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PROPERTIES AND USES OF TROPICAL WOODS, IV

By FREDERICK F. WANGAARD, ARTHUR KOEHLER, and ARTHUR F. MUSCHLER

YALE SCHOOL OF FORESTRY

This is the fourth report covering studies that have been conducted at the Yale School of Forestry on the properties of tropical American woods. These studies have been made in cooperation with the Office of Naval Research and the Bureau of Ships, United States Navy Department.

Previous reports in this series outlined the scope of these studies, which have been continuing since 1947, and described test procedures (16, 39, 99). Consequently these will be dealt with only briefly here. These earlier reports, covering some fifty species of tropical American woods, presented the results of tests to determine specific gravity, mechanical properties in both the green and air-dry conditions, shrinkage, decay resistance, and air-seasoning characteristics of each species. Although other phases of the project including studies of gluing, moisture absorption, weathering, and steam bending have been reported separately (2, 7, 8, 81, 94), results have also been summarized where appropriate under the descriptions of individual species in earlier reports of this series.

The purpose of this report is to present similar findings for an additional group of 25 tropical American woods as listed in Table 1. In this table the species are arranged alphabetically by generic name. The same arrangement is followed in the section entitled *Species Descriptions* which includes for each species information relative to the source of the timber, its availability, general characteristics, and utilization.

TABLE 1. INDEX TO SPECIES COVERED IN THIS REPORT

Common Name	Scientific Name
Ceiba	*Ceiba pentandra* (L.) Gaertn.
Freijo	*Cordia Goeldiana* Huber
Sapupira	*Diplotropis purpurea* (Rich.) Amsh.
Timbaúba	*Enterolobium Schomburgkii* Benth.
Matá-matá	*Eschweilera odora* (Poepp.) Miers
Morrão	*Eschweilera Blanchetiana* (Berg) Miers
Manbarklak	*Eschweilera subglandulosa* (Steud.) Miers
Coco de Mono	*Eschweilera tenax* Miers
Cupiuba	*Goupia glabra* Aubl.
Jarána	*Holopyxidium jarana* (Huber) Ducke
	Holopyxidium latifolium (Ducke) Knuth
Angelim	*Hymenolobium excelsum* Ducke
Sapucaia	*Lecythis paraensis* (Huber) Ducke
Castanha Sapucaia	*Lecythis usitata* Miers, var. *tenuifolia* Knuth
Marishiballi	*Licania buxifolia* Sandw.
Anauera	*Licania macrophylla* Benth.
	Licania sp.
Kaneelhart	*Licaria cayennensis* (Meissn.) Kosterm.
Itaúba	*Mezilaurus itauba* (Meissn.) Taub.
Manwood	*Minquartia guianensis* Aubl.
Burada	*Parinari campestris* Aubl.
Aiomoradan	*Parinari excelsa* Sabine
Parinari	*Parinari Rodolphi* Huber
Samán	*Pithecolobium Saman* (Jacq.) Benth.
Lechero	*Sapium biglandulosum* (L.) M. Arg.
Jobo	*Spondias Mombin* L.
Mahogany	*Swietenia macrophylla* King
Bethabara	*Tabebuia serratifolia* (Vahl) Nichols.
Pau d'Arco	*Tabebuia* sp.
Banak	*Virola surinamensis* (Rol.) Warb.
Acapú	*Vouacapoua americana* Aubl.

Mechanical Properties

The mechanical properties of 25 tropical American woods tested in both the green and air-dry conditions according to standard methods of the American Society for Testing Materials are presented in Table 2, together with comparable data for a number of well known domestic and tropical woods. In this and subsequent tables in this section of the report, the species are arranged in order of decreasing specific gravity (oven-dry weight and green volume). The values given in Table 2 are average values for each species. When more than one source of material for a species was sampled, the values for each source are shown in the section on *Species Descriptions*. The mechanical properties of each species are discussed individually in that section of this report.

The data of Table 2 confirm previously indicated relationships with specific gravity in that tropical timbers in the green condition display a general superiority in bending srtength, stiffness, crushing strength, and a number of other properties over domestic woods of comparable density (12, 97, 99). Upon seasoning, however, the tropical woods show a generally lesser degree of improvement than domestic woods in most strength properties, and their superiority is less evident or altogether lacking when conditioned to 12 percent moisture content. Various explanations, including a greater degree of lignification and a reduced fiber saturation point for tropical woods, have been offered for this difference in behavior of temperate and tropical woods (12, 96). As reported previously (99), air-dry strength in cleavage and tension across the grain was again commonly found to be less than the strength in the green condition. The effects of drying upon the properties of individual species are discussed under *Species Descriptions*.

						STATIC BENDING					COMPRESSION PARALLEL TO GRAIN									
Species	Source	Condition	Moisture Content	Specific Gravity		Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load	Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness[6]
			per-cent	oven-dry vol.	green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit-lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per speci-men
Kaneelhart (*Licaria cayennensis)*	British Guiana, Surinam	Green	30.4	1.10	0.96	18,380	22,270	3,820	4.75	13.6	11,640	13,390	4,280	2120	2210	3200	1260	1680	470	286.8
		Air Dry[1]	11.6			19,860	29,860	4,060	5.36	17.5	15,450	17,400	4,370	2020*	2900	2770*	430*	1970	290*	
Bethabara (*Tabebuia serratifolia)*	Brazil, Surinam	Green	31.2	1.06	0.92	14,220	22,560	2,920	4.55	27.6	8,890	10,350	3,110	2630	3060	2300	1340	2120	620	403.8
		Air Dry[1]	12.3			16,660	25,360	3,140	4.98	22.0*	9,000	13,010	3,260	3180	3680	2300	500*	2060*	380*	
Marishiballi (*Licania buxifolia)*	British Guiana	Green	37.3	1.07	0.88	10,570	17,070	2,930	2.27	13.4	6,190	7,580	3,230	2050	2250	1430	750	1620	360	213.3
		Air Dry[1]	12.5			19,440	27,660	3,340	6.49	14.2	10,050	13,390	3,360	—	3570	2230	250*	1750	220*	
Greenheart[2] (*Ocotea Rodiaei)*	British Guiana	Green	42.7	1.06	0.88	13,250	19,550	2,970	3.31	13.4	7,580	10,160	3,580	2260	2320	2040	1070	1730	610	—
		Air Dry[1]	14.8			16,200*	25,500*	3,700*	4.02*	22.0*	10,000*	12,920*	4,160*	2140*	2630*	1970*	1020*	1830*	—	
Sapucaia (*Lecythis paraensis)*	Brazil	Green	45.9	1.00	0.88	13,150	18,340	2,890	3.35	15.0	8,000	8,880	3,430	1740	2430	2170	1280	2000	620	295.8
		Air Dry[1]	13.1			18,170	27,540	3,380	5.36	26.3	9,160	13,280	3,650	3140	3100	1690*	580*	2060	280*	
Manbarklak (*Eschweilera subglandulosa)*	Surinam	Green	42.9	1.04	0.87	10,010	17,110	2,700	2.14	17.4	5,350	7,340	2,710	2120	2280	1350	1020	1630	420	365.9
		Air Dry[1]	12.7			14,000	26,470	3,140	3.72	33.3	6,000	11,210	3,150	2750	3480	2480	540*	2070	260*	
Jarana (*Holopyxidium jarana)*	Brazil	Green	48.6	1.02	0.85	11,170	19,690	2,390	2.82	—	6,930	7,670	2,700	1700[4]	2280	1850	1130	1800	480	359.9
		Air Dry[1]	13.0			17,820	30,170	2,910	6.22	—	8,940	12,540	3,150	3330*	3500	2340	640*	2220	400*	
Timbaúba (*Enterolobium Schomburgkii)*	Brazil	Green	60.0	0.96	0.82	10,290	16,490	2,820	2.21	13.8	5,200	7,430	3,220	1680	2000	1780	980	1850	520	285.1
		Air Dry[1]	13.7			14,920	23,540	3,180	4.09	21.6	8,020	11,520	3,300	1880	2330	1840	840*	2090	440*	
Matá-matá (*Eschweilera odora)*	Brazil	Green	52.7	0.96	0.81	8,940	14,380	2,420	2.04	9.8	5,140	6,760	2,670	1610	1740	1770	870	1410	390	239.1
		Air Dry[1]	14.2			13,740	23,020	2,830	3.70	26.5	6,210	10,730	3,800	2210	2620	1520*	330*	1420	220*	
Acapú (*Vouacapoua americana)*	Surinam	Green	47.9	0.91	0.79	12,450	15,850	2,620	3.44	14.5	7,280	9,170	2,750	1580	1610	1860	860	1510	380	202.6
		Air Dry[1]	12.7			13,720	21,640	2,530*	4.23	17.0	9,590	11,480	2,740*	1600	1730	1220*	550*	1890	335*	
Sapupira (*Diplotropis purpurea)*	Surinam, Brazil	Green	61.2	0.89	0.78	12,380	17,400	2,680	3.30	13.0	5,860	8,020	2,940	1880	1980	1290	700	1800	420	201.1
		Air Dry[1]	12.0			13,660	20,560	2,870	3.66	14.8	9,100	12,140	2,920	2030	2140	1200*	500*	1960	300*	
Anauera (*Licania macrophylla)*	Brazil, Surinam	Green	49.8	0.90	0.76	9,560	14,380	2,320	2.23	10.2	5,580	6,720	2,460	1720	1720	940	840	1320	380	207.6
		Air Dry[1]	11.5			13,550	20,650	2,530	4.09	15.4	8,160	11,010	2,680	2640	2560	1590	400*	1850	240*	
Manwood (*Minquartia guianensis)*	Costa Rica	Green	66.7	0.87	0.76	9,040	13,000	2,230	2.08	7.4	5,060	5,960	2,410	1290	1490	1480	700	1440	410	196.7
		Air Dry[1]	12.7			12,690	19,580	2,440	3.72	11.8	6,970	9,930	2,760	1320	1690	1320*	370*	1310*	210*	
Parinari (*Parinari Rodolphi)*	Brazil	Green	60.3	0.83	0.71	9,060	14,760	2,660	1.77	11.7	3,670	6,780	3,090	1580	1380	910	900	1340	440	144.6
		Air Dry[1]	13.5			14,220	21,740	2,930	3.88	17.1	8,420	11,960	3,070*	2410	2360	1590	370*	1590	240*	

						STATIC BENDING					COMPRESSION PARALLEL TO GRAIN									
Species	Source	Condition	Moisture Content	Specific Gravity		Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load	Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness[6]
			per-cent	oven-dry vol.	green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit-lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Cupiuba (*Goupia glabra*)	Surinam, Brazil	Green	65.7	0.80	0.70	8,180	11,480	1,810	2.08	7.6	4,880	6,170	2,140	1400	1380	1050	980	1550	430	131.9
		Air Dry[1]	12.2			10,380	15,300	2,150	2.80	9.5	5,200	8,350	2,460	1740	1700	1210	570*	1600	380*	
Burada (*Parinari campestris*) Aiomoradan (*Parinari excelsa*)	Surinam, British Guiana	Green	58.2	0.79	0.68	8,510	12,820	2,120	1.82	10.2	4,640	5,780	2,330	1310	1230	860	910	1390	400	150.8
		Air Dry[1]	11.6			13,480	20,230	2,640	3.90	15.4	7,420	10,470	2,860	1800	1810	1420	360*	1620	240*	
Itaúba (*Mezilaurus itauba*)	Peru, Brazil	Green	63.4	0.77	0.68	6,960	11,340	1,800	1.57	8.8	4,020	5,570	2,100	1020	1260	1130	970	1360	440	142.4
		Air Dry[1]	14.2			9,910	15,200	2,040	2.75	10.4	5,270	8,590	2,230	1210	1370	1680	630*	1560	360*	
Shagbark Hickory[3] (*Carya ovata*)	United States	Green	60	0.78	0.64	5,900	11,000	1,570	1.28	23.7	3,430	4,580	—	—	—	1040	—	1520	—	—
		Air Dry	12			10,700	20,200	2,160	3.01	25.8	—	9,210	—	—	—	2170	—	2430	—	
Angelim (*Hymenolobium excelsum*)	Brazil	Green	70.0	0.72	0.63	9,800	14,610	1,950	2.96	12.8	6,130	7,460	2,180	1640	1720	1360	860	1600	410	202.6
		Air Dry[1]	11.0			10,790	17,610	2,050	3.32	15.9	6,030*	8,990	2,280	2030	1720	1700	530*	2010	340*	
Coco de Mono (*Eschweilera tenax*)	Venezuela	Green	73.9	0.74	0.62	6,030	10,870	1,480	1.46	20.2	2,750	3,880	1,560	1220	1280	740	860	1200	360	302.5
		Air Dry[1]	12.0			7,680	14,460	1,760	1.96	18.5*	3,450	6,370	2,120	1630	1480	1200	540*	1640	280*	
White Oak[3] (*Quercus alba*)	United States	Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[5]
		Air Dry	12			8,200	15,200	1,780	2.27	14.8	4,760	7,440	—	1520	1360	1320	800	2000	450	
Teak[5] (*Tectona grandis*)	Burma	Green	52	0.62	0.58	7,250	11,380	1,580	1.89	10.0	4,120	5,490	1,760	900	980	1040	960	1300	420	84.4
		Air Dry[1]	11.2			8,160	13,770	1,670	2.51	9.3*	5,180	7,520	1,500*	1010	1100	1190	980	1360	340*	
Yellow Birch[3] (*Betula lutea*)	United States	Green	67	0.66	0.55	4,200	8,300	1,500	0.70	16.1	2,620	3,380	—	810	780	530	430	1110	270	—
		Air Dry	12			10,100	16,600	2,010	2.89	20.8	6,130	8,170	—	1480	1260	1190	920	1880	520	
Freijo (*Cordia Goeldiana*)	Brazil	Green	53.4	0.59	0.52	7,460	10,540	1,830	1.58	11.2	4,200	4,940	1,980	990	1030	520	610	1080	270	195.2
		Air Dry[1]	10.7			10,600	14,700	2,090	3.00	15.9	5,750	7,240	2,110	1300	1190	720	400*	1410	250*	
Black Walnut[3] (*Juglans nigra*)	United States	Green	81	0.56	0.51	5,400	9,500	1,420	1.16	14.6	3,520	4,300	—	960	900	600	570	1220	360	—
		Air Dry	12			10,500	14,600	1,680	3.70	10.7	5,780	7,580	—	1050	1010	1250	690	1370	320	
Samán (*Pithecolobium Saman*)	Venezuela	Green	—	0.51	0.48	4,880	8,100	910	1.51	10.4	2,720	3,760	1,000	800	750	600	470	1100	260	99.4
		Air Dry[1]	12.4			6,080	8,860	1,100	1.97	7.8*	3,920	5,070	1,110	900	850	830	460*	1280	240*	
Lechero (*Sapium biglandulosum*)	Venezuela	Green	81.6	0.51	0.45	4,800	7,700	1,480	0.88	5.5	2,470	3,200	1,610	650	520	560	500	890	270	83.9
		Air Dry[1]	11.3			6,870	10,790	1,680	1.61	8.5	4,100	6,120	2,060	910	700	650	490*	1050	240*	
Mahogany[5] (*Swietenia macrophylla*)	Central America	Green	79.6	0.51	0.45	5,500	8,960	1,340	1.13	9.1	3,080	4,340	1,520	820	740	680	740	1240	330	88.2
		Air Dry[1]	11.4			7,960	11,460	1,500	2.08	7.5	5,080	6,780	1,500*	970	800	1090	740	1230	340	

TABLE 2—*Continued*

						STATIC BENDING				
Species	Source	Condition	Moisture Content	Specific Gravity		Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load
			per-cent	oven-dry vol.	green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Mahogany (*Swietenia macrophylla)*	Brazil	Green	56.8	0.49	0.45	6,070	8,960	1,280	1.70	9.0
		Air Dry[1]	11.9			8,360	11,590	1,420	2.77	7.8*
Banak (*Virola surinamensis)*	Brazil	Green	93.8	0.50	0.42	3,580	5,600	1,640	0.46	4.1
		Air Dry[1]	11.4			6,900	10,950	2,040	1.40	10.0
Chestnut[3] (*Castanea dentata)*	United States	Green	122	0.45	0.40	3,100	5,600	930	0.59	7.0
		Air Dry	12			6,100	8,600	1,230	1.78	6.5
Jobo (*Spondias Mombin)*	Venezuela	Green	131.4	0.44	0.40	3,460	6,400	1,160	0.60	3.8
		Air Dry[1]	11.2			5,870	8,810	1,280	1.53	6.3
Yellow Poplar[3] (*Liriodendron tulipifera)*	United States	Green	64	0.43	0.38	3,400	5,400	1,090	0.62	5.4
		Air Dry	12			6,100	9,200	1,500	1.43	6.8
Ceiba (*Ceiba pentandra)*	Venezuela	Green	—	0.27	0.25	1,410	2,180	410	0.28	1.2
		Air Dry[1]	13.1			2,910	4,330	540	0.90	2.8

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[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 4) applies.

[2] Kynoch and Norton (54).

[3] Forest Products Laboratory, Madison, Wisconsin.

TABLE 2—*Continued*

		COMPRESSION PARALLEL TO GRAIN									
Species	Condition	Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness[6]
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit-lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per speci-men
Mahogany (*Swietenia macrophylla)*	Green	3,830	4,340	1,370	770	790	670	630	1140	320	82.4
	Air Dry[1]	5,170	6,470	1,500	960	970	900	610*	1250	300*	
Banak (*Virola surinamensis)*	Green	1,740	2,390	1,900	430	320	200	260	720	180	60.6
	Air Dry[1]	3,330	5,140	2,130	560	510	270	360	980	200	
Chestnut[3] (*Castanea dentata)*	Green	2,080	2,470	—	530	420	380	440	800	240	—
	Air Dry	3,780	5,320	—	720	540	760	460	1080	250	
Jobo (*Spondias Mombin)*	Green	2,000	2,560	1,090	580	530	490	600	770	260	74.1
	Air Dry[1]	2,680	4,410	1,560	750	520*	540	470*	1030	200*	
Yellow Poplar[3] (*Liriodendron tulipifera)*	Green	1,930	2,420	—	390	340	330	450	740	220	—
	Air Dry	3,550	5,290	—	560	450	580	520	1100	280	
Ceiba (*Ceiba pentandra)*	Green	780	1,060	460	250	220	100	170	350	110	23.5
	Air Dry[1]	1,580	2,380	600	350	240	320	250	550	130	

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[4] Hardness value limited by splitting.

[5] *Tropical Woods* 98 (99).

[6] Toughness values are the average of tests of green and air-dry specimens ⅝ x ⅝ x 10 inches loaded on the tangential face over an 8-inch span.

Shrinkage

Table 3 contains the results of standard A.S.T.M. shrinkage determinations on 25 tropical American woods. Average values for each species are shown for radial, tangential, longitudinal, and volumetric shrinkage from the green to oven-dry conditions. Comparable data are also shown for a number of well known domestic and tropical woods. These results support previous work (96, 99) in that the tropical species generally are characterized by lower shrinkage values than are domestic woods of comparable density. One species of the entire group represented here should be noted as an outstanding exception to this generalization. *Virola surinamensis* exhibited unusually high volumetric shrinkage, principally as the result of an abnormally high tangential component. More detailed study will be needed to ascertain the cause of this behavior.

Further details of the shrinkage characteristics of individual species are given under *Species Descriptions*.

Decay Resistance

The results of decay resistance tests involving a 4-month period of exposure of small heartwood specimens to pure cultures of typical white-rot and brown-rot fungi are given in Table 4. These tests follow the general pattern of those conducted at the Forest Products Laboratory by Scheffer and Duncan (82).

Both average weight loss for the species and maximum weight loss shown by an individual specimen are given in the table. Durability ratings based on these weight losses are also presented. The decay resistance of individual species is discussed under *Species Descriptions*. The ratings referred to in that section of this report are based upon average weight loss, and any variation indicated there is that between logs rather than variation within the heartwood of a single log.

TABLE 3. SHRINKAGE PROPERTIES OF TROPICAL AMERICAN WOODS[1]

Species	Source	No. of Logs	Specific Gravity	SHRINKAGE (percent)			
				Radial	Tangential	Longitudinal	Volumetric
			green volume basis				
Kaneelhart *(Licaria cayennensis)*	British Guiana, Surinam	4	0.96	5.4	7.9	0.17	12.5
Bethabara *(Tabebuia serratifolia)*	Brazil, Surinam	3	0.92	6.6	8.0	0.16	13.2
Marishiballi *(Licania buxifolia)*	British Guiana	3	0.88	7.5	11.7	0.21	17.2
Sapucaia *(Lecythis paraensis)*	Brazil	2	0.88	6.0	7.6	0.10	13.4
Manbarklak *(Eschweilera subglandulosa)*	Surinam	3	0.87	5.8	10.3	0.28	15.9
Jarana *(Holopyxidium jarana)*	Brazil	2	0.85	6.2	8.3	0.20	16.8
Timbaúba *(Enterolobium Schomburgkii)*	Brazil	4	0.82	3.8	8.8	0.26	13.9
Matá-matá *(Eschweilera odora)*	Brazil	3	0.81	6.7	10.0	0.10	17.1
Acapú *(Vouacapoua americana)*	Surinam	3	0.79	4.9	6.9	0.12	13.0
Sapupira *(Diplotropis purpurea)*	Brazil, Surinam	4	0.78	4.6	7.0	0.15	11.8
Anauera *(Licania macrophylla)*	Brazil, Surinam	6	0.76	6.1	9.9	0.26	16.2
Manwood *(Minquartia guianensis)*	Costa Rica	3	0.76	5.4	8.3	0.30	14.0
Parinari *(Parinari Rodolphi)*	Brazil	3	0.71	6.0	10.1	0.17	15.2
Cupiuba *(Goupia glabra)*	Brazil, Surinam	3	0.70	4.5	8.0	0.18	12.6
Burada *(Parinari campestris)* Aiomoradan *(Parinari excelsa)*	Surinam British Guiana	5	0.68	5.9	9.8	0.28	14.9
Itaúba *(Mezilaurus itauba)*	Brazil, Peru	4	0.68	2.4	7.0	0.32	10.6
Shagbark Hickory[3] *(Carya ovata)*	United States		0.64	7.0	10.5	—	16.7

TABLE 3—*Continued*

Species	Source	No. of Logs	Specific Gravity	Shrinkage (percent) Radial	Tangential	Longitudinal	Volumetric
			green volume basis				
Angelim (*Hymenolobium excelsum*)	Brazil	3	0.63	4.4	7.1	0.37	10.2
Coco de Mono (*Eschweilera tenax*)	Venezuela	2	0.62	3.4	6.4	0.55	10.9
White Oak[3] (*Quercus alba*)	United States		0.60	5.3	9.0	—	15.8
Teak[4] (*Tectona grandis*)	Burma		0.58	2.3	4.2	—	6.8
Freijo (*Cordia Goeldiana*)	Brazil	2+[2]	0.52	4.8	7.6	0.12	11.5
Black Walnut[3] (*Juglans nigra*)	United States		0.51	5.2	7.1	—	11.3
Samán (*Pithecolobium Saman*)	Venezuela	1+[2]	0.48	2.0	3.4	0.13	6.0
Lechero (*Sapium biglandulosum*)	Venezuela	3	0.45	3.3	6.6	0.27	9.2
Mahogany (*Swietenia macrophylla*)	Central America[3]		0.45	3.5	4.8	—	7.7
	Brazil	2	0.45	3.0	4.1	0.08	7.8
Banak (*Virola surinamensis*)	Brazil	2	0.42	5.3	12.4	0.00	17.6
Chestnut[3] (*Castanea dentata*)	United States		0.40	3.4	6.7	—	11.6
Jobo (*Spondias Mombin*)	Venezuela	3	0.40	2.9	6.3	0.27	10.0
Butternut[3] (*Juglans cinerea*)	United States		0.36	3.3	6.1	—	10.3
Ceiba (*Ceiba pentandra*)	Venezuela	3	0.25	2.1	4.1	0.14	7.7

[1] Shrinkage values represent shrinkage from green to oven-dry conditions expressed as a percentage of the green dimension.

[2] Test logs supplemented by plank material.

[3] Forest Products Laboratory, Madison, Wisconsin.

[4] Handbook of Empire Timbers (28).

TABLE 4. WEIGHT LOSS AND DECAY RESISTANCE OF TROPICAL AMERICAN WOODS IN PURE CULTURE TESTS

Species	Source	No. of Logs	Specific Gravity	White Rot[1] Average Weight Loss	White Rot[1] Average Resistance Class[2]	White Rot[1] Maximum Weight Loss	White Rot[1] Maximum Resistance Class[2]	Brown Rot[1] Average Weight Loss	Brown Rot[1] Average Resistance Class[2]	Brown Rot[1] Maximum Weight Loss	Brown Rot[1] Maximum Resistance Class[2]
			green vol. basis	percent		percent		percent		percent	
Kaneelhart (*Licaria cayennensis*)	Surinam, British Guiana	4	0.96	0.8	A	1.5	A	0.7	A	2.3	A
Bethabara (*Tabebuia serratifolia*)	Brazil, Surinam	3	0.92	2.6	A	11.0	B	0.7	A	1.8	A
Marishiballi (*Licania buxifolia*)	British Guiana	3	0.88	5.9	A	12.2	B	8.1	A	21.9	B
Sapucaia (*Lecythis paraensis*)	Brazil	2	0.88	4.1	A	18.3	B	2.8	A	14.6	B
Manbarklak (*Eschweilera subglandulosa*)	Surinam	3	0.87	9.6	A	28.2	C	1.6	A	3.2	A
Jarana (*Holopyxidium jarana*)	Brazil	2	0.85	0.9	A	1.6	A	0.5	A	0.8	A
Timbaúba (*Enterolobium Schomburgkii*)	Brazil	3	0.82	4.6	A	19.0	B	0.2	A	3.7	A
Matá-matá (*Eschweilera odora*)	Brazil	3	0.81	6.3	A	28.0	C	0.3	A	1.0	A
Acapú (*Vouacapoua americana*)	Surinam	3	0.79	0.7	A	5.0	A	0.5	A	2.2	A
Sapupira (*Diplotropis purpurea*)	Brazil, Surinam	4	0.78	5.5	A	12.8	B	3.0	A	12.6	B

TABLE 4—*Continued*

				White Rot[1]				Brown Rot[1]			
				Average		Maximum		Average		Maximum	
Species	Source	No. of Logs	Specific Gravity	Weight Loss	Resistance Class[2]	Weight Loss	Resistance Class[2]	Weight Loss	Resistance Class[2]	Weight Loss	Resistance Class[2]
			green vol. basis	percent		percent		percent		percent	
Anauera *(Licania macrophylla)*	Brazil, Surinam	6	0.76	15.6	B	30.3	C	8.0	A	41.6	C
Manwood *(Minquartia guianensis)*	Costa Rica	3	0.76	3.3	A	6.6	A	0.6	A	1.3	A
Parinari *(Parinari Rodolphi)*	Brazil	3	0.71	29.5	C	53.8	D	34.7	C	48.8	D
Cupiuba *(Goupia glabra)*	Brazil	1	0.72	5.0	A	11.0	B	5.3	A	7.7	A
	Surinam	2	0.68	11.2	B	28.3	C	39.2	C	60.3	D
Burada *(Parinari campestris)* Aiomoradan *(Parinari excelsa)*	Surinam British Guiana	5	0.68	33.7	C	46.5	D	6.6	A	27.3	C
Itaúba *(Mezilaurus itauba)*	Brazil, Peru	4	0.68	0.3	A	1.8	A	1.6-32.6	A-C	43.5	C
Angelim *(Hymenolobium excelsum)*	Brazil	3	0.63	6.1	A	26.2	C	4.4	A	21.4	B
Coco de Mono *(Eschweilera tenax)*	Venezuela	2	0.62	14.3	B	37.7	C	4.9	A	11.0	B
Teak *(Tectona grandis)*	Burma	—[3]	0.58	0.2	A	0.7	A	0.7	A	1.3	A

TABLE 4—*Continued*

				White Rot[1]				Brown Rot[1]			
				Average		Maximum		Average		Maximum	
Species	Source	No. of Logs	Specific Gravity	Weight Loss	Resistance Class[2]	Weight Loss	Resistance Class[2]	Weight Loss	Resistance Class[2]	Weight Loss	Resistance Class[2]
			green vol. basis	percent		percent		percent		percent	
Freijo *(Cordia Goeldiana)*	Brazil	3	0.52	0.6	A	8.8	A	1.9	A	6.0	A
Samán *(Pithecolobium Saman)*	Venezuela	1	0.48	21.1	B	25.7	C	2.4	A	4.0	A
Lechero *(Sapium biglandulosum)*	Venezuela	3	0.45	60.8	D	69.6	D	47.0	D	56.3	D
Mahogany *(Swietenia macrophylla)*	Central America	—[3]	0.45	22.6	B	41.0	C	0.2	A	1.2	A
	Brazil	2	0.45	28.5	C	56.5	D	7.0	A	24.0	B
Banak *(Virola surinamensis)*	Brazil	2	0.42	62.1	D	82.7	D	63.6	D	69.4	D
Jobo *(Spondias Mombin)*	Venezuela	3	0.40	72.0	D	84.2	D	62.8	D	71.1	D
Ceiba *(Ceiba pentandra)*	Brazil	3	0.25	75.6	D	90.1	D	15.9	B	29.6	C

[1] White rot—*Polyporus versicolor* (No. 720); Brown rot—*Poria monticola* (Madison No. 698, Davidson's No. 106).

