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ECOLOGICAL ANATOMY OF WOOD FROM *Guarea kunthiana* A. Juss. (MELIACEAE)

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ABSTRACT - Light and water availability are determining factors for variations in the anatomical and morphological characteristics of wood. In view of the above, the aim of this work was to carry out an anatomical-ecological analysis of the wood and leaf morphology of *Guarea kunthiana* A. Juss. (Meliaceae), occurring in the Cavernas do Peruaçu National Park (MG), to understand the plant-environment interactions and how these interactions affect the anatomical characteristics of the wood. For this purpose, three trees were selected considering the difference in botanical patterns of leaves and tree size, the distance to the watercourse that enters the cave and the incidence of light on them. Wood was collected from each sample nondestructively at DAP, from leaves at random heights and from light intensity. Anatomical characterization was then carried out using histological and macerate slides. To compare the morphological aspects of the leaves, the blade length, blade width, length/width ratio and blade area (A²) were determined. All characters were correlated using Spearman analysis to verify the influence of the environment on wood anatomy. The anatomical components found are common to the genus and family; proximity to watercourses has a greater influence on the number of anatomical elements than does light intensity. There is a strong association between leaf blade area and wood anatomy. It is concluded that the *G. Kunthiana* has anatomical adaptations for mesomorphic environments.
Keywords: wood anatomy, luminosity, phenotypic plasticity.

ANATOMIA ECOLÓGICA DA MADEIRA DE Guarea kunthiana A. Juss. *(MELIACEAE)*

RESUMO - A luminosidade e a disponibilidade de água são fatores determinantes para as variações nas características anatômicas e morfológicas na madeira. Diante do exposto, objetivou-se com o presente trabalho realizar uma análise anatômica-ecológica do lenho e da morfologia foliar da *Guarea kunthiana* A. Juss. (Meliaceae), ocorrente no Parque Nacional Cavernas do Peruaçu (MG), a fim de compreender a interação planta-ambiente e como isto afeta as características anatômicas da madeira. Para isso, foram selecionadas três árvores considerando a diferença de padrões botânicos de folhas e porte arbóreo, a distância até o curso d'água que adentra a caverna e a incidência de luz sobre as mesmas. De cada amostra coletou-se madeira de forma não destrutiva no DAP, folhas em alturas aleatórias e a intensidade luminosa. Em seguida, foi feita a caracterização anatômica por meio de lâminas histológicas e de macerado. Para comparação dos aspectos morfológicos das folhas foi determinado o comprimento da lâmina, largura da lâmina, proporção comprimento/largura e área da lâmina (A²). Todos os caracteres foram correlacionados pela análise de Spearman para verificar a influência do ambiente na anatomia do lenho. Os componentes anatômicos encontrados são comuns ao gênero e a família; a proximidade aos cursos d'água exerce maior influência na quantidade de elementos anatômicos do que a intensidade luminosa; existe uma forte associação entre a área da lâmina foliar e a anatomia da madeira. Conclui-se que a *G. kunthiana* possui adaptações anatômicas para ambientes mesomórficos.
Palavras-chave: anatomia do lenho, luminosidade, plasticidade fenotípica.

INTRODUCTION

Knowledge about the anatomy of wood is one of the main pillars for discerning its use; however, associating ecological behavior with environmental variations is a determining factor in predicting and understanding the behavior of species with regard to its use. Therefore, in-depth studies of the interactions between plants and the environment, called ecological anatomy, are necessary. Environmental factors such as water availability, soil conditions, altitude and latitude can influence the structure of the secondary xylem of a species, reflecting its organization. Characteristics such as the distribution and arrangement of the axial parenchyma; diameter, length and frequency of vessels; length and thickness of the fiber wall;

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height and width of the rays; and the presence or absence of growth layers and gelatinous fibers may vary depending on the environment (BOSIO et al., 2010; AMORIM et al., 2016).

Among the abiotic limitations to plant establishment, water plays a fundamental role. Species that have hydraulic mechanisms that are more efficiently adapted to the location in which they develop can achieve better photosynthetic performance and greater growth. The structure of the xylem has a great influence on the plant's ability to absorb and retain water. Larger conductive elements are expected to promote greater water rise but are more vulnerable to cavitation events (AMADO et al., 2015).

Light also affects the anatomical characteristics of wood. Bireahls et al. (2020) reported that the main changes in tree species due to solar radiation occur in the density, diameter and length of vessels; length and thickness of the fiber wall; and composition of the axial parenchyma.

