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Physical and Mechanical Properties of *Acacia Auriculiformis* A. Cunningham Ex Benth Used As Timber in Benin

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ABSTRACT

Acacia auriculiformis has been adopted in Benin as an energy wood through the firewood project since 1985. Increasingly, people use it as timber due to scarcity of conventional species and its availability while its physical and mechanical parameters are little known. It was determined the percentage of heartwood, density, modulus of elasticity and shear modulus of this wood in order to appreciate its current use as timber and to estimate its exploitable age. 18 trees of 5; 8-10 and 20 years were sampled from plantations of Sèmè, Pahou and Itchèdè-Toffo. It appears that from 8 years onwards, the percentage of *Acacia auriculiformis* heartwood is above 70%. With medium module of elasticity, the density and the mechanical parameters of Acacia auriculiformis have low variability between 8 and 20 years. Compared to species conventionally used, its current use is justified and suggest an exploitability age of 15 years to be refined.

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Introduction

Forests provide several important ecosystem services, including wood production. These services expose them to strong anthropogenic pressures [1] that contribute to deforestation. Between 2010 and 2015, the net annual decrease in global forest area was 3.3 million hectares [2]. Wood remains the main product of forestry. As a result, it constitutes an accessible raw material for populations with limited incomes and contributes substantially to job creation because it is produced and processed by essentially local channels, including artisans. Thus, the provision of multi-purpose forest resources by fast-growing plantations is a major alternative to mining-type harvesting in natural tropical forests. With a few exceptions, plantations were initially established to provide local fuelwood or supply local factories with timber [3-4]. Once mature, some of these trees, which were not intended for timber, are used in the more remunerative production of timber due to increased demand [4].

Acacia auriculiformis is a widely planted tropical species in the world [5]. In Benin, in order to deal with the problems of global warming and the energy problems of the population, wood energy plantations were set up in 1985. To this end, the "Firewood Plantations in Southern Benin" project, which was to be called the "Firewood Project" a few years later, was initiated and implemented to address the dendro-energy deficit in Benin's large urban areas. After fourteen (14) years of implementation (1986 to 1998), the project has achieved plantations covering nearly 10078 ha. The species most represented in each of these plantations are *Acacia auriculiformis*, *Eucalyptus sp* and *Anogeissus leiocarpa*; *Acacia auriculiformis* is the most abundant species. In the framework of this work, the particular case of *Acacia auriculiformis* interests us. Indeed, *Acacia auriculiformis* is a species introduced into Benin with an initial vocation of energy wood. It is a forest species originating from Australia (Northern Territory, Queensland), Papua New Guinea and Indonesia [5-6] but African countries are among the most recent to import it between 1960 and 1980 [5-8]. For use as fuel wood, the exploitable age is 4 years, whereas it is 10 years for timber [9]without any precision on the quality of the wood. *Acacia auriculiformis* is widely planted in southern Benin with an area of about 2000 ha to be planted in 2019. In Benin, *Acacia auriculiformis* is widely used in reforestation for its rapid growth allowing for high productivity and an average diameter increase of 2.3 cm per year at 6 years [10]. Although this species was initially intended for purely energy and fertiliser use in agroforestry systems [10], it is increasingly used for timber due to the scarcity of conventional species with high economic potential. It is now being used for furniture and construction. This information is confirmed by the work of Tonouéwa et al [10], Akouehou et al [8], Avikpo et al [11] who identified certain plantations of the species that are treated as high forest and exploited as timber, and Tonouéwa et al [12] who noted that the wood sold as timber is generally at least 8 years old with a diameter of more than 20 cm.

The only problem is that in this change in the behaviour of craftsmen towards this species, no technological reference has yet been established to justify the reasoned choice of its use in these different works, knowing that the use of a wood as a timber is also determined by its physical and mechanical properties [13].

In view of this specific context of *Acacia auriculiformis,* research questions arise: do the physico-mechanical characteristics of *Acacia auriculiformis* wood allow its use as timber*?*

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To answer this question, the overall objective of this work was to determine some physical and mechanical characteristics of *Acacia auriculiformis* wood.
Specifically, this involved to :

- determine the density, elasticity and shear modulus of *Acacia auriculiformis* wood taken from three state plantations in southern Benin of three different ages;
- compare the physical and mechanical characteristics of *Acacia auriculiformis* with those of conventional species usually used and highly prized in Benin in order to assess the probable age of exploitability as timber by analyzing these properties in the radial direction.

Experimental

Study area

This study took place in southern Benin. This area has a Sudano-Guinean climate characterized by two dry seasons (December to February and August to September) and two rainy seasons (April to July and October to November). The average temperature is about 27°C with a high relative humidity and an average annual rainfall of over 1100 mm. Pahou has a tropical ferruginous soil, Sèmè a hydromorphic sandy soil and Itchèdè-Toffo a ferralitic soil.