[2] Resistance classes:
A—0-10 percent decay; very durable.
B—11-24 percent decay; durable.
C—25-44 percent decay; moderately durable.
D—more than 44 percent decay; non-durable.

[3] Material tested included plank representing an unknown number of trees.

TABLE 5. AIR-SEASONING CHARACTERISTICS OF TROPICAL AMERICAN WOODS

Species	Source	No. of Logs	Specific Gravity	Rate of Drying[1]	Warp[2]			Checking and Splitting[2]		Case-hardening[3]
			green volume basis		Crook and Bow	Cup	Twist	End	Surface	
Kaneelhart *(Licaria cayennensis)*	Surinam	1	1.03	Fast	B	—	A	B	D	C
	British Guiana	3	0.89	Fast	B	A	B	A-B	B	B
Bethabara *(Tabebuia serratifolia)*	Brazil, Surinam	3	0.92	Fast	B	A	A-B	A-B	B	B
Marishiballi *(Licania buxifolia)*	British Guiana	3	0.88	Moderate	B	—	A-B	A	B	A-B
Sapucaia *(Lecythis paraensis)*	Brazil	2	0.88	Fast	B	A	A-B	A-B	B	B
Manbarklak *(Eschweilera subglandulosa)*	Surinam	3	0.87	Moderate	B	A	B	A-B	B	B
Jarana *(Holopyxidium jarana)*	Brazil	2	0.85	Fast	B	A	A-B	A	A-B	A-B
Timbaúba *(Enterolobium Schomburgkii)*	Brazil	3	0.82	Fast to Moderate	B-C	A	A-B	C	C-D	B
Matá-matá *(Eschweilera odora)*	Brazil	3	0.81	Fast	B-C	A	A	B	B	B
Acapú *(Vouacapoua americana)*	Surinam	3	0.79	Moderate	B	A-B	B	A-B	A-B	A-B
Sapupira *(Diplotropis purpurea)*	Surinam	3	0.78	Fast	C	A	B	B	B-C	B

TABLE 5—*Continued*

Species	Source	No. of Logs	Specific Gravity	Rate of Drying[1]	Warp[2]			Checking and Splitting[2]		Case-hardening[3]
			green volume basis		Crook and Bow	Cup	Twist	End	Surface	
Anauera *(Licania macrophylla)*	Surinam	3	0.76	Fast	B	A	B	B	B	B
	Brazil	3	0.75	Moderate	B-C	A	B-C	A	A-B	A-B
Manwood *(Minquartia guianensis)*	Costa Rica	3	0.76	Moderate to slow	B	A	A-B	A-B	B-C	A-B
Parinari *(Parinari Rodolphi)*	Brazil	3	0.71	Fast	B	A	B	A	B	B
Cupiuba *(Goupia glabra)*	Brazil, Surinam	3	0.70	Moderate	B	A	B	B	B	B
Burada *(Parinari campestris)*	Surinam	2	0.69	Fast	B	A	B	B	B	A
Aiomoradan *(Parinari excelsa)*	British Guiana	3	0.66	Fast	B-C	A	B-C	A	B	B
Itaúba *(Mezilaurus itauba)*	Brazil, Peru	4	0.68	Moderate	B-C	A	A-B	B-C	C	A-B
Angelim *(Hymenolobium excelsum)*	Brazil	3	0.63	Fast to Moderate	A-C	A	A-B	A-B	A-B	A
Coco de Mono *(Eschweilera tenax)*	Venezuela	2	0.62	Fast to Moderate	C	A	A	B	A-C	A
Freijo *(Cordia Goeldiana)*	Brazil	2	0.52	Fast	B	A	B	A-B	A-B	A

TABLE 5—*Continued*

Species	Source	No. of Logs	Specific Gravity green volume basis	Rate of Drying[1]	Warp[2] Crook and Bow	Warp[2] Cup	Warp[2] Twist	Checking and Splitting[2] End	Checking and Splitting[2] Surface	Case-hardening[3]
Lechero (*Sapium biglandulosum*)	Venezuela	3	0.45	Fast	B-C	A	A	A-B	A	A
Mahogany (*Swietenia macrophylla*)	Brazil	2	0.45	Fast	B	A	B	A	A	A
Banak (*Virola surinamensis*)	Brazil	2	0.42	Fast	B	A-B	B	A	A	B
Jobo (*Spondias Mombin*)	Venezuela	3	0.40	Fast	C	A	A-B	A-B	A-B	A

[1] Rate of drying based on April to November air-seasoning conditions, New Haven, Conn.
Fast: Less than 120 days to dry from green condition to 16 percent moisture content.
Moderate: From 120 to 200 days to dry from green condition to 16 percent moisture content.
Slow: Over 200 days from green condition to 16 percent moisture content.

[2] Warp, checking and splitting: Checking and splitting based on minimum utilization of 1 linear foot and surfacing to standard size; warp based on 4-foot length.
None (A) — none observed.
Slight (B) — less than 5 percent waste.
Moderate (C) — 5 to 25 percent waste.
Severe (D) — Over 25 percent waste.

[3] Casehardening:
None (A) — none observed.
Slight (B) — slight stress.
Severe (C) — fully casehardened

Seasoning Characteristics

The air-seasoning characteristics of all but two of these tropical woods are presented in Table 5. Ceiba and Samán were not included in the seasoning phase of this study. In Table 6 these woods are classified as to their ease of seasoning. A number of domestic woods are included for comparison. Seasoning characteristics of individual species are summarized under *Species Descriptions*.

Use Classification for Tropical Woods

The purpose of this section is to present in summary form an evaluation of each of the woods included in this report from the standpoint of present use as well as potential uses for which the timber appears to be adapted on the basis of its properties as determined thus far in this study. Additional recommendations are included in the individual species descriptions.

TABLE 6. CLASSIFICATION OF TROPICAL AMERICAN WOODS AS TO THEIR EASE OF SEASONING

Group I

(Easy to season)

Species	Specific Gravity green volume basis
Bethabara (*Tabebuia serratifolia*)	0.92
Kaneelhart (*Licaria cayennensis*) (British Guiana)	0.89
Sapucaia (*Lecythis paraensis*)	0.88
Jarana (*Holopyxidium jarana*)	0.85
Anauera (*Licania macrophylla*) (Surinam)	0.76
Parinari (*Parinari Rodolphi*)	0.71
Burada (*Parinari campestris*)	0.69
Freijo (*Cordia Goeldiana*)	0.52
Shortleaf Pine (*Pinus echinata*)	**0.46**
Mahogany (*Swietenia macrophylla*)	0.45
Lechero (*Sapium biglandulosum*)	0.45
Banak (*Virola surinamensis*)	0.42
Yellow Poplar (*Liriodendron tulipifera*)	**0.38**

TABLE 6—*Continued*

Group II

(Moderately difficult to season)

Species	Specific Gravity green volume basis
Kaneelhart *(Licaria cayennensis)* (Surinam)	1.03
Marishiballi *(Licania buxifolia)*	0.88
Manbarklak *(Eschweilera subglandulosa)*	0.87
Matá-matá *(Eschweilera odora)*	0.81
Acapú *(Vouacapoua americana)*	0.79
Sapupira *(Diplotropis purpurea)*	0.78
Anauera *(Licania macrophylla)* (Brazil)	0.75
Cupiuba *(Goupia glabra)*	0.70
Aiomoradan *(Parinari excelsa)*	0.66
Angelim *(Hymenolobium excelsum)*	0.63
Coco de Mono *(Eschweilera tenax)*	0.62
Black Walnut *(Juglans nigra)*	**0.51**
Paper Birch *(Betula papyrifera)*	**0.48**
Jobo *(Spondias Mombin)*	0.40

Group III

(Difficult to season)

Species	Specific Gravity green volume basis
Timbaúba *(Enterolobium Schomburgkii)*	0.82
Manwood *(Minquartia guianensis)*	0.76
Itaúba *(Mezilaurus itauba)*	0.68
White Oak *(Quercus alba)*	**0.60**

Agricultural Implements and Vehicles

Among the more important properties of woods for these purposes are high shock resistance, toughness, high bending strength, resistance to splitting and checking, and freedom from warp. Ability to hold fastenings, particularly screws, is also important. Domestic woods commonly used are Ash, Hickory, Oak, Rock Elm, and Persimmon.

Bethabara
Coco de Mono
Jarána
Kaneelhart
Sapucaia
Sapupira
Timbaúba

Boatbuilding

Uses for wood in boatbuilding are varied, including decking, planking, frames, keels, shaft logs, and numerous other specific components. The properties desired for several of these uses are stated briefly in the following paragraphs.

Decking—Desirable characteristics in a decking wood include freedom from warp, low shrinkage, hardness, abrasion resistance, good weathering characteristics, low moisture absorption, durability, and moderate weight. The heartwood of the following species possesses characteristics that indicate suitability for decking.

Acapú
Angelim
Freijo
Itaúba

Planking—Central American Mahogany, Port Orford Cedar, Alaska Yellow Cedar, and Teak are considered highly desirable for planking. The following woods having comparable strength characteristics as well as such properties as good weathering characteristics, durability, low shrinkage, and low moisture absorption appear suitable for this use.

Angelim
Freijo
Itaúba
Mahogany

Frames—Boat frames require high strength in relation to density, particularly bending strength and impact resistance. Steam-bent frames require, in addition, ability to be bent to relatively sharp curvatures after steaming, with a maximum retention of strength. Good fastening characteristics and decay resistance are desirable.

Jarána
Sapupira
Timbaúba

Keels and Under-water Structural Members—Strength without excessive stiffness, durability, low moisture absorption, and resistance to marine borers are the most important characteristics desired in keels and similar structural components of boats. Although it does not have all of the desired characteristics, White Oak is typical of the type of wood usually employed for this purpose.

Acapú
Aiomoradan
Anauera
Burada
Coco de Mono
Itaúba
Manbarklak
Marishiballi
Matá-matá
Parinari
Sapucaia
Timbaúba

Construction Timbers

Desirable properties include high strength in relation to density, moderate to low shrinkage, and a minimum of checking and splitting. The timber should be obtainable in large sizes and long lengths.

Acapú
Aiomoradan
Angelim
Bethabara
Burada
Cupiuba
Itaúba
Jarána
Kaneelhart
Manbarklak
Manwood
Sapucaia
Sapupira
Timbaúba

Cross Ties

The principal properties desired in woods for this use are resistance to crushing across the grain, a minimum of splitting and checking, ability to hold fastenings, and durability unless the timber is to be treated.

Acapú
Angelim
Bethabara
Coco de Mono
Cupiuba
Itaúba
Jarana
Kaneelhart
Manbarklak
Manwood
Matá-matá
Sapucaia
Sapupira
Timbaúba

Exterior Use

The ability to weather well and remain in place governs the selection of woods for this purpose.

Angelim
Cupiuba
Freijo
Mahogany
Samán

Flooring

Qualities desired in flooring woods are hardness, low shrinkage, freedom from warping and checking, good machining characteristics, and good appearance in all but utility and factory flooring.

Acapú
Aiomoradan
Angelim
Bethabara
Burada
Coco de Mono
Cupiuba
Itaúba
Jarána
Kaneelhart
Manwood
Sapupira
Timbaúba

Frame Construction (Tropical)

Ease of working, stability, ease of nailing, adequate size, and resistance to deterioration are among the more important considerations for woods suitable for tropical frame construction.

Acapú
Angelim
Coco de Mono
Cupiuba
Freijo
Itaúba
Manwood
Marishiballi
Matá-matá
Samán
Sapupira
Timbaúba

Furniture and Cabinet Work

Desirable properties of woods for these uses include sufficient strength and hardness for the purpose, good machining properties, low shrinkage, attractive appearance and good finishing characteristics when used for exposed surfaces, and good gluing and mechanical fastening properties.

Acapú
Angelim
Banak
Bethabara
Cupiuba
Freijo
Itaúba
Jarána
Jobo
Kaneelhart
Lechero
Mahogany
Samán
Sapupira
Timbaúba

Instruments

Professional and scientific instruments generally require a wood of uniform low shrinkage properties, free from warping tendencies, and of uniform fine texture. Good machining and finishing characteristics are essential. Boxwood and Mahogany are among the favored woods for this use.

Bethabara
Kaneelhart
Mahogany

Marine Piling and Construction

Timbers for this purpose must possess resistance to marine borers as well as meet the necessary strength and size requirements.

Acapú
Aiomoradan
Anauera
Burada
Manbarklak
Marishiballi
Matá-matá
Parinari
Sapucaia

Millwork

Good machining, freedom from warp, low shrinkage, and attractiveness are among the more important characteristics of woods for this purpose. Where the millwork is for exterior use, good weathering properties and durability are essential.

Angelim
Banak
Freijo
Lechero
Mahogany
Samán

Patterns

Woods for pattern making must satisfy exceptionally rigid requirements with respect to dimensional stability, uniform texture, and ease of working.

Ceiba
Freijo
Mahogany
Samán

Sporting and Athletic Goods

The requirements for uses of this nature vary considerably. For example, in certain goods woods having the exceptional toughness of Ash and Hickory are needed; while for other uses, where hardness is the principal consideration, woods similar to Dogwood and Persimmon are required. In general, high strength in bending and resistance to splitting together with hardness and toughness are necessary. Other desired characteristics include attractiveness and good machining properties.

Bethabara
Jarána
Kaneelhart
Sapucaia

Tool Handles

Handle wood for hammers, axes, mauls, and similar types of tools must possess high impact strength. Ash and Hickory are woods commonly used for handles of this kind. Handles for knives, screwdrivers, saws, chisels, and tools of like nature require high resistance to splitting and, in some instances, hardness; ability to take an attractive finish is also important. Maple, Cocobolo, and Cherry are among the woods commonly used.

Bethabara
Jarána
Sapucaia
Sapupira

Veneer and Plywood

The diversified uses of veneer and plywood require a wide range of wood properties and characteristics. In addition to strength properties sufficient for the purpose involved, the wood must glue readily and be relatively free from warping and checking. Attractive grain or figure is highly important in considering species for furniture face veneer or decorative panelling. The logs must also be large enough to make possible efficient veneer manufacture.

Utility

Banak
Ceiba
Cupiuba
Jobo
Lechero

Decorative

Acapú
Angelim
Freijo
Jarána
Mahogany
Samán
Timbaúba

Species Descriptions

This section contains individual descriptions of each of the species listed in Table 1. Included are discussions of nomenclature and occurrence of the species, tree descriptions, general characteristics of the wood, and its properties and uses based on a literature review as well as on the results of this study.

CEIBA *Ceiba pentandra* (L.) Gaertn.

This light species of timber is known by various names including Cotton Tree, Silk-cotton Tree, Corkwood, Ceibo, Pochote, Bonga, Ceiba Bonga, Sumahuma da Varzea, Kapokier, Habillo, Kankantrie, and Koddobakkoe.

It grows naturally from the Tropic of Cancer in Mexico southward through Central America to Colombia, Venezuela, and Ecuador. It is also found on the west coast of Africa, Andaman Islands, and the Malay Peninsula and Archipelago, but not in India, although planted there. It is common on slopes and hillsides as well as flats and swamps, preferring rich fertile soils along streams and alluvial basins.

The tree is one of the largest of the tropical forests, attaining a maximum height of 150 feet and a diameter of 7 feet above the buttresses which often are of plank form and wide spreading. The trunk, which is cylindrical or at times thicker in the middle part, is smooth or covered with large conical spines.

The freshly cut heartwood is tan colored, streaked with russet or yellowish tan. The sapwood is of about the same color and is difficult to distinguish from the heartwood. The dry wood is very light grayish brown, sometimes with a pinkish tinge, and often discolored by blue-staining fungi.

The pores, which are open, are readily visible on end surfaces as openings and on longitudinal surfaces as grooves. They are mostly isolated and evenly distributed, although occasionally in radial rows of two to four. The parenchyma is not readily visible even with a lens, but it does occur as fine tangential lines limiting growth rings and as extremely numerous fine tangential lines between the rays, seen best on moistened surfaces. Although the larger rays have a width equal to about half of the tangential diameter of the pores, they are inconspicuous on all surfaces because of their color. The wood is without distinct odor or taste.

The average specific gravity of Ceiba is 0.25 (0.22-0.30), based on volume when green and weight when oven dry. Green weight is about 44 pounds per cubic foot and the weight at 12 percent moisture content averages 18 pounds per cubic foot. Although it is classed as exceedingly light in weight, the wood feels harsh or gritty, quite unlike Balsa, which feels soft and silky.

Logs tested in this study were initially sawed into planks for drying while in storage. As a result the seasoning characteristics of the wood were not observed systematically. After drying, the plank material appeared free of any appreciable checking and warping but incipient decay was noted in both heartwood and sapwood.

The strength properties of Ceiba, which is lighter in weight than any common domestic wood, are proportionately low. The properties of this species are discussed here on the basis of test results obtained from three logs originating in Venezuela. In general, the density and strength of this material are somewhat less than values previously determined for Ceiba from Colombia (14), as shown in the accompanying table. In the unseasoned condition, Ceiba is much weaker than Butternut *(Juglans cinerea)* in all respects, averaging only one-half to one-third as strong as that species.

Upon air drying, Ceiba showed a marked improvement in most properties. All properties in static bending and compression parallel to the grain, as well as compression and tension perpendicular to the grain, and shear, increased proportionately as much or more than is common for domestic hardwoods, and only hardness values showed a lesser degree of improvement.

The air-seasoned wood is also low in strength in comparison with the lightest common domestic species. Although having two-thirds the density of Butternut, Ceiba averages only about one-half as strong. On the other hand Ceiba is about twice as dense as Balsa *(Ochroma lagopus)* and from the comparison of these species in the accompanying table, it will be seen that air-dry Ceiba is distinctly stronger than Balsa in all respects. Ceiba is characterized by static-bending and crushing strengths that are approximately twice those of average density Balsa. Resistance to cleavage, shear, and tension across the grain, are also about twice as great for Ceiba, whereas side hardness and compression perpendicular to the grain values are three or more times as great for Ceiba as for Balsa.

Shrinkage of Ceiba is low as might be anticipated on the basis of its low density. Volumetric shrinkage of 7.7 percent is equal to that of Mahogany as shown in the accompanying table. However, the ratio of tangential shrinkage (4.1 percent) to radial shrinkage (2.1 percent) is considerably greater in the case of Ceiba. Previously published shrinkage values for Ceiba, based on material from Colombia, also appear in the table.

Species and Source	SHRINKAGE (percent)			
	Radial	Tangential	Longitudinal	Volumetric
Ceiba				
(Ceiba pentandra)				
Venezuela	2.1	4.1	0.14	7.7
Colombia[1]	4.5	5.7	—	9.1
Mahogany[2]				
(Swietenia macrophylla)				
Central America	3.5	4.8	—	7.7

[1] Curran, H. M., *Tropical Woods* 19: 11-38 (14).
[2] Forest Products Laboratory, Madison, Wis.

The wood is reported to be extremely low in resistance to decay and insect attack (14, 77, 91). Logs not removed promptly from the forest discolor and decay rapidly. In durability tests conducted as a part of this study, Ceiba was found to be non-durable to a white-rot fungus. However,

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		STATIC BENDING: Fiber Stress at Proportion-al Limit	STATIC BENDING: Modulus of Rupture	STATIC BENDING: Modulus of Elas-ticity	STATIC BENDING: Work to Proportion-al Limit	STATIC BENDING: Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Ceiba	Venezuela	3									
(Ceiba			Green[2]	—	0.27	0.25	1,410	2,180	410	0.28	1.2
pentandra)			Air Dry[1]	13.1			2,910	4,330	540	0.90	2.8
	Colombia[3]		Green	184	0.30	0.27	2,000	2,800	470	0.50	1.6
			Air Dry[1]	14			3,100*	4,200*	600*	0.93*	2.4*
Butternut[4]	United		Green	104	0.40	0.36	2,900	5,400	970	0.52	8.2
(Juglans cinerea)	States		Air Dry	12			5,700	8,100	1,180	1.59	8.2
Balsa[5]											
(Ochroma											
lagopus)	Ecuador		Air Dry	12	0.13	—	1,200	2,100	420	—	—

Species	Condition	COMPRESSION PARALLEL TO GRAIN: Fiber Stress at Proportion-al Limit	COMPRESSION PARALLEL TO GRAIN: Maximum Crushing Strength	COMPRESSION PARALLEL TO GRAIN: Modulus of Elasticity	Hardness		Compression Perpen-dicular to Grain	Tension Perpen-dicular to Grain	Shear	Cleavage	Toughness
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at pro-portional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Ceiba											
(Ceiba pentandra)											
Venezuela	Green[2]	780	1,060	460	250	220	100	170	350	110	23.5
	Air Dry[1]	1,580	2,380	600	350	240	320	250	550	130	
Colombia[3]	Green	—	1,300	—	340	300	290	220	480	120	—
	Air Dry[1]	—	2,490*	—	400*	240*	660*	—	830*	—	
Butternut[4]											
(Juglans cinerea)											
United States	Green	2,020	2,420	—	410	390	270	430	760	220	—
	Air Dry	4,200	5,110	—	570	490	570	440	1170	220	
Balsa[5]											
(Ochroma lagopus)											
Ecuador	Air Dry	900	1,250	—	170	80	70	115	245	55	—

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[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] Based upon tests of logs originally sawed into planks, air seasoned, and subsequently soaked to simulate the green condition.

[3] Curran, H. M., *Tropical Woods* 19: 11-38. Data should be considered only a rough indication of the species properties, as a portion of material tested was somewhat decayed and the number of tests very limited (14).

[4] U. S. Dept. Agr. Tech. Bul. 479 (64).

[5] Forest Products Laboratory, Madison, Wisconsin. Report No. 1511 (100).

when exposed to a brown-rot fungus, it was shown to be very durable to durable.

Owing to its extremely low density Ceiba is readily worked. Despite its ease of working, machining characteristics of the wood are generally poor, because of the quality of machined surfaces. The wood can be sawn without difficulty along the grain but cross cutting results in woolly surfaces. Extreme care is required in boring to minimize torn grain. Planed surfaces were rated fair.

The species has gained considerable importance as the source of "kapok," which is the floss surrounding the seeds. Kapok is used throughout the world in the manufacture of buoys, life belts, life-saving jackets, and as a stuffing for cushions, pillows, mattresses, and similar articles. Almost the entire commercial supply of kapok is obtained from Java, where the trees are widely planted in fence-rows, gardens, and along roadsides. Ceiba is little used locally in the American tropics except for dugout canoes and rafts. Record (77) reports the exportation of large quantities of logs from Guatemala to Germany for use as a substitute for Douglas Fir as plywood corestock. Kiln-dried lumber would be suitable for packing boxes, slack cooperage, toys, and light construction (14, 87). The wood is not comparable with Balsa as regards buoyancy and insulation qualities. Recent consideration has been given to the suitability of the wood for paper pulp.

References: 14, 44, 53, 68, 73, 77, 78, 87, 88, 91.

FREIJO *Cordia Goeldiana* Huber

The wood of this species is known as Cordia Wood, Jenny Wood, and Brazilian Walnut in United States markets, and as Frei Jorge or Freijo in Brazil.

The species occurs in the upland forests in the eastern part of the Atlantic zone of Pará and in the Tocantins and Xingu River basins. Trees of large size are found in these forests.

The freshly cut heartwood is yellowish brown in color, and the sapwood, which is from 1 to 2 inches in width, is tan colored. Dry heartwood varies from oatmeal and light brown to dark brown in color, sometimes variegated. The wood has a pronounced luster. The grain is generally straight and the texture medium. The pores in the outer sapwood are barely visible without a lens as minute openings and in the inner sapwood and heartwood as light-colored dots on end surfaces due to being filled with tyloses. On longitudinal surfaces the pores are visible as brownish grooves in the outer sapwood and as brownish lines farther toward the interior of the tree. Parenchyma occurs in the form of extremely fine tangential lines $\frac{1}{16}$ to $\frac{1}{2}$ inch or so apart, probably limiting seasonal growth layers. The rays are distinctly visible on end surfaces without a lens and conspicuous on radial surfaces. The wood has a spicy odor when freshly cut.

Freijo is classed as a heavy wood with an average specific gravity of 0.52 (0.48-0.63) based on green volume and oven-dry weight. The weight per cubic foot when green is 50 pounds and at 12 percent moisture content it is 39 pounds.

Freijo is easy to air season and dries rapidly with a minimum of defect. Slight warping was observed in the form of crook and twist in the drying of lumber from the logs of this study. End and surface checking was slight as was case-hardening. Such minor defect as occurred in seasoning would doubtless be minimized if stock were dried at a slower rate.

The unseasoned wood of Freijo is generally superior in its mechanical properties to that of other species of comparable density. This superiority is exhibited in all static-bending and compression parallel to grain properties as well as in side hardness and toughness. On this basis the wood is average in end hardness, shear, and tension across the grain, and inferior only in compression perpendicular to the grain and cleavage resistance.

In the unseasoned condition Freijo closely resembles Teak in many of its properties, as shown in the accompanying table. Although somewhat lighter in weight than Teak, Freijo is essentially equivalent to Teak in all properties except compression and tension perpendicular to the grain, shear,

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		STATIC BENDING				
							Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Freijo (*Cordia Goeldiana*)	Brazil	2+[2]	Green	53.4	0.59	0.52	7,460	10,540	1,830	1.58	11.2
			Air Dry[1]	10.7			10,600	14,700	2,090	3.00	15.9
	Brazil[3]		Green	—	—	0.49	5,000	11,600	1,610	—	—
			Air Dry[1]	15			—	13,600*	—	—	—
	Brazil[4]		Air Dry	12	0.55	—	—	13,340	1,860	—	13.0
Teak[5] (*Tectona grandis*)	Burma		Green	52.0	0.62	0.58	7,250	11,380	1,580	1.89	10.0
			Air Dry[1]	11.2			8,160	13,770	1,670	2.51	9.3*
Black Walnut[6] (*Juglans nigra*)	United States		Green	81	0.56	0.51	5,400	9,500	1,420	1.16	14.6
			Air Dry	12			10,500	14,600	1,680	3.70	10.7

Species	Condition	COMPRESSION PARALLEL TO GRAIN			Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity							
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Freijo (*Cordia Goeldiana*) Brazil	Green	4,200	4,940	1,980	990	1030	520	610	1080	270	195.2
	Air Dry[1]	5,750	7,240	2,110	1300	1190	720	400*	1410	250*	
Brazil[3]	Green	4,050	5,310	2,120	—	—	—	—	—	—	—
	Air Dry[1]	—	6,690*	—	—	—	—	—	—	—	—
Brazil[4]	Air Dry	—	7,590	—	1260	1000	—	—	1310	280	
Teak[5] (*Tectona grandis*)	Green	4,120	5,490	1,760	900	980	1040	960	1300	420	84.4
Burma	Air Dry[1]	5,180	7,520	1,500*	1010	1100	1190	980	1360	340*	
Black Walnut[6] (*Juglans nigra*) United States	Green	3,520	4,300	—	960	900	600	570	1220	360	—
	Air Dry	5,780	7,580	—	1050	1010	1250	690	1370	320	

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[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] Based upon tests of two logs and a shipment of plank material representing an unknown number of trees.

