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DENDROLOGICAL DESCRIPTION AND ARCHITECTURE OF THE LEAF VENATION PATTERN OF THREE SPECIES BELONGING TO THE FABACEAE FAMILY

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Resumo

Descrição Dendrológica e Arquitetura do Padrão de Venação Foliar de Três Espécies Pertencentes à Família Fabaceae. Estudos dendrológicos e de diafanização podem auxiliar na diferenciação de espécies em campo, contribuindo com a prática de manejo. Objetivou-se com este estudo descrever os caracteres macromorfológicos e a venação foliar das espécies *Copaifera martii*, *Dalbergia spruceana e Libidibia ferrea*. A caracterização foi realizada com uso de ficha dendrológica, sendo avaliados fuste e folhas, e a descrição da venação foi feita com a técnica de diafanização. Observou-se para a espécie *Copaifera martii* ocorrência de oxidação da casca viva, inicialmente bege mudando para laranja escuro, folhas de consistência coriácea, padrão de venação craspedódroma e a venação marginal fimbrial. *Dalbergia spruceana* apresentou oxidação de cor creme amarelado para vermelho, presença de exsudato do tipo resina, ramos das folhas com ocorrência de lenticelas e estípulas, padrão de venação broquidódroma e venação marginal do tipo recurvada. *Libidibia ferrea* apresentou desprendimento da casca, com ritidoma liso de aspecto manchado, coloração acinzentada, presença de pulvínulo e lenticelas em todos os ramos, com padrão de venação broquidódroma festonada e venação marginal do tipo recurvada. As características dendrológicas do fuste em conjunto com a arquitetura foliar e a venação podem subsidiar estudos taxonômicos para o reconhecimento e diferenciação de táxons.
Palavras-chave: Dendrologia, Diafanização foliar, Fuste.

Abstract

Dendrological studies and means of diaphanization can help in the manipulation of species in the field, with the practice of management. The objective of this study was to describe the macromorphological characters and leaf venation of the species *Copaifera martii*, *Dalbergia spruceana*, and *Libidibia ferrea*. The characterization was carried out using a dendrological form, the trunk and leaves were evaluated, and the description of the venation was made through the diaphanization technique. It was observed that the *Copaifera martii* species supporting the live bark, initially beige changing to dark orange, leaves of leathery consistency, craspedodromous venation pattern, and marginal fimbrial venation. *Dalbergia spruceana* oxidized from yellowish-cream to red presented a resin-type exudate, leaf branches with lenticels and stipules, brochidodromous venation pattern, and recurved marginal venation. *Libidibia ferrea* presented bark detachment, a smooth and spotted rhytidome, grayish color, pulvinules and lenticels in all branches, and scalloped, brochidodromous pattern with recurved marginal venation. The dendrological characteristics of the trunk, together with the leaf and venation architecture, can augment taxonomic studies for the identification and differentiation of taxa.
Keywords: Dendrology, Leaf diaphanization, Trunk.

INTRODUCTION

Around a third of the world's tropical forests are concentrated in Brazil, and the Amazon biome comprises approximately 30% of tropical forests (CHAVES *et al*., 2013; SILVA *et al*., 2014). For forestry professionals, the identification of tree species in ecologically distinct regions is still a great challenge, as tree individuals reach heights greater than 30m and are often in difficult-to-access locations.

The diverse composition of the Amazon forest and the limited knowledge of the tree species is one of the reasons hindering efficient use of its resources (OLIVEIRA *et al*., 2008). Studies that seek to identify and describe vegetative characteristics are relevant for the conservation, preservation and exploration of forest remnants and areas. When recognizing trees in the field, the use of vernacular names can suppress the real geographic occurrence of the species, as there is a great variation in these names and their associations with different species; however, they present similar characteristics to the untrained eye (MARTINS-DA-SILVA, 2002). A species can have dozens of vernacular names, causing them to be confused and consequently be exploited in a disorderly and unsustainable manner (CAMARGOS *et al*., 2001).

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The heterogeneity in tree phenology can make it impossible to observe the flowering and fruiting phenophases, which are structures used for taxonomic identification. In this way, the description and recognition of tree species can be obtained through dendrology, a branch of science specialized in the study of trees.

