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ANATOMICAL IDENTIFICATION OF TROPICAL WOODS TRADED IN LAVRAS, BRAZIL

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Anatomical characterisation of wood plays an important role in the recognition and confirmation of identity of commercially important timbers. Hence, the objective of the present study is to establish macroscopic identity of tropical wood species commercialised in Lavras, city of Minas Gerais/Brazil, and to verify whether the commercial names given to these species differentiate them from other wood species studied. Wood planks were obtained from commercial timber industries in Lavras region. The samples were passed through identification screening, anatomical characterisation, commercial nomenclatural analysis and visual comparison between the samples collected with available reference materials. According to the results, the trade nomenclature used for lumber industry was in agreement with the literature, except for the taxon *Goupia glabra* (Goupiaceae), and its common name Perobinha should be replaced by Cupiuba. Evaluation of several features affirmed that the axial parenchyma patterns, the vessel porosity and the presence of storied rays were essential to distinguish families, tribes and typical forest species of the Brazilian flora. Based on the results it was concluded that wood anatomy is an effective mechanism in the identification of commercial timbers, including endangered taxa such as *Cedrela* (Meliaceae).

Keywords: Brazilian species, wood identification, screening methodology, wood anatomy, macroscopic analysis, spatial patterns, axial parenchyma

INTRODUCTION

Brazilian forests are a natural habitat of thousands of tropical species, bearing the greatest diversity of vascular plants worldwide (Zappi et al. 2015). The challenges encountered in estimating the richness of species include sampling methodology employed in forest inventories, proper identity of trees and the inappropriate use of popularly given names (ter Steege et al. 2016).

According to International Tropical Timber Organization (ITTO 2017), Brazil is the largest producer and exporter of sawn timber in Latin America, supplying aproximately 46% of continental production. In 2016, the total volume exceeded 8,000,000 m^3, an increase of 52.3% from 2015 (Brazilian Forest Service 2017). The increase in production is due to the large demand for tropical lumber, mainly for construction activities in Asian Countries (ITTO 2017).

The production, consumption and trade of this renewable resource are among the global strategies evaluated for the conservation of Brazilian flora. The Brazilian flora has more than 2,600 taxa listed in the Convention on International Trade in Endangered Species (CITES), of which 2% are considered timber species (Scarano & Silva 2018).

Combating illegal logging and informal tropical timber trade is essential for the development of sustainable forest management (Lima et al. 2018). The application of laws prohibiting the commercialisation of timber products without traceability has resulted in the high demand for mechanisms capable of verifying the origin of timber, including forensic identification methodologies (Dormontt et al. 2015).

Among the many existing techniques, identification of wood by microscopic method is the most widespread technique throughout the world, which and has a high degree of scientific reliability (Carlquist 2001, Gasson 2011, Ruffinato et al. 2015).

Macroscopic analysis is a basic strategy of practical studies in wood anatomy. In Brazil, the main centers of wood technology use the anatomical procedure by Coradin and Muñiz (1992) as the traditional method for tropical timber classification.

According to Dormontt et al. (2015), the efficiency of this technique depends on the degree of training of the observer and the quality of the comparative auxiliary material. For these authors, the research on anatomical identification should prioritise the distinction between similar or closely allied woody species, new screening methodologies and scientific validation of timber products.

The main difficulties encountered in recognising the taxa, due to the diversity of existing trees, are visual similarities among woods, variations occurring between families, genera, individuals, and similar popular names for the same species (Hermanson & Wiedenhoeft 2011).

Therefore, the objective of this study was to identify, macroscopically, tropical woods traded in Lavras region, Minas Gerais State, in order to verify whether the commercial names given refer to the taxa identified, through reports and analysis of the anatomical peculiarities that differentiate the wood of the species studied.

MATERIALS AND METHODS

The study was conducted in the Laboratory of Wood Anatomy, Department of Forest Sciences (DCF), Federal University of Lavras (UFLA), Minas Gerais, Brazil. Three companies of Lavras and two sawmills, one located in Nepomuceno and the other in Rio Vermelho, Minas Gerais State, provided six tropical hardwood planks each for identification; in total thirty specimens were analysed. The samples were conditioned in plastic bags, registered and subjected to macroscopic screening.

The central planks were oriented perpendicular to growth rings. After the preparation, samples of approximately 8 cm^3 (Figure 1) were produced in the DCF machining laboratory.

