

**WOOD AXIAL CHARACTERIZATION OF 32-YEAR-OLD
Croton piptocalyx Müll. Arg. EUPHORBIACEAE¹**

**CARACTERIZAÇÃO AXIAL DA MADEIRA DE *Croton piptocalyx* Müll. Arg.
EUPHORBIACEAE COM 32 ANOS DE IDADE**

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ABSTRACT – This paper aims to characterize the wood anatomy of *Croton piptocalyx*. To carry out an investigation of axial variation, discussing it in a functional context, helping to increase knowledge about the species. Five randomly selected 32-year-old trees were felled at the Luiz Antonio Experimental Station, located in Luiz Antonio City, São Paulo state, Brazil. From stems, discs were cut from six different stem heights (stem base, 1 m, 2 m, 3 m, 4 m, and 5 m). For each disc, samples close to the bark were removed for wood anatomy studies and specific gravity calculation. Wood anatomy of *C. piptocalyx* generally agrees with that of other species of the genus as described in the literature. However, variation in both quantitative and qualitative data could be related to tree age and species differences. Axial variations found in vessel element length, vessel diameter and ray height can be respectively related to the hypothesized Typical Radial Pattern based on the occurrence of shorter and narrower cells in younger parts of the wood, involving vessel element length and diameter, and mechanical requirement in the case of higher rays at the trunk base.

Keywords: caixeta; specific gravity; tropical wood; wood anatomy.

RESUMO – Nosso objetivo foi caracterizar anatomicamente a madeira de *Croton piptocalyx*, investigando a variação axial e discutindo-a em um contexto funcional, contribuindo para aumentar o conhecimento sobre a espécie. Cortamos aleatoriamente cinco árvores com 32 anos de idade na Estação Experimental de Luiz Antonio, na cidade de Luiz Antonio, São Paulo, Brasil. Dos troncos retiramos discos em seis alturas diferentes (base do tronco, 1 m, 2 m, 3 m, 4 m e 5 m). Em cada um dos discos, retiramos amostras próximas à casca para estudos anatômicos e determinação da densidade aparente. A anatomia da madeira de *C. piptocalyx* em geral é similar com o que já está descrito na literatura para outras espécies do gênero. No entanto, há variações quantitativas e qualitativas, que em parte podem estar relacionadas às diferenças na idade de árvores e, obviamente, à diferença entre espécies. As variações axiais no comprimento dos elementos de vaso, diâmetro do vaso e altura do raio, devem estar relacionadas, respectivamente, ao Típico Padrão Radial, caracterizado pela ocorrência de células menores e mais estreitas em partes mais jovens da madeira (comprimento do elemento de vaso e diâmetro do vaso) e aos requerimentos mecânicos, no caso dos raios mais altos na base do tronco. –

Palavras-chave: caixeta; densidade aparente; madeiras tropicais; anatomia da madeira.

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1 INTRODUCTION

The genus *Croton* comprises 316 species in Brazil, of which 252 are endemic, occurring throughout the country. *Croton piptocalyx* Müll. Arg., commonly known as caixeta, is a native and endemic species in Brazil, distributed in the northeast (Bahia state) and southeast (Minas Gerais, Rio de Janeiro and São Paulo states) in the Atlantic Forest (Cordeiro et al., 2016). Its wood has low density, low durability under adverse conditions, and it shows no distinctive color between heartwood and sapwood. It can be used for internal work, ceilings, toys, light artefacts or boxes, etc. The tree shows rapid growth, and may be used in recovery planting (Lorenzi, 2002).

The wood of some species of this genus have already been studied (Luchi, 2004; Wiedenhoef, 2008; Wiedenhoef et al., 2009; Longui et al., 2012; Novello et al., 2012; Sieglöch et al., 2012). However, no studies in the literature have reported on *C. piptocalyx* wood. Therefore, this paper examines the axial variations in stem of this native Brazilian species in order to expand knowledge about axial transport of water and mechanical requirements. The results provide information about wood quality along the trunk, as well as ecophysiology of this species. Thus, results can be interpreted and used in future studies of the species.

To study the structure and function of wood is essential to understand how anatomical features interact directly influences physical and mechanical properties and their variations along the trunk, in turn giving a particular wood quality for specific purposes (Wiedenhoef, 2010). In particular, this paper characterizes the wood anatomy of *Croton piptocalyx* by investigating axial variations within a functional context.

