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E-mail:jfewr@yahoo.com

ISBN: 2141 – 1778

Oyelere et al., 2019

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RADIAL AND AXIAL VARIATION IN RING WIDTH OF CARIBBEAN PINE (*Pinus caribaea* MORELET) IN AFAKA PLANTATION, KADUNA STATE, NIGERIA

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ABSTRACT

*This paper examines the within tree variation (radial and axial) in Ring Width of Caribbean Pine (*Pinus caribaea* Morelet) Plantation Grown in Afaka plantation, Kaduna State, Nigeria. Samples of wood used in this study were obtained from different age series of *P. caribaea*. Fifteen trees were randomly harvested with their total tree height and diameter at breast height (DBH) measured. Discs of 5 cm in thickness were obtained at breast height. Additional bolts of 20 cm for pulping materials were obtained at the base, middle and top of trees sampled among the age series. Each disc was cut at the pith, smoothed and the numbers of rings were counted. Each disc was then divided into sections based on the ring numbers and the ring width were measured and recorded. The result showed that there was radial variation in the ring widths where the rings closest to the pith had the highest mean value of 8.4580 ± 0.24608 mm, 8.3920 ± 0.32679 mm, 6.5560 ± 0.14006 mm at Diameter at Breast Height (DBH), 25% Total Height of Tree (THT) and 50% THT, respectively while the ring width decreases from pith to bark with rings closest to the bark having a mean value of 1.0580 ± 0.10514 mm, 1.0100 ± 0.09187 mm, 1.1940 ± 0.13743 mm at DBH, 25% THT and 50% THT respectively which are significantly different ($p < 0.05$). Axially, there is no variation in the ring width of the growth rings ($p > 0.05$).*

Keywords: Silviculture, dendrochronology, growth rate, wood property, wood quality

INTRODUCTION

Variability in wood makes it exhibit certain behaviours that are not favourable for different end uses which affect the quality of the product (Ishiguri *et al.*, 2007; Sharma *et al.*, 2013). Wood is quite variable and a significant portion of variation can be attributed to genetic factor and growing conditions i.e. wood produced by trees of the same species are not identical even when grown under the same or similar conditions (Bown, 2016). Variation in wood characteristics within the individual tree is basically related to changes resulting from ageing of the cambium and modifications imposed on the cambial activity by the environmental conditions, genetical and silvicultural effect (Walter and Menzies, 2010). Uniformity in wood is highly desired as it means the same will display a similar character.

Anatomical properties such as tracheid length and growth characteristics such as growth ring width are one of the most essential tools for understanding tree growth and its reaction to varying climatic settings (Tian *et al.*, 2009). They form the basis for wood anatomy which includes dendroclimatology, dendrochronology, and dendroecology (Sousa *et al.*, 2012). They are valuable instruments in forest management as well as in product manufacturing as they are closely connected with tree growth rate and wood properties (Oluwadare, 2007). This is an indication that information on radial variation pattern of ring width and tracheid length can facilitate tree growth and wood quality in forest management and wood utilization (Anoop *et al.*, 2014; Saravanan *et al.*, 2013). Reports from

different research have shown that radial variation in anatomical properties and growth characteristics are caused by both specific environmental factors, forest management practices and within controlled genetic factors (Mmolotsi *et al.*, 2013)

Growth rate, as measured by the width of annual rings, is considered to influence wood density. The width of the growth ring indicates the rate of growth of the tree. When there is fast growth, wider growth rings will be produced than when there is slow growth. The effect of growth ring will indicate in the density of wood (Osadare, 2001). For the growth rate-wood density relationship, different responses among the major tree groups (softwoods, ring-porous hardwoods, diffuse-porous hardwoods) have been recognized (Adamopoulos *et al.*, 2010). Most studies indicate that high wood density in ring-porous hardwoods is associated with fast growth (Shinya and Zhang, 2002). According to Kretschmann and Cramer (2007), the width of earlywood remains fairly constant from year to year while the dense latewood with fewer vessels increases as ring width increases. However, there are some exceptions to this generalization. The first rings near the pith (juvenile wood) do not necessarily follow the above pattern and the proportion of different types of cells might also have a substantial influence on wood density. Ring width was not found to be an accurate indicator of wood density in a number of ring-porous species such as *Quercus falcata*, *Q. nigra*, *Q. stellata*, *Q. suber*, *Carya ovata*, *C. tomentosa* and *C. illinoensis* (Shinya and Zhang, 2002). There were several reports that (annual) ring density decreases with increasing ring width, for instance in Norway spruce (Bouriaud *et al.*, 2015). Wood density was also proved to vary between trees (Guilley *et al.*, 2004). The importance of basic density as a sole trait that is often measured in wood cannot be over-emphasized. It is a trait that gives an indication of the relative value of other wood properties such as strength properties, calorific value and pulp properties (Gomez *et al.*, 2010). Ring width has

