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Original Article

Silviculture

Dendrological Characterization as Inspection Resources of Caatinga Wood Market

Rayssa de Medeiros Morais[1], Maria do Carmo Learth Cunha[2], Gregório Mateus Santana[1], Juarez Benigno Paes[3]

[1]Universidade Federal Rural do Rio de Janeiro – UFRRJ, Seropédica/RJ, Brasil
[2]Universidade Federal de Campina Grande – UFCG, Campina Grande/PB, Brasil
[3]Universidade Federal do Espírito Santo – UFES, Jerônimo Monteiro/ES, Brasil

ABSTRACT

This study aimed to distinguish five native forest species of the Caatinga Biome from the exotic invasive *algaroba* (*Prosopis juliflora* (Sw.) DC.), considering dendrologic characteristics of bark and wood, in order of providing subsidies for the inspection of the wood market in this Biome. The native species studied were *jurema-preta* (*Mimosa tenuiflora* (Willd.) Poir.), *angico branco* (*Anadenanthera colubrina* var. *colubrina* (Vell.) Brenan), *angico vermelho* (*Anadenanthera colubrina* var. *cebil* (Gris.) Alts.), *aroeira (Myracrodruon urundeuva* Allem) and *braúna-do-sertão (Schinopsis brasiliensis* Engl.). Studied species were recognized using dendrology identification records, containing characteristics of bark, heartwood and sapwood coloration; and the organoleptic proprieties like color, smell and taste, used for safe wood logs identification. The macroscopic characteristics, organized in dichotomous key, allowed the differentiation among the species, available in logs, during inspection.

Keywords: dendrology, wood, bark, regulatory agencies.

1. INTRODUCTION

In the Brazilian semi-arid region, the unsustainable exploitation and commercialization, often illegal, of woody species from Caatinga Biome, is used to subsidize the local economy, supplying biomass for energy purposes, and non-wood forest products (Paes et al., 2013; Medeiros et al., 2014; Campello, 2015). Firewood and charcoal account for 30% of the states and municipalities energy matrix; in addition to meeting the domestic demand for cooking of 70% of families in the Brazilian Northeast Region (Campello, 2015).

The three main forest exploitation methods in the Caatinga are illegal deforestation and forest management for wood production, and legal deforestation for alternative land use; the latter two being authorized by competent bodies (Pareyn, 2010). Thus, the Caatinga Biome forest resources have been intensively exploited, as a result of the anthropic action in the region (Medeiros et al., 2014). It is necessary to enforce mitigating measures (Pereira et al., 2014) such as the requirement that commercialized wood originates from managed areas or reforestation, as recommended by the Brazilian Forest Code, Brasil (2012), Article 31, Law 12.651.

Wood can be obtained also from the exploration of exotic species, without the need for authorization (Ndagijimana et al., 2015), among these species exploited commercially in the Caatinga, stands *Prosopis juliflora* (Sw.) DC., known as *algaroba* (Pegado et al., 2006; Farias et al., 2013). This species was introduced and disseminated as an economic alternative, by adapting it in several semi-arid regions of the world and by its versatile use as firewood, wood and forage (Pegado et al., 2006).

As a result, and with the frequency in which commercially banned native trees are illegally exploited, it is necessary to develop scientific-based strategies in order to differentiate native species from the Caatinga Biome exotic species, especially the *Prosopis juliflora*, contributing to the efficiency of inspection by the responsible organs and technicians (Alves et al., 2012).

Dendrology as an identification tool uses knowledge based on botany, taxonomy and wood macroscopic anatomy to recognize the wood. The tree is studied from vegetative features, such as the bark color, structure, appearance, trunk size and shape, presence of aculeus and or thorns, fruits, leaves shapes and types, seeds, exudations, and the existence of peculiar smell (Panshin & De Zeeuw, 1980; Gonzales, 2008; Rotta et al., 2008; Castillo, 2010; Silva & Costa e Lima, 2010; Alves et al., 2012).

Knowledge of the dendrological characteristics of native species marketed is essential for various purposes, including a practical subsidy and inspection by regulatory agencies to differentiate native and exotic forest species.

Therefore, this work aimed to identify, from the bark and wood characteristics, five native forest species of the Caatinga Biome and to distinguish them from the exotic species *Prosopis juliflora*, elaborating a dichotomous key, which provides subsidies for inspection the wood market in this Biome.

2. MATERIAL AND METHODS

2.1. Species selection and material collection for dendrological analysis

The sample of native species included: *Mimosa tenuiflora* (Willd.), *Anadenanthera colubrina* var. *colubrina* (Vell.) Brenan, *Anadenanthera colubrina* var. *cebil* (Gris.) Alts., *Myracrodruon urundeuva* Allem, *Schinopsis brasiliensis* Engl. The group of exotic species was composed by *Prosopis juliflora* (Sw.) DC. Even though the *Myracrodruon urundeuva* and *Schinopsis brasiliensis* species are threatened with extinction, they are often illegally marketed in the region. All species were selected taking into account the indications of technicians responsible for the forest division of the Superintendency of Environmental Management - *SUDEMA*, *João Pessoa, Paraíba*.

