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Variation in Bark proportion, Grain Orientation, Sapwood and Heartwood of Some Plantation Grown Sudano Sahelian Wood Species

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Abstract

The study investigate the variation in grain orientation, bark proportion, sapwood and heartwood proportion of *Eucalyptus camaldulensis*, *Leucaena leucocephala*, *Prosopis juliflora* and *Ziziphus mauritiana.* Sample trees with clear bole were randomly selected from the 0.5 hectare Department of Forestry and Wildlife nursery located within the campus of University of Maiduguri. Three discs of 6cm thickness each were obtained at three sampling points i.e. base, middle and top along the sampling height to investigate the selected properties. There is a significant variation in all the properties examined among the tree species and along the sampling height except for grain orientation along the sampling height ($P > 0.05$). The highest sapwood proportion was found in *Prosopis juliflora* with 57.53% sapwood while the highest heartwood proportion was found in Eucalyptus camaldulensis (71.54%) followed by *Leucaena leucocephala* with 57.59%. The highest grain orientation was 3.23^{o} and the least, $2.48\ ^{o}$ in *Leucaena leucocephala* and *Ziziphus mauritiana* respectively. The study provided information on wood quality attributes of the selected plantation-grown species which are comparable to other hardwood species. This can be used in determining their application for either heavy works and for building, construction and other purposes.
Keywords: Physical properties, sampling height, bark proportion, grain orientation, sapwood, heartwood.

Introduction

Tree as a living organism, undergoes a continuous change in its components as it grows, making it a dynamic system. Wood, being a product of different trees, each with different individual characteristics, are subject to variation in its constituents and composition as a result of the tree physiology and environmental factors (Downs *et al.,* 2009). Understanding the extent of variations of wood properties is important because the suitability of wood for a particular purpose is determined by the variability of one or more of its characteristics. For example, variation in the proportion of heartwood and sapwood within the tree stem influences wood properties such as; strength, durability and suitability in pulp and paper production (Pillai *et al.,* 2013). Similarly, the direction of grain along the stem affects the application of wood in service. Grain orientation is usually parallel along the stem, variation in grain orientation either along or across the bole can cause deviation in the direction of the grain. These variations can affect the wood during conversion and drying process (Simonaho *et al.,* 2004). Therefore, the availability of scientific knowledge on the properties and behaviour of wood will make it possible to develop more efficient methods of using wood as a natural raw material.

The importance of wood as a raw material in the nation's development cannot be over-emphasised. The forest of Nigeria, like most tropical forest is richly endowed; supporting different species of which some are preferred due to their high commercial values over others. Conversely, excessive harvesting beyond natural sustainable limit has led to reductions in number of the mature timbers of those species leaving the natural forest with younger, immature stands that can barely support higher harvests in the future. In addition to overexploitation, low productivity and lack of satisfactory regeneration of the desired species has become a challenge to achieving sustainable management of tropical forest. These uncertainties associated with the present situation of tropical forests have resulted into shifting interest toward plantation species especially in the much drier regions of the world (Chamshama *et al.,* 2009). Utilisation of plantation-grown species as an alternative to the overused ones will create opportunity to balance the gap between demand and supply of wood and wood products with a minimum impact on the forest and the environment. However, introducing alternative plantation species may face the difficulty of acceptance for utilisation as a result of limited information on their properties (Barany *et al.,* 2003). Hence, this study was conducted to investigate the grain orientation, bark proportion, sapwood and heartwood proportion of some selected plantation-grown sudano sahelian wood species namely; *Eucalyptus camaldulensis*, *Leucaena leucocephala*, *Prosopis juliflora* and *Ziziphus mauritiana* to determine their utilisation potentials for timber production.