The species *Guarea Kunthiana* A. Juss. (Meliaceae), the object of the present study, is popularly known as canjambo, mancore, jatuaúba, figo-do-mato, peloteira, pau d'arco or jitó. It is native, non-endemic and present in the phytogeographical domains of the Amazon, Cerrado and Atlantic Forest (FLORA DO BRASIL, 2019). This species requires little care for cultivation and can be cultivated in full sun or in semishade environments, where it accepts most of the soil (GIACON, 2016), as its fruits attract the attention of birds, and its flowering occurs almost year-round, making it useful for recovery. of the degraded areas. The high density of its wood (0.82 g/cm³) has led to the recommendation of civil construction and the furniture industry (LORENZI, 1998).

There are few studies on secondary xylem involving the genus *Guarea*, and the most recent was carried out for the species*Guide guide*by da Silva et al. (2021). For *G. kunthiana* there are no reports on its anatomical structure in Brazilian biomes; only one study was carried out in Venezula by León (2006), which made it necessary to deepen the anatomical knowledge about the wood of this species and increase the list of information in the literature.

The occurrence *of Guarea kunthiana* in Gruta do Janelão, one of the main caves in the Cavernas do Peruaçu National Park, in Minas Gerais has drawn the attention of researchers because of its high phenotypic plasticity; that is, the phenotypes are expressed in different ways depending on the environmental conditions where the plant grows. finds. There are differences in the dendrological characteristics of the leaves and the size of the tree throughout the entire length of the cave, depending on the light intensity that each individual receives. In this sense, the anatomical-ecological study of the wood and leaf morphology *of Guarea kunthiana* in in the Cavernas do Peruaçu National Park contributes to the understanding of plant-environment interactions and how phenotypic plasticity affects the anatomical characteristics of wood. Furthermore, pioneering studies of plants that develop in cave environments have been conducted, which highlights the importance of this research.

MATERIAL AND METHODS

The study area comprises the interior of the Gruta do Janelão cave, located in the Cavernas do Peruaçu National Park in the northern region of the State of Minas Gerais, Brazil (Figure 1). In the park, there is a predominance of the seasonal deciduous forest, popularly known as dry forest, which is a formation that contains deciduous tree-shrub species (GBPE, 1999).

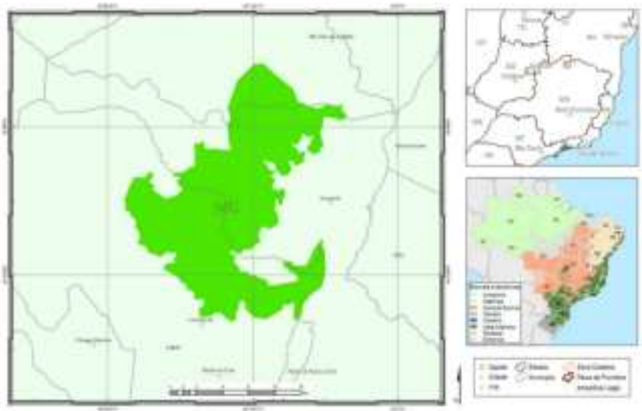

FIGURE 1 - Location of Cavernas do Peruaçu National Park, Minas Gerais. Source: Ministry of the Environment (2007).

Three *Guarea kunthiana* w trees were selected on the basis of the morphological characteristics of the aerial parts of the plants, considering the difference in leaf botanical patterns and tree size; additionally, considering the distance of the samples as a selection criterion in relation to the watercourse that enters the cave (Peruaçu River) and the incidence of light on them (Table 1).

The incidence of luminosity (L) was measured using an analog luxmeter device (Gossen brand, Panlux Electronic model, with a 4 cm diameter receiver). For this purpose, four readings were taken at 1 m from the ground at each collection point (north, south, east and west of each tree), and a Tukey test (5% probability of error) was subsequently applied to determine the means (Table 1). The climatic conditions of average precipitation, relative air humidity and wind speed inside the Gruta do Janelão cave could not be taken, considering the absence of data from meteorological stations from the National Institute of

Meteorology (INMET) and meteorological *stations*.

