

AXIAL AND RADIAL EVALUATION OF THE BASIC DENSITY AND FIBER DIMENSIONS OF *Guazuma crinita* MARTIUS WOOD

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Resumo

Avaliação axial e radial da densidade e dimensões básicas de fibras em madeira de Guazuma crinita Martius
Este trabalho teve por objetivo avaliar a variação radial e axial da densidade básica e das dimensões das fibras da madeira da árvore *Guazuma crinita* Mart. Foram usadas dez árvores com idades de cinco e de oito anos oriundas de plantações florestais do setor de Maquizapallo, localizado na cidade de Puerto Inca, Huánuco, no Peru. As variáveis analisadas foram a densidade básica tendo por referência a norma NTP 251.011: 2014, e as dimensões das fibras. As árvores foram derrubadas e seccionadas em pedaços de 4 metros, divididos em três partes – basal, média e apical – para a determinação da densidade e avaliações das fibras. Em geral, a densidade básica e as características anatômicas avaliadas diminuem da base para a ápice; desse modo, estas aumentam da medula para o córtex, no que a idade da árvore teve influência significativa na densidade básica mas não nas características anatômicas; não obstante, por ser a densidade básica maior para 8 anos seu emprego poderia ser em usos que não exijam suportar grandes esforços e ser usada comercialmente. *Palavras-chave:* bolaina blanca (“moço branco”), características anatômicas, propriedades físicas.

Abstract

The objective of the work was to evaluate the radial and longitudinal variation of the basic density and fiber dimensions of the *Guazuma crinita* Mart. Ten trees of five and eight years were used. They came from forest plantations of Maquizapallo located in the city of Puerto Inca, Huánuco – Peru. The variables analyzed were basic density based on the standard NTP 251.011: 2014, and the fibers characteristics. The trees were felled and sectioned into 4-meter logs, divided into three parts basal, middle and apical for density determination and fiber evaluations. In general, the basic density and the anatomical characteristics evaluated decrease from the base to the apex, meanwhile, they increase from the marrow to the cortex where age had a significant influence on the basic density but not on the anatomical characteristics, however, since the basic density is greater for 8 years, it could be used where no great effort is needed and also commercially.

Keywords: bolaina blanca, anatomic characteristics, physical properties.

INTRODUCTION

In South America the plantings are composed by species with short cycle and rapid growth, especially Pine and Eucalyptus; however, when wood from other species is considered, mostly the natives, the awareness about its properties or previous experience of use in industrial scale are small (VALENTE *et al.*, 2013). Peru is the country with the biggest delay in the continent on reforestry matters, even though there are 10,5 million of hectares suitable to reforestry plantations. The surface, according to official data, does not reach 10 %. One of the main causes is the scarce development of knowledges that facilitate to increase productivity and competitiveness in the reforestry sector, being of high priority the generation of scientific and technological knowledge to produce quality wood (SERFOR, 2016).

Guazuma crinita (“bolaina blanca”, or “moço branco”) is a species to wood use of rapid growth, deriving from secondary forests, becoming in the last few years a species with good potential to its manufacturing, processing and commercialization (PUTZEL *et al.*, 2013). The demand for this wood grew significantly, standing out among the twenty main species exploited in national-level (SERFOR, 2016), reaching a volume of wood in logs of 56119,05 m³ and of 3118,06 m³ in the case of already sawed wood, enabling the public and private sectors to establish plantations of this species, because of its short rotation cycles and high productivity, making it possible to obtain profits in short-term when compared to wood products derived from primary forests (IIAP, 2009). In 2018, the country had about 20 thousand hectares of “bolaina blanca”. The more moderate projections indicate that this species will reach around 200 thousand hectares in 2025 (SOUNDRE, 2019).

