Ser. Bot.8(1),1992

ANATOMICAL STUDY OF THE WOOD OF THE GENUS HEVEA

Introduction

In Brazil, the area of geographic distribution of the genus Hevea (Fig.1) covers the whole of Hileia, that is, the States of Amazonas, Para, Acre and Amapa, upto the 77th Meridian the north-east part of the State of Maranhao, the north of the States of Mato Grosso and Rondonia. Outside the borders of Brazil the genus Hevea has been observed in the Guyanas, Venezuela, Colombia, Equador, Peru and Bolivia, in the forests contiguous to the Brazilian Amazon. The northern-most ends for Hevea are Upper Orinoco and Lower Essiquibo and the southern-most point is the sub-Andine East Bolivia (Ducke & Black, 1954). As regards the size, all the species are trees, with the exception of Hevea camporum, which is a shrub growing in the Amazonic sand plains. In general they are medium to big sized trees and the biggest trees belong to the species H. Guianensis and H. brasiliensis, which may reach 50 m of height and 1 to 1.5 m of DAP (Pieres, 1973).

At times the positive identification of the wood is possible only through the botanical characteristics of the tree. However, in many cases the structural diversity of the wood, associated to the known variations such as colour, weight and look of the grain-figure provide a correct means of identification (Panshin, 1970).

Heywood (1970) points out that the anatomy of the wood has been successfully used in various groups of plants, which has helped to establish the systematic position of primitive families of angiosperms without conductor vessels, such as Winteraceae, Trochodendraceae and others.

The works carried out earlier on the anatomy of Hevea wood were very elementary, both at the level of repetitions and of ~~on the anatomy of Hevea~~ species, since the majority of the studies carried out concerned mostly Hevea braziliensis, as it is the most important species as a producer of latex.

With the anatomic data obtained in the present research, we draw up a dichotomic key based on the quantitative anatomic characteristics of the wood, for separation of the species studied, or at least for offering information for such a study. In this way, we tried to contribute to the clarification of some points still obscure in the botanical taxonomy, considering that this is a complex matter which one could understand from the voluminous synonymy which involves more than 100 binomies or trinomies.

Material and Methods

The majority of the samples of the species studied came from Belem (Baldwin's Chart - CPATU/EMBRAPA), but the samples of Hevea camargoana were collected from Joanes, in the municipality of Salvaterra in Para State and those of Hevea camporum were collected from Tapajos (Para) and from Rovaima. The species Hevea paludosa was collected from the Tunui mountain range, in Amazon and from Uquitos, in Peru.

For each species we collected samples from 3 to 5 trees from the region closest to the bark and at a height of 1.30 m (DAP); we have to point out that in the case of H. Paludosa the samples were taken only from two trees, considering the scarcity and the difficulty in collecting the material.

The identification of the herborized material was done by Dr. Joao Murca Pires, Botanical Researcher of the Paraense Emilio Goeldi Museum, Belem, Para.

The botanical material corresponding to the species studi are archived in the herbariums of CPATU/EMBRAPA and of Goeldi Museum in Belem, Para, with the following collector numbers:

Hevea benthamiana Muell. Arg.

Nelroa Rosa 260; Manoel Cordeiro 1621 and Benedito Ribeiro (1829, 1836 and 18358).

Hevea brasiliensis (H.B.K.) Muell. Arg.

Nelson Rosa (3610 and 3612): Nelo T. Silva 4945 and Emmanuel Oliveira 5957.

H. Camporum Ducke

Nilo T. Silva 4523 and Pires (10907 c 14480)

H. guianensis Aubl.

Nelson Rosa 262, Bento Pena 752, Manoel Cordeiro 1620

H. Microphylla Ule

Bento Pena 763; Manoel Cordeiro 1625 and Benedito Ribeiro 1827

H. nitida Mart. ex Muell Arg.

Nelson Rasa 264; Bento Pena 755 and Benedito Ribeiro 1837

H. Paludosa Ule

Osvaldo Nascimento 227 and Pires 13254

H. Pauciflora (Spruce ex Benth.) Muell Arg.

Nelson Rosa 265, Benedito Ribeiro 1830 and Pires 13254.

H. Rigidifolia (Spruce ex Benth.) Muell Arg.

Benedito Ribeiro (1931, 1832, 1833, 1834 and 1835)

H. Spruceana (Benth.) Muell Arg.

Nelson Rosa 267; Bento Pena (757, 758 and 759)

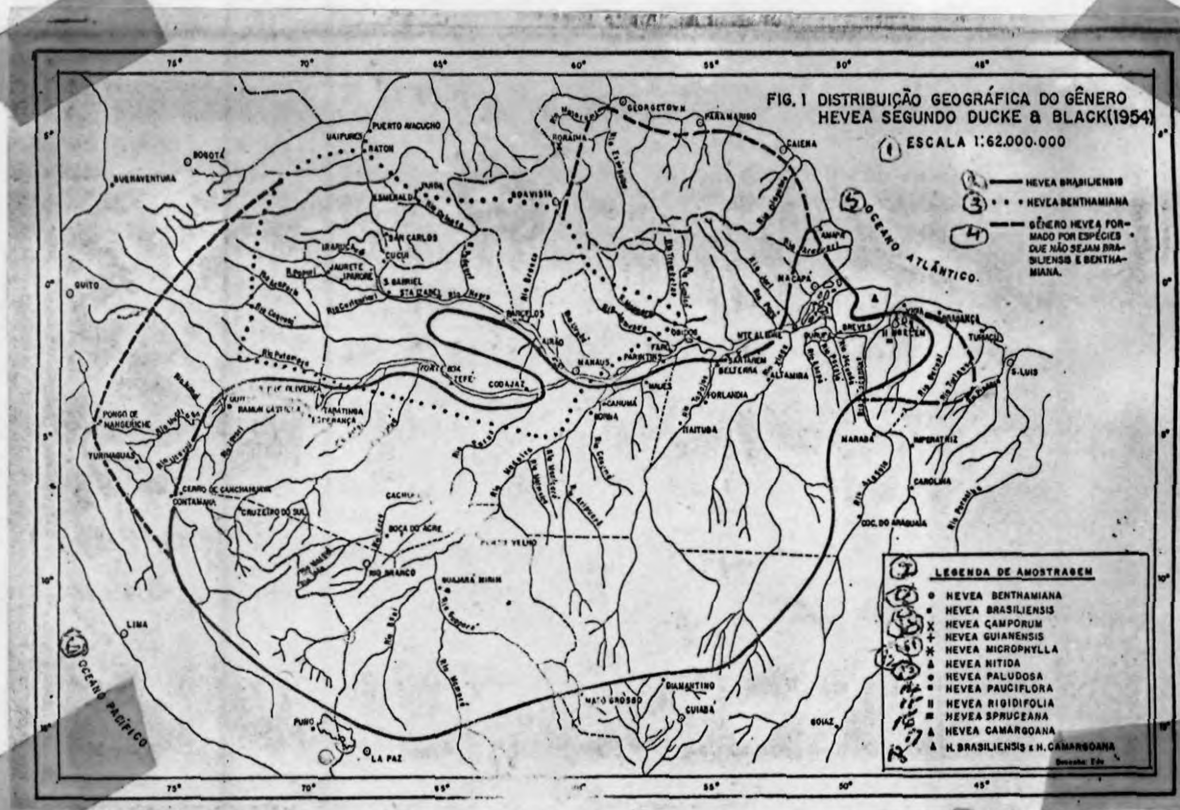


Fig.1. Geographic distribution of the genus Hevea according to Ducke and Black (1954).