In order to obtain the images, the samples were polished using 80–600 wet - dry sandpapers (Nascimento et al. 2017). The records were made at the Multidisciplinary Laboratory of Electron Microscopy (LEM), Department of Phytopathology, UFLA. The macroscopic images were captured using a digital camera with 12.7-megapixel resolution, connected to a fluorescence stereomicroscope with NIS-Elements D 3.2 software.

Wood identification consists of visual evaluation of the anatomical and non-anatomical properties of wood, analysis of commercial nomenclature, and the segregation of specimens by comparison with samples recorded at DCF's wood library collection [Embrapa Amazônia Oriental (IANw)], and reference material (Mainieri & Chimelo 1989, Coradin & Muñiz 1992, Camargos et al. 2001, Ferreira & Hopkins 2004, Coradin et al. 2010, Wheeler 2011, Zenid & Ceccantini 2012, Ruffinatto et al. 2015).

Validation of wood identification was performed at the Laboratory of Trees, Wood and Furniture (LAMM), Technological Research Institute, São Paulo (IPT-SP) where the materials were compared to the sources of IPT's wood xylarium [Calvino Mainieri (BCTw)], the largest collection of tropical timber in Brazil.

RESULTS AND DISCUSSION

From the thirty samples analysed, ten tropical timbers were differentiated by wood anatomy, among the taxa traded in the region of Minas Gerais. It also occurred in the commerce of São Paulo and Rio de Janeiro States (Santini Junior 2013, Nascimento et al. 2017). The identified

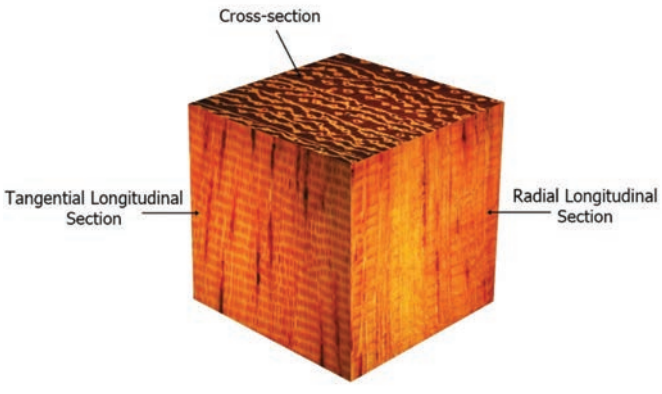

Figure 1 Standard sample for macroscopic analysis

timber species are listed in alphabetical order, with scientific names, commercial names, family, biome of occurrence and conservation status (Table 1).

The results obtained identified six commercial types of wood belonging to the family Fabaceae. According to Lewis et al. (2005), this is the third largest family of vascular plants worldwide. Brazil has about 2,756 Fabaceae species cataloged, from which 1,507 are endemic (Zappi et al. 2015). The other families represented are Anacardiaceae, Goupiaceae, Lecythidaceae and Meliaceae, each with a specific taxon.

In the analysis of commercial names, the only conflicting species with misidentification was *G. glabra* (Goupiaceae). This taxon has also been identified as *Angelim pedra*, cambará, cedrinho, garapa, guajará and peroba (Zenid 1997, Nascimento et al. 2017).

In Minas Gerais, the species has been traded as Perobinha. However, this name refers to two native species, *Aspidosperma* sp. (Apocynaceae) and *Paratecoma peroba* (Bignoniaceae), and the most appropriate commercial name should be cupiuba (Camargos et al. 2001).

Goupia glabra appears as a viable alternative to species established by use, however, it presents less commercial value compared to traditional woods, and it has regulated forest management in the Amazon (Brancalion et al. 2018).

Among the identified woods, only cedro [*Cedrela* sp. (Meliaceae)] is at a risk of extinction, and is listed in Appendix III of the list of endangered CITES species. The widespread exploitation of timber by different industries, deforestation and loss of habitat are the main threats to the conservation of this taxon (Martinelli & Moraes 2013).

Some of the specimens identified in the genus have valuable taxa under threat such as *Cedrela fissilis, C. lilloi* and *C. odorata* from the family Meliaceae, and *Hymenaea parvifolia*, *Hymenolobium excelsum* and *Peltogyne maranhensis* from the family Fabaceae (Martinelli & Moraes 2013). However, it was not possible to confirm the species by mere macroscopic analysis.

According to Zenid and Ceccantini (2012), the sensorial analysis of the woods allowed great interaction in the process of screening and identification. The analysis of wood anatomy was fundamental for the identification and authentication of wood identity. The macroscopic anatomical characterisation of tropical woods is presented in Table 2.