Distinguishing species in a clear and objective way is necessary to minimize economic losses and contributes to maintaining biodiversity. This is considered a branch of botany and addresses the taxonomy, morphology, and anatomy, among other characters of arboreal individuals, and it can be used as an instrument for studying the macromorphological characteristics of trees (MILLER, 2015). The application of botanical-dendrological characterization allows for the differentiation of similar species and avoids possible inaccuracies caused by disordered use of vernacular names referring to trees (MEDEIROS *et al*., 2022).

Using macromorphological dendrological characteristics, it becomes possible to group tree individuals into botanical families and genera, highlighting specific characters at the species level. Characteristics of the trunk, rhytidome, dead bark, living bark and sapwood are important to separate the species, but leaf morphology can also help and reduce the likelihood of errors during recognition and identification.

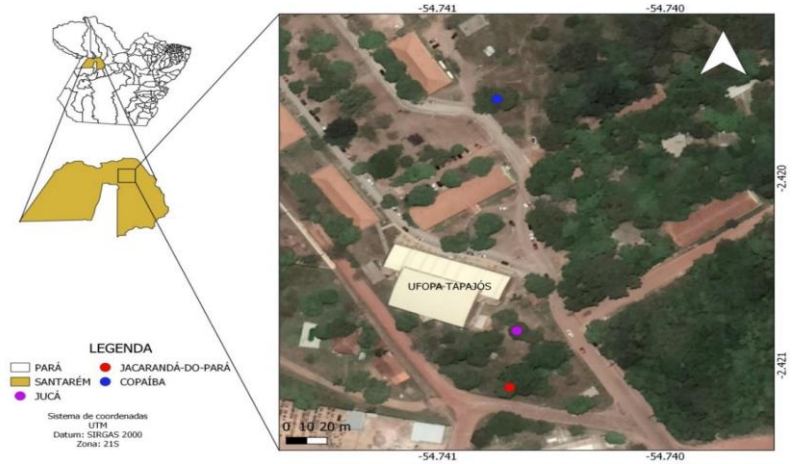
In conjunction with the macromorphology of trees, leaf architecture is also one of the practical forms for botanical identification, as the veins present characteristics that enable the taxonomic identification of species (MARTINS-DA-SILVA *et al*., 2014). Therefore, the diaphanization technique for classification of leaf venation, combined with dendrological characterization, can help differentiate between similar species.

Distinguishing species in a logical and evident way minimizes economic losses and favors the maintenance of biodiversity. Based on the above, the objective was to carry out the dendrological characterization and description of the architecture of leaf venation pattern in the Fabaceae family. This was done in particular for the species *Libidibia ferrea* (Mart. ex Tul.) L. P. Queiroz, *Copaifera martii* Hayne, and *Dalbergia spruceana* Benth, present in Santarém-PA, and this study aimed to generate information that can assist in the recognition and botanical identification of these species.

MATERIALS AND METHODS

Study Area

The study was carried out on the Santarém *campus*, Tapajós Unit of the Federal University of Western Pará (UFOPA), municipality of Santarém, located in the Lower Amazon region of Western Pará (Figure 1). The municipality has a hot and humid climate, and according to Köppen and Geiger, the climate is classified as Am. The average annual temperature varies from 25 to 28 ° C, has an average relative humidity of 86%, and presents an average rainfall of 1,920 mm (INMET, 2020).



Source: Geographic Information System QGIS 3.4.6 (QGIS, 2018).
Figure 1. Location of the Tapajós campus of the Federal University of Western Pará
Figura 1. Localização do campus Tapajós da Universidade Federal do Oeste do Pará.

The three chosen species have the largest number of individuals in the area and are important for timber. Among these species, two belong to the Caesalpinioideae subfamily and one to the Faboideae subfamily. Leaf samples were collected from trees on the campus with listing registration numbers HSTM003340, HSTM009652, HSTM004654, identified on site, and subsequently sent for analysis in the Laboratory of Forest Seeds. This research is part of the project registered with the National System for Management of Genetic Heritage and Associated Traditional Knowledge (*Sistema Nacional de Gestão do Patrimônio Genético e do Conhecimento tradicional Associado, SISGEN*) under protocol A259F5F.