(1) Scale: 1:62,000,000 (2) Hevea brasiliensis. (3) Hevea benthamiana (4) Hevea genus formed by species which are not brasiliensis or benthamiana. (5) Atlantic Ocean. (6) Pacific Ocean (7) Legend of sampling (8) Hevea benthimiana (9) Hevea brasiliensis (10) Hevea camporum (11) Hevea guianensis (12) Hexx Hevea nitida. (13) Hevea paludosa (14) Hevea pauciflora (15) Hevea rigidifolia (16) Hevea spruceana (17) Hevea camargoana (18) H. Brasiliensis and H.camargoana.

The test bodies were previously prepared in dimensions of 2 x 2 x 1 cm and then subjected to softening by means of cooking in water. In the case of Hevea camporum, due to the small diameter of the stem (about 1.5 cm) we utilized a whole disc with 2 cm of height. We prepared about 5 plates per sample The sections obtained from samples attacked by staining fungi were washed clean with sodium hypochlorite.

For dissociation of fibrous elements, we adopted Schultze's method cited by Shimoya (1966), but instead of concentrated nitric acid, we utilized a 50% solution and some granules of potassium chlorate. After maceration, which was completed in 3 to 5 minutes, the dissociated material was placed in a filter paper funnel for washing with distilled water. Then the macerated material was left in 1% safranine for 24 to 72 hours.

For intervascular parenchymo-vascular and ray-vascular punctuations; for diamter of the cells of the axial parenchyma and for width of the uniseriated rays, we made 25 measurements per sample.1 In the determination of the number of pores/mm^2 we made 100 countings per sample.

Onthe basis of the quantitative data, we computed the following parameters: average, standard deviation and coefficient of variation.

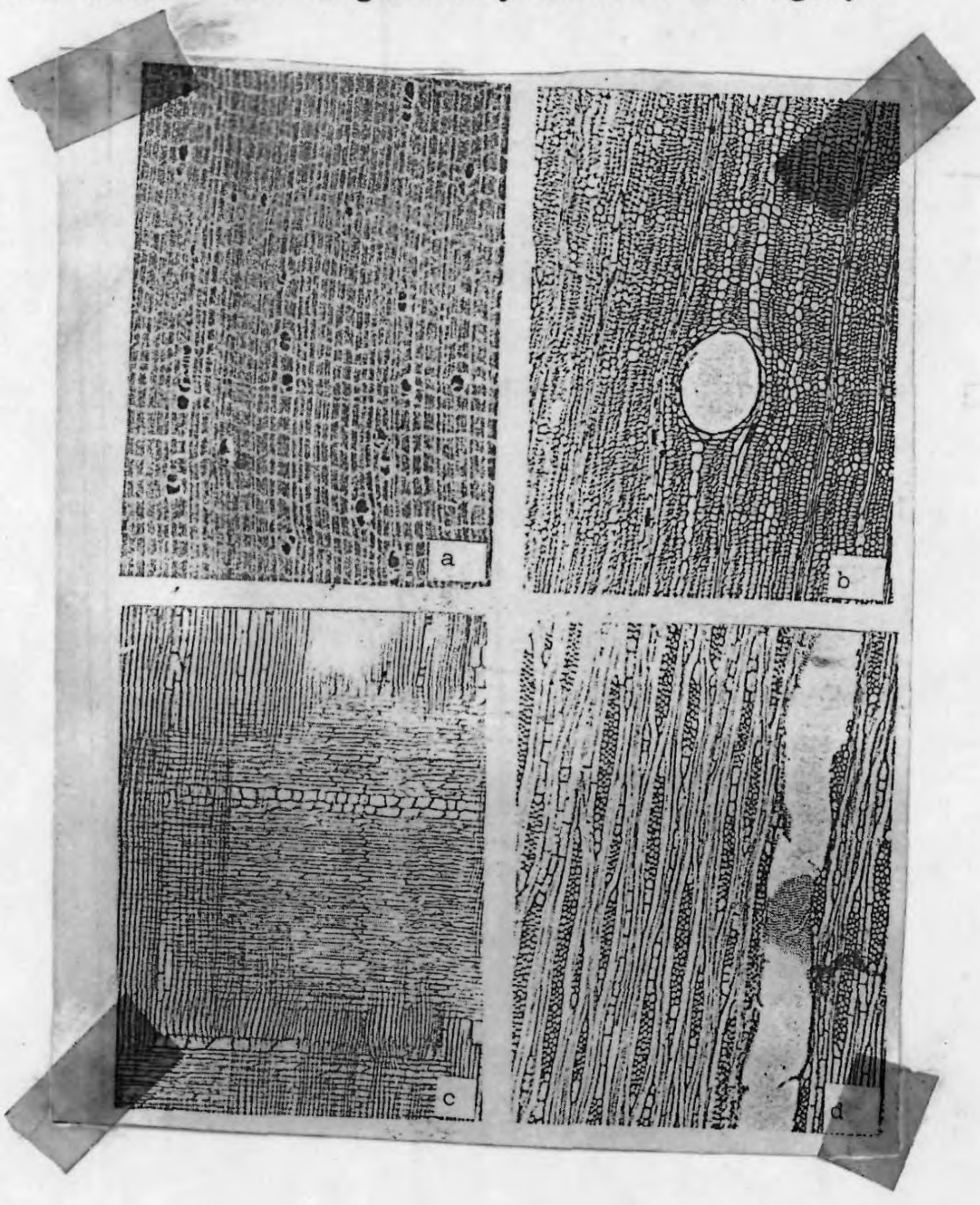
We utilized the SNK test (Student, Newman and Keuls) for comparison between the averages of some histometric data such as number of pores/mm^2, tangential diameter, thicknessof the wall of the vessels, number of rays/mm, width of the multiseriated rays in cells, length, total diameter, diameter of lumen and thickness of the wall of the fibres.

Photomacrographs were obtained by utilizing Tessovar-Zeiss and photomicrographs were obtained by using Olympus and Carl Zeiss photomicroscopes with kodak film Plus - X Pan 125 ASA-22 DIN and were printed on Kodak photographic paper fine F3.

