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Quantitative features of *Cedrela odorata* L. wood (Meliaceae)

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ABSTRACT – (Quantitative features of *Cedrela odorata* L. wood (Meliaceae)). *Cedrela odorata* L. (Meliaceae) occurs in the Atlantic forest, Amazon rain forest, riparian forest of the country, and wetlands, which demand species adapted to their water conditions. Studies in ecological wood anatomy demonstrated that weather factors' variations have direct influence on the wood anatomical structure and that the fragmentation of the natural habitats is a direct cause of the edge effect which alters the abiotic aspects of the location, interfering consequently in its vegetation. A comparative analysis of 20 anatomical quantitative features of the wood structure was performed in populations of *Cedrela odorata* growing inside and on the edge of the swamp forest and granulometric analysis was made on the soil. The quantitative data were submitted to the Mann-Whitney's nonparametric test, presenting a statistically significant value decrease in the eleven wood features mean for the specimens growing in the edge of swamp forest.

Key words - edge effect, swamp forest, wood anatomy

RESUMO – (Características quantitativas do lenho em *Cedrela odorata* L. (Meliaceae)). *Cedrela odorata* L. (Meliaceae) ocorre na Mata Atlântica, floresta pluvial amazônica e nas matas ciliares do interior do país, em ambientes brejosos que demandam espécies adaptadas às suas condições hídricas. Estudos em anatomia ecológica do lenho têm demonstrado que a variação dos fatores climáticos atua diretamente na estrutura anatômica do lenho e que o efeito de borda causado pela fragmentação dos habitats naturais altera os aspectos abióticos e bióticos do local, interferindo na vegetação. Efetuou-se análise comparativa quantitativa de 20 características anatômicas do lenho de espécimes de *Cedrela odorata* do interior e da borda da mata de brejo e análise granulométrica do solo. Os dados quantitativos foram submetidos à prova não paramétrica de Mann-Whitney e demonstraram uma diminuição estatisticamente significativa nas médias dos valores de onze características dos espécimes da borda da mata de brejo.

Palavras-chave - anatomia de madeira, efeito de borda, mata de brejo

Introduction

Cedrela is a neotropical genus of Meliaceae with by several species, whose principal are *Cedrela odorata* L., *C. angustifolia* Sessé & Moc. and *C. fissilis* Vell. (Manieri & Chimelo 1989).

In Brazil, *Cedrela odorata* receives many popular denominations under *cedro* (cedar, white cedar, odorous cedar, swamp cedar, pink cedar and red cedar) (Lorenzi 1998); outside Brazil it is known as cedar, ceder, colorado cedar, castillas cedar, dulce cedar, bitter cedar, and "redceder" (Loureiro & Silva 1968, Manieri & Chimelo 1989).

According to Richter & Dallwitz (2000) its wood presents density between 0.43-0.51 g/cm³, classified as light and soft, being also easy to work with (Lorenzi 1992). Due the high economical value and low linear and volumetric retractability (Manieri & Chimelo 1989), its wood is widely used in civil and naval construction as well as in the manufacture of fine furniture and musical instruments. The yearly growth of highly visible layers (Dünisch *et al.* 2003) makes easy the age determination, rendering the species a great potential for dendrochronological studies.

Cedrela odorata is common in the Atlantic forest, the Amazonic rain forest and inside riparian forests allover tropical Brazil, not occurring in the Brazilian *cerrado* (savanna) (Lorenzi 1992). Outside Brazil it grows in the Mexican Pacific coast, Central America, in great part of South America, and in the Occidental India from the Greater and Lesser Antilles to Trinidad and Tobago. It was also introduced in southeastern Florida and Europe (Loureiro & Silva 1968). This wide geographic range is another attribute for its importance in dendrochronology.

In the beginning of the 20th century it was believed that *C. odorata* could grow in any dry land (Pereira 1914); however, the species is characteristic of wetlands (Torres *et al*. 1994).

The swamp forests (named 'hygrophilic forests' by Leitão Filho, 1982) have typically a smaller variety of wood species, since the constant presence of water in the soil demands specific survival adaptations,

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interfering in their natural selection (Leitão Filho 1982, Joly 1991, Ivanauskas *et al*. 1997, Toniato *et al*. 1998).