however been acknowledged as a highly variable characteristic, and several major sources of annual density variations (Morling, 2002).

Phenotypic plasticity plays an important role in plant fitness and is especially important in long-lived trees (Chuine and Beaubien, 2010). All pine species grown in Nigeria are grown to provide long fibre pulp to produce pulp and paper as it has been used internationally for this purpose (Oluwadare, 2007). However, due to lack of the non-functional paper mills in Nigeria, its potential to serve this purpose has been jeopardized. Hence, the established plantations are being exploited for timber and in order to ensure the efficient and sustainable utilization of this species. It is, therefore, necessary to investigate the wood properties in meeting the objective of establishment as well as alternative wood utilization. This paper provides information on the radial and axial variation of the ring width of Caribbean Pine with a view of providing information on the suitability of the species for different end-use requirement.

MATERIALS AND METHODS

Study Area

Samples of wood used in this study were obtained from five age series of *P. caribaea* grown in guinea savanna at Afaka, Kaduna Nigeria. Afaka Forest Reserve is situated some 30km N-W of Kaduna township, along Kaduna – Lagos Express Highway road, and is about 12,243.760 hectares in a real extent (Nwadiolor, 2001). Afaka Forest Reserve was established in 1954 as an experimental plantation site to increase the productivity and arrest the deterioration and desertification of the semi-arid zone of the Northern Guinea Savannah of Nigeria (Nwadiolor, 2001). The Afaka Forest Reserve is situated west of Kaduna on latitude 10°7'N and longitude 7°17'E on 600 m above sea level. Mean annual rainfall is about 1300 mm with daily minimum and maximum temperatures of 18°C and 24°C respectively.

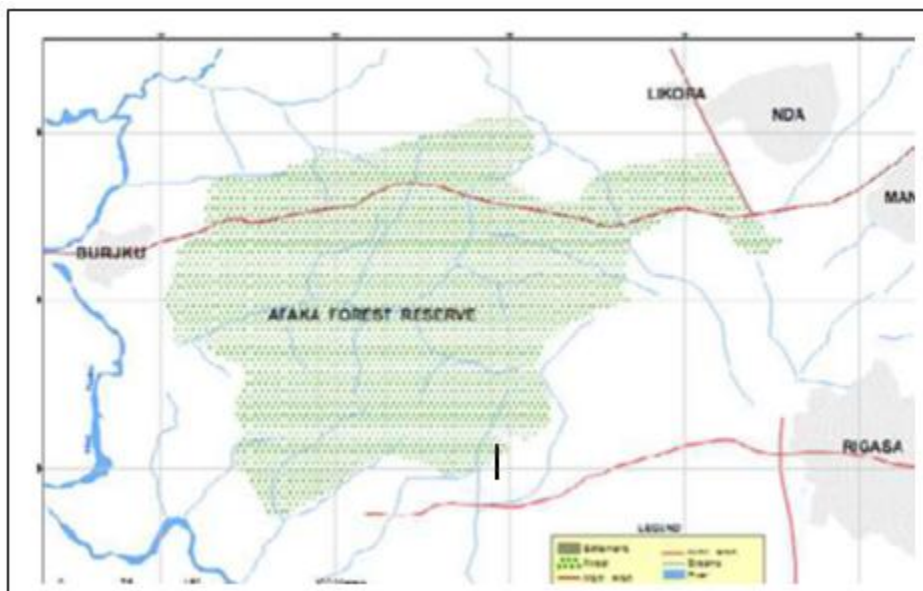


Fig. 1: Map of Afaka Forest Reserve

Source: Department of Geography, NDA Kaduna

Sampling Technique

A reconnaissance survey of the plantation was carried out to know the different age series available. The trees were randomly selected from different age series. Fifteen trees were randomly harvested with their total tree height and diameter at breast height measured. Discs of 5 cm in the thickness were obtained at breast height. Additional bolts of 20 cm for pulping materials were obtained at the base (DBH), middle (25% THT) and top

(50% THT) of trees sampled in the different age series (Fig. 2). The experimental design adopted for the study is a Completely Randomized Design (CRD) and data obtained were subjected to Analysis of Variance at $\alpha_{0.05}$.