Dendrological characterization

The dendrological characterization was carried out with the aid of a dendrological form adapted from Miller and Blum (2018).This process evaluated characteristics of the trunk, such as position in relation to the soil, shape and base. The rhytidome was characterized according to its color, appearance, and resistance. The inner bark was characterized according to its color, odor, and occurrence of exudation. The sapwood was characterized only according to the color. The leaves of the species were characterized according to their composition, phyllotaxis, color, occurrence of odor after maceration, and presence of appendages and other elements such as stipules, lenticels and hairiness, shape of the blade, margin, base, and apex. These elements were described according to Martins-da -Silva *et al.*(2014) and Souza *et al.* (2013).

Diaphanization of leaves

To diaphanize the leaves, the technique required making the samples semi-transparent, adapted from the methodology used by Filho (2020) on ten undamaged and intact leaflets. After diaphanization, the leaflets were mounted on glass slides and photographed for better observation and description of the venation. To describe and classify leaf venation patterns, the Manual of Leaf Architecture (2009) was used. They were classified according to primary, secondary, intersecondary, tertiary, quaternary, and fifth order venation. The freely ending veins (FEVs) which are veins that end freely, and areolation, which are the smallest areas of leaf tissue surrounded by veins (ELLIS *et al*., 2009), were also noted.

RESULTS

Copaibarana –*Copaifera martii* Hayne.

Dendrological description

Under local conditions, *C. martii* presented an inclined trunk, circular in shape, channeled base of the trunk, gray colored rhytidome with an incidence of mosses, having a dirty and rough appearance, and stiff resistance (Figure 2A). The inner bark was beige in color (Figure 2B), presented an unpleasant odor when oxidized, changed color changes from live bark to a dark orange tone, and was absent of exudate. The sapwood is cream colored, turning slightly orange after oxidation (Figure 2C). The leaves are compound, pinnate, paripinnate, phyllotaxy alternate disticus, has 2 to 3pairs of leaflets, leathery consistency, discolored color (Figure 2D), color of the adaxial side dark green and abaxial side light green, pleasant odor after maceration, petiolate, with the presence of pulvinus, petiolate leaflets and pulvinule, in addition to a cylindrical rachis and the presence of stipules. The leaflets of *C. martii* are ovate in shape, have an entire margin, a rounded base and an emarginate apex.

Figure 2. Dendrological characteristics: A - Position and shape of trunk, rhytidome and base shape, B - Bark and sapwood C - Oxidation, D - Leaf architecture.

Figura 2. Características dendrológicas: A – Posição e forma do fuste, ritidoma e forma da base, B – Casca e alburno C – Oxidação, D – Arquitetura foliar.

Diaphanization

The venation pattern of *C. martii* is pinnate, as it has a single central vein. The secondary veins are of the craspedodrome type and present uniform spacing between them. The angle formed by the secondary ribs in relation to the central rib is uniform (Figure 3A), and the intersecondary ribs are strong, similar to the secondary ones. Tertiary veins are of the random reticulated type, where anastomosis occurs at random angles. The angle of the third-order veins in relation to the first is obtuse, and their variability is inconsistent, as it varies randomly over the slide (Figure 3B). Quaternary veins are regular polygonal reticulated, and anastomosis occurs (closure angles) with other veins to form polygons of random shape and size (Figure 3B).

Areolations are well developed and of relatively consistent size and shape. The FEVs branch two or more times (Figure 3C). The marginal venation formed at the ends of the secondary veins is secondary marginal, which are orders of higher veins fused into one vein running (Figure 3A).