2 MATERIAL AND METHODS

2.1 Study Site and Sampling

The experimental planting was established in 1979 at the Luiz Antonio Experimental Station in the municipality of Luiz Antonio, São Paulo state, Brazil, and spacing of 3 x 2 m. The planting was located at latitude 21°40'S, longitude 47°49'W, and altitude of 550 m. The average annual rainfall is 1,365 mm over oxisols or sandy textured soils. Climate is Aw in the Köppen classification (Centro de Pesquisas Meteorológicas e Climáticas Aplicadas à Agricultura – CEPAGRI, 2016).

Five 32-year-old trees were collected from an exploratory forest inventory. Discs 8 cm thick were collected from six different stem heights (stem base, 1 m, 2 m, 3 m, 4 m, and 5 m). For each disc, samples ($\approx 3 \times 2 \times 2$) close to the bark were removed for wood anatomy studies and specific gravity determination.

Table 1. Dendrometric data of 32-year-old *Croton piptocalyx* trees.

Tabela 1. Dados dendrométricos das árvores de *Croton piptocalyx* aos 32 anos de idade.

Tree	Diameter at breast height (cm)	Height (m)
1	16.0	14.2
2	15.5	13.6
3	15.5	13.0
4	15.5	14.5
5	15.0	15.5
mean	15.5	14.2

2.2 Anatomical Analysis

Macroscopic description was performed using a 10x hand lens according to Coradin and Muniz (1992). Microscopic terminology followed the IAWA list (IAWA Committee, 1989). For wood description, samples 1 m from the ground were taken.

Small pieces (2 cm³) were cut from the side of samples, and macerations were prepared according to the modified Franklin method (Berlyn and Miksche, 1976), modification is due to differences in the concentration of hydrogen peroxide in solution that is higher in our study. Then, samples were boiled for about 60 min in water, glycerin and alcohol (4:1:1), and 16 µm transverse and longitudinal (tangential and radial) sections were cut with a sledge microtome. Sections were clarified and stained with a 1% solution of safranin, washed with distilled water and mounted in a solution of water and glycerin (1:1) on slides. All anatomical measurements were performed using an Olympus CX 31 microscope equipped with a camera (Olympus E330 EVOLT) and a computer with image analyzer software (Image-Pro 6.3).

Specific gravity was determined according to Glass and Zelinka (2010). Samples of 3 x 2 x 2 cm were dried at standard temperature to reach about 12% moisture content. Then, sample mass and volume (12% moisture content) displaced by immersion in water were determined with a semi-analytical balance.

We initially undertook descriptive statistical analysis. We performed normality tests to check the distribution of data. For axial characterization, positions were considered separately and based on the normal data distribution. A parametric analysis of variance (one-way analysis of variance) was performed. When a significant difference was observed, we used the Tukey's test to identify pairs of significantly different means. We also carry out linear regression to relate anatomical features and specific gravity to axial position.

3 RESULTS AND DISCUSSION

3.1 Macro and Microscopic Anatomical Description of *Croton piptocalyx*

Sapwood and heartwood are indistinct, white, creamy or pale, imperceptible odor, moderate brightness, moderately hard to cut, straight grain, medium texture and average specific gravity of 561 kg.m⁻³.

Growth ring boundaries distinct and marked by radially flattened fibers (Figure 1a). Wood diffuse porous. Vessels visible without hand lens. Vessels partly solitary and some vessels have radial pattern (2 and 4) (Figure 1a) 5.8 (5.7-6.2)/sq. mm, 155 (150-167) µm in tangential diameter, vessels in radial pattern. Vessel elements 771 (753-778) µm long, including tails. Intervessel pits alternate (8 µm) (Figure 1b); vessel-ray pits (7.8 µm) similar to intervessel pits (Figure 1c). Simple perforation plates (Figure 1d-e). Fibers with simple to minutely bordered pits, Fibers thin to thick-walled, 1,170 (1,098-1,238) µm long. Axial parenchyma distinct only with hand lens, apotracheal diffuse and diffuse in aggregates, sometimes in faint narrow bands (Figure 1a). Rays 4/mm, 1-3-seriate, 44 (41-46) µm wide, and 396 (392-432) µm tall, 14-50 cells in height, with procumbent body ray cells and rows of upright and/or square marginal cells (Figure 1f-g). Mineral inclusions (crystals) in axial parenchyma and rays (Figure 1f). Brownish organic inclusions in vessels, axial parenchyma and rays.

