Scientific Article

HYDRAULIC TRAITS OF *Jacaranda copaia* (AUBL.) D. DON. (BIGNONIACEAE) IN THE SOUTHWEST AMAZON

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ABSTRACT – Trees transport water from underground to the atmosphere through the evapotranspiration process. Climate change can significantly compromise this process due to changes in land use, such as deforestation. This study aimed to characterize the hydraulic and anatomical attributes of *Jacaranda copaia* (Aubl.) D. Don (Bignoniaceae), in the Southwestern Brazilian Amazon. For this purpose, the xylem vulnerability curve of this species was described. The frequency and diameter of the xylem vessels and the stomata density were also measured. Finally, a hydraulic attribute of *Jacaranda copaia* was compared to other species at global, tropical, and Amazonian levels. The findings show that, in the region studied, the species *Jacaranda copaia* has diffuse-porous woods and numerous vessels (average vessel ranging from 8 to 14 nº/mm^2) with small (<50µm) to medium (between 100 and 200 µm) diameters. The average stomatal density ranged from 289 to 309 stomata/mm^2. The xylem hydraulic resistance to embolism (Ψ_{50}) ranged from -0.814 to -2.400 MPa, with relatively narrow hydraulic safety margins (HSM_{50} ranging from -0.312 to 1.122; HSM_{88} ranging from 0.204 to 1.709). The average values of Ψ_{50} detected were similar to a large percentage of arboreal species at global, tropical, and Amazonian levels. Possibly, the studied species presents a more “risky” hydraulic strategy, with relatively narrow hydraulic safety margins, due to its dynamic character of fast growth, typical of pioneer species.

Keywords: Stomatal density; Hydraulic traits; Jacaranda.

TRAÇOS HIDRÁULICOS DE Jacaranda copaia *(AUBL.) D. DON. (BIGNONIACEAE) NO SUDOESTE AMAZÔNICO*

RESUMO – As árvores transportam água do subsolo para a atmosfera através do processo de evapotranspiração. As mudanças climáticas podem comprometer significativamente esse processo devido a mudanças no uso da terra decorrentes, por exemplo, do desmatamento. O objetivo deste estudo foi caracterizar os atributos hidráulicos e anatômicos de ***Jacaranda copaia*** *(Aubl.) D. Don (Bignoniaceae) no sudoeste da Amazônia brasileira. Para tanto, foi descrita a curva de vulnerabilidade do xilema desta espécie. A frequência e o diâmetro dos vasos do xilema e a densidade dos estômatos também foram medidos. Finalmente, um atributo hidráulico de* ***Jacaranda copaia*** *foi comparado a outras espécies em nível global, tropical e amazônico. Os achados mostram que, na região estudada, a espécie* ***Jacaranda copaia*** *possui lenhos de porosidade difusa e vasos numerosos (vasos médios variando de 8 a 14 nº/mm*^{2}*) com diâmetros pequenos (<50µm) a médios (entre 100 e 200 µm). A densidade estomática média variou de 289 a 309 estômatos/mm*^{2}*. A resistência hidráulica do xilema à embolia (*Ψ_{50}*) variou de -0.814 a -2.400 MPa, com margens de segurança hidráulica relativamente estreitas (*MSH_{50} *variando de -0.312 a 1.122;* MSH_{88} *variando de 0.204 a 1.709). Em geral, os valores médios de* Ψ_{50} *detectados foram semelhantes a uma grande porcentagem de espécies arbóreas em nível global, tropical e amazônico. Possivelmente, a espécie estudada apresenta uma estratégia hidráulica* *mais "arriscada" (ou seja, margens de segurança hidráulica relativamente estreitas), devido ao seu caráter dinâmico de crescimento rápido, típico de espécies pioneiras.*

Palavras-Chave: Densidade estomática; Características hidráulicas; Jacaranda.

1. INTRODUCTION

Tropical forests are important for maintaining regional and global CO_2 fluxes, contributing with approximately one-third of global net primary productivity (Field et al., 1998). In addition, the processes of evapotranspiration and condensation in this region feed the global atmospheric circulation, promoting the precipitation in South America and in Northern Hemisphere (Malhi et al., 2008). These important processes are facing major threats due to the global climate change. The frequency, duration, and intensity of the dry period, as well as heat stress, have increased in the last years (Aragão et al., 2007; Marengo et al., 2008; Jiménez-Muñoz et al., 2013; Jiménez-Muñoz et al., 2016). This increase is resulting in changes in composition, structure, and biogeography of these tropical forests (Brienen et al., 2015; Esquivel-Muelbert et al., 2017; Aguirre-Gutiérrez et al., 2019; Aguirre-Gutiérrez et al., 2020).

