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Does heartwood formation early process in Beninese coppice teak stands?

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ABSTRACT

Teak heartwood formation process is less documented especially in Benin where the species has been widely established by farmers under coppice regime and provide woods largely used by consumers in cities. The objectives of this study were to determine the beginning age of heartwood formation process in coppice teak plantations and the impact of age and plant communities on heartwood percentage. Based on 54 discs sampled from plantations of divers ages in the two widest plant communities spread in Atlantic department, percentages of heartwood were assessed and compared as function of trees age and plant communities. Our findings revealed that heartwood formation begins early and that the coppice regime tends to quicken the heartwood formation process. The percentage of heartwood diminishes along tree from the base to the crown base while generally it increases with the age once the process began. There was statistically no difference between heartwood percentages formed at different ages. But at the same age significant difference exists between plant communities. Sound place choices for coppice teak stands establishment could help farmers to improve the physic-mechanical, chemical and biological characteristics of their woods as they depend on heartwood formation and percentage.

Keywords: *Duramen formation, Heartwood percentage, Coppice teak plantation, Plant communities, Benin*

I. INTRODUCTION

Teak (*Tectona grandis* L.F) is among the first forest trees species used under tropic [1]. It is a fast grown species holding exceptional wood qualities and highly appreciated on the international market. As being multipurpose wood, teak is used in carpentry, joinery, furniture, cabinet making, veneers and boat construction [2; 3]. As result of its good wood properties, teak has been widely planted and its rotation length shortened to supply the increasing needs of consumers.

Studies were carried out to assess the impact of growth rate, rotation length, stand age and ecological zones on the overall wood characteristics. They reported that teak could produce timbers of optimum strength in relatively short rotation of about 20-years [1]. The process of heartwood formation begins early at 7-years-old in Togolese teak plantations and wood density was significantly correlated to trees age [4]. The same authors have found significant difference of modulus of elasticity between juvenile and adult wood and influence of ecological zones on teak wood properties. This latter finding has been supported by another study which has revealed impact of ecological factors on wood biophysical properties in Togo [5].

In Benin, teak is grown at shorter rotation length of about 6-years by farmers in their private plantations whence they supply consumers with pools for construction and other purposes [6; 7; 8]. The scope of uses made of private teak woods led us to assume that contrary to seeds-based plantations, heartwood formation in Beninese coppice teak stands is an early process. This study aims therefore to: (i) determine the beginning age of heartwood formation in coppice teak stands; and (ii) assess the impact of age and plant communities on heartwood percentage.

II. MATERIALS AND METHODS

Study Area

The study was carried out in five communes located in the

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department of Atlantic which is itself located in the southern Benin between 6°18'' and 6°58'' Northern latitude and 1°56'' and 2°30'' Eastern longitude (Figure 1).