The following variables of the sample trees were measured:

- (a) Diameter at breast height over bark (DBH)
- (b) Total tree height (TH)

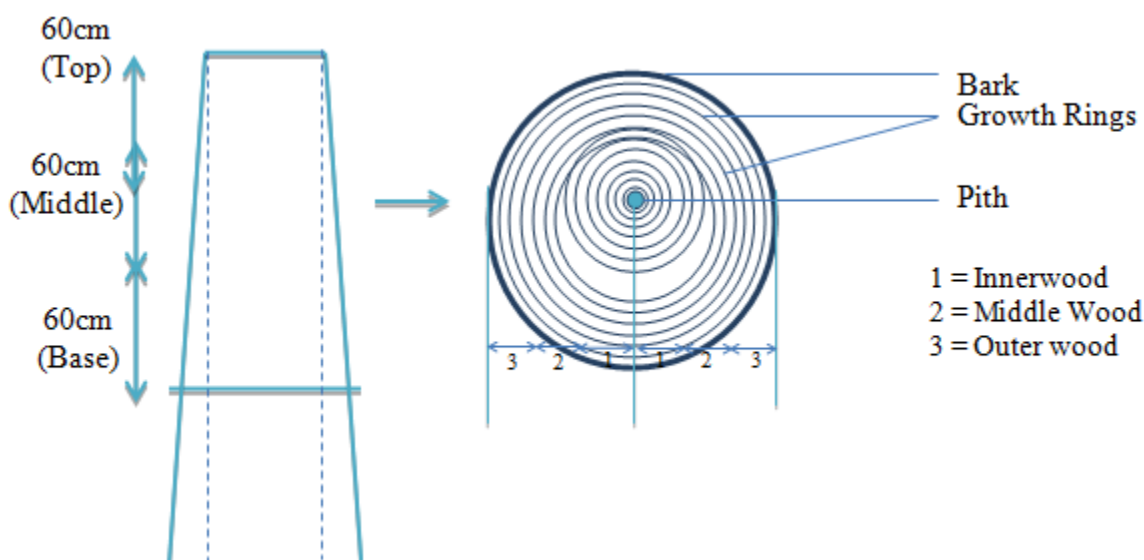


Fig. 2: Schematic Diagram of Sample Collection

From the 2.5cm thick disc, a radial strip of 5cm in width was cut which was later halved. Each of the halves was planned and the annual ring numbered from pith to bark. From the visible bands of

darkened latewood; it was easier to identify the growth rings of the tree. The number of annual growth rings was later determined by counting using a magnifying hand lens.



Plate 1: Transverse Surface of *Pinus caribaea* disc

Ring Width Determination (in millimeter, mm)

The ring width determination was estimated by direct measurement on the transverse surface of each disc from the pith towards the bark using a magnifying hand lens over a calibrated transparent ruler. This involved measuring the distance between the transition zone of the late wood of previous years and the early wood of succeeding year.

Data Analysis

Data collected were analyzed using analysis of variance (ANOVA) by adopting Statistical Package for the Social Sciences (SPSS) version 20.

RESULTS

Radial Variation of Ring Width

The result in Table 1 shows the radial variation of mean ring width of *Pinus caribaea* at various level i.e. DBH (base), 25% (middle) and 50% (top) of total tree height. At DBH, the rings closer to the pith has the highest mean of 8.458 mm and ring 16-20 and 21-26 have the lowest mean of 1.512 mm and 1.058 mm respectively, the trend was also the

same at 25% of total height of tree where the rings closest to the pith i.e. ring 1-6 has the highest mean value of 8.392 mm, followed by ring 7-12 having a mean value of 2.864 mm and ring 13-18 has a mean value of 1.4 mm while the farthest ring class from the pith i.e. closest rings to the bark has the lowest mean ring width of 1.01 mm which is not significantly different from ring 13-18 but is different from ring 1-6 and 7-12. At 50% of the total height of the tree, the result also follows the same trend where ring 1-6 has the highest mean value of 6.556 mm, ring 7-12 has a mean value of 2.26 mm while ring 13-18 which is the closest to the bark has a mean value of 1.194 mm.

