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SCIENTIFIC ARTICLE

Physical properties and utilization potential of *Eucalyptus urophylla* × *E. camaldulensis* wood as a function of stem height

Propiedades físicas y potencial de aprovechamiento de la madera de *Eucalyptus urophylla* × *E. camaldulensis* en función de la altura del fuste

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ABSTRACT

Forest plantations with the *Eucalyptus* genus are widely distributed due to the versatility of species and derived hybrids grouped in this taxon. Paraguay has more than 200,000 hectares planted, predominantly with eucalyptus, and the national forest industry uses a high percentage of wood from exotic species as raw material. To optimize the utilization of these forest resources, it is essential to characterize the physical properties of wood according to its position in the stem. With the objective of determining the physical properties of *Eucalyptus urophylla* × *E. camaldulensis* wood at different stem heights and establishing its utilization potential, wood samples were obtained at 25, 35, 45, and 55% of the total height from seven-year-old individuals from a commercial plantation in Caazapá. Moisture content was determined according to UNE EN 13183-1 standard, green and basic apparent specific weight according to NP No. 115 standard, and anisotropy coefficient according to NP No. 116 standard. ANOVA at 5% significance and regression analysis demonstrated that the sampling height level was significant for the anisotropy coefficient and basic apparent specific weight, respectively. These findings suggest that wood can be classified for utilization in the pulp industry and in structural products according to the height of material extraction.

Keywords: density, moisture content, forest industry, eucalyptus, anisotropy.

RESUMEN

Las plantaciones forestales con el género *Eucalyptus* se encuentran ampliamente difundidas debido a la versatilidad de las especies e híbridos derivados agrupados en este taxón. Paraguay posee más de 200.000 hectáreas plantadas, predominantemente con eucalipto, y la industria forestal nacional emplea como materia prima un elevado porcentaje de madera proveniente de especies exóticas. Para optimizar el aprovechamiento de estos recursos forestales, es fundamental caracterizar las propiedades físicas de la madera según su posición en el fuste. Con el objetivo de determinar las propiedades físicas de la madera de *Eucalyptus urophylla* × *E. camaldulensis* a diferentes alturas del fuste y establecer su potencial de aprovechamiento, se obtuvieron muestras de madera al 25, 35, 45 y 55% de la altura total de individuos de siete años provenientes de una plantación comercial de Caazapá. Se determinó el contenido de humedad según norma UNE EN 13183-1, el peso específico aparente verde y básico según norma NP núm. 115, y el coeficiente de anisotropía según norma NP núm. 116. El ANOVA al 5% de significancia y el análisis de regresión demostraron que el nivel de altura de muestreo fue significativo para el coeficiente de anisotropía y el peso específico aparente básico, respectivamente. Estos hallazgos sugieren que la madera puede ser clasificada para su aprovechamiento en la industria de la celulosa y en productos estructurales según la altura de obtención del material.

Palabras claves: densidad, contenido de humedad, industria forestal, Eucalipto, anisotropía.

INTRODUCTION

Worldwide, there are 4,060 million hectares of forest, of which 131 million correspond to forest plantations. South America has the largest area of plantations where introduced species predominate (FAO, 2020). Species of the *Eucalyptus* genus are native to Australia and widely cultivated in South America. Wood from these species and their hybrids possesses qualities that allow their use as raw material in the paper, construction, and energy industries (charcoal, firewood) (Telles et al., 2018). Certain species are widely used for extracting essential oils from their leaves, with medicinal, industrial, and perfumery applications (Vitti & Brito, 2003). Wood from the *Eucalyptus urophylla* × *E. camaldulensis* hybrid stands out for its energy uses (Fioravante Reis & Paludzyszyn Filho, 2011; Barreiros, Ribeiro, Dias, Gouvea, Reis & Silva, 2021), making it the subject of studies characterizing its physical and chemical properties considering factors such as plantation age and site, among others.

Wood possesses certain properties, which are grouped into chemical, anatomical, physical, and mechanical. Knowledge of these allows proper classification based on the final use intended for the material. Physical properties are grouped into moisture content, specific weight (real and apparent), swelling, shrinkage, among others (Suirezs & Berger, 2009). Determination and knowledge of these properties is fundamental, especially in young plantations due to the need to utilize raw material in early stages to obtain various types of products or to evaluate the incidence of plantation spacing on wood, among other factors (Hsing, Paula & Paula, 2016).