The distribution of *Guazuma crinita* is wide in the neotropics, ranging from Central America to Brazil in the amazon region. In terms of altitude, it is found until 1500 m above sea-level. The trees reach diameters of 25

to 80 cm and 15 to 30 m of total height, with straight trunk and ramifications since the last third (REYNEL *et al.*, 2003). It belongs to the Malvaceae family, being an important species to reforestry and agroforestry plantations in the Peruvian Amazon basin, serving as an indicator of fertility of the soil and growing rapidly, with the rotation age of 6 to 12 years in the Peruvian Amazon. The trees grow in dense plantation areas of up to 1200 specimens/hectare in young fallow (< 3 years) and up to 500 mature trees (≥ 25 cm of DBH – Diameter at Breast Height) by hectare after harvest (IIAP, 2009; WEBER *et al.*, 2011).

The quality of the wood is linked to its anatomy and physical and mechanical qualities. Anatomically, in the tropical species of America, it has been observed different patterns of variation in the cellular dimensions, which is explained by the activity of the cambial cells. They produce along a certain period elements of bigger dimensions, until reaching stabilization in more advanced ages along the radius of the tree. The fibers located in the rings of growth closer to the pith present smaller dimensions than the ones situated in the growth rings closer to the cortex of the trunk (VALENTE *et al.*, 2013; LIMA *et al.*, 2011). For example, the length of the fiber until the cortex are referred in the *Gallesia integrifolia* (ANDRADE *et al.*, 2009), the *Cariniana legalis* (GARCIA *et al.*, 2009), the *Anadenanthera colubrina* (SUCKOW *et al.*, 2009) and *Anadenanthera peregrina* (VALENTE *et al.*, 2013). It was also noted an enlargement in the thickness of the wall of fiber and a reduction in the diameter and lumen of the pith fibers in relation to the cortex. Although, Zanon *et al.*, (2008) did not observe significant statistical variations in *Croton floribunda*, in *Piptadenia gonoacantha*, and Longhi *et al.* (2010) also did not find clear tendencies of variation in the diameter of the fibers.

At the same time, regarding physical properties, the density is an indicative of wood quality, constituting a good index to various purposes, being a feature capable of genetic improvement and considered highly transferable by inheritance (Trautwein *et al.*, 2014). The density is explained by the heterogeneous structure, as consequence to the growth of the tree: extremely complex process and influenced by climate, soil, competition among trees, forestry techniques and age. Even so, differences in the density according to axial and radial position of the tree are found (IGARTÚA; MONTEOLIVA, 2010). Thus, for example, axially the density in *Ficus insipida* enlarges the base to the apex, and radially the pith to the cortex.; in *Amburana cearenses*, Portal *et al.* (2019) found the same radial behavior. In the broad-leaved of diffuse porosity species, it is to expect density variations even among trees, despite the strong genetic determinism, because there are found differences among trees of the same location and age (DOWNES, cited by IGARTÚA AND MONTEOLIVA, 2010). Therefore, this variability has an impact in its industrial use, because it affects the final product (LIMA *et al.*, 2011).

The wood density of the *Guazuma crinita* varies genetically according to its origin. The results according to its origins and tests of provenance suggest that the sources of rapid growth can be selected in a younger age without reducing significantly the density of the wood (WEBER; SOTELO-MONTES, 2008). Likewise, evaluations of variation among the main physical properties, according to its sources, cope with the significant statistical differences in the physical properties, except the density of green wood (TUISIMA-CORAL *et al.*, 2017).

The data of average basic density of the wood of *Guazuma crinita* at eight years of age is 433 kg/m³ (TUISIMA-CORAL *et al.*, 2017), number slightly bigger than Weber e Sotelo-Montes (2008) reported to 32 months (417 kg/m³). This variation is due to environmental factors, with low influence of age, because it is susceptible to strong genetic control (TUISIMA-CORAL *et al.*, 2017). Reports about basic density indicate that it is bigger in the base than the superior part of the trunk; besides that, the trees had lower density and bigger differences between the inferior and superior portions of the trunk, but this relations depended on the source of the seed and the growth zone (WEBER; SOTELO-MONTES, 2008), as well as the variation in radial direction, just as in the longitudinal direction are related to the age of the tree, the sample, the genotype and environmental conditions.