Table 1: Sampling scheme

Department	Plateau	Ouémé	Atlantique
Sector	Itchèdè-Toffo	Sèmè-Podji	Pahou
Plots of 1000 m^2 installed	3	3	3
Number of trees cut	6	6	6
Number of trays cut	18	18	18

Figure 1: Picture showing the cutting of the samples and their numbering from pith to sapwood

Measurement of parameters

Dendrometric characteristics

The dendrometric parameters determined are: stand density (N), mean tree diameter (d), mean bole height (h) and mean total height (ht).

Stand density (N)

The density of a stand represents the number of stems present on a given surface. It is generally expressed in number of stems per hectare.

$$N = \frac{n \times 1000}{S} \qquad (1)$$

Where S is the area of the sample plot (in m^2) and n is the number of trees or the number of feet in the plot.

The arithmetic mean diameter of the trees $(\bar{d})$

The arithmetic mean diameter is obtained by the following formula:

$$\bar{d} = \frac{1}{n}\sum_{i=1}^{n} di \qquad (2)$$

Where n is the total number of individuals in the stand (or density), di = diameter of the shaft i.

The average total height $(\bar{h})$

The average total height of the trees on a plot is obtained by the following formula:

$$\bar{h} = \frac{1}{n}\sum_{i=1}^{n} h_i \qquad (3)$$

Where n is the total number of individuals in the stand (or density), hi = height of tree i.

Density

The density of the sample is the ratio of the mass to the volume of the specimen stabilized at 12% water content. It is expressed in kilograms per cubic meter (kg/m^3). The mass of the test piece is determined by a balance with a resolution of 0.01 g and the dimensions (width and thickness), which allow the volume to be calculated, are measured using an electronic calliper with a resolution of 0.01 mm. The length is measured with a tape measure accurate to 0.05 cm. Measurements are made in a temperature and relative humidity-controlled chamber, which allows the samples to be stabilized at 12% water content.

Proportion of heartwood

The proportion of heartwood is influenced by the age of the wood and the growth rate of the tree. To measure the percentage of heartwood, the radii from pith to bark (R_1, R_2, R_3, R_4) and from pith to heartwood boundary (r_1, r_2, r_3, r_4) were measured (Figure 2). The total cross-sectional area (total pellet area noted St) and heartwood area (heartwood area noted SHW) are calculated for each pellet using the root mean square of at least four orthogonal radii and up to eight if the cross-section is very irregular [14-15].

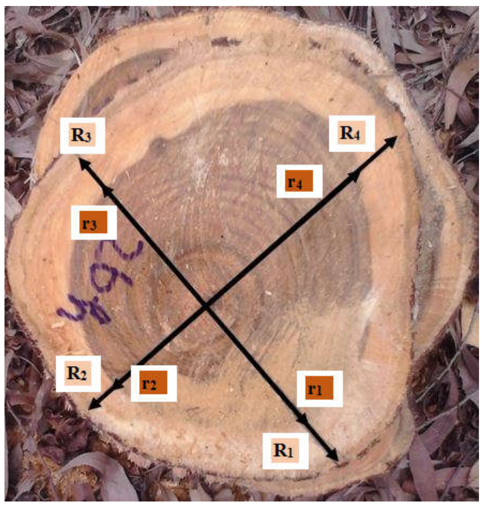
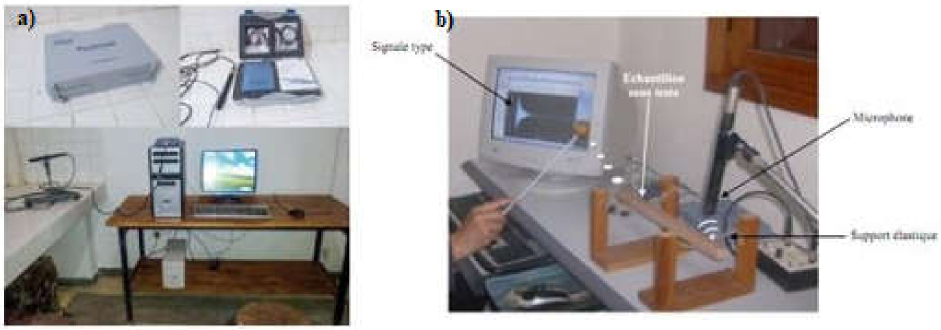


Figure 2: Picture showing orthogonal radii inscribed on the cross-section of a wooden slab

Table 2: Percentage of heartwood and bark thickness according to the position of the wood in the tree of *Acacia auriculiformis* seedlings in the state plantations of Sèmè, Pahou and Itchèdè-Toffo

Sector	Sèmè				Pahou		Itchèdè-Toffo			
Wood position	Percentage of heartwood (%)		Bark thickness (cm)		Percentage of heartwood (%)		Percentage of heartwood (%)		Bark thickness (cm)	
	m	se	m	se	m	se	m	se	m	se
5m	59.27	6.21	0.8	0.08	67.94	2.12	46.05	3.27	0.18	0.03
1m30	69.71	2.65	1.04	0.11	69.14	1.79	51.27	1.52	0.35	0.04
Base	71.91	1.93	1.18	0.11	71.89	1.22	56.64	1.4	0.35	0.08
p	0.08ns		0.04*		0.29ns		0.01*		0.06ns	