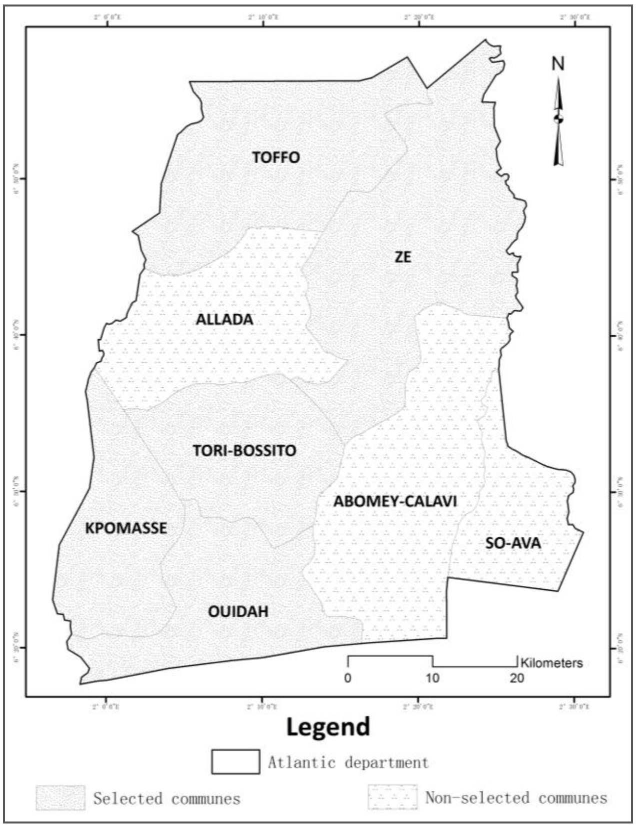

Figure 1: Geographic location of selected communes in the department of Atlantic.

The department is under the tropical climate with 1,200 mm as mean annual rainfall and 27 to 31°C for the monthly mean temperature. The natural vegetation has been degraded and the landscape is dominated by fallows, croplands and tree plantations. Several acres of land were cultivated in teak by farmers. Plantations are characterized by various plant communities which had formerly been described. *Mallotus oppositifolius* and *Paullinia pinnata*-community and *Mallotus oppositifolius* and *Macrosphyra longistyla*-community are the most spread plant communities in the Atlantic department. They are characterized by acidic soil containing high organic matter [6]. These two plants communities were considered in this study.

Sampling and Field Data Collection

Nine plantations were selected on agreement of plantation owners in the study area (Table 1).

Table 1: Distribution of the size of sampled units according to plant communities and ages.

	MOPP	MOPP	MOPP	MOPP	MOML	MOML	MOML	Total
Age (years)	2.5	3.5	5	5.5	3	5	7	
NP	1	1	2	2	1	1	1	9
NT	2	2	4	4	2	2	2	18
ND	6	6	12	12	6	6	6	54

Captions: MOPP=*Mallotus oppositifolius* and *Paullinia pinnata*-community; MOML=*Mallotus oppositifolius* and *Macrosphyra longistyla*-community; NP=Number of plantation; NT=Number of trees; ND=Number of 5 cm thick discs.

In these plantations, the three first lines of trees at the edge were left and two trees of similar diameters were randomly selected in the inmost part of the stand (Figure 2). Their heights were measured with the clinometer and the level of breast height (1.30 m) materialized before they were felled at 5 cm above ground.

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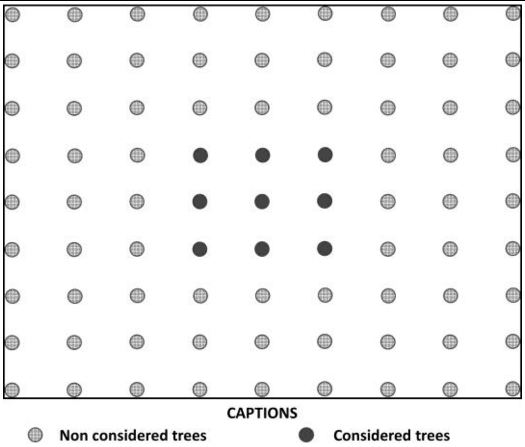

Figure 2. Placement of selected trees for heartwood percetages estimation.

Then the diameter was measured at three levels along the felled tree: the base, the breast height and the base of the crown. The base and the base of the crown were also materialized and disc of 5 cm thick, were then sawn and removed (Figure 3).

Figure 3: Picture showing the sawn of 5 cm thick disc.

Estimation of heartwood percentage

Fifty four (54) wood discs were sanded, and eight radii were used to measure the distance between the pith and the heartwood boundary and the cambium along (Figure 4).