The study of the characterization of the wood of *Guazuma crinita* is justified according to the very few existent information about the variability of the wood derived of plantations, since the present work had as objective to evaluate the basic density and fiber dimension, as well as its internal variation in longitudinal and radial direction, looking to a better knowledge of its technological properties, relating it to quality parameters.

MATERIALS AND METHODS

The wood of *Guazuma crinita* is derived of forestry plantations of the Maquizapallo sector, in the city of Puerto Inca, Huánuco, Peru; geographically located in the coordinates 9°37'43" South and 74°58'28" West; with 145 m of altitude (Figure 1). The zone presents an annual average of precipitation of 2482 mm, with minimum temperature of 22° C and maximum 35° C. The plantation soil is alluvial, with loamy texture and silty loam; pH de 5,5, organic matter of 4%; CIC of 10,8 meq/100g and effective depth bigger than 90 cm. The wood samples were collected in field in november/2016. The spacing between trees was 3 x 3 m. The characteristics of trees are shown in the Table 1.

Tabela 1. Dados dos espécimes amostrados.
Table 1. Data from evaluated trees.

Age	Nº individual	DBH(cm)	H total (m)	H omercial (m)
5 years (63 months)	1	18,8	16,0	12,8
	2	21,6	17,4	15,4
	3	21,6	17,0	13,2
	4	22,0	17,5	14,8
	5	21,3	16,0	13,4
8 years (103 months)	1	26,4	25,0	20,6
	2	27,7	26,0	21,3
	3	27,1	20,0	15,9
	4	26,1	22,0	18,0
	5	26,1	19,0	15,9