[3] Brotero and Vieira (5).

[4] Dept. Sc. and Indus. Research (Gt. Britain), Forest Products Research Bul. No. 28 (1a).

[5] A. V. Thomas (93); Handbook of Empire Timbers (28); unpublished Yale results for plank material received from the New York Naval Shipyard.

[6] U. S. Dept. Agr. Tech. Bul. 479 (64).

and cleavage which are lower than for Teak, and toughness which is apreciably greater. Freijo is of nearly the same density as Black Walnut and compares rather favorably with that species, exceeding it in all static-bending properties except work to maximum load (shock resistance), and also in compression parallel to the grain, tension across the grain, and hardness, but being slightly deficient in compression perpendicular to the grain, shear, and cleavage.

Upon air drying, Freijo showed substantial improvement in most properties but only in work to maximum load did this improvement exceed that commonly shown by domestic hardwoods. Decreases in strength occurred in both tension across the grain and cleavage upon air drying.

In the air-dry condition the wood of Freijo is also above average for its density in static-bending properties and side hardness, and about average in longitudinal compression, end hardness, and shear. It is somewhat below average in tension and compression across the grain and in cleavage resistance. As in the green condition, air-dry Freijo is quite similar to Teak. Bending properties differ chiefly in the greater stiffness and shock resistance of Freijo. Compression parallel to the grain, side hardness, and shear values are nearly identical for both species. Again the table shows, however, the deficiency of Freijo in compression and tension across the grain as well as in cleavage resistance. The foregoing comparison with Teak applies equally well to a comparison of the properties of air-dry Freijo with those of Black Walnut.

Freijo is moderate in shrinkage. Radial shrinkage of 4.8 percent, tangential shrinkage of 7.6 percent, and volumetric shrinkage of 11.5 percent are nearly identical to corresponding values for Black Walnut. The accompanying tabulation includes even lower values from another source in Brazil. Comparison with Teak, however, shows that Freijo undergoes nearly twice the dimensional change of Teak in drying from the green to the oven-dry condition.

Species and Source	SHRINKAGE (percent)			
	Radial	Tangential	Longitudinal	Volumetric
Freijo				
(Cordia Goeldiana)				
Brazil	4.8	7.6	0.12	11.5
Brazil[1]	3.2	6.7	—	9.1
Black Walnut[2]				
(Juglans nigra)				
United States	5.2	7.1	—	11.3
Teak[3]				
(Tectona grandis)				
Burma	2.3	4.2	—	6.8

[1] Brotero and Vieira (5).
[2] U. S. Dept. Agr. Tech. Bul. 479 (64).
[3] Handbook of Empire Timbers (28).

The use of Freijo in place of Teak in naval construction (55) indicates that the wood is highly resistant to decay. This is confirmed in the present study in which Freijo proved to be very durable upon exposure to both a white-rot fungus and a brown-rot fungus.

Cordia Goeldiana has been rated by Edmondson (23) as moderately resistant to marine borers. This evaluation is based upon observation after 6-9 months of exposure in heavily infested Hawaiian waters. However, in tests conducted at Wrightsville, North Carolina, as a part of the present study, Freijo specimens showed evidence of very heavy marine borer attack in 12 months (11). Heartwood of Freijo is considered very resistant to attack by the dry-wood termite of the West Indies and is comparable to Mahogany in this respect (107).

Freijo is easy to work. Surfaces resulting from sawing and planing are moderately smooth, though slight fuzziness is noticeable on cross-cut material. Some torn grain was encountered in boring the wood. The wood is readily glued with a variety of adhesives. Heartwood is quite resistant to moisture absorption, comparing rather closely with White Oak in its resistance to side-grain penetration.

Ducke (22) reports the wood was formerly exported from the Amazon region in considerable quantities, chiefly to

Portugal, for making cooperage. The timber subsequently left the market, although it is suggested the wood may regain its place when more abundant supplies are available. In this connection it has been reported (77) that Portuguese users found that the wood when used in casks imparts an objectionable flavor to wines. Recently, Freijo has been employed in Brazil chiefly in the construction of airplanes and propellers (4). Lecointe (55) states the wood is much used in Belem (Pará) for carpentry and joinery. The wood has been imported into the United States in small quantities for many years (77). A New York furniture manufacturer suggested, after employing the wood in 1927, that Freijo is suitable for fine furniture and for panelling (84). Record (79) reported that during World War I sample logs, under the name Brazilian Walnut, were shipped to the United Statse for trial as gunstocks and airplane propellers. The wood was subsequently employed in limited quantities as a Walnut substitute in furniture and in instrument boards of automobiles. Its good appearance and ability to retain its shape make the wood well suited for furniture, millwork, decorative veneer, boat construction, and many industrial uses.

References: 1a, 4, 5, 11, 22, 23, 44, 55, 77, 79, 84, 107.

SAPUPIRA *Diplotropis purpurea* (Rich.) Amsh.

(=*D. guianensis* Benth.)

The names Supupira and Sucupira are commonly applied to this species in Brazil. Elsewhere it is known as Zwarte Kabbes (Surinam), Tataboo (British Guiana), Coeur Dehors (French Guiana), and Taku (37).

Sapupira occurs in the rain and seasonal forests of the uplands of the Guianas and in Pará and Amazonas in Brazil (21). It is a medium to fairly large sized tree, 90 to 100 feet in height and up to 24 inches in diameter. The trunk is cylindrical and unbuttressed (25).

The freshly cut heartwood is chocolate brown in color, and the sapwood, which is one-half to one inch wide, is cream to tan colored. The color of the dry heartwood resembles that of coffee with a small amount of cream in it.

The grain of the wood is straight or slightly interlocked or sometimes weakly wavy and the texture of the wood is very coarse. The pore openings are visible without a lens, but the pores are made more conspicuous by surrounding layers of light colored parenchyma which often connect pores in short radial, tangential or diagonal rows. The pores are mostly open but a small percentage contain a white or yellow substance, quite noticeable as colored lines on longitudinal surfaces. Very weakly defined growth layers are discernible. The rays are very fine and inconspicuous on all surfaces. The wood is without characteristic odor or taste. The average specific gravity of the wood is 0.78 (0.70-0.97) based on volume when green and weight when oven dry. The weight when green is 78 pounds per cubic foot, and at 12 percent moisture is 58 pounds.

Sapupira is moderately difficult to air season. Rapid drying is accompanied by slight warping in the form of cup and twist, and moderate crook. Slight end and surface checking and casehardening were observed in experimental drying. Milder conditions, resulting in slower drying, would doubtless reduce such defects.

In a number of its strength properties, particularly in the green condition, Sapupira is superior to the strongest of domestic woods. This superiority is also evident when the unseasoned wood is compared with other tropical species of similar high density. On this basis, Sapupira is above average in all static-bending properties except work to maximum load as well as in crushing strength. It is average for its density in shock resistance, hardness, shear, and cleavage, and below average in compression and tension across the grain.

The accompanying table affords a direct comparison with Hickory from which it is apparent that the unseasoned wood of Sapupira is much stronger and stiffer than Hickory in static bending. It is also much stronger than Hickory in compression parallel to the grain. Sapupira also exceeds

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		Static Bending: Fiber Stress at Proportional Limit	Static Bending: Modulus of Rupture	Static Bending: Modulus of Elasticity	Static Bending: Work to Proportional Limit	Static Bending: Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Sapupira *(Diplotropis purpurea)*	Surinam	3	Green	61.2	0.86	0.76	12,720	17,460	2,750	3.45	13.0
			Air Dry	11.5			14,170	19,910	2,790	4.08	14.1
	Brazil	1	Green	—	0.92	0.79	12,030	17,350	2,620	3.14	13.0
			Air Dry	12.6			13,140	21,200	2,950	3.24	15.4
	Average	4	Green	61.2	0.89	0.78	12,380	17,400	2,680	3.30	13.0
			Air Dry	12.0			13,660	20,560	2,870	3.66	14.8
Hickory[2] *(Carya ovata)*	United States		Green	60	0.78	0.64	5,900	11,000	1,570	1.28	23.7
			Air Dry	12			10,700	20,200	2,160	3.01	25.8
White Oak[2] *(Quercus alba)*	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
			Air Dry	12			8,200	15,200	1,780	2.27	14.8

Species	Condition	Compression Parallel to Grain: Fiber Stress at Proportional Limit	Compression Parallel to Grain: Maximum Crushing Strength	Compression Parallel to Grain: Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Sapupira *(Diplotropis purpurea)*											
Surinam	Green	6,430	8,170	2,880	1930	1930	1260	740	1690	370	182.8
	Air Dry[1]	8,770	11,580	2,950	1970	1930	1540	440*	1920	270*	
Brazil	Green	5,280	7,880	3,000	1830	2040	1320	660	1910	480	219.4
	Air Dry[1]	9,440	12,700	2,900*	2090	2340	850*	550*	2000	320*	
Average	Green	5,860	8,020	2,940	1880	1980	1290	700	1800	420	201.1
	Air Dry[1]	9,100	12,140	2,920*	2030	2140	1200*	500*	1960	300*	
Hickory[2] *(Carya ovata)*											
United States	Green	3,430	4,580	—	—	—	1040	—	1520	—	—
	Air Dry	—	9,210	—	—	—	2170	—	2430	—	
White Oak[2] *(Quercus alba)*											
United States	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[3]
	Air Dry	4,760	7,440	—	1520	1360	1320	800	2000	450	

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[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] U. S. Dept. Agr. Tech. Bul. 479 (64).

[3] Value obtained for plank material received from the New York Naval Shipyard.

Hickory in compression across the grain and shear, but falls considerably below Hickory in shock resistance as measured by work to maximum load. A more complete comparison may be made with White Oak from which it is seen that unseasoned Sapupira is superior in all properties except tension across the grain and cleavage.

Upon air drying, the wood increased only slightly in most mechanical properties. Only in work to maximum load was the proportional increase as great as that commonly shown by domestic hardwoods. Compressive strength across the grain decreased slightly upon air seasoning, and strength in tension across the grain and cleavage resistance showed a substantial decrease.

The air-dry wood of Sapupira is above average for its density in stiffness and in compression parallel to grain properties. It is equal to the average in static-bending strength, elastic resilience, hardness, and shear, and below average in shock resistance, compression and tension perpendicular to the grain, and cleavage resistance. When compared with Hickory, as in the accompanying table, air-dry Sapupira is markedly superior in modulus of elasticity, crushing strength, and proportional limit stress in static bending. These two woods are comparable in modulus of rupture, but Hickory stands well above Sapupira in shock resistance, compression across the grain, and shear. Air-dry White Oak is also superior to Sapupira in compression and tension across the grain and cleavage resistance. White Oak is comparable to Sapupira in shock resistance and shearing strength, but in static-bending strength, stiffness, crushing strength, and hardness Sapupira retains its advantage by a wide margin.

The following tabulation permits of convenient comparison between Sapupira and White Oak on the basis of both green and air-dry properties. In each case a value of 100 has been arbitrarily assigned to White Oak.

	Specific gravity	Bending strength	Stiffness	Shock resistance	Crushing strength
Green	130	210	214	112	225
Air Dry		135	161	100	164

	Side hardness	Shear	Bearing strength	Cleavage resistance
Green	187	144	157	100
Air Dry	157	98	91	67

In spite of its high density, Sapupira exhibits moderate shrinkage. As shown in the table, shrinkage values of 4.6 percent radially, 7.0 percent tangentially, and 11.8 percent volumetrically compare closely with those for Black Walnut and are considerably less than corresponding values for White Oak.

Species and Source	SHRINKAGE (percent) Radial	Tangential	Longitudinal	Volumetric
Sapupira				
(Diplotropis purpurea)				
Brazil	4.7	7.4	0.12	11.8
Surinam	4.4	6.7	0.18	11.7
Average	4.6	7.0	0.15	11.8
Black Walnut[1]				
(Juglans nigra)				
United States	5.2	7.1	—	11.3
White Oak[1]				
(Quercus alba)				
United States	5.3	9.0	—	15.8

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

Woods of the genus *Diplotropis* are resistant to decay (77, 41). Fanshawe (25) rates Sapupira as moderately durable. Results of this study indicate that this species is very durable in resistance to both a white-rot and a brown-rot fungus. On the basis of marine-borer exposure tests conducted in Hawaiian waters, Edmondson (23) rates *Diplotropis purpurea* as having little resistance to attack by these organisms. Similar results were shown in tests conducted at Wrightsville, North Carolina as a part of the present study in which Sapupira from Brazil and Surinam underwent fairly heavy attack by marine borers in exposures of 12-16 months (10, 11). Silica content, commonly associated with marine-borer resistance, has been reported by Amos (1) to be negligible.

The wood is moderately difficult to work, and resulting surfaces, especially in planing, are fair to poor due to the coarse texture and frequent irregularity of grain. Tests made by Harrar (37) showed that Sapupira ranks high in screw-holding power.

Sapupira and its closely related species are extensively used in the Amazon region for heavy and durable construction (77). Fanshawe (25) reports that in British Guiana the wood is used for boat building, house framing, flooring, furniture, and turnery. It is considered suitable in the Guianas for interior work, carriage building, and tool handles. Ducke (22) states that the species is used extensively in local industries in the Amazon region for civil and naval construction and crossties. It is sawed in mills at Pará, but only insignificant quantities are exported.

References: 1, 10, 11, 18, 21, 22, 23, 25, 37, 41, 68, 77, 80.

TIMBAÚBA *Enterolobium Schomburgkii* Benth.

Other names for this species include Timbó, Timbó de Mata, Timborana, Fava de Rosca, Poirier, Vinhatico, and Angelim Orelha de Negro.

Timbaúba grows in Central America, French Guiana, northern Brazil, and Peru, preferring non-inundated sandy soil. It is one of the largest trees of the virgin forest, often exceeding 120 feet in height, although commonly occurring as a smaller tree in younger forests.

The freshly cut heartwood is deep orange brown in color and the sapwood, which is about two inches in width, is cream to tan colored. The dry heartwood is light yellowish brown, sometimes with darker streaks, and the sapwood is deep cream in color. The grain is usually straight, sometimes interlocked. The wood is of medium texture.

The pore openings are barely visible to the naked eye on end surfaces. They are clearly indicated as light colored specks, however, as they are surrounded by parenchyma which frequently projects tangentially on both sides of the pores, occasionally connecting pores in short tangential or echelon rows. The pores are partly filled with a whitish or light amber colored substance. On longitudinal surfaces they appear as fine grooves. Vaguely defined growth layers are visible due to irregularly spaced narrow darker zones in which there are fewer pores. The rays are fine and inconspicuous on all surfaces. The dry wood lacks any apparent odor or taste. The average specific gravity of the wood is 0.82 (0.70-0.87) based on volume when green and weight when oven dry. The green weight per cubic foot is 82 pounds, and the weight at 12 percent moisture content is 62 pounds.

Timbaúba is rated difficult to air season. Wood dried at a fast to moderate rate developed moderate seasoning defects in the form of crook and surface checking. In addition, slight end checking was noted along with slight casehardening. Slower drying under mild conditions is recommended.

As might be anticipated for a wood of its high density, Timbaúba surpasses all well known domestic woods in most strength properties. In comparison with other tropical woods of similar density, the unseasoned wood of Timbaúba is close to the average in static-bending strength, resilience, work to maximum load, crushing strength, shear, tension perpendicular to the grain, and cleavage. It is above average in stiffness and toughness, and somewhat below average in hardness and transverse compression.

The unseasoned wood is compared with that of the somewhat heavier Greenheart in the accompanying table which shows a slight superiority for Greenheart in all properties except work to maximum load and shear. In these two properties Timbaúba and Greenheart are equivalent.

Upon air drying, Timbaúba showed moderate improvement in most strength properties, but only in work to maxi-

							STATIC BENDING				
Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Timbaúba (*Enterolobium Schomburgkii)*	Brazil	4	Green	60.0	0.96	0.82	10,290	16,490	2,820	2.21	13.8
			Air Dry[1]	13.7			14,920	23,540	3,180	4.09	21.6
Greenheart[2] (*Ocotea Rodiaei)*	British Guiana		Green	42.7	1.06	0.88	13,250	19,550	2,970	3.31	13.4
			Air Dry[1]	14.8			16,200*	25,500*	3,700*	4.02*	22.0*
White Oak[3] (*Quercus alba)*	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
			Air Dry	12			8,200	15,200	1,780	2.27	14.8

		COMPRESSION PARALLEL TO GRAIN									
Species	Condition	Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Timbaúba (*Enterolobium Schomburgkii)* Brazil	Green	5,200	7,430	3,220	1680	2000	1780	980	1850	520	285.1
	Air Dry[1]	8,020	11,520	3,300	1880	2330	1840	840*	2090	440*	
Greenheart[2] (*Ocotea Rodiaei)* British Guiana	Green	7,580	10,160	3,580	2260	2320	2040	1070	1730	610	—
	Air Dry[1]	10,000*	12,920*	4,160*	2140*	2630*	1970*	1020*	1830*	—	
White Oak[3] (*Quercus alba)* United States	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[4]
	Air Dry	4,760	7,440	—	1520	1360	1320	800	2000	450	

[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] Kynoch and Norton (54).

[3] U. S. Dept. Agr. Tech. Bul. 479 (64).

[4] Values obtained for plank material received from the New York Naval Shipyard.

mum load was the proportionate increase in strength greater than that generally shown by domestic hardwoods. Tensile strength across the grain and cleavage resistance were both reduced substantially in drying.

The air-dry wood is above average for species of similar density in elastic resilience and in proportional limit stress in static bending and compression parallel to the grain. It is average in other static-bending properties, crushing strength, tension across the grain, and cleavage, and below average in hardness, compression across the grain, and shear. As shown in the accompanying table, the slight superiority of Greenheart over Timbaúba previously noted for the green condition, is retained in the air-dry condition. These two species are comparable in work to maximum load values and Timbaúba displays slightly greater shear strength than does air-dry Greenheart.

For convenience, a tabulation is given in which both the green and air-dry properties of Timbaúba are compared with those of White Oak. All values are relative, White Oak having been arbitrarily assigned a rating of 100.

	Specific gravity	Bending strength	Stiffness	Shock resistance	Crushing strength
Green	137	198	226	119	208
Air Dry		155	178	146	155

	Side hardness	Shear	Bearing strength	Cleavage resistance
Green	189	148	214	124
Air Dry	171	104	139	98

Timbaúba is characterized by volumetric shrinkage of 13.9 percent, substantially less than that of White Oak as shown in the accompanying table. Radial and tangential shrinkage values of 3.8 and 8.8 percent, respectively, are both less than corresponding values for White Oak but the ratio of tangential to radial shrinkage indicates a considerable lack of uniformity in this respect.

Species and Source	SHRINKAGE (percent) Radial	Tangential	Longitudinal	Volumetric
Timbaúba *(Enterolobium Schomburgkii)* Brazil	3.8	8.8	0.26	13.9
White Oak[1] *(Quercus alba)* United States	5.3	9.0	—	15.8

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

The heartwood of this species, unlike some of the other species of the genus *Enterolobium*, is highly resistant to decay. Upon exposure to both a white-rot and a brown-rot fungus, Timbaúba proved to be very durable.

Record and Hess (77) report that woods of the genus *Enterolobium* vary in consistency from light, soft, and spongy to rather heavy and hard. Timbaúba is of the latter type and is moderately difficult to work because of its density. Smooth surfaces resulted in planing and sawing, while some torn grain was encountered in boring. Workmen are occasionally allergic to the dust, which has a pungent odor.

Most of the information available in the literature pertaining to uses of the wood appear to be based upon the lower density species of *Enterolobium*. It is reported that Timbaúba is used for civil and naval construction and cabinet work in Brazil.

References: 17, 58, 63, 73, 77, 80.

MATÁ-MATÁ *Eschweilera odora* (Poepp.) Miers

This species is also called Kakeralli, Manbarklak, and Matá-matá Preta. It grows in the upland rain forests of the Guianas and the lower Amazon Basin. The tree is medium to large-sized, being 90 to 120 feet high and 16 to 20 inches in diameter, with mottled blackish and brown bark. The bole is straight and of good form, with a clear length of 40 to 60 feet, and is unbuttressed or only slightly so (25, 42).

Freshly cut heartwood is light brown to olive brown in color, and the sapwood, which is from 1 to 4 inches in width, is yellowish tan. The color of the dry wood is practically the same. Heartwood lacks a distinctive odor or taste. The wood is straight grained and of medium texture.

The pores in the heartwood are visible on smoothly cut end surfaces as light-colored dots instead of openings due to being plugged with tyloses. With a lens it can be seen that they frequently are in radial rows of 2 or 3 and occasionally even 4. On longitudinal surfaces the pores appear as inconspicuous lines rather than grooves on account of being filled with tyloses. On a smoothly cut end surface fine tangential lines about half the radial diameter of an average pore apart can be seen with a hand lens. These lines vary periodically in spacing thereby giving rise to a zonation approximating growth layers in appearance. The rays are very small and inconspicuous on all surfaces. The average specific gravity of the wood is 0.81 (0.73-0.90) based on green volume and oven-dry weight. Weight per cubic foot in the green condition is 77 pounds and at 12 percent moisture content is 62 pounds.

Test material was also obtained from one tree of *Eschweilera Blanchetiana* (Berg) Miers which grew in Brazil where it is known as Morrão. The heartwood of this species had a dark liver color when green and the sapwood, which was 2¼ inches wide, was tan to light brown in color. The dry heartwood is walnut colored. The wood is straight grained, and generally comparable to that of *E. odora*, although finer in texture. The average specific gravity of Morrão, based on tests of a single log is 0.78 (oven-dry weight and green volume).

Matá-matá is rated as moderately difficult to air season. Warp in the form of slight cup and twist and slight to moderate crook accompanied the rapid drying which occurred in this study. End and surface checking was slight. Milder conditions of drying would likely reduce these defects and are recommended for this species.

The density and strength properties of Matá-matá are, generally speaking, in excess of those shown by the denser domestic woods. In comparison with other tropical woods of similar density, however, the unseasoned wood of Matá-matá is below average in all properties except modulus of elasticity and compressive strength across the grain.

Matá-matá is compared with unseasoned Greenheart, a somewhat denser wood, in the accompanying table which shows the definite superiority of Greenheart in every respect. *Eschweilera odora* is also generally inferior in its mechanical properties to the closely related *E. subglandulosa* (see Table 2), and Black Kakeralli *(E. Sagotiana)* (16, 99). Data based on a single log of another related species, *E. Blanchetiana*, are also shown for comparison in the accompanying table. Although unseasoned Matá-matá is much stronger and stiffer than White Oak in static bending and compression parallel to the grain, and clearly superior in hardness, compression across the grain, and toughness, its remaining properties in tension across the grain, shear, and cleavage are quite similar to those of Oak.

Upon air drying, the wood showed substantial improvement in most of its properties but decreased in compression across the grain, tension across the grain, and cleavage. Shear strength remained practically constant. Only in work to maximum load, side hardness, and modulus of rupture were proportionate increases in strength equal to or greater than those commonly shown by domestic hardwoods. The decreases in strength noted were probably associated in part with seasoning checks.

In static-bending and compression parallel to grain properties and hardness, the air-dry wood of Matá-matá compares more favorably with other woods of like density, but it is below average in compression perpendicular to the grain, and particularly in tension perpendicular to the grain, shear, and cleavage. The air-dry wood surpasses that of Greenheart in shock resistance and is comparable to that species in hardness, but in all other respects Matá-matá is inferior to Greenheart. It is also somewhat below the related species *E. subglandulosa* (Table 2) and *E. Sagotiana* (16, 99) in nearly

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		STATIC BENDING Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Matá-matá (*Eschweilera odora)*	Brazil	3	Green	52.7	0.96	0.81	8,940	14,380	2,420	2.04	9.8
			Air Dry[1]	14.2			13,740	23,020	2,830	3.70	26.5
Morrão *(Eschweilera Blanchetiana)*	Brazil	1	Green	—	0.99	0.78	9,770	12,580	1,870	1.85	—
			Air Dry[1]	12.4			13,520	21,210	2,530	4.24	—
Greenheart[2] *(Ocotea Rodiaei)*	British Guiana		Green	42.7	1.06	0.88	13,250	19,550	2,970	3.31	13.4
			Air Dry[1]	14.8			16,200*	25,500*	3,700*	4.02*	22.0*
White Oak[3] *(Quercus alba)*	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
			Air Dry	12			8,200	15,200	1,780	2.27	14.8

Species	Condition	COMPRESSION PARALLEL TO GRAIN Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Matá-matá *(Eschweilera odora)* Brazil	Green	5,140	6,760	2,680	1610	1740	1770	870	1410	390	239.1
	Air Dry[1]	6,210	10,730	3,800	2210	2620	1520*	330*	1420	220*	
Morrão *Eschweilera Blanchetiana)* Brazil	Green	3,200	4,990	2,570	1520	1480	1030	730	1320	220	162.6
	Air Dry[1]	6,420	9,550	3,000	2840	2950	1840	470*	2040	220	
Greenheart[2] *Ocotea Rodiaei)* British Guiana	Green	7,580	10,160	3,580	2260	2320	2040	1070	1730	610	—
	Air Dry[1]	10,000*	12,920*	4,160*	2140*	2630*	1970*	1020*	1830*	—	
White Oak[3] *Quercus alba)* United States	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[4]
	Air Dry	4,760	7,440	—	1520	1360	1320	800	2000	450	

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[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of ting (col. 5) applies.

[2] Kynoch and Norton (54).

[3] U. S. Dept. Agr. Tech. Bul. 479 (64).

[4] Values obtained for plank material received from the New York Naval Shipyard.

all properties, although slightly exceeding the latter in elastic resilience, and work to maximum load (shock resistance).

The following tabulation provides a convenient comparison of the green and air-dry properties of Matá-matá and White Oak. In each case the value for White Oak is taken as 100.

	Specific gravity	Bending strength	Stiffness	Shock resistance	Crushing strength
Green	135	173	194	84	190
Air Dry		151	159	179	145

	Side hardness	Shear	Bearing strength	Cleavage resistance
Green	164	113	214	93
Air Dry	192	71	115	49

Matá-matá displays slightly more shrinkage than does White Oak. Radial shrinkage of 6.7 percent, tangential shrinkage of 10.0 percent, and volumetric shrinkage of 17.1 percent are compared with data for Oak and Greenheart in the accompanying table. Also shown are shrinkage data for the closely related *Eschweilera Blanchetiana* which appears to undergo less shrinkage than *E. odora*.

	SHRINKAGE (percent)			
Species and Source	Radial	Tangential	Longitudinal	Volumetric
Matá-matá *(Eschweilera odora)* Brazil	6.7	10.0	0.10	17.1
Morrão *(Eschweilera Blanchetiana)* Brazil	4.9	8.8	0.07	13.3
Greenheart[1] *(Ocotea Rodiaei)* British Guiana	8.2	9.0	—	16.8
White Oak[2] *(Quercus alba)* United States	5.3	9.0	—	15.8

[1] Kynoch and Norton (54).
[2] U. S. Dept. Agr. Tech. Bul. 479 (64).

The wood is reputed to be highly resistant to insects and decay (22, 42). Matá-matá crossties placed in poorly drained soil in Brazil lasted 8 to 10 years and those in well-drained soil remained sound for 15 to 20 years (41). Material employed in this study was very durable in resistance to both a white-rot and a brown-rot fungus. Similar durability was also shown by other species of the genus, including *E. subglandulosa*, *E. Blanchetiana*, *E. tenax*, and *E. Sagotiana*.

