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Morphometric Analysis of the Fibres in the Trunk of Alstonia boonei

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Abstract
The morphometric analysis of fibres in the trunk of *Alstonia boonei* was carried out in both the axial and radial directions by following standard procedures. Microscopic examinations of the fibres showed medium-sized, thick-walled and aseptate librifom fibres with living protoplasm. The mean lengths (µm), mean diameters (µm), lumen widths (µm) and mean cell wall thickness (µm) of the entire fibres in the trunk of the species were 1025.50 ± 0.24, 27.85 ± 8.13, 19.49 ± 8.26 and 4181.20 ± 2.17 respectively. The data obtained were subjected to statistical analyses such as ANOVA and Duncan Multiple Range Test (D.M.R.T). As a result, the mean fibre lengths and diameters decreased significantly at $P \leq 0.05$ from base to top of the trunk. However, they increased from core-wood to outer-woods but the increment was only significant at ($P \leq 0.05$) in the lengths of fibres along the radial plane of the trunk. In the same vein, the mean cell wall thickness of the fibres along the axial plain of the trunk were 3560.30 ± 1.15, 3896 ± 1.21 and 5086.30 ± 3.19 for the base, middle and top positions respectively. On the other hand, it increased inconsistently from core-wood to outer-wood with the values of 4216.70 ± 1.55, 3762.30 ± 1.34 and 4564.50 ± 3.12 respectively. Statistics showed that the increase was significant ($P \leq 0.05$) along the axial axes but insignificant along the radial axes.Conclusive recommendations of the species as shelterbelts for inhabitants of areas disturbed by wind and windstorms as well as constructions of yam and animal barns for subsistent and commercial agriculturists were made.
Keywords: Morphometric, *Alstonia boonei*, libriform fibres, medium-sized, trunk.

1. Introduction

Alstonia boonei De Wild. is a tall forest tree, which can reach 45 metres (148ft) in height and 3 metres (9.8ft) in girth, the bole being cylindrical and up to 27 metres (89ft) in height with high, narrow, deep-fluted buttresses. The leaves are borne in whorls at the nodes, the leaf is oblanceolate, the the apex rounded to acuminate and the lateral veins prominent and almost at right angles to the midrib. The flowers are yellowish-white and borne in lax terminal cymes. The fruits are pendulous, paired, slender follicles up to 16 centimeters long, containing seeds bearing a tuft of silky, brown floss at either end to allow dispersal by the wind. The latex is white and abundant (Burkhill, 1985).

According to Gill *et. al.* (1983), the need to thoroughly investigate the basic structure of tree plants from the tropics has been stressed by Metcalfe (1972). To the author's knowledge, this demand has not received the much expected attention. In the recent time, many researchers are primarily concerned with the phytochemical and medicinal values of tropical plants with little interest in the study of the structure of the cells and tissues that serve as the framework for the biochemical and medicinal properties of plants. Consequently, information on the internal structures of the trunk of tree plants in the tropics is scanty, inaccessible and old. The recent ones are few and needs to be added upon to meet the increasing demand for anatomical information by students and researchers in plant anatomy, plant pathology, plant ecology, plant taxonomy, forestry and agronomy. In order to bridge the gap, however, the author and his collaborators in the recent time have studied the tissues and cells in some tropical tree plants and herbacious species as reported in Otoide *et. al.,*(2012), Otoide (2013a & b), Otoide (2014a & b), Otoide (2015) and Otoide (2016). Otoide *et. al*.,(2012) studied the percentage moisture content and vessel elements in stem of *Adansonia digitata* and reported variations in the length and diameter of vessels as well as in percentage moisture contents along the axial and radial directions of the trunk. Similarly, Otoide (2013a) reported poor leaf development, ruptured stomatal ledges, plugged stomatal pores and irregularly fused cell boundaries in the leaves of *Euphorbia heterophylla, Chromolaena odorata, Commelina diffusa and Kyllinga pumila* growing naturally within the radii of 0.1m to 0.25m from the exhaust-pipe of domestic power generators commonly used in homesteads in Nigeria. In the same vein, Otoide (2013b) reported the presence of libriform, non-septate and medium sized fibres in the stem of a fully grown species of *Adansonia digitata*. Similarly, Otoide (2014a) studied the fibres in the stem of *Afzelia africana* by measuring their lengths and diameters in micrometer. He reported extremely short nature of fibres and recommends that the species be exploited for construction works and any other production in which woods with extremely short fibre length will not negatively affect the end product of productions. Otoide (2014b) observed the stomatal types, epidermal cell structures, damaged epidermal cells and plugged stomatal pores in the polluted leaves of some group of plants such as *Polyalthia longifolia, Digitaria gayana and Trianthema portulacastrum* growing within the radii of 0.1-0.25m to exhaust-pipes of power generators. Moreso, Otoide (2015) studied the dimensions of the vessels and rays in the trunk of *Afzelia africana* and reported short and narrow, open-ended vessels containing simple perforation plates. He also recommended multiseriate and heterogeneous nature of rays in the species. In the vein, Otoide (2016) studied the axial and radial variations in wood density and moisture of the trunk of *Afzelia africana* and reported that the wood density and moisture of the species increased with the height of the trunk and varied both in axial and radial directions of the trunk.