5m = at 5m height in the tree, 1m30 = at 1m30 height, Base = at the base of the tree, m= mean; se = standard error, *significant difference at the 5% level, ns= non-significant difference at the 5% level



[17] [18]

Figure 3: Picture showing "BING" experimental device

Thus, for the total area we have:

$$St = \frac{\left(\pi \sum_{i=1}^{4} R_i^{\,2}\right)}{4} \qquad (4)$$

For the heartwood surface we have:

$$SHW = \frac{\left(\pi \sum_{i=1}^{4} r_i^{\,2}\right)}{4} \qquad (5)$$

The percentage P of heartwood was calculated in relation to the total surface area of the disc by the relationship:

$$P = \frac{SHW}{St} \times 100 \qquad (6)$$

Measurement of modulus of elasticity and shear modulus

The modulus of elasticity and the shear modulus were measured on the same specimens as those used to measure the density of the wood. The device shown in figure 3 is used for the test. It consists of a microphone (LEM, Type EMU 4535), a data acquisition card (Pico Technology Type PicoScope 3224), a computer, an elastic system on which the wood material to be characterized is placed. The system is driven by the BING (Beam Identification by Non-destructive Grading) software, initially developed to evaluate wood material, in its version 9. The method was developed by CIRAD [16]. The principle of the measurement was largely developed in the work of Baillères et al. [16] cited by Hounlonon et al [17] and Kouchadé et al [18] and is based on the spectral analysis of natural bending vibrations.

Method of statistical analysis

The data were analyzed using excel and R software for ANOVA. A comparison of the means was made according to the radial position of the wood in the tree and the study station.

Results and Discussion

Dendrometric parameters and percentage of heartwood

The statistical analysis of some dendrometric parameters and the proportion of heartwood of *Acacia auriculiformis* from the three study sites is summarized in Table 2.

The study of the wood slices collected shows that the percentage of heartwood at man's height is on average about 70% for the Sèmè and Pahou plantations and 52% for the Itchèdè-Toffo plantation.

The plantation of Sèmè, 20-year-old seedlings is a mixture of *Acacia auriculiformis* and *Eucalyptus camaldulensis*, with *Acacia auriculiformis* dominating. The density of *Acacia auriculiformis* plants is 143 plants per hectare and that of *Eucalyptus camaldulensis* is 53 plants per hectare. Several illegal cuttings are noted. The litter is thick. The average diameter of *Acacia auriculiformis* trees is 28.3 cm, the average height of the shafts is 17.4 m and the total height is 24.2 m. *Eucalyptus camaldulensis* trees have an average diameter of 59.2 cm, the bole height is 22.9 m and the total height is 28.8 m.

The study of cut wood trays shows that the percentage of heartwood and bark thickness of *Acacia auriculiformis* species decreases from the base to the crown as shown in Figure 4. The percentage of heartwood at man's height is about 70%.

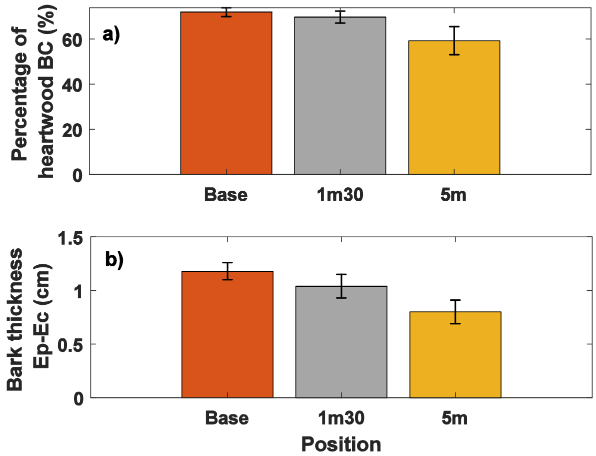


Figure 4: Percentage of heartwood (**a**) and bark thickness (**b**) of *Acacia auriculiformis* in Sèmè

The Pahou plantation is pure, but there are a few old *Eucalyptus camaldulensis* plants that were spared during the cuttings, and some *Acacia mangium* and palm plants are also present. The *Acacia auriculiformis* plantations are young, with an average age of 8 to 10 years. The density of *Acacia auriculiformis* plants is 516 plants per hectare. The average diameter of the trees is 23 cm, the height of the bole is 8 m and the total height is 12.2 m.
Acacia auriculiformis trees in this plantation have an average heartwood percentage of 70%. This percentage of heartwood (figure 5) decreases from the crown to the base of the tree, but there is no significant difference between the variations of these parameters from the base to the top of the tree.