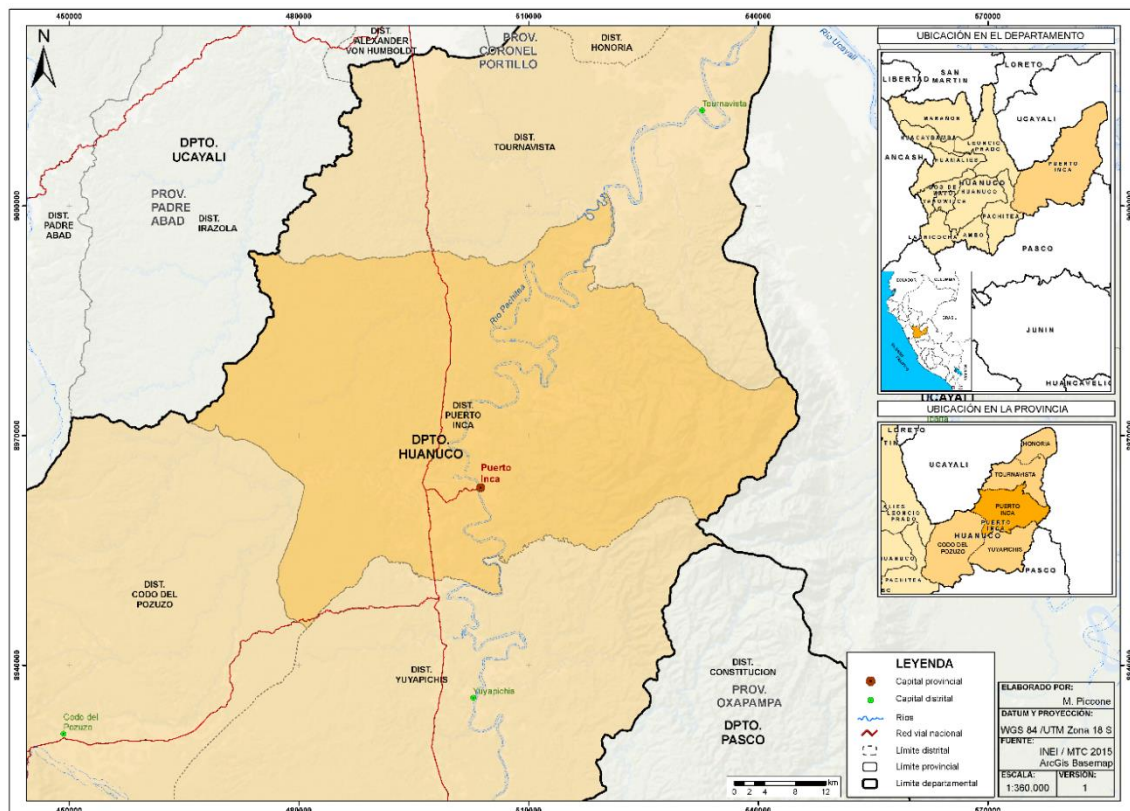


Figura 1. Localização das plantações de *Guazuma crinita* em Huánuco (Peru)
Figure 1. Plantation of *Guazuma crinita* in Huánuco (Perú).

Cut, collect and preparation of the wood samples

In the moment of the cut the trees were five years old (63 months) and others, eight years old (103 months). Five trees were selected by age following the Peruvian Technical Standard 251.008:2012; the ones that were cut, to what the comercial height measure were used, dividing in three part (basal, middle and apical), meeting

the methodology Valente *et al.* (2013), taking a meter of each piece of the inferior portion to determinate the density and evaluate the fibers. From the separated meter, it was taken a 5 cm slice to the evaluation of the dimensions of the fibers (length, thickness of the wall, diameter of the lumen and total width), in three different parts of the trunk and three radial positions to each height. With the remaining wood, the basic density was determined (Figure 2).

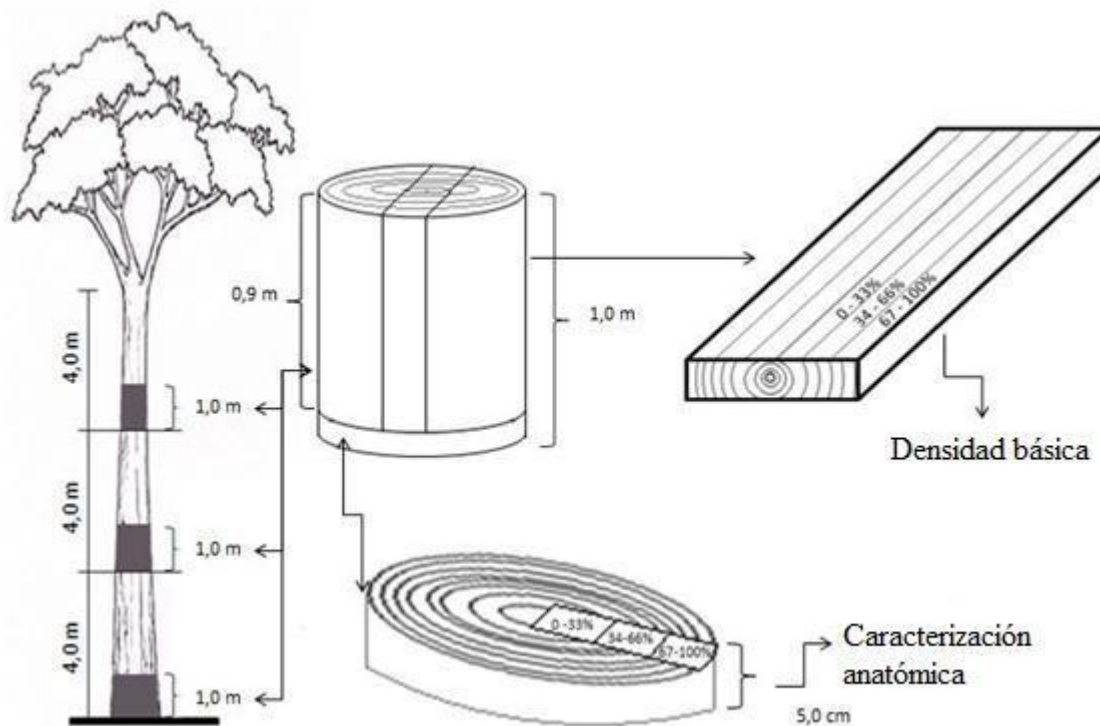


Figura 2. Posições das amostras para determinação da densidade básica e avaliação das fibras.
 Figura 2. Samples position for analysis of basic density and fiber dimension.