Among the many characteristics analysed, distribution of axial parenchyma segregated the largest number of species. According to Spicer (2014), parenchyma arrangements are defined by the interaction of axial and radial structures of wood, where these continuously organised cells form spatial patterns capable of distinguishing similar taxa.

In the analysis of tauari [*Couratari* sp. (Lecythidaceae)], the reticulated axial

Table 1 Tropical species traded in Lavras region, Minas Gerais State

	Scientific name	Commercial name	Family	Biome	Status
I	*Astronium lecointei*	Muiracatiara	Anacardiaceae	A	-
II	*Cedrela* sp.	Cedro	Meliaceae	A, Ca, C, MA	*
III	*Couratari* sp.	Tauari	Lecythidaceae	A, MA	-
IV	*Diplotropis* sp.	Sucupira	Fabaceae	A, MA	-
V	*Dipteryx* sp.	Cumaru	Fabaceae	A, Ca, C	-
VI	*Goupia glabra*	Cupiuba	Goupiaceae	A, C	-
VII	*Hymenaea* sp.	Jatoba	Fabaceae	A, Ca, C, MA	*
VIII	*Hymenolobium* sp.	Angelim-pedra	Fabaceae	A, C, MA	*
IX	*Peltogyne* sp.	Pau-roxo	Fabaceae	A, Ca, C, MA	*
X	*Vataireopsis* sp.	Angelim	Fabaceae	A, MA	-

Biome: A – Amazon, Ca – Caatinga (desert vegetation), C – Cerrado (savanna), MA – Mata Atlântica (coastal forest), P – Pampa (prairie), adapted from Flora do Brasil 2020; Status: * some taxa threatened, based on Livro Vermelho da Flora do Brasil (Martinelli & Moraes, 2013)

Table 2 Macroscopic features for hardwood identification (Ruffinato et al. 2015)

	MACROSCOPIC FEATURES							
Tropical species	Growth rings	Vessels porosity	Vessels groupings	Tyloses	Vessel deposits	Predominant parenchyma pattern	Ray storying (TLS)	Intercellular canals (TLS)
Astronium lecointei	Indistinct	Diffuse	Solitary and multiples 2–3	Present	Absent	Indistinct	Absent	Radial (Figure 2-A2)
Cedrela sp.	Present	Semi-ring (Figure 2-B1)	Solitary and multiples 2–3	Absent	Gums	Marginal	Absent	Absent
Couratari sp.	Present	Diffuse	Solitary and multiples 2–3	Present	Absent	Reticulate (Figue 2-C1)	Absent	Absent
Diplotropis sp.	Indistinct	Diffuse	Solitary and multiples 2–3	Variable	Yellow	Vasicentric (Figure 2-D1)	Absent	Absent
Dipteryx sp.	Variable	Diffuse	Solitary and multiples 2–3	Variable	Resin-oil	Lozenge-aliform (Figure 2-E1)	Present (Figure 2-E2)	Absent
Goupia glabra	Indistinct	Diffuse	Exclusively solitary (Figure 2-F1)	Present	White	Diffuse (Figure 2-F1)	Absent	Absent
Hymenaea sp.	Present	Diffuse	Solitary and multiples 2–3	Variable	Resin-oil	Lozenge-aliform (Figure 2-G1)	Absent	Absent
Hymenolobium sp.	Present	Diffuse	Solitary and multiples 2–3	Present	Dark	Confluent (Figure 2-H1)	Present (Figure 2-H2)	Absent
Peltogyne sp.	Present	Diffuse	Solitary and multiples 2–3	Present	White	Unilateral Aliform (Figure 2-I1)	Absent	Absent
Vataireopsis sp.	Variable	Diffuse	Solitary and multiples 2–3	Present	Yellow	Confluent (Figure 2- J1)	Absent (Figure 2-J2)	Absent

Implied plane of observation is transverse, if there are different plans, it will be indicated in the column 'Character' in brackets, TLS = tangential section

parenchyma was identified as a special character (Figure 2-C1). This arrangement is typical in other important timber species of Lecythidaceae, such as *Allantoma lineata*, *Bertholletia excelsa*, *Cariniana micrantha* and *Lecythis pisonis* (Coradin et al. 2010). However, the genus *Couratari* differs from other Tauaris by the yellow color of the heartwood (Figure 2-C2) (Bernal et al. 2011).

