ecologically diverse tree species, and used the rings to estimate the age and long-term mean growth rates of trees from these species. For three additional species, they demonstrated the existence of recognizable growth zones in the wood. All investigated

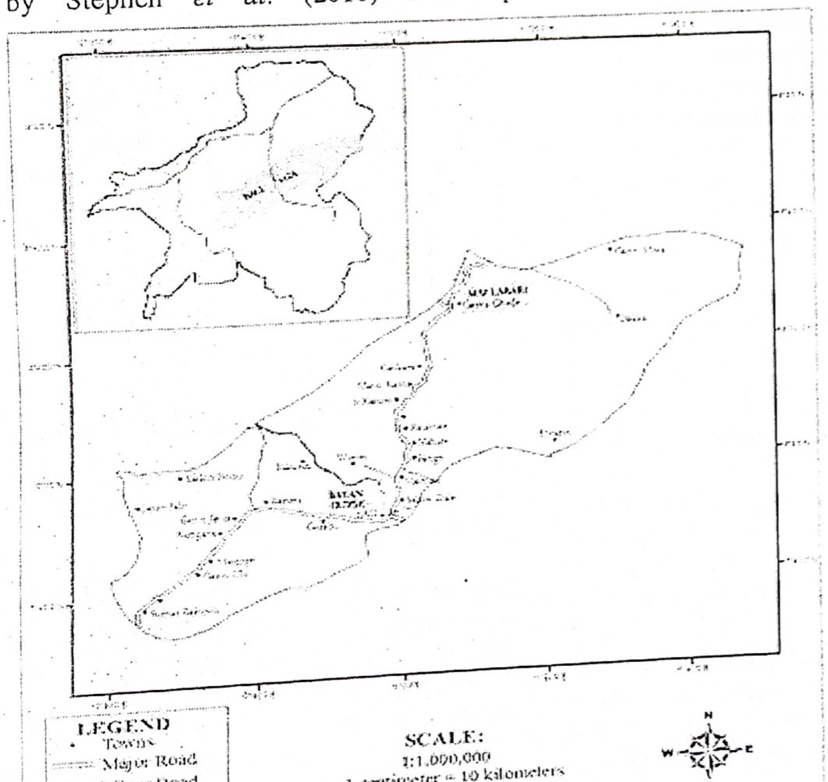

Figure 2: Bali L.G. showing study sites

species formed visible rings that varied considerably in distinctiveness. *Balizia elegans, Dipteryx panamensis, Pentaclethra macroloba,* and the two subcanopy species, *Guatteria aeruginosa*. and *Protium pittieri,* all showed distinct rings. All the three deciduous species showed distinct rings. The distinctiveness of the growth rings varied among the evergreen species and were therefore suitable for tree ring analysis.

The aim of this study was to determine if Rosewood (*Pterocarpus erinaceus*) produce distinct growth rings and to determine the reliability of the annual growth rings in tree age determination and the relationship between the number of growth rings and age of the tree and stem diameter.

MATERIALS AND METHODS

Description of the Study Area

Two study sites were sampled, namely Mai-Labari and Bayan-Dutse all in Bali local government area of Taraba State, Nigeria (Figures 1 and 2). Mai-Labari is located between latitude 08° 21 '22.4" N and longitude 011° 11'28.2" E. While Bayan-Dutse is located between latitude 07° 46 '27.3" N and longitude 010° 58'05.2" E behind Bali Mountain. Bali local government area of Taraba State falls within the Guinea Savanna Agro-ecological zones characterized by heavy wooded vegetation along major water course (Emeka and Abbas, 2011). Common forest species include: *Pterocarpus erinaceus, Khaya senegalensis, Parkia clappertoniana, Butyrospermum paradoxium.* The most important human occupation in the area includes fishing, crop farming, livestock rearing, petty trading and civil servants. All the sites are natural forests which are under pressure due to human activities especially overexploitation of *P. erinaceus.*

Preparation of Sample Plots and Data Collection

Four (4) Plots made up of two (2) each from Mai-Labari and Bayan-Dutse were mapped out measuring 100m x 100m each. In each of the plots, four (4) sub-plots of 25 m x 25m (0.0625 ha) (Figure 3), were located using Geographic Positioning System (GPS). Data from *P. erinaceus* population in the study areas were collected by means of forest inventories where *P. erinaceus* stands in the 16 sub-plots were counted and classified into Basal Area (B_A) classes ranging as: 20 – 40cm (7.87 ¬ 15.75 inches) and 50 – 70cm (19.69 - 27.56 inches) labelled as Medium (M) and Large (L) respectively (Nicholas and Jill, 2000). The two Basal areas classes; Medium (M) and Large (L) were established in each plot and four (4) stem discs each were removed from each sub-plot, by so doing a total of 32 stem discs were collected in the study areas. All the girths (g) values were converted to diameter, while the diameter (D) was used to calculate the Basal area (B_A) using the relationship;

$$D = g/\pi \quad \text{.......................................} \quad (i)$$

$$B_A = \pi D^2/4 \quad \text{.......................................} \quad (ii)$$

Where; g = girth (cm), D = Diameter (M), and

B_A = Basal Area (M^2)

π = Mathematical Constant, P_i = 3.142 (Nicholas and Jill, 2000).