To collect wood samples, a nondestructive method was used; this method involved removing small portions of wood with the aid of a Pressler probe, and sampling was conducted at chest height (1.3 m from the ground). Branches with leaves were also collected at random heights to help individuals identify species and analyze leaf morphology. The exsiccates made from the collected material were incorporated into the Herbarium of the Institute of Agricultural Sciences, belonging to the Federal University of Minas Gerais (UFMG).

TABLE 1 - Information from the three samples of *Guarea Kunthiana* collected inside the Gruta do Janelão cave in the Peruaçu Caves in National Park (MG).

Samples	Plant height (m)	Plant diameter in DBH (cm)	Distance from the watercourse (m)	Luminosity (L)
1	9	9.67	57.5	0.02 b*
2	16	18.84	19.7	0.06 a
3	12	13.62	2.3	0.02 b

Where * means followed by the same letter in the column do not differ statistically according to the Tukey test at a 5% probability of error.

The anatomical histological and macerate slides were made at the Wood Technology Laboratory, located at the Federal University of Paraná (UFPR). The technique used to make slides consisted of boiling the three samples; sectioning the specimens (transverse, longitudinal, radial and tangential); and passing through double staining (1% safranin and 1% blue) with the aid of a sliding microtome. astra 1%), dehydrated (alcoholic battery: 30%, 50%, 75%, 90%, 95%, absolute alcohol), diaphanized (xylene) and then assembled. For the maceration slides, the samples were transformed into sticks, followed by boiling (50% glacial acetic acid, 38% 130 V hydrogen peroxide and 12% distilled water), maceration, coloring, dehydration, clearing and assembly.

The anatomical characterization followed the guidelines and terminologies proposed by the Iawa Committee (1989), and the number of measurements was set at 25. For all the quantitative wood attributes, standard deviations and mean, minimum and maximum values [S + X (mín - max)] were calculated.

As a way of relating the anatomy of wood to the efficiency of water transport and susceptibility to cavitation during water conduction, the ecological indicators (CARLQUIST, 1977) of vulnerability (IV) were calculated by Equation 1 and mesomorphy (IM): by Equation 2.

$$IV = \frac{DLP}{FP} \qquad \text{(Equation 1)}$$

Where:
IV = ecological vulnerability index,
DLP = average pore lumen diameter (µm)
FP = average pore frequency (pores mm^{-2}).

$$IM = IV \times CV \qquad \text{(Equation 2)}$$

Where:
IM = mesomorphy index,
IV = Vulnerability index
CV = average vessel length (µm).

To compare the morphological aspects of the leaves, three leaves were randomly collected from branches, totaling 18 leaflets (sample 1), 25 leaflets (sample 2) and 30 leaflets (sample 3), used for linear determination of the blade length dimensions (CL), blade width (LL), length/width ratio (L/W) and blade area (A^2). Length was defined as the distance between the point at which the petiole was inserted on the leaf blade and the end opposite the leaf, and width was defined as the largest dimension perpendicular to the length axis. These measurements were obtained with a precision ruler and measuring tape. The area of the blade (A^2) was calculated as the product of two dimensions, CL and LL, resulting in an area of a rectangle due to the oval or lanceolate shape of the leaf, deducting 30% of the area of the rectangle.

Comparisons of the average anatomical characteristics of the woods, ecological indicators (vulnerability and mesomorphy indices) and morphological information of the leaves were evaluated using the Tukey test ($p<0.05$) in Excel software. The correlation between these characteristics was determined by the Spearman correlation coefficient using the Jamovi statistical program (THE JAMOVI PROJECT, 2022).

RESULTS AND DISCUSSION

In Figure 2, a microscopic description of *Guarea kunthiana* wood was constructed by evaluating the histological anatomical slides and macerate through the analysis of the three samples, which revealed indistinct growth rings; a few vessels [6.3 ± 2.6 (1.0 - 14.0) pores mm^{-2}], representing 16% of the wood volume; a radial arrangement; a rounded section, tending to oval [123.0 ± 40.2 (38.8 - 210.8) µm]; thick walls [7.0 ± 4.1 (0.7 - 28.6) µm]; and vessels with uniform diffuse porosity, grouped in clusters of 3-6 (4%), radial multiples of 2-3 (51%) and solitary (45%) (Figure 2A). Vascular elements of medium length [548.7 + 137.5 (166.9 - 861.2) µm] were also verified; simple, transverse perforation plates and long appendages [56.6 ± 28.2 (16.6 - 189.9) µm] were observed at one or both ends; small intervascular pits [3.31 + 0.51 (2.40 - 4.97) µm] were extremely numerous and rounded and alternate, with an included lenticular opening, horizontal or in the shape of a coalescing slit; and ray-vascular pits [3.55 + 0.80 (2.12-5.02) µm] were similar to intervascular pits in terms of shape, arrangement and opening (lenticular, included, horizontal); parenchyma-vascular pits [3.49 + 0.46 (2.18 - 4.42) µm], similar to intervascular and nonabundant tylos (Figure 2B, 2F), helical thickenings, striations, ornaments and deposits, absent.