No studies reporting on *Croton piptocalyx* wood anatomy were found to compare with our results. Thus, comparisons are made with other species of the genus. Using that basis of comparison, the wood anatomy of *Croton piptocalyx* generally agrees with that of other species of the genus such as described in the literature, including *Croton urucurana* (Luchi, 2004), some other 159 species of the genus (Wiedenhoeft, 2008) and *Croton floribundus* (Longui et al., 2012). However, as a result of tree age and species differences, the quantitative data do vary. Importantly, in *C. piptocalyx*, no laticifers in rays were observed, as reported by Wiedenhoeft et al. (2009) in 159 *Croton* species and by Sieglösch et al. (2012) in *Croton dracunculoides*. Sieglösch et al. (2012) also reported septate fibers with bordered pits in *Croton dracunculoides* and *Croton pycnocephalus*, but these features were not found in *C. piptocalyx*. In *Croton echioides*, Novello et al. (2012) observed mostly solitary vessels, as well as multiple pairs and clusters, gelatinous fibers, and uniseriate rays, which are all distinct features of *C. piptocalyx*.

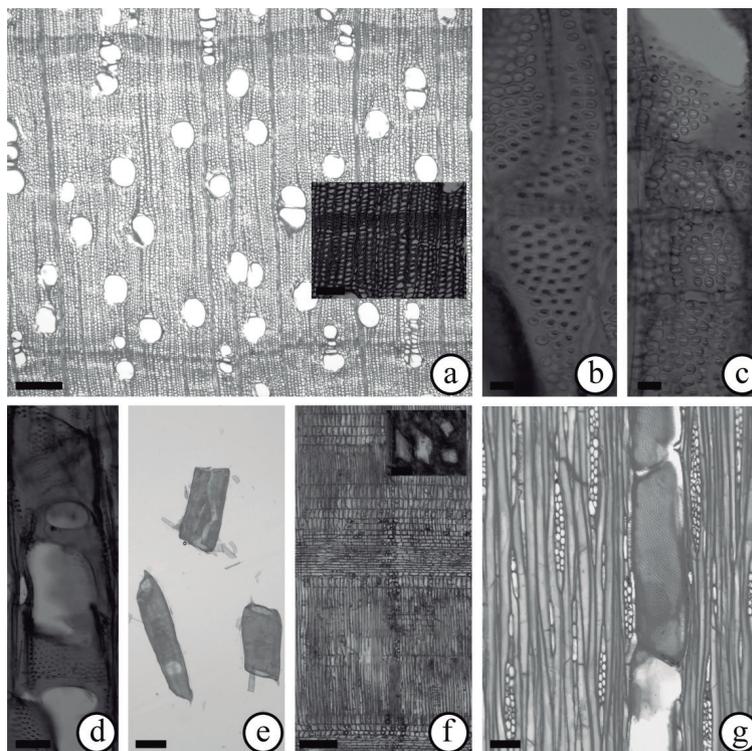


Figure 1. Wood features of *Croton piptocalyx*. a. Transverse section (detail showing growth ring). b. Intervessel pits (tangential section). c. Vessel-ray pits (radial section). d. Vessel element with simple perforation plate (radial section). e. Vessel elements (macerate). f. Radial section, rays with procumbent body ray cells and rows of upright and/or square marginal cells. g. Tangential section showing rays. Scale bar in a = 300 μm (detail 150 μm), in b and c = 10 μm , in d = 50 μm , in e = 100 μm , in f = 300 μm (detail 15 μm), and in g = 100 μm .

Figura 1. Características da madeira de *Croton piptocalyx*. a. Secção transversal (em detalhe a marcação de um anel de crescimento). b. Pontoações intervasculares. c. Pontoações raio vasculares. d. Elemento de vaso com placa de perfuração simples. e. Elementos de vaso. f. Secção radial mostrando raios heterogêneos com células marginais eretas e/ou quadradas. g. Secção longitudinal mostrando os raios. Barras de escala em a = 300 μm (detalhe 150 μm), em b e c = 10 μm , em d = 50 μm , em e = 100 μm , em f = 300 μm (detalhe 15 μm), em g = 100 μm .

3.2 Axial Variation

Values from the base to five meters in height are shown in Table 2. From one-way analysis of variance, vessel element length, vessel frequency and ray frequency do not vary significantly. Whereas other wood features and specific gravity oscillated but without a clear pattern among axial position. Out of all anatomical features, linear regressions showed that just vessel element length, vessel diameter and ray height varied axially ($p < 0.001$), decreasing from stem base to five meters in height (Figure 2).

Decreasing vessel element length from stem base to five meters in height could be explained by the difference in cambial age, which is younger at the highest position and therefore produces

more short cells. According to Lachenbruch et al. (2011), the vertical pattern of wood properties (trunk base to tip) is similar to the radial pattern (pith to bark). The authors reported that one hypothesis supporting typical radial pattern (e.g., shorter cells with smaller diameter and thinner cell walls) is the idea of “developmental constraints” That is, in younger or smaller trees, this concept holds that cambial initials are derived from the apical meristem where cells are small, leading to the production of small, short cells. However, as trees become older or larger, a number of cambial divisions have already been made, allowing the initials to ‘mature’ gradually, as a consequence of the number of cambial divisions already made, thus making products that are now optimal for the tree.