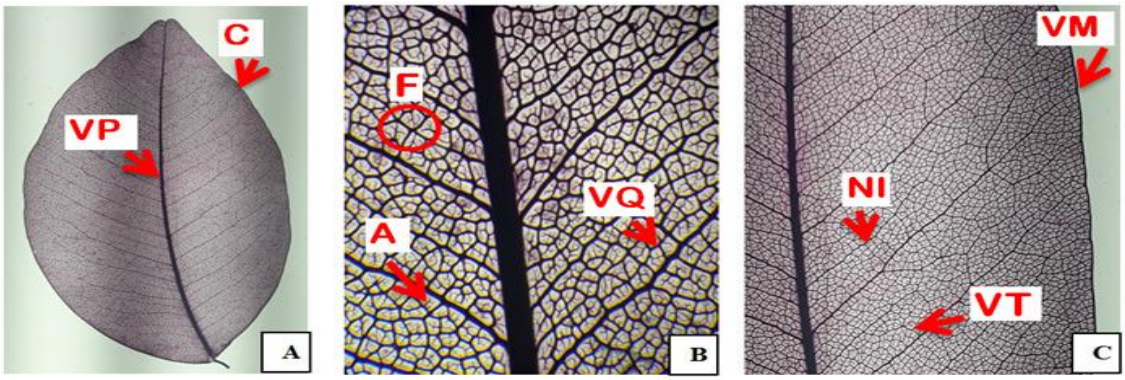


Figure 3. Venation pattern: A - pinnate venation (VP), craspedodroma (C), B - quaternary veins (VQ), areolation (A), FEVs (F), C - intersecundary veins (NI), tertiary veins (VT), marginal venation (VM).

Figura 3. Padrão de venação: A – venação pinada (VP), craspedódroma (C), B – veias quaternárias (VQ), areolação (A), FEVs (F), C – nervuras intersecundárias (NI), veias terciárias (VT), venação marginal (VM).

Jacarandá-do-pará – *Dalbergia spruceana* Benth.

Dendrological description

Under local conditions, the species *D. spruceana* presented an inclined trunk, circular in shape, trunk with a straight base, greyish-brown rhytidome, with a striated appearance (Figure 4A). The plant presents rigid resistance, an inner bark of a yellowish cream color (Figure 4B), pleasant odor, and oxidation causing a red color, in addition to the presence of red, resin-type exudate that is in scarce quantity (Figure 4C), and it also has slow secretion flow. The sapwood is cream colored (Figure 4C) and slightly reddish after oxidation. Leaves have many qualities, such as compound, pinnate, imparipinnate, phyllotaxis alternate disticus (Figure 4D), membranous consistency, discoloration, adaxial side dark green and abaxial side light greencolors, pleasant odor, petiolate, presents pulvinus, both petiolate leaflets and a cylindrical rachis, and present stipules and lenticels. The leaflets are elliptical in shape, have an entire margin, a rounded base, and an obtuse apex.

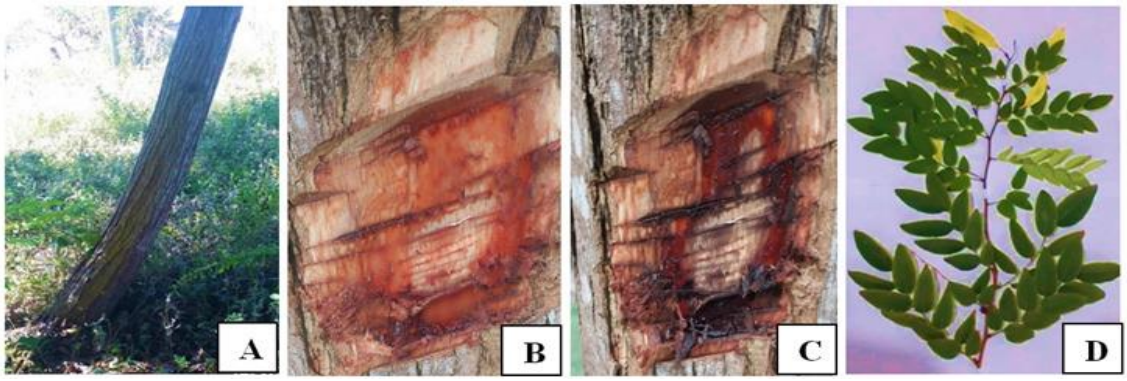


Figure 4. Dendrological characteristics: A - Position and shape of the trunk, rhytidome and shape of the base, B - Bark and sapwood C - Oxidation and exudate, D - Leaf architecture.

Figura 4. Características dendrológicas: A – Posição e forma do fuste, ritidoma e forma da base, B – Casca e alburno C – Oxidação e exsudato, D – Arquitetura foliar.

Diaphanization

The venation of *D. spruceana* is pinnate as it has a single central vein, and the secondary veins are brochidodromous with irregular spacing between them. The angle formed by the secondary ribs in relation to the central rib is uniform (Figure 5A), and the intersecondary ribs are as strong as the adjacent ones. Tertiary veins are of the random reticulated type, where anastomosis occurs at random angles. The angle of the third-order veins in relation to the first is inconsistent, as it varies randomly across the slide (Figure 5B). The quaternary and fifth-order veins are regular polygonal reticulated, and anastomosis occurs with other veins to form polygons of random shape and size (Figure 5C).