The analysis of the basic density was conducted according to the procedures described in the standard NTP 251.011: 2014. The discs, to the different heights of the five trees, were marked and cut samples in three radial positions in the direction marrow-cortex (at 1/3, 2/3 and 3/3 of the marrow), to the acquisition of macerated material. To the fibers temporary histologic slides were prepared, gathering light microscopy images in amplifications of 40 and of 400x to the measurement of the dimensions of 25 fibers with the programme of image analysis “Leica Application”, determining length, width and diameter of the lumen, and estimating the thickness of the wall through half of the difference between width and diameter of the lumen.

Statistical Analysis

To the analysis of the data, the programme R was used, considering each tree as a repetition. The effect of the axial and radial positions was evaluated through the analysis of variance (ANOVA). At last, the Tukey test was applied with 95% of reliability, when the differences between the effects were observed.

RESULTS

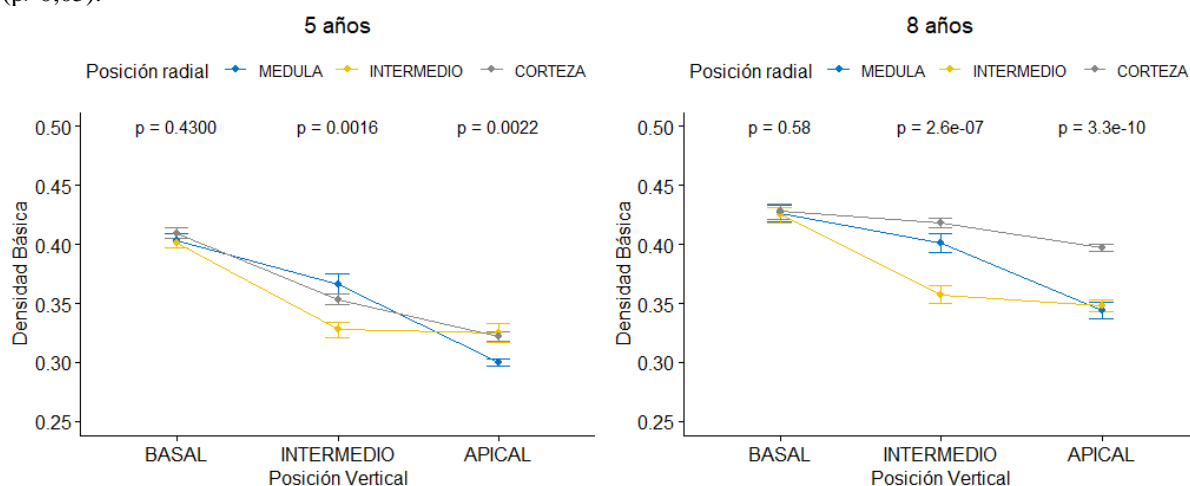
The average value and the variability coefficients of basic density and dimensions of the wood fiber of the *Guazuma crinita* to the two ages presented on the Table 2 and the tendencies of variation are observed in the Figure 3.

Tabela 2. Valores médios de densidade básica e dimensões de fibras de *Guazuma crinita* nas direções axial e radial.

Table 2. Mean value from basic density and fiber dimensions for *Guazuma crinita* in axial and radial direction.