These climate changes have increased tree mortality, which is a frequent concern in science (Allen et al., 2010; Phillips et al., 2010; Aguirre-Gutiérrez et al., 2020). Studies carried out in the last three decades indicate a relationship between extreme drought periods along the Amazon basin, decrease in plant growth rates, and increase in tree mortality (Allen et al., 2010; Brienen et al., 2015). These longer drought periods reduce stomatal conductance, and consequently gas exchange (Marenco et al., 2006), negatively influencing net carbon assimilation (Tyree e Ewers, 1991) and plant growth rate (Brienen et al., 2015).

In addition, intense droughts can also generate negative impacts on the hydraulic architecture of trees, compromising the transporting of water from the roots to the leaves (Cruiziat et al., 2002). To enable water pumping in plants, the sap flow must be continuous along the water transport system, maintaining the hydraulic connection between the soil and the atmosphere (Steppe et al., 2015). According to Rowland et al. (2015), in prolonged dry periods hydraulic failure, more than the reduction in the supply of unstructured carbohydrates, triggers the death of trees. The increased tension of the water column in the xylem, due to the increased demand for evaporation in dry periods and the non-supply of water by the soil, results in the rupture of the water column (cavitation) and the formation of air bubbles (embolism) (Tyree e Zimmerman et al., 2002). Embolism reduces hydraulic conductance, limiting the ability of plants to deliver water to aboveground tissues, and potentially affecting stomatal opening, with consequent reduction in photosynthetic rates (Brodribb et al., 2007). The hydraulic architecture of plant species, such as wood characteristics, affect plant resistance to embolism. Plant species with wider xylem vessels, for example, tend to be more vulnerable to embolism (Olson et al., 2018).

A way to assess the susceptibility of a plant to cavitation is performed through the xylem vulnerability curve, which determines the relationship between the water potential (Ψ), and its corresponding loss of hydraulic conductivity (Sperry et al., 1988). This xylem vulnerability curve and the characteristics of the xylem hydraulic architecture can provide valuable information about the probable resistance to drought and the limitations imposed to the species by environmental stresses (Tyree e Ewers, 1991). The xylem vulnerability curve reveals the water potential tolerated by a plant, before the beginning the xylem cavitation process.

The water potentials Ψ_{50} and Ψ_{88} are indices of embolism resistance in terms of percentage loss of xylem hydraulic conductivity. When a plant reaches the water potentials of Ψ_{50} and Ψ_{88}, 50% and 88% of the vessels, respectively, are embolized (Tyree and Zimmerman et al., 2002; Choat et al., 2012). The difference between the minimum water potential of a plant under natural conditions (Ψ_{min}) and Ψ_{50} or Ψ_{88} represents a hydraulic safety margin (HSM_{50} or HSM_{88}), in which the plant maintains its functionality in a given environment (Choat et al., 2012). The HSM indicates whether the plant is more or less resistant to drought, ecologically delimiting the environments in which it can develop (Eller et al., 2018).

The intensification of severe drought events calls for understanding the ecophysiological behavior of tree species, especially those with a wide distribution in the Neotropics, such as *Jacaranda copaia* (Aubl.) D. Don. (Bignoniaceae). This species is a pioneer tree that reaches between 25-35 m in height and up to 75 cm in diameter (Gentry and Morawetz, 1992). It has a uniform distribution in the environment, occurring in clearings, degraded areas, forest edges, and inside the forest (Guariguata et al., 1995). In Brazil, the species has a wide distribution in the Amazon basin (Maués, 2006), with records in the states of Acre, Amazonas, Amapá, Pará, Rondônia, Maranhão, and Mato Grosso (BFG, 2021), and in countries such as French Guiana, Guiana, Suriname (Vattimo, 1980), Ecuador, and Peru (Gentry, 1992).

In this context, this study aimed to describe the hydraulic traits (Ψ_{foliar}, Ψ_{50}, Ψ_{88}, HSM_{50}, HSM_{88}, and xylem vulnerability curve), frequency and diameter of xylem vessels, and stomata density of the tree species *Jacaranda copaia* in the southwest of the Brazilian Amazon. The water potential values (Ψ_{50}) of this species was then compared with other tree species at global, tropical, and Amazonian levels.