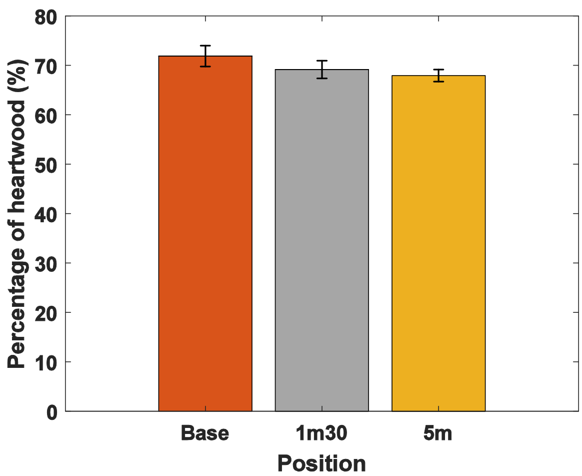


Figure 5: Percentage of heartwood of *Acacia auriculiformis* in Pahou

At Itchèdè-Toffo, the plantation is pure (i.e. not mixed with any other species) with a density of 790 trees per hectare. The trees have an average diameter of 17.2 cm, an average bole height of 7 m and a total height of 12.5 m. These plantations are very young at 5 years old.
The average percentage of heartwood of the samples taken in these plantations is 52% for an average bark thickness of 0.35 cm. Analysis of these results (Figure 6) shows that there is a significant difference between the percentages of heartwood in *Acacia auriculiformis trees* sampled in the Itchèdè-Toffo state plantations.

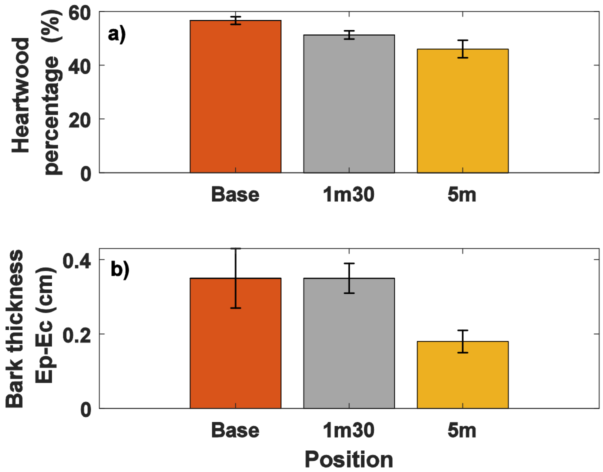


Figure 6: Percentage of heartwood (**a**) and bark thickness (**b**) of *Acacia auriculiformis* in Itchèdè-Toffo

A comparison of the *Acacia auriculiformis* plantations in Pahou and Sèmè shows that the growth of Acacia auriculiformis in Pahou is the highest. The two plantations being subjected to the same rainfall regime, this difference in growth could be explained by the type of stand and/or the type of soil or even the age. In Sèmè, *Acacia auriculiformis* is grown in a mixed stand, the competition effect of *Eucalyptus camaldulensis* which is very demanding in water could explain this difference.
Acacia auriculiformis wood has a high percentage (70%) of heartwood in the Sèmè and Pahou forests, which are respectively 20 years old and 8 to 10 years old, whereas it is only 52% in the 5-year-old Itchèdè-Toffo stand. These results show that the hardening of *Acacia auriculiformis* is early and that it evolves very little between 8 and 20 years of age. The same findings were made by Tonouéwa [10] on stands ranging from 4 to 29 years old. Thus, from 8 years onwards, the percentage of heartwood of *Acacia auriculiformis* varies very little. It is therefore possible that this visually perceptible characteristic is the trigger for the current use of this wood by craftsmen. Similarly, the high and stable proportion of heartwood in relatively old trees could also allow us to project the probable age of exploitability to between 8 and 20 years, the age of the Sèmè and Pahou plantations. Tonouéwa [19] already proposed a 15-year rotation for well-followed *Acacia Auriculiformis* plantations on specific soils. However, physical-mechanical characteristics and durability remain indispensable criteria for proposing species for a given use. Indeed, durability also remains an important criterion. Although not assessed in this work, *Acacia auriculiformis* has a moderate natural durability of the heartwood [20]. This durability can be seen in the dark colour of its heartwood and the presence of molecules such as phenol, tannins and other aromatic compounds in the wood [20]. Trials in India show that its wood is resistant to fungi from 8 years onwards [21]. Further tests in Bangladesh confirm the species' high natural durability to fungi [22].

Physical and mechanical characteristics

The density, elasticity and shear moduli of *Acacia auriculiformis* in the different sectors are presented in the graph in figure 7.

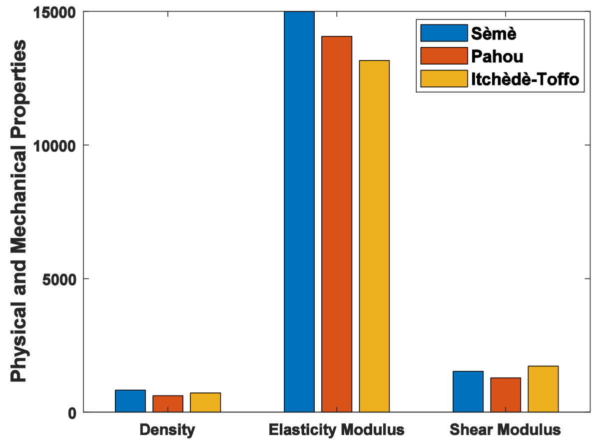


Figure 7: Density, elasticity and shear moduli of *Acacia auriculiformis* according to sectors