Average Values						
		DB (g/cm ³)	L (mm)	D (µm)	DL (µm)	EP (µm)
5 years (63 months)		0.358	1.369	28.050	21.915	3.071
		(0.051) (14) ¹	(0.186) (14)	(5.056) (18)	(5.031) (23)	(0.655) (21)
8 years (103 months)		0.396	1362	26.947	20.525	3.204
		(0.048) (12)	(0.191) (14)	(5.163) (19)	(5.333) (26)	(0.615) (19)
Axial direction						
5 years (63 months)	Basal	0.405 a ²	1.493 a	27.526 b	21.292 b	3.12 a
		(0.03) (7)	(0.164) (11)	(4.878) (18)	(4.712) (22)	(0.593) (19)
	Intermedia	0.350 b	1.334 b	28.001 ab	21.613 b	3.198 a
		(0.042) (12)	(0.154) (12)	(4.617) (16)	(4.639) (21)	(0.709) (22)
	Apex	0.340 c	1.279 c	28.624 a	22.84 a	2.896 b
		(0.043) (13)	(0.168) (13)	(5.577) (19)	(5.567) (24)	(0.619) (21)
8 years (103 months)	Basal	0.426 a	1.408 a	27.232 a	20.702 ab	3.265 a
		(0.040) (9)	(0.206) (15)	(5.509) (20)	(5.845) (28)	(0.646) (20)
	Intermedia	0.395 b	1.379 a	26.323 b	19.952 b	3.166 a
		(0.043) (11)	(0.174) (13)	(4.881) (19)	(4.885) (24)	(0.556) (18)
	Apex	0.365 c	1.302 b	27.285 a	20.922 a	3.182 a
		(0.038) (10)	(0.177) (14)	(5.036) (18)	(5.189) (25)	(0.640) (20)
Radial direction						
5 years (63 months)	1 (0-33%)	0.357 a	1.267 c	28.37 a	22.406 a	2.982 b
		(0.057) (16)	(0.195) (15)	(5.140) (18)	(5.098) (23)	(0.569) (19)
	2 (34-66%)	0.353 a	1.390 b	27.787 a	21.685 a	3.06 ab
		(0.050) (14)	(0.166) (12)	(5.087) (18)	(5.091) (23)	(0.673) (22)
	3 (67-100%)	0.363 a	1.449 a	27.994 a	21.655 a	3.171 a
		(0.045) (12)	(0.144) (10)	(4.934) (18)	(4.878) (23)	(0.701) (22)
8 years (103 months)	1 (0-33%)	0.392 b	1.243 c	28.037 a	21.833 a	3.082 c
		(0.053) (14)	(0.164) (13)	(5.029) (18)	(5.114) (23)	(0.618) (20)
	2 (34-66%)	0.379 b	1.396 b	26.721 b	20.299 b	3.211 b
		(0.050) (13)	(0.174) (12)	(5.534) (21)	(5.703) (28)	(0.569) (18)
	3 (67-100%)	0.415 a	1.450 a	26.082 b	19.444 b	3.319 a
		(0.032) (8)	(0.173) (12)	(4.712) (18)	(4.885) (25)	(0.639) (19)

DB: densidade básica; L: comprimento das fibras; D: diâmetro das fibras; DL: diâmetro de lumen; EP: espessura da parede das fibras; 1: medula; 2: intermédia; 3: córtex; ¹Valores entre parênteses de esquerda à direita debaixo do promédio, correspondem ao desvio padrão e a coeficiente de variação respectivamente; ²Médias seguidas da mesma letra dentro de uma mesma coluna, não diferem estatisticamente entre sí, pelo teste de Tukey ($p > 0,05$).