Among the most important physical properties for wood characterization are shrinkage, density, and moisture content. Shrinkage is the decrease in wood volume when losing hygroscopic water, below the fiber saturation point, to the anhydrous state. It is a parameter that allows knowing the dimensional stability of raw material in its cutting planes (tangential, longitudinal, and radial), as well as the wood's retractility or shrinkage coefficient (Suirezs & Berger, 2009). The value of dimensional variation in wood's tangential and radial planes is used to calculate the material's anisotropy coefficient. The coefficient is associated with a scale that allows classifying wood according to its tendency to suffer deformations and cracks, qualities of interest according to the use intended for the material (Calvo et al., 2007).

On the other hand, specific weight or density is one of wood's most important qualities. From this, it is possible to classify raw material into heavy, light, or very light wood, which in turn translates to its workability capacity. Furthermore, this property is closely associated with other physical and mechanical characteristics of wood, suggesting the quality or use that can be attributed to the material (Suirezs & Berger, 2009). Wood density, like other properties, is influenced by the site where the species develops (Labbé, Droppelmann, Balocchi & Peredo, 2013). Even in the same species, these characteristics can be expressed differently as a consequence of cultivation site variation (Calvo et al., 2007).

Wood moisture content is the amount of water that constitutes its structure. It is a quality that influences raw material in terms of quality, applications, and wood behavior in events such as resistance to biological agent attack, its physical and mechanical properties, product elaboration, and cellulose yield, among others (Suirezs & Berger, 2009).

According to data published in 2021 by the National Forest Institute (INFONA), Paraguay has an extension of 206,470.33 hectares of plantations, predominantly of *Eucalyptus* genus species. The same entity reports, in data relative to the 2022 forest industries census, that the highest percentage of raw material used comes from exotic species, with 68% of the total, while the rest corresponds to native species with various applications. These data support the importance of knowledge of wood technological properties for optimal commercial utilization.

Knowledge of physical properties of a species cultivated in a specific site allows guiding its uses and applications in developing new products, as well as making silvicultural decisions to maximize economic benefit of plantations according to their location. In this context, and considering the importance of eucalyptus in Paraguay, the objective of the research was to determine the physical properties of *Eucalyptus urophylla* × *E. camaldulensis* wood at different stem heights and establish its utilization potential.

MATERIALS AND METHODS

The study was conducted in a pure even-aged stand of *Eucalyptus urophylla* × *E. camaldulensis*, commercially known as VM01 and established in 2015. The stand is located at Curuzú ranch, Coronel Maciel district, Caazapá department, Paraguay, where the average annual minimum temperature is 21.8°C and the maximum is 40.6°C, the average relative humidity is 70.5%, and precipitation is 1,495 mm/year (DINAC, 2022). The initial planting density was 1,315 trees ha^{-1}, with a spacing of 4 m × 1.9 m, managed for energy biomass production without pruning or thinning.

Diameter at breast height (DBH) values were obtained from measurements of 675 trees in the stand (Table 1). Data were recorded in the Inventree® application, exported to Excel format for processing, and grouped for determining frequency distribution and diameter classes. Based on this data, six individuals of *E. urophylla* × *E. camaldulensis* representative of different diameter classes were felled.

A completely randomized design arranged in split plots was used. Table 2 presents the experiment description.

From each individual, cross-sections were extracted according to the stem division method by Hohenadl (Prodan, Peters, Cox, & Real, 1997) in the established proportions of the total height of each tree in meters. Samples were identified and coded in the field, packed, and sent to the Wood and Derivatives Quality Laboratory of the Forest Engineering Program, FCA/UNA. In the carpentry workshop, the discs were debarked and prepared, after which test specimens were extracted for the corresponding analytical determinations.

Table 1. Initial dendrometric variables of *Eucalyptus urophylla* × *E. camaldulensis* VM01 individuals selected for the study. Caazapá, Paraguay, 2022.