2. MATERIALS AND METHODS

2.1. Study area

This work was carried out at the Fazenda Experimental Catuaba – FEC (10º 04'S 67º 37'W), located in the municipality of Senador Guiomard, Acre, Brazil. In this place, there is a forest fragment of approximately 1,200ha, in which the Dense Ombrophylous Forest predominates, with forest patches dominated by the bamboo species *Guadua weberbaueri* (Castro et al., 2013). Average annual rainfall is around 1,986 mm, with monthly averages ranging from 299.0 mm in the rainy season (October to April) to 28.9 mm in the dry season (June to August) (Duarte, 2020). The average annual temperature is 23ºC, with little variation throughout the year (Duarte, 2006).

2.2. Hydraulic traits and stomatal characteristics

To describe the hydraulic traits and the stomatal characteristics, four individuals of *Jacaranda copaia* with diameter at breast height (DBH) > 10 cm, and with branches and leaves from the canopy top completely exposed to sunlight were used. A branch with fully expanded and mature leaves, with no record of herbivory, was collected from each of the four trees, using specific climbing equipment.

To analyze the stomatal characteristics, three leaves per branch and one leaflet per leaf were used, totaling three samples (leaflets) per tree and 12 samples considering the four trees studied. In leaflets, stomatal characteristics were measured in three fields (subsamples of 0.1 mm^2), as described below.

Initially, to prepare the slides used in the stomata characterization, a quick-drying glue (based on Ethyl cyanoacrylate) was applied to the central region of the adaxial and abaxial surface of each leaflet. A slide was placed on the glue, and after drying, the leaflet was carefully separated from the slide (Kröber et al., 2015). Subsequently, the slides were photographed with 100x magnification (10x eyepiece and 10x objective lens) to observe the stomata density, and with 400x magnification (10x eyepiece and 40x objective lens) to verify the stomatal length, using an optical microscope (Bioptika) with attached camera (Tucsen -16 mp Live resolution).

Subsequently, stomata density was quantified, and the stomatal length was measured using an open-source software for processing images (Image J) (Ferreira and Rasband, 2012; Kröber et al., 2015). In each image containing the epidermal impression of the analyzed leaflets, a network of quadrants with 100,000μm^2 (0.1mm^2) was created. Three of these quadrants (sub-samples) were randomly selected and submitted to stomatal counting, using the "multi-point" tool. The "straight" tool (Kröber et al., 2015) was also used to measure the guard cells length. All stomata present in the selected quadrants were measured, however, to measure the guard cell width, only closed stomata were considered.

To measure the hydraulic traces, five proof bodies of each evaluated branch were used, which ranged from 2.0 to 3.0 cm in diameter, totaling five samples per tree and 20 samples considering the four trees evaluated in the present study. All proof bodies remained 24 hours in a solution of water, glycerin and alcohol. After this period, 12-15μm cross-sectional histological sections were prepared from these proof bodies on the sliding microtome (Leica 2010R), which were washed in distilled water and submerged in bleach for clarification, within a period of two hours. Subsequently, each cross-sectional histological section was washed in distilled water and dehydrated in a series of alcoholic solutions of 50%, 70%, 90%, and 100%. The best sections were stained in 1% safranin solution. After removing the excess of this dye with distilled water, another dye (xylene) was used. The selected sections were placed on glass slides with resins (Canada Balsam or Entelan), and covered with coverslips (Trevizor, 2011). Finally, the same equipment used to measure the stomata density was used to evaluate the frequency and diameter of xylem vessels. For this, the procedures and standards established by the International Association of Wood Anatomists (1989) were followed and the open-source software for processing images (Image J) was used.

2.3. Xylem vulnerability curve and hydraulic safety margins (HSM)

The xylem vulnerability curve is a sigmoid function that expresses the relationship between the percentage loss of hydraulic conductance (PLC) and the xylem water potential (Ψ_x), from a condition of total hydration to its complete desiccation. For the construction of the xylem vulnerability curve, information from the following variables was used: leaf water potential (Ψ_f), minimum water potential (Ψ_{min}), xylem water potential (Ψ_x), and the amount of air coming from the branches during the drying process (representative of the hydraulic conductance of vessels). From the xylem vulnerability curve, the indices of xylem hydraulic resistance to embolism (Ψ_{50} and Ψ_{88}) were identified.