Table 3: Density, modulus of elasticity and shear modulus of *Acacia auriculiformis* wood collected in the Sèmè, Pahou and Itchèdè-Toffo plantations

Sector	Density (kg/m³)		Modulus of elasticity (MPa)		Shear modulus (MPa)	
	m	se	m	se	m	se
Sèmè	825.16a	3.41	14991.17a	110.87	1532.70b	55.23
Pahou	616.57b	2.11	14066.78b	120.71	1284.34a	33.48
Itchèdè-Toffo	722.92c	5.83	13164.47c	197.73	1726.13b	140.46
P value	0.000***		0.000***		0.000***	

m = mean, se= standard error; ***significant difference at 0.1% level

Table 4: Summary of data on the density and modulus of elasticity of some of Benin's prized wood species

Species	Density (kg/m³)	Modulus of elasticity (MPa)	Authors
Acacia auriculiformis	825.17	14 991.17	This study
Afzelia africana	700 - 880	13700	[27]
	800	17020	[28]
Milicia excelsa (Iroko)	640	12840	[28]
Kaya senegalensis (cailcedrat)	780	11650	[28]
Kaya ivorensis (African mahogany)	570	11820	[28]
Teak (*Tectona grandis*)	800	12913 - 14628	[17]
	670	13740	[28]
	550 à 660	12280	[29]
Gmelina arborea	490	9120	[28]
	400 à 510	5500 - 10800	[1]
	440 à 510	7500 - 9100	[30]
Anthonotha fragrans	688	14160	[18]

The analysis of these parameters presented in Table 3 shows that there is a significant difference at the 0.01% threshold between the density, modulus of elasticity and shear modulus of *Acacia auriculiformis* wood from the different plantations studied.

Acacia auriculiformis wood from Sèmè has the best density and the best modulus of elasticity. *Acacia auriculiformis* wood has a density ranging from 616.57 to 825.17 kg/m³, a modulus of elasticity varying between 13164.47 and 14991.17 MPa for a shear modulus varying from 1284.35 to 1726.13 MPa.

The physical and mechanical characteristics determined in the course of this work confirm the advantages of wood from this species. Indeed, the *Acacia auriculiformis* woods tested have a density varying between 617 and 825 kg/m³, a modulus of elasticity oscillating between 13164 and 14991 MPa for a shear modulus varying from 1284 to 1726 MPa. MacDicken and Brewbaker [23] found a density of 600-750 kg/m³ for *Acacia auriculiformis* in India. In Malaysia, an average density of 610 kg/m³ decreasing along the trunk from 630 to 580 kg/m³ was found for *Acacia auriculiformis* [24]. In Japan, on *Acacia auriculiformis* wood from Indonesia, Hasegawa et al [25] found a mean density of 679 kg/m³. Kumar et al [26] found a density of 722 kg/m³ for a modulus of elasticity 160500 kg/cm² or about 15740 MPa for *Acacia auriculiformis* in India. The same trends were confirmed by Tonouéwa [19].

The enthusiasm of craftsmen for using it as timber cannot be assessed without comparing it to other species conventionally used in Benin. Indeed, compared to these highly prized species in Benin (Table 4), *Acacia auriculiformis* has very appreciable physical and mechanical characteristics. The physical and mechanical properties of *Acacia auriculiformis* compared to those of teak show that this wood is of high quality. Indeed, *Acacia auriculiformis* wood is easy to work and offers a good finish with sharp tools [31]. The heartwood of *Acacia auriculiformis* is hard, medium-heavy and durable and is valued in cabinet making. It is suitable for pulp, kraft and semi-chemical paper [6]. Orwa et al [32] found that this

wood is excellent for making toys, handicrafts, various furniture, tool handles and construction if wood of appropriate circumference is available. Tonouéwa [19] found that from a young age (4-7 years), *Acacia auriculiformis* has high basal densities in the order of 500-600 kg/m^3, comparable to those of mature wood of several timber species such as *Tectona grandis* and *Khaya senegalensis*. The physical and mechanical characteristics of mature *Acacia auriculiformis* in Benin are also comparable to those of *Pterocarpus erinaceus* and *Afzelia africana*. The average modulus of elasticity of *Acacia auriculiformis* is about 14594 MPa, a value largely superior to the moduli of iroko which is 12840 Mpa, Kaya senegalensis which is 11650 MPa, and okoumé which is 9670 Mpa [27]. These values found in our study are in the range of the moduli of elasticity of some woods such as teak (13740 MPa), *Eucalyptus grandis* (15200 MPa), African ebony (15500 MPa), barwood also called kosso (15670 MPa) [28].
With a density higher than that of iroko, cailcedrat, African mahogany, teak and *Gmelina arborea*, the *Acacia auriculiformis* wood studied has a modulus of elasticity higher than those of the same species mentioned above. The use of this wood species as timber by our populations and craftsmen (**Figure 8)** is therefore not without interest.