Figure 2B shows the presence of axial parenchyma, which represented 20% of the volume of the wood, paratracheal type aliform in bands, encompassing the vessels. The bands had an average width of 4 cells, reaching up to 6 cells. The parenchymatous series, generally formed by 2-11 cells, measured 539.35 ± 140.65 (235.86 - 843.93) µm in height and 25.84 ± 4.30 (15.11 - 37.49) µm wide.

In Figure 2C, heterogeneous radii were found, totaling 25% of the wood volume, with an abundance of 10 ± 2.91 (3 - 16) radii mm^{-2}. The uniseriate rays corresponded to 90% of the radial tissue, presenting procumbent cells, with a height of 288.34 ± 85.69 (135.11 - 534.70) µm, width of 16.45 ± 3.98 (6.12 - 27.22) µm and width of 9.16 ± 3.24 (3.00 - 20.00) cells. The multiseriate rays (10%) were entirely biseriate (Figure 2E) and were composed of cells procumbent to the center and generally an upper row of square cells [311.07 + 84.49 (123.54 - 515.70) µm height], with 10.58 + 2.78 (4.00 - 16.00) cells and 26.86 + 7.81 (15.05 - 55.96) µm wide. The aggregated rays, two different sizes and fused rays, were considered absent, in addition to the surrounding cells, perforated with rays and latericuliform.

The fibers occupied the largest percentage of the wood volume (39%), being libriform and septate (Figure 2D), medium [1455.97 + 218.14 (1055.25 - 2037.25) µm] and thin [4.86 + 1.30 (2.75 - 8.28) µm]. Simple, oblique slit-shaped pits were visible in the radial plane of the wall. Gelatinous fibers, helical thickenings and tracheids were absent. Other characteristics observed were crystals in chambers in the axial parenchyma cells, in addition to the absence of a stratified structure; oil cells; and cellular and intercellular channels, including phloem, medullary macules, glandular cysts and trabeculae.