Individuals	**1**	**2**	**3**	**4**	**5**	**6**
DBH (cm)	18,1	17,4	18,6	11,6	21,3	18,8
Total height (m)	22,50	22,4	23,4	16,5	21,35	23,6
Diameter classes [LI – LS]	11,4 – 13,4		15,6 – 19,7		19,8 – 21,8	
(cm)	11,6		18,2		21,3	
Rf (%)	8		48		1,2	

Where: DBH: diameter at breast height, ht: total height, LI: lower limit, LS: upper limit, Rf: relative frequency

Table 2. Description of split-plot experimental design. Caazapá, Paraguay, 2022.

Design	Completely randomized split plots	
Factor	**Level**	**Description**
Main plot		
Material genético	*Eucalyptus urophylla* × *Eucalyptus camaldulensis*	6 individuals evaluated
Subplot		
Longitudinal position	4 levels	Percentage of total stem height (%)
	Level 1	25%
	Level 2	35%
	Level 3	45%
	Level 4	55%

All determinations were performed in triplicate for each parameter evaluated, using a Shimadzu UX6200H analytical balance with 0.01 g precision.

Determination of green and basic apparent specific weight

It was determined according to Paraguayan standard NP No. 115 (Wood: Method for determining apparent specific weight) (INTN, 1974). Volume was determined by the water immersion method. Green apparent specific weight was calculated using equation (1):

$$P_E = \frac{Ps}{Vs} \qquad (1)$$

Where:

S_W: Green apparent specific weight (g cm⁻³)

Wg: Weight of specimen in green state (g)

Vg: Volume of specimen in green or saturated state (cm³)

Once the volume of specimens in green state was determined, they were placed in an oven at a temperature of 103±2°C until constant weight was obtained. For calculating basic apparent specific weight, equation (2) was used:

$$P_{Eb} = \frac{Pa}{Vs} \qquad (2)$$

Where:

S_{Wb}: Basic apparent specific weight (g cm⁻³)

Wo: Weight of specimen in oven-dry state (g)

Vg: Volume of specimen in green or saturated state (cm³)

Determination of moisture content by the oven-drying method

It was performed according to European standard UNE EN 13183-1 (Determination of moisture content of sawn timber by oven-drying method), applying equation (3):

$$\omega = \frac{mi-mo}{mo} \times 100 \qquad (3)$$

Where:

ω: Moisture content expressed in %

mi: Initial mass of specimen (g)

mo: Oven-dry mass of specimen (g)

Determination of shrinkage anisotropy coefficient

For determining the anisotropy coefficient, rectangular prisms were extracted from the cross-sections in which the tangential, radial, and longitudinal planes were identified. Paraguayan standard NP No. 116 (Wood: Method for determining shrinkage) was used (INTN, 1974).

Total tangential shrinkage was calculated according to equation (4):

$$C_{tt} = \frac{dvt-dsht}{dvt} \times 100 \qquad (4)$$

Where:

S_{tt}: Tangential shrinkage from green state (MC >30%) to oven-dry state (MC = 0%), expressed in %

d_{gt}: Tangential dimension in green state (MC >30%) (cm)

d_{odt}: Tangential dimension in oven-dry state (cm)

Total radial shrinkage was calculated according to equation (5):

$$C_{rt} = \frac{dvr - dshr}{dvr} \times 100 \qquad (5)$$

Where:

S_{rt}: Radial shrinkage from green state (MC >30%) to oven-dry state (MC = 0%), expressed in %

d_{gr}: Radial dimension in green state (MC >30%) (cm)

d_{odr} Radial dimension in oven-dry state (cm)

With the radial and tangential shrinkage values, the Anisotropy coefficient (Ac) was calculated using equation (6):

$$Ac = ßt / ßr \qquad (6)$$

Where:

Ac: Shrinkage anisotropy coefficient

ßt: Tangential shrinkage

ßr Radial shrinkage

Data processing was performed using InfoStat® statistical software. Data were subjected to F and t tests, as well as ANOVA analysis of variance. When interaction between factors (longitudinal position and diameter classification) was identified, they were compared using Tukey›s test. Regression models were proposed for those parameters that presented significant differences with respect to stem height percentage, considering a significance level of 5%.