Materials and Methods

Sample Collection and Preparation

Samples for this study were obtained from the Department of Forestry and Wildlife nursery in the University of Maiduguri, Nigeria. The nursery was established in 2007 and is located on latitude 11 ˚ 30"N and longitude 14˚45"E in an altitude of about 354m above sea level (Sotannde *et al.,* 2010). Four trees of clear bole without any damage or attack by insect or fungi were randomly selected, felled and all the branches were neatly removed from each tree. Three discs of 6cm thickness each were obtained at three sampling points i.e. the bottom (30cm of the sampling height), middle (50% of sampling height) and top (80% of the sampling height) along the stem. After measurement of tree diameters, the discs were sawn and cut according to BS 373 (Poku *et al.,* 2001) to measure the bark proportion, grain orientation, sapwood and heartwood proportion.

Determination Bark Proportion (%)

Bark proportion was determined by placing a calibrated ruler on the transverse surface of the disc to measure diameter outside bark and the diameter inside bark i.e. the wood. Bark thickness was obtained as the difference between diameter outside bark and diameter inside bark expressed in percentage i.e.:

$BT = DoB - DiB$ 1

Where:
BT = Bark thickness
DoB = Diameter outside bark
DiB = Diameter inside bark

Determination of Heartwood and Sapwood proportion

Heartwood and sapwood proportion were first evaluated by visual estimation of the difference in the colour of the wood zones. The darker colour zone was taken to be the heartwood portion which was clearly distinguished from the lighter-coloured sapwood portion. The diameter of the heartwood was also measured with the aid of a calibrated ruler. The diameter was later subtracted from the actual wood diameter to obtain the sapwood diameter. This could be represented through the relationship given below:

$SwD = WD - HwD$..2

Where:
SwD = Sapwood diameter
WD = Wood diameter
HwD = Heartwood diameter

Measurement of Grain Orientation

The direction parallel to the longitudinal axis of most of the tapered wood is called grain direction. Wood grains normally have their orientation essentially parallel to the longitudinal axis of the stem. But in many cases, grain orientation is at a slight angle to the longitudinal axis of the stem. Therefore, the grain orientations were measured to the longitudinal axis of the sampled discs in both outer wood (sapwood) and the inner wood (heartwood), according to Saikia *et al.* (1997). To measure the grain angle of the outer wood, the bark of each billet was peeled and polished with an orbital sander to make grain direction conspicuous. An HP pencil was then used to draw a line parallel to the main axis of the discs; the deviation of the grains was then measured to the line with the aid of a protractor. From each disc, ten grains were measured in the north-south and east-west directions. The same procedure was adopted for the heartwood, except that each billet was first sawn from the sapwood to the heartwood and planed for easy identification of the grain (Sotannde *et al.*, 2010).

Result and Discussion

Analysis of variance from Table 1 shows significant difference in bark proportion, grain orientation, heartwood and sapwood proportion among the species. However, there is no significance difference in bark proportion, heartwood proportion and grain orientation along the sampling height of the studied species (P>0.05).

Bark Proportion (%)

Bark protects the wood from extreme temperature, drought, provides mechanical protection to the softer inner bark and also helps to limit evaporation (Raven *et al.*, 1999). It is the conductor of food material and is often rich in chemical substances such as tannin and dyes derived from plant metabolism. Different bark types have different physiological properties related to the ecology of the different tree species and provide different habitats for bark-living arthropods (Nicolai, 1986). Table 2 showed among tree variation in bark proportion. It was observed that *E. camaldulensis* has the highest bark proportion (10.47%) and *Leucaena leucocephala* has the lowest (4.51%). Variation along the sampling height showed a decreasing trend in bark proportion from base to top (Fig.1). The result obtained can be compared with the findings of Ogunwusi (2013) who worked on *Butyrospermum paradoxum*, *Albizia zygia*, *Lanea acida*, *Parkia felicoida* and *Isoberlina doka* with 13.6%, 10.77%, 7.82%, 11.06% and 10.80%, respectively. However, bark proportion in this study was less than the one found in Ogunwusi (2013) and in Diaz-Maroto *et al* (2017). "This might be linked to the age of the four selected species. Given that they are trees, they tend to thinner and less bark proportion when compared to the more mature species". The thickness and proportion of the bark correlates with geographical factors, such as moisture availability, tree age and diameter classes (Sonmez *et al.*, 2007). In all the species studied, the bark proportion decreased from the base to the top of the tree. The same trend was reported by Miranda *et al.* (2015) as it is expected that tree bark greatly decreased from base to top. The proportion of bark could in some ways also affect the log yield of a particular species, that is; larger logs had a lower proportion of bark (Wehenkel *et al*., 2012). Therefore, the less bark proportion from the studied species could mean increase in their log yield.