Within each plot, the stem with Medium (M) and Large (L) diameter of *Pterocarpus erinaceus* were selected for the study (Plate I).

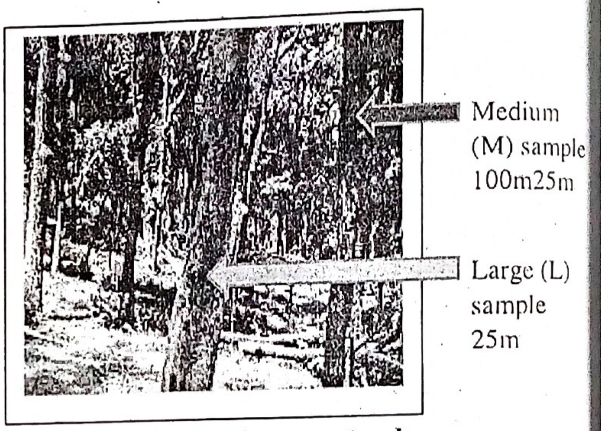

Plate I. Sample *P. erinaceus* stands

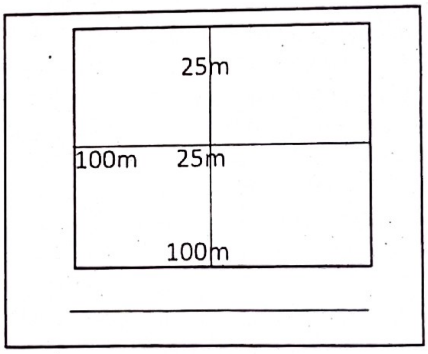

Figure 3. Sample plots

The assumption is that, the Medium and Large *Pterocarpus erinaceus* in each plot is matured enough and therefore were more reliable in determining the relationship between age and number of rings. The stem discs collected were trimmed and smoothened out to clearly show the growth rings for analysis.

Growth Ring Identification and Marking

Stem discs were air-dried and transverse sections were sanded with sandpaper (100 – 1200 grits). Samples were investigated macroscopically, as well as microscopically to investigate which wood anatomical features are responsible for the visible coloured layers and to identify possible growth ring boundaries using the conventional methods in Jansen *et al.* (1998). Marking process for growth-ring boundaries was done in four radii as in Buruh *et al.* (2016), and rings were counted and cross-checked along the four radii. Number of ring boundaries were cross-checked for their consistency along the four radii. By doing this the possibility of missing a ring boundary due to its indistinctiveness or marking a false ring boundary was minimized.

Data Analysis

Pearson Product Moment Correlation Coefficient and Paired Samples T-test were used to analyze annual growth rings and age relationship and diameter respectively using SPSS software package version 6.0 (StaSoft, inc. 2003).

RESULTS

Growth Rings in sampled *Pterocarpus erinaceus*

0Macroscopic investigation of the sanded stem discs revealed a clear alternation of dark and light brown growth layers as shown in (Plate II A). The lighter colour results from the higher number of vessels which is further enhanced by polishing sanded stem discs (Plate II B). Under a low magnification (x10 objectives), these coloured layers were found as a reflection of changing vessels density, with light layers exhibiting a higher vessel density than the dark layer as shown in (Plate II C). Under high magnification (x40 objectives), the polished stem discs' revealed no distinct boundary, but rather a gradual transition in the vessel density between the light and dark layer as shown in (Plate II D).