This present study is another demonstration of the author's interest in examining the basic wood structure of tree plants in the tropics.

2. Materials and Methods

2.1 Collection of Materials

A fully grown tree of *Afzelia africana* which could be of about 70 years old was felled at the diameter at chest height (1.3meters above ground level), from Igbo oluwa quarters in Iworoko village, Ekiti State, Nigeria. The log was thereafter taken to the Department of Wood Technology and Utilization (WT&U) of the Forest Research Institute of Nigeria (FRIN), Ibadan, Nigeria for identification and microscopic preparations for anatomical study.

2.2 Experimental Procedures and Maceration of Wood Samples

The procedures used in this assessment strictly followed Otoide *et. al.*, (2012) The bole length of the felled tree was measured with the aid of a measuring tape from the level of chest height, to the crown and the value was 1.10meters. Thereafter, transverse disc of 20cm thick axially was cut from the base, middle and the top of the log. A total of three transverse discs was cut out of the entire log. Each of the discs was divided longitudinally into two semi-circular hemispheres with the line of division passing through the pith. One of the two semi-circular hemispheres was tagged as the Northern hemisphere and the other one, the Southern hemisphere. Only the Northern semi-circular hemispheres were used for the whole of the experiments while the Southern semi-circular hemispheres were discarded. The base, middle and the top semi-circular hemispheres were further divided into three regions, with the lines of division parallel to the equator, which passes through the centre of the pith. These three regions were labelled as:

- **Core** (C),
- **Middle** (M) and
- **Outer** (O).

Five blocks of the dimension, 2cm x 2cm x 2cm and another five blocks of the dimension, 2cm x 2cm x 6cm cut out of the core, middle and outer blocks earlier extracted from the three semi-circular hemispheres, each of which was cut out from the base, middle and the top of the log. On the base disc, five replicate extracts, each from the core, middle and the outer regions of the semi-circular hemisphere were cut out, making a total of 15 blocks of the dimension, 2cm x 2cm x 2cm and also a total of 15 blocks of the dimension, 2cm x 2cm x 6cm. A total of 30 blocks were extracted separately from the Base, Middle and the Top of the log. Ground total of 90 blocks of wood pellets was extracted from the whole of the tree trunk/log. All the 90 blocks of wood pellets were used for the whole of the experiments involved in the study.

2.3 Maceration of Wood Samples

In order to determine the length and width of vessels and rays in the trunk of this species, the method outlined by Otoide, *et. al.,* (2012) was followed.

Thin slivers of wood materials were removed from the whole of the 2cm x 2cm x 2cm blocks and placed in separate test tubes containing mixture of equal amount of hydrogen peroxide and acetic acid (i.e. in ratio 1:1) individually, such that no slivers of different blocks were placed together in a test tube. The test tubes were then placed inside an electric oven for 4 hours at 80ºC. The test tubes were then removed from the oven and shaken properly so as to defibrize the slivers. The test tube samples were then dropped on clean cover slides with the aid of a pipette and the slides were viewed under a calibrated microscope. Length and width measurements of vessel members and rays were averages of 50 measurements.

2.4 Experimental Design

The Experimental Design adopted for this work is a two Factorial in a Complete Randomized Design (C.R.D) with different replications of the test Samples.

Factor A: The longitudinal direction (Base, Middle and Top) of the trunk.

Factor B: The radial directions, where the sample sticks were collected (The Core, Middle and Outer) region of the trunk.