Table 1: Analysis of Variance on variation in wood properties among and within the selected species

Sources of Variation	df	BKP (%)	SWP (%)	HWP (%)	Grain Orientation (θ^o)
Species (S)	3	40.06*	2471.52*	2007.67*	4.68*
Sampling height (SH)	2	0.08^{ns}	125.67*	12.03^{ns}	0.75^{ns}
S*SH	6	38.39^{*s}	28.32^{ns}	41.83^{ns}	1.36*
Error	24	2.42	29.32	33.13	1.51
Total	35				

* = Significant (P < 0.05), ns = not significant (P > 0.05), df = Degree of freedom, BKP = Bark proportion, SWP = Sapwood proportion, HWP = Heartwood proportion

Table 2: Among Tree Variation in BKP, SWP, HWP and grain orientation

Species	BKP (%)	SWP (%)	HWP (%)	Grain Orientation (θ^o)
Eucalyptus camaldulensis	10.47 ± 0.84^a	15.31 ± 1.17^d	71.54 ± 3.02^a	2.69 ± 0.18^{cd}
Leucaena leucocephala	4.51 ± 1.15^d	36.20 ± 2.69^c	57.59 ± 2.41^b	3.23 ± 1.03^a
Prosopis juliflora	5.25 ± 0.76^{cd}	57.53 ± 3.23^{ab}	35.53 ± 1.37^c	2.86 ± 0.39^{bc}
Ziziphus mauritiana	6.50 ± 0.33^b	52.87 ± 2.02^b	37.43 ± 1.03^c	2.48 ± 0.21^d

BKP = Bark proportion, SWP = Sapwood proportion, HWP = Heartwood proportion. Variables with the same alphabet in the same column are not significantly difference (p>0.05).

Heartwood and Sapwood Proportion (%)

Prosopis juliflora had the highest sapwood proportion (57.53%) while *Leucaena leucocephala* had the lowest sapwood proportion 36.20% (Table 2). *Eucalyptus camaldulensis* had the highest percentage of heartwood 71.54% followed by *Leucaena leucocephala* (57.59%) while the least sapwood proportion 35.53% was observed in *Prosopis juliflora* (Table 2). Along the sampling height, there is a consistent increase in sapwood proportion from the base to the top. It increased from 11.91% at the base to 17.58% at the top in *Eucalyptus camaldulensis* and from 31.13% at the base to 41.14% at the top in *Leucaena leucocephala* (Fig 2). Heartwood proportion showed a decreasing trend from base to top along the sampling height in all the studied species. It decreased from 74.83 – 69.13% and 64.52 – 51.43% in *Eucalyptus camaldulensis* and *Leucaena leucocephala* respectively (Fig 3). Such pattern of axial variation in heartwood has been reported in some *Eucalyptus* species such as *E. globulus* (Miranda *et al.*, 2015). According to Hillis (1987) this type of within-tree variation of heartwood is generally found in hardwood and softwood species and could be derived from the process of heartwood formation that starts at a certain tree age and size and progresses outwards in the radial direction and upwards in the axial direction. The result obtained from this study is similar to those found in some plantation-grown tropical hardwood species as reported by Moya and Munoz (2010); Ogunwusi (2013); Sabrina *et al.* (2018). Sapwood is the outer portion of a wood stem, trunk or log usually distinguishable from the core or heartwood by its brighter colour. In the living tree, the sapwood is responsible not only for the conduction of sap but also for the storage and synthesis of biochemicals. Starch grains are stored in the parenchyma cells and can be easily seen using a microscope. The starch content of sapwood can have an important influence on the wood industry (Wiedenhoeft and Miller, 2005). However, the presence of sapwood in wood is of little advantage to wood utilisation because of what it contains. From the studied species, *P. juliflora* and *Z. mauritiana* were observed to have high sapwood proportion when compared to *E. Camaldulensis* and *Leucaena leucocephala.* This implies that the species will require treatment with preservatives before utilisation. *E. Camaldulensis* and *Leucaena leucocephala* on the other hand could be more durable among the studied species becouse of the high heartwood proportion (Table 2).