The result also indicates that there is a significant difference in the mean of the ring width among different ring number classes at various levels. At DBH, the ring widths are significantly different ($p < 0.05$) from one another along the ring numbers moreover ring 16-20 and 21-26 are not significantly different ($p > 0.05$) from each other. At 25% total height of the tree, it follows the same trend as DBH level, the ring widths are significantly different

($p < 0.05$) from one another along the ring numbers moreover ring 13-18 and 19-22 are not significantly different ($p < 0.05$) from each other. At 50% total

height of the tree, the ring widths are significantly different from one another at 1% and 5% level of significance.

Table 1: Descriptive and ANOVA on mean radial variation in Ring width (mm) of *Pinus caribaea* (Afaka) at various levels

Position	Ring Number (Pith – Bark)	Minimum Ring Width	Maximum Ring Width	Mean \pm SE	Sig.
DBH	1-5	7.79	9.23	8.4580 \pm 0.24608 ^a	0.000**
	6-10	4.41	5.35	5.0120 \pm 0.17471 ^b	
	11-15	1.81	3.39	2.5180 \pm 0.25943 ^c	
	16-20	0.94	1.92	1.5120 \pm 0.16402 ^d	
	21-26	0.80	1.39	1.0580 \pm 0.10514 ^d	
25% THT	1-6	7.36	9.37	8.3920 \pm 0.32679 ^a	0.000**
	7-12	2.34	3.37	2.8640 \pm 0.18057 ^b	
	13-18	0.86	1.78	1.4000 \pm 0.17481 ^c	
	19-22	0.77	1.25	1.0100 \pm 0.09187 ^c	
50% THT	1-6	6.09	6.95	6.5560 \pm 0.14006 ^a	0.000**
	7-12	1.71	3.09	2.2600 \pm 0.24876 ^b	
	13-18	0.83	1.52	1.1940 \pm 0.13743 ^c	

**= significant at 0.01, *=significant at 0.05

Axial variation in ring width

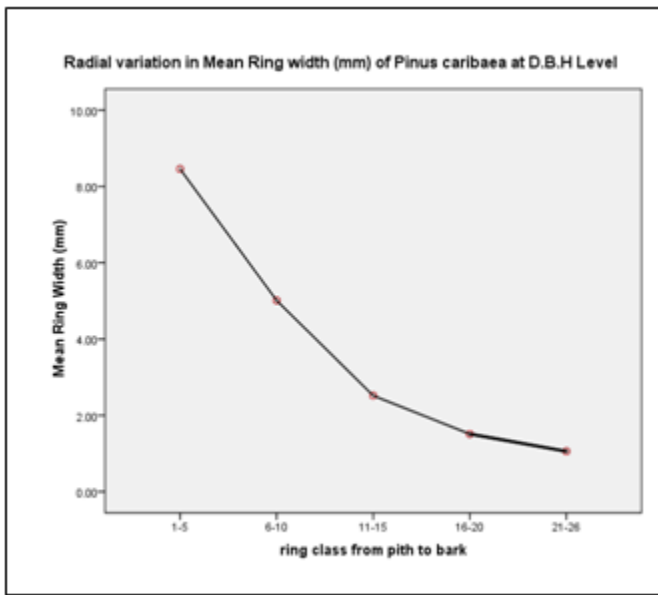
The result in Table 2 shows the axial variation in ring width along different position from top to the base of the tree which display the mean ring width (mm) value of 3.176 mm, 3.146 mm and 3.336 mm for DBH level, 25% of total height of tree and 50% of total height of tree respectively. It also shows that there was no significant difference in the ring width

(mm) from base to top of the tree at 95% significance level (i.e. $p = 0.05$) which implies that there was no variation in the ring width of the plantation grown *P. caribaea* from base to top. The trends of the variation in radial and axial directions are shown in Figure 1 below which supports the claims of the result discussed above.