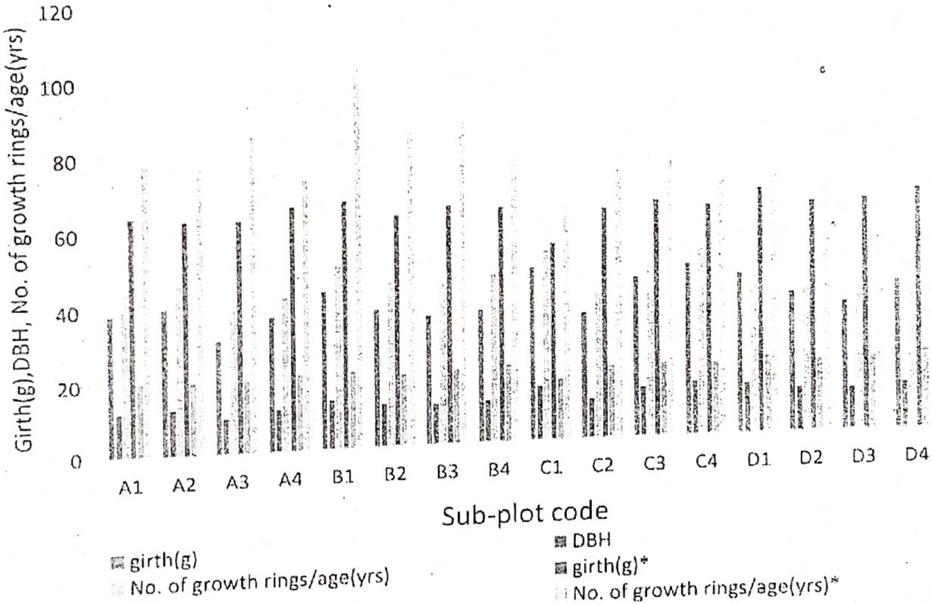

Figure 4. Girth, DBH, No. of growth rings/age of Medium(M) and Large(L) sample of*Pterocarpus erinaceus*

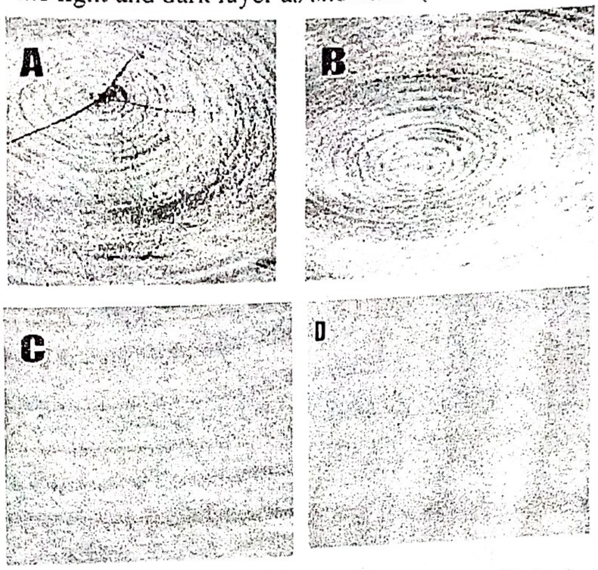

Plate II. (A) Macroscopically unpolished *Pterocarpus erinaceus* stem disc showing a clear alternation of dark and light layers. (B) Macroscopically polished *P. erinaceus*stem disc. (C) Magnified *P. erinaceus* stem disc revealing the changing vessel density. (D) Microscopic stem disc slide revealing no distinct boundary between light and dark layers.

Key: girth(g), DBH and No. of growth rings/age(yrs) for Medium sample, girth(g)*, DBH*, No. of growth rings/age(yrs)* for Large sample

Medium sampled *P. erinaceus* in plot C_1 had the highest number of growth rings/age with 52, girth and DBH of 47.6 and 15.2 inches respectively, followed by plot C_4 with 51, girth and DBH of 47.2 and 15.0 inches. While plots A_3 and D_3 had the lowest number of growth rings/age with 39 each, girth and DBH of 31.1,35.8 inches and 9.9, 11,8 inches respectively.

Large sampled *P. erinaceus* in plot B_1 had the highest number of growth rings/age with 103, girth, DBH of 67.3 and 21.4 inches, followed by sampled *P. erinaceus* in plot B_3 with 88 growth rings/age, girth and DBH of 64.9 and 20.7 inches respectively, while sampled *P. erinaceus* in plot C_1 had the lowest number of growth rings/age with 61, girth and DBH of 53.8 and 17.1 inches respectively.

Tables 1: Pearson Product Moment Correlation Analysis Between Treatments of *P. erinaceus*

Variables	N	Girth(M)	DBH(M)	No. of growth rings/age (M)	Girth(L)	DBH(L)	No. of growth rings/age(L)
Girth	4	-	0.000	0.048	0.235	0.236	0.137
DBH(M)	4	0.000	-	0.048	0.234	0.235	0.135
No. of growth rings/age (M)	4	0.048	0.048	-	0.202	0.203	0.269
Girth(L)	4	0.235	0.234	0.202	-	0.010	0.160
DBH(L)	4	0.236	0.235	0.203	0.000	-	0.162
No. of growth rings/age (L)	4	0.137	0.135	0.269	0.160	0.162	-

M = Medium samples, L = Large samples, N = No. of plots

From Table 1, the correlation analysis between girth of the tree against age revealed that there is no strong significant difference (r^2 =0.234, 0.235,0.236) and for the samples calculated for all individuals in the plots, there were no significant correlation between the girth and DBH, number of growth rings/age.