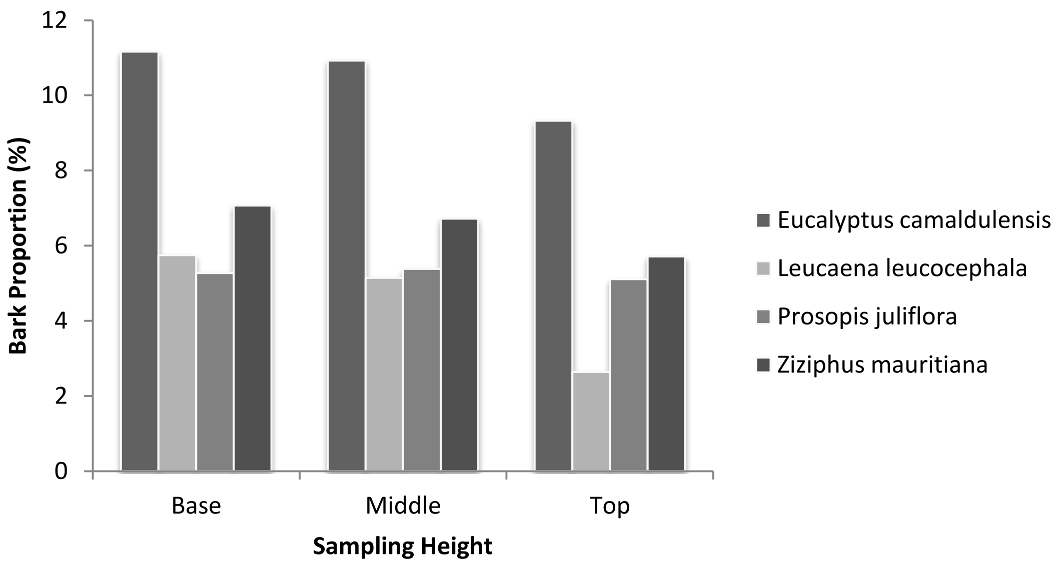

Figure 1: Variation in bark proportion along sampling height of the selected species

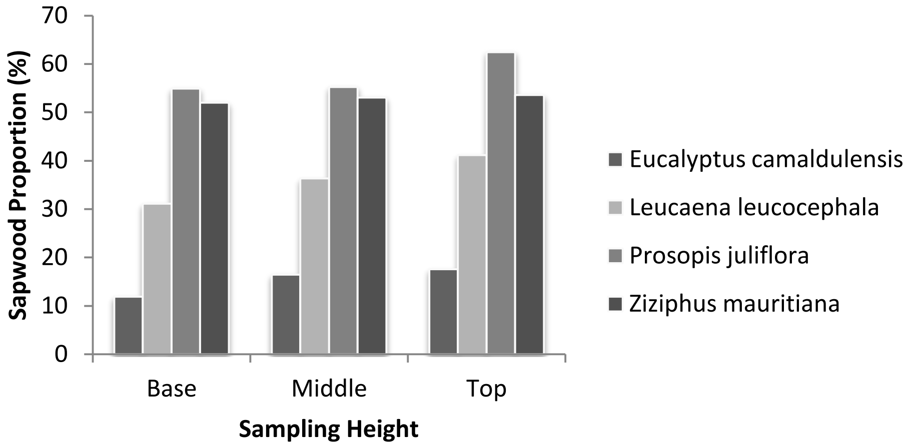

Figure 2: Variation in sapwood proportion along sampling height of the selected tree species