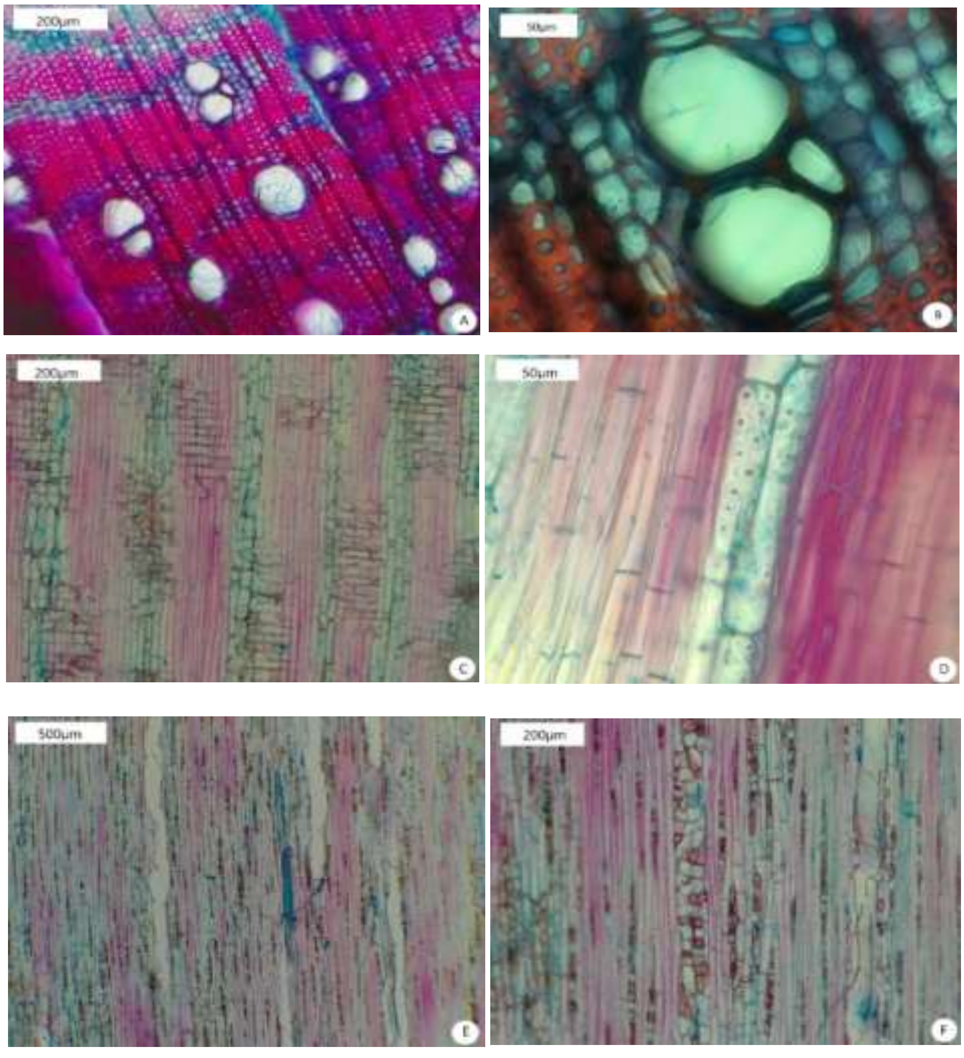

FIGURE 2 - A. Transverse plane of the wood with evidence of solitary pores in multiple radials and in clusters. **B.** Pores with tyloses and paratracheal parenchyma in the transverse plane. **C.** Heterogeneous rays composed of cells procumbent to the center and with an upper row of square cells in a radial plane. **D.** Radial plane with details for the libriform and septate fibers and axial parenchyma cells. **E.** Rays predominantly biseriate in the tangential plane. **F.** Vessels similar to tylose in the tangential plane.

The main anatomical characteristics of wood *Guarea kunthiana*, such as small to medium pores, radial multiples, simple perforation plates, medium vascular elements, small intervascular pits, and the presence of crystals and heterogeneous rays, commonly occur in Meliaceaceae, a botanical family known for being quite homogeneous in terms of wood anatomy (KRIBS, 1930; METCALFE and CHALK, 1972). The species also has characteristics described by Record (1941) in the genus *Guarea*: medium pores, solitary or multiple pores, small intervascular pits, wide rays 1-2 cells, small intervascular pits, ray-vascular, abundant axial parenchyma, and a series of crystalline and chambered fibers.

The quantitative composition of the wood *G. Kunthiana* differed *from G. lessoniana* from Rio Grande do Sul, described in the study by Marchiori (1985), as it presented 7.3% and 6.7% more radial parenchyma tissue and pores, respectively, and 15.3% less axial parenchyma tissue.

In the present study, the fibers were found to be libriform and septate, similar to the findings of the study by Marchiori (1985) with *G. lessoniana*. Interestingly, Verna (1979) did not mention the presence of septa in fibers in the two Argentine species studied, *G. pohlii* C. DC. e *G. spiciflora* A. Juss. The percentage of heterogeneous rays (10%) appears to be new in the description of the species. Léon (2006), when describing *the G. Kunthiana* in Venezuela predominantly mentions homogeneous and rare heterogeneous uniseriate rays, corroborating the findings of Metcalfe and Chalk (1972), as characteristic of the radial tissue in the genus mentioned above.

The quantitative anatomical characteristics of the wood of the three trees sampled at different points inside the Gruta do Janelão region are presented in Table 2, where the statistical analysis showed no significant difference for the vast majority of the anatomical information. Sample 1 was located 57.5 m from the watercourse and contained pores with relatively small diameters and high frequencies. When the plant is in an environment with little available water resources, it invests in a greater number of pores and less thickness so that the probability of embolism decreases, and if the water flow is interrupted, there will be other pores available (MELO JÚNIOR et al., 2017).

TABLE 2 - Anatomical quantitative characters of wood *Guarea kunthiana*, considering the analysis of the three samples collected in Gruta do Janelão.