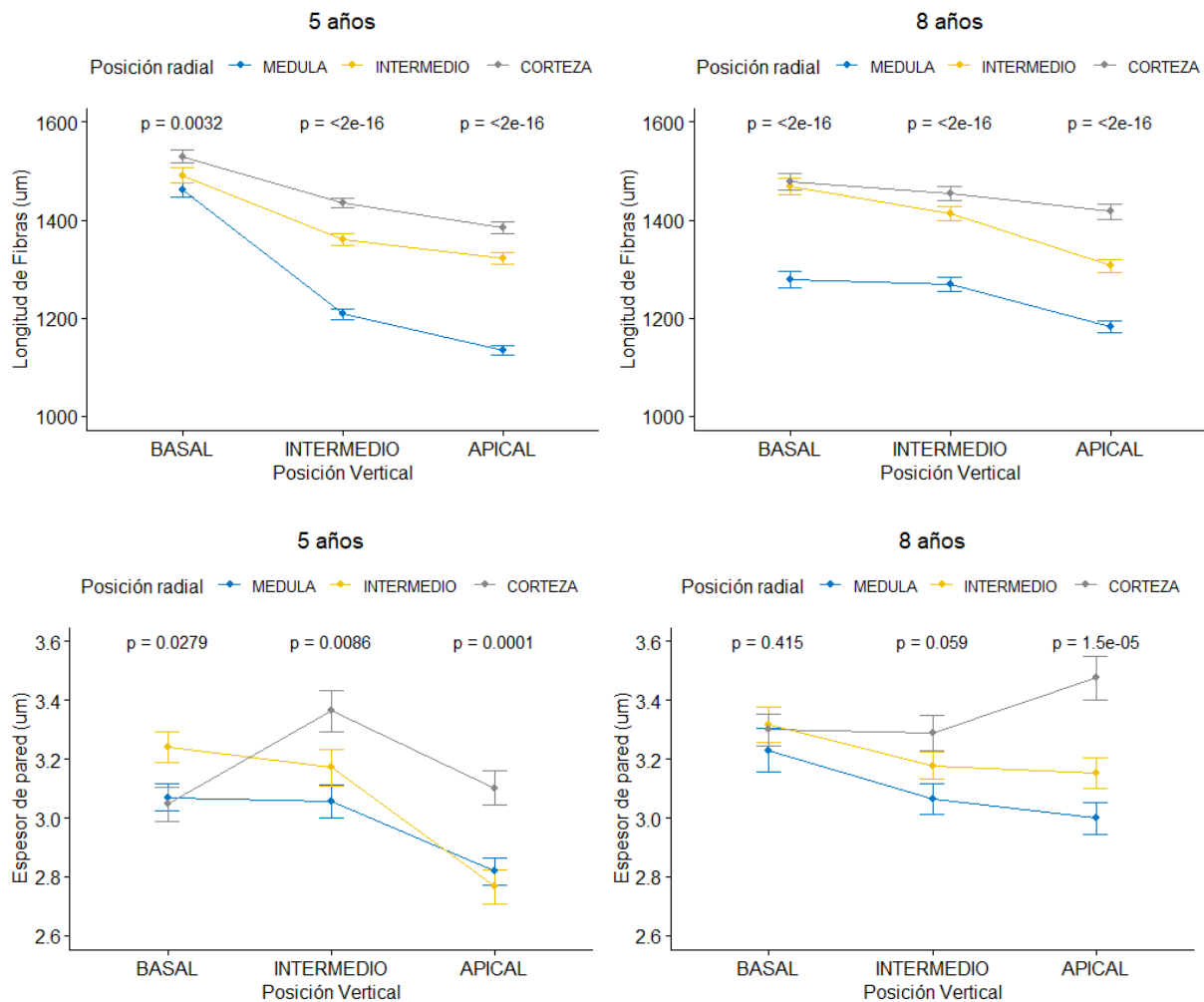


Figura 3. Padrões de variação axial e radial para a densidade básica, comprimento e espessura da parede das fibras para 5 e 8 anos.

Figure 3. Patterns of axial and radial variation for basic density, fibers length and fiber wall thickness for 5 and 8 years.

DISCUSSION

It is noted that the average values of basic density increase from 0,377 to 0,396 g/cm³ to the ages of 5 and 8 years respectively. The values decrease from the base to the apex, and at the same time in the radial direction increase from the marrow to the cortex (Figure 2). In both directions there are statistics differences to the three positions; except in the radial direction to the 1 and 2 positions, which are statistically equal to the age of 5 years and to the 1 position close the marrow, that is bigger than the intermediate position to the age of 5 years.