Timbers of the genus *Eschweilera* are also reputed to be highly resistant to attack by marine borers, presumably because of their silica content. Amos determined the silica content of *Eschweilera odora* as 0.3 percent, but other results as high as 2.0 percent have been obtained (1, 42). Matá-matá and Morrão represent the more highly resistant species of the genus *Eschweilera* insofar as marine-borer resistance is concerned. In tests conducted at Wrightsville, North Carolina, as a part of the present study, small heartwood specimens of Matá-matá were only slightly damaged during the first year of exposure under conditions extremely favorable to marine-borer attack (10, 11). The closely related Morrão *(E. Blanchetiana)* also demonstrated a high degree of resistance in an earlier series of tests at the same location. No evidence of attack was observed during the first year of exposure, and only slight damage was inflicted during the second year. Although gradually deteriorating until fairly heavy marine-borer activity was evident during the fourth year, *E. Blanchetiana* is rated extremely resistant to marine borers on the basis of its performance relative to other species during the first two years of exposure.

Some species of *Eschweilera* are apparently only moderately resistant. *E. Sagotiana* exhibited moderate to fairly heavy borer activity in 16 months at Wrightsville, North Carolina (9, 10, 98) and Edmondson (23) has reported *E. corrugata* of British Guiana to be only moderately resistant on the basis of 12 months' exposure in Hawaii. Chemical analysis of samples of *Eschweilera odora* from the same logs that furnished exposure test specimens at Wrightsville showed a total ash content of 1.18 percent and silica content of 0.619 percent, whereas *E. Sagotiana* has a silica content of 0.18-0.221 percent (98).

Both Matá-matá and the closely related species, *E. Blanchetiana*, were difficult to machine and rapidly dulled cutting edges of tools because of their high silica content and density. This is similar to the experience with other species of the genus *Eschweilera*, except for *E. tenax* which has a relatively low silica content. Smooth surfaces were obtained with Matá-matá when tools were properly maintained.

Matá-matá is reported by Ducke (22) as being in general use throughout the Amazon region for posts, railway crossties, and carpentry, although apparently not exported. Fanshawe (25) states the wood is used locally in British Guiana for piling and is suitable also for house framing and railway crossties. Horn (42) reports the wood is highly esteemed in Brazil as foundation timbers for buildings, bridge timbers, mud sills, wharf members, piling and crossties. The high silica content of the wood, which makes for difficult sawing, probably will limit extended use of the wood in sawed form. Its resistance to marine borers, however, recommends it for use as marine piling and durable construction.

References: 1, 9, 10, 11, 16, 22, 23, 25, 41, 42, 73, 77, 98, 99.

MANBARKLAK

Eschweilera subglandulosa (Steud.) Miers
(= *Lecythis subglandulosa* Steud.)

The Dutch name Manbarklak is also applied to a closely related species, namely *E. longipes* (Poit.) Miers, and sometimes also to other species of the genus *Eschweilera. E. subglandulosa* is also called Barklak, Kakeralli, Black Kakeralli, Toledo Wood, and many local names. This species, one of about 80 in the genus *Eschweilera*, grows in the Guianas where mature trees attain a height of 100 feet with a straight, cylindrical trunk and somewhat fluted and buttressed base.

The color of the unseasoned heartwood is greenish yellow to olive brown, and the sapwood which is creamy tan colored is from 1½ to 4½ inches wide. It is not well differentiated in color from the heartwood. The dry heartwood is brownish buff colored and is contrasted more sharply with the yellowish sapwood. The wood is typically straight grained and of fine texture. It has no characteristic odor.

The pores are barely visible on the end surface of sapwood as minute openings and in the heartwood as lighter colored specks as the pores are densely plugged by tyloses. On longitudinal sapwood surfaces the open pores appear as grooves. Numerous fine lines of parenchyma spaced from one-half to two-thirds of the diameter of the pores apart are visible with a hand lens on end surfaces. Slight variations in the spacings of the lines of parenchyma are responsible for a faint appearance of growth layers. The rays are very fine and inconspicuous on all surfaces. The average specific gravity, based on green volume and oven-dry weight, is 0.87 (0.79-0.92). Weight per cubic foot in the green condition is 78 pounds and at 12 percent moisture content it is 67 pounds.

Manbarklak is moderately difficult to air season. Stock which dried at a moderate rate showed slight warp in the form of crook and twist. Slight end and surface checking accompanied by slight casehardening was also observed.

The strength properties of Manbarklak are, generally speaking, far in excess of those shown by any domestic wood. With the notable exception of shock resistance in which Manbarklak is outstandingly high, however, the unseasoned wood of this species is average or below the average in strength anticipated on the basis of its high density. Bearing strength in compression across the grain is particularly low.

Its properties compare rather closely with those of Black Kakeralli *(Eschweilera Sagotiana)* (16, 99) and, as shown in the accompanying table, unseasoned Manbarklak is only slightly inferior to Greenheart *(Ocotea Rodiaei)* in nearly all mechanical properties. In shock resistance this species surpasses Greenheart.

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		Static Bending: Fiber Stress at Proportional Limit	Static Bending: Modulus of Rupture	Static Bending: Modulus of Elasticity	Static Bending: Work to Proportional Limit	Static Bending: Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Manbarklak (*Eschweilera subglandulosa*)	Surinam	3	Green	42.9	1.04	0.87	10,010	17,110	2,700	2.14	17.4
			Air Dry[1]	12.7			14,000	26,470	3,140	3.72	33.3
Greenheart[2] (*Ocotea Rodiaei*)	British Guiana		Green	42.7	1.06	0.88	13,250	19,550	2,970	3.31	13.4
			Air Dry[1]	14.8			16,200*	25,500*	3,700*	4.02*	22.0*
White Oak[3] (*Quercus alba*)	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
			Air Dry	12			8,200	15,200	1,780	2.27	14.8

Species	Condition	Compression Parallel to Grain: Fiber Stress at Proportional Limit	Compression Parallel to Grain: Maximum Crushing Strength	Compression Parallel to Grain: Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Manbarklak (*Eschweilera subglandulosa*) Surinam	Green	5,350	7,340	2,710	2120	2280	1350	1020	1630	420	365.9
	Air Dry[1]	6,000	11,210	3,150	2750	3480	2480	540*	2070	260*	
Greenheart[2] (*Ocotea Rodiaei*) British Guiana	Green	7,580	10,160	3,580	2260	2320	2040	1070	1730	610	—
	Air Dry[1]	10,000*	12,920*	4,160*	2140*	2630*	1970*	1020*	1830*	—	
White Oak[3] (*Quercus alba*) United States	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[4]
	Air Dry	4,760	7,440	—	1520	1360	1320	800	2000	450	

[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] Kynoch and Norton (54).

[3] U. S. Dept. Agr. Tech. Bul. 479 (64).

[4] Values obtained for plank material received from the New York Naval Shipyard.

Upon air drying, the wood improved substantially in strength, equalling the average proportionate increase shown by domestic hardwoods in bending strength and compression perpendicular to the grain and exceeding this average in side hardness and work to maximum load (shock resistance). As frequently noted in the drying of dense tropical woods, marked decreases occurred in tensile strength across the grain and cleavage resistance upon air seasoning. These decreases are probably attributable in part to seasoning checks.

The air-dry wood compares more favorably with other species of similar high density. In such a comparison, Manbarklak is above average in shock resistance, side hardness, and bearing strength across the grain, and approximately average in bending strength and end hardness. The wood is slightly below average in crushing strength, and clearly below average in shear, tension across the grain, and cleavage resistance. Manbarklak compares favorably in the air-dry condition with the closely related Black Kakeralli and, as shown in the table, is distinctly superior to Greenheart in shock resistance as measured by work to maximum load as well as in hardness and compressive strength across the grain. These species are essentially comparable in static-bending strength, elastic resilience, and shear, but Manbarklak lacks the high degree of stiffness that characterizes Greenheart and is inferior to Greenheart in tension across the grain.

A convenient comparison with White Oak is given in the following tabulation of relative values for Manbarklak properties. White Oak has been arbitrarily assigned a rating of 100 in each case.

	Specific gravity	Bending strength	Stiffness	Shock resistance	Crushing strength
Green	145	206	216	150	206
Air Dry		174	176	225	151

	Side hardness	Shear	Bearing strength	Cleavage resistance
Green	215	130	163	100
Air Dry	256	104	188	58

Although Manbarklak is much denser than White Oak, the two are characterized by nearly identical shrinkage values. Radial shrinkage of 5.8 percent, tangential shrinkage of 10.3 percent, and volumetric shrinkage of 15.9 percent are each only slightly greater than corresponding values for White Oak as shown in the table.

Species and Source	SHRINKAGE (percent)			
	Radial	Tangential	Longitudinal	Volumetric
Manbarklak *(Eschweilera subglandulosa)* Surinam	5.8	10.3	0.28	15.9
White Oak[1] *(Quercus alba)* United States	5.3	9.0	—	15.8

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

The wood is reputed to be highly durable (77). In this study, heartwood was found to be very durable to durable in resistance to a white-rot and very durable upon exposure to a brown-rot fungus. These results agree generally with those for other species of the genus *Eschweilera,* including *E. tenax, E. odora, E. Blanchetiana,* and *E. Sagotiana.* Manbarklak has a reputation for exceptional resistance to marine-borer attack, presumably due to the presence of silica which has been determined for some samples as high as 1.31 percent based on the dry weight of the wood (1). In marine-borer exposure tests conducted at Wrightsville, North Carolina as a part of this study, *Eschweilera subglandulosa* showed only slight evidence of marine-borer activity after 12 months' immersion (11). Silica content, determined on samples from the same logs as the exposure specimens, was 0.688 percent. Total ash content was 1.22 percent (98).

Manbarklak proved difficult to work because of its high silica content and density. Rapid dulling of cutting edges was observed, although slate-smooth surfaces resulted in all machining operations when tools were properly maintained.

According to Pfeiffer (68) two species, *E. subglandulosa* and *E. longipes,* enter the export trade from Surinam as Manbarklak. Because of its marine-borer resistance, decay resistance, and high strength, the wood is particularly valued for marine construction, especially in brackish waters. Record and Hess (77) report that piles supporting the railway bridge across the Saramacca Canal at Beekhuizen, Surinam were sound and fit for further use after 17 years of service. The waters were infested with the most destructive of shipworms, which severely attacked Greenheart *(Ocotea Rodiaei)* in less than two years. In a further demonstration of its marine-borer resistance, Manbarklak gave the best performance of a number of highly resistant species after 15 years of exposure to marine-borer attack in an experimental installation at Balboa, Canal Zone.

References: 1, 11, 16, 33, 68, 73, 77, 98, 99.

COCO DE MONO *Eschweilera tenax* Miers (= *Lecythis tenax* Moritz)

This species appears to differ considerably from the other species of *Eschweilera* described in this paper. The following discussion is based upon material from the State of Portuguesa, Venezuela, where this species, together with many others, is of secondary commercial importance, overshadowed by Mahogany, Spanish Cedar, and a few durable construction timbers. Little information is available concerning the size or abundance of this species but the trees from which test material was obtained were of medium size, 60-80 feet in height and 2-3 feet in diameter at the stump.

The freshly cut heartwood was buff to reddish tan in color, and the sapwood, which was 4½ inches wide, was light yellowish to barely distinguishable from the heartwood. The dry heartwood is light brown and the sapwood yellowish tan. The grain varies from straight to slightly interlocked. Texture is uniform and fine. The pores are barely visible to the unaided eye as minute openings in the end surface of the sapwood but not in the heartwood where they are densely plugged with tyloses. Examination with a hand lens shows that they often are in radial pairs. On longitudinal surfaces the pores are barely visible as fine grooves or lines. The lines of parenchyma, as seen with a hand lens on end surfaces, are considerably wider and spaced farther apart than in Manbarklak and Black Kakeralli, being about the width of a pore apart except in certain narrow zones in which they are closer together thereby vaguely differentiating growth layers of variable width. The rays are very fine on all surfaces. The average specific gravity of the wood, based on green volume and oven-dry weight, is 0.62 (0.58-0.67). Weight per cubic foot in the green condition is 67 pounds and at 12 percent moisture content it is 48 pounds.

The wood is rated moderately difficult to air season. This rating is based on a fast to moderate rate of drying which was accompanied by moderate defect, especially apparent in cases where drying was rapid. Warp was observed only in the form of moderate crook. Surface and end checking was absent in material which dried at a moderate rate but moderate in cases where drying was rapid. Casehardening was slight. Seasoning defects would doubtless be reduced under milder conditions resulting in a slower rate of drying.

The unseasoned wood of Coco de Mono is above the average anticipated for a wood of its density in shock resistance, approximately average in bending strength, elastic resilience, hardness, and tension across the grain, and below average in shear, stiffness, and particularly so in compression parallel and perpendicular to the grain.

The wood of *Eschweilera tenax* is neither as dense nor as strong as that of the other species of *Eschweilera* shown in Table 2, or of Black Kakeralli *(Eschweilera Sagotiana)* (16, 99), although in shock resistance it is somewhat comparable to these related species. In the accompanying table Coco de Mono is compared with Hickory. The unseasoned wood closely resembles Hickory in density and in all static-bending properties including work to maximum load (shock resistance), but is inferior to Hickory in the other properties for which comparative values are available, including crushing strength, compression across the grain, and shear. Coco de

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		STATIC BENDING				
							Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Coco de Mono (*Eschweilera tenax*)	Venezuela	2	Green	73.9	0.74	0.62	6,030	10,870	1,480	1.46	20.2
			Air Dry[1]	12.0			7,680	14,460	1,760	1.96	18.5*
Shagbark Hickory[2] (*Carya ovata*)	United States		Green	60	0.78	0.64	5,900	11,000	1,570	1.28	23.7
			Air Dry	12			10,700	20,200	2,160	3.01	25.8
White Oak[2] (*Quercus alba*)	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
			Air Dry	12			8,200	15,200	1,780	2.27	14.8

Species	Condition	COMPRESSION PARALLEL TO GRAIN									
		Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Coco de Mono (*Eschweilera tenax*) Venezuela	Green	2,750	3,880	1,560	1220	1280	740	860	1200	360	302.5
	Air Dry[1]	3,450	6,370	2,120	1630	1480	1200	540*	1640	280*	
Shagbark Hickory[2] (*Carya ovata*) United States	Green	3,430	4,580	—	—	—	1040	—	1520	—	—
	Air Dry	—	9,210	—	—	—	2170	—	2430	—	
White Oak[2] (*Quercus alba*) United States	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[3]
	Air Dry	4,760	7,440	—	1520	1360	1320	800	2000	450	

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[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] U. S. Dept. Agr. Tech. Bul. 479 (64).

[3] Values obtained for plank material received from the New York Naval Shipyard.

Mono is superior to White Oak in all bending properties including shock resistance, crushing strength, hardness, and tension across the grain, but is exceeded slightly by Oak in bearing strength, shear, and cleavage resistance.

Only a slight improvement was noted in most properties of this species upon air drying. In no instance was the proportionate increase as great as that commonly occurring in the drying of domestic hardwoods. Several properties including work to maximum load, tension perpendicular to the grain, and cleavage resistance decreased upon air seasoning.

In the air-dry condition the wood of this species is comparable to that of most other woods of similar density only in shock resistance and hardness. It is below average on this basis of comparison in all other mechanical properties and particularly in compression parallel to the grain. It is surpassed in all respects by Hickory and, with the exception of shock resistance and hardness, also by White Oak. A convenient comparison with the latter, on the basis of relative values in both the green and air-dry conditions is given in the following table in which values for White Oak are taken as 100 in each case.

	Specific gravity	Bending strength	Stiffness	Shock resistance	Crushing strength
Green	103	131	118	174	109
Air Dry		95	99	125	86

	Side hardness	Shear	Bearing strength	Cleavage resistance
Green	121	96	89	86
Air Dry	109	82	91	62

Coco de Mono is characterized by low shrinkage in relation to its density. Radial shrinkage of 3.4 percent, tangential 6.4 percent, and volumetric 10.9 percent are each approximately two-thirds of the corresponding value for White Oak of approximately equal density.

Species and Source	SHRINKAGE (percent)			
	Radial	Tangential	Longitudinal	Volumetric
Coco de Mono (*Eschweilera tenax*) Venezuela	3.4	6.4	0.55	10.9
White Oak[1] (*Quercus alba*) United States	5.3	9.0	—	15.8

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

Material exposed in this study proved durable in resistance to a white-rot and very durable in resistance to a brown-rot fungus. In this respect, the wood appears to be quite similar to other species of the genus *Eschweilera*, including *E. subglandulosa*, *E. odora*, and *E. Sagotiana*. Coco de Mono is moderately resistant to marine-borer attack but is classed among the lesser resistant species of the genus *Eschweilera*. Specimens exposed to marine borers at Wrightsville, North Carolina, as part of the current study, showed evidence of moderate marine-borer activity after 16 months and of fairly heavy borer activity after two years of exposure. The test specimens were heavily damaged after three years' immersion. This performance matched that of Greenheart under similar conditions (10, 11). Samples of Coco de Mono from the same source as the exposure specimens had a total ash content of 1.60 percent but contained only 0.079 percent silica (98).

The lack of silica and moderate density resulted in comparative ease of machining not exhibited by other species of the genus. There appeared to be little dulling of the cutting edges of tools. The wood is only moderately difficult to work. Planing, boring, and sawing operations produced smooth surfaces of high quality.

Information is lacking in the literature regarding the utilization of this species. The characteristics of the wood do not qualify it for some uses for which other species of the genus *Eschweilera* are adapted, such as marine construction. However, because of its workability and resistance to decay the wood could undoubtedly find use in general construction and possibly in such products as heavy duty flooring.

References: 10, 11, 16, 98, 99.

CUPIUBA *Goupia glabra* Aubl.
(= *Goupia paraensis* Hub.)

The principal common names applied to this species are Cupiuba and Tento in Brazil; Kabukalli and Goupi in British Guiana; Kopie or Copie in Surinam; and Sapino in Colombia. In addition many other local names are used in different countries.

Cupiuba grows in the uplands of the lower Amazon, the Guianas, and the hinterlands of Colombia. It is found in all of the state of Pará, Brazil, but most frequently around Belém. It is dominant in the seasonal rain forests on sandy soils. The trees are very large, up to 120 feet high in the Guianas, and logs 60 feet long, squaring 30 inches, are obtainable although many of them are smaller. The trunks are buttressed to a height of about 6 feet. Freshly cut stumps exude a gelatinous substance with an unpleasant odor.

The freshly cut heartwood is orange-tan to dark russet brown in color. The sapwood is cream to tan colored and from 2 to 6 inches wide. The dry heartwood unexposed to light for any length of time resembles that of native Red Gum *(Liquidambar styraciflua)* in color and the sapwood is pink, also resembling that of Red Gum. The unseasoned wood is characterized by a fetid odor which, although greatly reduced after drying, is still apparent in seasoned material. The grain is extremely interlocked. The pores are barely visible as minute openings on smoothly cut end surfaces under favorable light conditions. They are scattered singly and evenly except for irregularly spaced narrow bands in which they are slightly less numerous thereby demarcating inconspicuously defined growth layers. On longitudinal surfaces they appear as fine grooves of about the same size as in native Birch. In the sapwood the pores are open but in

the heartwood many contain light amber to dark reddish brown gum seen best on longitudinal surfaces. The rays are very fine and inconspicuous on all surfaces. Further details as to structure are given by Kribs (53).

The average specific gravity of the wood is 0.70 (0.62–0.75) based on volume when green and weight when oven dry. The weight per cubic foot is 73 pounds when green and 52 pounds at 12 percent moisture content.

Results of air-seasoning studies show the wood to be moderately difficult to dry. A moderate rate of drying was accompanied by only slight defect in the form of warp, checking, and casehardening.

The following discussion of the strength properties of Cupiuba is based upon the averages derived from testing of material of this species from Brazil and Surinam. In comparison with other woods of like density the properties of unseasoned Cupiuba are above average in elastic resilience and tension across the grain; average in stiffness, crushing strength, end hardness, shear, and cleavage; below average in modulus of rupture, side hardness, and bearing strength; and particularly low in shock resistance.

A comparison with unseasoned Pecan in the accompanying table shows that Cupiuba is superior to the considerably lower density Pecan in every property except work to maximum load. In the latter property, indicative of shock resistance, Pecan exceeds Cupiuba in the approximate ratio of 2:1. The superiority of Cupiuba is most apparent in its greater crushing strength and stiffness. A similar comparison with White Oak is also shown.

Upon air drying, Cupiuba improved moderately in most strength properties but in every case the proportionate increase was less than that shown generally by domestic hardwoods. Tensile strength across the grain showed a serious decrease and cleavage resistance a moderate decrease upon air seasoning.

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		STATIC BENDING: Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Cupiuba *(Goupia glabra)*	Brazil	1	Green	67.6	0.82	0.72	8,800	12,440	1,820	2.35	8.4
			Air Dry[1]	12.3			10,420	15,220	2,210	2.76	8.8
	Surinam	2	Green	63.8	0.78	0.67	7,560	10,510	1,800	1.80	6.9
			Air Dry[1]	12.0			10,340	15,380	2,090	2.85	10.2
	Average	3	Green	65.7	0.80	0.70	8,180	11,480	1,810	2.08	7.6
			Air Dry[1]	12.2			10,380	15,300	2,150	2.80	9.5
Pecan[2] *(Carya pecan)*	United States		Green	63	0.69	0.60	5,200	9,800	1,370	1.18	14.6
			Air Dry	12			9,100	13,700	1,730	2.81	13.8
White Oak[2] *(Quercus alba)*	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
			Air Dry	12			8,200	15,200	1,780	2.27	14.8

Species	Condition	COMPRESSION PARALLEL TO GRAIN: Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Cupiuba *(Goupia glabra)*											
Brazil	Green	5,500	6,880	2,010	1530	1520	1140	1030	1790	510	139.3
	Air Dry[1]	5,300*	8,460	2,520	2050	1980	1280	560*	1690*	380*	
Surinam	Green	4,270	5,460	2,260	1260	1240	960	920	1310	340	124.5
	Air Dry[1]	5,110	8,240	2,400	1430	1420	1140	580*	1500	380	
Average	Green	4,880	6,170	2,140	1400	1380	1050	980	1550	430	131.9
	Air Dry[1]	5,200	8,350	2,460	1740	1700	1210	570*	1600	380*	
Pecan[2] *(Carya pecan)*											
United States	Green	3,100	3,990	—	1270	1310	960	680	1480	420	—
	Air Dry	5,180	7,850	—	1930	1820	2130	—	2080	660	
White Oak[2] *(Quercus alba)*											
United States	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[3]
	Air Dry	4,760	7,440	—	1520	1360	1320	880	2000	450	

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[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] U. S. Dept. Agr. Tech. Bul. 479 (64).

[3] Value obtained for plank material received from the New York Naval Shipyard.

The air-dry wood is below the average anticipated for a wood of its density in every property, the greatest deficiency occurring in shock resistance. Although exceeding air-dry Pecan in static-bending strength, Cupiuba ranks slightly below Pecan in hardness and substantially below Pecan in compression across the grain, shear, cleavage, and shock resistance.

A convenient comparison with White Oak in both the green and air-dry conditions is given in the following tabulation in which the value for White Oak is in each case taken as 100.

	Specific gravity	Bending strength	Stiffness	Shock resistance	Crushing strength
Green	117	138	145	66	173
Air Dry		101	121	64	112

	Side hardness	Shear	Bearing strength	Cleavage resistance
Green	130	124	127	102
Air Dry	125	80	92	84

Shrinkage of Cupiuba averages 4.5 percent radially, 8.0 percent tangentially, and 12.6 percent volumetrically. As shown in the accompanying tabulation, these values are slightly less than corresponding values for Pecan and appreciably less than for White Oak, although Cupiuba exceeds both species in density.

	SHRINKAGE (percent)			
Species and Source	Radial	Tangential	Longitudinal	Volumetric
Cupiuba				
(Goupia glabra)				
Brazil	3.9	8.2	0.28	12.0
Surinam	5.1	7.8	0.08	13.2
Average	4.5	8.0	0.18	12.6
Pecan[1]				
(Carya pecan)				
United States	4.9	8.9	—	13.6
White Oak[1]				
(Quercus alba)				
United States	5.3	9.0	—	15.8

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[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

Cupiuba is reputed to be only slightly resistant to decay (25). It is reported that ties placed in a railroad track in Johannesburg, South Africa, were removed after being in service only 13 months (41). Somewhat contradictory results were obtained in this study, as heartwood exposed to a white-rot fungus proved to be very durable to durable. The wood was very durable to moderately durable in resistance to a brown rot. Ducke (22) states the wood is susceptible to termite attack when weathered and dry.

Goupia glabra was found by Edmondson (23) to have little resistance to marine borers in tests involving 6-9 months immersion in Hawaiian waters. Similar results were obtained at Wrightsville, North Carolina (11), where small specimens of Cupiuba were heavily damaged during the first year of exposure. Samples from the same logs that provided material for exposure test specimens averaged 0.61 percent in total ash content and only 0.046 percent in silica (98). A high silica content (0.5 percent or more) is commonly associated with a high degree of marine-borer resistance for wood in general.

The wood is moderately difficult to work. Smooth surfaces were obtained in sawing and boring operations. In planing, however, torn and chipped surfaces are difficult to avoid because of the strongly interlocked grain.

Record and Hess (77) report that Cupiuba is suitable for heavy and durable construction and for furniture. According to Ducke (22), the wood is cut in all the eastern parts of the State of Pará, Brazil, where it is the most popular of the secondary timbers and is used in cheap construction and joinery. Fanshawe (25) states the wood is used locally in British Guiana for heavy construction, house framing, flooring, decking, punt bottoms, and canoes. It is also considered suitable for railway crossties, paving blocks, furniture, and plywood. Earlier reports stated that natives in the savannas of British Guiana prefer canoes made of Cupiuba to all others because they resist splitting upon exposure to the sun (40, 92).

References: 11, 17, 22, 23, 25, 40, 41, 53, 77, 80, 92, 98.

JARÁNA *Holopyxidium jarana* (Huber) Ducke
(= *Eschweilera jarana* [Huber] Ducke)
(= *Lecythis jarana* [Huber] A. C. Smith)

This wood is also known as Inhauba in Brazil. Jarána is a large tree of the upland forests of eastern Brazil, being particularly abundant along the lower Tapajoz River (22, 58).

The fresh heartwood is light brown to blood red in color. When dry, the heartwood is salmon pink and the sapwood, which is about 2½ inches wide is yellowish cream. The wood is straight grained and uniformly fine textured. The pores are not visible without magnification either as openings on the end surfaces or as grooves on longitudinal surfaces. As seen under a lens they are filled with tyloses and are either isolated or in short radial rows of two or three. Numerous fine tangential lines of parenchyma spaced about the width of a pore apart are visible with a lens on the end surface. Dark zones occurring at frequent intervals, in which the parenchyma lines are absent and pores are fewer, mark growth layers. The rays are inconspicuous on all surfaces. The specific gravity, based on volume when green and weight when oven dry averages 0.85 (0.79-0.89). Weight per cubic foot when green is 79 pounds and at 12 percent moisture it is 65 pounds.

The wood of a closely related Brazilian species, *Holopyxidium latifolium* (Ducke) Knuth, was also included in this study. The dry heartwood of this species is salmon pink in color, similar to that of *H. jarana*. The pores also are similar in size and distribution but the lines of parenchyma are wider and more conspicuous on end and radial surfaces. Its specific gravity averaged 0.81 (0.77-0.83) based on oven-dry weight and green volume. Weight per cubic foot in the air-dry condition was 65 pounds.

Jarána is rated as easy to air season. In this study it exhibited rapid drying in spite of its relatively high density. Drying was accompanied by only slight defect in the form of warp, surface checks, and casehardening. Such minor defects as

occurred would doubtless be minimized under milder conditions resulting in a slower drying rate.