The recognition of standard characteristics is a challenge in wood identification when the parenchyma is not visualised through the lens. However, the anatomical evaluation can reveal other peculiarities in wood. In *Astronium lecointei* (Anacardiaceae), the parenchymal cells are indistinct, but the tangential longitudinal section has radial secretory channels (black spots) (Figure 2-A2).

The characteristic odor of the heartwood, in response to secondary metabolite deposition in the secondary xylem, is the key peculiarity for the identification of *Goupia glabra* (Goupiaceae). In the wood, it was possible to observe diffuse apotracheal axial parenchyma, exclusive solitary vessel elements, obstructed or not by tyloses (Figure 2 F-1), and rectilinear vascular lines with white occlusions (Figure 2 F-2).

The anatomical composition of Fabaceae showed the greatest morphological variation among the taxa. In *Diplotropis* sp. (Fabaceae), besides the accentuated fibrous aspect (Figure 2D-2), the predominant axial parenchyma vasicentric distribution was observed in the transverse section (Figure 2D-1). *Dipteryx* sp. (Fabaceae), which is traded as cumaru, has wood vessels obstructed by resin-oil and predominant aliform in lozenge shape axial parenchyma (Figure 2-E1), and in the tangential section the wood rays were storied, a key peculiarity for the identification of this genus (Figure 2E-2). The genera *Hymenolobium* sp. and *Vataireopsis* sp., commercialised as angelim, are from the Fabaceae family, and they have accentuated fibrous aspect, coarse texture and predominance of confluent axial parenchyma, in common. However, *Hymenolobium* sp. has more parenchyma (Figure 2 H-1) and irregularly storied wood rays (Figure 2 H-2), different from *Vataireopsis* sp., which presents less axial parenchyma, a darker colored fibrous tissue (Figure 2 J-1) and without ray storying (Figure 2 J-2). *Peltogyne* sp. (Fabaceae) belongs to the subfamily Caesalpinioideae and is known as pau-roxo. Usually, the wood has a purple-colored heartwood and lighter sapwood. The axial parenchyma is predominantly unilateral aliform or linear in extension. The growth rings are defined by marginal parenchyma lines (Figure 2 I-1) and dark colored extractives in the vascular lines (Figure 2 I-2). *Hymenaea* sp. (Fabaceae) is a tropical species widely used by the construction industry due to the number of high trees and their natural durability and quality of timber products. The Brazilian cherry or jatoba wood has resin-oil in the vascular lines (Figure 2 G-2), thin lozenge-aliform axial parenchyma and marginal parenchyma delimiting growth rings (Figure 2 G-1). As in *Peltogyne* sp. and *Hymenaea* sp., cedro wood, [*Cedrela* sp. (Meliaceae)] has marginal lines of axial parenchyma defining growth rings. However, only in *Cedrela* sp. the semi-porous ring porosity occurred (Figure 2B-1). The wood also showed the presence of gums in vessel elements, giving a bright appearance in the vascular lines (Figure 2B-2).

Astronium lecointei (Anacardiaceae) and *G. glabra* (Goupiaceae) are species of the Amazon basin with plenty of research in technological characterisation. The peculiarities found in this study were also reported by Mainieri and Chimelo (1989), Coradin et al. (2010), Wheeler (2011) and Santini Junior (2013).

In general, members of Lecythidaceae have reticulate axial parenchyma. This feature has been reported by other researchers of the genus *Couratari* (Mainieri & Chimelo 1989, Alves & Angyalossy-Alfonso 2002, Coradin et al. 2010, Bernal et al. 2011, Wheeler 2011).

Most of the hardwoods used in civil construction in Brazil belongs to the family Fabaceae (Mainieri & Chimelo, 1989). It is the third largest family of angiosperms in terms of species, after Asteraceae and Orchidaceae, and second in economic importance, after grasses of Poaceae. Legume Phylogeny Working Group (2017) has reclassified the Fabaceae into six subfamilies, i.e. Cercidoideae, Detarioideae, Duparquetioideae, Dialioideae, Caesalpinioideae and Papilionoideae.

Through macroscopic analysis, common peculiarities were recognised, such as fibrous aspect in genus *Diplotropis, Dipteryx, Hymenolobium* and *Vataireopsis* (Fabaceae & Papilionoideae), and the definition of growth rings by marginal parenchyma in *Hymenaea* and *Peltogyne* (Fabaceae & Detarioideae).

Two types of Fabaceae wood are traded as Sucupira, i.e. *Bowdichia* sp. and *Diplotropis* sp.