2.5 Statistical Analysis

Analysis of Variance (ANOVA) was conducted to test the relative importance of various sources of variation on the length (µm) and width (µm) of the vessels and rays. The main effects considered were differences along the longitudinal (i.e. Axial) and Radial Positions. The Follow up test was conducted, using Duncan Multiple Range Test (D.M.R.T). This was done to know the significant difference between the two Means at P≤0.05.

The mathematical Model for the two Factors factorial experiment is given as:

Yij = u + Ai + Bj + (AB)ij + Eij

Where:

μ = General mean of individual observation;
Ai = Effect of Factor A;
Bj = Effect of Factor B;
(AB)ij = Effect of interaction between Factor A and B;
Eij = Effect of interaction Error term.

3. Results and Discussion

The morphometric analysis of the fibres in the trunk of *Alstonia boonei* De Wild. have been summarised in tables 1-5 and further illustrated in figure 1.

The mean length (μm) of fibres along both the axial and radial axes of the trunk was 1025.5±0.24. At the core, middle and outer woods the mean lengths (μm) of fibres were 1130.2 ± 0.25, 869.6 ± 0.09 and 932.2 ± 0.21, 1092.8 ± 0.18, 908.5 ± 0.23 and 989.3 ± 0.25 and 1211.0 ± 0.27, 1025.7 ± 0.26 and 1070.4 ± 0.24 for the basal, middle and top axial positions of the trunk respectively. The axial and radial means for the basal, middle and top positions of the trunk 1144.7 ± 0.24, 934.6 ± 0.21 and 997.3 ± 0.23 and 977.3 ± 0.22, 996.9 ± 0.23 and1102.3 ± 0.26 respectively. Significant differences (P≤ 0.05) existed in the mean fibre lengths between the base, middle and top positions as well as between the core, middle and outer woods regions of the trunk respectively (Table 1). In the same vein, the overall mean diameter (μm) of fibres in the trunk was 27.85 ± 8.13. At the core, middle and radial regions of the trunk the diameters of fibres were 28.48 ± 7.99, 32.12 ± 7.26 and 31.16 ± 7.83, 27.83 ± 6.90, 27.02 ± 9.91 and 25.70 ± 8.27 and 27.27 ± 8.87, 22.98 ± 7.51 and 28.13 ± 5.76 for the basal, middle and top positions respectively. The mean diameters (μm) at both axial and radial regions were 30.59 ± 7.72, 26.85 ± 8.35 and 26.13 ± 7.70 and 27.86 ± 7.84, 27.37 ± 9.00 and 28.33 ± 7.58 respectively. Significant differences (P ≤ 0.05) existed in the diameters of fibres from base to top of the trunk while there were no significant differences along the radial regions from core, middle and outer woods respectively (Table 2).

The overall mean lumen width of fibres in the entire trunk was 19.49 ± 8.26. The mean width (μm) of lumen of fibres in the trunk of the species were 20.45 ± 7.67, 25.76 ± 6.83 and 24.19 ± 7.53 at the base, 19.49 ± 6.59, 19.14 ± 9.74 and 18.53 ± 8.58 at the middle, and 18.33 ± 7.97, 14.65 ± 6.61 and 14.88 ± 6.83 at the top for each of the core, middle and top woods respectively. Significant differences (P ≤ 0.05) existed in the lumen width along the axial positions of the trunk from base to top whereas, there were no significant differences along the radial regions from core to outer woods respectively (Table 3). Similarly, the overall mean cell wall thickness of fibres in the entire trunk was 4181.2 ± 2.17. The mean cell wall thickness (μm) of the fibres were 4014.7 ± 1.19, 3181.5 ± 1.01 and 3484.5 ± 1.13 at the base, 4166.3 ± 1.33, 3939.0 ± 1.30 and 3585.5 ± 0.97 at the middle and 4469.3 ± 2.05, 4166.3 ± 1.52 and 6623.5 ± 4.63 at the top of the trunk for each of the core, middle and outer woods respectively. The axial means of the cell wall thickness of the fibres were 3560.3 ± 1.15, 3896.9 ± 1.21 and 5086.3 ± 3.19 for the base, middle and top of the trunk respectively. Conversely, the radial means were 4216.7 ± 1.55, 3762.3 ± 1.34 and 4564.5 ± 3.12 for the core, middle and outer woods respectively. Significant differences (P ≤ 0.05) existed in the fibre cell wall thickness along the axial positions (from base to top) of the trunk (Table 4) whereas there were no significant differences along the radial regions (from core to outer woods).