With the natural habitats fragmentation due to the great expansion of the agriculture and cattle-raising (Williams-Linera *et al*. 1998), the contact regions of the natural vegetation fragment with the anthropic area undergoes physical alterations called edge effect (Murcia 1995), that acquire greater importance with the decrease in the size of the fragments (Metzger 1999).

The edge effects can be both physical and biological (Murcia 1995). The first comprehend changes in weather factors such as solar radiation, temperature, and wind, that lead to environmental changes (Matlack 1993); the biological are related to abundance, distribution and structural alterations of the species (Fox *et al.* 1997). However, these effects never were analyzed through anatomical wood structure of swamp forests species, although classic studies of the ecological wood anatomy have demonstrated that the weather factors alterations be directly linked to the anatomical structure of the wood by influencing the xylogenesis (Carlquist 1975, 1980, Baas 1982), which may also be susceptible to changes in soil moisture (Luchi 2004a, 2004b, 2005).

This main goal of this study was to verify the edge effect in the quantitative anatomical characteristics of the *Cedrela odorata* wood by a comparative structural analysis of specimens that are growing inside the swamp forest, the typical environment for the species, with those growing on the edge of the swamps, where the environmental conditions might be altered.

Material and methods

The wood and soil samples were collected in an fragment of swamp forest inside the Reserva Biológica e Estação Experimental de Mogi-Guaçu, in Mogi-Guaçu municipality, São Paulo State, Brazil (22°15’02”-22°14’43” S, 47°08’50”-47°07’60” W). The area of about 12 ha is north-limited by *Pinus* plantation, in the south and east by orange farm and in the west by a paved road. The climate, is Cwa, hot humid with dry winters, with mean temperatures above 22 °C in warmer months and above 18 °C in the coldest ones. The mean rainfall is 250 mm in January, the wettest month, and less than 30 mm in July, the driest month, apparently with two well defined seasons (Setzer 1946, 1966).

Three specimens with similar trunks diameters were chosen from both inside and edge (orange farm) of the swamp forest and sampled by a non-destructive method (Luchi *et al.* 2005) at the breast height. The samples were registered and stored in the Wood Collection of the Instituto de Botânica (SPw) of Secretaria do Meio Ambiente de São Paulo (table 1).

Table 1. Specimens data of *Cedrela odorata* L. (DBH = diameter at breast height).

Area	SPw	Heigth (m)	DBH (cm)
Inside of the swamp forest	2067	15	27
	2069	13	20
	2152	15	25
Edge of the swamps forest	2253	8.0	12
	2254	8.5	15
	2255	8.5	13

The samples were fixed in FAA in 50% ethanol and stored in 70% ethanol. Histological sections 15 to 20 µm of thick were obtained with sliding microtome in transversal, tangential and radial longitudinal sections from the last four growth rings. The sections were stained and mounted in histological slides according to usual techniques of wood anatomy (Johansen 1940, Sass 1951). Macerations were made according to Franklin’s test modified by Normand (1972), and mounted in glycerin jelly. Counting and measuring were made in Jenamed 2 microscope coupled to Retarmed 2 system in macerated tissue and in histological sections. Twenty anatomical parameters were analysed: vessels per square millimeter, vessel diameter, vessel element length, intervessel pit diameter, vessel-ray pit diameter, ray per millimeter, ray height in micrometer, ray height in number of cells, ray width in fibers in micrometer, ray width in fibers in number of cells, ray width in axial parenchyma in micrometer, ray width in axial parenchyma in number of cells, fibre length, fibre diameter, fibre lumina diameter, fibre wall thickness, axial parenchyma percentage, vessel percentage, fibre percentage and ray percentage, as recommended IAWA Committee (1989), for each characteristic in each sample (n = 30). The data set was submitted to the Mann-Whitney’s non-parametric test, equal to the two averages test for independent samples, at a 5% probability level, by using BioEstat v.2.0 (Ayres *et al.* 2000).

Granulometric analysis were performed for the soil of both areas by the densimeter method (Camargo *et al.* 1986), in the Soil and Plants Nutrition Department of the Escola Superior de Agricultura Luiz de Queiroz – Universidade de São Paulo.