Jarána far exceeds any well known domestic wood in density and in most strength properties. In comparison with other tropical woods of equal density, the unseasoned wood is above average in bending strength, toughness, and tension across the grain. It is about average in elastic resilience, side hardness, shear, and cleavage, and below average in stiffness, crushing strength, bearing strength, and end hardness. However, the wood split consistently when undergoing end hardness tests and consequently the values shown in the accompanying table may not accurately represent this property. The table also shows data for a single log of the closely related *Holopyxidium latifolium*, which appears to be slightly less dense and proportionately less strong in most respects, differing appreciably from *H. jarana* only in its lower resistance to compression perpendicular to the grain.

In a comparison with Greenheart, green Jarána is shown to be at least equivalent to that species in static-bending strength, side hardness, tension across the grain, and shear, but somewhat below Greenheart in stiffness, elastic resilience, crushing strength, end hardness, bearing strength, and cleavage.

Upon air drying, Jarána improved substantially in most properties although only in modulus of rupture and hardness were the proportionate increases as great as those commonly shown by domestic woods. Considerable loss in strength occurred in cleavage and tension perpendicular to the grain on air seasoning.

In the air-dry condition Jarána compares more favorably in most respects with other very high density species. The wood is above average on this basis of comparison in all static-bending properties except stiffness as well as in crushing strength, hardness, and cleavage. It falls below average only in stiffness, shear, and tension perpendicular to the grain. The data for Jarána are rather generally supported by the results of limited tests conducted on *H. latifolium* which

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		Static Bending: Fiber Stress at Proportional Limit	Static Bending: Modulus of Rupture	Static Bending: Modulus of Elasticity	Static Bending: Work to Proportional Limit	Static Bending: Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Jarána											
(Holopyxidium	Brazil	2	Green	48.6	1.02	0.85	11,170	19,690	2,390	2.82	—
jarana)			Air Dry[1]	13.0			17,820	30,170	2,910	6.22	—
(Holopyxidium	Brazil	1	Green	—	0.94	0.81	9,140	18,330	2,270	2.06	21.2
latifolium)			Air Dry[1]	16.2			12,630	25,600	2,860	3.07	43.7
Greenheart[2]											
(Ocotea Rodiaei)	British Guiana		Green	42.7	1.06	0.88	13,250	19,550	2,970	3.31	13.4
			Air Dry[1]	14.8			16,200*	25,500*	3,700*	4.02*	22.0*
White Oak[3]											
(Quercus alba)	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
			Air Dry	12			8,200	15,200	1,780	2.27	14.8

Species	Condition	Compression Parallel to Grain: Fiber Stress at Proportional Limit	Compression Parallel to Grain: Maximum Crushing Strength	Compression Parallel to Grain: Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Jarána *(Holopyxidium jarana)*											
Brazil	Green	6,930	7,670	2,700	1700	2280	1850	1130	1800	480	359.9
	Air Dry[1]	8,940	12,540	3,150	3330*	3500	2340	640*	2220	400*	
(Holopyxidium latifolium)											
Brazil	Green	5,460	8,450	2,960	1990	2000	1880	970	1800	550	344.9
	Air Dry[1]	6,380	11,590	3,200	2860	2690	1460*	1070	2040	700	
Greenheart[2] *(Ocotea Rodiaei)*											
British Guiana	Green	7,580	10,160	3,580	2260	2320	2040	1070	1730	600	—
	Air Dry[1]	10,000*	12,920*	4,160*	2140*	2630*	1970*	1020*	1830*	—	
White Oak[3] *(Quercus alba)*											
United States	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[4]
	Air Dry	4,760	7,440	—	1520	1360	1320	800	2000	450	

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[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] Kynoch and Norton (54).

[3] U. S. Dept. Agr. Tech. Bul. 479 (64).

[4] Value obtained for plank material received from the New York Naval Shipyard.

was somewhat less dense, but proportionately nearly as strong as *H. jarana* in most properties. Hardness values of *H. latifolium* were somewhat low as were elastic resilience and transverse compressive strength, but both tension perpendicular to the grain strength and cleavage resistance were greater in *H. latifolium*. The extremely high work to maximum load values for *Holopyxidium latifolium*, direct data on which are lacking in the case of Jarána, substantiate the high toughness values for both species in emphasizing the remarkable shock resistance of these closely related species. In a comparison with Greenheart as shown in the accompanying table, the seasoned wood of Jarána is clearly superior in bending strength, elastic resilience, end and side hardness, transverse compression, and shear. It is comparable to Greenheart in crushing strength and is surpassed by Greenheart only in stiffness and tension across the grain.

The following table compares both green and air-dry Jarána with White Oak on the basis of relative values. White Oak has been arbitrarily assigned a value of 100 in each case.

	Specific gravity	Bending strength	Stiffness	Shock resistance[1]	Crushing strength
Green	142	237	191	248	215
Air Dry		198	163	248	169

	Side hardness	Shear	Bearing strength	Cleavage resistance
Green	215	144	223	114
Air Dry	257	111	177	89

[1] Based on average values for green and air-dry toughness in this instance as comparable work to maximum load values, ordinarily employed, are not available.

Volumetric shrinkage of Jarána is 16.8 percent, comparable to that of White Oak although the wood is nearly half again as dense as Oak. Radial and tangential shrinkage values are 6.2 and 8.3 percent, respectively, and indicate greater uniformity for Jarána than for Oak in these two directions. The somewhat less dense *Holopyxidium latifolium* exhibits lower shrinkage values as shown in the accompanying tabulation.

Species and Source	SHRINKAGE (percent)			
	Radial	Tangential	Longitudinal	Volumetric
Jarána *(Holopyxidium jarana)* Brazil	6.2	8.3	0.20	16.8
(Holopyxidium latifolium) Brazil	4.4	7.5	0.00	13.7
White Oak[1] *(Quercus alba)* United States	5.3	9.0	—	15.8

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

The wood is reputed to be durable (22). This is borne out in this study by the results of exposure to a white-rot and a brown-rot fungus. In each case, Jarána was found to be very durable. The closely related species, *H. latifolium*, also proved to be very durable when exposed to both fungi. Jarána ties placed in poorly drained soil in Brazil lasted 6 to 8 years and ties used in well-drained soil remained sound 10 to 12 years (41). Jarána is low in resistance to marine borers. In tests conducted at Wrightsville, North Carolina (11) small specimens were subjected to heavy attack within the first year of exposure. Silica content, frequently associated with marine-borer resistance, was only 0.087 percent and total ash content 0.75 percent, both based on oven-dry weight of the wood (98).

Both species of *Holopyxidium* proved to be moderately difficult to work because of their density. Resulting smooth surfaces were obtained in sawing, boring, and planing. No pronounced dulling of cutting edges was observed.

Limited information is available in the literature as to the utilization of Jarána, although the wood appears to be extensively employed locally. Ducke (22) states that the wood is considered excellent in the Amazon region for carpentry and railway crossties. It is milled along the Bragança railroad in the region of Santarém in eastern Brazil, and is highly esteemed in the local trade. Because of its strength properties, and particularly because of its outstanding shock resistance, Jarána should find application as a replacement for such woods as Hickory.

References: 11, 22, 41, 58, 98.

ANGELIM *Hymenolobium excelsum* Ducke

This species is also called Angelim Pedra, and Angelim do Pará. It should not be confused with Angelin (*Andira inermis* [Sw.] H.B.K.) which it superficially resembles.

Angelim is one of the largest and most elegant trees of the upland forests of the lower Amazon (22), where it sometimes attains a height of 150 feet and a diameter of 10 feet.

The color of the unseasoned heartwood varies from light orange-tan to orange-brown. The fresh sapwood, which is from 1 to 4 inches wide, is light cream in color. The heartwood of dry wood is light brown in color; the sapwood grayish white. The grain may be straight or interlocked. Texture is uneven and rather coarse. The pores are visible to the unaided eye as openings on the end grain and as grooves on longitudinal surfaces. They are partly filled with a buff to amber colored granular material. The pores are mostly scattered individually but occasionally are in radial rows of two to six, but are surrounded and connected tangentially by relatively wide bands of parenchyma often wider than the intervening bands of wood fibers. Alternating dark zones of fibers and light zones of parenchyma give the wood a striking figure of the Partridge wood type, particularly on tangential surfaces. The rays are storied, very small, and inconspicuous on all surfaces except as revealed by fine "ripple marks" on tangential surfaces.

The average specific gravity of the wood is 0.63 (0.53-0.73) based on volume when green and weight when oven dry. The average weight per cubic foot in the green condition is 67 pounds, and at 12 percent moisture content it is 47 pounds.

Angelim is classified as moderately difficult to air season based on observations made during the present study. Rate of drying was fast to moderate, rapid drying being accompanied by moderate warping. Slight surface and end checking occurred under similar conditions. Moderate rates of drying would tend to eliminate these defects.

The strength properties of the unseasoned wood generally exceed those of other species of comparable density. While this is particularly true of compressive strength, exceptions should be noted in the case of stiffness, shock resistance, tension perpendicular to the grain, and cleavage which are about average for a wood of this density.

In the acompanying table, Angelim is compared with Hickory having approximately the same density. The green wood of Angelim exceeds that of Hickory by a wide margin in all static-bending properties except work to maximum load (shock resistance). It is also superior in compression, both parallel and perpendicular to the grain, and is comparable to Hickory in shear. A more complete comparison is permitted with White Oak which is only slightly lighter in weight than Angelim. With the single exception of cleavage resistance in which these woods are equivalent, Angelim is superior to White Oak and this is particularly evident in compressive strength parallel and perpendicular to the grain, elastic resilience, static-bending strength, hardness, and stiffness.

In general, the wood increased only slightly in strength upon air drying. Only in shock resistance was the proportionate increase in strength as high as that commonly shown by domestic hardwoods. Side hardness remained unchanged as did proportional limit stress in compression parallel to the grain, and appreciable losses in strength occurred in tension across the grain and cleavage.

When air dry, comparison of the strength properties of Angelim with those of other species of similar density is not so favorable as in the green condition. Elastic resilience, proportional limit stress in compression parallel to the grain, and

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		STATIC BENDING					COMPRESSION PARALLEL TO GRAIN			Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
							Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load	Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity							
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Angelim (*Hymenolobium excelsum*)	Brazil	3	Green	70.0	0.72	0.63	9,800	14,610	1,950	2.96	12.8	6,130	7,460	2,180	1640	1720	1360	860	1600	410	202.6
			Air Dry[1]	11.0			10,790	17,610	2,050	3.32	15.9	6,030*	8,990	2,280	2030	1720	1700	530*	2010	340*	
Shagbark Hickory[2] (*Carya ovata*)	United States		Green	60	0.78	0.64	5,900	11,000	1,570	1.28	23.7	3,430	4,580	—	—	—	1040	—	1520	—	—
			Air Dry	12			10,700	20,200	2,160	3.01	25.8	—	9,210	—	—	—	2170	—	2430	—	
White Oak[2] (*Quercus alba*)	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[3]
			Air Dry	12			8,200	15,200	1,780	2.27	14.8	4,760	7,440	—	1520	1360	1320	800	2000	450	

[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] U. S. Dept. Agr. Tech. Bul. 479 (64).

[3] Value obtained for plank material received from the New York Naval Shipyard.

hardness remain above average; static-bending strength, crushing strength, and shock resistance are about average; and all other properties are below the average for a wood of this density. The accompanying table shows that Angelim is slightly superior to Hickory in proportional limit stress in static bending and in elastic resilience but that it is somewhat inferior to Hickory in modulus of rupture, stiffness, crushing strength, bearing strength, shear, and notably deficient when compared to Hickory in shock resistance. In most respects the air-dry wood may be considered to be intermediate in strength to White Oak and Hickory, but even here exceptions must be noted in tension across the grain and cleavage resistance, for in these respects Angelim is surpassed by White Oak.

Although slightly heavier than White Oak, Angelim is characterized by a volumetric shrinkage only two-thirds that of Oak. Values for radial shrinkage of 4.4 percent, tangential shrinkage of 7.1 percent, and volumetric shrinkage of 10.2 percent are compared with shrinkage values for White Oak in the accompanying table. The close similarity of Angelim to Black Locust, widely known for its dimensional stability, is also shown in the table.

Species and Source	SHRINKAGE (percent) Radial	Tangential	Longitudinal	Volumetric
Angelim *(Hymenolobium excelsum)* Brazil	4.4	7.1	0.37	10.2
White Oak[1] *(Quercus alba)* United States	5.3	9.0	—	15.8
Black Locust[1] *(Robinia pseudoacacia)* United States	4.4	6.9	—	9.8

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

Little information is available in the literature concerning the durability of the species. In the present study heartwood proved to be very durable to durable upon exposure to a white-rot and very durable in resistance to a brown-rot fungus. Angelim is apparently only moderately resistant to marine borers. In exposure tests conducted at Wrightsville, North Carolina as a part of this study, small specimens showed evidence of moderate marine-borer activity after 12 months' immersion in infested waters (11). Total ash content of the wood is 0.37 percent and silica content, frequently associated with marine-borer resistance, only 0.002 percent (98).

The wood presented no problems in machining. It was easily worked and smooth surfaces resulted in all operations. No appreciable dulling of cutting edges was observed. The wood is easy to glue. Moisture absorption is intermediate, comparable to that of Mahogany. The wood withstands weathering quite well. Unpainted panels showed very little checking, although appreciable surface roughness had developed, after four years of exposure to the weather in New Haven. The wood is rated poor to fair in steam-bending quality.

Record and Hess (77) report that the timber is useful for strong and durable construction. Ducke (20) states that all woods of the genus *Hymenolobium* yield hard and strong timber which is employed industrially at Pará, chiefly in naval construction. It is also used in turnery with excellent results. He adds, however, that the quantity of Angelim, specifically, is limited and the timber is marketed internally only in small quantities (22).

References: 2, 7, 8, 11, 20, 22, 75, 77, 81, 94, 98.

SAPUCAIA *Lecythis paraensis* (Huber) Ducke

This species is also called Paradise Nut and Castanha Sapucaia. It is abundant in Pará and the lower Amazon on low land annually inundated by the crest of the flood.

The Sapucaias are tall trees, commonly 5-6 feet in diameter and free of limbs for 50-60 feet. The seeds, contained in large leathery conical fruits, are much esteemed for eating and are exported to Europe in considerable quantities where they are sold as Sapucaia nuts (26).

The freshly cut heartwood is orange tan in color, with some darker streaks; the sapwood, which is 2 to 2½ inches wide, is cream tan to cream yellow in color. The dry heartwood is salmon colored, and the sapwood creamy yellow in color. The wood is straight grained and fine textured. The pores are visible distinctly on end surfaces as whitish dots and on longitudinal surfaces of the heartwood as lighter colored lines due to being filled with light-colored tyloses. They are mostly solitary, occasionally in pairs, and evenly distributed over the cross section. Numerous fine light-colored tangential lines of parenchyma spaced from one-fourth to one-half the radial diameter of the pores apart can be seen with a hand lens. Gradual narrowing down of the spacing of the parenchyma lines followed by an abrupt increase in the spacing sharply defines growth layers. The rays are very fine and inconspicuous on all surfaces. The wood lacks any distinctive odor or taste.

The average specific gravity of the wood is 0.88 (0.85-0.92) based on green volume and oven-dry weight. The weight of the green wood is 80 pounds and that of the wood at 12 percent moisture content is 66 pounds per cubic foot.

The wood of another species of this genus, namely *Lecythis usitata* Miers var. *tenuifolia* Knuth, known locally as Castanha Sapucaia, was also tested under this project. This timber grows in the upland forests of Brazil. The nuts are small and of little value.

The color of the fresh heartwood was darker (liver color) but, when dry, about the same as that of *L. paraensis*. The gross anatomical features are practically the same for the two woods except that in Castanha Sapucaia the growth zones are limited by a wider line of parenchyma, or possibly two lines very close together. The grain was straight or slightly interlocked. Average specific gravity of *L. usitata tenuifolia* was 0.93 based on oven-dry weight and green volume. Weight per cubic foot in the air-dry condition was 69 pounds.

Sapucaia is rated easy to air season. In spite of its relatively high density, lumber dried rapidly with little defect. Crook, twist, end checking, and casehardening were all observed to be slight.

The wood of Sapucaia is denser and stronger than that of any domestic species. When compared with other tropical woods of similar high density, the unseasoned wood is above average in shock resistance, tension, and compression across the grain, cleavage, and side hardness, and equal to the average in other properties including bending and crushing strengths. The accompanying table permits of a comparison with unseasoned Greenheart and indicates the close similarity of these woods in nearly all mechanical properties. Sapucaia is slightly superior to Greenheart in shock resistance and shear and somewhat below Greenheart in stiffness and crushing strength. The table also presents comparable data based on a single log of Castanha Sapucaia *(Lecythis usitata* var. *tenuifolia)*, which, although slightly heavier than *Lecythis paraensis*, was found to be weaker in nearly all respects in the green condition.

Upon air drying, the wood improved substantially in most properties, but only in modulus of rupture, work to maximum load, and end hardness was the proportionate increase as great as that commonly shown by domestic hardwoods. Shear strength remained virtually unchanged, whereas compression and tension across the grain and cleavage resistance suffered considerable decrease upon air seasoning. It is probable that at least a part of such decreased strength is attributable to seasoning checks.

The air-seasoned wood is equal to or above average for woods of comparable high density in all static-bending properties including work to maximum load, and also in crushing strength and hardness, but it is below the average for such woods in transverse compression and tension, shear, and cleavage resistance. In the air-dry condition Sapucaia appears to be superior to the denser Castanha Sapucaia in static-bending strength, stiffness, and crushing strength, but is surpassed by the latter species in shock resistance, hardness, compression and tension across the grain, shear, and cleavage resistance. When compared with Greenheart, the air-dry wood of

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		STATIC BENDING				
							Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Sapucaia (*Lecythis paraensis*)	Brazil	2	Green	45.9	1.00	0.88	13,150	18,340	2,890	3.35	15.0
			Air Dry[1]	13.1			18,170	27,540	3,380	5.36	26.3
Castanha Sapucaia (*Lecythis usitata* var. *tenuifolia*)	Brazil	1	Green	—	1.05	0.93	11,280	16,440	2,430	2.97	12.7
			Air Dry[1]	13.7			13,120	24,550	2,600	3.67	32.4
Greenheart[2] (*Ocotea Rodiaei*)	British Guiana		Green	42.7	1.06	0.88	13,250	19,550	2,970	3.31	13.4
			Air Dry[1]	14.8			16,200*	25,500*	3,700*	4.02*	22.0*
White Oak[3] (*Quercus alba*)	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
			Air Dry	12			8,200	15,200	1,780	2.27	14.8

Species	Condition	COMPRESSION PARALLEL TO GRAIN			Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity							
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Sapucaia (*Lecythis paraensis*) Brazil	Green	8,000	8,880	3,430	1740	2430	2170	1280	2000	620	295.8
	Air Dry[1]	9,160	13,280	3,650	3140	3100	1690*	580*	2060	280*	
Castanha Sapucaia (*Lecythis usitata* var. *tenuifolia*) Brazil	Green	6,710	8,540	2,840	1830	2290	1270	890	1920	590	396.1
	Air Dry[1]	8,080	10,680	2,880	3480	3560	2580	900	2480	540*	
Greenheart[2] (*Ocotea Rodiaei*) British Guiana	Green	7,580	10,160	3,580	2260	2320	2040	1070	1730	610	—
	Air Dry[1]	10,000*	12,920*	4,160*	2140*	2630*	1970*	1020*	1830*	—	
White Oak[3] (*Quercus alba*) United States	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[4]
	Air Dry	4,760	7,440	—	1520	1360	1320	800	2000	450	

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[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] Kynoch and Norton (54).

[3] U. S. Dept. Agr. Tech. Bul. 479 (64).

[4] Value obtained for plank material received from the New York Naval Shipyard.

Sapucaia is slightly superior in static-bending strength, elastic resilience, shock resistance, crushing strength, and shear. It is substantially above Greenheart in hardness, but is somewhat less stiff and is inferior to Greenheart in transverse compression and especially in tension across the grain. In cleavage and tension across the grain, Sapucaia is also surpassed by air-dry White Oak.

The following table presents a convenient comparison of both green and air-dry properties of Sapucaia with those of White Oak. In each case a value of 100 has been assigned to Oak.

	Specific gravity	Bending strength	Stiffness	Shock resistance	Crushing strength
Green	146	221	231	129	249
Air Dry		181	190	178	179

	Side hardness	Shear	Bearing strength	Cleavage resistance
Green	229	160	262	148
Air Dry	228	103	128	62

Shrinkage of Sapucaia is low in relation to its density. Volumetric shrinkage of 13.4 percent is less than that of White Oak, and radial and tangential shrinkage values of 6.0 and 7.6 percent, respectively, indicate exceptional uniformity in these two directions. Castanha Sapucaia is shown in the accompanying tabulation to be similar to Sapucaia in shrinkage.

Species and Source	SHRINKAGE (percent)			
	Radial	Tangential	Longitudinal	Volumetric
Sapucaia *(Lecythis paraensis)* Brazil	6.0	7.6	0.10	13.4
Castanha Sapucaia *(Lecythis usitata* var. *tenuifolia)* Brazil	5.2	6.2	0.08	11.5
White Oak[1] *(Quercus alba)* United States	5.3	9.0	—	15.8

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

The wood was found in this study to be very durable upon exposure to both a white-rot and a brown-rot fungus. This confirms a local reputation for high resistance to decay. Sapucaia ties placed in poorly drained soil in Brazil lasted 6 to 8 years and those in well-drained soil remained sound 10 to 15 years (41). Sapucaia has been noted by Edmondson (23) as highly resistant to marine-borer attack on the basis of 12 months' exposure in heavily infested Hawaiian waters. Small specimens exposed at Wrightsville, North Carolina have also shown a considerable degree of resistance, having undergone only slight deterioration after one year of immersion. The closely related *Lecythis usitata* var. *tenuifolia*, exposed in an earlier series at the same location, displayed a similar resistance, undergoing only slight attack during the first two years of exposure, and only gradually succumbed, showing evidence of fairly heavy marine-borer activity in the fourth year of exposure. Under the same conditions Greenheart showed signs of moderate attack in 16 months and of heavy damage in 2½ years (10, 11). Chemical analyses conducted on material from the same logs that supplied exposure test specimens of Sapucaia, showed a total ash content of 0.41 percent and a silica content of only 0.048 percent (98).

Moderate difficulty was encountered in working the wood because of its density. Surfaces obtained in planing, sawing, and boring operations were smooth, and no appreciable dulling of cutting edges was observed.

Record and Hess (77) suggest that woods of the genus *Lecythis* are suitable for heavy construction and purposes requiring a strong, resilient material. Local uses of Sapucaia in Brazil include civil and naval construction, wheel spokes, wagon poles, ship keels and beams, and crossties (26).

References: 10, 11, 17, 23, 26, 41, 50, 56, 69, 77, 98.

MARISHIBALLI *Licania buxifolia* Sandw.

This species of timber grows in British Guiana where it is common in the Wallaba (*Eperua falcata* Aubl.) forests. The typical tree, which is 90 to 110 feet in height, has a large crown and an unbuttressed bole 50 to 60 feet long. The diameter usually is 16 to 24 inches, and occasionally up to 36 inches.

The freshly cut heartwood is reddish brown to dark brown in color. The sapwood, which is from 1½ to 2½ inches wide, is light reddish tan or light brown. When dry, the heartwood is medium brown in color and the sapwood is tan. It is without characteristic odor or taste. The wood is straight-grained and fine in texture. Zoned growth layers are practically absent. The pores, which are barely visible to the unaided eye on the end surface are arranged in a vague, irregular radial pattern, although the individual pores are mostly isolated. The pores in the heartwood contain tyloses. With a hand lens numerous fine tangential lines of parenchyma can be seen between the pores, usually less than a radial pore diameter apart. The rays are very fine. On smoothly cut longitudinal surfaces the pores are visible as very fine grooves.

The average specific gravity of the wood is 0.88 (0.83-0.95) based on green volume and oven-dry weight. Weight per cubic foot in the green condition is 75 pounds and at 12 percent moisture content is 68 pounds.

This species is rated moderately difficult to air season. Material observed in the present study exhibited a moderate rate of drying which was accompanied by slight warping and surface checking. Casehardening appeared to be very slight.

Most of the strength properties of Marishiballi are considerably in excess of those shown by any domestic wood. In comparison with other tropical species of similar high density, however, the unseasoned wood is somewhat below average in strength. This is particularly true in the case of tension across the grain and cleavage resistance. Stiffness, on the other hand, is higher than the average anticipated for a wood of its density.

As shown in the accompanying table, the mechanical properties of the unseasoned wood are equal to those of Greenheart in shock resistance (work to maximum load) and

slightly below Greenheart in bending strength, hardness, shear, and stiffness. The deficiencies of Marishiballi are more apparent in compression parallel to the grain, and particularly in tension and compression perpendicular to the grain and in cleavage. The table also reveals a striking superiority of Marishiballi over White Oak in all properties except work to maximum load, tension perpendicular to the grain, and cleavage.

Upon air drying, the wood increased moderately in most mechanical properties. The proportionate increase in strength exceeded that generally shown by domestic hardwoods in elastic resilience and side hardness, and was comparable to that of most domestic species in proportional limit stress, modulus of rupture, and work to maximum load in static bending. Other increases were less than would be anticipated on the basis of the behavior of domestic woods, and considerable loss in strength in both cleavage and tension across the grain occurred as a result of drying.

The air-dry wood of Marishiballi is somewhat above average for its density in static-bending strength, elastic resilience, and side hardness, and about average in other properties with the exception of shock resistance, shear, tension across the grain, and cleavage resistance. In the three last named properties, the wood is notably deficient. The relative strengths and weaknesses of the wood are clearly shown in a comparison with Greenheart in the accompanying table.

A convenient comparison of both the green and air-dry properties of Marishiballi with those of White Oak is presented in the following tabulation in which White Oak has been assigned arbitrarily a rating of 100.

	Specific gravity	Bending strength	Stiffness	Shock resistance	Crushing strength
Green	146	206	234	116	213
Air Dry		182	188	96	180

	Side hardness	Shear	Bearing strength	Cleavage resistance
Green	212	130	172	86
Air Dry	263	88	169	49

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		STATIC BENDING: Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Marishiballi *(Licania buxifolia)*	British Guiana	3	Green	37.3	1.07	0.88	10,570	17,070	2,930	2.27	13.4
			Air Dry[1]	12.5			19,440	27,660	3,340	6.49	14.2
Greenheart[2] *(Ocotea Rodiaei)*	British Guiana		Green	42.7	1.06	0.88	13,250	19,550	2,970	3.31	13.4
			Air Dry[1]	14.8			16,200*	25,500*	3,700*	4.02*	22.0*
White Oak[3] *(Quercus alba)*	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
			Air Dry	12			8,200	15,200	1,780	2.27	14.8

Species	Condition	COMPRESSION PARALLEL TO GRAIN: Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Marishiballi *(Licania buxifolia)* British Guiana	Green	6,190	7,580	3,230	2050	2250	1430	750	1620	360	213.3
	Air Dry[1]	10,050	13,390	3,360	—[4]	3570	2230	250*	1750	220*	
Greenheart[2] *(Ocotea Rodiaei)* British Guiana	Green	7,580	10,160	3,580	2260	2320	2040	1070	1730	610	—
	Air Dry[1]	10,000*	12,920*	4,160*	2140*	2630*	1970*	1020*	1830*	—	
White Oak[3] *(Quercus alba)* United States	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[5]
	Air Dry	4,760	7,440	—	1520	1360	1320	800	2000	450	

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[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] Kynoch and Norton (54).

[3] U. S. Dept. Agr. Tech. Bul. 479 (64).

[4] End hardness values precluded due to splitting under test.

[5] Value obtained for plank material received from the New York Naval Shipyard.

Shrinkage of Marishiballi is high for a tropical wood, exceeding that of Greenheart in every respect. It is, however, no greater than that of a number of domestic hardwoods of much lower density. Radial shrinkage of Marishiballi is 7.5 percent, tangential shrinkage 11.7 percent, and volumetric shrinkage 17.2 percent. As shown in the accompanying table each of these is greater than the corresponding value for White Oak.