Anatomical quantitative characters of wood	Samples		
	1	2	3
Pore frequency (pores mm^{-2})	8.08 a*	3.50 c	5.45 b
Total pore diameter (µm)	106.04 b	116.96 b	145.56 a
Pore lumen diameter (µm)	90.49 b	104.42 b	131.78 a
Pore wall thickness (µm)	7.78 a	6.27 a	6.89 a
Length of vascular elements (µm)	525.66 b	618.59 a	609.90 ab
Appendage length (µm)	51.39 a	51.44 a	66.81 a
Diameter of intervascular pits (µm)	3.22 b	3.71 a	3.15 b
Diameter of vascular ray points (µm)	4.06 a	2.94 b	3.32 ab
Diameter of vascular parenchyma pits (µm)	3.44 a	3.50 a	3.54 a
Height of the axial parenchyma series (cells)	5.00 b	6.04 ab	6.68 a
Height of the axial parenchyma series (µm)	531.21 ab	492.84 b	594.00 a
Axial parenchyma serial width (µm)	24.37 b	25.59 ab	27.56 a
Ray frequency (rays mm^{-2})	8.00 b	12.00 a	11.00 a
Height of uniseriate rays (cells)	7.96 a	9.56 a	10.15 a
Uniseriate ray width (µm)	269.18 a	290.33 a	309.83 a
Height of multiserial rays (cells)	18.62 a	14.23 b	16.50 ab
Height of multiserial rays (µm)	9.31 b	10.70 ab	12.50 a
Width of multiserial rays (µm)	286.24 b	282.70 b	379.14 a
Fiber length (µm)	32.51 a	20.95 b	23.75 b
Total fiber diameter (µm)	1477.98 a	1315.10 b	1574.83 a
Fiber lumen diameter (µm)	10.69 a	7.92 b	11.03 a
Fiber wall thickness (µm)	4.96 a	5.31 a	4.32 b

Where * means followed by the same letter in the column do not differ statistically according to the Tukey test at a 5% probability of error.

Vessel frequency is an important anatomical aspect for indicating xeromorphism and mesomorphism, and although frequency is expected to be inversely proportional to the diameter of vessel elements, it is not closely related and can vary independently to a large extent (CARLQUIST, 2001). According to the same author, values above 100 vessels mm^{-2}, considered high, are typical of xerophilic species, while low frequencies normally occur in species from humid tropical forests.

Fibers are tissues that also respond to water availability. Longer fibers and thin walls were measured in sample 3, which seems to favor the flow of water in the wood. On the other hand, the greater development of mechanical support tissues, especially in sample 2, may be related to the low water availability in the environment in which it is located (MELO JÚNIOR et al., 2012; MONTEIRO, 2017). Given the above, it can be inferred that sample 2 is the oldest tree among the three, with greater dendrometric dimensions in height and diameter; thus, the high probability of the sample corresponding to the portion of adult wood explains the lower values in the length of the trees. fibers.

The influence of the environment on the anatomical development of wood is an old and widely discussed subject (MELO JUNIOR et al., 2017; GONÇALVES et al., 2020; ALMEIDA et al., 2022). In the 1930s, Webber (1936) demonstrated a tendency for desert plants to have narrow growth rings and numerous and shorter pores. In the literature, there are works that clarify the adaptations of the wood of mesic and xeric plants, as in Paula et al. (2018) and Silva; Souza and Gomes (2021); however, underground locations, such as caves and caves, are still little researched.

As they are long-lived beings, trees are subject to a wide spectrum of environmental conditions, forcing them to develop adaptation mechanisms and high phenotypic plasticity, including in wood anatomy (AITKEN; BEMMELS, 2016; CUNY et al., 2019; KLISZ et al., 2019). The concept of phenotypic plasticity refers to the ability of the same genotype to produce different phenotypes so that the organism can adjust its development and physiology in response to the characteristics of the environment (RIBEIRO et al., 2020).

Factors such as altitude, latitude, flooding, drought, pollution and solar radiation can significantly alter the secondary tissues of plants (POPKOVA et al., 2018; CUNY et al., 2019; ALMEIDA et al., 2022). Studies related to solar radiation have shown that the main changes occur in the density, diameter and length of vessels; fiber wall length; fiber wall thickness; and composition of the axial parenchyma (BIREAHLS et al., 2020). In the present work, it was not possible to establish a relationship between the quantitative characteristics of plant wood and light intensity, as the sample that received more light (sample 2) statistically presented only intervascular pits of greater diameter.