The leaf water potential (Ψ_f) expresses the water condition of a plant, being reduced when it releases water vapor when transpiring. To measure the leaf water potential (Ψ_f), in the dry period, a branch of approximately 30 cm in length was collected from each individual at different times: dawn (between 3:30 am to 5:30 am); morning (7:00 am to 9:00 am); noon (11:00am–01:00 pm); and afternoon (02:00 pm to 04:00 pm). From one leaf of each branch, three to five leaflets were detached, which were deposited in a zip lock plastic bags. To avoid transpiration and desiccation of the leaflets, the researchers blew inside the plastic bag before closing it. To perform the measurements, after a maximum of 15 minutes, the material was taken to the Scholander pressure chamber (model 1505D-EXP, PMS Instrument Company 1725 Geary Street SE, Albany OR 97322-USA), which was located in the sampling area and was attached to a nitrogen cylinder (Scholander e Hammel, 1965). From the collected daily values of leaf water potential (Ψ_f) in the dry period (diurnal curve), the minimum water potential (Ψ_{min}) was identified, which represents the water stress level in natural conditions, experienced by plants in the field.

To measure the amount of air coming from the branches during the drying process (representative of hydraulic conductance of vessels) and the xylem water potential (Ψ_x), the pneumatic method and the Scholander pressure chamber technique were used, respectively. These variables were measured in the rainy season. During this season, a branch approximately 1.5m long was collected from each of the four individuals, always at dawn (3:30 a.m. to 5:30 a.m.). Soon after the branches were collected, each one of them was identified and their base wrapped in a damp cloth to avoid drying out. Subsequently, the branches were stored in black plastic, sealed with adhesive tape, in order to avoid transpiration and moisture loss. The branches remained involved in the black plastic for one hour, in order to balance the xylem water potential in the branch and in the leaf. After this period, in the improvised laboratory at FEC, the branches were cut into pieces of 45-60 cm, and a silicone hose was installed at the base of each piece to attach it to the pneumatic apparatus. The pneumatic apparatus (Pereira et al., 2016) measures the amount of air in the xylem, following the pressure changes and provides the percentage of air leakage, which represents the percentage loss of hydraulic conductance (PLC), represented in the curve as percentage of air discharge (PAD).

In the pneumatic method, a syringe without a needle was used as a vacuum source. The airflow from de branch was measured using a transducer and a millivoltmeter (precision of 0.01 kPa). As soon as the branch was connected to the vacuum reservoir, the initial pressure was measured (Pi in kPa). Subsequently, the airflow from the branch was extracted into the vacuum reservoir for two minutes, and then the final pressure (Pf in kPa) was measured. To balance the xylem water potential in the branch and in the leaf, the branch was again involved in the black plastic for another hour. This procedure was repeated until the branch was completely desiccated, a condition confirmed by its appearance and the result obtained in the Scholander pressure chamber (great pressure and absence of water droplets).

The amount of air moles (Δn) discharged from the branch into the vacuum reservoir, considering the ideal gas laws, was calculated as follows:

$(\Delta n=(Pf-Pi)V)/RT$

In this equation, Pf = final pressure (in kPa), Pi = initial pressure (in kPa), V = volume of the vacuum reservoir (0.0082 L), R = gas constant (8.314 kPa L mol^{-1} K^{-1}), and T = temperature (in Kelvin) of the environment.

The volume of air discharged (in µl) (AD) was calculated by transforming Δn into an air volume equivalent to atmospheric pressure (Patm in kPa) according to the equation:

$AD=(\Delta nRT/P_{atm})10^6$

The percentage of air discharge (PAD in %) was defined in the same way as the percentage loss of hydraulic conductance (PLC in %), through the following equation:

$PLC/PAD=100(ADi-ADmin)/(ADmax-ADmin)$

In this equation, ADi = volume of air discharged (in µl) at each measurement, ADmin = minimum volume of air discharged (in µl) when the branch is fully hydrated, and ADmax = maximum volume of air discharged (in µl) at the lowest xylem water potential (Pereira et al., 2016; Bittencourt et al., 2018).

$PAD=100/(1+\exp((S/25)(\Psi-b)))$

These results were used to construct the xylem vulnerability curve (Tavares and Galbraith, 2017; Pereira et al., 2016; Bittencourt et al., 2018; Zhang et al., 2018).

2.4. Vulnerability of *Jacaranda copaia* in tropical forests

To position the Ψ_{50} values detected in this study for *Jacaranda copaia* among the values of this index detected for other arboreal species at global, tropical, and Amazonian levels, histograms were constructed with information published in several scientific articles. For the histogram built with Ψ_{50} values at global and tropical level, a compilation made by Choat et al. (2012) with information from different species was used. For the Amazon level, this information was found in different published articles (Barros et al., 2019; Oliveira et al., 2018; Rowland et al., 2015; Santiago et al., 2018).