The test bodies for photomacrographs were duly prepared by utilizing iron lixa No. 400 under running water and JUNG microtome with appropriate blade.

<u>Hevea brasiliensis (HBK) Muell. Arg.</u>

Parenchyma with lines in concentric bundles (with upto six cells of width), regularly spaced, sinuous, continuous, at times interrupted and anastomose; there is also scarce paratracheals; series with 3-7-12 cells (500-972-1500 µm) of height and 10-28-48 µm of width; crystals very frequent with upto five chambers for cells. Vessels diffused, solitary (60.55%), multiples of 2 (31%), radial multiples of upto 12 vessels, occasionally racemiform; very few pores (0-2.4-12 pores/mm^2), of average diameter (54-161-290 µm of diameter); section oval in the solitary vessels and flattened in the multiple vessels; vascular elements very long (232-803-1500 µm), with short appendices at one or both the ends; perforation plates simple; thickness of the wall with 4-7-16 µm of width; thyloses rarely present and crystals occassionally present in the thyloses; intervascular punctuations big (8-12-22 µm of diameter), areolated and alternate, polygonal contour, elongated, roundish and oval; opening in horizontal, oblique and inclusive cleft. Heterogeneous rays, the uniseriated show erect and square cells; the multiseriated show predominance of procumbent cells and rarely there are rays with upto five bundles of square cells in the middle of the ray; in some stretches the square cells show a tendency towards latericuliform cells; numerous rays (6-9-15 rays/mm); the uniseriated rays are very fine (15-24-40 µm)l the multi-seriated rays are fine (22-45-73 µm); with 2-3.5-6 cells of width; as regards height, the uniseriated rays are extremely short (0.1-0.42-0.9 mm), with 1-5-13 cells; the multiseriated rays are very short (0.2-0.67-1.7 mm) with 6-23-67 cells; roundish granulations of reddish colour very frequent. Fibres libriform, not septate, gelatinous, thin (fine), short (0.8-1.41-1.9 mm of length), of average size (14-25-48 µm of width)l wall with 1-4-11 um of thickness; punctuations simple, opening in linear, oblique, inclusive, and exclusive cleft; in the intersection with the cells of the ray and parenchyma they are conspicuously areolated (radial plane). Growth rings demarcated by fibrous zones with wall of cells thicker and tangentially flattened. (Fig.3).



Fih.*3. Anatomical aspects of the secondary xylem of H. brasiliensis.

a - Macroscopic look (10 X) transverse section).
b - Microscopic look (50 X) transverse section).
c - Radial longitudinal section)50 X).
d - Tangential longitudinal section (50 X).

Macroscopic anatomical characteristics of the genus Hevea

Parenchyma is distinguishable only under lens in the species H. camporum, H. camargoana and H. paludosa and visible to the naked eye in all the rest of the species; it appears in fine lines in the majority of the species, but in H. camporum it exists in scarce aliform, with linear extension, visible only under lens. Pores are distinguishable with naked eye in the majority of the species, with the exception of H. camporum, H. paludosa and H. camargoana, which are visible only under lens, pores range from very few to numerous (1.4 to 32 pores/mm^2) but in the majority they range from few to average (2.3-11 pores/mm^2); vascular lines can be distinguished with naked eye in the majority of the species; perforation plates simple; thyloses range from occasional to very frequent. Rays on the top range from very fine to fine and in the tangential face they are irregularly arranged. Growth rings are distinguishable with naked eye and are demarcated by dark fibrous zones.

Microscopic anatomical characteristics of the genus Hevea

Parenchyma in fine, concentric lines with 1-3 cells of width, regularly spaced, sinuous and continuous. Occasionally there is scarce aliform parenchyma, of linear extension in H. camporum; series with 3-18 (5-8.8 µm cells and 410-1530 (790-1000 µm) of height; 8-61 (26-37 µm) of width. Vessels diffused, solitary (30-54%), multiple of 2-3(34%), radial multiples of upto 12 vessels, occasionally racemiform; 0-32 (2-3-11) pores/mm^2; tangential diameter with 28-294 (103-164 µm); oval section in the solitary pores and polygonal in the multiple; vascular elements with 150-1500 (618-820 µm) of length; perforation plates simple; thickness of the wall with 2-16 (5-8) µm of width; thyloses present in the majority of the species studied; intervascular punctuations 8-34

(9-14) µm of diameter; areolated, alternate; polygonal contour roundish, oval and elongated; opening in horizontal cleft slightly oblique, inclusive and exclusive and, occasionally, coalosced close to the perforation plates; ray-vascular punctuations with 6-26 (9-14) µm of diameter; pores semi-areolated, alternate and, occasionally, with tendency to be escalarfform, polygonal contours oval, roundish, triangular and elongated; opening in horizontal cleft; inclusive to exclusive and, occasionally, show coalescence close to the perforation plates. Rays heterogeneous, the uni-seriated being constituted by erect and square cells and the multiseriated showing in the majority of the species up to four bundles of cells; 3-16 (7.4-10.4) rays-mm; the uniseriated rays are very fine (18-28 µm); the multiseriated rays are very fine to fine (28-45 µm) with 2 to 3.5 cells of width; As regards height, the uniseriated rays are extremely short (0.24-0.42 mm) with 4-6.6 cells; the multiseriated range from extremely short to short (0.41-0.67 mm) with 12-23 cells; crystals occasionally present and granulations of orange and reddish colour very frequent in H. benthamiana and H. brasiliensis respectively; silica grains present in H. benthamiana (Fig.13), fibres libriform; not septate, gelatinous and thin, presence of spiralled thickness in the wall of the fibres of some specimens of H. camargoana; short (1.1-1.4 mm), medium(25-34 µm); wall with 3-7 µm of thickness; punctuations simple and opening in cleft linear and oblique; in the intersection with the cellsof the ray and parenchyma, they are conspicuously areolated; growth rings demarcated by fibrous zones with the wall of the cells thicker and tangentially flattened.