We analyzed dendrological characteristics of five specimens of each forest located in the municipalities of *Patos, Maturéia, São José de Espinharas, São José dos Cordeiros* and *Santa Terezinha*, *Paraíba* State. We cut and analyzed one tree per location. The species *Anadenanthera colubrina* var. *colubrine, Andaenanthera colubrina* var. *cebil,* and *Myracrodruon urundeuva* were obtained in an area of forest management located at *Agro Mercantil Urtigas S.A*, *Santa Terezinha*; *Mimosa tenuiflora* and *Prosopis juliflora* from the Health Center and Rural Technology (*CSTR*), Federal University of *Campina Grande* (*UFCG*), *Patos*, and *Schinopsis brasiliensis* was provided by a rural owner in the *São José dos Cordeiros* municipality, with the authorization of Superintendence of Environment Administration - *SUDEMA*.

2.2. Dendrological description and bark characteristics

Information regarding the diameter at breast height (DBH), characteristics of bark and organoleptic were obtained in the field before cut. Characteristics within and among species with registration in different growth stages were evaluated. We evaluated the specimens' mentioned organs features descriptions. Information from the cross-section such as wood color and distinction between heartwood and sapwood were evaluated in the Forestry Product Laboratory, of the Academic Unit of Forest Engineering - *UAEF* located in the *CSTR* of the *UFCG*, *Patos, Paraíba*.

The bark characteristics (rhytidome, phloem and exudates) were analyzed according to the recommendations by Ramalho (1979), Ribeiro et al. (1999) and Silva et al. (2005). We described the rhytidome regarding appearance (smooth, rough, with aculeus), color, dehiscence, presence of fissure, lenticels, ease cutting, and thickness. For the phloem (inner bark) we described the consistency, structure, thickness and appearance.

The rhytidome was removed with a knife to analyze the color and its internal surface, followed by the same analysis to characterize the inner bark. As to the presence of exudates, or liquids released when the plant is cut, its presence or absence and, when present, its consistency, flow velocity, viscosity and color after exposure to air were observed.

2.3. Characteristics of heartwood and sapwood, organoleptic and dichotomous key

Characteristics such as color and the possible distinction between heartwood and sapwood were studied. For this, 24 transverse discs, 4 cm thick, were prepared; two from the basal and two from the apical portions of each specimen. Color was defined from the samples comparison with the Munsell soil color charts, Munsell Color (2005), to avoid personal subjective evaluation.

The following organoleptic characteristics were observed: smell and taste, analyzed according to the protocol contained in Zenid & Ceccantini (2007). Smell and taste were recorded only as present or absent, with no details (subjective assessment). We analyzed only the color of the rhytidome and the cross section.

Digital photographic records were made for the rhytidome, inner bark, heartwood and sapwood to illustrate the dendrological characteristics and the differences among them. The wood macroscopic characteristics were recorded in a dendrological record, following recommendations by Ramalho (1979), Ribeiro et al. (1999) and Silva et al. (2005), which provided subsidies for the dichotomous key elaboration.

3. RESULTS AND DISCUSSION

The observed dendrological characteristics were taken from individuals with different DBHs, reflecting distinct life stages, which may influence their characteristics (Table 1). Variations in the trees characteristics with different DBHs were observed both among species and among individuals.

3.1. Characteristics and distinctions among forest species

Tables 2, 3 and 4 present the macroscopic characteristics of rhytidome, inner bark and wood, respectively.

Table 1. List of diameters at breast height for individuals from the forest species: *Prosopis juliflora*, *Mimosa tenuiflora*, *Anadenanthera colubrina* var. *colubrina*, *Anadenanthera colubrina* var. *cebil*, *Myracrodruon urundeuva*, and *Schinopsis brasiliensis*.

Forest species	Family	Diameters at Breast Height - DBH (cm)				
		DBH 1	DBH 2	DBH 3	DBH 4	DBH 5
P. juliflora	Fabaceae	14**	16.8	9 + 6*	12	14
M. tenuiflora	Fabaceae	12	10**	8	7	6
A. colubrina var. *colubrina*	Fabaceae	27	13.5	32	37	8**
A. colubrina var. *cebil*	Fabaceae	16	16	35	11	14**
M. urundeuva	Anacardiaceae	17	22	13**	16	15
S. brasiliensis	Anacardiaceae	23	30	15 + 16*	18 + 17*	51**

*bifurcated individuals; **individuals collected for evaluations.

Table 2. Macroscopic characteristics for rhytidome from the forest species: *Prosopis juliflora*, *Mimosa tenuiflora*, *Anadenanthera colubrina* var. *colubrina*, *Anadenanthera colubrina* var. *cebil*, *Myracrodruon urundeuva*, and *Schinopsis brasiliensis*.