3. RESULTS

3.1. Xylem anatomy

The sampled branches of *Jacaranda copaia* have diffuse-porous woods, without distinct growth rings, solitary vessels and in groups of two, three, five or more. Among the studied individuals, the average vessel frequency ranged from 8 to 14 nº/mm², and the average vessel diameter ranged from 68 to 85 µm (Table 1). For all individuals, vessel diameters ranged from very small (<50µm) to medium (between 100 and 200 µm) (Table 1), according to the Iawa classification (1989).

3.2. Stomatal characteristics

According to the analyzed material, the stomatal complexes of *Jacaranda copaia* are hypostomatic, that is, they are located only on the abaxial surface of

Table 1 – Xylem characteristics of four individuals of *Jacaranda copaia* sampled at Fazenda Experimental Catuaba (FEC), Acre, Brazil. For each individual, the measurements were performed on slides made from five proof bodies, totaling five samples per individual.
Tabela 1 – *Características do xilema de quatro indivíduos de* ***Jacaranda copaia*** *amostrados na Fazenda Experimental Catuaba (FEC), Acre, Brasil. Para cada indivíduo, as medidas foram realizadas em lâminas confeccionadas a partir de cinco corpos de prova, totalizando cinco amostras por indivíduo.*

Individuals	Frequency of xylem vessels (nº/mm²)				Vessel diameter (µm)			
	Min.	Max.	Average	Standard deviation	Min.	Max.	Average	Standard deviation
1	6	18	10	2.93	18	191	81	30.17
2	5	11	8	1.86	36	151	84	22.17
3	11	19	14	2.45	30	171	68	25.06
4	5	14	8	2.74	26	142	85	22.53

Note: Diameters: =<50µm (very small), < 100µm (small), between 100 and 200 µm (medium) and > 200 µm (Large).
Nota: Diâmetros: =<50µm (muito pequeno), < 100µm (pequeno), entre 100 e 200 µm (médio) e > 200 µm (Grande).

Table 2 – Stomatal characteristics of four individuals of *Jacaranda copaia* sampled at Fazenda Experimental Catuaba (FEC), Acre, Brazil. For each sample (leaflets) of each individual, the stomatal characteristics were measured in three fields (subsamples of 0.1 mm2), totaling nine sub-samples per tree.
Tabela 2 *– Características estomáticas de quatro indivíduos de* ***Jacaranda copaia*** *amostrados na Fazenda Experimental Catuaba (FEC), Acre, Brasil. Para cada amostra (folíolos) de cada indivíduo, as características estomáticas foram medidas em três campos (sub amostras de 0.1 mm²), totalizando nove sub amostras por árvore.*

Individuals	Guard cells length (µm)				Stomatal density (stomata/mm²)			
	Min.	Max.	Average	Standard deviation	Min.	Max.	Average	Standard deviation
1	14.19	29.41	21.25	2.89	303	317	309	6.94
2	17.82	31.63	23.61	2.61	243	337	289	46.71
3	17.05	31.73	22.44	2.6	277	317	292	21.43
4	17.64	30.4	21.86	2.99	270	330	301	30.06

the leaflet. The stomata are rounded and anomocytic, since the subsidiary cells surrounding the stomate are not differentiated from the other epidermal cells. The guard cells are reniform. Finally, the average length of guard cells ranged from 21.25 to 23.61 µm, and the average stomatal density ranged from 289 to 309 stomata/mm² (Table 2).

3.3. Xylem vulnerability curve

From the xylem vulnerability curves, a variation in the Ψ_{50} values between individuals was observed (ranged from -0,814 to -2,400 MPa) (Table 3). Only for individual number 01, Ψ_{min} was smaller than Ψ_{50}; for the other individuals, the pattern observed was the opposite (Ψ_{min} greater than Ψ_{50}) (Figure 1). Consequently, it was observed that individual number 01 was the one with the lowest values of HSM_{50} and HSM_{88}, and in general, the values of these parameters were not similar between individuals (Table 3).

3.4. Vulnerability of *Jacaranda copaia* in tropical forests

In general, the Ψ_{50} values of *Jacaranda copaia* (-1.86 MPa) are similar to the values of this index detected for other arboreal species at global, tropical, and Amazonian levels. More specifically, it was detected that the Ψ_{50} value of this species belongs to the class interval that includes data of 40% of the arboreal species of Amazon Forest, 35% of the arboreal species of Tropical Forest and 25% of the arboreal species considering world data (Figure 2).