Figure 8: Picture showing some works made with *Acacia auriculiformis* wood

It would therefore be possible to use them in structural and furnishing works, as some local wood material specialists already do so well. It is therefore imperative to complete this work by extending the range of samples and to carry out studies on the hygroscopic behavior of this species under high humidity and temperature gradients, especially during the African monsoon.
The other reason why craftsmen could use it more and more as timber is its availability. Indeed, this species has a great ability to reproduce easily in a wide range of ecological conditions. This has led to its reputation as an invasive species in some continents, notably in Asia, America and Africa [33]. Its invasiveness is also noted in America and Asia in countries and states such as Florida, India and Singapore [34-35]. It should be noted that the species has a high capacity for natural regeneration. As a result, it readily populates newly abandoned land and can be found beyond its range but does not affect the integrity of native forests [35].

Variation of technological characteristics according to the radial position of the wood

The study of the radial variation of the physical-mechanical characteristics of *Acacia auriculiformis* wood from the pith to the sapwood (Table 5), shows that there is a significant difference at the 0.1% threshold between the density and the modulus of elasticity of *Acacia auriculiformis* wood from the Pahou and Itchèdè-Toffo plantations according to the radial position of the wood in the tree. As for the shear modulus, there is no significant difference between these data from the pith to the sapwood of the tree. The density and modulus of elasticity evolve globally in a chronological way from the pith to the sapwood, with the highest densities and moduli near the sapwood as shown in figures 9 and 10.

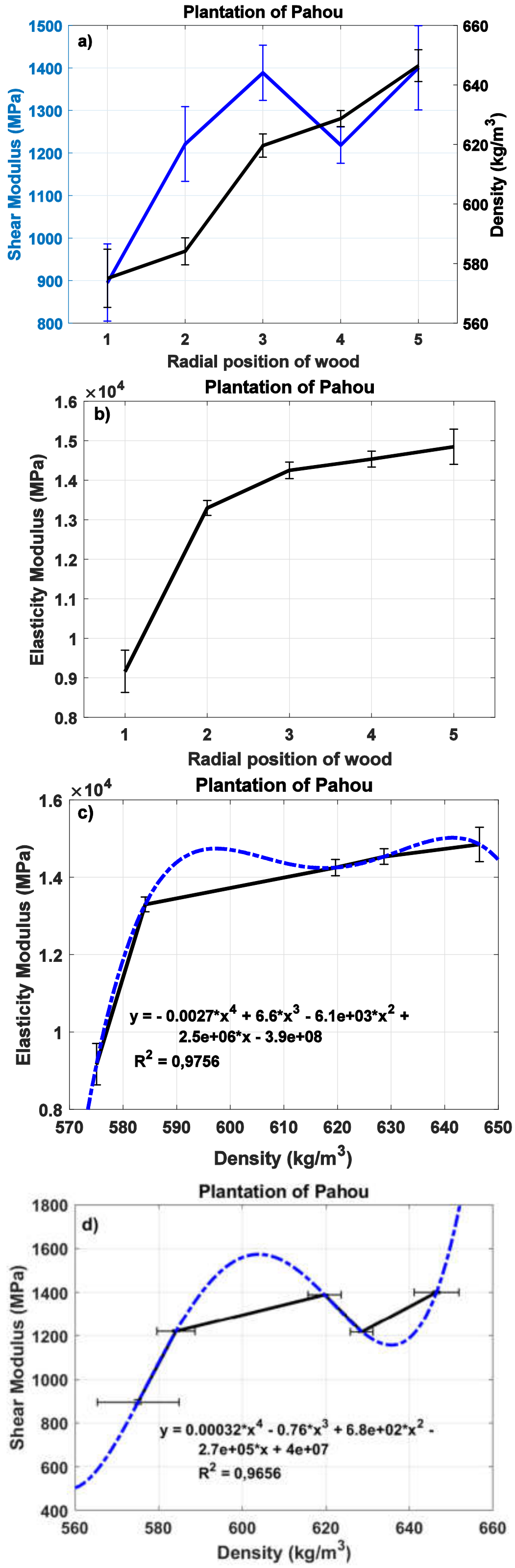


Figure 9: Variation of density, shear modulus and modulus of elasticity as a function of radial position (a, b); elasticity and shear moduli as a function of density (c, d) of *Acacia auriculiformis* wood in Pahou