Rhytidome	Forest species					
	P. juliflora	*M. tenuiflora*	*A. colubrina* var. *colubrina*	*A. colubrina* var. *cebil*	*M. urundeuva*	*S. brasiliensis*
External appearance	Rough	Rough	With aculeus, less abundant.	With aculeus, more abundant.	Rough	Rough
Rhytidome color	Blackened gray	Dark brown	Light gray	Reddish-brown	Light gray to dark gray	Blackened gray
Lenticels	Greater presence in the apical part	Greater presence in the apical part	Absent	Absent	Greater presence in the apical part in individuals with DBH>13 cm	Greater presence in the apical part in individuals with DBH>18 cm
Dehiscence	Indehiscent	Dehiscent in individuals with DBH> 12 cm	Indehiscent	Indehiscent	Dehiscent in the form of concave blades.	Indehiscent in individuals with DBH <18 cm / Dehiscent DBH >23 cm
Fissures	Presence in the basal part in individuals with DBH >16 cm	Presence in the basal part in individuals with DBH >10 cm	Absent	Present, formed by the aculeus rows	Absent	Absent
Stretch marks	Present individuals with DBH <16 cm	Present	Present, striking characteristic	Present when the aculeus is less abundant	Absent	Present where there is no dehiscent

DBH = Diameters at Breast Height.

Table 3. Macroscopic characteristics for inner bark from the forest species: *Prosopis juliflora, Mimosa tenuiflora, Anadenanthera colubrina* var. *colubrina, Anadenanthera colubrina* var. *cebil, Myracrodruon urundeuva, and Schinopsis brasiliensis.*

Inner bark	Forest species					
	P. juliflora	*M. tenuiflora*	*A. colubrina* var. *colubrina*	*A. colubrina* var. *cebil*	*M. urundeuva*	*S. brasiliensis*
Color	Orange	Reddish	Yellow-orange	Red-orange and yellowish tones in the interior	Red-pink	Orange
Structure	Laminated	Laminated	Laminated	Laminated	Non-Laminated	Non-Laminated
Ease of cutting	Smooth	Smooth	Hard	Hard	Hard	Smooth
Exudation	Absent	Present	Exudation from wood	Absent	Present	Present
Exudation speed	Without exudation	Slow	Late	Without exudation	Late	Fast
Color change with air exposure	Present. Light yellow	Present. Reddish-brown	Present. Presents darkening	Present. Reddish-brown	Present. Color becomes dark	Present. Color becomes dark

The comparison, in pairs, among the native species and the *Prosopis juliflora*, indicated that there is greater similarity between them and *Mimosa tenuiflora*, regarding the rhytidome of both forest species (Table 2, Figure 1), which may complicate the distinction in the absence of more details. The most relevant dendrological characteristics for this distinction consisted of the inner bark color, the presence of exudation and the distinction among heartwood and sapwood (Tables 3 and 4, Figure 2).

In the *Prosopis juliflora*, the inner bark color is orange (Figure 2a), with no exudation (Figure 2c), and there is a clear distinction between the heartwood and sapwood (Figure 2e), which are dark brown - 7.5YR 4/6 and light yellow-gray-5y 8/3, respectively, according to the classification obtained in the color chart of Munsell Color (2005). In *Mimosa tenuiflora*, the inner bark has intensely red when freshly cut (Figure 2b), yellow fast flowing exudation (Figure 2d), and less clear distinction between the heartwood and sapwood (Figure 2f).

The distinction of the *Prosopis juliflora* with *Anadenanthera colubrina* var. *colubrina* and *Anadenanthera colubrina* var. *cebil* was detected through the rhytidome

Table 4. Macroscopic characteristics of wood (heartwood and sapwood) from the forest species: *Prosopis juliflora, Mimosa tenuiflora*, *Anadenanthera colubrina* var. *colubrina*, *Anadenanthera colubrina* var. *cebil*, *Myracrodruon urundeuva*, and *Schinopsis brasiliensis*.

Heartwood	Forest species					
	P. juliflora	***M. tenuiflora***	***A. colubrina* var. *colubrina***	***A. colubrina* var. *cebil***	***M. urundeuva***	***S. brasiliensis***
Distinction	Distinguished clearly	Distinct	Little distinct	Distinct	Distinct	Little distinct in the individual with DBH> 50 cm
Heartwood color	Strong brown (7.5YR 4/6)	Brown (5Y 8/4)	Light brown (7.5YR 6/4)	Light brown (7.5YR 6/4)	Pinkish (5YR 7/3)	Dark red (2.5YR 3/6)
Sapwood color	Light grayish yellow (5Y 8/3)	Light grayish yellow (7.5YR 5/4)	Pale brown (2.5Y 8/4)	Pinkish (7.5YR 8/4)	Pale brown (10YR 8/2)	Red-Yellowish (5YR 4/6)

In what: DBH = Diameters at Breast Height. Value in parentheses = Munsell Color (2005).