When relating the anatomical characteristics of vessel frequency, diameter and length, sample 2 had higher rates of vulnerability and mesomorphy (Table 3). The vulnerability index reflects individuals' predisposition to suffer embolism. An index lower than 1 implies a lower propensity for cavitation (CARLQUIST, 1977), which was not reported in any of the samples studied. In this case, vessels with a larger diameter are efficient at achieving conduction; however, they are more vulnerable to water interruption due to embolism (DÓRIA et al., 2016).

TABLE 3 - Ecological indicators of the *samples from Guarea Kunthiana*, considering the analysis of the three samples collected in Gruta do Janelão.

Samples	Vulnerability Index	Mesomorphy index
1	11.81 b*	6,324.74 b
2	44.52 a	26,325.66 a
3	25.13 b	14,854.13 b

Where * means followed by the same letter in the column do not differ statistically according to the Tukey test at a 5% probability of error.

In plants with a higher vulnerability index (IV), there is a high risk of cavitation, especially under negative pressure, when the soil has low water availability. Otherwise, under conditions of environmental stress, the plant invests in a greater number of smaller diameter vessels to reduce the risk of embolism, as the vessels thus have greater adhesion of water to their walls, preventing the formation of air bubbles. (SCHOLZ et al., 2014).

According to the information proposed by Carlquist (1977), a lower vulnerability index implies better adaptation to an environment with low water availability, suggesting that the species *Guarea kunthiana* is a mesomorphic plant and that the controlled humidity and temperature conditions in the cave environment are reflected in the structuring of its secondary xylem.

For the mesomorphy index (MI), values above 200 indicate whether the plant has anatomical structures adapted to conditions with low humidity, that is, mesomorphic plants (CARLQUIST, 1977). All the samples were adaptable, with shorter vessels that were resistant to collapse and deformation. For comparison purposes with species from different vegetation, Melo Junior et al. (2016) reported IM values of 1.118,14 for species from Campo Rupestre and 1.326,35 for the Campo Cerrado. It was also verified that individuals from the Cerrado have higher IV values (19.7) and mesomorphism patterns similar to those of the samples studied in the present work.

Inside the Janelão Cave, sample 2 was located on a skylight, which explains the higher light intensity (0.06 lx), height (16 m) and diameter (18.84 cm) data. As a result, the leaves of this sample (Table 4) had smaller dimensions than did those of sample 3 (0.02 lx of luminosity). The plants exposed to greater light intensity and far from the watercourse tend to have smaller leaves, so that the contact between the leaf blade and the sun's rays is lessened, saving water in this process of evapotranspiration and controlling water stress.

The intensity of light received by the plant directly influences water loss since the increased absorption of sunlight leads to an increase in the plant's internal temperature and greater water loss through the leaf stomata (TAIZ et al., 2017). Photosynthetic carbon gain differs greatly between leaves that receive sunlight (sun leaves) and leaves in shade (shade leaves) (MONTPIED et al., 2009; EVANS and CLARKE, 2019). Some studies have shown trends toward smaller sizes for leaves in the sun than for leaves in the shade, as in Pereira et al. (2013), *who studied Lithraea molleoides;* Guerra et al. (2015), *and ComHandroanthus chrysotrichus*. The leaves from sample 3 had greater values for length, width and blade area. Light intensity combined with water availability contributes to leaf growth.

At lower light levels, the increase in leaf area in sample 3 was responsible for maximizing light capture and maintaining the efficiency of the photosynthesis process. Leaf area is an important variable in the study of plant ecology because it is associated with many aspects of plant growth and survival and is a characteristic of resource use strategies (BASTOS et al., 2019). A lower leaf area may represent a greater investment in mechanical fabrics (CABRAL et al., 2018), as observed in samples 1 and 2.

TABLE 4 - Morphological *characteristics of leaves of Guarea kunthiana* according to the analysis of the three samples collected in the Gruta do Janelão region.

Samples	Length of blade (cm)	Width of blade (cm)	Length/ blade width	Area of blade (cm^2)
1	32.67 a	48.73 b	0.70 a	1,627.06 b
2	35.13 a	48.69 b	0.72 a	2,136.16 b
3	56.67 b	71.65 a	0.79 a	5,554.12 a

where * means followed by the same letter in the column do not differ statistically according to the Tukey test at a 5% probability of error.