The border soil was also analyzed concerning the humidity at the weight basis (µ) (Reichardt 1985), collected at the depth of 0-10 cm in three standard points, near the trees from where the wood samples were collected. The collecting of soil samples happened once a month, during 12 months, always in the second fortnight of each month.

Results and discussion

Table 2 shows the areas are quite distinct as for their granulometry, the internal with a very-clay texture while the edge area presented two spots as sandy loam, a texture similar to the one observed in 'cerrado' soils (Luchi *et al.* 2005), which typically present a relatively low capacity for water retention (Coutinho 2009). The third edge sample stands out for presenting a lesser percentage of total sand and almost twice the percentage of clay, being classified as sandy clay loam and tending to a texture more similar to those inside the swamp, which granted it a higher percentage of soil humidity (figure 1) than spots 1 and 2, indicating that perhaps the edge effect on the soil of this swamp fragment is not so marked yet, though the edge effect be not considered a natural and continuous but a phenomenon rather abrupt and with a very quick dynamic (Bettoni *et al.* 2007).

Table 2. Granulometric analysis of estudied areas.

Area	Spot	Total sand (%)	Silt (%)	Clay (%)	Soil texture
Inside of the swamp forest	1	8	19	73	very clay
	2	11	20	69	very clay
	3	15	10	75	very clay
Edge of the swamp forest	1	74	8	18	sandy loam
	2	74	8	18	sandy loam
	3	58	8	34	sandy clay loam

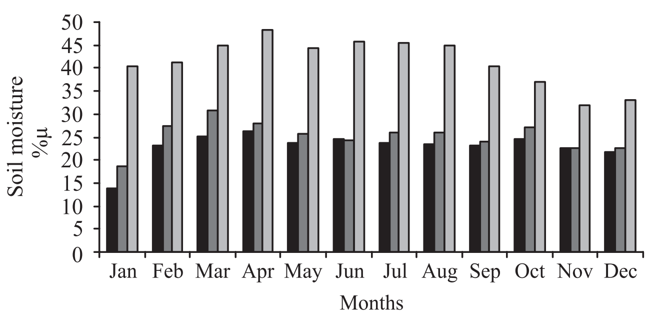


Figure 1. Data of soil moisture (% µ) for each point sampled (■ = point 1; ■ = point 2; □ = point 3).

The border effect defined as a structural alteration in the composition and/or relative abundance of species in the peripheral part of the fragment may be observed in the lowest heights and smaller diameters (table 1) of the edge specimens, compared to those inside the swamp. Similar data was obtained by Barros (2006) in a mountain forest fragment and by Bettoni *et al.* (2007) in a riparian forest fragment.

Table 3 shows the results of the Mann-Whitney's test for anatomical features and the figure 2 shows the graphic with the averages of the variables, which are significantly different from each other, for the specimens from inside the swamp and the specimens from the edge.

Table 3. Results of Mann-Whitney proof ($P < 0,05$).

Analized characteristics	Probability
Vessels per square millimeter	0.4356
Vessel diameter	0.0000 *
Vessel element length	0.0172 *
Intervessel pit diameter	0.0183 *
Vessel-ray pit diameter	0.0077 *
Ray per millimeter	0.0000 *
Ray height (µm)	0.0000 *
Ray height (number of cells)	0.0000 *
Ray width in fibers (µm)	0.0000 *
Ray width in fibers (number of cells)	0.0000 *
Ray width in axial parenchyma (µm)	0.0000 *
Ray width in axial parenchyma (number of cells)	0.0017 *
Fibre lengths	0.0187 *
Fibre diameter	0.0200 *
Fibre lumina diameter	0.0000 *
Fibre wall thickness	0.0000 *
Axial parenchyma percentage	0.4092
Vessel percentage	0.0732
Fibre percentage	0.1111
Ray percentage	0.2026

* = significant at 5%

The vessel per square millimeter is usually lower in species that grow in more humid environments and higher in those of dry environments (Bass 1973, Barajas-Morales 1985, Lindorf 1994). However, Luchi (2004a), analyzing the anatomical characteristics of the *Croton urucurana* Baill. from soils with different levels of humidity, demonstrated that the higher vessel per square millimeter averages occurred in specimens from more humid and flooded areas.