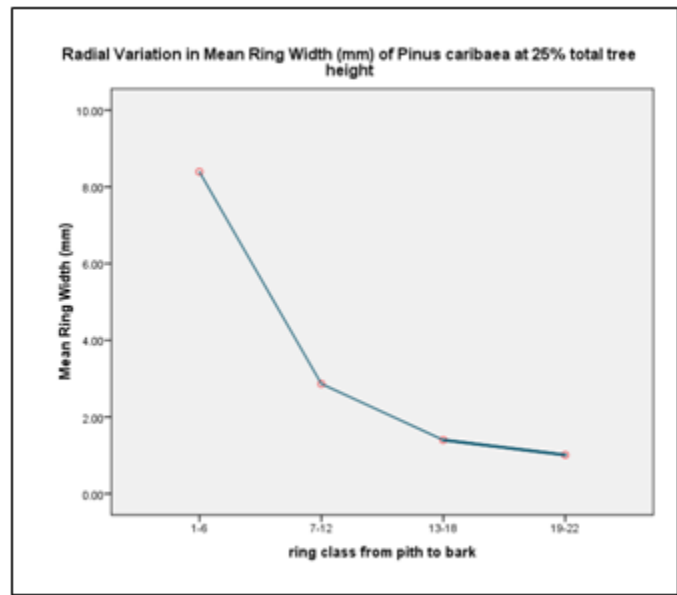
Table 2: Descriptive and ANOVA on mean axial variation in Ring width (mm) of *Pinus caribaea* (Afaka) at various levels

Position	Minimum	Maximum	Mean \pm S.E	Sig.
DBH	3.45	4.03	3.7160 \pm 0.10332 ^a	0.092 ^{ns}
25%	3.12	3.72	3.4160 \pm 0.10884 ^a	
50%	3.02	3.71	3.3360 \pm 0.13626 ^a	

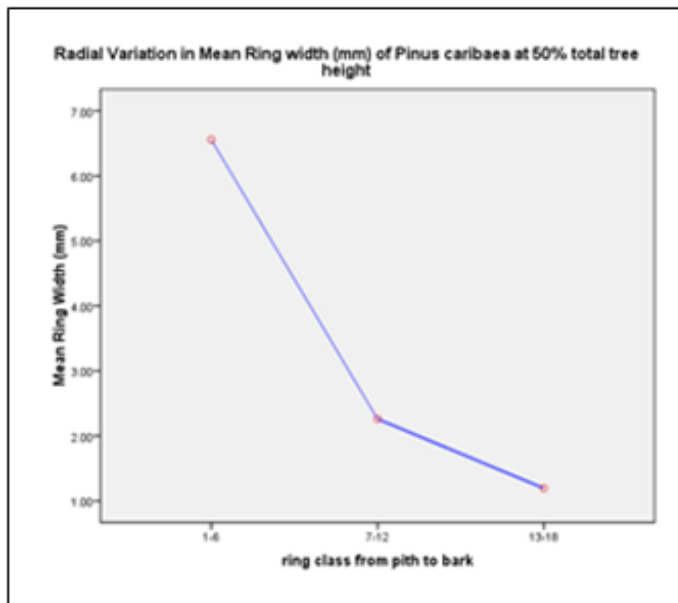
ns = Not Significant



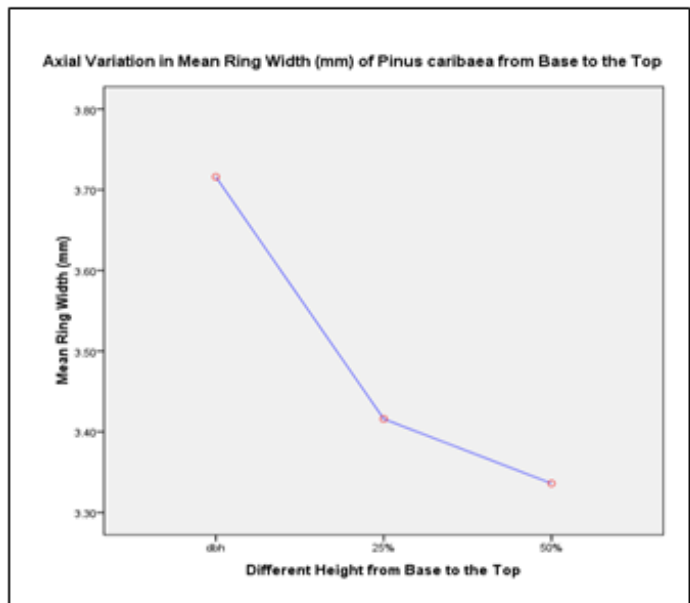
(A)