Areolation is well developed, as the areolas are relatively consistent in size and shape, and the FEVs branch two or more times. Marginal venation is composed of recurved veins, branching close to the margin, and joining the secondary vein (Figure 5C).

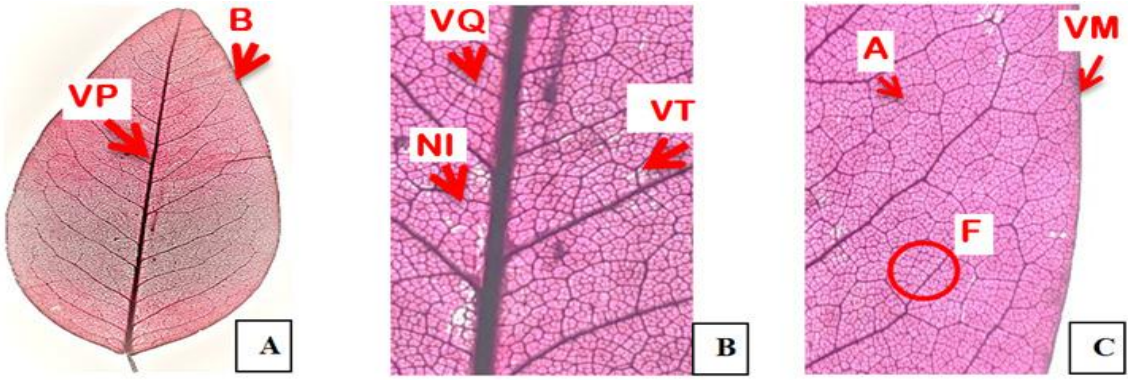


Figure 5. Venation pattern: A - pinnate venation (VP), brochidodroma (B), B - intersecundary veins (NI), tertiary veins (VT), quaternary veins (VQ), C - areolation (A), FEVs (F), marginal venation (VM).
Figura 5. Padrão de venação: A – venação pinada (VP), broquidódroma (B), B – nervuras intersecundárias (NI), veias terciárias (VT), veias quaternárias (VQ), C – areolação (A), FEVs (F), venação marginal (VM).

Jucá –*Libidibia ferrea* (Mart. ex Tul.) L. P. Queiroz

Dendrological description

The species *Libidibia ferrea* (jucá) was characterized locally with an inclined trunk, circular in shape (Figure 6A), and straight base. It presented brown colored rhytidome with a scaly appearance, peeling of the bark, with a smooth rhytidome, mottled appearance, grayish color (Figure 6B), and medium resistance. The inner bark is green in color, has a pleasant odor, lacks exudate, and the sapwood is cream colored (Figure 6C). The leaves are compound, bipinnate, phyllotaxis alternate couplet (Figure 6D), petiolate, present pulvinus, pinnae with up to 10 pairs, petioles, and pulvinules, in addition to a cylindrical rachis, hairiness on the rachis, and presence of lenticels on all branches. The leaflets are opposite, with an oblong shape, entire margin, asymmetrical base and straight apex, membranous consistency, discolored color, dark green adaxial side, light green abaxial side and leaflets with a pleasant odor after maceration.

Figure 6. Dendrological characteristics: A - Position and shape of the trunk, B - Ritidome and shape of the base, C - Bark and sapwood D - Leaf architecture.
Figura 6. Características dendrológicas: A – Posição e forma do fuste, B – Ritidoma e forma da base, C – Casca e alburno D – Arquitetura foliar.

Diaphanization

The venation pattern of *L. ferrea* is pinnate, as it has a single central vein. The secondary veins are of the scalloped brochidodrome type and present irregular spacing between them. The angle formed by the secondary ribs in relation to the central rib decreases smoothly towards the base (Figure 7A), and the intersecondary ribs are as strong as the adjacent ones. Tertiary veins are of the random reticulated type, where anastomosis occurs at random angles. The angle of the third-order veins in relation to the first is inconsistent, as it varies randomly across the slide (Figure 7B). Quaternary veins are regular, reticulated polygonal veins that anastomose with other veins to form polygons of random shape and size (Figure 7C).