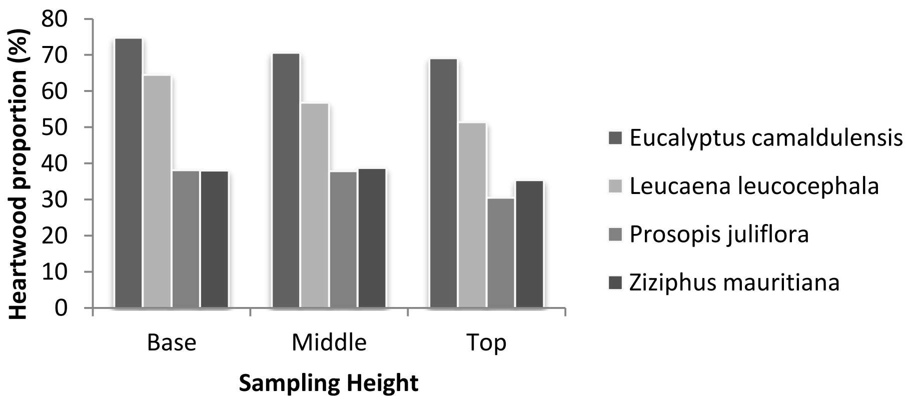

Figure 3: Variation in heartwood proportion along sampling height of the selected species

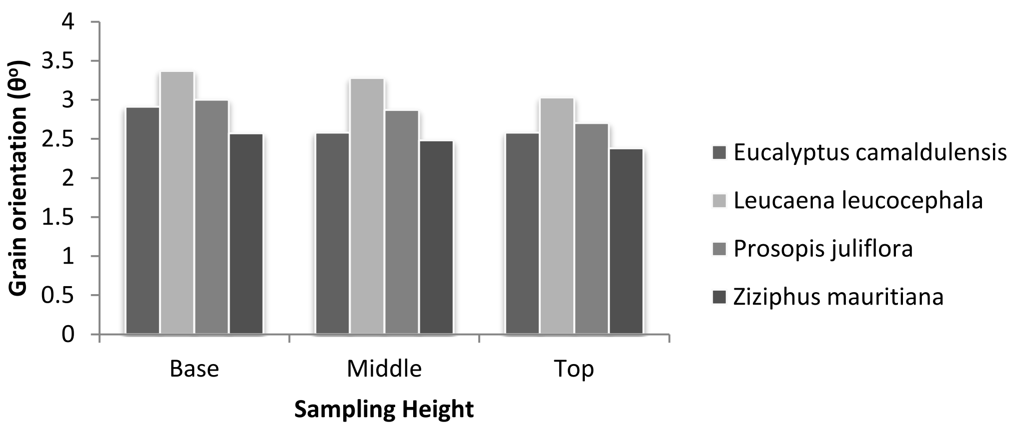

Figure 4: Variation in grain orientation along sampling height of the selected species

Grain Orientation

The degree of variation in grain angle among the species was observed to be highest in *Leucaena leucocephala* (3.23^{o}) and the lowest grain angle was observed in *Ziziphus mauritiana* 2.48^{o} (Table 2). Meanwhile, grain angle variation along the sampling height showed a somewhat inconsistent decreasing pattern from the base to the top in some of the studied species. Grain orientation decreased in all the studied species except in *Eucalyptus camaldulensis* where there was no clear variation between the middle and the top of the sampling position (Fig 4). Decreasing grain angle along the sampling height seems to follow a pattern common to some tropical hardwood species. This agrees with the result of grain orientation research on plantation grown 9-years old *Khaya senegalensis* carried out by Sotannde *et al.* (2015). The lower grain angles observed in this study may not have any adverse impact on the wood characteristics like mechanical and dimensional stability (Dinwoodie, 2000).

Conclusion

The study showed that bark proportion, grain orientation, sapwood and heartwood proportion are significantly different among species and within the stem of tree species growing on the same location. The study has also provided information on wood quality attributes of the selected plantation-grown species which are comparable to other hardwood species. With the results obtained from this and other related studies, it is necessary to pursue the plantation establishment of this species vigorously as this will help to step down the total dependence on those over-exploited species that are disappearing from the market.

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