	SHRINKAGE (percent)			
Species and Source	Radial	Tangential	Longitudinal	Volumetric
Marishiballi *(Licania buxifolia)* British Guiana	7.5	11.7	0.21	17.2
Greenheart[1] *(Ocotea Rodiaei)* British Guiana	8.2	9.0	—	16.8
White Oak[2] *(Quercus alba)* United States	5.3	9.0	—	15.8

[1] Kynoch and Norton (54).

[2] U. S. Dept. Agr. Tech. Bul. 479 (64).

Woods of the genus *Licania* are reputed to be low in resistance to decay (77). In durability tests conducted as a part of this study, however, Marishiballi heartwood was rated very durable in resistance to both a white-rot and a brown-rot fungus.

Marishiballi is a member of a genus *(Licania)* which is widely known for the high silica content and marine-borer resistance of its wood. In tests conducted at Wrightsville, North Carolina as a part of this study, Marishiballi has displayed extremely high resistance to attack. Small samples showed no evidence of attack in the first 9 months of exposure and only slight marine-borer activity after 20 months (10, 11). It would appear that *Licania buxifolia* is deserving of a rating at least equal to that of "considerable resistance" given by Edmondson (23) to the closely related *L. densiflora* on the basis of tests in Hawaiian waters. Chemical analyses of samples from the same logs from which exposure specimens for the Wrightsville tests were obtained

showed for *L. buxifolia* a total ash content of 0.88 percent and silica content of 0.432 percent (98). Other species of *Licania* have been reported to contain as much as 2.5 percent silica (1).

The wood is difficult to work owing to its high density and silica content. Although smooth surfaces resulted in planing, boring, and sawing operations, rapid dulling of cutting edges was observed.

Marishiballi is reported to be useful for house framing and paving blocks (25, 92). Record and Hess (77) note that species of the genus *Licania* are being used locally in the tropics for charcoal and for heavy construction not in contact with the ground. The high marine-borer resistance of this species suggests application in piling and other marine construction.

References: 1, 10, 11, 23, 25, 77, 92, 98.

ANAUERA *Licania macrophylla* Benth.

This wood is also known as Anaura (Brazil); Sponsehoedoe, Kauston (Surinam); Marishiballi (British Guiana); Gris-gris, Gris-gris Coumate, and Gris-gris Rouge (French Guiana).

The species grows in Surinam, British Guiana, French Guiana, and the lower Amazon region of Brazil. It is frequent in the overflow woodlands of the Amazon estuary up to the mouth of the Xingu River, but it is also found in the upland forests of the lower Amazon region. The tree is of medium size, ranging from 65 to 80 feet in height and 20 to 36 inches in diameter (3).

The wood when freshly cut is reddish brown sometimes with light and dark streaks around the pith. The sapwood, which is ½ inch to 1½ inches wide, is tan colored. The seasoned heartwood is moderately dark brown with a reddish tinge. The wood is straight grained and of medium to fine texture. The pores on the end surface are at the limit of vision to the unaided eye, but on planed longitudinal surfaces they appear distinctly as fine grooves. In the heartwood a few pores are filled with a white deposit; some contain tyloses, but most of them are open. The pores are scattered singly without forming any distinct pattern. The rays are very fine on the end surface as seen with a hand lens and inconspicuous on longitudinal surfaces. The parenchyma occurs in numerous fine tangential lines, spaced less than the diameter of a pore apart except at irregular intervals where the spacing is wider resulting in a darker colored zone mildly demarcating growth layers.

The specific gravity based on volume when green and weight when oven dry averages 0.76 (0.70-0.81). The average weight per cubic foot in the green condition is 71 pounds and at 12 percent moisture content is 58 pounds.

In this study the wood from Surinam was found to be easy to air season while that from Brazil proved to be moderately difficult. That from Surinam dried at a fast rate while that from Brazil dried at a moderate rate. Slight defect in the form of warping, checking, and casehardening was observed in material from both sources. Warping in the form of crook and twist was slightly more severe in the material from Brazil. Material from one log of *Licania* sp. exhibited seasoning characteristics very similar to those of Anauera from Surinam.

The strength properties of Anauera from Brazil and Surinam are not appreciably different, and the average strength values presented in the accompanying table may be considered representative of the species. Although not included in the species average, data based upon tests of a single log from Surinam, designated as Anauera but unidentified as to species, are also shown in the table. These values are in rather close agreement with the averages shown for *L. macrophylla* with respect to strength as well as density.

Although most of the strength properties of Anauera compare favorably with those of the strongest domestic woods, the unseasoned wood is generally weaker than that of other tropical species of similar high density. Modulus of elasticity, however, is slightly higher than average for woods of comparable density.

The unseasoned wood is markedly superior to Hickory in all static-bending properties except work to maximum load (shock resistance), as well as in all compression parallel to grain strength properties. It is slightly exceeded by Hickory, however, in compression perpendicular to the grain, and in shear. Further data on Hickory are lacking for comparison, but there is little doubt that Hickory exceeds Anauera by a considerable margin in toughness. Comparison with White Oak reveals the even greater superiority of Anauera in static-bending properties, with the exception of shock resistance in which these woods are approximately equal, as well as in compression parallel to the grain, hardness, compression perpendicular to the grain, and toughness. The unseasoned wood is comparable to White Oak in shear, tension across the grain, and cleavage.

The wood increased moderately in most mechanical properties upon drying. The proportionate increase in strength exceeded that shown generally by domestic hardwoods only in work to maximum load, side hardness, and shear. Other increases were less than those exhibited by most domestic woods and serious loss of strength upon air drying was shown in tension across the grain and in cleavage resistance.

The air-dry wood of Anauera compares favorably with other woods of similar high density in strength properties in compression parallel to the grain and hardness. It is equivalent to the average wood of comparable high density in static-bending strength and stiffness, and below average in shock resistance, compression perpendicular to the grain, shear, tension perpendicular to the grain, and cleavage resistance. In the last two properties the deficiency of Anauera is striking. Comparison of the air-dry wood with Hickory in the accompanying table again reveals the superiority of Anauera in static-bending strength, stiffness, and crushing strength, but very evident deficiencies occur in shock resistance, compressive strength perpendicular to the grain, and shear. Other data for comparison of these two species are lacking, but some remarkable comparisons may be made with White Oak. Air-dry Anauera is almost twice as hard as

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		Static Bending				
							Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Anauera (*Licania macrophylla*)	Brazil	3	Green	47.3	0.90	0.75	10,090	15,500	2,490	2.34	11.2
			Air Dry[1]	11.3			14,360	21,140	2,320*	4.86	—
	Surinam	3	Green	52.3	0.91	0.76	9,040	13,250	2,140	2.12	9.2
			Air Dry[1]	11.7			12,740	20,160	2,750	3.32	15.4
	Average	6	Green	49.8	0.90	0.76	9,560	14,380	2,320	2.23	10.2
			Air Dry[1]	11.5			13,550	20,650	2,530	4.09	15.4
Anauera (*Licania* sp.)	Surinam	1	Green	47.9	0.90	0.75	10,410	15,120	2,490	2.46	16.6
			Air Dry[1]	12.3			14,300	21,360	2,920	3.99	17.4
Shagbark Hickory[2] (*Carya ovata*)	United States		Green	60	0.78	0.64	5,900	11,000	1,570	1.28	23.7
			Air Dry	12			10,700	20,200	2,160	3.01	25.8
White Oak[2] (*Quercus alba*)	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
			Air Dry	12			8,200	15,200	1,780	2.27	14.8

Species	Condition	Compression Parallel to Grain			Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity							
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Anauera (*Licania macrophylla*)											
Brazil	Green	6,180	7,060	2,640	1740	1740	970	820	1370	410	163.7
	Air Dry[1]	8,260	11,390	2,780	2580	2430	1740	470*	2010	240*	
Surinam	Green	4,980	6,370	2,290	1700	1710	910	860	1260	350	251.4
	Air Dry[1]	8,050	10,620	2,580	2700	2690	1440	320*	1700	240*	
Average	Green	5,580	6,720	2,460	1720	1720	940	840	1320	380	207.6
	Air Dry[1]	8,160	11,010	2,680	2640	2560	1590	400*	1850	240*	
Anauera (*Licania* sp.)											
Surinam	Green	4,740	5,780	2,920	1440	1520	940	770	1170	300	217.1
	Air Dry[1]	8,540	11,390	2,650*	2630	2400	1370	330*	1680	260*	
Shagbark Hickory[2] (*Carya ovata*)											
United States	Green	3,430	4,580	—	—	—	1040	—	1520	—	—
	Air Dry	—	9,210	—	—	—	2170	—	2430	—	
White Oak[2] (*Quercus alba*)											
United States	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[3]
	Air Dry	4,760	7,440	—	1520	1360	1320	800	2000	450	

[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] U. S. Dept. Agr. Tech. Bul. 479 (64).

[3] Value obtained for plank material received from the New York Naval Shipyard.

Oak, only slightly stronger than Oak in compression across the grain, slightly weaker than Oak in shear, and only about half as resistant as Oak in tension across the grain and cleavage.

Anauera exhibits considerable shrinkage although even this is no more than that shown by many domestic hardwoods of appreciably lower density. As shown in the accompanying tabulation, good agreement was found between shrinkage data based on material from sources in Brazil and Surinam. Average values of 6.1 percent for radial, 9.9 percent for tangential, and 16.2 percent for volumetric shrinkage are only slightly greater than comparable values for White Oak. Shrinkage values determined for *Licania* sp. of Surinam are also shown in the table.

	SHRINKAGE (percent)			
Species and Source	Radial	Tangential	Longitudinal	Volumetric
Anauera				
(*Licania macrophylla*)				
Brazil	5.4	9.2	0.21	16.2
Surinam	6.8	10.6	0.31	16.2
Average	6.1	9.9	0.26	16.2
Anauera				
(*Licania* sp.)				
Surinam	5.8	11.4	0.26	16.6
White Oak[1]				
(*Quercus alba*)				
United States	5.3	9.0	—	15.8

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

As is the case with other woods of the genus, Anauera is reputed to be low in resistance to decay (42, 68, 77). Material tested in this study, however, ranged in resistance to decay from very durable to moderately durable when exposed to both a brown-rot and a white-rot fungus. Results from one log of *Licania* sp. classify this wood as durable to both a white-rot and a brown-rot fungus. *Licania macrophylla* appears to be representative of the more highly resistant species of the genus with respect to marine-borer attack. Only slight activity of these organisms was noted in small samples of Anauera during the first year of exposure in heavily infested waters at Wrightsville, North Carolina (11). This performance is comparable to that noted by Edmondson (23) for *Licania densiflora* in Hawaiian waters. Chemical analyses of samples from the same logs used in the Wrightsville tests, originating in Brazil and Surinam, showed remarkable similarity, averaging 1.98 percent in total ash content and 1.52 percent of silica based on oven-dry weight of the wood (98). This represents the highest silica content of any of the tropical American species that have been tested at New Haven. Other references (42) cite the high resistance of *Licania macrophylla* to attack by marine borers, and the high silica content reported here is confirmed by Amos (1) who reports a silica content of 1.8 percent for this species.

Machining characteristics of the wood are poor owing to its density and extremely high silica content. Rapid dulling of cutting edges was observed, although smooth surfaces resulted in all operations when tools were kept sharp.

Woods of the genus *Licania* are reported to be used locally for charcoal and for heavy construction not in contact with the ground (77). Although difficult to saw and plane, structural timbers can be shaped with adze or axe. On account of its high density, dulling effect on sharp-edged tools, and only moderate decay resistance, efficient use of this wood is limited largely to underwater marine construction.

References: 1, 3, 11, 23, 42, 57, 68, 77, 98.

KANEELHART *Licaria cayennensis* (Meissn.) Kosterm. (= *Acrodiclidium cayennense* [Meissn.] Mez)

This species is also known as Brown Silverballi, Wabaima, Waibama (British Guiana); Kanerie Hoedoe, Nagre Hoedoe, Sieroeaballi Tatroe (Surinam); Bois Canelle, Cedre Flibustier (French Guiana).

The logs used for test purposes were obtained from British Guiana and Surinam. The species also grows in French Guiana. Although numerous species of *Licaria* grow in tropical America, there is little information concerning them. A closely related species, *Licaria canella* (Meissn.) Kosterm., which also is called Kaneelhart, has a somewhat wider distribution including Trinidad and the Amazonian district (73). Kaneelhart is a medium-sized tree, attaining a height of 100 feet or more and a diameter of about 2 feet. The trees from which the test logs from British Guiana were obtained grew in association with Greenheart on hilly terrain.

The freshly cut heartwood of *Licaria cayennensis* is orange yellow in color becoming yellowish brown to coffee brown on drying and exposure. The water extract of the heartwood is light yellow but becomes red on addition of alkali. The sapwood is light yellowish brown and ½ inch to 2 inches in width. The freshly cut unseasoned wood is characterized by a fragrant odor, most of which is lost upon drying.

The grain is straight or slightly interlocked and texture is fine. The growth rings, when discernible, are weakly and vaguely defined by narrow zones of wood relatively poor in pores. The pores are barely visible on smoothly-cut end surfaces and are filled with tyloses. On longitudinal surfaces they can be seen as fine grooves. Parenchyma in any form is not visible with a lens. The rays are very fine on end surfaces, and inconspicuous on longitudinal surfaces. The average specific gravity based on green volume and oven-dry weight is 0.96 (0.87-1.04). Weight in the green condition is 78 pounds and at 12 percent moisture content is 72 pounds per cubic foot.

Kaneelhart showed some variability in air-seasoning characteristics depending upon the source of stock. Material from British Guiana and Surinam dried at a rapid rate, although somewhat more defect resulted in the latter which represented the denser material. Results of these tests indicate a rating of easy to season for stock originating from British Guiana and a rating of moderately difficult to season for stock from Surinam. The rapid rate of drying observed for the limited stock available from Surinam appears exceptional in view of its extreme density. However, slight warp was accompanied by severe surface checking. Moderate casehardening was also observed. On the other hand, the rapid rate of drying observed for stock originating from British Guiana was accompanied only by slight warping, checking, and casehardening.

Kaneelhart is an exceptionally dense and strong timber as shown in the accompanying table. Data on this species are shown for material originating in British Guiana and Surinam. Although the sample from Surinam was somewhat denser and rather generally stronger, these differences are probably not significant insofar as source is concerned, and the data from both sources have been averaged to represent the species. Most of the strength properties of Kaneelhart are far in excess of those characteristic of any domestic wood. Even when compared with other tropical woods approaching it in density, Kaneelhart in the green condition is superior in all static-bending properties except work to maximum load, as well as in compression parallel and perpendicular to the grain, and toughness. It is equivalent in tension across the grain and work to maximum load to the average value that might be anticipated for a wood of corresponding density, and below such an average only in hardness, shear, and cleavage.

Kaneelhart equals unseasoned Greenheart in shock resistance and exceeds that species in every other mechanical respect except hardness and cleavage resistance. Even in the latter instances the differences are not great. In the green condition, Kaneelhart surpasses White Oak in every mechanical property, with marked superiority in stiffness, crushing strength, bearing strength, bending strength, elastic resilience, hardness, and toughness. In these properties values for Kaneelhart are two to four times as great as those for Oak.

Upon air drying, Kaneelhart improved slightly in most properties but only in side hardness and work to maximum load in static bending were these increases as great as those normally shown for domestic hardwoods. End hardness and strength in compression perpendicular to the grain decreased slightly, and resistance to tension across the grain and cleavage dropped to a marked extent upon seasoning.

The air-seasoned wood of Kaneelhart is equal or superior to other woods approaching it in density in all static-bending

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		STATIC BENDING				
							Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Kaneelhart *(Licaria cayennensis)*	British Guiana	3	Green	35.2	1.02	0.89	14,450	19,570	3,380	3.78	13.3
			Air Dry[1]	11.4			18,220	27,060	3,570	5.29	17.1
	Surinam	1	Green	25.6	1.19	1.03	22,320	24,970	4,260	5.72	13.8
			Air Dry[1]	11.9			21,500*	32,670	4,540	5.44*	17.9
	Average	4	Green	30.4	1.10	0.96	18,380	22,270	3,820	4.75	13.6
			Air Dry[1]	11.6			19,860	29,860	4,060	5.36	17.5
Greenheart[2] *(Ocotea Rodiaei)*	British Guiana		Green	42.7	1.06	0.88	13,250	19,550	2,970	3.31	13.4
			Air Dry[1]	14.8			16,200*	25,500*	3,700*	4.02*	22.0*
White Oak[3] *(Quercus alba)*	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
			Air Dry	12			8,200	15,200	1,780	2.27	14.8

Species	Condition	COMPRESSION PARALLEL TO GRAIN					Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity	Hardness						
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Kaneelhart *(Licaria cayennensis)*											
British Guiana	Green	8,590	10,160	3,650	1720	2080	2110	1250	1980	480	223.3
	Air Dry[1]	13,060	15,690	3,760	1900	2560	2440	470*	1910*	310*	
Surinam	Green	14,680	16,620	4,900	2520	2340	4290	1280	1380	460	350.2
	Air Dry[1]	17,840	19,100	4,980	2150*	3230	3100*	390*	2030	270*	
Average	Green	11,640	13,390	4,280	2120	2210	3200	1260	1680	470	286.8
	Air Dry[1]	15,450	17,400	4,370	2020*	2900	2770*	430*	1970	290*	
Greenheart[2] *(Ocotea Rodiaei)*											
British Guiana	Green	7,580	10,160	3,580	2260	2320	2040	1070	1730	610	—
	Air Dry[1]	10,000*	12,920*	4,160*	2140*	2630*	1970*	1020*	1830*	—	
White Oak[3] *(Quercus alba)*											
United States	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[4]
	Air Dry	4,760	7,440	—	1520	1360	1320	800	2000	450	

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[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] Kynoch and Norton (54).

[3] U. S. Dept. Agr. Tech. Bul. 479 (64).

[4] Value obtained for plank material received from the New York Naval Shipyard.

properties except work to maximum load, and also in compression parallel and perpendicular to the grain. It is somewhat below the average anticipated for a wood of its very high density in hardness, shear, work to maximum load in bending, and particularly low in tension across the grain and cleavage resistance.

As shown in the accompanying table, seasoned Kaneelhart compares favorably with Greenheart in static-bending strength, stiffness, crushing strength, side hardness, compressive strength across the grain, and shear. It is somewhat less resistant than Greenheart to shock as measured by work to maximum load, and much weaker in tension across the grain which is associated with resistance to checking and splitting. The air-dry wood surpasses White Oak by a wide margin in most properties, although only equivalent to Oak in shear strength and considerably below Oak in tension perpendicular to the grain and cleavage resistance. The following tabulation, in which values for White Oak are taken as 100, permits a convenient comparison of the relative properties of Kaneelhart and Oak in both the green and air-dry conditions.

	Specific gravity	Bending strength	Stiffness	Shock resistance	Crushing strength
Green	160	269	306	117	377
Air Dry		196	228	118	234

	Side hardness	Shear	Bearing strength	Cleavage resistance
Green	208	134	386	112
Air Dry	213	98	210	64

Kaneelhart is unusually low in shrinkage in consideration of its exceptionally high density. Material from British Guiana and Surinam showed comparable values. An average radial shrinkage of 5.4 percent is comparable to that of White Oak, and shrinkage values of 7.9 percent tangentially and 12.5 percent volumetrically are substantially less than those of White Oak.

Species and Source	SHRINKAGE (percent)			
	Radial	Tangential	Longitudinal	Volumetric
Kaneelhart				
(Licaria cayennensis)				
British Guiana	5.3	7.4	0.25	12.2
Surinam	5.6	8.4	0.09	12.8
Average	5.4	7.9	0.17	12.5
White Oak[1]				
(Quercus alba)				
United States	5.3	9.0	—	15.8

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

Excellent resistance to decay was shown by the wood in exposures completed as a part of this study. Material from both sources proved very durable in resistance to both a white-rot and a brown-rot fungus. Durability reports are lacking in the literature although Record and Hess (77) state that the closely related species *Licaria canella* is noted for its resistance to decay. Kaneelhart showed only light marine-borer activity after 12 months' exposure to attack in heavily infested waters at Wrightsville, North Carolina. Fairly heavy damage was noted, however, after 20 months' immersion (10, 11). This performance is supported by the observations of Edmondson (23) that the closely related *Licaria canella* of British Guiana showed little resistance to attack when tested in Hawaiian waters. Chemical analyses have shown *Licaria cayennensis* to have an extremely low ash content of 0.03-0.08 percent and a negligible silica content (1, 98, 105,106). Although spectrographic analysis of the ash showed a medium intensity for silicon (105), the significance of this is limited by the extremely low ash content of the wood.

The wood is difficult to work although smooth surfaces resulted in planing, boring, and sawing. Considerable care was required in the boring operation to overcome a tendency to splinter. The slightly interlocked grain had little effect on surface quality. No appreciable dulling of tools was observed, which can be explained by the very slight trace of silica in the wood. The wood can be glued satisfactorily but the gluing operation requires special care because of the extremely high density of this species.

The literature contains no direct reference to the utilization of this species. The closely related *Licaria canella* is referred to by Record and Hess (77) as being of similar specific gravity to *L. cayennensis*, and Fanshawe (25) reports that the former species is used in British Guiana for boat building, canoes, furniture, interior work, and general carpentry. However, he describes the wood as being only moderately heavy, 40 to 45 pounds per cubic foot, and easily worked, which is so contradictory to the results of this study of *Licaria cayennensis* as to raise serious doubt concerning the similarity of these species.

Kaneelhart should be adapted to special uses that require a wood involving qualities of extreme hardness, bending or compressive strength, abrasion resistance, and durability. Pfeiffer (68) has suggested that such uses include furniture, musical instruments, parquet flooring, bridge decking and flooring, and durable construction, both above and below water, so long as the marine borer hazard is low.

References: 1, 10, 11, 23, 25, 68, 73, 77, 94, 98, 105, 106.

ITAÚBA *Mezilaurus itauba* (Meissn.) Taub.
(= *Silvia itauba* [Meissn.] Pax)

The lighter colored wood of this species is known as Itaúba Amarella and the darker wood as Itaúba Preta. Other names used are Kaneerjoe, Apisie-ie, Tapinhoa, and Siroeaballi Tataro. It is also called Kaneelhout but should not be confused with Kaneelhart (*Licaria cayennensis* [Meissn.] Kosterm.).

Itaúba grows in the Guianas and eastern Amazonas to northwestern Matto Grosso in Brazil. It is a large upland tree sometimes over 120 feet in height and 30 inches in diameter.

The freshly cut heartwood is light to dark olive brown in color, and the sapwood, which is about one inch wide, is tan to light brown in color. The dry heartwood is dark olive brown and the sapwood light grayish brown. The wood has an oily appearance and feel, but no distinctive odor when dry. The grain is straight or interlocked and the texture of the wood is fine. The pores are barely visible on the end surface but appear as fine grooves or lines on longitudinal surfaces. In the heartwood they are more or less completely plugged with tyloses, although in the sapwood they are open. They frequently occur in radial rows of 2 to 6. Parenchyma is not distinctly visible even with a lens. Variations in the porosity of the wood produce vague growth zones. The rays are fine and inconspicuous on all surfaces.

The average specific gravity of the wood is 0.68 (0.54-0.77) based on green volume and oven-dry weight. The weight per cubic foot when green is 69 pounds, and at 12 percent moisture content it is 51 pounds.

Itaúba is rated difficult to air season. Material which dried at a moderate rate developed slight to moderate defect in the form of crook, twist, and both surface and end checking. Only slight casehardening occurred during air seasoning. In order to keep warping and checking at a minimum, mild seasoning conditions should be employed.

In comparison with other woods of similar density, Itaúba in the unseasoned condition is below average in all static-bending properties except stiffness, as well as in hardness, shear, and shock resistance. It is approximately equal to the average in stiffness, crushing strength, transverse compression and tension, and resistance to cleavage. The *Mezilaurus itauba* represented in these tests came from Brazil and Peru. The Brazilian wood was considerably denser and accordingly stronger than that from Peru, but due to the limited amount of Brazilian material available for testing, no significance is attached to these differences. This discussion is based upon average results.

As shown in the accompanying table, unseasoned Itaúba compares favorably with the appreciably lighter weight Teak in stiffness, hardness, and compression across the grain. It is also superior to Teak in toughness, although values for this property are based on an average of green and air-dry test results. In most other properties, including modulus of rupture, crushing strength, tension across the grain, shear,

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		STATIC BENDING Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Itaúba (*Mezilaurus itauba*)	Brazil	1	Green	51.1	0.84	0.75	8,310	13,150	1,880	2.06	9.2
			Air Dry[1]	12.8			10,510	16,380	2,080	3.04	10.8
	Peru	3	Green	75.7	0.70	0.61	5,600	9,530	1,710	1.08	8.5
			Air Dry[1]	15.6			9,310	14,030	2,000	2.47	9.9
	Average	4	Green	63.4	0.77	0.68	6,960	11,340	1,800	1.57	8.8
			Air Dry[1]	14.2			9,910	15,200	2,040	2.75	10.4
	Brazil[2]		Green	—	0.90[3]	0.79[3]	7,350	16,700	2,100	—	—
			Air Dry	15.0			—	18,300	—	—	—
White Oak[4] (*Quercus alba*)	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
			Air Dry	12			8,200	15,200	1,780	2.27	14.8
Teak[5] (*Tectona grandis*)	Burma		Green	52	0.62	0.58	7,250	11,380	1,580	1.89	10.0
			Air Dry[1]	11.2			8,160	13,770	1,670	2.51	9.3*

Species	Condition	COMPRESSION PARALLEL TO GRAIN Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Itaúba (*Mezilaurus itauba*)											
Brazil	Green	4,970	6,700	2,100	1270	1610	1520	1200	1550	560	135.9
	Air Dry	6,110	9,400	2,250	1460	1660	2080	700*	1760	400*	
Peru	Green	3,060	4,440	2,090	770	900	740	740	1170	330	149.0
	Air Dry	4,430	7,780	2,210	950	1080	1290	560*	1360	310*	
Average	Green	4,020	5,570	2,100	1020	1260	1130	970	1360	440	142.4
	Air Dry	5,270	8,590	2,230	1210	1370	1680	630*	1560	360*	
Brazil[2]	Green	6,180	8,360	2,380	—	—	—	—	—	—	—
	Air Dry	—	10,600	—	—	—	—	—	—	—	
White Oak[4] (*Quercus alba*) United States	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[6]
	Air Dry	4,760	7,440	—	1520	1360	1320	800	2000	450	
Teak[5] (*Tectona grandis*) Burma	Green	4,120	5,490	1,760	900	980	1040	960	1300	420	84.4
	Air Dry[1]	5,180	7,520	1,500*	1010	1100	1190	980	1360	340*	

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[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] Brotero and Vieira (5).

[3] Estimated from apparent specific gravity at 15 percent moisture content.

[4] U. S. Dept. Agr. Tech. Bul. 479 (64).

[5] A. V. Thomas (93); Handbook of Empire Timbers (28); unpublished Yale results for plank material received from the New York Naval Shipyard.

[6] Value obtained for plank material received from the New York Naval Shipyard.

and cleavage, Itaúba and Teak are approximately equal. Itaúba is also shown to be superior to White Oak in the unseasoned condition in all properties except shock resistance and end hardness.

Upon air drying, Itaúba improved moderately in nearly all mechanical properties but only in work to maximum load (shock resistance) was the proportionate increase as great as that generally shown by domestic hardwoods. Substantial losses in strength were shown in cleavage and tensile strength across the grain.

In the air-dry condition, Itaúba is equal to the average anticipated on the basis of its density only in crushing strength, compression perpendicular to the grain, and cleavage resistance. In all other mechanical properties, Itaúba is below average. When compared with Teak, however, Itaúba is shown to be superior in every property except tension across the grain, and in most of them the margin of difference is measured approximately by the difference in density between these two species.