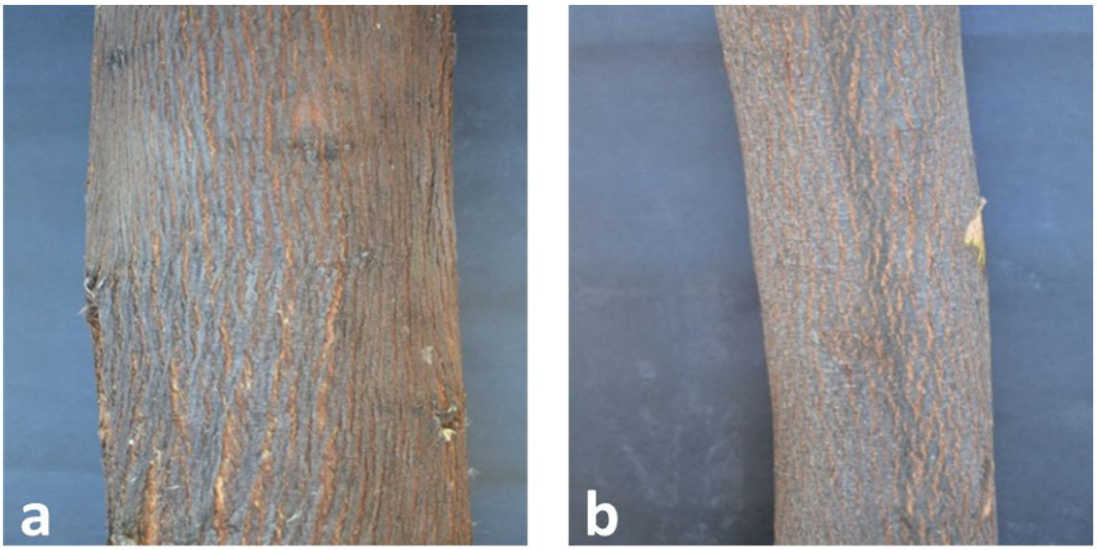

Figure 1. Comparison of rhytidomes from species *Prosopis juliflora* (a) and *Mimosa tenuiflora* (b).