Although the data relative to the soil texture grants characteristics of a dryer environment to the edge soil, the consequences of this fact were not revealed by five of the observed characteristics in the studied *Cedrela odorata* specimens, which presented no difference in the vessel per square millimeter averages from both areas, as well by the tissue quantification data of the axial parenchyma, vessels, fibres and rays, which also did not present variations between the inside and the edge specimens, a very important feature to be considered in dendrochronological studies.

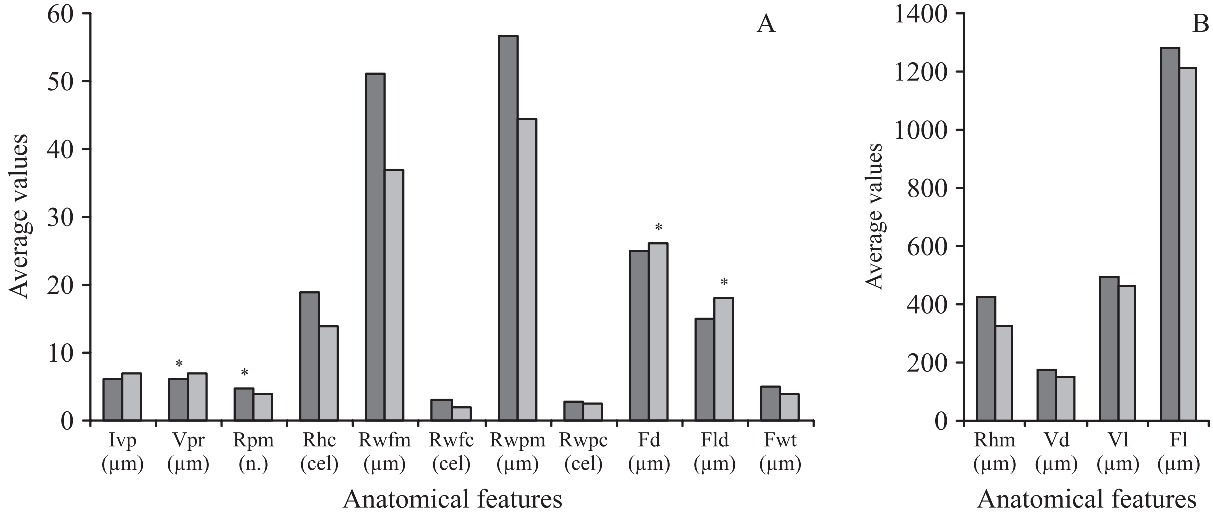


Figure 2. Results of the Mann-Whitney test. The average values for the anatomical features are presented for each studied place. Inside area (■); edge area (■); Ivp = intervessel pits diameter; Vrp = vessel-ray pits diameter; Rpm = ray per milimetre; Rhc = ray height (number of cells); Rwfm = ray width in fibres (µm); Rwfc = ray width in fibres (number of cells); Rwpm = ray width in axial parenchyma (µm); Rpc = ray width in axial parenchyma (number of cells); Fd = fibre diameter; Fld = fibre lumina diameter; Fwt = fibre walls thickness; Rhm = ray height (µm); Vd = vessel diameter; Vl = vessel element length; Fl = fibre lengths (* = greater means for edge area specimen). The means were in different groups: A, B to adapt the scales.

Nevertheless, eleven characteristics showed values significantly lower for the specimens on the edge of the swamp forest: diameter and length of vessel elements, ray per millimeter, ray height in micrometer and in number of cells, ray width in fibres in micrometer and in number of cells, ray width in axial parenchyma in micrometer and in number of cells, fibres length and fibre wall thickness; some of these characteristics may be confronted figures 3-6 and 11-12.

The decrease of vessel diameter for the edge specimens coincides with the already reported for species of dryer environments (Baas *et al.* 1983, Baas & Carlquist 1985), where this feature represents an adaptation to hydraulic safety, since elements of lower caliber diminish the possibility of embolism in the case of a hydric stress endanger the hydric flow of the vessel. Data similar to these were obtained for *Croton urucurana* (Luchi 2004a).