4. DISCUSSION

According to the results of this study, *Jacaranda copaia* has diffuse-porous woods, without distinct growth rings, solitary vessels or in group, average vessel frequency ranging from 8 to 14 nº/mm², and vessel diameters ranging from small to medium (average tangential diameter of 79 µm). Its leaves are hypostomatic with anomocytic stomata and reniform guard cells. The hydraulic traits of the studied individuals showed relatively narrow hydraulic safety margins (HSM_{50} and HSM_{88}), and, in general, the average values of Ψ_{50} detected were similar to a large percentage of arboreal species at global, tropical, and Amazonian levels.

The xylem vessels of *Jacaranda copaia* were classified as small and numerous, according to Iawa (1989). Xylem vessels with small diameters may have greater resistance to cavitation, a lower possibility

Table 3 – Xylem vulnerability indices and hydraulic safety margins of four individuals of *Jacaranda copaia* sampled at Fazenda Experimental Catuaba (FEC), Acre, Brazil. Ψ_{min} = minimum water potential; Ψ_{md} = mean water potential; Ψ_{50} = water potential at 50% xylem cavitation; Ψ_{88} = water potential at 88% xylem cavitation; MSH_{50} = hydraulic safety margin at 50% xylem cavitation and MSH88 = hydraulic safety margin at 88% xylem cavitation.
Tabela 3 *– Índices de vulnerabilidade do xilema e margens de segurança hidráulica de quatro indivíduos de* ***Jacaranda copaia*** *amostrados na Fazenda Experimental Catuaba (FEC), Acre, Brasil.* Ψ_{min} *= potencial hídrico mínimo;* Ψ_{md} *= potencial hídrico médio;* Ψ_{50} *= potencial hídrico a 50% de cavitação do xilema;* Ψ_{88} *= potencial hídrico a 88% de cavitação do xilema;* MSH_{50} *= margem de segurança hidráulica a 50% de cavitação do xilema e* MSH_{88} *= margem de segurança hidráulica a 88% de cavitação do xilema.*

Individuals	Ψ_{min} (MPa)	Ψ_{md} (MPa)	Ψ_{50} (MPa)	Ψ_{88} (MPa)	MSH50 (MPa)	MSH88 (MPa)
1	-1.126	-1.038	-0.814	-1.330	-0.312	0.204
2	-1.278	-1.255	-2.400	-2.987	1.122	1.709
3	-1.256	-1.238	-1.455	-2.316	0.199	1.060
4	-1.289	-1.268	-1.805	-2.116	0.516	0.827