TABLE 1: Mean Length (μm) of Fibres Along the Axial and Radial Axes of the Trunk of *Alstonia boonei*

AXIAL AXES	RADIAL AXES			
	Core Wood	**Middle Wood**	**Outer Wood**	**Axial Means**
BASE	1130.20 ± 0.25	1092.80 ± 0.18	1211.00 ± 0.27	1144.70 ± 0.24^{a}
MIDDLE	869.60 ± 0.09	908.50 ± 0.23	1025.70 ± 0.26	934.60 ± 0.21^{c}
TOP	932.20 ± 0.21	989.30 ± 0.25	1070.40 ± 0.24	997.30 ± 0.23^{b}
Radial Means	977.30 ± 0.22^{c}	996.90 ± 0.23^{b}	1102.30 ± 0.26^{a}	1025.50 ± 0.24

Means with different letters on the rows column are significantly different from one another at P≤0.05.

TABLE 2: Mean Diameters (µm) of Fibres Along the Axial and Radial Axes of the Trunk of *Alstonia boonei*

AXIAL AXES	RADIAL AXES			
	Core wood	**Middle wood**	**Outer wood**	**Axial means**
BASE	28.48 ± 7.99	32.12 ± 7.26	31.16 ± 7.83	30.59 ± 7.72[a]
MIDDLE	27.83 ± 6.90	27.02 ± 9.91	25.70 ± 8.27	26.85 ± 8.35[b]
TOP	27.27 ± 8.87	22.98 ± 7.51	28.13 ± 5.76	26.13 ± 7.70[c]
Radial means	27.86 ± 7.84[a]	27.37 ± 9.00[a]	28.33 ± 7.58[a]	27.85 ± 8.13

Means with the same letters on the rows are not significantly different at $P \leq 0.05$ but means with different letters on the column are significantly different at $P \leq 0.05$.

TABLE 3: Mean Width (µm) of Fibre Lumen Along the Axial and Radial Axes of the Trunk of *Alstonia boonei*

AXIAL AXES	RADIAL AXES			
	Core wood	**Middle wood**	**Outer wood**	**Axial means**
BASE	20.45 ± 7.67	25.76 ± 6.83	24.19 ± 7.53	23.47 ± 7.57[a]
MIDDLE	19.49 ± 6.59	19.14 ± 9.74	18.53 ± 8.58	19.06 ± 8.27[b]
TOP	18.33 ± 7.97	14.65 ± 6.61	14.88 ± 6.83	15.95 ± 7.24[c]
Radial means	19.43 ± 7.36[a]	19.85 ± 8.99[a]	19.20 ± 8.48[a]	19.49 ± 8.26

Means with the same letters on the rows are not significantly different at $P \leq 0.05$ but means with different letters on the column are significantly different at $P \leq 0.05$.

TABLE 4: Mean Cell Wall Thickness of Fibres Along the Axial and Radial Axes of The Trunk of *Alstonia boonei*

AXIAL AXES	RADIAL AXES			
	Core wood	**Middle wood**	**Outer wood**	**Axial means**
BASE	4014.70 ± 1.19	3181.50 ± 1.01	3484.50 ± 1.13	3560.30 ± 1.15[c]
MIDDLE	4166.30 ± 1.33	3939.00 ± 1.30	3585.50 ± 0.97	3896.90 ± 1.21[b]
TOP	4469.30 ± 2.05	4166.30 ± 1.52	6623.50 ± 4.63	5086.30 ± 3.19[a]
Radial means	4216.70 ± 1.55[a]	3762.30 ± 1.34[a]	4564.50 ± 3.12[a]	4181.20 ± 2.17

Means with the same letters on the rows are not significantly different at $P \leq 0.05$ but means with different letters on the column are significantly different at $P \leq 0.05$.