RESULTS AND DISCUSSION

The results obtained for each of the physical properties evaluated are presented below, analyzing the effects of sampling height on each parameter and discussing their implications for the potential utilization of wood.

Determination of green apparent specific weight

The analysis of variance for the green apparent specific weight parameter is presented in Table 3

Determination of basic apparent specific weight

According to ANOVA, the sampling height factor showed significant effect on basic apparent specific weight. The contrast analysis is presented in Table 4.

The regression analysis for the height level factor is presented in Figure 1. The regression line represents a direct relationship between stem height and basic apparent specific weight of wood. That is, for every 10% increase in individual height, basic apparent specific weight will present an increase pattern of 12.6 g cm^{-3}. A similar longitudinal increase pattern was observed by Labbé et al. (2013) in *E. globulus* woods, where they observed a density increase from base to apex of studied individuals, a finding consistent with the results of this work.

Suirezs and Berger (2009) determined a wood classification according to basic apparent density ranges, considering light woods as those with densities between 351 and 550 g cm^{-3}, and semi-heavy woods as those with densities between 551 and 750 g cm^{-3}. According to these authors and the values obtained in this work, *Eucalyptus urophylla* × *E. camaldulensis* wood obtained in the Caazapá area could be classified as light to semi-heavy wood, a result that agrees with what is reported in the literature for other eucalyptus species (Monteoliva, Barotto & Fernández, 2015; Gauna et al. 2022).

Table 3. Green apparent specific weight averages (g·m^{-3}) in wood samples of *Eucalyptus urophylla* × *Eucalyptus camaldulensis* at 7 years. Caazapá, Paraguay, 2022.

Diameter classes [LI – LS] A	**Height level (% total height) B**				**Total marginal average**
	25	**35**	**45**	**55**	
11,4 – 13,4	1269,59 a	1329,69 a	1264,76 a	1357,04 a	1305,27 A
15,6 – 19,7	1012,55 a	1021,22 a	1031,11 a	1039,77 a	1026,16 A
19,8 – 21,8	1083,22 a	1119,31 a	1119,2 a	1128,8 a	1112,63 A
Treatments	**F-value (5%)**	**Contrasts**	**F-value (5%)**	**Regression**	**T-value (5%)**
A	23,23*	Linear	F=2,34 ns	Constant	ns
B	$1,24^{ns}$	Quadratic	$F=2,1x10^{-3\ ns}$	Slope	ns
A*B	$0,39^{ns}$	Cubic	$F=1,37^{ns}$		
CV (%)	5,42				

Obs.: Means with common letters are not significantly different (p<0.05) for comparisons of means between diameter classes.
Means with common letters are not significantly different (p<0.05) for interactions:
Diameter classes × Height level (% total height).
LI: Lower limit of diameter class. LS: Upper limit of diameter class. A: Diameter class factor. B: Height factor. AB: Interaction between factors.
F-value: Test statistic. T-value: Test statistic.
"ns": not significant.
*: significant.
CV (%): coefficient of variation of the ANOVA model.

Table 4. Basic apparent specific weight averages ($kg \cdot m^{-3}$) in wood samples of *Eucalyptus urophylla* × *Eucalyptus camaldulensis* at 7 years. Caazapá, Paraguay, 2022.

Diameter classes A [LL – UL]	Height level (% total height) B 25	35	45	55	Total marginal average
11,4 – 13,4	574,54 a	567,06 a	592,26 a	620,33 a	588,55 A
15,6 – 19,7	487,01 b	479,84 b	497,88 b	518,9 b	495,91 B
19,8 – 21,8	513,84 b	530,24 b	532,07 b	547,56 b	530,93 B
Treatments	**F-value (5%)**	**Contrasts**	**F-value (5%)**	**Regression**	**T-value (5%)**
A	15,79*	Linear	F=11,97*	Constant	10,66*
B	4,55*	Quadratic	$F=1,64^{ns}$	Slope	$1,15^{ns}$
A*B	$0,32^{ns}$	Cubic	$F=0,05^{ns}$		
CV (%)	4,55	$r^2=0,1162$			

Obs.: Means with common letters are not significantly different (p<0.05) for comparisons of means between diameter classes.
Means with common letters are not significantly different (p<0.05) for interactions:
Diameter classes × Height level (% total height).
LI: Lower limit of diameter class. LS: Upper limit of diameter class. A: Diameter class factor. B: Height factor. AB: Interaction between factors.
F-value: Test statistic. T-value: Test statistic.
"ns": not significant.
*: significant.
CV (%): coefficient of variation of the ANOVA model.