Areolation follows the moderately developed pattern, being irregular in shape, and more or less variable in size. The FEVs branch two or more times. Marginal venation is composed of recurved veins, branching close to the margin and joining the secondary vein (Figure 7C).

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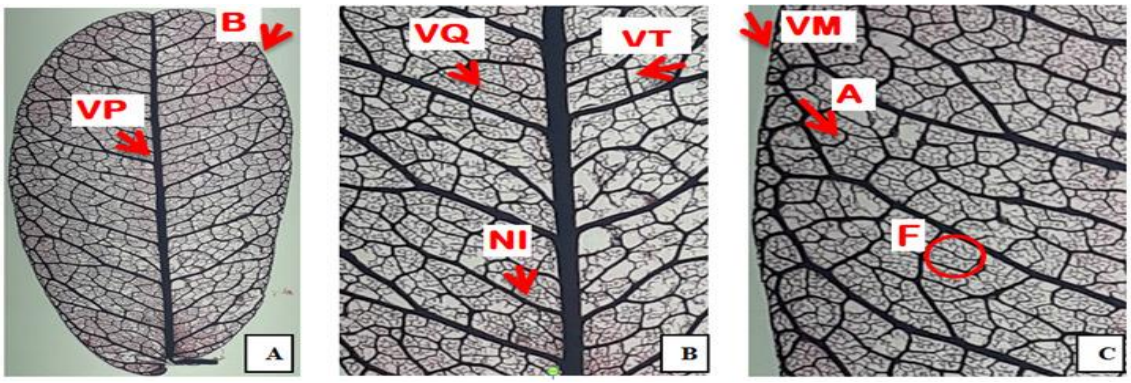

Figure 7. Venation pattern - A: pinnate venation (PV), festooned bronchidodroma (B), B: intersecondary veins (NI), tertiary veins (VT), quaternary veins (QV), C: areolation (A), FEVs (F), marginal venation (VM).

Figura 7. Padrão de venação – A: venação pinada (VP), bronquidódroma festonada (B), B: nervuras intersecundárias (NI), veias terciárias (VT), veias quaternárias (VQ), C: areolação (A), FEVs (F), venação marginal (VM).

DISCUSSION

The species *Copaifera* martii (copaibarana), when present in forests, has less leathery leaflets compared to its development in more open environments. According to Martins-da-Silva (2008), *Copaifera martii* in the state of Pará compared to the syntype *Copaifera rigida* in the state of Piauí, being two different taxa, present different leaflets although they are similar in relation to the flowers. However, when compared in west of Pará, they are difficult to differentiate due to the overlapping of vegetative characters, and in this region, the leaflets may have different shapes and apex.

With this overlapping of vegetative characters, another way to assist studies in the identification and recognition of species and their varieties can be the leaf venation pattern. Obermuller *et al.* (2011) sought, based on species' venation patterns, to reliably and rigorously identify and separate timber species often confused by popular names in forest inventories. They described the morphological characters of the trunk and leaves, together with the leaf patterns and the analyzed characteristics, and published the Illustrated Guide and Manual of Leaf Architecture for Timber Species of the Western Amazon (*Guia Ilustrado e Manual de arquitetura foliar para Espécies Madeireiras da Amazônia Ocidental*).

Regarding the leaves, the species *C. martii* has a leathery consistency similar to the classification by Costa (2020), along with other characteristics that help differentiate species of the same genus.

Observation of the macromorphological characters of *C. martii* can help differentiate it from similar species also belonging to the genus *Copaifera*. This is the case between *C. martii* and *C. pubiflora*, which have the shape of leaflets and seeds with white arils as similar characteristics. However, these two are mainly differentiated by the opposite leaflets, leatheryquality, and with a revolute margin in *C. martii*, contrasted by opposite leaflets, leathery quality, and straight marginin *C. pubiflora* (MATTOS *et al.*, 2018).

Mainly in the field, there is difficulty in recognizing and identifying species belonging to the genus *Copaifera* in terms of overlapping vegetative characteristics; however, these can be differentiated through leaf characters, which makes the study of architecture and leaf venation important.