The correlations between the anatomical characteristics of the wood plants and the morphology of the leaves, light intensity and vulnerability and mesomorphy indices were determined based on the Spearman correlation coefficient (Table 5). A very strong negative correlation was observed only between the total diameter of secondary xylem fibers and the length/width ratio of the leaf blade. Regarding leaf attributes, the laminar area had the highest association with wood anatomy; that is, the larger the laminar area was, the greater the vessel frequency was. Thick vessel walls reduce the lamina area; that is, the greater the height of the axial and radial parenchyma series is, the smaller the lamina area.

TABLE 5 - Spearman correlation between the anatomical *characteristics of wood Guarea kunthiana* and morphology, luminosity (LUM), vulnerability index (IV) and mesomorphy index (IM).

Anatomical characters of wood	Morphology				Luminosity	Indices	
	CL	LL	C/L	A^2	LUM	IV	IM
Pore frequency (pores mm^{-2})	0.82	ns	ns	0.74	ns	-0.65	-0.69
Total pore diameter (µm)	ns	ns	ns	ns	ns	0.61	0.50
Pore lumen diameter (µm)	ns	ns	ns	ns	ns	0.60	0.52
Pore thickness (µm)	ns	ns	ns	-0.77	ns	ns	ns
Vascular element length (µm)	ns	ns	ns	ns	-0.53	0.34	0.47
Appendix length (µm)	ns	ns	ns	ns	ns	ns	ns
Intervascular puncture diameter (µm)	ns	ns	ns	ns	-0.75	ns	ns
Radius-vascular puncture diameter (µm)	ns	ns	ns	ns	ns	ns	ns
Parenchymal-vascular pit diameter (µm)	ns	ns	ns	ns	ns	ns	ns
Axial parenchyma cell number (cells)	ns	ns	ns	ns	ns	ns	ns
Axial parenchyma series height (µm)	ns	ns	ns	-0.75	ns	ns	ns
Axial parenchyma series width (µm)	ns	ns	ns	ns	ns	ns	ns
Spoke frequency (spokes mm^{-2})	ns	ns	ns	ns	ns	0.43	0.46
Uniseriate radius cell number (cell)	ns	ns	-0.68	ns	ns	ns	ns
Uniseriate radius height (µm)	ns	ns	ns	-0.70	ns	ns	ns
Uniseriate ray width (µm)	ns	ns	ns	ns	ns	-0.34	-0.30
Multiserial ray cell number (cell)	ns	ns	ns	ns	ns	0.57	0.60
Multiserial ray height (µm)	ns	ns	ns	ns	ns	ns	n.s
Multiserial ray width (µm)	ns	ns	ns	ns	ns	-0.42	-0.45
Fiber length (µm)	ns	ns	ns	ns	ns	0.28	0.34
Total fiber diameter (µm)	ns	ns	-0.90	ns	ns	ns	ns
Fiber lumen diameter (µm)	ns	ns	ns	ns	ns	-0.35	-0.39
Fiber thickness (µm)	ns	ns	ns	ns	0.55	ns	ns

CL = blade length (cm), LL = blade width (cm), L/L = blade length–to–blade width ratio, A2 = blade area (cm^2). ns = nonsignificant correlation; >0.9 = very strong correlation; 0.89 to 0.7 = strong correlation; 0.69 to 0.4 = moderate correlation; 0.39 to 0.2 = weak correlation. LUM = north, south, east and west.

Bachtold and Melo Júnior (2015) found in studies with *Calophyllum brasiliense* Camb. that the leaves are closely linked with the anatomy of the wood. Leaf tissue is mainly responsible for morphofunctional adjustments in plants, where the responses to these adjustments are recognized by vascular exchange and reflected in the development of xylem cells. Regarding luminosity, both the length of the vascular element and the diameter of the intervascular spots decrease as the light intensity increases. Additionally, the more light there is, the greater the photosynthetic rate and, consequently, the greater the growth, suggesting an increase in the thickness of the fiber wall.

In general, future work can be carried out, for example, through an ecological comparison of the anatomy of *wood Guarea kunthiana* sampled from second vegetation, in addition to that of Gruta do Janelão. Additionally, other environmental attributes, such as relative air humidity and soil nutrition, which can be equally influential characteristics in plant development, should be checked.

CONCLUSIONS

The main anatomical characteristics of wood *Guarea kunthiana* are common in the genus and family Meliaceae.

The quantitative anatomical data seemed to be more influenced by the distance the plant was from the watercourse than by the light intensity it received.

Ecological indices suggest that plant characteristics are adaptable to mesomorphic environments.

The area of the leaf blade was the attribute that showed the greatest association with the anatomy of the wood.

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