Dichotomic key for separation of the species of Hevea on the basis of the quantitative anatomic characters of the wood

1.a - Average diameter of the vessels upto 109 µm........ 2

1.b - Average diameter of vessels of 120-164 µm......... 4

2.a - Upto 32 pores/mm^2 (average 11 pores/mm^2)----- H. camporum

2.b - Upto 15 pores/mm^2 (average 2.4-3 pores/mm^2) 3

3.a - Fibres with wall thickness of 2-8 µm (average 5µm) H.camargoana

3.b - Fibres with wall thickness of 5-11 µm (average 7 µm)... H.paludosa

4.a - Multiseriated rays with upto 69 cells of height (average 23 cells)...... H.brasilienses

4.b - Multiseriated rays with upto 52 cells of height (average 20-20)................ 5

5.a - Average diameter of vessels 120-140 µm........ 6

5.b - Average diameter of vessels 157-164 µm........ 9

6.a - Multiseriated rays with 42-52 cells of height.... 7

6.b - Multiseriated rays with upto 36 cells of height.... 8

7.a - Uniseriated rays with width upto 44 cm........ H. spruceana

7.b - Uniseriated rays with width upto 28 µm... H.nitida

8.a.- Multiseriated rays frequently with 2-3 cells of width .... H.guianensis

8.b - Multiseriated rays frequently with 3 cells of width........ H.microphilla

9.a - Multiseriated rays with average width of 42 µm.. H.benthamiana

9.b - Multiseriated rays with average width of 28-29µm.... 10

10.a - Multiseriated rays with average height of 0.62mm. H.rigidifolia

10.b - Multiseriated rays with average height of 0.4mm H.pauciflora

(for fig.13 please see next page)

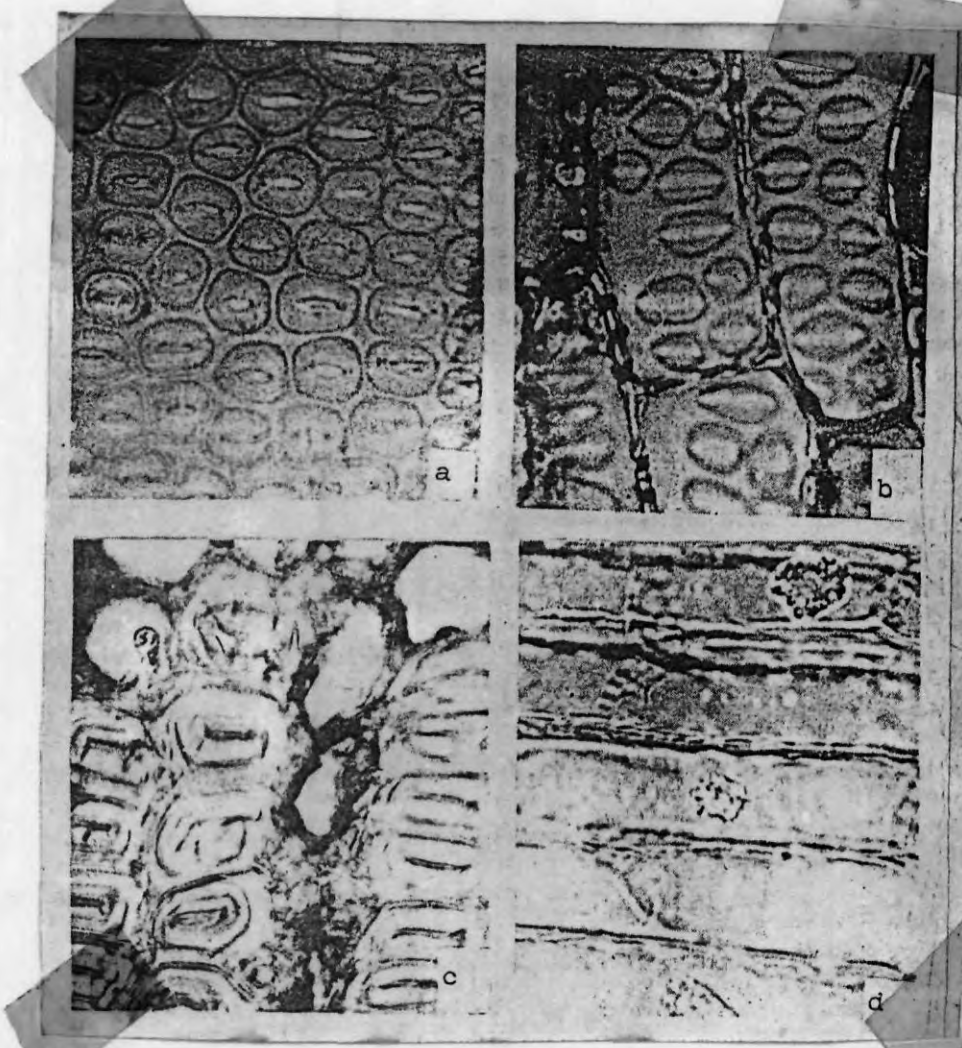


Fig.13. Detail ofthe secondary xylem of the genus Hevea: showin the intervascular punctuations (a), vascular parenchyma (b), gelatinous fibres (c) and silica grains in the rays (d).

Statistical analysis (SNK Test)

In the SNK test (Student, Newman and Keuls), the species studied were considered as treatments and, in order to facilitate its conclusion, the species were placed in alphabetic order and enumerated in the following manner:

T_1 - H. benthamiana

T_2 - H. brasiliensis

T_3 - H. camargoana

T_4 - H. camporum

T_5 - H. guianensis

T_6 - H. microphylla

T_7 - H. nitida

T_8 - H. paludosa

T_9 - H. pausiflora

T_{10} - H. rigidifolia

T_{11} - H. spruceama

The results are demonstrated in Table 1 and the species or treatments which are united by horizontal bars do not show significant differences between themselves.

It was found that in the majority of the species studied, the thickness of the walls of the vessels is a weak element to separate them. In the case of the fibres, the differences betweeen species also are small, with the exception of H. paludosa with thicker wall fibres and H. spruceana with finer walls.

Table 1 - Result of the statistical analysis comparing the averages of the species studied, utilising SNK Test (level of significance 0.5)

Number of pores/mm^2

T_4 $\underline{T_7 T_{10}}$ $\underline{T_1\ T_5}$ $\underline{T_8\ T_6\ T_2\ T_3\ T_9\ T_{11}}$

Tangential diameter of the vessels in µm

$\underline{T_9 = T_2\ T_{10}\ T_1}$ $\underline{T_7\ T_5\ T_{11}}$ $\underline{T_6\ T_4\ T_8\ T_3}$

Thickness of the wall of the vessels (in µm)

T_1 $\underline{T_2\ T_6\ T_9\ T_4\ T_5\ T_7\ T_{10}\ T_{11}}$ $\underline{T_3\ T_8}$

Number of rays per mm

$\underline{T_{11}\ T_{10}\ T_4}$ $\underline{T_7\ T_5\ T_9}$ $\underline{T_2\ T_6}$ $\underline{T_1\ T_3}$ $\underline{T_8}$

Width of the multiseriated rays in cells

T_2 T_{11} $\underline{\underline{T_6 T_7 T_3 T_5 T_8 T_{11} T_8}\ T_{10}}$ T_4

Length of the fibres in mm

$\underline{T_2\ T_9}$ $\underline{T_1\ T_3\ T_5\ T_7}$ $\underline{T_{11}\ T_8}$ $T_{10}\ T_6\ T_9$

Total diameter of fibres (in μm)

$\underline{T_{11}T_{13}}$ $\underline{T_6\ T_8}$ $\underline{T_1\ T_9\ T_5}$ $T_7\ T_{10}$ T_2 T_4