The species *Dalbergia spruceana* (Brazilian rosewood, jacarandá-do-pará) presented compound, pinnate leaves, alternate phyllotaxis, elliptical leaflets, entire margin, rounded base, and obtuse apex. This is similar to the characteristics described by Mattos *et al.* (2018) and differs by the presence of pulvinus, stipules and lenticels, as observed in this study and not described by the author.

Dendrological characterization is used in many works. Miller and Blum (2018) carried out the dendrological characterization of the Fabaceae family in a remnant of mixed rainforest in Curitiba. They were able to differentiate all 14 species occurring at the site by their characteristics of trunk, rhytidome, inner bark, branches, leaves and other relevant vegetative characteristics, demonstrating the versatility of dendrology as a science of practical application in the identification of tree species through morphological characters.

In the inner bark of the species *D. spruceana*, there was oxidation of a yellowish cream color to red and the presence of a red resin-type exudate, a resinous material characteristic of the genus (PONTES *et al.*, 2018).

Characteristics of the inner bark, for example, are of great assistance in the field, and when associated with information on leaves and branches, they help to improve species identification (VÖLTZ; BLUM, 2020).

The vein pattern was classified from the first to the last vein found, and the species *D. spruceana* goes up to the fifth order of venation. Most angiosperm leaves have four to seven orders of venation, following a sequence.The primary and secondary veins are the main structures of the leaf, and the tertiary veins onwards are the smaller veins, forming a type of mesh or reticulum (OBERMULLER, *et al.*, 2011).

Menegatti *et al.* (2016) used leaf characters exclusively to identify species of Melastomataceae, occurring in the Planalto Sul Catarinense. In a study in the state of Tocantins, it was possible to differentiate 54 tree and shrub species using vegetative characteristics, such as the appearance of the trunk, the color of the rhytidome, and the composition of the leaves, in areas of the cerrado sensu stricto biome (CÂNDIDO *et al.*, 2019).

Regarding the species *Libidibia ferrea*, the appearance of the rhytidome and detachment of the bark that left whitish spots on the trunk were identifying macromorphological characteristics observed in this study. They facilitate the recognition of the species and were also observed in the work carried out by Campos Filho and Sartorelli (2015).

The species *L. ferrea* has four varieties: *Libidibia ferrea* var. *ferrea*, *Libidibia ferrea* var. *glabrescens*, *Libidibia ferrea* var. *leiostachya*, and *Libidibia ferrea* var. *parvifolia*. They may present complex variations in morphological characteristics, especially in the leaves, and may be from different taxa (OLIVEIRA, 2020).

Jucá has the presence of lenticels, also noted in the study by Lima (2020). These characteristics of the species can be combined with the study of the leaf venation pattern to support studies involving the four native varieties of the species. They are typically confused during forest inventories, and they all have the same characteristic in relation to very heavy wood (CAMPOS FILHO E SARTORELLI, 2015).

In a study on tree species occurring in the Auguste de Saint-Hilaire forest, Cabral *et al.* (2016) used leaf architecture to identify, describe, and select characteristics from the external leaf morphological architecture that were useful for separating ten species. The venation pattern observed for the ten tree species was considered relevant for the separation of species and contributed to the knowledge and identification of tree species in the forest fragment.

CONCLUSIONS

By carrying out this study, it was possible to conclude that:

- The macromorphological characterization of tree species is extremely important, as such characteristics as those described here are useful in the field and in helping parabotaniststo recognize and differentiate species.
- Dendrological descriptions and leaf architecture, through the diaphanization technique, also provide support for taxonomic studies.
- The species studied have similarities in their composition, phyllotaxis, and color, in addition to the presence of some appendages, which are characteristics of the Fabaceae family.
- Despite the overlapping of dendrological characters, *C. Marttic*an be identified by the beige color of the internal bark that oxidizes after cutting and turns dark orange, often associated with the opposite, leathery leaflets with a revolute margin; *D. spruceana* presents a yellowish cream inner bark that turns red after oxidation and slightly reddish sapwood associated with red resin-type exudate; and *L. ferrea* presents smooth rhytidoma with a mottled appearance and green inner bark, associated with lenticel branches.
- Dendrological studies, by supporting taxonomic studies, also influence the correct and sustainable exploitation of species in timber management, avoiding the exploitation and commercialization of similar species that can be confused when identified in the field.

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