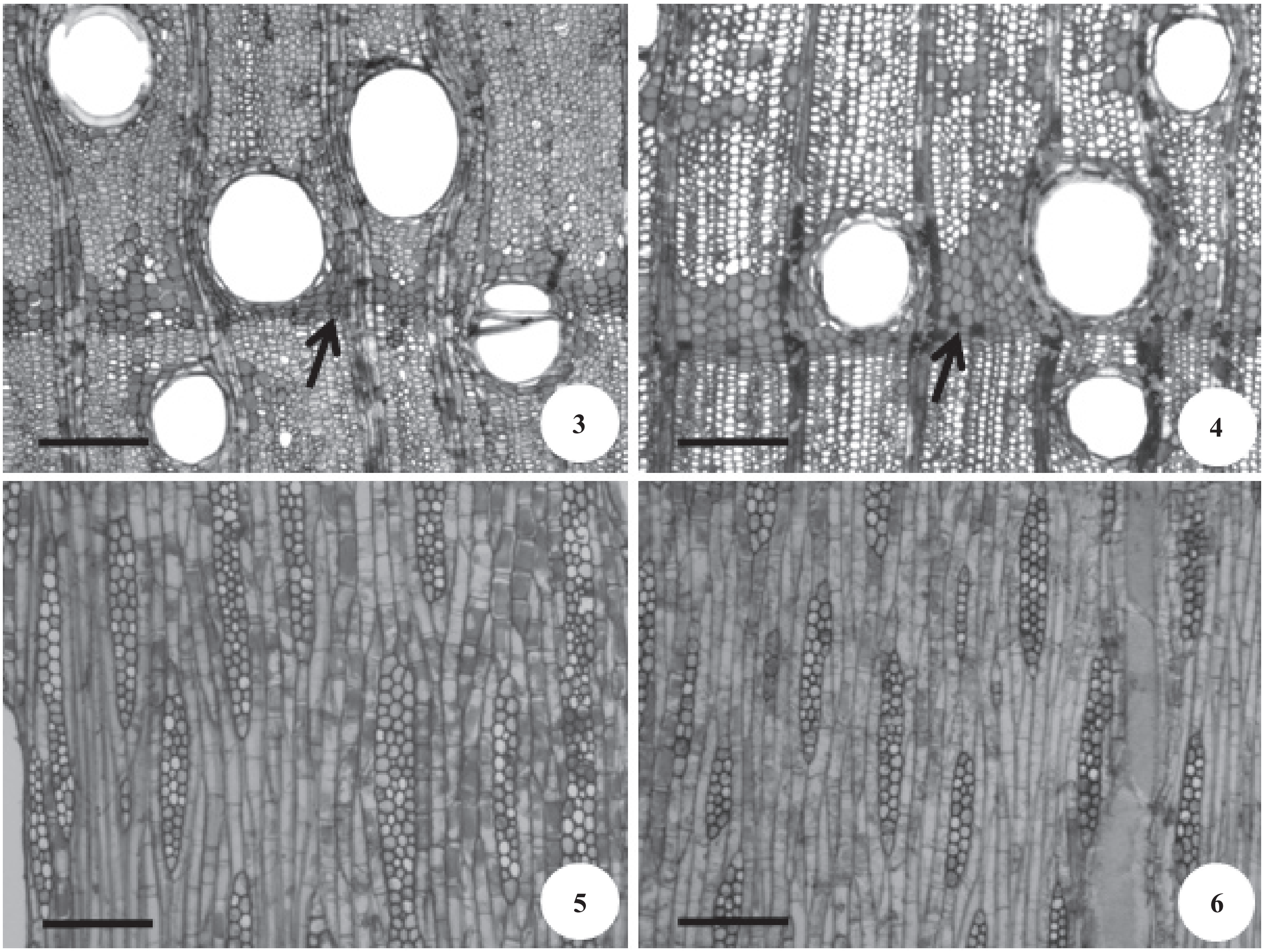
The length of vessels element and fibres is usually bigger in specimens where the hydric availability is higher because the fusiform initials that originates these cells will present a bigger cell turgor, resulting in bigger axial elements (Levitt 1980). The *Cedrela* edge specimens shows statistically lower values than those from inside the swamp, reflecting therefore the lower degree of humidity in the edge soil, as verified by the granulometric analysis.