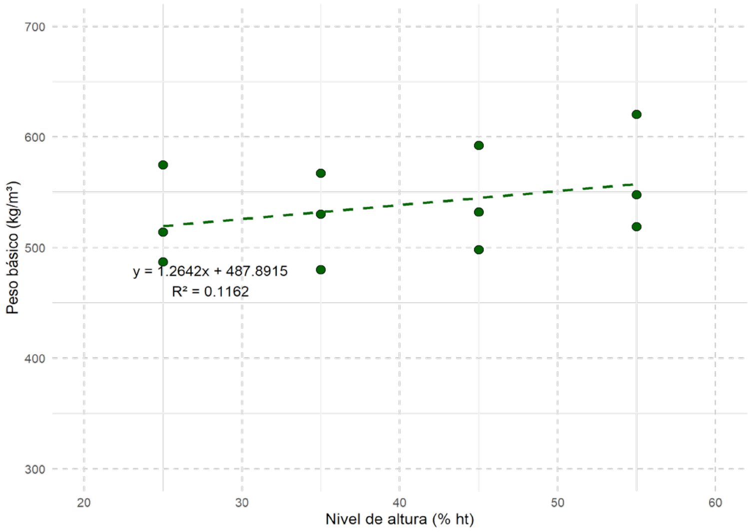

Figure 1. Regression of basic apparent specific weight variable as a function of stem height of 7-year-old *Eucalyptus urophylla* × *Eucalyptus camaldulensis* individuals. Caazapá, Paraguay, 2022.

Basic apparent specific weight, or basic density, is an important property for cataloging energy biomass quality (Brun et al., 2018; da Cunha et al., 2021). Characterization works for energy utilization purposes are well developed in eucalyptus. Brun et al. (2018) evaluated this parameter in wood from three genetic materials of 4.5-year-old *Eucalyptus* sp., obtaining values of 490, 500, and 550 g cm^{-3}, respectively.

Barbosa et al. (2023) determined an average value of 483 g cm^{-3} for six-year-old *E. urophylla* × *E. camaldulensis* wood under coppice management. Quinhones (2011) evaluated physical characteristics of seven-year-old *E. urophylla* × *E. camaldulensis* wood, obtaining an average of 560 g cm^{-3} for basic apparent specific weight of the material. Barreiros et al. (2021) obtained an average of 492 g cm^{-3} for clones of the same hybrid with an average age of seven years, classifying the wood as appropriate for energy purposes. Lima et al. (2020) evaluated this property in *Eucalyptus* spp. clones and suggested that materials with densities greater than 500 g cm^{-3} are ideal for charcoal production. The values of 588.55, 495.91, and 530 g cm^{-3} obtained are consistent with available literature.

It is important to mention that higher basic apparent specific weight is expected to result in higher combustion power. However, high basic wood densities cause greater difficulties in the initial direct fuel burning process, so a density interval between 650 and 800 g cm^{-3} is suggested for medium to hard woods (Barreiros et al., 2021). Protásio et al. (2021) reached a similar criterion from studies of *Eucalyptus* spp. wood quality parameters, concluding that woods with basic densities less than or equal to 500 g cm^{-3} are not recommendable as raw material for obtaining charcoal for metallurgical purposes.

On the other hand, in technological evaluation of wood as raw material for obtaining kraft cellulose, basic density is used as an important quality parameter, along with other properties such as material chemistry and plantation age, among others (Doldán, Fariña & Tarigo, 2008; de Morais, Longue Júnior, Colodette, Morais & Jardim, 2017). De Morais et al. (2017) determined that basic densities between 460 and 480 g cm^{-3} are adequate indicators for wood from *E. grandis* and *E. urograndis* clones aged between one and eight years for pulping purposes.