Diameter of the lumen (in μm) of the fibres

$T_{11}T_3$ $\underline{T_1T_9}$ $\underline{T_2T_6T_5T_7}$ $\underline{T_{10}T_8}$ T_4

Thickness of the wall of the fibres (in μm)

T_8 $\underline{T_3\ T_4\ T_6\ T_{10}}$ $\underline{T_1\ T_2\ T_5\ T_7\ T_9}$ T_{11}

Table 2 - Biometric chart of the vessels of 11 species of Hevea studied

1	H. bemtha-miana 2	H. brasi-liensis 3	H. Camar-goana 4	H. Campo-rum 5	H. guia-nensis 6	H. micro-phylla 7	H. nitida 8	H. palu-dosa 9	H. pauci-flora 10	H. rigid-folia 11	H. spru-ceana 12
Mp- pf /pres/mm²											
Maximum	13	12	15	32	21	8	14	15	10	20	9
Average	4.2	2.4	2.4	11.0	3.9	2.5	5.0	3.0	2.3	4.9	2.3
Minimum	0	0	0	0	0	0	0	0	0	0	0
Standard deviation	2.7	2.2	1.8	4.7	3.2	1.4	2.9	3.0	1.9	3.2	1.8
Coefficient of variation	64.3	91.7	74.6	41.8	66.7	56.8	58.0	58.2	82.6	65.3	78.3
Tangential diameter											
Maximum	24.8	290	200	190	214	196	270	161	250	294	204
Average	157	161	103	109	133	120	140	105	164	159	133
Minimum	54	54	56	28	53	52	57	66	40	81	44
Standard deviation	35.9	34.9	29.0	22.4	30.8	31.9	29.0	22.9	30.3	31.7	36.4
Coefficient of variation	22.8	18.6	28.3	21.9	23.2	24.7	20.7	21.8	18.5	20.0	19.9
Length of vascular element (µm)											
Maximum	1360	1500	1100	950	1140	1020	1200	969	1470	1200	1100
Average	820	803	618	640	753	631	739	682	762	735	748
Minimum	380	332	150	418	294	200	320	313	429	150	377

Table 2 continued

1	2	3	4	5	6	7	8	9	10	11	12
Standard deviation	177.2	178.1	138.5	124.9	161.5	161.3	166.8	138.8	198.6	162.6	156.4
Coefficient of variation	21.5	20.5	22.4	19.5	21.4	26.4	22.6	20.3	22.5	22.2	20.9
<u>Thickness of width (µm)</u>											
Maximum	12	16	8	8	8	10	10	8	12	10	8
Average	8	7	5	6	6	7	6	5	7	6	6
Minimum	4	4	2	4	4	4	4	4	4	4	4
Standard deviation	2.2	2.5	1.5	1.7	1.6	1.6	1.7	1.5	2.1	2.0	1.6
Coefficient of variation	28.6	36.8	29.4	30.3	27.6	21.9	25.7	28.3	30.0	30.3	26.7
<u>Diameter of intervascular punctuation(µm)</u>											
Maximum	16	22	34	14	14	16	17	13	13	18	15
Average	11	12	12	11	10	9	12	10	14	12	11
Minimum	8	8	9	8	8	8	10	8	8	8	8
Standard deviation	1.3	1.8	1.0	1.0	1.4	0.9	1.5	1.5	1.8	1.3	1.3
Coefficient of variation	11.5	14.6	8.4	9.4	13.3	8.2	9.4	12.5	13.2	10.9	11.4

table 2 continued

1	2	3	4	5	6	7	8	9	10	11	12
Diameter of parenchyma-vascular punctuation (µm)											
Maximum	24	30	18	20	12	13	18	16	13	20	17
Average	14	14	11	12	10	10	12	12	11	12	12
Minimum	8	7	8	7	8	8	8	9	8	8	8
Standard deviation	2.3	3.2	1.9	2.0	1.4	1.1	2.1	1.9	1.5	2.1	1.9
Coefficient of variation	11.6	22.7	17.5	16.5	13.6	10.[illegible]	17.1	20.2	13.6	16.8	16.4
Diameter of ray-vascular punctuation (µm)											
Maximum	21	22	19	26	15	14	19	13	16	19	20
Average	13	12	14	12	12	10	12	9	12	12	13
Minimum	8	7	8	8	8	6	8	8	8	8	8
Standard deviation	2.1	2.1	1.9	2.7	1.5	1.6	1.2	1.5	1.9	2.5	2.2
Coefficient of variation	19.8	17.3	14.3	23.0	12.8	14.8	10.3	28.3	16.4	20.5	16.9

Table 3 - Biometric Chart of the axial parenchyma of the 11 species of Hevea studied

	H. benthamiana	H. brasibensis	H. camargoana	H. camporum	H. guianensis	H. microphylla	H. nitida	H. paludosa	H. pauciflora	H. rigidifolia	H. spruceana
1	2	3	4	5	6	7	8	9	10	11	12
Height of the series (µm)											
Maximum	1530	1500	1382	1330	1274	1233	1204	1050	1260	1520	1350
Average	924	972	892	1000	912	866	932	790	888	968	871
Minimum	410	500	640	461	742	475	579	480	574	570	450
Standard deviation	161.5	164.9	124.6	174.9	160.2	138.2	145.6	121.5	207.2	156.8	158.0
Coefficient of variation	17.3	16.9	13.9	17.5	17.6	15.5	15.6	15.4	23.3	16.2	17.7
Height of the series (cells)											
Maximum	18	12	11	11	15	11	13	8	7	13	10
Average	8.8	7.3	6.0	5.8	8.8	7.3	7.0	5.6	5.1	7.0	7.1
Minimum	3	3	3	4	5	4	4	4	3	4	3
Standard deviation	1.8	1.5	1.1	1.5	2.1	1.6	1.8	1.5	1.3	1.4	1.6
Coefficient of deviation	26.5	20.5	18.3	25.8	23.8	21.0	25.7	26.8	25.5	20.0	22.5
Diameter of the cells (µm)											
Maximum	61	48	44	44	34	40	36	35	38	45	40
Average	32	28	37	31	28	32	26	28	28	28	29
Minimum	8	10	24	22	21	24	14	22	21	20	18
Standard deviation	6.2	5.4	4.7	4.6	3.7	4.4	4.0	4.4	5.9	3.7	3.7
Coefficient of variation	19.5	19.5	22.5	14.7	13.3	13.4	15.6	15.8	20.9	13.0	12.8

Table 4 - Biometric chart of the rays of the 11 species of Hevea studied - Determined values