For convenient comparison with White Oak the following tabulation has been prepared in which relative values for the green and air-dry properties of Itaúba are shown. In each case the corresponding value for White Oak is 100.

	Specific gravity	Bending strength	Stiffness	Shock resistance	Crushing strength
Green	113	137	144	76	156
Air Dry		100	114	70	115

	Side hardness	Shear	Bearing strength	Cleavage resistance
Green	119	109	136	105
Air Dry	101	78	127	80

Itaúba is moderate in shrinkage. Its average volumetric shrinkage of 10.6 percent is comparable to that of Black Walnut which is only three-fourths as dense as Itaúba. Radial shrinkage of 2.4 percent is especially low and Itaúba is comparable to Teak in this respect, but tangential shrinkage of 7.0 percent is much greater than that of Teak. The ratio of tangential to radial shrinkage is unusually high.

Species and Source	Shrinkage (percent) Radial	Tangential	Longitudinal	Volumetric
Itaúba				
(Mezilaurus itauba)				
Brazil	2.4	6.6	0.36	9.2
Peru	2.5	7.4	0.27	11.9
Average	2.4	7.0	0.32	10.6
Black Walnut[1]				
(Juglans nigra)				
United States	5.2	7.1	—	11.3
Teak[2]				
(Tectona grandis)				
Burma	2.3	4.2	—	6.8

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).
[2] Handbook of Empire Timbers (28).

The wood is reputed to be highly resistant to decay and insects (22, 42, 77). This reputation is only partially borne out by results of the present study. Itaúba proved to be very durable upon exposure to a white-rot fungus, but ranged from very durable to moderately durable when exposed to a brown-rot fungus. The wood is also thought to be highly resistant to marine borers. Horn (42) makes the following statement, "On account of its resistance to marine borers this wood is preferred over all other Amazonian hardwoods for the bottom planking of boats and ships." Although direct experimental evidence concerning marine-borer resistance of Itaúba is lacking, Edmondson found the closely related species *Silvia Duckei* (= *Mezilaurus Duckei*) to have little resistance to attack in Hawaiian waters (23).

Itaúba proved to be difficult to machine. All logs that were studied exhibited a strongly interlocked grain which affected the quality of surfaces, especially in planing. Torn grain was avoided in boring only with difficulty. No appreciable dulling of cutting edges was noted, however.

The heartwood is extremely resistant to moisture absorption (81).

The wood is described by Ducke (19, 22, 77) as being the most useful timber of the Lower Amazon, especially for naval construction and general carpentry. Itaúba has also been widely employed in Portugal in large casks used for storage purposes. Its present utilization, however, appears to be almost entirely local with the exception of crossties, which are exported in limited quantities (41). Other local uses include telephone poles, tight cooperage, and all kinds of carpentry (4). The similarity of Itaúba to Teak in many of its properties suggests that it may serve as a suitable replacement for Teak in numerous applications where that wood is now highly favored.

References: 4, 19, 22, 23, 41, 42, 50, 51, 73, 77, 79, 81.

MANWOOD *Minquartia guianensis* Aubl.

Sometimes this species is also called Black Manwood by English-speaking peoples. Locally it is called Manu in Costa Rica; Plátano in Nicaragua; Criollo, Urari, and Urodibe in Panama; Wanania and Mincoa in British Guiana; Aratta and Konthout in Surinam; Pechiche in Ecuador; Huacapú in Peru; and Acariguara, Acapú, and Araciúba in Brazil.

This species grows from Nicaragua to Ecuador and eastward in the Guianas and Brazil. It is found in the hot lowland forests on both the Caribbean and Pacific watersheds in Panama, and above the flood level in all Amazonia.

The tree is up to 100 feet in height and 36 inches in diameter. Buttresses are low or lacking altogether. It has a swollen base which, together with higher portions of the bole, has very deep oblong depressions or holes making it difficult to convert into lumber. Occasionally the trunks are hollowed out by ants.

The color of the freshly cut heartwood is dark brown, sometimes streaked with black. The sapwood, which is three-fourths inch to 1½ inches in width, is tan to mustard yellow in color. The dry heartwood is plain brown without any reddish tinge. The logs that were received for test purposes were straight grained, although the wood is also reported to have interlocked grain (77). The pores are invisible without a lens on the end surface. They are arranged in radial rows of two to six and more or less filled with tyloses. Numerous fine tangential lines of parenchyma,

spaced about the diameter of a pore apart, can be seen with a good hand lens. Growth layers are very obscurely defined.

The average specific gravity of the wood is 0.76 (0.72-0.79) based on its volume when green and weight when oven dry. The weight per cubic foot is 79 pounds when green and 57 pounds at 12 percent moisture content.

Considerable difficulty was encountered in drying the wood. Although drying at a moderate to slow rate in air-seasoning piles, a slow rate seems to be necessary if face checking is to be avoided. Material drying at a moderate rate developed slight end checking and slight to moderate surface checking. Slight warp in the form of crook and twist and slight casehardening were also observed.

Nearly all the strength properties of unseasoned Manwood are below the average that might be anticipated on the basis of its high density. It is particularly low in work to maximum load (shock resistance). Only in stiffness and in proportional limit stress in static bending and longitudinal compression does the wood compare with most species of like density. When compared with Hickory, characterized by an appreciably lower density, Manwood is considerably stronger and stiffer in static bending, and stronger in both longitudinal and transverse compression, as shown in the accompanying table. It is, however, slightly below Hickory in shear strength and far less resistant to impact as indicated by the low value in work to maximum load. In a comparison with White Oak for which more complete data are available, Manwood greatly exceeds Oak in all static-bending properties (except work to maximum load) and also in compression parallel and perpendicular to the grain, and hardness, but it is only slightly stronger than Oak in shear and is inferior to Oak in tension across the grain and cleavage resistance.

Upon air drying, Manwood showed a moderate improvement in static-bending and compression parallel to grain properties, but only in work to maximum load and modulus of rupture did this improvement equal or exceed that commonly shown by domestic hardwoods. In compression per-

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		Static Bending: Fiber Stress at Proportional Limit	Static Bending: Modulus of Rupture	Static Bending: Modulus of Elasticity	Static Bending: Work to Proportional Limit	Static Bending: Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Manwood *(Minquartia guianensis)*	Costa Rica	3	Green	66.7	0.87	0.76	9,040	13,000	2,230	2.08	7.4
			Air Dry[1]	12.7			12,690	19,580	2,440	3.72	11.8
Shagbark Hickory[2] *(Carya ovata)*	United States		Green	60	0.78	0.64	5,900	11,000	1,570	1.28	23.7
			Air Dry	12			10,700	20,200	2,160	3.01	25.8
White Oak[2] *(Quercus alba)*	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
			Air Dry	12			8,200	15,200	1,780	2.27	14.8

Species	Condition	Compression Parallel to Grain: Fiber Stress at Proportional Limit	Compression Parallel to Grain: Maximum Crushing Strength	Compression Parallel to Grain: Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Manwood *(Minquartia guianensis)* Costa Rica	Green	5,060	5,960	2,410	1290	1490	1480	700	1440	410	196.7
	Air Dry[1]	6,970	9,930	2,760	1320	1690	1320*	370*	1310*	210*	
Shagbark Hickory[2] *(Carya ovata)* United States	Green	3,430	4,580	—	—	—	1040	—	1520	—	—
	Air Dry	—	9,210	—	—	—	2170	—	2430	—	
White Oak[2] *(Quercus alba)* United States	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[3]
	Air Dry	4,760	7,440	—	1520	1360	1320	800	2000	450	

[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] U. S. Dept. Agr. Tech. Bul. 479 (64).

[3] Value obtained for plank material received from the New York Naval Shipyard.

pendicular to the grain, shear, tension across the grain, and cleavage, and particularly in the last two named properties, the wood decreased in strength upon drying.

The air-dry wood is close to the average for woods of comparable density in static-bending strength, stiffness, and elastic resilience but is below average in its other properties, especially shock resistance, hardness, shear, cleavage, and tension and compression across the grain. Even when compared with the considerably lighter Hickory, air-dry Manwood is only slightly stiffer and stronger in compression. Hickory is slightly stronger in static bending and much higher in shock resistance, compression across the grain, and shear.

A convenient comparison of both the green and air-dry properties of Manwood with those of White Oak is made in the following tabulation in which the corresponding value for White Oak is 100.

	Specific gravity	Bending strength	Stiffness	Shock resistance	Crushing strength
Green	127	157	178	64	164
Air Dry		129	137	80	146

	Side hardness	Shear	Bearing strength	Cleavage resistance
Green	140	115	178	98
Air Dry	124	66	100	47

Although Manwood is one-fourth again as dense as White Oak, its shrinkage characteristics are similar to those of that species. Radial shrinkage of 5.4 percent, tangential shrinkage of 8.3 percent, and volumetric shrinkage of 14.0 percent compare closely with published values for White Oak.

	SHRINKAGE (percent)			
Species and Source	Radial	Tangential	Longitudinal	Volumetric
Manwood				
(Minquartia guianensis)				
Costa Rica	5.4	8.3	0.30	14.0
White Oak[1]				
(Quercus alba)				
United States	5.3	9.0	—	15.8

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

Manwood is reputed to be highly resistant to decay and termites (57, 68, 77). Scheffer and Duncan have rated the heartwood of *Minquartia guianensis* as very resistant to decay on the basis of soil tests and pure-culture tests involving white-rot fungi (82). This rating of durability is substantiated by results of the present study. Upon exposure, the wood proved very durable in resistance to both a white-rot and a brown-rot fungus. In marine-borer exposure tests conducted at Wrightsville, North Carolina as a part of this study, Manwood showed light marine-borer activity after 12 months' immersion but was subjected to fairly heavy attack during the second year of exposure (11). Total ash content of the wood was found by chemical analysis to be 0.93 percent but silica content was only 0.034 percent (98).

Owing to its density, Manwood presents some difficulty in machining, although resulting surfaces of straight-grained material are smooth. An interlocked grain, which is sometimes present, would tend to affect the quality of the surface, especially in planing. No pronounced dulling of cutting edges was observed.

The wood has for some time been valued for its durability and strength. Record and Hess (77) report few woods equal its reputation for durability in contact with the ground. As a result, it finds use mainly for railroad and tram crossties, telephone poles, fence and house posts, and similar purposes for which strength and durability are required. In Panama, French Guiana, and the Amazon region, it is highly esteemed for fence posts, ties, and heavy, durable construction (74). Cooper (13) reports the species is scattered and difficult to locate in the bush, which may hamper commercial exploitation on a large scale.

References: 11, 13, 25, 44, 55, 57, 68, 74, 77, 79, 82, 98.

BURADA *Parinari campestris* Aubl. (= *Parinarium campestre* Aubl.)

AIOMORADAN *Parinari excelsa* Sabine

Other spellings for the common name of *Parinari campestris* are Buhurada, Behoeroda, Beherada, and Boorhoorada. It is also called Vonkhout and Witte Foengoe in Surinam, Parinari in Brazil, and Gri-gri in French Guiana.

Burada grows in the Guianas, Trinidad, and northern Brazil. It is a common tree in British Guiana where it grows in the rain forests and seasonal forests of low rainfall on high, well drained sites and occasionally in marsh land. In Surinam, although not abundant, it commonly occurs scattered in the forest.

The trees average about 75 feet in height and up to 30 inches in diameter, and sometimes attain a height of 130 feet and a diameter of 48 inches. The bole may be 60 to 80 feet in length, the lower part of which is commonly buttressed for a height of about 15 feet.

Freshly cut heartwood is tan to orange brown in color, being only slightly darker than the tan colored sapwood which is about 1½ inches in width. The heartwood when dry is light brown in color resembling Butternut. Although the sapwood is somewhat lighter colored, it is not clearly defined from the heartwood. The wood is usually straight grained. On a smoothly cut end surface the pores are distinctly visible to the unaided eye. Although they are almost entirely isolated, they have a faint tendency to arrangement in an irregular radial pattern. The pores are open and appear as distinct grooves on longitudinal surfaces. The rays are very fine, even under a hand lens. Numerous fine tangential lines of parenchyma about one-half to two-thirds of the radial diameter of the pores apart are visible on end surfaces. Occasionally the spacing is slightly greater, giving rise to vague, irregularly spaced growth zones, although often entirely wanting. The wood is without any characteristic odor.

The wood of Aiomoradan, *Parinari excelsa* Sabine, of British Guiana has practically the same color and density as Burada. Samples of this species, however, contained some tyloses and occasionally white deposits in the pores.

The average specific gravity of Burada and Aiomoradan, based on green volume and weight when oven dry is 0.68 (0.61-0.72). Weight per cubic foot in the green condition is 67 pounds and at 12 percent moisture content it is 51 pounds.

Burada is rated easy to air season while Aiomoradan is rated moderately difficult. Each dried rapidly but with some defect resulting from checking and warping. Burada exhibited slight checking and slight warp in the form of crook and twist. Slight casehardening was observed in a portion of the material seasoned. In the case of Aiomoradan, surface checking and casehardening were again slight while warp was moderate. Milder conditions, resulting in a moderate rate of drying, would minimize seasoning defects, especially checking, in both species.

As shown in the accompanying tabulation, the strength properties of *Parinari campestris* and *P. excelsa* are nearly identical. Consequently, the data for these two species have been combined, and the average values are considered representative of both species. Burada and Aiomoradan are approximately average in strength in static bending and compression parallel to the grain when compared in the green condition with other tropical woods of similar density. They exceed most such woods in stiffness, but are relatively low in hardness, shear, tension across the grain, and cleavage, and are particularly low in compression across the grain and toughness.

Burada and Aiomoradan are slightly heavier than Hickory and the unseasoned wood is much stiffer and proportionately stronger than Hickory in static bending and longitudinal compression, but Hickory is appreciably higher in compression across the grain, shear, and especially in shock resistance. These woods are greatly superior to unseasoned White Oak in all static-bending properties except work to maximum load, as well as in compression parallel to the grain. They are quite similar to White Oak in other properties including hardness, transverse compression and tension, cleavage, shear, and shock resistance.

Upon air drying, the wood improved substantially in most strength properties. Increases in work to maximum load and

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		STATIC BENDING				
							Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Burada *(Parinari campestris)*	Surinam	2	Green	53.8	0.80	0.69	8,980	12,750	2,120	1.95	10.4
			Air Dry[1]	11.8			13,280	20,120	2,610	3.86	15.2
Aiomoradan *(Parinari excelsa)*	British Guiana	3	Green	62.6	0.78	0.66	8,040	12,890	2,110	1.69	10.1
			Air Dry[1]	11.5			13,680	20,340	2,660	3.94	15.7
	Average	5	Green	58.2	0.79	0.68	8,510	12,820	2,120	1.82	10.2
			Air Dry[1]	11.6			13,480	20,230	2,640	3.90	15.4
Shagbark Hickory[2] *(Carya ovata)*	United States		Green	60	0.78	0.64	5,900	11,000	1,570	1.28	23.7
			Air Dry	12			10,700	20,200	2,160	3.01	25.8
White Oak[2] *(Quercus alba)*	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
			Air Dry	12			8,200	15,200	1,780	2.27	14.8

Species	Condition	COMPRESSION PARALLEL TO GRAIN		Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		Fiber Stress at Proportional Limit	Maximum Crushing Strength								
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Burada *(Parinari campestris)* Surinam	Green	4,780	5,800	2,180	1340	1270	850	910	1380	400	156.7
	Air Dry[1]	7,200	10,260	2,790	1570	1830	1590	410*	1720	250*	
Aiomoradan *(Parinari excelsa)* British Guiana	Green	4,500	5,750	2,480	1280	1190	880	910	1400	400	144.9
	Air Dry[1]	7,630	10,680	2,920	2030	1790	1240	310*	1510	220*	
Average	Green	4,640	5,780	2,330	1310	1230	860	910	1390	400	150.8
	Air Dry[1]	7,420	10,470	2,860	1800	1810	1420	360*	1620	240*	
Shagbark Hickory[2] *(Carya ovata)* United States	Green	3,430	4,580	—	—	—	1040	—	1520	—	—
	Air Dry	—	9,210	—	—	—	2170	—	2430	—	
White Oak[2] *(Quercus alba)* United States	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[3]
	Air Dry	4,760	7,440	—	1520	1360	1320	800	2000	450	

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[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] U. S. Dept. Agr. Tech. Bul. 479 (64).

[3] Value obtained for plank material received from the New York Naval Shipyard.

side hardness exceeded those shown by the majority of domestic hardwoods whereas modulus of rupture, stiffness, and crushing strength increased at approximately the normal rate for domestic woods. Other increases were less than normal and strength in tension across the grain and cleavage resistance decreased to a marked degree upon seasoning.

In comparison with other species of like density, the air-seasoned wood is above average in all static-bending properties, except work to maximum load, and in longitudinal compression. It is equivalent to most such woods in hardness; slightly below average in compression across the grain, shock resistance, and shear; and very low in cleavage resistance and in tension across the grain.

The air-dry wood is slightly stronger than Hickory in bending and longitudinal compression, but far below Hickory in shock resistance, compression across the grain, and shear. A similar comparison with White Oak for which data are more complete, shows that Burada and Aiomoradan are far superior in static-bending strength, elastic resilience, compression parallel to the grain, and hardness. These woods are comparable to Oak in shock resistance and compression across the grain, but are surpassed by Oak in shear, tension perpendicular to the grain, and cleavage.

Burada and Aiomoradan exhibit similar characteristics in shrinkage. Average radial shrinkage is 5.9 percent, tangential 9.8 percent, and volumetric 14.9 percent. In all respects these values are quite similar to those of domestic White Oak.

	SHRINKAGE (percent)			
Species and Source	Radial	Tangential	Longitudinal	Volumetric
Burada				
(Parinari campestris)				
Surinam	5.9	10.0	0.30	14.6
Aiomoradan				
(Parinari exclesa)				
British Guiana	5.9	9.7	0.27	15.2
Average	5.9	9.8	0.28	14.9
White Oak[1]				
(Quercus alba)				
United States	5.3	9.0	—	15.8

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

References to the decay resistance of these woods are somewhat contradictory. Fanshawe (25) describes both species as moderately resistant to decay, whereas Record and Hess (77), referring to Burada, state that the wood is resistant to insect attack but not durable in contact with the ground. In the present study both Burada and Aiomoradan were found to be moderately durable when exposed to a white-rot organism and very durable upon exposure to a brown-rot fungus. The timbers of the genus *Parinari* are noted for their high silica content and marine-borer resistance, and Burada and Aiomoradan are not exceptions to this generalization. In tests conducted at Wrightsville, North Carolina as part of the present investigation, both woods showed only slight evidence of marine borer activity after one year's immersion and later observations, limited to Aiomoradan, revealed only moderate damage after 20 months of exposure (11). In the same tests Greenheart suffered rather heavy attack in its second year of exposure. Total ash content, determined on material from the same logs that supplied test specimens for the exposure study, was 1.29 percent for Burada and 1.05 percent for Aiomoradan. Silica content percentages were notably high, 0.902 and 0.576 respectively (98). Earlier, Amos (1) reported the silica content of Burada as 0.84 percent.

Because of their high silica content and density both species are difficult to machine. Rapid dulling of cutting edges was observed, although smooth surfaces were obtained in planing, boring, and sawing operations when tools were properly maintained.

The wood of these species is apparently little used in spite of qualities which recommend both Burada and Aiomoradan as salt-water piling. The former has been suggested suitable for furniture and excellent for framing (40, 92). However, it is further reported the wood turns badly, takes nails badly, and develops only a fair polish. Fanshawe (25) states that both are useful for salt-water piling, house framing, heavy construction, and railway ties. Neither species is employed locally in British Guiana at the present time. The chief potential use of these woods appears to be in marine construction, especially when continuously submerged so that decay cannot affect them.

References: 1, 11, 25, 40, 68, 77, 92, 98.

PARINARI *Parinari Rodolphi* Huber (= *Parinarium Rodolphi* Huber)

The name of this species is also spelled Parinary and Paranary. In Brazil it is also called Farinha Secâ. Parinari grows in the upland rain forests of the lower Amazon region in Brazil. It is a medium to large-sized tree with a large dense crown.

The freshly cut heartwood is light yellow or tan to deep orange brown. When dry it is tan colored. The sapwood, which is from 1 inch to 2½ inches wide, is barely distinguishable from the heartwood. The wood is straight grained. No growth zones of different texture or color are present. The pores are visible as minute openings on smoothly cut end surfaces where they are isolated but arranged vaguely in an irregular radial pattern. On longitudinal surfaces the pores are distinctly visible as fine grooves. Numerous fine tangential lines of parenchyma spaced about half the diameter of a pore apart are visible with a lens on smoothly cut end surfaces. The rays are very small on all surfaces. The wood has no distinctive odor. The average specific gravity of the wood based on volume when green and weight when oven dry is 0.71 (0.62-0.75). Weight per cubic foot in the green condition is 71 pounds and at 12 percent moisture it is 54 pounds.

The wood is easy to air season based on results of this study. In this respect, it is similar to *P. campestris*. Material air dried at a rapid rate accompanied by only slight seasoning defect. Surface checking, warping, and casehardening caused only slight degrade. A slower rate of drying would tend to reduce even this slight degrade.

Most of the strength properties of Parinari exceed those of any domestic wood. In the green condition this species is above the average shown by other tropical woods of comparable high density in stiffness and crushing strength. In a similar comparison, it is about average in static-bending strength, end hardness, and cleavage, and below average in elastic resilience, shock resistance, side hardness, shear, and both tension and compression across the grain.

In the accompanying table, the properties of the unseasoned wood are compared with those of Hickory, which is somewhat lower in density than Parinari. It is evident that Parinari is much stiffer than Hickory and also that it exceeds the latter in bending and crushing strengths, but it is also apparent that Parinari is inferior to Hickory in compression across the grain, shear, and particularly in shock resistance as measured by work to maximum load. Parinari is comparable or superior to White Oak in all strength properties and its superiority is particularly marked in modulus of elasticity, and in static-bending and crushing strength. These woods are nearly identical in shock resistance as measured either by work to maximum load or by toughness.

Most of the properties of Parinari improved substantially upon air drying, although only in work to maximum load, proportional limit stress in longitudinal compression, and hardness was the proportionate increase equal to or greater than that shown by most domestic woods. Substantial losses in strength occcurred in tension across the grain and in cleavage.

The air seasoned wood compares more favorably with other tropical woods of equal density. In such a comparison Parinari is average or above average in all static-bending properties including work to maximum load, as well as in longitudinal compression, and hardness. It is below average, however, in shear, cleavage, and tension and compression perpendicular to the grain. The relative comparison made with Hickory in the green condition also holds true for the air-dry wood as shown in the accompanying table. Although far superior to White Oak in bending, compression parallel to the grain, and hardness, the air-dry wood is surpassed by Oak in shear, tension across the grain, and cleavage.

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		STATIC BENDING: Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Parinari *(Parinari Rodolphi)*	Brazil	3	Green	60.3	0.83	0.71	9,060	14,760	2,660	1.77	11.7
			Air Dry[1]	13.5			14,220	21,740	2,930	3.88	17.1
Shagbark Hickory[2] *(Carya ovata)*	United States		Green	60	0.78	0.64	5,900	11,000	1,570	1.28	23.7
			Air Dry	12			10,700	20,200	2,160	3.01	25.8
White Oak[2] *(Quercus alba)*	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
			Air Dry	12			8,200	15,200	1,780	2.27	14.8

Species	Condition	COMPRESSION PARALLEL TO GRAIN: Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Parinari *(Parinari Rodolphi)* Brazil	Green	3,670	6,780	3,090	1580	1380	910	900	1340	440	144.6
	Air Dry[1]	8,420	11,960	3,070*	2410	2360	1590	370*	1590	240*	
Shagbark Hickory[2] *(Carya ovata)* United States	Green	3,430	4,580	—	—	—	1040	—	1520	—	—
	Air Dry	—	9,210	—	—	—	2170	—	2430	—	
White Oak[2] *(Quercus alba)* United States	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[3]
	Air Dry	4,760	7,440	—	1520	1360	1320	800	2000	450	

[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] U. S. Dept. Agr. Tech. Bul. 479 (64).

[3] Values obtained for plank material received from the New York Naval Shipyard.

A convenient comparison of both green and air-dry properties with those of White Oak is given in the following tabulation in which the corresponding value for Oak is 100.

	Specific gravity	Bending strength	Stiffness	Shock resistance	Crushing strength
Green	118	178	213	101	190
Air Dry		143	165	115	161

	Side hardness	Shear	Bearing strength	Cleavage resistance
Green	130	107	110	105
Air Dry	174	80	120	53

Shrinkage of Parinari is comparable to that of White Oak as shown in the accompanying tabulation. Radial shrinkage of 6.0 percent and tangential shrinkage of 10.1 percent are both slightly higher than corresponding values for Oak, but the independently determined volumetric shrinkage of 15.2 percent is slightly less than the published value for White Oak.

	SHRINKAGE (percent)			
Species and Source	Radial	Tangential	Longitudinal	Volumetric
Parinari *(Parinari Rodolphi)* Brazil	6.0	10.1	0.17	15.2
White Oak[1] *(Quercus alba)* United States	5.3	9.0	—	15.8

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

Woods of the genus *Parinari* are reputed to be low in resistance to decay (77). This is substantiated by current test results which indicate that Parinari is moderately durable in resistance to both a white-rot and a brown-rot fungus. Thus agreement is shown with *P. campestris* and *P. excelsa* in the case of the white-rot organism, although the rating of resistance to the brown-rot fungus is somewhat lower for *P. Rodolphi* than for these related species.

As mentioned in the preceding species description, woods of the genus *Parinari* are noted for their high silica content and marine-borer resistance. In marine-borer studies at Wrightsville, North Carolina, *Parinari Rodolphi* showed only slight evidence of marine-borer activity during 12 months of exposure in heavily infested waters (11). Its performance thus compares with that of Burada and Aiomoradan as previously discussed. Chemical analyses of samples from the same source as the exposure specimens showed a total ash content of 1.09 percent and silica content of 0.804 percent (98). The latter appears to be typical of other results reported for various species of the genus (1).

Parinari proved to be difficult to machine because of its high silica content and density. In this respect, there appears to be no fundamental difference between the three species tested of the genus *Parinari*. Rapid dulling of cutting edges was observed, although smooth surfaces were obtained when tools were properly maintained.

Horn (42) reports the wood is widely used in Brazil for keels and keelsons in shipbuilding because of its resistance to marine borers. Because of difficulties encountered in sawing the wood, the members are generally shaped with an axe or adze. Parinari is further employed in Brazil, with *Eschweilera odora*, as piling and dock timbers in teredo-infested waters.

References: 1, 11, 42, 77, 98.

SAMÁN

Pithecolobium (Pithecellobium) Saman (Jacq.) Benth.
(=*Samanea Saman* [Jacq.] Merrill)

This timber is known as Samán in Colombia, Venezuela, Central America and Puerto Rico. In Brazil it is called Bordão de Velho. It is also known as Campano, Sanaguare, Urero, Algarrobo de País, Aguango, Genízaro, Cenízero, Correto, Zorra, and Rain Tree in various parts of its range. The last name, or its Spanish equivalent–Árbol de la Lluvia–is used because the leaflets condense atmospheric moisture during the night which causes a continuous dripping in the morning and at certain times in the day (30).

Samán grows in Central America, northern South America, and the West Indies. It is characteristic of open woods and is usually left standing when land is cleared partly because of the shade its large crown affords and partly because its sweet pods make excellent cattle food. The tree is also extensively planted in the tropics.

Samán is a large deciduous tree, up to 125 feet in height and 3 to 4 and even 6 feet in diameter, although Williams (101) reports that in northeastern Peru it is a small tree.