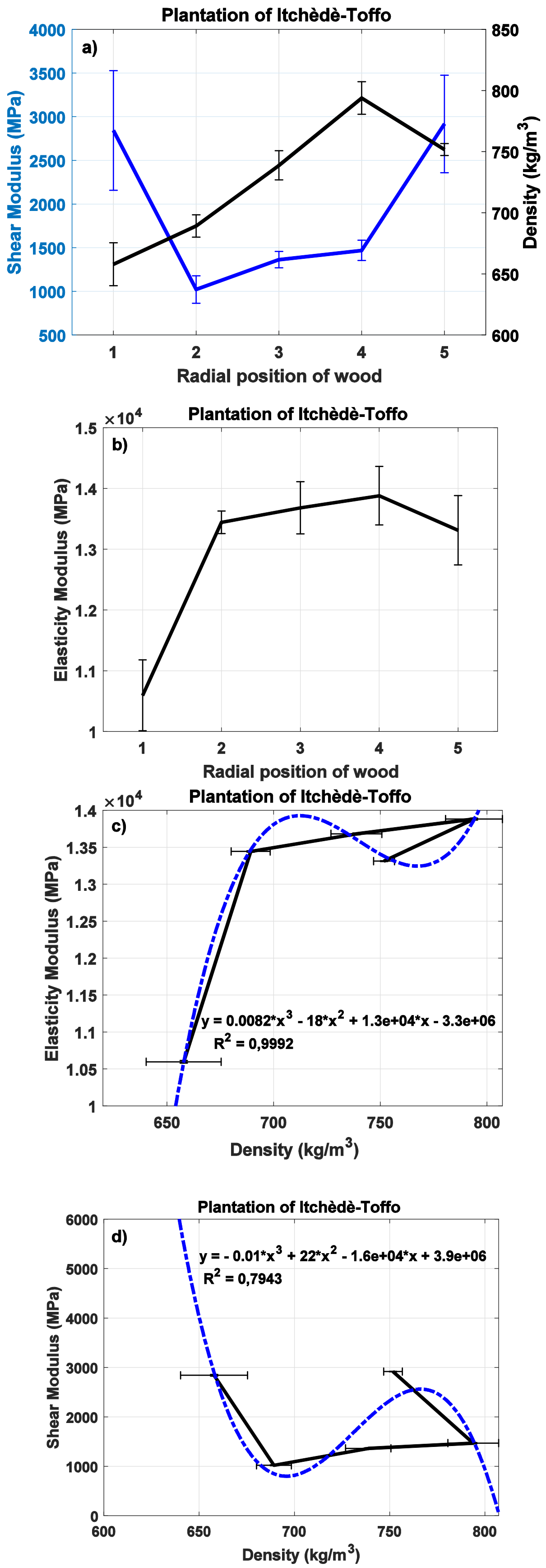


Figure 10: Variation of density, shear modulus and modulus of elasticity as a function of radial position (a, b); elasticity and shear moduli as a function of density (c, d) of *Acacia auriculiformis* wood at Itchèdè-Toffo

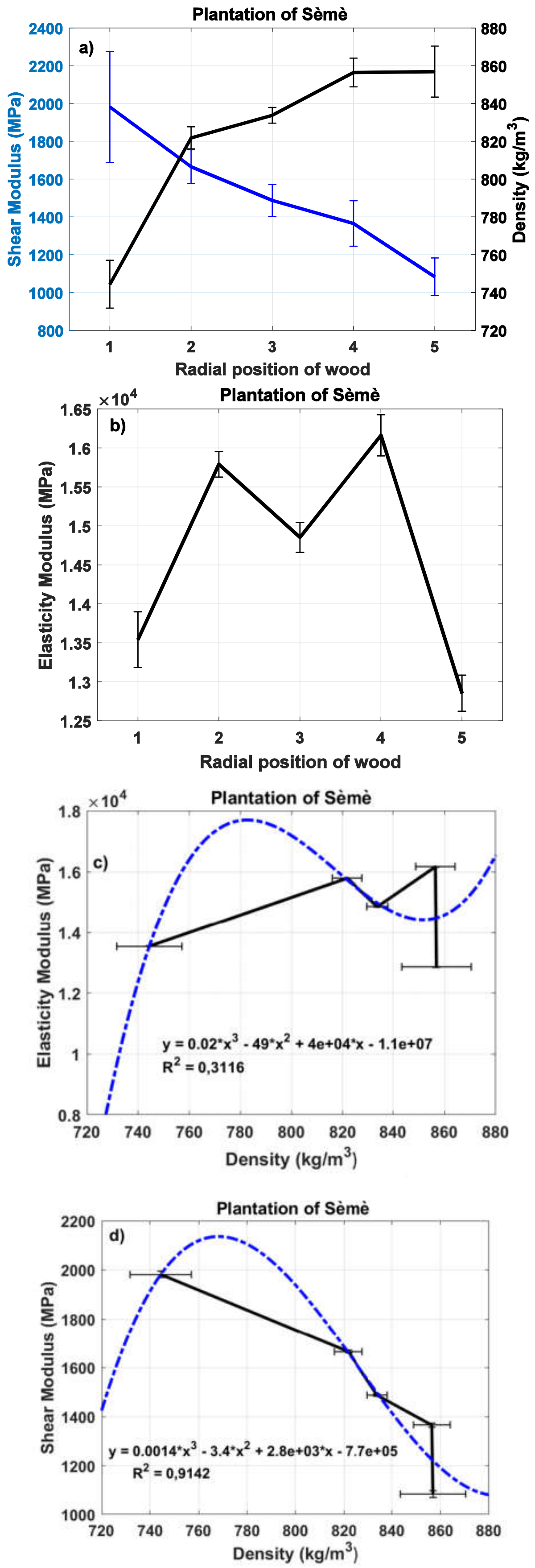


Figure 11: Variation of density, shear modulus and modulus of elasticity as a function of radial position (a, b); elasticity and shear moduli as a function of density (c, d) of *Acacia auriculiformis* wood in Sèmè