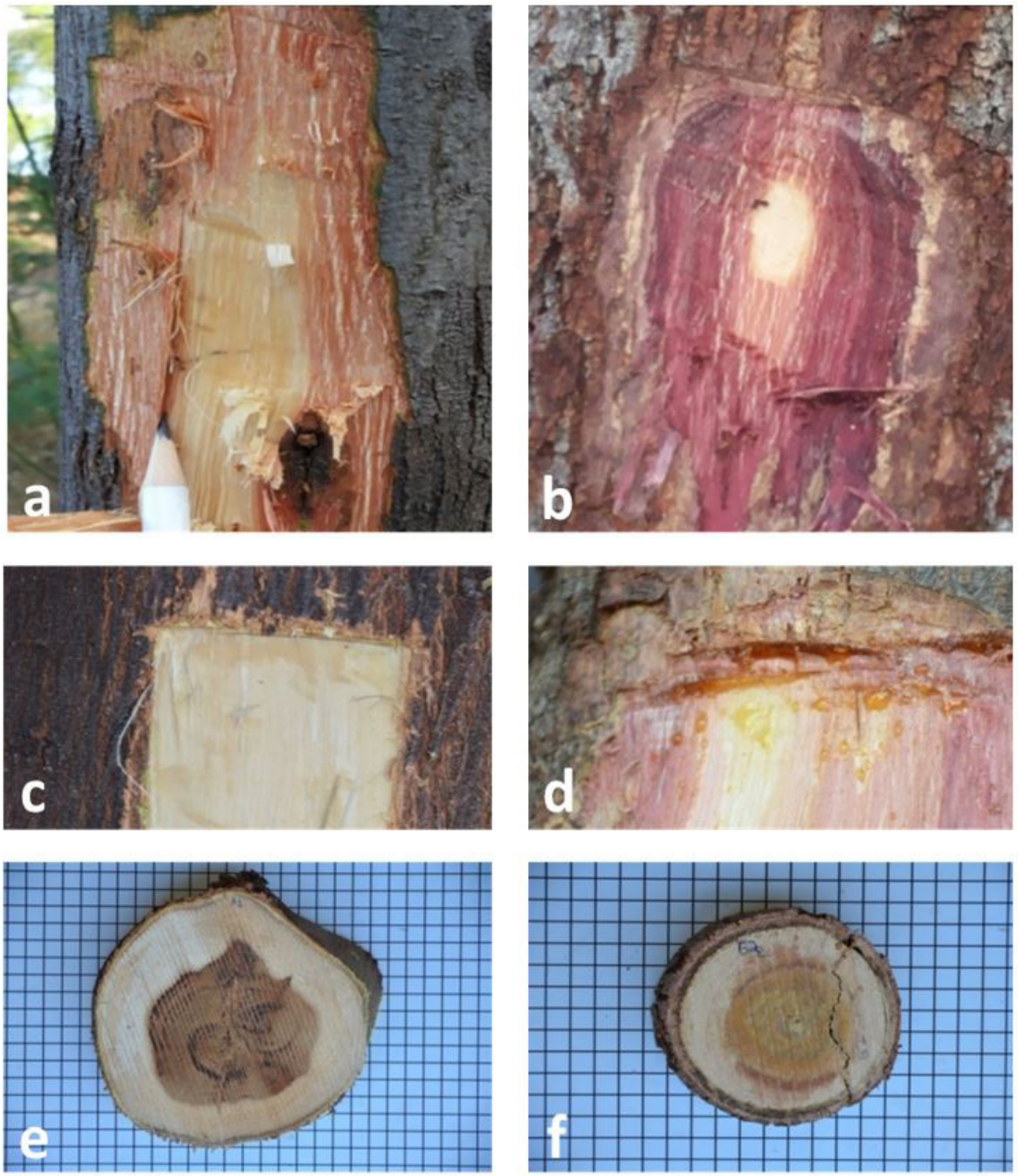

Figure 2. Comparison of inner bark (a, b), exudation presence (c, d) and wood (e, f) from the forest species: *Prosopis juliflora* (a, c, e) and *Mimosa tenuiflora* (b, d, f).

(Table 2, Figure 3). The aculeus presence (> 2 cm in height), crest, pyramidal or pointed form, with greater abundance in the *Anadenanthera colubrina* var. *cebil* (Figure 3c) and smaller in the *Anadenanthera colubrina* var. *colubrina* (Figure 3b) determine this distinction. In the *Prosopis juliflora*, the rhytidome is rough and has no aculeus (Figure 3a). These characteristics are important aspects of differentiation. Garlant et al. (2002) recognized and differentiated the species *Cedrela fissilis* Vell. and *Cabralea canjerana* subsp. *canjerana* (Vell.) Mart. (Meliaceae), with precision, only from the rhytidome pattern.

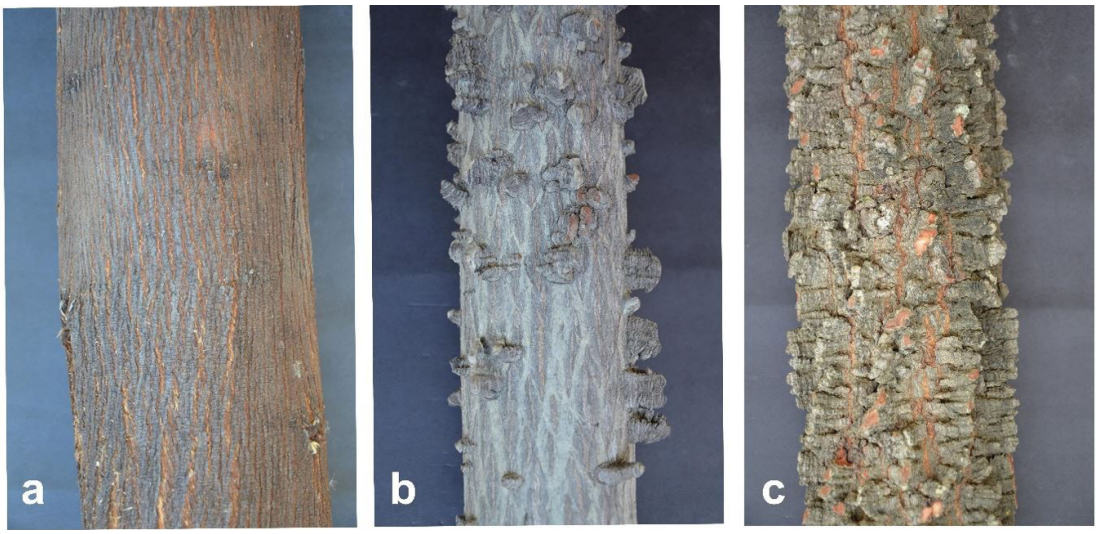

Figure 3. Comparison of rhytidomes from the forest species: *Prosopis juliflora* (a), *Anadenanthera colubrina* var. *colubrina* (b), *Anadenanthera colubrina* var. *cebil* (c).

The main dendrological characteristics found to distinguish the *Prosopis juliflora* from *Myracrodruon urundeuva* were rhytidome dehiscence, inner bark structure and the exudation presence (Tables 2 and 3, Figure 4). In the *Myracrodruon urundeuva,* the rhytidome is dehiscent, detaching itself in irregular and concave blades (Table 2, Figure 4b). The inner bark has exudation close to the sapwood, with a yellowish color and uniform appearance (Table 3, Figure 4f). The *Prosopis juliflora* rhytidome is indehiscent (Figure 4a), the inner bark shows no exudation (Figure 4e) and the structure is laminated (Table 3; Figure 4c).