Data concerning the rays are rarely mentioned, though existing papers show the highest ray per millimeter values, both in the height and width of the rays, for specimens of more xeric ecosystems such as savannas, *cerrado*, caatinga (Outer & Veenendaal 1976, Chimelo & Mattos Filho 1988, Pereira 1990) or even in gallery forest (Luchi 1998) characterized for a lower hydric availability, the opposite of the found here for the edge specimens for *Cedrela odorata*.

Fibres with thicker walls appear frequently in dryer environments, as observed by Fahn *et al*. (1986) in Mediterranean and desertic species, by Alves & Angyalossy-Alfonso (2002) for Brazilian species of low humidity environments. However, although it has been statistically confirmed a thickening in the fibres walls of *Croton urucurana* in dryer areas (Luchi 2004a) and in *Xylopia aromatica* (Lam.) Mart. in *cerrado* (Luchi *et al*. 2005), opposite results had been obtained in *Guarea macrophylla* Vahl, *Casearia sylvestris* Sw. and *Nectandra megapotamica* (Spreng.) Mez from hydrically more favorable gallery forest (Luchi 1998), just like it was verified here for the *Cedrela odorata* specimens from inside the swamp.

By the other side, four characteristics are proved statistically higher for specimens from the swamp edge: the diameter of intervessel pits (figures 7-8) and vessel-ray pits (figures 9-10), the fibres diameter and the fibres lumina diameter (figures 11-12).

The intervessel pits and vessel-ray pits diameter are characteristics that are still hardly used in any approach relating the wood anatomy to the environmental



Figures 3-6. Wood of *Cedrela odorata*. 3-4. Transverse sections, compare tangential diameter of vessels, and note banded parenchyma (arrow), growth ring boundary. 3. Inside area specimen. 4. Edge area specimens. 5-6. Tangential sections, compare rays dimension. 5. Inside area specimen. 6. Edge area specimen. Bar = 200 µm.

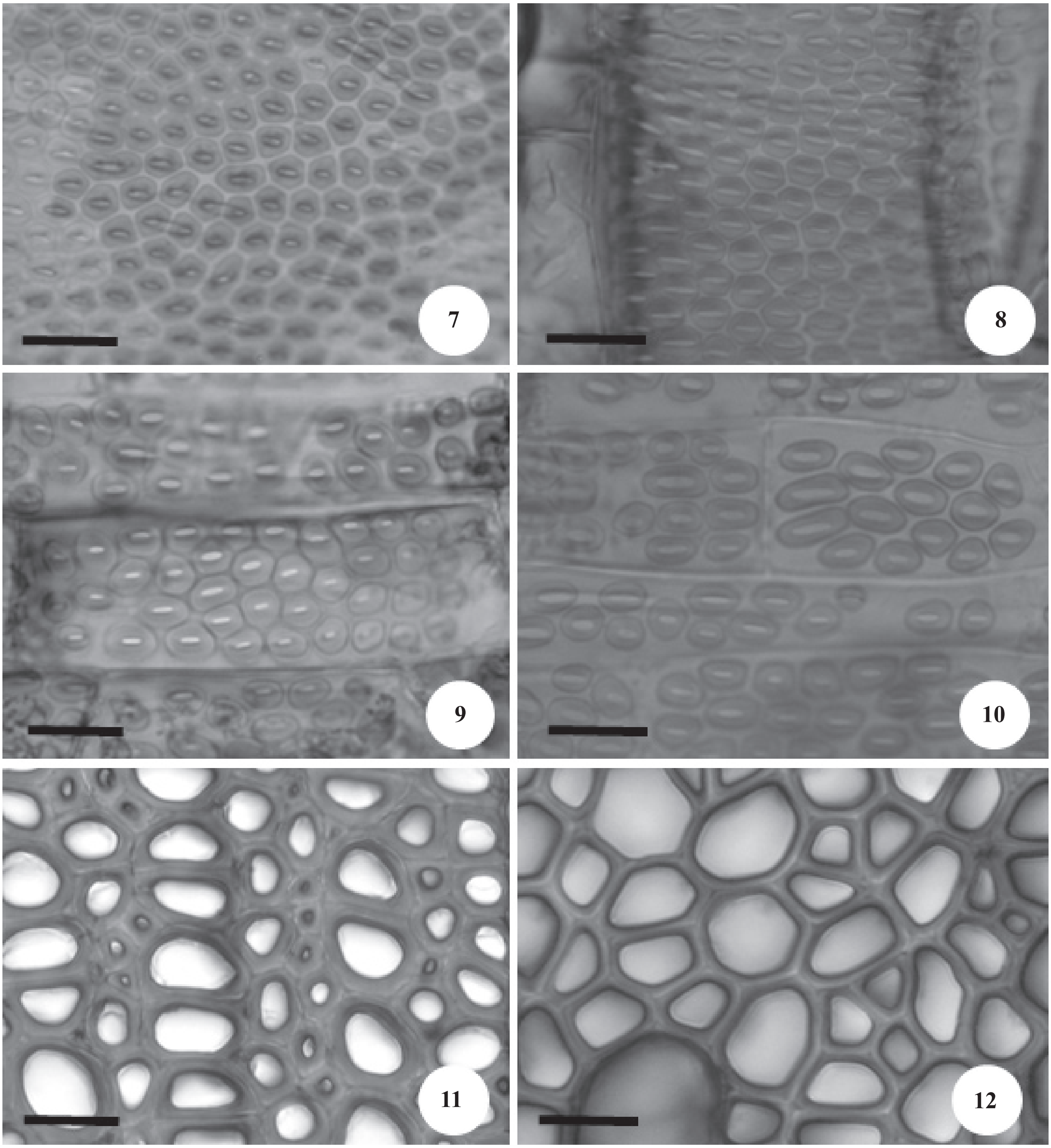
variations, in spite of the important role performed by them plant transportation system (Holbrook & Zwieniecki 2005).