Table 5: Density, modulus of elasticity and shear modulus of *Acacia auriculiformis* wood as a function of the radial position of the wood in the tree of the Pahou, Itchèdè-Toffo and Sèmè state plantations

Sector	Radial position of the wood		1	2	3	4	5	P value
Itchèdè-Toffo (5 years)	Density (kg/m^3)	m	657.85	689.23	738.79	793.88	751.75	0.000***
		se	17.57	9.15	11.91	13.31	4.9	
	Modulus of elasticity (MPa)	m	10596.4	13443.3	13681.2	13881	13312.3	0.001**
		se	583.81	18.29	429.72	482.02	569.88	
	Shear modulus (MPa)	m	2842.24	1021.55	1363.32	1468.96	2916.77	0.33ns
		se	684.96	156.96	92.8	116.04	558.16	
Pahou (8 to 10 years)	Density (kg/m^3)	m	657.85	689.23	738.79	793.88	751.75	0.000***
		se	17.57	9.15	11.91	13.31	4.9	
	Modulus of elasticity (MPa)	m	10596.4	13443.3	13681.2	13881	13312.3	0.001**
		se	583.81	184.29	429.72	482.02	569.88	
	Shear modulus (MPa)	m	2842.24	1021.55	1363.32	1468.96	2916.77	0.33ns
		se	684.96	156.96	92.8	116.04	558.16	
Sèmè (20 years old)	Density (kg/m^3)	m	744.42	821.81	833.77	856.42	856.86	0.000***
		se	12.65	5.85	4.16	7.6	13.47	
	Modulus of elasticity (MPa)	m	13542.3	15790.2	14853.3	16162.6	12853.7	0.156ns
		se	357.35	163.14	191.42	264.54	231.48	
	Shear modulus (MPa)	m	1981.68	1666.02	1487.3	1365.15	1083.48	0.000***
		se	294.24	89.8	85.15	120.51	99.24	

m = mean, se= standard error; ***significant difference at the 0.1% level, ns= non-significant difference

Thus, there is a significant difference at the 0.1% threshold between the density and shear modulus of *Acacia auriculiformis* wood from the Sèmè plantations as a function of the radial position of the wood in the tree, whereas there is none between the density and modulus of elasticity. Thus, despite the increasing evolution of density from pith to sapwood at the Sèmè site, the modulus of elasticity fluctuates (Figure 11).

In the evaluation of the age of exploitability, we had to analyze the radial variation of density, modulus of elasticity and shear modulus, from the heartwood to the sapwood. The results show the progressive evolution of these parameters in the tree at the level of the youngest stands (Pahou, 8 to 10 years old and Itchèdè-Toffo, 5 years old), on the other hand, for the wood coming from Sèmè with a stand of 20 years old, very little variation is noted in the radial direction. This can be explained by the excessive presence of juvenile wood in the younger stands. Thus, depending on the radial growth of the tree, there is the formation of juvenile wood close to the pith and mature wood close to the sapwood [36]. Juvenile wood generally has inferior characteristics to mature wood although the differentiation between these two zones in the wood varies from species to species e.g., for *Pinus brutia*, the differentiation is found at the twelfth growth ring [37]. The growth of the tree during its first years of life is rapid and involves a low density of wood. This density increases as this growth decreases. The tree invests in surviving in its environment as an adult with high wood density. Wood density increases from pith to sapwood [38-39], but there are species whose density decreases from pith to sapwood [38]. However, the characteristics of the sapwood are generally lower than those of the heartwood. Wood density explains the mechanical behavior of the tree and is a major functional trait of the tree [38]. The radial increase in density from the heartwood to the sapwood for the young stand explains that the mature wood forms gradually and reaches its stability between 15 and 20 years of age as observed in the Sèmè stand. This age range could be ideal for the exploitability of a plantation of *Acacia auriculiformis*. The variation in radial wood density can also be explained by changes in the anatomical characteristics of the wood, which vary during the growth of the tree, especially in the early years. For example, in *Heliocarpus appendiculatu*, 85% of the variation was explained by the differentiation of axial parenchyma into fibres [38]. Pending a large-scale study on plantations of different ages, from 10 years, the exploitable age of *Acacia auriculiformis* can be estimated at 15 years as proposed by Tonouéwa [19].

Conclusions

The study of the percentage of heartwood, density, elasticity and shear moduli of three different ages of *Acacia auriculiformis was* undertaken in three regions of southern Benin (Pahou, Sèmè and Itchèdè-Toffo). This study shows that the percentage of heartwood is high after 10 years and is strongly related to the values of the physico-mechanical parameters. The physico-mechanical parameters obtained are acceptable and better than those of conventionally used species. This justifies the use of *Acacia auriculiformis* as timber. The low variation in density at all points of the heartwood of *Acacia auriculiformis* from the age of 10 years onwards suggests an exploitable age of 15 years on average for its use as timber.

Apart from the physico-mechanical characteristics, the durability and availability of the species certainly played a role in its use as timber. However, the age of exploitability remains to be refined by further studies.

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Conflicts of Interest:

In view of this submission the authors declare that there are no conflicts of interest.

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