From Table 2, the result revealed that the differences between the girth and DBH is highly significant (0.001) at ($P<0.05$) with mean difference 29.66, while the girth and number of growth rings/age shows significant different with mean difference at -13.58.

Table 2: T - test Analysis for four (4) different parts of Stem of *P. erinaceus* in Medium and Large samples.

Treatment	Mean	Std. Deviation	Std. error mean	T-test	Significant
Girth(M) & DBH(M)	29.7	3.9	1.9	14.9	0.001
No. of growth rings/age(M) & Girth(L)	-13.6	9.1	4.5	-3.0	0.058
DBH(L) & No. growth rings/age(L)	-50.6	5.4	2.7	-18.7	0.000
No. of growth rings/age(L) & DBH(L)	50.6	5.4	2.7	18.7	0.000

M = Medium samples, L = Large samples

DISCUSSION

Annual growth rings and age of sampled *Pterocarpus erinaceus*

Pterocarpus erinaceus species studied formed visible rings that varied in distinctiveness which represents annual growth rings. This is in line with the identified annual growth rings in *Pterocarpus angolensis* from western Zimbabwe. This makes annual growth rings reliable in tree age determination of *Pterocarpus erinaceus*. This is also in line with the findings of Esther and Deborah (2002) who demonstrated the existence of reliable annual growth rings in five ecologically diverse tree species and used the rings to estimate the age and long-term mean growth rates of trees from these species.

Tree-ring counting in medium and large sampled trees was straight foward and ring boundaries were easy to distinguish.. Studies carried out by Stephen *et al.* (2010) on Miombo woodland species in Zambia also reported that growth ring boundaries were reasonably distinct in all three species studied.The presence of annual growth rings observed in the stem discs of *P. erinaceus* was in accordance with the presence of annual growth rings observed in *Boswellia papyrifera* by (Worbes *et al.*, 2003; Verheyden *et al.*, 2004; Schöngart *et al.*, 2006) as reported by Buruh *et al.* (2016). This is evident that tree ring analysis can be reliably used to study growth rates and age determination in *P. erinaceus*, since *B. papyrifera* and *P. erinaceus* are tropical deciduous species and both exhibits annual growth rings.

For example, in Figure 4, plotsA - A_4, the number of growth rings in sampled trees is equal to the number of years; In plot A_1, the number of growth rings is 44 aged 44 years; Similarly, in plots A_2, A_3 and A_4, the number of growth rings were 46, 39 and 42 respectively, which is the same with the ages 46 years 39 years and 42 years respectively. This indicates how reliable annual growth rings of trees is in age determination. The results from Figure 1 showed that the number of growth rings is equal to the number of years in all the sampled *P. erinaceus*.

Correlation between variables

Correlation analysis between girth and age revealed that there is no strong significant difference ($r^2 = 0.234, 0.235, 0.236$) and for the samples calculated for all individuals in the plot, there were also significant correlation between the girth and DBH. The result showed a significant correlation between age and girth, and age of tree and diameter at breast height (Table 1). Ming-Hsun *et al.* (2011) said significant relationship between the age distributions may be implied that all the sampled trees have similar ecological view point.

The positive correlation between the age and girth and DBH means that as the age of the tree increases, the girth and the DBH also increases.

Paired sampleT-test Analysis

The result revealed that the differences between the girth and the diameter at breast height is highly significant (0.001) at ($P < 0.05$) with mean difference of 29.7, while the girth and number of growth rings and age shows significant different with mean difference at -13.6 (Table 2).

The age of the tree at the time of investigation varies considerably between and within the Medium and Large samples of the study. The negation is as a result of the sample reaching its ultimate mature state at different levels in a mature forest (Ming-Hsun *et al.*, 2011).

Although there is significant difference between the age and girth and DBH of the sampled trees, age - size relations should be use cautiously as diameter may not reflect the true age of the sampled trees.

CONCLUSION

Tree-ring analysis is a potential tool to provide reliable information about growth rate and age for trees that forms annual growth rings. The existence of dark and light concentric layers with clear ring boundary which represent annual growth rings in *Pterocarpus erinaceus* is an indication that tree ring analysis provides a direct method for age determination and it is likely to be the most accurate method for tree age. The significant positive correlation between age and girth and age and DBH is an additional instrument to the determination of the age of *P. erinaceus*.

Recommedation

In future, the use of tree ring analysis as a tool to understand growth dynamics and age structure of *Pterocarpus erinaceus* and other tree species and their response to climate variability should be strengthen in Taraba State, Nigeria.

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