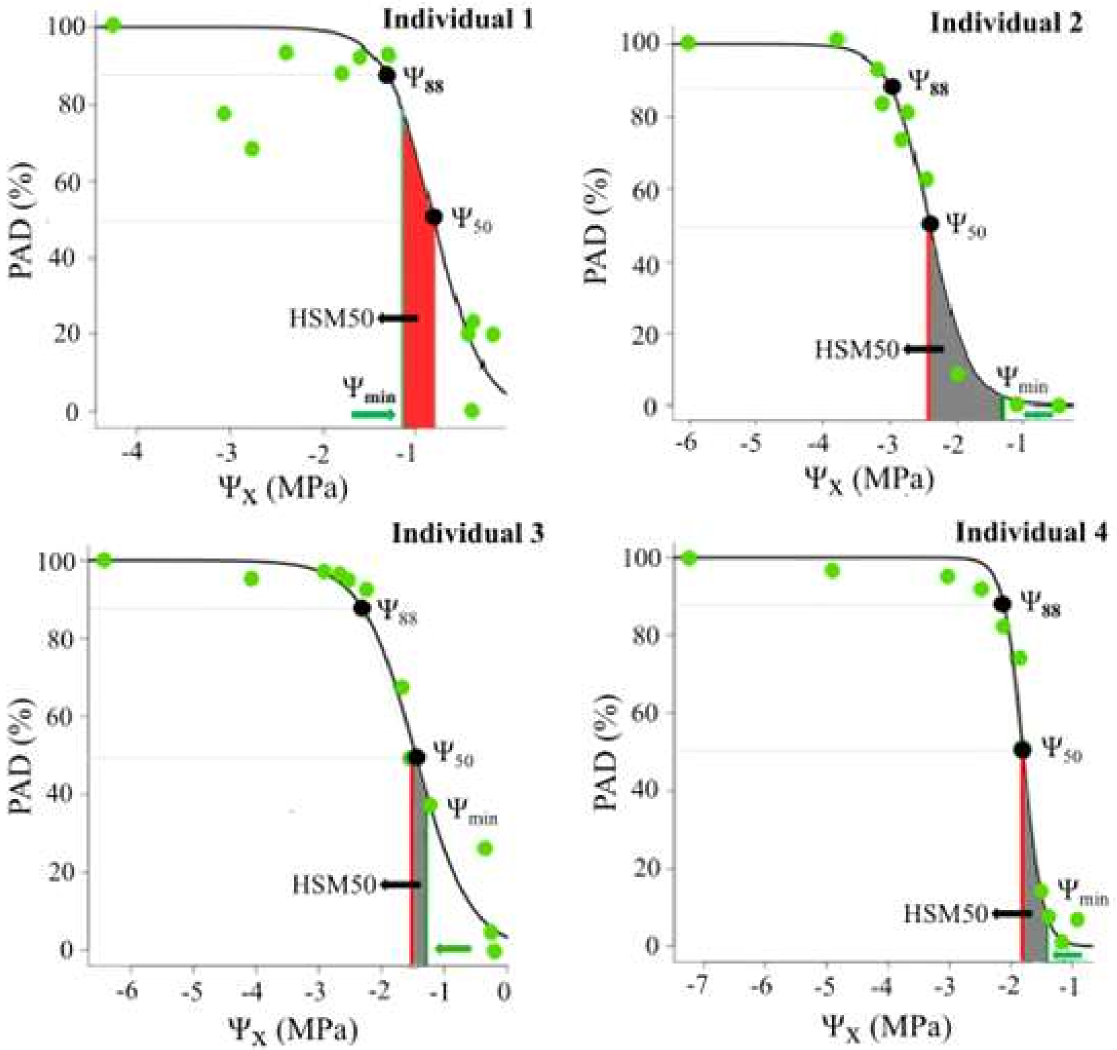

Figure 1 – Xylem vulnerability curves of four individuals of *Jacaranda copaia* sampled at Fazenda Experimental Catuaba, Acre, Brazil. The curves show percentage of air discharge (PAD) as a function of the xylem pressure (Ψ_x). Ψ_{50} and Ψ_{88} represent the water potencial (MPa) when 50% and 88% of the xylem vessels are embolized, respectively. Ψ_{min} represents the lowest value of water potential measured under natural conditions. The gray and red areas in the graphs represent the hydraulic safety margins (difference between Ψ_{50} and Ψ_{min}).

Figura 1 *– Curvas de vulnerabilidade do xilema de quatro indivíduos de* ***Jacaranda copaia*** *amostrados na Fazenda Experimental Catuaba, Acre, Brasil. As curvas mostram a porcentagem de descarga de ar (PAD) em função da pressão do xilema (Ψ_x). Ψ_{50} e Ψ_{88} representam o potencial hídrico (MPa) quando 50% e 88% dos vasos do xilema estão embolizados, respectivamente. Ψ_{min} representa o menor valor do potencial hídrico medido em condições naturais. As áreas cinza e vermelha nos gráficos representam as margens de segurança hidráulica (diferença entre Ψ_{50} e Ψ_{min}).*

of hydraulic failure and, consequently, greater safety in water transport (Cai e Tyree, 2010; Brodribb et al., 2016; Adams et al., 2017; Scoffoni et al., 2017; Olson et al., 2018). However, this relationship must be used with care, since different species may have xylem vessels with the same diameter and different vulnerabilities (Tyree e Sperry, 1989). According to Hacke et al. (2007), narrow vessels can be vulnerable or resistant to cavitation, expressing a wide range of Ψ_{50}, while wide vessels tend to always be vulnerable.