	H. benthamiana	H. brasiliensis	H. camargoana	H. camporum	H. guianensis	H. merophylla	H. nitida	H. paludosa	H. pauciflora	H. rigidifolia	H. spruceana
1	2	3	4	5	6	7	8	9	10	11	12
Rays/mm											
Maximum	12	15	16	15	13	12	13	12	13	15	14
Average	8	9	8	10.2	9.5	8.7	9.7	7.4	9.4	10.3	10.4
Minimum	3	6	5	5	6	5	6	4	6	4	7
Standard deviation	1.3	1.2	1.6	1.8	1.4	1.2	1.3	1.4	1.4	1.5	1.3
Coefficient of variation	16.2	13.3	20.1	18.0	14.7	14.6	13.4	16.1	14.9	14.7	25.2
Height of multiseriated rays (mm)											
Maximum	1.0	1.7	1.4	0.9	1.3	0.9	1.4	0.8	1.1	1.5	1.5
Average	0.55	0.67	0.54	0.41	0.48	0.48	0.63	0.54	0.44	0.62	0.62
Minimum	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Standard deviation	0.18	0.22	0.20	0.14	0.10	0.10	0.10	0.11	0.18	0.20	0.21
Coefficient of variation	32.4	32.0	35.2	32.4	26.2	20.0	15.9	19.8	41.0	32.1	33.0

1	2	3	4	5	6	7	8	9	10	11	12
Height of multiseriated rays (cells)											
Maximum	40	69	34	29	36	30	52	18	50	49	42
Average	18.5	23.2	13.4	13.0	19.3	17.0	20.0	12.3	19.2	19.6	18.9
Minimum	7	6	4	4	7	7	5	6	7	7	6
Standard deviation	6.2	6.6	5.1	4.1	4.9	4.8	6.9	3.1	5.4	6.2	6.1
Coefficient of variation	33.5	28.9	38.0	31.5	28.8	27.9	34.3	25.4	28.4	31.6	32.4
Height of uniseriated rays (cells)											
Maximum	0.7	0.9	1.1	0.7	0.8	0.8	0.7	0.4	0.6	0.7	07
Average	0.33	0.42	0.40	0.39	0.30	0.26	0.29	0.31	0.24	0.36	0.37
Minimum	0.1	0.1	0.2	0.1	0.1	0.1	0.08	0.06	0.07	0.07	0.1
Standard deviation	0.10	0.10	0.10	0.09	0.10	0.10	0.08	0.07	0.08	0.10	0.10
Coefficient of variation	30.0	23.8	31.7	22.6	38.9	33.3	30.2	23.9	33.5	27.8	25.3
Height of uniseriated rays (cells)											
Maximum	14	13	14	20	14	15	15	6	11	12	20
Average	6.6	5.0	6.0	5.2	5.0	6.0	6.0	4.0	4.8	6.0	6.5
Minimum	2	1	2	2	2	2	2	2	2	2	2
Standard deviation	2.1	2.0	2.1	2.1	1[illegible].8	1.9	1.9	1.1	1.6	1.8	2.1
Coefficient of variation	31.8	40.0	35.3	36.2	35.3	29.2	32.2	26.8	33.3	30.5	32.3

Table 4 **continued**

1	2	3	4	5	6	7	8	9	10	11	12
Width of multiseriated rays (µm)											
Maximum	76	73	60	53	46	52	48	72	42	49	52
Average	42	45	38	29	32	33	33	40	28	29	34
Minimum	18	22	20	20	17	20	21	24	13	15	19
Standard deviation	7.3	7.2	7.7	4.5	5.3	5.8	5.9	10.6	5.2	5.2	5.1
Coefficient of variation	17.4	24.5	20.3	15.4	16.6	16.4	17.7	26.3	18.8	17.7	15.1
Width of multiseriated rays (cells)											
Maximum	4	6	4	4	3	4	5	3	4	3	4
Average	3.0	3.5	2.6	2.1	2.6	2.8	2.8	2.4	2.6	2.6	2.6
Minimum	2	2	2	2	2	2	2	2	2	2	2
Standard deviation	0.5	0.5	1.9	0.3	0.5	0.5	0.6	0.5	0.4	0.4	0.4
Coefficient of variation	16.7	14.3	23.5	15.0	19.2	35.7	21.4	20.8	15.4	16.7	15.4
Width of uniseriated rays (µm)											
Maximum	46	40	44	32	33	36	28	34	25	32	44
Average	28	25	25	21	20	20	19	25	18	20	26
Minimum	8	15	8	14	14	16	12	17	11	12	17
Standard variation	5.7	4.2	5.4	4.0	3.2	5.4	2.9	4.3	3.0	3.2	4.5
Coefficient of variation	20.4	17.5	21.1	14.6	16.2	24.3	14.8	16.9	12.8	15.7	13.0

Table 5: Biometric chart of the fibresof the 11 species of Hevea studied - values determined

	H. benetha-miana	H. brasi-liensis	H. camara-goana	H. campo-rum	H. guia-nensis	H. micro-phylla	H. nitida	H. palu-dosa	H. pauci-flora	H. rigidi-folia	H. spruce-ana
1	2	3	4	5	6	7	8	9	10	11	12
Length (mm)											
Maximum	1.9	1.9	2.1	1.6	1.8	1.6	1.9	1.8	1.9	1.8	1.9
Average	1.32	1.41	1.29	1.10	1.28	1.27	1.27	1.22	1.38	1.20	1.24
Minimum	0.8	0.8	0.8	0.5	0.8	0.6	0.6	0.8	0.8	0.5	0.8
Standard deviation	0.2	0.2	0.1	0.2	0.2	0.2	0.4	0.2	0.4	0.2	0.2
Coefficient of variation	15.1	14.3	10.8	16.2	16.7	16.7	31.5	16.4	28.1	16.7	16.1
Tangential diameter (µm)											
Maximum	42	48	48	37	40	40	39	39	39	40	57
Average	28	25	33	24	27	31	26	30	28	26	34
Minimum	15	14	20	11	13.9	20	16	17	20	11	17
Standard deviation	5.1	5.8	5.2	4.2	5.2	4.7	3.9	5.1	4.2	3.8	7.8
Coefficient of variation	17.8	22.8	15.5	17.6	19.4	29.2	15.1	17.2	15.0	14.4	22.9
Diameter of the lumen (µm)											
Maximum	36	39	36	25	29	28	29	22	29	26	54
Average	21	19	23	14	18	19	18	15	20	16	27

~~Table 5 vonyimu~~
Table 5 continued

1	2	3	4	5	6	7	8	9	10	11	12
Minimum	8	8	8	4.6	6	11	9	8	12	8	12
Standard deviation	4.7	4.7	3.9	3.5	4.6	2.5	3.7	4.1	4.0	3.5	6.0
Coefficient of variation	22.5	24.9	17.1	24.1	25.8	12.5	20.4	27.3	20.5	42.9	21.9
<u>Thickness of wall (μm)</u>											
Maximum	7	11	8	9	7	7	6	11	7	12	7
Average	4	4	5	5	4	5	4	7	4	5	3
Minimum	1	1	2	1	2	2	2	5	2	3	2
Standard deviation	0.6	0.8	1.4	2.4	1.4	0.9	0.8	1.5	1.0	1.0	0.9
Coefficient of variation	15.4	18.6	25.9	51.1	31.8	18.4	21.0	20.5	25.0	20.4	25.7

Discussion

The family Euphorbiaceae possesses 250 genera and more than 500 species of trees and shrubs. The wood of this family shows big variation in structure and in its properties. In general the pores are not very numerous and frequently tend to form radial lines. The parenchyma is not much developed, very fine, irregular, usually showing concentric lines or tangentially spaced. The rays are very fine, inconspicuous and not stratified (Record and Mell, 1924).