Values greater than 570 g cm^{-3} indicate a decrease in pulping capacity by the kraft method for eucalyptus woods according to Doldán et al. (2008), who evaluated basic densities of five *Eucalyptus* spp. species aged between eight and 10 years, obtaining values distributed in ranges from 423 to 559 g cm^{-3}. They determined the highest gross cellulose yield average of 54.5% for *E. globulus* at an average basic density of 520 g cm^{-3} of the material.

While basic wood density is an extremely important parameter when evaluating the quality of genetic material for energy or pulping purposes, this characteristic must be accompanied by other determinations such as calorific capacity, fixed carbon content, chemical characterization, pulping yield, and paper properties, among others, according to the plantation objective.

Determination of anisotropy coefficient

The anisotropy coefficient is obtained by calculating the quotient between shrinkage of the wood's tangential plane and shrinkage in the radial plane, and is a parameter that allows knowing the dimensional stability of wood, important information for structural applications and for the furniture industry.

Suirezs and Berger (2009) establish that anisotropy values between 1.2 and 1.5 are considered excellent for uses where warping is not permitted. From 1.6 to 1.9 the wood is considered normal, and it presents limitations in its applications when the anisotropy value is greater than 2.0. The wood shrinkage anisotropy coefficient values presented significant effects according to sampling height levels in the ANOVA analysis. The data are reported in Table 5.

The regression analysis for the height level factor is presented in Figure 2.

The regression line shows an inverse trend between stem height and wood anisotropy coefficient. For every 10% increase in individual height, the anisotropy coefficient presents a decrease pattern of 0.11. Calvo et al. (2007) found variations in wood anisotropy coefficient as a function of stem height in 17-year-old *Eucalyptus grandis* specimens cultivated in Argentina, where the coefficient presented a decreasing trend with increasing height, a finding congruent with the results of this work.

Cardoso, Cagno, Cárdenas and Gatto (2013) establish a wood classification according to their anisotropy coefficients: in general, values greater than 2 suggest unstable woods or woods with difficulties according to material applications.

Considering the values obtained in determining the anisotropy coefficient, it can be considered that seven-year-old *Eucalyptus urophylla* × *E. camaldulensis* wood is normal to unstable in terms of dimensional stability (Suirezs & Berger, 2009). From the regression analysis, a trend of decreasing anisotropy coefficient with height is observed, suggesting that wood could increase its dimensional stability with stem height. This fact must be corroborated by conducting physical-mechanical tests on wood obtained from the highest zones of the stem.

Table 5. Anisotropy Coefficient (Ac) averages in wood samples of *Eucalyptus urophylla* × *Eucalyptus camaldulensis* at 7 years. Caazapá, Paraguay, 2022.

Diameter classes A [LL---UL]	Height level (% total height) B				Total marginal average
	25	**35**	**45**	**55**	
11,4 – 13,4	1,96 a	2,37 a	1,9 a	1,59 a	1,95 A
15,6 – 19,7	1,96 a	1,75 a	1,66 a	1,44 a	1,70 A
19,8 – 21,8	1,88 a	2,01 a	1,63 a	1,7 a	1,81 A
Treatments	**F-value (5%)**	**Contrasts**	**F-value (5%)**	**Regression**	**T-value (5%)**
A	0,93^{ns}	Linear	F=9,22*	Constant	11,37*
B	4,16*	Quadratic	F=1,66^{ns}	Slope	-2.75*
A*B	0,80^{ns}	Cubic	F=1,61^{ns}		
CV (%)	16,76	r^2=0,4309			

Obs.: Means with common letters are not significantly different (p<0.05) for comparisons of means between diameter classes.
Means with common letters are not significantly different (p<0.05) for interactions:
Diameter classes × Height level (% total height).
LI: Lower limit of diameter class. LS: Upper limit of diameter class. A: Diameter class factor. B: Height factor. AB: Interaction between factors.
F-value: Test statistic. T-value: Test statistic.
"ns": not significant.
*: significant.
CV (%): coefficient of variation of the ANOVA model.