The distinction between *Schinopsis brasiliensis* and *Prosopis juliflora* is possible by the presence of exudation and the inner bark structure, since the first is present in the *Schinopsis brasiliensis* and absent in the *Prosopis juliflora* (Table 3, Figure 5). The exudation flow in the *Schinopsis brasiliensis* is fast, viscous, transparent, and becomes light brown with time (Figure 5b). Regarding the inner bark structure, the *Schinopsis brasiliensis* has a non-laminated structure (Figure 5d) and the laminated *Prosopis juliflora* (Figure 5c) that separates when it is handled. For rhytidome, we observed difference in the stretch marks, present in both species (Table 2). In the *Schinopsis brasiliensis*, the stretch marks are more superficial, with lenticels in their area (Figure 5e), while in the *Prosopis juliflora* these are deeper and with generally light brown streak (Figure 5e). In the *Schinopsis brasiliensis*, this characteristic was observed in individuals with DBH ≤18 cm, with a change in the rhytidome characteristics with increasing DBH (Table 1), behavior also reported for *Schinopsis quebracho* (Giménez et al., 2000).

We estimate that the time between the species cut and the transports for commercialization is of only a few days, and might not affect the studied characteristics. Also, with time, we observed modifications such as darkening in the inner bark color and exudation absence, although the latter could be visible in the form of crystallized resin in places that suffered mechanical damages (without modifications in the other characteristics).

Studies of recognition and identification from forest species using dendrological characteristics were developed for individual species and specific biomes. In *Tahuamanu* and *Alto Huallaga* areas, in *Lima*, *Peru*, for example, studies were developed for 26 forest species of commercial importance (Castillo & Nalvarte, 2007). For the phytophysiognomies of the Brazilian Cerrado, identification keys of tree species were constructed from dendrological characteristics

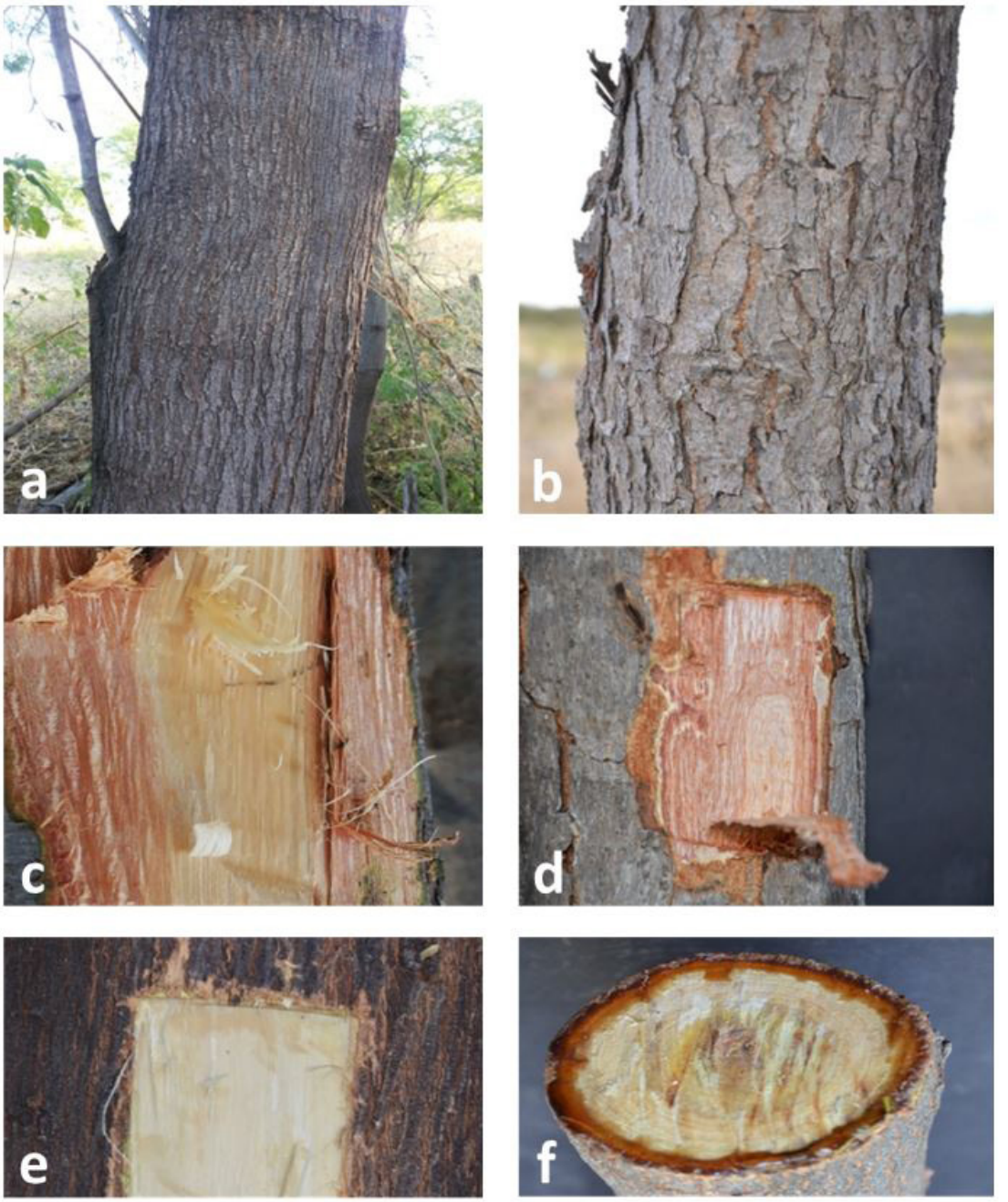

Figure 4. Comparison of dehiscence (a, b), inner bark structure (c, d), and exudation (e, f) from the forest species: *Prosopis juliflora* (a, c, e) and *Myracrodruon urundeuva* (b, d, f).