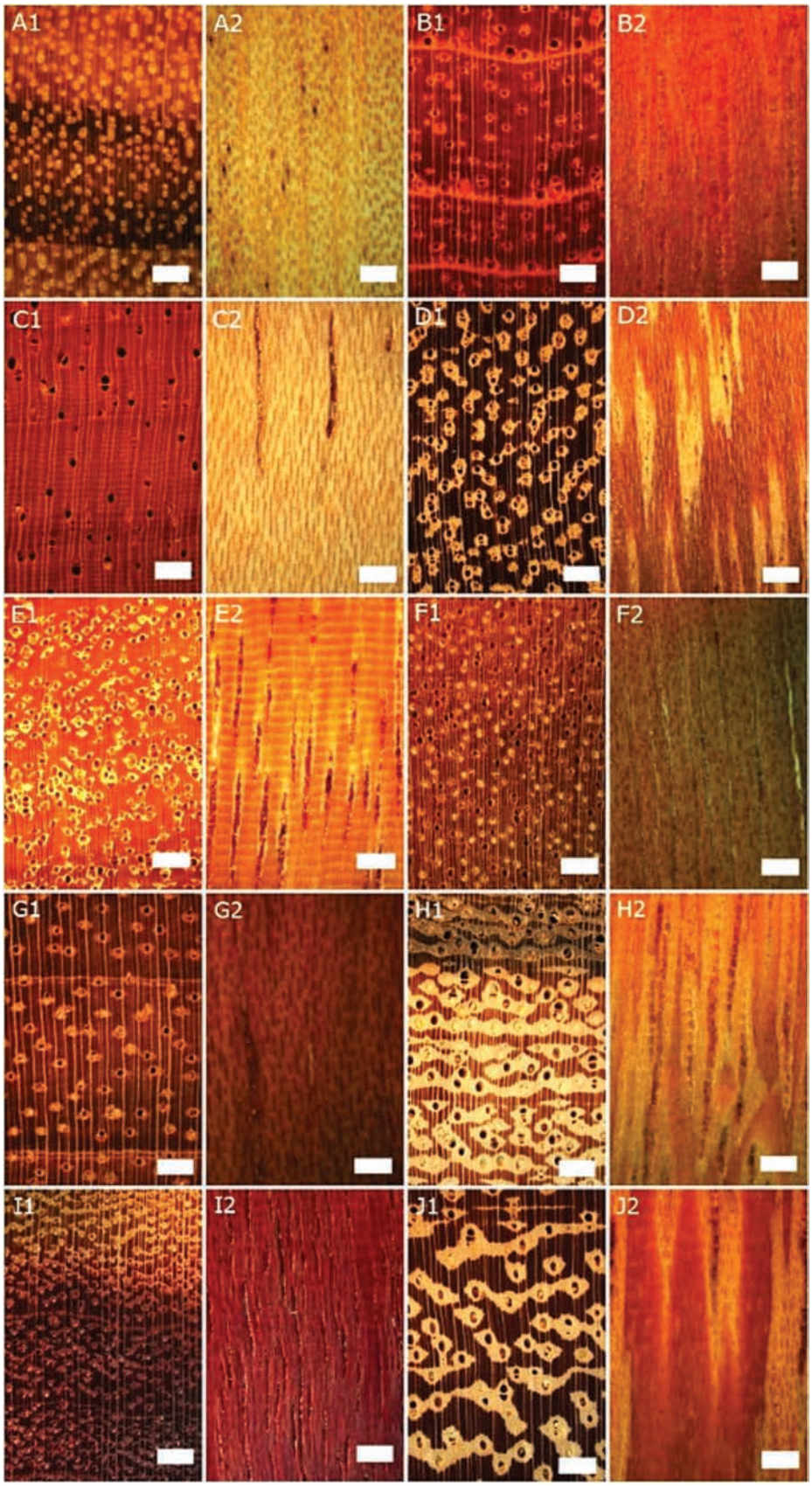

Figure 2 Macroscopic photo of tropical woods; the letter shows species; 1 = cross-section, 2 = longitudinal section; tropical taxa: *Astronium lecointei* (A), *Cedrela* sp. (B), *Couratari* sp. (C), *Diplotopis* sp. (D), *Dipteryx* sp. (E), *Goupia glabra* (F), *Hymenaea* sp. (G), *Hymenolobium* sp. (H) *Peltogyne* sp. (I), *Vataireopsis* sp. (J); scale bar 1000 µm

Both are visually identical in color and fibrous aspect, with high density. According to Mainieri and Chimelo (1989), the cellular structures of these genera are similar. Nevertheless, Santini Junior (2013) and Soares et al. (2014) reported the difference between these taxa, particularly in the stratification of wood rays, as *Bowdichia* sp. has this feature, while *Diplotropis* sp. does not have rays storying.