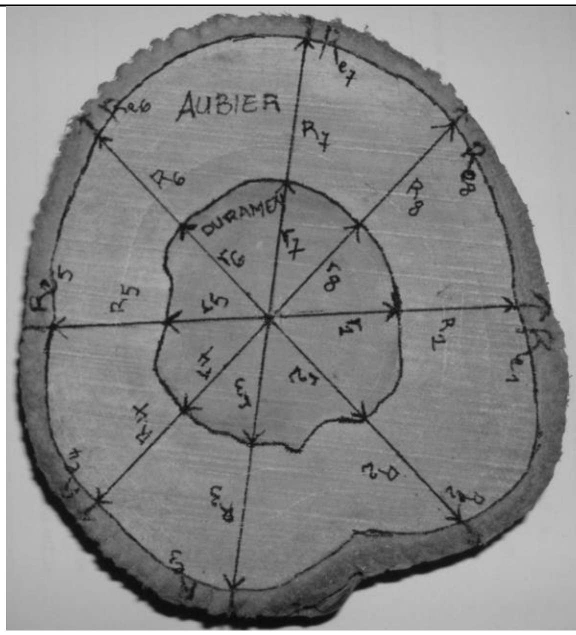

Figure 4: Picture showing the heartwood and sapwood with the 8 radii on the cross-sectional disc.

On the freshly cut discs, heartwood was easily identified due to its deep color. The cross-sectional area of heartwood was then calculated based on equations bellow provided by [9] and [10].

$S_t = \frac{\pi\left(\sum_{i=1}^{8} R_i^2\right)}{8}$ $S_{HW} = \frac{\pi\left(\sum_{i=1}^{8} r_i^2\right)}{8}$ where S_t is the total cross-sectional area of the discs except tree's back; and S_{HW} the cross-sectional area of heartwood.

Heartwood as a percentage of the total cross-sectional area of the discs was then determined.

An analysis of variance or its alternative non-parametric test Kruskal-wallis was performed to determine the difference between heartwood percentages as a function of tree age. For same age the student t-test was used to compare plant communities.

IV. RESULTS

The Table 2 summarizes the heights and diameters of the felled trees and their heartwood percentage.

Table 2: Characteristics and heartwood percentages according to plant communities and ages.

	MOPP	MOPP	MOPP	MOPP	Sig	MOML	MOML	MOML	Sig
Age (years)	2.5	3.5	5	5.5		3	5	7	

NO	2	2	4	4		2	2	2	
H	8.5c	7.9c	10.3b	11.6a	**0.000**	10.2	10.4	11.8	0.313
DTB	13.5	12.0	13.7	14.7	0.463	11.8	16.4	18.0	0.054
DBH	9.7ab	8.3b	10.0ab	10.8a	**0.027**	9.0c	11.4b	13.3a	**0.000**
DCB	6.4	6.4	6.2	7.3	0.256	5.2	9.1	7.4	0.055
PHwTB	0	0	7.6	9.3	0.063	11.8	16.6	41.4	0.156
PHwBH	0	0	1.2	5.4	0.496	7.6	7.9	18.4	0.239
PHwCB	0	0	0	0	-	0	2.3	0	0.465

Captions: MOPP=*Mallotus oppositifolius* and *Paullinia pinnata*-community; MOML=*Mallotus oppositifolius* and *Macrosphyra longistyla*-community; NO=Number of observation; H=height (m); DTB=Diameter at tree's base (cm); DBH=Diameter at breast height (cm); DCB=Diameter at crown's base (cm); PHwTB=Percentage of heartwood at tree's base (%); PHwBH=Percentage of heartwood at breast height (%); PHwCB=Percentage of heartwood at crown's base (%).
For each plant community, numbers with same letters on the same row are not significantly different at 5%.