(Silva et al., 2005; Silva & Pereira, 2009; Silva & Costa e Lima, 2010).

Similarly, Rodrigues et al. (2012) obtained dendrological descriptions of *Cariniana legalis* (Lecythidaceae) through the external morphological aspects of the species and the results obtained were reliable in the species identification. Alves et al. (2012) used such studies for the recognition of forest species marketed in the *Espírito Santo* state, since these characteristics can contribute to guarantee the smoothness in commercialization, avoiding fraud and greater guarantee in the wood quality used in the state, therefore, a tool of extraordinary use.

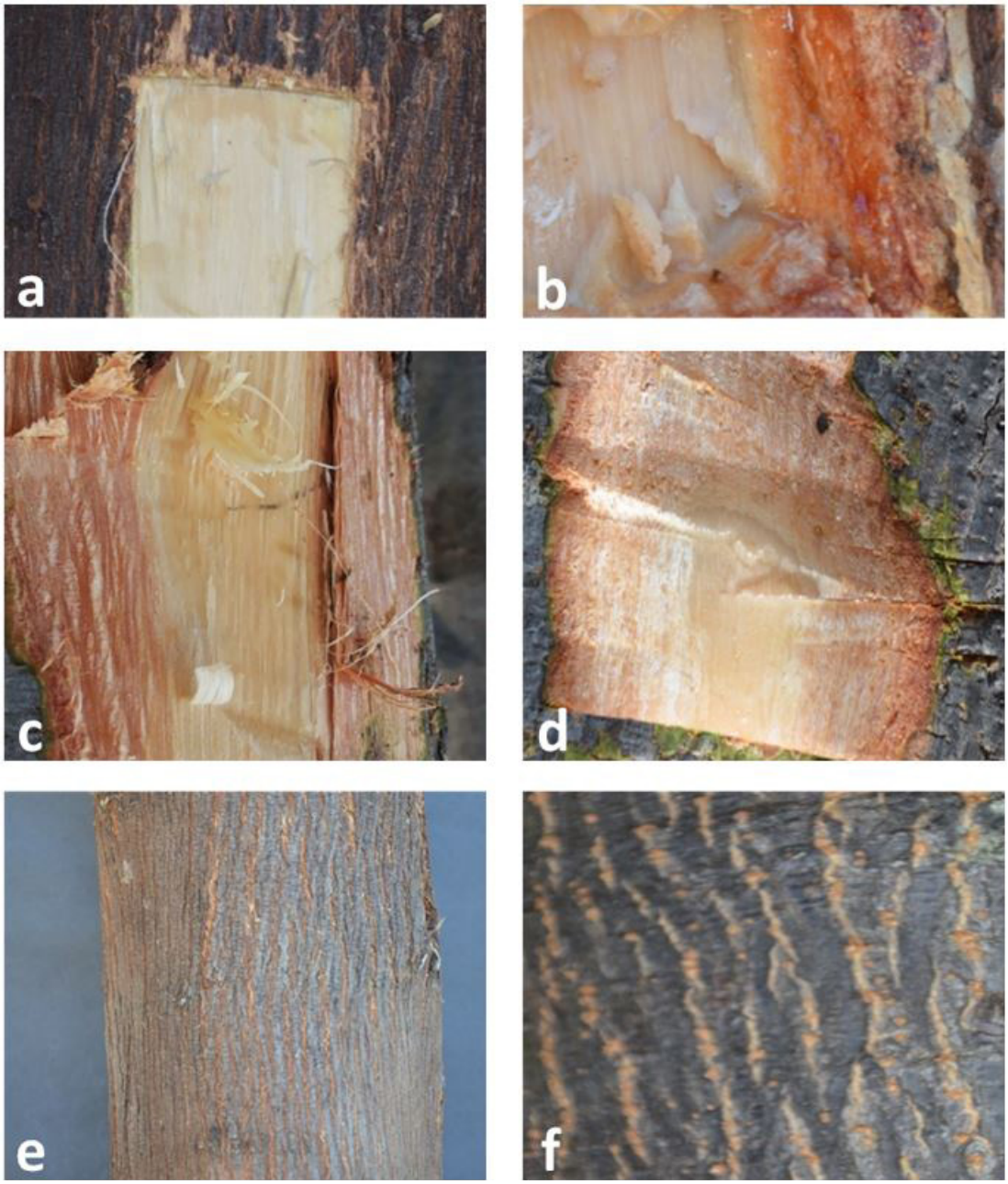

Figure 5. Comparison in the exudation presence (a, b), inner bark structure (c, d), and stretch marks (e, f) from the forest species: *Prosopis juliflora* (a, c, e) and *Schinopsis brasiliensis* (b, d, f).