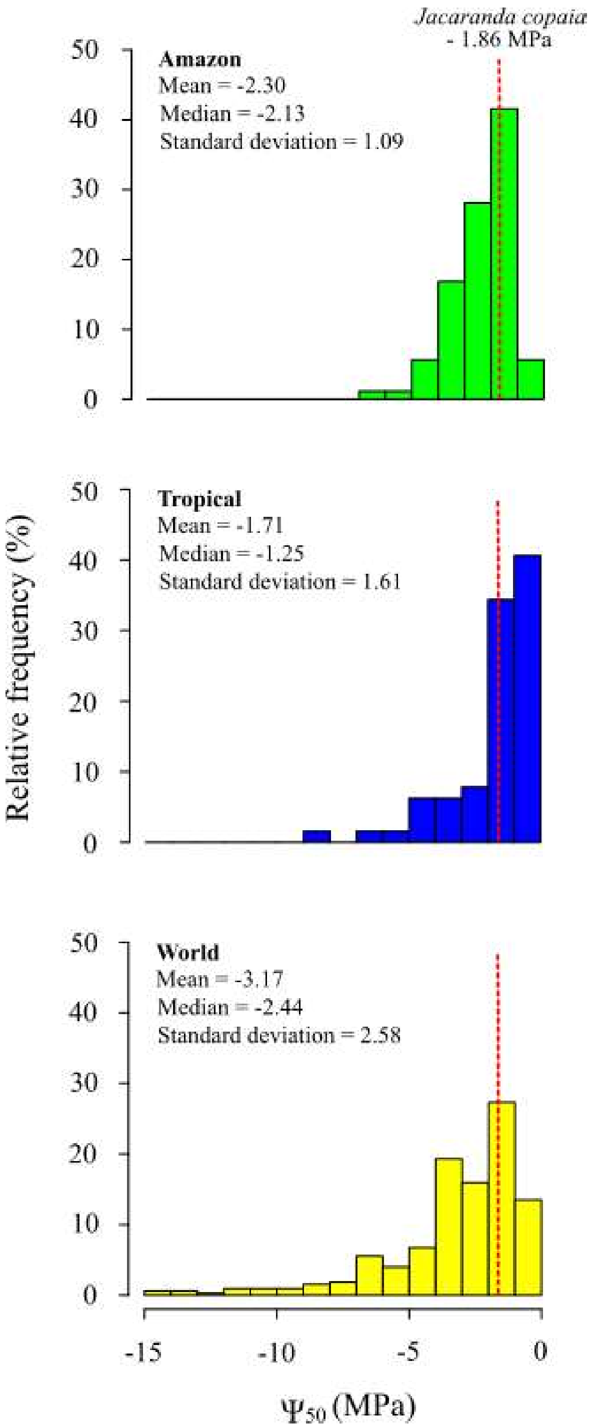

Figure 2 – Distribution of Ψ_{50} (MPa) values with data of arboreal species from Amazon Forest (green), Tropical Forest (blue) and world data (yellow).

Figura 2 *– Distribuição dos valores de Ψ_{50} (MPa) com dados de espécies arbóreas da Floresta Amazônica (verde), Floresta Tropical (azul) e dados mundiais (amarelo).*

The four individuals of *Jacaranda copaia* studied showed narrow hydraulic safety margins, with HSM_{50} values ranging from -0.312 to 1.122 MPa and HSM_{88} values ranging from 0.204 to 1.709 MPa. Choat et al. (2012) also observed narrow hydraulic safety margins (close to 1 MPa) for 70% of the arboreal species studied. According to the authors, the HSM reflects the plant hydraulic strategy to survival in the environment. Plants with low (or even negative) hydraulic safety margins tend to experience more embolism and, therefore, have a greater potential risk of hydraulic failure. This characteristic may indicate long-term reductions in productivity and survival due to increased aridity. It is also important to emphasize that small differences were detected between the values of HSM_{50} and HSM_{88}, and these differences were smaller than 1 MPa for all evaluated individuals. Barros et al. (2019), working in different regions of the Brazilian Amazon, observed greater differences between HSM_{50} and HSM_{88}. In tropical forests with low and high rainfall seasonality, this difference was approximately 2 and 3 MPa, respectively.

The average values of Ψ_{50} detected for *Jacaranda copaia* (average = -1.86 MPa) were similar to values detected for other arboreal species distributed in tropical forests, mainly in the Amazon. Extremely similar average values of Ψ_{50} were detected for arboreal species distributed in seasonally flooded valleys located in the Brazilian Amazon (mean = -1.70 MPa), and for other arboreal species distributed in tropical forests (mean = -1.60MPa) (Oliveira et al., 2018). More negative Ψ_{50} values were detected in tropical seasonal forests (drier) (Oliveira et al., 2018; Barros et al., 2019). The less negative Ψ_{50} values detected in the present study for *Jacaranda copaia*, and for other arboreal species distributed in tropical forests, together with the detection of narrow hydraulic safety margins for this species, are possibly related to a low resistance to embolism.

5. CONCLUSION

Possibly, *Jacaranda copaia* presents a more “risky” hydraulic strategy, with relatively narrow hydraulic safety margins, due to its dynamic character of rapid growth, characteristic of pioneer species. However, considering that in severe arid conditions, plants with narrow safety margins tend to present a greater risk of embolism and hydraulic failure, it is necessary to investigate the effects of severe droughts on the behavior of this arboreal species. Finally, these results contribute to knowledge about embolism resistance of arboreal species in the Brazilian Amazon.

AUTHOR CONTRIBUTIONS

RTO and MS conceived the initial idea; RTO, MAO, and JARS conducted the feldwork; RTO, MAO, and JARS conducted lab analysis; RTO, PNM, and JVT carried out the data analyses; and RTO led the writing with assistance from all the authors.

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