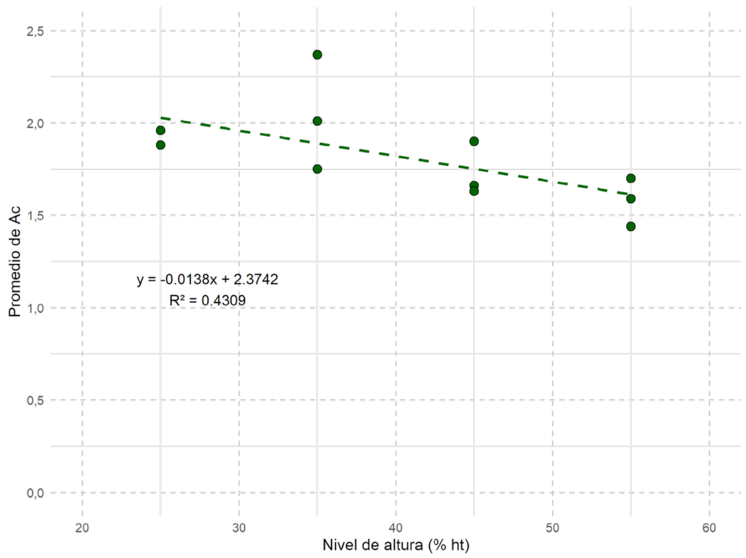

Figure 2. Regression of Anisotropy Coefficient (Ac) variable as a function of stem height of 7-year-old *Eucalyptus urophylla* × *Eucalyptus camaldulensis* individuals. Caazapá, Paraguay, 2022.

Table 6. Moisture content averages (MC%) in wood samples of *Eucalyptus urophylla* × *Eucalyptus camaldulensis* at 7 years. Caazapá, Paraguay, 2022.

Diameter classes [LL---UL]	Height level (% total height)				Total marginal average
	25	35	45	55	
11,4 – 13,4	115,16 a	126,45 a	123,59 a	116,34 a	120,39 A
15,6 – 19,7	102,04 a	102 a	101,56 a	95,56 a	100,29 A
19,8 – 21,8	115,81 a	116,21 a	106,56 a	105,78 a	111,09 A
Tratamientos	**F-value (5%)**	**Contrasts**	**F-value (5%)**	**Regression**	**T-value (5%)**
A	29,04*	Linear	F=1,17 ns	Constant	ns
B	0,82ns	Quadratic	F=1,11ns	Slope	ns
A*B	0,32ns	Cubic	F=0,19ns		
CV (%)	11,02				

Obs.: Means with common letters are not significantly different (p<0.05) for comparisons of means between diameter classes.
Means with common letters are not significantly different (p<0.05) for interactions:
Diameter classes × Height level (% total height).
LI: Lower limit of diameter class. LS: Upper limit of diameter class. A: Diameter class factor. B: Height factor. AB: Interaction between factors.
F-value: Test statistic. T-value: Test statistic.
"ns": not significant.
*: significant.
CV (%): coefficient of variation of the ANOVA model.

Wood moisture content

According to the analysis of variance, height level was not a significant source of variation for moisture content. The contrasts are presented in Table 6.

Moisture content is closely related to the initial weight of harvested wood (Omonte, Sáez-Carrillo, Ananías & Valenzuela-Hurtado, 2019). From a technological point of view, this parameter is related to density, storage, and transportation, among other factors. Material resistance to attack by xylophagous organisms is associated with the presence of water within wood (Doldán, 2003). Moisture content values greater than 100% in the studied samples suggest that wood from this species possesses high saturation in its green state. In industry, initial wood moisture content is an important factor in drying process decision-making, since the material is prone to suffering deformations, among other phenomena, making its final utilization difficult (Touza & Pedras Saavedra, 2002).

CONCLUSIONS

Moisture content, green apparent specific weight, basic apparent specific weight, and anisotropy coefficient of seven-year-old *Eucalyptus urophylla* × *E. camaldulensis* VM01 wood obtained in Coronel Maciel district, Caazapá department were determined. The sampling height factor was significant for the physical parameters anisotropy coefficient and basic apparent specific weight.

The basic apparent specific weight values obtained showed that this species is suitable for use in the charcoal production industry and presents potential for utilization for cellulose extraction purposes according to height. The anisotropy coefficient showed a reduction as stem height increased.

Based on these results, studies on determination of physical-mechanical properties could be expanded to explore possible structural applications of wood from the upper zones of individuals.

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