(B)



(C)



(D)

Figure 3: Trend showing the radial, (A-C), and axial, (D), variation in ring width (mm) of Plantation Grown *Pinus caribaea*

DISCUSSION

Radial Variation of Ring Width

Trees and shrubs grown in temperate climates produce growth rings that reflect the spring onset and autumn cessation of cambial division and cell differentiation. The study shows that there is radial variation in the width of the growth ring at different sampling height along the tree which is

corroborated with study done by Diaz *et al.*, (2007); Mmolotsi *et al.*, (2013) and Pant, (2003) that radial variation exist in temperate tree species which may be caused by a specific environmental factors, forest management practices and within controlled genetic factors or the interaction between or among these factors which in turn influence cambial activity (Osadare, 2001).

Growth rings affect softwood and hardwood quality with the width of the rings and the ratio of earlywood to latewood within each ring both contributing to wood anatomies as well as wood quality (Ishiguri *et al.*, 2007; Saravanan *et al.*, 2013). The narrower the growth ring, the higher the proportion of latewood cells present in each ring. This has the effect of increasing the wood stiffness in the outer region of trunks especially at lower levels in the tree. Variations in the proportion of early to latewood are also a result of species differences and climatic variations. The different properties of early and latewood tracheids and fibres in softwoods and hardwood respectively have significant effects on both wood quality and tree physiology (Bhat *et al.*, 2001; Walter and Menzies, 2010). The variety of cell types present in hardwoods increases the complexity of the cell pattern within the rings.

Many variations in tree rings were due to variation year to year in abundant rainfall which increases growth thus producing a wider ring. Drought decreases growth, producing a narrower ring. Crowding of neighboring trees, this causes a series of narrow rings. Crowding is suspected when the series of narrow ring is more than three (Guo and Chen, 2011).

Growth ring has also been identified as an indication for growth rate which in turn affects the density as well as some other properties that determine the suitability of a species for a particular end use (Osadare, 2001; Adamopoulos *et al.*, 2010; Bouriaud *et al.*, 2015; Evans, 1991). There were several reports that (annual) ring density decreases with increasing ring width, for instance in Norway spruce (Shinya and Zhang, 2002; Lundgren, 2004; Bouriaud *et al.*, 2015). It is very important to establish the difference between juvenile and mature wood when studying the effect of growth rate on basic density. Wide growth rings and low density are associated with juvenile wood close to

the pith and narrow growth rings and high density are typical for mature wood (Mata *et al.*, 2012).

Axial Variation in Ring width

There was no variation in the growth ring width along the height of the tree i.e. from base to top of the tree. This trend may change as a result of formation of reaction wood as well as incidence of defects such as knots which is the point of attachment between the branch and the bole and as such cause deviation of ring width from normal at that particular point where it is found. This result is corroborated by the findings of Yu *et al.* (2014) who reported that there is no variation in the mean ring width along different position on the stem of a tree, however, the variation of the annual ring width greatly differed among different ring ages. In contrary, Udoakpan (2013) reported that there is a strong correlation between the ring width and level of merchantable length without a definite pattern.

CONCLUSION

Based on this study, the following conclusions were made. There was radial variation in the growth ring width of *Pinus caribaea*, while there was no variation in the axial trend of the growth ring width of this species. It was also established that the pattern varies considerably and sometimes contradictorily, even for the same species.

Recommendations

Pinus caribaea has been selected for different end use because of its vigor, stem quality, branch habit and crown characteristics. It is also recommended that the use of more positions should be taken into consideration during determination of ring width so as to avoid the influence of reaction wood; this is because ring width is one of the most essential tools for understanding tree growth and its reaction to varying climatic settings.

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