Table 2. Wood quantitative anatomical features of *Croton piptocalyx* from stem base to 5 m in high.Tabela 2. Características anatômicas quantitativas da madeira de *Croton piptocalyx* da base do tronco até 5 m de altura.

	Wood Features								
	VEL	VD	VF	FL	FWT	RH	RW	RF	SG
Base	776a	167a	6.1a	1238a	5.4a	426ab	43ab	4.0a	565ab
1 m	777a	155b	6.2a	1098b	5.3ab	430a	43ab	4.1a	528c
2 m	771a	155b	5.8a	1170ab	4.9b	396bc	44ab	4.0a	561ab
3 m	760a	156b	6.2a	1147ab	5.2ab	394bc	41b	4.5a	536bc
4 m	745a	151b	6.2a	1204ab	5.6a	392bc	41b	4.3a	563ab
5 m	755a	150b	5.9a	1154ab	5.5a	390c	45a	4.0a	570a
Mean	764	156	6.1	1169	5,3	405	43	4.2	554

VEL = Vessel element length (μm), VD = Vessel diameter (μm), VF = Vessel frequency ($\text{n}^\circ \text{mm}^{-2}$), FL = Fiber length (μm), FWT = Fiber wall thickness (μm), RH = Ray height (μm), RW = Ray width (μm), RF = Ray frequency ($\text{n}^\circ \text{mm}^{-1}$), SG = Specific gravity (kg m^{-3}). Different letters indicate statistical significance at $p < 0.05$ level.

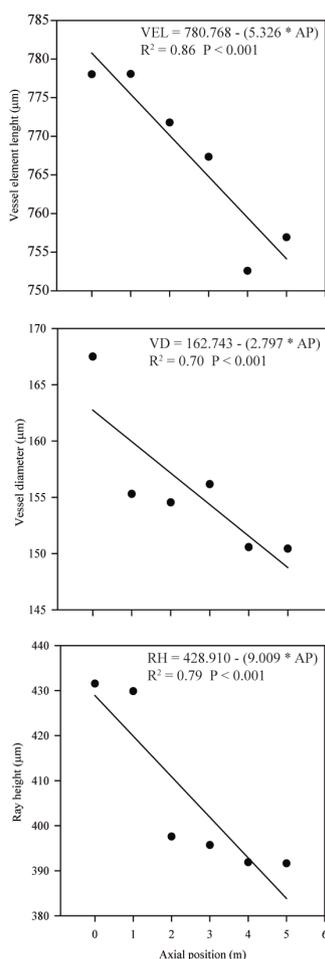


Figure 2. Relationship among wood features of 32-year-old *Croton piptocalyx* as a function of axial position (AP). a. Vessel element length (VEL); b. Vessel diameter (VD); c. Ray height (RH).

Figura 2. Características da madeira de *Croton piptocalyx* com 32 anos em relação à posição axial (AP). a. Comprimento do elemento de vaso (VEL) b. Diâmetro do vaso (VD) c. Altura do raio (RH).

Vessel diameter significantly decreased from the stem base up to five meters. Recent studies have shown an axial widening of vessel elements from the stem apex to base of trees (Anfodillo et al., 2006; Bettiati et al., 2012; Olson and Rosell, 2013; Petit and Crivellaro, 2014). Tapering in xylem architecture is crucial for tree growth in order to maintain hydraulic efficiency (Petit and Anfodillo, 2009; Anfodillo et al., 2013a, b).

Ray height also significantly decreased from the stem base up to five meters. As reported by Casteren et al. (2012), wood will be stronger in the radial direction as compared to tangential one, depending on the proportion of rays since, according to Matheck and Kubler (1997), rays “lock” growth rings like bolts to prevent them from sliding over one another. Higher rays in *Croton piptocalyx* could increase the mechanical strength at the trunk base, a location with high mechanical requirement.

5 CONCLUSIONS

Wood anatomy of *C. piptocalyx* generally agrees with that of other species of the genus as described in the literature. However, variation in both quantitative and qualitative data could be related to tree age and species differences. Axial variations found in vessel element length, vessel diameter and ray height must be related respectively to the hypothesized Typical Radial Pattern based on the occurrence of shorter and narrower cells in younger parts of the wood (vessel element length and vessel diameter) and mechanical requirement in the case of higher rays at the trunk base.

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