Record (1938), studying the structure of the secondary xylem of the genera of Euphorbiaceae, concluded that these genera show very big pores, with exclusively simple perforation, distinctly areolated and big punctuations. The characteristics mentioned by the said author agree partly with those in the species studied, since the majority show medium pores, according to the standard classification COPANT (1973), but it is important to point out that Record (1938) studied only H. brasiliensis and H. nitida. Loureiro and Silva (1968) macroscopically described the wood of H. guianensis and stated that this species shows upto 3 pores/mm^2 and the diameter of the pores ranged between 100 and 300 µm. The data found in this work for this species (Table 2) differ mainly with regard to the average tangential diameter (133 µm), since they are microscopic measurements.

The distribution of the vessels show that in the transverse section they can be seen as solitary or aggregates of various sizes and forms. The solitary vessels are of oval or circular contour and the multiple vessels are flattened in the zones of mutual contact (Esau 1959). These characteristics are very frequent in the wood of the species of Hevea in which the vessels are solitary, radial, multiple and, occassionally racemiform.

Thyloses are very frequent in the vessels of Hevea; they occur in the heart of the tree and at times in the alburnum. The presence of these thyloses is very important, since, according to Eames and Macdaniels (1953), they reduce the attack of fungi and the entry of water and oxygen; they are more frequent in the heart of the wood, but they can be found also in the alburnum.

Metcalfe and Chalk (1950) stated that H. brasiliensis and H. spruceana show very distinct parenchyma, typically apotracheal in continuous uni-and biseriated bundles, frequently containing crystals in chamber with eight cells and some times with four . Record (1944) studied H. brasiliensis and H. nitida and reported the presence of abundant parenchyma, reticulate and irregular. The parenchyma observed in Hevea, more especially in the species H. brasiliensis, H. nitida and H. spruceana partially agrees without the data of literature, since in Hevea, besides apotracheal parenchyma in fine lines, one finds aliform paratracheal parenchyma of linear extension. The height of the series and the width of the cells of the axial parenchyma of Hevea do not contribute for the separation of the species, although H. guianensis shows series in greater number of cells and H. paludosa and H. pauciflora in lesser number (Table 3). Presence of crystals in chamber was observed in the parenchyma of the species of Hevea, but this is not a positive characteristic for the separation of the species since not all the samples (trees) of a determined species show crystals with regularity.

Milanez (1932), studying the modifying action of calcium on the cellular structures, observed that the elements of the secondary wood which more commonly enclose crystals belong to the parenchyma. The author also found crystals in the cells of the rays, although with lesser frequence. In the structure of the secondary xylem of Hevea the presence of crystals in the parencyma is more frequent than in the rays.

The rays of H. brasiliensis and H. spruceana, described by Metcalfe and Chalk (1950), show almost the same characteristics reported in this work, which only highlight the fact that the rays of Hevea are fine. Record (1938), studying H. brasiliensis reported that this species shows rays with upto six cells of width and upto 30 cells of height . The species studied (Table 4) shows rays with upto six cells of width (average 35 cells) and upto 69 cells of height (average 23 cells). In general the rays of Hevea are heterogeneous and this is in agreement with the anatomical descriptions of Metcalfe and Chalk (1950), Record (1944) and Hess (1948). The rays of the species of Hevea studied by us are, in their majority, heterogeneous type II, according to the old classification of Cribs (1959) , today no more used, in conformity with IAWA (1989), that is, uniseriated rays composed of erect and square cells or only of erect cells. The multiseriated rays have the extremities shorter than the multiseriated part (tangential section) and are constituted by erect and square cells (radial section). In the species H. camargoana, H. camporum and H. paludosa there is no predominance of the horizontal cells over the square or erect cells and hence these species are closer to the classification of rays type I of cribs (1959).

It is important to point out that many species of Hevea show mixed rays, that is to say, layers of procumbent (horizontal) cells intermingled with bundles of erect and square cells or only erect cells.

According to Core et al. (1979), in normal growth, some trees deposit in the cells organic compounds like silica, which are frequently found in the form of sand. According to Espinosa de Pernia and Peres Mogollon (1985), silica commonly occurs in the radial cells and at times in the axial parenchyma and fibres, the more common forms being ovoid, globular, irregular oblong and in aggregates.

According to Welle (1976), the genus Hevea does not possess silica in the structure of the secondary xylem. However, in one of the samples of H. benthamiana, roundish granules of silica were observed in the rays, which can be seen in the radial section (Fig.13).

According to the standards COPANT (1973), all the species show, on an average, short and thin fibres, with the exception of H. microphylla which are very short and H. spruceana, very thin.

The presence of gelatinous fibres is very frequent in the genus Hevea and this agrees with the description of Metcalfe and Chalk (1950) for the group Crotonoidae, in which the genus Hevea is included. The gelatinous fibres can be recognized in the transverse section due to the fact that the internal layer of the wall is highly refractory, having an appearance of gelatin or mucilage. These fibres have been found in many genera of folhosae, making it an important element in the separation of families. Other researches reveal that the gelatinous fibres tend to occur on one side of the stem and subsequent studies show that this characteristic of the tissue is, in general, known as wood of tension (Rendle 1937).

According to Reinders (1955), the fibrotracheoids show a moderately elongated length and usually possess thick walls and somewhat big areolated punctuations. These punctuations are very numerous in the tangential longitudinal plane, while the libriform fibres are small, simple and very frequent in the radial longitudinal plane. The fibres of Hevea show simple punctuations and are more frequent in the radial longitudinal plane.

In some samples of H. camargoana the presence of spiralled thickness was noticed in the fibres. It shouldbe pointed out that this characteristic was not mentioned in the bibliography consulted.

It can be observed in Table 5 that the values obtained in respect of length, diameter and thickness of the walls of the fibres are not parameters indicative for separation of the species of Hevea studied.

Within one tree, there is a horizontal variation in the structure of wood, from medulla to bark, and a vertical variation from the base to the top(Tsoumis 1968). Variability can also exist from tree to tree of the same species, from locality to locality, or even within the same tree, the influences affecting these changes being climate,soil, humidity, spacing, age and, undoubtedly, genetic factors (Jane 1970 and Panshin 1970). The number of vessels existing in a determined area is of relative interest and is a character very variable between the different species; one can find this variation between botanically identical individual trees also. In spite of these variations, their average frequency is an index which should not be rejected for being related with some physical properties (Pereira 1933).