The collected values of density are smaller that the one related by Weber and Sotelo-Montes (2008) to the same age. In the axial direction the basic density decreases from the base to the tree top, which is explained by the bigger compression of the tissues due to the overlapping of cells along the trunk and the tree top (ALI *et al.*, 2010); even so, this variation arise from the different radial and longitudinal positions (WEBER; SOTELO-MONTES, 2008; TUISIMA-CORAL *et al.*, 2017; TRAUTENMÜLLER *et al.*, 2014). The radial behavior of increase of the basic density of the marrow in direction the cotex is related in other broad-leaved plants such as *Anadenanthera peregrina* (VALENTE *et al.*, 2013) e em plantações de *Tectona grandis* (LIMA *et al.*, 2011).

In the fibers length, to both ages the values are similar; axially it is observed a decrease from the base to the apex; and only to the basal and intermediate portion to the age of 8 years there are no statistics differences between them. Radially statistic differences are presented to the three positions with a increase of the marrow in direction to the cortex (Figure 2). In the diameter of the fibers there is no dtermined tendency; although, axially to both ages higher values in apex portion are noted; at the same time, to 8 years the basal and apex level are statistically equal, but higher in the intermediate level. Radially, to the age of 5 years there are no statistic

differences in the 3 positions; and to 8 years the positions 2 and 3 are equal, but with lower values closer to the marrow.

As for the diameter of the lumen longitudinally, to the age of 5 years it is bigger in the apex portion than in basal and intermediate level, which are statistically equal; to 8 years the basal level has an interaction with the intermediate and apex levels. In the radial direction, to both ages there are no statistical differences between them; except in the position 1, close to the marrow, that has higher value than the position 2 and 3.

In the thickness of the wall of the fiber this value increases with the age and axially tends to be homogeneous, except to the apex level at 5 years, which is lower. Radially an increase was noted in the marrow-cortex direction; with significant statistical difference in the 3 positions to both ages, except position 2 at 5 years.

Altogether, the values obtained to fibers in the present study are slightly higher than the ones obtained in the anatomical evaluation in the *Guazuma crinita* in natural forest situation, which related a length of 657 μm , fiber diameter of 18 μm and thickness of the wall of 3 μm (ACEVEDO; KIKATA, 1994).

This same pattern of axial and radial variation was found to length and thickness of the wall of the fibers to other broad-leaved plants; similarly in axial direction to the *Anadenanthera colubrina* (SUCKOW *et al.*, 2009) and in radial direction to the *Anadenanthera peregrina* (VALENTE *et al.*, 2013) and (*Parkia gigantocarpa* (MIRANDA; CASTELO, 2012).

The variability coefficient to the DB is 14% to 5 years and 12% to 8 years. Although, to the *Ficus insipida* coefficients of variation of 5,99% to 39,1% are found (VIDAL *et al.*, 2011). To the *Anadenanthera peregrina* Valente *et al.* (2013) reports a variability coefficient of 17,86%; in contrast, Trautenmüller *et al.* (2014) finds variability coefficients 5,2% and 12,54% to the basic density in *Cordia americana* and *Alchornea triplinervia* respectively.

The variability coefficients found (Table 2) are within the range noted by other authors and, as for specific characteristics, can be considered slightly high. These differences are possibly due to the individual variability among five trees of the *G. crinita*, and mainly due to age. It is important to add that Igartúa and Monteoliva (2010), quoting Wilkes (1988), note that difference among trees in the same location and age can be found.

Altogether, the average anatomical values to both ages are similar; however, the density to 8 years is higher and its use could be in commercial scale that does not require to endure big efforts.

CONCLUSIONS

According to the obtained results to basic density and anatomic characteristics of the *Guazuma crinita* to 5 and 8 years it is possible to conclude that:

- The basic density and length of the fibers present significant variations in the axial and radial directions to both ages.
- The diameter of the fiber does not show determined tendency to both directions; although the diameter of the lumen presents significant difference in the axial direction, but not in the radial direction.
- The thickness of the wall to both ages presents significant differences in the radial direction, but not in the axial direction.
- Altogether, the basic density and anatomical characteristics evaluated decrease from the base to the apex, it increases from the marrow to the cortex.
- The age variable had significant influence over the basic density, but not over the anatomical characteristics.

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