Luchi (1998), working in two distinct forested areas verified the highest statistically significant values for the intervessel pits diameter and the vessel-ray pits diameter in gallery forest specimens of *Guarea macrophylla*, characterized by a lesser hydric availability similar to that obtained here in *Cedrela odorata* specimens from the edge of the swamp.

Antagonistic results were already reported for environments considered mesic or with a greater availability of water, viz., bigger intervessel pit diameters in *Casearia sylvestris* and vessel-ray pit diameter in *Psychotria carthaginensis* Jacq. in specimens of one of the gallery forests (Luchi 1998), bigger intervessel pit diameters in specimens of *Copaifera langsdorffii* Desf. from semideciduous mesophytic forest (Marcati *et al*. 2001) and for intervessel pit diameter in specimens of *Croton urucurana* from a flooded area (Luchi 2004a) and for both kinds of pit in the wood stem of *Xylopia aromatica* specimens from a *cerrado* with a greater availability of water in the soil (Luchi *et al*. 2005).

The fibre diameter is another characteristic without bibliographical reference that may be related to environment just like the fibre lumina diameter.

For the fibre diameter only one result, contradictory, was obtained from literature, with the highest fibre diameter values obtained for the wood stem of *Croton urucurana* specimens from moist and flooded areas (Luchi 2004a). On the other hand, corroborating the data obtained for *Cedrela odorata*, Luchi (1989) has also verified the highest fibre lumina diameters for *Guarea macrophylla* and *Eugenia repanda* O. Berg in specimens



Figures 7-12. Wood of *Cedrela odorata*. 7-8. Tangential sections, showing intervessels pits. 7. Inside area specimen. 8. Edge area specimen. 9-10. Radial sections, showing vessel-ray pits. 9. Inside area specimen. 10. Edge area specimen. 11-12. Transverse sections, showing fibre diameter, fibre lumina diameter and fibre walls thickness. 11. Inside area specimen. 12. Edge area specimens. Bar = 20 µm.

of gallery forest statistically characterized by a lesser hydric availability.

The structural differences observed in individuals of *Cedrela odorata* in the edge of swamp forest were clearly related to decreased water availability, which is reflected in the xilogenesis. The lower water availability is related to structural differences found in the soil of forest edge. This, in turn, may indicate an aspect of the edge effect, where the exposed open areas lead to a change microclimatic condition (Kapos 1989). The greater penetration of sunlight, higher temperatures and evapotranspiration imply in reduction of both air and soil humidity, favoring thus the occurrence of water stress.

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