The intraspecific variation occurring in the species of Hevea is more frequent in the vessels, especially with regard to the arrangement, number per mm^2 and tangential diameter. The variation which occurs in the axial parenchyma is not very evident. Meanwhile, the width of the rays (multiseriated and uniseriated) shows small variations in the species studied.

According to Metcalfe and Chalk (1950) these variations in Hevea concerning the number of pores/mm^2, tangential diameter, length of vascular elements and quantity of parenchyma, are characteristics which can be influenced by the environment, and hence are not very important for taxonomical purposes.

Under the macroscopic aspect, identification of the species of Hevea on the basis of diameter of pores, number of pores/mm^2 and their arrangement, that is, greater or lesser percentage of solitary pores or multiple pores, is quite difficult. There are some exceptions as in the cases of H. camargoana, H. camporum and H. paludosa, which possess very small diameter, making their recognition with naked eye very difficult, but, under lens, it is found that H. camporum shows greater number of pores per mm^2 in relation to H. camargoana and H. paludosa.

Sobreder (1908) reported the presence of scalariform perforation plates in the vessels of some genera of the family Euphorbiaceae, including Hevea.

Metcalfe and Chalk (1950) mention the occurrence of spiralled thickness in the vessels of some genera of the said family, such as Alchornea, Cleidion, Elateriosperum, Mallotus, Pogonophora and Trewia. In the case of Hevea, the presence of similar striations and the spirralled thickness was reported, but these are not evident in the vessels of H. benthiamiana. It is important to clarify that within the five samples examined, these characteristics were observed in sample Nos. 1621, 1836 and 1838, occurring close to the perforation plates.

Conclusions

Our study, basedon macroscopic and microscopic anatomic characteristics of the wood, concluded the following:

- The genus Hevea, with regard to the macroscopic structure of the wood, is very uniform, making the identification of the species under this aspect very difficult.
- The microscopic anatomic characteristics of the wood are more indicative for the identification of the species of Hevea, particularly the rays.
- Under the qualitative point of view, some species like H. brasiliensis and H. camporum are easily recognized by the rays, since the former shows rays with 1-6 cells of width and the latter shows predominantly uni-and biseriated rays.
- The presence of spiralled thickening in the fibres was observed in some specimens of H. camargoana.
- The species H. benthamiana showed some scalariform type perforation plates and silica granules in the cells of the rays, but these anatomic characteristics occurred only in one of the samples examined.
- In about 50% of the species of Hevea studied, rhomboid crystals occurred in chamber or isolated in the parenchyma and occassionally, in the rays.
- The presence of gelatinous fibres is a very frequent characteristic in the secondary xylem (wood) of the species of Hevea.

<u>Bibliographic references</u>

1. Core, H.A.; Cote, W.A. and Day, A.C. 1979. Structure and identification Syracuse, University Press, 182p. (Syracuse wood Science series, 6).
2. Description of general macroscopic and microscopic characteristics of the woods of dicotyledonous angiosperms, 1937, COMPANT, 19p, mimeographed.

3. Ducke, A.and Black, G.A. 1954. Notes on the phytogeography of Brasilian Amazon. Technical Bulletin of the Agronomical Institute of North Belen, (29): 1-62.

4. Eames, A.J. and Macdaniels, L.H. 1953. An introduction to plant anatomy combay , McGraw-Hill, 427 p.

5. Esau, K. 1959, Vegetal anatomy. Barcelona, Omega, 729.

6. Espinoza de Pernia, N. and Peres Mogollon, A. 1985. Crystals and silica in dicotylidenous woods of Latin America. Meridas University of Andes, Faculty of Forest Sciences, Centre of Post Graduate studies, 50 p.

7. Hess R. W. 1948. Parenchyma in numerous concentric bands. Trop. Woods, (94): 29-52.

8. Heyqood, V.H. 1970. Vegetal taxonomy. Sao Paulo,USP, 108p (USP) Studies of Biology, 5).

9. Lawa Committee. Lawa list of mocroscopic features for hardwood identification. Lawa Bull. n. s. 10: 219-232.

10. Jane, F.W. 1970. The structure of wood. London, Adms and Charles Vlack, 478 .

11. Kribs, D.A. 1959. Commercial foreign woods on the american market. Pennsglvamnia.? State University.

12. Loureiro, A.A. andSilvea M.F. 1968. Catalogue of the woods of Amazon. Belem, SUDAM, 2v.

13. Metcalfe, C.R. and Chalk, L. 1950. Anatomy of the dicolyledons. Oxford, Charenden Press, 2v.

14. Milanez, F.R. 1932. Modification action of calcium oxalate on cellular structures. Forest Review, Rio de Janeiro, 2(3); 51-11.

15. Panschin, A.J. 1970. Textbook of wood technology. 3rd edition New York, McGraw Hill, 2v.

16. Pereira, J.A. 1933. Contribution to the micrographic identification of our woods. Sao Paulo, Pαlytechnic. School of Sao Paulo, 165p(Polytechnic School of Sao Paulo,9).

17. Pires, J.M. 1973. Review of the genus Hevea. Description of species and geographic distribution. Project: Botany; Sub project: Review of the genus Hevea. SUDHEVEA/DNPEA-IPEAN Conference. Annual report, July 1972/July 1973. Belem, EPEAN, p 6-77

18. Record, S.J.1938. The American woods of the family euphobiaceae Trop.Woods, (54): 7-40.

19. Record, S.J. 1944. Dicotyledons woods with parenchyma reticulate, Trop. Woods. (77): 27-36.

20. Record, S.J. and Mell, C.D. 1924. Timbers of tropical America. New Hawen, Yale University, 610 p.

21. Reinders, E. 1955. Fiber - tracheids, libriform wood fibres, and systematics in wood anatomy.Trop. Woods.(44): 30-5.

22. Rendle, B.J. 1937. Gelatinous wood fibres, Trop. Woods. (52): 11-9.

23. Richter, H.G. and Gomes, A.V. Programme of the microtechnique course, s.n.t. mineographed.

25. Solereder, H. 1908. Systematic anatomy of the dicotyledons; a handbook for laboratories of pure and applied Botany, Oxford Clarendon, 2v.

24. Shimoya, C. 1966. Notions of cytolαgical technique.Vicosa, UREMG, 69p.

26. Titmuss, F.H.A.1948. Concise encyclopedia of world timbers. London,Technical Press,156p.

27. Tsounies, F. 1968. Wood as naw material. Oxford,Pergaman Press 276 p.

28. Welle, B.J.H. Ter. 1976, Silica grains in woody plants on the netropics, especially rurinam. Leiden Bot. Ser.(3): 107-42.

Received on 21.5.'90

Appwoved on 27.3.'91