Key of dendrological characteristics of the commercialized studied species

1a. Aculeus present 2
1b. Aculeus absent.....3
2a. Light gray rhytidome; indehiscent; longitudinal stretch marks of dark gray color, with or without orange streak; separable with difficulty to the knife blows, fibrous; smooth inner surface of uniform coloration, green or orange in function on the sapwood distance; thin thickness (<1 mm), without lenticels. Hard inner bark of difficult cutting, not brittle and dry, smooth inner part, with yellow-orange coloring darkening with exposure to air; laminated structure with overlapping layers and average thickness

(5-12 mm); presence of exudation late, resinous, reddish. Distinction between heartwood and inconspicuous sapwood, with light brown heartwood (7.5YR 6/4) and pale brown sapwood (2.5Y 8/4) ....*Anadenanthera colubrina* var. colubrina.

2b. Reddish brown rhytidome; indehiscent; presence of deep fissures formed by aculeus aligned longitudinally; separable with difficulty to the knife blows, fibrous; smooth inner surface, green color, thin thickness (<1 mm), without lenticels. Hard inner bark with difficulty cutting, not brittle; dry consistency, smooth inner part, red-orange coloring becoming light brown-red with exposure to air; laminated structure with overlapping layers, average thickness (5-12 mm); absent exudation. Distinction between heartwood and sapwood, with light brown heartwood (7.5YR 6/4) and pinkish sapwood (7.5YR 8/4) .....*Anadenanthera colubrina* var. cebil.

3a. Laminated inner bark structure 4

3b. Non-laminated inner bark structure 5

4a. Consistency of smooth inner bark, easy to cut, brittle and dry, smooth inner part, orange coloring, becoming dark with exposure to air; non-laminated structure, average thickness (5-12 mm); sticky and clear exudation of medium abundance and fast flow. Rough rhytidome; light gray to dark gray; indehiscent in individuals with DBH <18 cm and with longitudinal stretch marks; separable with ease and lenticels along longitudinally disposed stretch marks; dehiscence in individuals with DBH> 18 cm, detaching in irregular portions; separable with difficulty with knife blows, granular, thin thickness (<1 mm). Distinction between heartwood and sapwood, with dark red heartwood (2.5YR 3/6) and yellowish red sapwood (5YR 4/6) ..... *Schinopsis brasiliensis.*

4b. Consistency of hard inner bark with difficulty cutting, not brittle and dry; smooth inner part, red-pink coloring becoming darkening with exposure to air; non-laminated, average thickness (5-12 mm); resinous exudation of medium abundance and late flow. Rough rhytidome, blackened gray; dehiscent, with detachment on irregular and concave blades; absence of fissures and stretch marks; separable to knife blows, granular, smooth inner surface of greenish coloration, thin thickness (<1 mm); lenticels in longitudinal and or dispersed rows. Distinction between heartwood and sapwood, with pink heartwood (5YR 7/3) and very pale brown sapwood (10YR 8/2) .... *Myracrodruon urundeuva.*

5a. Inner bark of reddish color 6a

5b. Inner bark of orange color 6b

6a. Present, resinous exudation with medium abundance and slow flow; inner bark with smooth consistency with ease to cut, not brittle and dry; laminated structure with medium thickness (5-12 mm); change of color from reddish to brown-pinkish with exposure to air. Rough rhytidome, dark brown to blackish gray; dehiscent in individuals with DBH> 12 cm, detachment in irregular portions; superficial fissures and stretch marks without distinct staining; separable to the knife blows, fibrous; smooth inner surface of uniform pink to reddish color, medium thickness (2-4 mm); lenticels visible between the stretch marks. Distinction between heartwood and sapwood, with brown heartwood (5Y 8/4) and light yellowish gray sapwood (7.5YR 5/4) ..... *Mimosa tenuiflora.*

6b. Exudation absent; smooth inner bark consistency with easy of cutting, not brittle and dry; thin thickness laminated structure (<5 mm); orange inner bark changing to light yellow with exposure to air. Rough rhytidome, blackened gray; indehiscent; with vertical green or brown stretch marks; separable with difficulty to the knife blows, fibrous; smooth inner surface, of greenish color, medium thickness (2-4 mm); with lenticels. Distinction between heartwood and sapwood, with strong brown heartwood (7.5YR 4/6) and light yellowish-gray sapwood (5y 8/3) .... *Prosopis juliflora.*

4. CONCLUSION

The dendrological characteristics of the rhytidome, inner bark and wood available at the time of inspection (wood in logs), along with the elaborated dendrological characteristic key, allow the precise identification and distinction among the studied species, avoiding confusion among the studied native species and the *Prosopis juliflora*, in the act of inspection.

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CORRESPONDENCE TO

Rayssa de Medeiros Morais
Departamento de Produtos Florestais, Universidade Federal Rural do Rio de Janeiro – UFRRJ, Rodovia BR 465, Km 7, Campus Universitário, Zona Rural, CEP 23890-000, Seropédica, RJ, Brasil
e-mail: rayssaengflorestal@gmail.com

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