All sampled trees have more than 8 m height and their diameter at breast height is ranged from 9 to 13.3 cm. the analyses of variance realized revealed significant differences between some parameters values with respect to plant communities and ages. Like the diameter, the percentage of heartwood diminishes along tree from the base to the base of the crown while generally it increases with the age once heartwood formation began. The process of heartwood formation is definitely early in Beninese coppice teak stands. Indeed, at 5-years-old whatever the plant community, there is heartwood already formed at trees' breast height. While duramen is formed at 3-years-old in Mallotus oppositifolius and Macrosphyra longistyla-community (MOML-community) it appeared at 5-years-old in Mallotus oppositifolius and Paullinia pinnata-community (MOPP-community) despite the high diameter of subjects. This reveals that heartwood formation is a physiological process related to the maturity of the species rather than the diameter size. However, in MOML-community, the heartwood proportions at 7-years-old are greater than 5-years-old for all diameters except diameter at the base of the crown. Differences observed between heartwood percentages are not statistically significant at 5% of probability regarding the stands' ages but rather regarding the plant communities for heartwood percentage at breast height (Table 3)

Table 3: Characteristics and heartwood percentages according to plant communities at 5-years-old.

	MOPP	**MOML**	**Sig**
Age (years)	5	5	
NO	4	2	
H	10.3	10.4	0.884
DTB	13.7	16.4	0.291
DBH	10.0	11.4	0.095
DCB	6.2b	9.1a	**0.012**
PHwTB	7.6	16.6	0.111
PHwBH	1.2b	7.9a	**0.037**
PHwCB	0	2.3	0.178

Captions: MOPP=*Mallotus oppositifolius* and *Paullinia pinnata*-community; MOML=*Mallotus oppositifolius* and *Macrosphyra longistyla*-community; NO=Number of observation; H=height (m); DTB=Diameter at tree's base (cm); DBH=Diameter at breast height (cm); DCB=Diameter at crown's base (cm); PHwTB=Percentage of heartwood at tree's base (%); PHwBH=Percentage of heartwood at breast height (%); PHwCB=Percentage of heartwood at crown's base (%).
For each plant community, numbers with same letters on the same row are not significantly different at 5%.

V. DISCUSSION

The presence and amount of heartwood formed in trees determine the wood qualities and the range of end-uses. Its formation is phenomenon which has been reported to start at 7-years-old for Togolese teak plantations [4]. However, unlike Togolese teak plantations, heartwood formation happened to begin earlier in Beninese teak stands where the study was carried out. The heartwood formation process started around 3-years-old or 5-years-old depending on the undergrowth plant community. The silvicultural regime could justify the precocity of the heartwood formation observed. Indeed Togolese teak plantations were seeds-based while in the studied coppice teak stands trees have been felled and then new stems sprout from the stumps. This silvicultural regime tends to quicken heartwood formation in teak. Percentage of heartwood produced at 7-years at base of trees (41%) is greater than more aged trees (12 to 18-years) from Togolese seeds-based plantations (around 35%); however the later produced two times more heartwood at breast height than in Beninese plantations. In addition the diminishing of the heartwood from the base to the breast height was sharp and more than two times faster. The radial growth of heartwood is then lower under coppice regime than seeds-based.

Plant community influences heartwood formation process. This fact has been reported by [4] and [5] in Togolese teak plantations where authors found significant relationship between wood properties including heartwood percentage and the ecological zones as well as the plant communities. Other factors such as density and age influence the process [4; 5]. The absence of relation between stand age and heartwood percentage could result from the low age of stands due to the short rotation and the sample size.

Should coppice teak stand being managed after establishment like seeds-based plantation (one shoot per stump, density, thinning); it is likely that the stand produces earlier more durable woods (high percentage of heartwood formed in short time) than simple seeds-based plantations.

VI. CONCLUSION

Coppice teak stands establishment became part of farmers' activities in Benin and supplies consumers with woods for various purposes. Heartwood formation improves woods' properties and durability while it widens its end-uses. This study allowed to lighten the process of heartwood formation in teak and has revealed that this process started twice earlier in coppice than in seeds-based plantations. The fact that trees were often felled and new stems sprout up from their stumps shortens heartwood formation time in teak. There was no difference between heartwood percentages formed at different ages but at same age (5-years-old) significant difference exists between plant communities. This impact of plant communities on the formation of heartwood could be used to guide farmers towards the most suitable places for the establishment of their plantations.

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