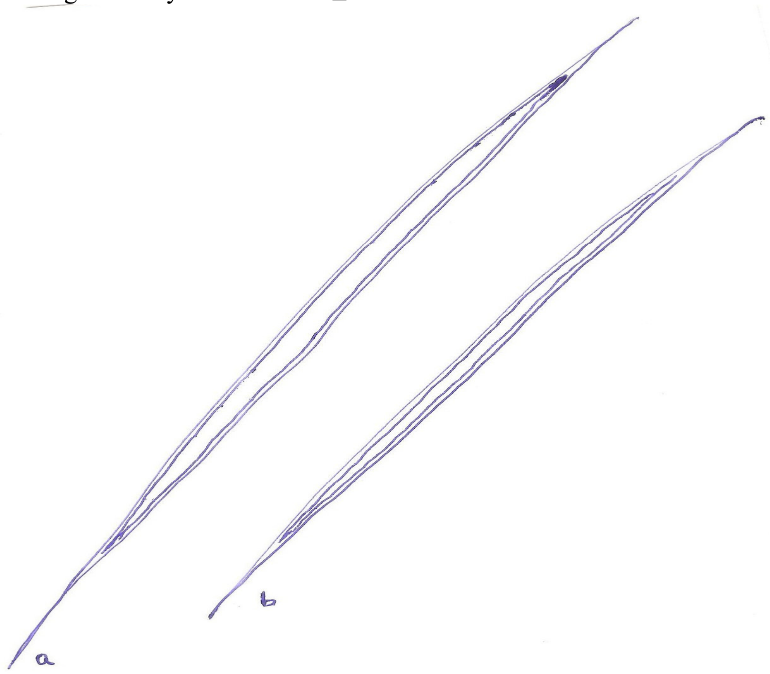

Fig. 1 (a-b): Libriform fibres in the trunk of *Alstonia boonei* De Wild. X400

The overall mean length (µm) and diameter (µm) of fibres in the trunk of *Alstonia boonei* were 1025.50±0.24 and 27.85±0.18 respectively. These figures, according to Metcalfe and Chalk (1989) fall within the class known as medium-sized fibres. Still, microscopic observations of the fibres showed that they were living as they contained protoplasm; libriform with simple pits, thick-walled and aseptate in morphology [fig. 1

(a-b)].

The mean fibre diameter (µm) obtained in the present study is within the range typical of the dicotyledons. This further confirmed the taxonomic hierarchy of this taxon as a dicotyledonous tree plant. In the same vein, the results obtained from the present morphometric study revealed that the mean lengths and diameters of the libriform fibres increased radially from core to outer-woods with increase in the height of the trunk (i.e from base to top). This increase was significant at P≤0.05 (Tables 1 and 2). This nature and developmental pattern of the fibres is not strange since Metcalfe and Chalk (1989) asserted that it has been almost universally found that length and diameters of fibre cells in stem increases outward from the pith region. These trends are advantageous to the species as fibres are the principal mechanical or supporting cells in the wood, and the strength and several other properties of hardwoods largely depend on the size and morphology of the fibre cells it contained. In this view, *Alstonia boonei* would be able to resist stress and strain resulting from environmental parameters and anthropogenic activities.

The mean cell wall thickness (µm) of the libriform and aseptate fibres found in the species under investigation both along the axial and radial axes of the trunk equalled 4181.20±2.17. This is high enough to provide mechanical support to the trunk of this species. This assertion is corroborated by the previous assertions by Metcalfe and Chalk (1989) that the mechanical strength of most dicotyledonous woody stems largely depends on the morphology of the wood fibres and on their capacity to elongate by intrusive growth. Both fibre-tracheids and libriform fibres supply mechanical support in this way. Results obtained from the morphometric analysis revealed that the cell wall thickness (µm) of the fibres increased significantly (P≤0.05) as the plant increased in height. However, this increment was not significant (P≤0.05) from core-wood to outer-wood (Table 4).

The mean widths (µm) of the fibre cell lumen on the other hand, were observed to have increased significantly (P≤0.05) along the axial plane of the trunk from base to top as the plant increases in height. They however decreased from core-wood to outer-wood both at the base, middle and top positions of the trunk. Though the decrease was not significant at (P≤0.05) (Table 3), it is traceable to the increase in the lengths of the fibres in the outer-woods at the three different locations of the trunk. This is because as the fibre cells undergo elongations through the process of intrusive growth the width of lumen reduces without affecting wall thickness.

4. Conclusion: In view of the foregoing, the information supplied about the species in the present study recommends it to subsistent and commercial farmers as wood for construction of yam and animal barns and in addition, as shelter belts for inhabitants in areas pruned to ecological problems due to wind and wind storms. From the industrial perspective Runkels' ratio which is useful in the determination of pulping efficiency of wood fibres is a function of both fibre length and fibre diameter which are deducible from the morphometric data obtained in the present study. Analyses of the physical properties such as wood density and percentage moisture content as well as the chemical analysis should be urgently carried out. In addition, the slenderness ratio, flexibility coefficient and Runkels' ratio which are important parameters of the industrial values of wood fibres should be carried out as well.

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