In this study, cumaru and angelim-pedra [*Hymenolobium* sp. (Fabaceae)], presented this particularity. Other authors reported similar cellular composition in *Dipteryx* sp. (Mainieri & Chimelo 1989, Gasson 1999, Coradin et al. 2010). However, the parenchyma arrangements of this taxon had interspecific variation (Alves & Angyalossy-Alfonso 2000, Alves & Angyalossy-Alfonso 2002).

Due to the similarity of the angelim woods, it is difficult to segregate them by macroscopic methods. The arrangement, amount of axial parenchyma and the rays storying are anatomical peculiarities that separate this group (Ferreira & Hopkins 2004). Similar characterisations have also been described by Mainieri and Chimelo (1989), Ferreira and Hopkins (2004), Coradin et al. (2010) and Santini Junior (2013).

In addition to similarity of wood, the number of species recognised as angelim is an obstacle to their identification. According to Camargos et al. (2001), there are 97 taxa from 17 different families. However, the true angelims are *Andira* sp., *Dinizia* sp., *Hymenolobium* sp., *Vatairea* sp. and *Vataireopsis* sp. (Ferreira & Hopkins 2004).

For different taxa of *Peltogyne* sp., it was possible to find variations in the distribution of axial parenchyma within the composition, width and stratification of the radial parenchyma, and the distinction between growth rings (Alves & Angyalossy-Alfonso 2000, Alves & Angyalossy-Alfonso 2002, Melandri & Pernia 2009).

Hymenaea sp. (Fabaceae) has more than 90 common names and Jatoba is the most suitable for commercialisation (Camargos et al. 2001). The anatomical features related to genus were reported by other authors (Mainieri & Chimelo 1989, Melandri & Pernia 2009, Coradin et al. 2010, Santini Junior 2013). The predominant parenchyma patterns in Brazilian cherry wood was losange-aliform arrangement associated with vessels and marginal lines that delimit the growth ring boundaries. *Hymenaea* sp. taxa manifest periodicity of cambial growth, this particularity has a great interest in dendroecological studies (Albuquerque et al. 2016, Barbosa et al. 2018). The deciduous *Cedrela* sp. trees (Meliaceae) occur in tropical deciduous forests. During the dry season, their cambial activity is reduced, leading to the formation of annual growth rings marked by the porosity of the wood (Dünisch et al. 2002). This particularity has made the genus the most used for dendrochronological studies in tropical vegetation (Dünisch et al. 2002, Marcati et al. 2006, Barbosa et al. 2018).

The species of Meliaceae, cedro (*Cedrela odorata*), and mogno (*Swietenia macrophylla*) are among the most valued and commercialised timbers in the world, being explored for more than 200 years in Brazil, often in illegal trade (Martinelli & Moraes 2013). Two types of timbers are visually similar, but it is possible to separate these taxa macroscopically. The wood of the two trees has marginal lines of axial parenchyma delimiting growth rings and gums in its vessels. However, in cedros xylem, the porosity of semi-porous ring occurs, whereas in mognos the distribution happens in a diffused manner (Mainieri & Chimelo 1989, Coradin et al. 2010). As a perspective, timber identification tends to evolve towards species recognition by machine visions. However, the change depends on new techniques of image acquisition for validation and the quality of reference material in the database (Hermanson & Wiedenhoeft 2011).

CONCLUSION

The macroscopic evaluation in secondary xylem shows special patterns in wood. Axial parenchyma was the most useful anatomical peculiarity in the separation of tropical timbers. The porosity of vessel elements, ray storying and organoleptic characteristics such as color, odor and fibrous appearance aided in wood identification. In general, the commercial names were in agreement with the literature, except for taxon *G. glabra* (Goupiaceae). The recommendation is to replace the name perobinha, used in Lavras, Minas Gerais, by cupiuba, to avoid frauds and illegal timber trade. The anatomical identification was confirmed as an efficient scientific mechanism for the separation of commercial woods, including taxa that are under threat of extinction, such as *Cedrela* sp. (Meliaceae). In addition, wood anatomy is essential in the creation of strategies for conservation, presenting as a field of basic

science for dendroecological studies in tropical species.

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