The freshly cut heartwood is dark chocolate brown in color, and the sapwood, which is from 1¼ to 2½ inches wide, is white to yellow or light cinnamon. The dry heartwood is light brown in color with darker streaks, resembling Butternut or Circassian Walnut in this respect. The grain of the wood is straight or irregular in part. It is reported that slow-growth material tends to be darker and more cross-grained than fast-grown wood. The pores, which are mostly open, are readily visible to the unaided eye. Small quantities of a dark amber colored gum occur in the pores which are scattered singly or occasionally in radial rows of two to four with a slight tendency to echelon arrangement. They are surrounded by a wide zone of parenchyma which often extends laterally connecting several pores in tangential or diagonal rows. The parenchyma is not conspicuous because it is of about the same color as the surrounding tissue. The rays are fine and inconspicuous on all surfaces.

The average specific gravity of the logs tested is 0.48 (0.37-0.56) based on volume when green and weight when oven dry. The weight per cubic foot at 12 percent moisture content is 35 pounds.

Logs tested in this study were initially sawed into plank for drying while in storage. Consequently, seasoning characteristics of the wood have not been observed. Plank material, however, appeared to be free of any excessive checking and warping.

Most of the strength properties of Samán in the unseasoned condition are about average for a wood of its weight

class. However, work values in static bending are above average, tensile strength across the grain and cleavage are below average, and modulus of elasticity is very low.

In the accompanying table, Samán is compared with Butternut and Mahogany. For the most part green Samán is shown to be intermediate to these two species, although both are of lower density than Samán. In all static-bending properties except modulus of elasticity, Samán closely approaches Mahogany and actually exceeds Mahogany in elastic resilience and work to maximum load. Samán also approaches the strength of unseasoned Mahogany in compression parallel and perpendicular to the grain, hardness, and shear and surpasses Mahogany by a small margin in toughness. In stiffness, tension across the grain, and cleavage resistance, Samán more nearly resembles the weaker Butternut.

Upon air drying, the wood improved slightly in most properties, but in no case did the proportionate increase equal that shown by most domestic hardwoods. Work to maximum load (shock resistance) decreased considerably upon drying and both tensile strength across the grain and cleavage resistance dropped off slightly.

The air-dry wood of Samán is below the average anticipated on the basis of its density in all strength properties except hardness. Deficiencies are noted particularly in modulus of rupture and modulus of elasticity. When compared with air-dry Butternut and Mahogany, Samán is again shown to be intermediate in most respects but it more closely resembles the weaker Butternut. The resemblance to Butternut is close in all static-bending properties, compression parallel to the grain, shear, tension perpendicular to the grain and cleavage. Samán is intermediate to Butternut and Mahogany in compression across the grain, and approximately equivalent to Mahogany in hardness.

Shrinkage of Samán is exceptionally low. Volumetric shrinkage, for example, is less than half that normally anticipated for a domestic wood of comparable density.

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		Static Bending: Fiber Stress at Proportional Limit	Static Bending: Modulus of Rupture	Static Bending: Modulus of Elasticity	Static Bending: Work to Proportional Limit	Static Bending: Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Samán (*Pithecolobium Saman*)	Venezuela	2	Green	—	0.51	0.48	4,880	8,100	910	1.51	10.4
			Air Dry[1]	12.4			6,080	8,860	1,100	1.97	7.8*
Butternut[2] (*Juglans cinerea*)	United States		Green	104	0.40	0.36	2,900	5,400	970	0.52	8.2
			Air Dry	12			5,700	8,100	1,180	1.59	8.2
Mahogany[3] (*Swietenia macrophylla*)	Central America		Green	79.6	0.51	0.45	5,550	8,960	1,340	1.13	9.1
			Air Dry[1]	11.4			7,960	11,460	1,500	2.08	7.5

Species	Condition	Compression Parallel to Grain: Fiber Stress at Proportional Limit	Compression Parallel to Grain: Maximum Crushing Strength	Compression Parallel to Grain: Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Samán (*Pithecolobium Saman*)											
Venezuela	Green	2,720	3,760	1,000	800	750	600	470	1100	260	99.4
	Air Dry[1]	3,920	5,070	1,110	900	850	830	460*	1280	240*	
Butternut[2] (*Juglans cinerea*)											
United States	Green	2,020	2,420	—	410	390	270	430	760	220	—
	Air Dry	4,200	5,110	—	570	490	570	440	1170	220	
Mahogany[3] (*Swietenia macrophylla*)											
Central America	Green	3,080	4,340	1,520	820	740	680	740	1240	330	88.2
	Air Dry[1]	5,080	6,780	1,500*	970	800	1090	740	1230	340	

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[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] U. S. Dept. Agr. Tech. Bul. 479 (64).

[3] Heck (38); Kynoch and Norton (54); unpublished Yale results for plank material received from the New York Naval Shipyard.

Radial shrinkage of 2.0 percent, tangential shrinkage of 3.4 percent, and volumetric shrinkage of 6.0 percent are all appreciably less than corresponding values for Central American Mahogany.

Species and Source	SHRINKAGE (percent) Radial	Tangential	Longitudinal	Volumetric
Samán *(Pithecolobium Saman)* Venezuela	2.0	3.4	0.13	6.0
Mahogany[1] *(Swietenia macrophylla)* Central America	3.5	4.8	—	7.7

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[1] Forest Products Laboratory, Madison, Wis.

Samán is reputed to be durable (48, 77). Decay resistance tests in this study confirm this in that wood exposed to a white-rot fungus was rated durable while that exposed to a brown-rot fungus was rated very durable.

The wood is easy to work because of its moderate density. Planed surfaces showing moderate grain variation were fairly smooth, but care was required with such stock to obtain satisfactory results in boring.

In spite of its wide range, both natural and planted, Samán has never been considered a valuable commercial timber. It is used locally for dug-out canoes, split posts, solid wheels of ox carts, and heavy construction (77, 101). In the widely distributed areas of the tropics where it is planted, the trees are generally too valuable for shade in parks and pastures to be used otherwise. Selected lumber has an attractive grain and color. Such material finds limited use, at least in Costa Rica, for medium quality furniture and cabinetwork (66, 91) and deserves consideration for export. Special uses for which Samán may be adapted, particularly because of its low shrinkage, include patternmaking.

References: 30, 43, 48, 60, 66, 73, 77, 79, 91, 101.

LECHERO *Sapium biglandulosum* (L.) M. Arg. (= *Sapium aucuparium* Jacq.)

This species is known as Lechero in Venezuela and Pão de Leite in São Paulo, Brazil.

Lechero grows in Colombia and on the inland savannas of Venezuela, on the mountain slopes of the Windward and Leeward Islands, in all parts of São Paulo, Brazil, and probably in adjacent territory. The trees from which test logs were obtained came from the state of Portuguesa, Venezuela, where Lechero is a secondary species growing in association with the more valuable Mahogany and Spanish Cedar (95). These trees were mature, 70-100 feet in height and 2-3 feet in diameter.

The freshly cut heartwood is cream to buff colored and the sapwood, which is ½ to 1 inch wide is cream colored. The dry heartwood is light dingy brown in color.

The grain is straight to slightly interlocked. The pores are barely visible without a lens on end surfaces. They are scattered promiscuously for the most part but occasionally two to four are in radial rows. The pores are open throughout. On longitudinal surfaces they appear as distinct grooves. Short, irregular tangential lines of parenchyma extending from ray to ray are barely visible with a hand lens. The rays are fine and inconspicuous on all surfaces. The average specific gravity of the wood is 0.45 (0.42-0.51) based on green volume and oven-dry weight. The weight per cubic foot when green is 51 pounds, and at 12 percent moisture it is 34 pounds.

Lechero dried rapidly in air-seasoning piles with relatively little defect. Warp included slight to moderate crook and slight twist. End checking and casehardening were also slight. During drying severe mold and stain occurred on both sapwood and heartwood. Undoubtedly both could have been prevented by a preservative chemical dip treatment of the green lumber.

In comparison with other woods of like density, unseasoned Lechero is above average in stiffness, approximately

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		Static Bending				
							Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Lechero *(Sapium biglandulosum)*	Venezuela	3	Green	81.6	0.51	0.45	4,800	7,700	1,480	0.88	5.5
			Air Dry[1]	11.3			6,870	10,790	1,680	1.61	8.5
Water Tupelo[2] *(Nyssa aquatica)*	United States		Green	97	0.52	0.46	4,200	7,300	1,050	0.98	8.3
			Air Dry	12			7,200	9,600	1,260	2.41	6.9
Yellow Poplar[2] *(Liriodendron tulipifera)*	United States		Green	64	0.43	0.38	3,400	5,400	1,090	0.62	5.4
			Air Dry	12			6,100	9,200	1,500	1.43	6.8

Species	Condition	Compression Parallel to Grain			Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity							
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Lechero *(Sapium biglandulosum)* Venezuela	Green	2,470	3,200	1,610	650	520	560	500	890	270	83.9
	Air Dry[1]	4,100	6,120	2,060	910	700	650	490*	1050	240*	
Water Tupelo[2] *(Nyssa aquatica)* United States	Green	2,690	3,370	—	800	710	590	600	1190	340	—
	Air Dry	4,280	5,920	—	1200	880	1070	700	1590	360	
Yellow Poplar[2] *(Liriodendron tulipifera)* United States	Green	1,930	2,420	—	390	340	330	450	740	220	—
	Air Dry	3,550	5,290	—	560	450	580	520	1100	280	

[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] U. S. Dept. Agr. Tech. Bul. 479 (64).

average in bending strength and compression across the grain, and below average in its other mechanical properties including shock resistance, crushing strength, hardness, shear, and resistance to splitting. The wood is comparable in density and most strength properties to Water Tupelo *(Nyssa aquatica)*, as shown in the accompanying table. Lechero exceeds Water Tupelo in stiffness, but is deficient in shock resistance, hardness, shear, transverse tension, and cleavage resistance. In all the last named properties, Lechero is intermediate to Tupelo and Yellow Poplar.

Upon air drying, Lechero improved substantially in nearly all properties although the proportionate increase equalled or exceeded that commonly shown by domestic hardwoods only in work to maximum load, crushing strength, and side hardness. Slight decreases occurred in tension across the grain and cleavage resistance as a result of air seasoning.

In the air-dry condition Lechero compares more favorably with other species in its density class, exceeding the average in stiffness and falling below average only in hardness, compression across the grain, shear, and elastic resilience. As shown in the table, the air-dry wood is comparable to Water Tupelo in bending and crushing strength; superior in stiffness; but deficient in both end and side hardness, compression and tension across the grain, shear, and cleavage resistance. Lechero is superior to Yellow Poplar in hardness and compression across the grain and generally comparable to that species in shear, transverse tension, and cleavage.

Among woods of comparable density, Lechero is relatively low in shrinkage. Radial and tangential shrinkage values of 3.3 and 6.6 percent, respectively, are both less than corresponding values for Yellow Poplar, a considerably lighter wood. Volumetric shrinkage averages 9.2 percent.

Species and Source	SHRINKAGE (percent)			
	Radial	Tangential	Longitudinal	Volumetric
Lechero *(Sapium biglandulosum)* Venezuela	3.3	6.6	0.27	9.2
Yellow Poplar[1] *(Liriodendron tulipifera)* United States	4.0	7.1	—	12.3

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

The wood is reputed to be low in resistance to decay and insect attack (25, 95). Results of the present study confirm this reputation, in that Lechero was found to be non-durable when exposed to a white-rot fungus and moderately durable to non-durable with respect to a brown-rot organism.

Lechero is easy to work because of its low density. Both straight and slightly interlocked-grain stock sawed and planed to a fairly smooth surface. Fuzzy surfaces were encountered in boring, but there appeared to be no tendency toward torn grain.

Lack of resistance to decay and insects requires that the logs be sawed without delay and the boards dipped in a toxic chemical and dried promptly. The wood has no special local uses in Venezuela (71). It is reported as being used for roofing beams, rafters, and interior woodwork in São Paulo (67). Curran (14) lists no known uses of the wood in Colombia. Similarly, Fanshawe (25) reports the species finds no local employment in British Guiana but could be useful for interior construction, box boards, and plywood. Aside from such uses, Lechero has obvious possibilities as a source of wood pulp.

References: 14, 25, 67, 71, 77, 95, 103.

JOBO

Spondias Mombin L.

In English this species is called Hog Plum, Jamaica Plum, Yucatan Plum, and Spanish Plum. The following are some of the local names applied to it: Jobito in Cuba; Hobo and Jobo in Mexico, Central America, and other Spanish speaking countries; Marapa and Mérida in Venezuela; Hoeboe, Monbé, and Moppé in Surinam; Ajuelo in Peru; and Hubu in British Guiana.

This species is widely distributed, although scattered, over a large part of tropical America. It is found especially in open, upland forests but is reported as most common on younger ridges in Surinam. It also grows naturally in West Africa and is planted in Java (73). The fruit, which is known as Ciruela or Ciruelo Agrio, looks and tastes somewhat like a plum and is eaten by the natives.

The tree is of medium to large size, up to 130 feet in height and 48 inches in diameter, unbuttressed, cylindrical except for the basal swelling or at times coarsely furrowed, with a clear bole up to 60 to 80 feet long (25).

The heartwood when freshly cut is cream to buff colored, the sapwood is of about the same color and difficult to distinguish from the heartwood. The sapwood may be as much as 4 inches wide. The wood darkens only slightly upon drying and exposure.

The grain is straight or slightly interlocked and the wood is coarse textured. The pores are readily visible on end surfaces, where they are scattered singly or occasionally in radial rows of two to four. They are mostly open, although some tyloses occur in the heartwood. On longitudinal surfaces the pores are distinct as grooves or as slightly darker lines against a light background. Very fine lines of parenchyma barely visible with a lens, together with a narrow layer in which the pores are somewhat less numerous or almost absent, mark off inconspicuous growth layers. The rays are fine and inconspicuous on all surfaces. The wood is without characteristic odor or taste.

The wood is relatively light in weight. Its average specific gravity, based on volume when green and weight when oven dry, is 0.40 (0.37-0.42). Weight per cubic foot when green is 58 pounds, and at 12 percent moisture it is 29 pounds.

Jobo dries readily due to its low density but drying is accompanied by defects that cause the wood to be classified as moderately difficult to season. During air seasoning there developed moderate warp in the form of crook and twist. End and surface checking was slight. Severe mold formed on sapwood while moderate mold was observed on heartwood during the drying period.

The strength properties of Jobo are discussed here on the basis of test results from material originating in Venezuela. They are compared in the accompanying table with previously available data on somewhat lighter weight wood of this species of Colombian origin (14).

The unseasoned wood of Jobo is generally comparable in strength to that of other species of similar moderate density. In such a comparison only side hardness and tension across the grain are clearly above average, and shear and work to maximum load (shock resistance) are below average. Unseasoned Jobo is compared with Yellow Poplar in the accompanying table which shows that the slightly heavier Jobo surpasses Yellow Poplar, usually only by a small margin, in every property except elastic resilience and work to maximum load. The most significant of these differences are probably the substantially greater hardness and strength in compression across the grain shown by Jobo.

Upon air drying, Jobo showed moderate increases in most strength properties but only in elastic resilience and work to maximum load were these increases as great as those commonly shown by domestic hardwoods. Side hardness remained virtually unchanged and tension across the grain and cleavage resistance decreased substantially upon air seasoning.

The air-dry wood of Jobo compares closely to the average properties anticipated for a wood of its density in static bending, hardness, and shear. It lies above the average in tension perpendicular to the grain, and below the average in compressive strength both parallel and perpendicular to the grain. The wood is quite similar to Yellow Poplar in its air-dry properties. As shown in the table, Yellow Poplar is slightly superior in bending strength, stiffness, compression and tension perpendicular to the grain, shear, and cleavage.

pecies	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		STATIC BENDING				
							Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
obo											
Spondias	Venezuela	3	Green	131.4	0.44	0.40	3,460	6,400	1,160	0.60	3.8
lombin)			Air Dry[1]	11.2			5,870	8,810	1,280	1.53	6.3
	Colombia[3]		Green	116	0.38	0.34	3,500	4,700	740	0.93	2.5
			Air Dry[1]	10.9			4,300*	6,200*	1,100*	0.99*	2.9*
'ellow Poplar[2]											
Liriodendron	United		Green	64	0.43	0.38	3,400	5,400	1.090	0.62	5.4
ulipifera)	States		Air Dry	12			6,100	9,200	1,500	1.43	6.8

Species	Condition	COMPRESSION PARALLEL TO GRAIN			Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity							
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Jobo											
(Spondias Mombin)	Green	2,000	2,560	1,090	580	530	490	600	770	260	74.1
Venezuela	Air Dry[1]	2,680	4,410	1,560	750	520*	540	470*	1030	200*	
Colombia[3]	Green	—	2,570	—	460	410	400	300	820	300	—
	Air Dry[1]	—	4,520*	—	570*	330*	630*	—	1050*	—	
Yellow Poplar[2]											
(Liriodendron											
tulipifera)	Green	1,930	2,420	—	390	340	330	450	740	220	—
United States	Air Dry	3,550	5,290	—	560	450	580	520	1100	280	

[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] U. S. Dept. Agr. Tech. Bul. 479 (64).

[3] Curran, H. M., *Tropical Woods* 19: 35-38. Data should be considered only a rough indication of the species properties, as a portion of the material tested was somewhat decayed and the number of tests very limited (14).

The superiority of Yellow Poplar is somewhat greater in compression parallel to the grain, but these two species are comparable in elastic resilience and shock resistance, and Jobo is appreciably higher than Poplar in both end and side hardness.

The wood of *Spondias Mombin* is characterized by moderate shrinkage. As shown in the accompanying table, volumetric shrinkage of 10.0 percent is less than that of Yellow Poplar and about the same as that of Butternut *(Juglans cinerea)*, both of somewhat lower density than Jobo. Radial shrinkage of 2.9 percent is exceptionally low and tangential shrinkage of 6.3 percent is intermediate to that of Butternut and Yellow Poplar.

	SHRINKAGE (percent)			
Species and Source	Radial	Tangential	Longitudinal	Volumetric
Jobo *(Spondias Mombin)* Venezuela	2.9	6.3	0.27	10.0
Butternut[1] *(Juglans cinerea)* United States	3.3	6.1	—	10.2
Yellow Poplar[1] *(Liriodendron tulipifera)* United States	4.0	7.1	—	12.2

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

The wood is reputed to be low in resistance to decay and insect attack (77). Durability tests of this study also show Jobo to be non-durable when exposed to a white-rot and a brown-rot fungus. Insect damage on logs as received from Venezuela was moderate and restricted to the sapwood. Moderate stain was present in both sapwood and heartwood, however.

The wood is easy to work because of its low density. Although the wood tested included material with slightly interlocked grain, fairly smooth surfaces were obtained in both sawing and planing. Boring produced a fuzzy surface with no tendency toward torn grain.

Several authors (25, 77) suggest that the wood is suitable for making boxes and crates, utility plywood, and for interior construction. For satisfactory use as lumber, the logs would have to be sawed without delay and the boards dipped in a toxic chemical and dried promptly to avoid deterioration by insects and fungi. Most of the lumber cut in Venezuela is utilized in shipping containers and bottle cases for soft drinks (95). The wood has also been used for making match sticks (25, 77). In many localities common use is made of the tree as living fence posts (66, 91). Standley (87) reports that the wood has been used in Brazil for paper pulp. This possibility has been explored by the Imperial Institute of London and a good yield of pulp was obtained which bleached to produce a strong white paper (46, 47).

References: 14, 25, 46, 47, 59, 63, 65, 66, 68, 73, 77, 87, 91, 95, 101, 102.

MAHOGANY *Swietenia macrophylla* King

Mahogany is so well known as to require no detailed description. It is unquestionably the most valuable timber tree in tropical America. Although recognizing several species of *Swietenia*, Record and Hess (77) conclude that for commercial purposes "all of the Mahogany of continental North and South America can be considered as one botanical species, *Swietenia macrophylla* King."

The range of this species has been reported (77) to extend from the Yucatan Peninsula through Central America into Colombia and Venezuela, with an extensive outpost in the headwaters of the Amazon and a number of its tributaries in Peru and western Brazil. With such a wide distribution it is only natural to question the influence of geographical occurrence on the density and technical properties of the wood. Record and Hess (77) conclude that, although variation is evident "the differences . . . which occur throughout the entire range are not appreciably greater than can be found within the boundaries of one small country."

The following discussion relates to the properties of *Swietenia macrophylla* King growing in high virgin forest in the vicinity of Marabá on the lower Rio Tocantins in the

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		STATIC BENDING				
							Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
ahogany Swietenia acrophylla)	Brazil	2	Green	56.8	0.49	0.45	6,070	8,960	1,280	1.70	9.0
			Air Dry[1]	11.9			8,360	11,590	1,420	2.77	7.8*
ahogany Swietenia acrophylla)	Central America[2]		Green	—	0.52	0.46	5,270	8,830	1,280	1.24	8.8
			Air Dry[1]	11.6			7,300	11,400	1,520	2.03	6.6*
	Central America[3]		Green	58	0.50	0.45	6,120	9,240	1,290	—	10.2
			Air Dry	12			8,810	11,140	1,430	—	6.8
	Mexico Nicaragua[4]		Green	101.2	0.50	0.45	5,100	8,800	1,460	1.02	8.4
			Air Dry[1]	10.6			7,760	11,840	1,540	2.12	9.2
	Average		Green	79.6	0.51	0.45	5,500	8,960	1,340	1.13	9.1
			Air Dry[1]	11.4			7,960	11,460	1,500	2.08	7.5

Species	Condition	COMPRESSION PARALLEL TO GRAIN			Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity							
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Mahogany (*Swietenia macrophylla*) Brazil	Green	3,830	4,340	1,370	770	790	670	630	1140	320	82.4
	Air Dry[1]	5,170	6,470	1,500	960	970	900	610*	1250	300*	
Mahogany (*Swietenia macrophylla*) Central America[2]	Green	2,900	3,940	1,470	890	750	630	700	1330	320	88.2
	Air Dry[1]	5,340	7,010	1,470	940	840	1160	780	1380	330	
Central America[3]	Green	—	4,540	—	750	650	710	—	1310	—	—
	Air Dry	—	6,430	—	880	760	1210	—	1050	—	
Mexico, Nicaragua[4]	Green	3,250	4,530	1,570	810	820	700	770	1080	340	—
	Air Dry[1]	4,830	6,910	1,530*	1080	790*	910	710*	1260	360	
Average	Green	3,080	4,340	1,520	820	740	680	740	1240	330	88.2
	Air Dry[1]	5,080	6,780	1,500*	970	800	1090	740	1230	340	

[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] Based on a shipment of plank material representing an unknown number of trees.

[3] Heck (38).

[4] Kynoch and Norton (54).

state of Pará, Brazil. This occurrence is considerably to the north and east of the range of the species as generally reported in Brazil (6, 77), but is in the area in which Froes (29) discovered Mahogany in 1943. A considerable number of large Mahogany trees have subsequently been reported from this locality.

The trees from which test logs were obtained were 80 to 90 feet in height with a clear bole of 50 feet and a diameter of approximately 30 inches at stump height.

No departure from the normal characteristics of Mahogany from Central America was evident in color, texture, grain, or density. Average specific gravity of the wood based on oven-dry weight and green volume is 0.45 (0.41-0.58), identical to the average for several sources. Weight per cubic foot in the green condition is 44 pounds and in the air-dry condition it is 33 pounds.

Mahogany from Brazil proved to be easy to air season in tests conducted as a part of this study. In this respect, it is comparable to material from the usual American sources. Lumber dried rapidly with a minimum of defect in the form of slight crook and twist.

Most of the strength properties exhibited by the unseasoned wood of the Mahogany from Brazil involved in these tests are close to the average anticipated for a wood of comparable density. Proportional limit stresses in static bending and longitudinal compression and elastic resilience are above average, and toughness is below average.

In the accompanying table, values for Mahogany from Brazil are compared directly with data for this species from several sources in Central America and Mexico. No differences in density or strength of any consequence are shown between the data for Mahogany from these various sources.

The wood increased only moderately in strength upon air drying. Without exception, the proportionate increase in strength was less than that generally shown for the corresponding property by domestic hardwoods. In work to maximum load, tension perpendicular to the grain, and cleavage, Mahogany from Brazil showed slight decreases upon drying. These effects are similar to those shown by Mahogany from Central America, although the latter remained unchanged in strength in tension across the grain and cleavage upon drying.

In its air-dry properties this species is also close to the average for a wood of its density. Proportional limit stresses in static bending and longitudinal compression, elastic resilience, side hardness, compression across the grain, tension across the grain, and cleavage resistance are slightly above average, and shock resistance somewhat below average. The close similarity between the values for Mahogany from the various American sources previously noted in the green condition prevails also with respect to the air-dry wood. It seems reasonable to conclude that Mahogany from Brazil is comparable to Mahogany from Central America and Mexico with respect to density and strength.

The Mahogany from Brazil that was included in this study compares closely in shrinkage characteristics with Mahogany from other sources. The similarity is clearly shown in the accompanying table. Volumetric shrinkage of the Brazilian material is 7.8 percent, slightly more than half as much as would normally be anticipated for a wood of this density. Radial shrinkage of 3.0 percent and tangential shrinkage of 4.1 percent are typical of the uniform shrinkage for which Mahogany is so well known.

Species and Source	SHRINKAGE (percent)			
	Radial	Tangential	Longitudinal	Volumetric
Mahogany				
(Swietenia macrophylla)				
Brazil	3.0	4.1	0.08	7.8
Central America[1]	3.5	4.8	—	7.7

[1] Forest Products Laboratory, Madison, Wis.

On the basis of decay resistance tests conducted as a part of this study, the Brazilian Mahogany tested appears to be slightly less durable than material from Central America. The former proved to be durable to moderately durable in resistance to a white-rot organism and very durable to durable upon exposure to a brown-rot fungus. Material from commercial sources in Central America was found to be very durable to durable when exposed to a white-rot and very durable to a brown-rot fungus. These limited tests cannot, however, be assumed to reflect a fundamental difference in decay resistance of material from the two sources. Mahogany exhibits little resistance to marine borers. In exposure tests conducted at Wrightsville, North Carolina as a part of this study, *Swietenia macrophylla* from Central America withstood attack during the first year but was heavily damaged after 16 months' exposure (10). The material from Brazil was destroyed during the first year of immersion (11). Edmondson also found that South American Mahogany *(Swietenia macrophylla)* had little resistance to marine borers in tests conducted in Hawaii (23). Chemical analyses of samples from the same logs that supplied specimens exposed at Wrightsville showed an average total ash content of 0.60 percent and an average silica content of only 0.034 percent (98).

Observations made during the preparation of test specimens indicate no basic difference in the machinability of Mahogany from Brazil as compared with material from Central America. The wood is easily worked and smooth surfaces result from planing, boring, and sawing operations.

The results of these tests all indicate the close similarity of Mahogany from the Rio Tocantins valley in Brazil to that from other sources for which data were previously available, and lend confirmation to the conclusion that the wood of the species is not affected by wide geographical differences in origin. There appears to be no reason why *Swietenia macrophylla* from Brazil should not enjoy the same preference for a wide variety of purposes that has marked the use of Mahogany since the 16th century.

References: 6, 10, 11, 23, 29, 38, 54, 77, 98.

BETHABARA *Tabebuia serratifolia* (Vahl) Nichols.
(= *Tecoma serratifolia* G. Don)

This species is also known in the export trade as Surinam Greenheart, Arcwood, Noibwood, and Bastard Lignum-vitae. It is called Wassiba, Groenhart, and Alahorre in Surinam; Hakia in British Guiana; Pau d'Arco, Ipe and Ipe Tobaco in Brazil; and by numerous other names.

This species grows in Mexico, Central America, Colombia, Bolivia, Peru, Paraguay, Venezuela, the Guianas, and in Brazil as far south as São Paulo. It forms pure stands in some areas but prefers the sides and tops of ridges to swampy ground.

It is a deciduous tree of medium height in many areas (102), but becomes one of the tallest trees in the uplands of the Amazon with a trunk that will square 30 inches of heartwood. The trunks are usually straight and frequently buttressed.

The heartwood of freshly cut wood is yellowish green and the sapwood, which is 1½ to 3½ inches wide, is cream colored. The dry heartwood is light to dark olive brown, often with lighter or darker streaks. The dry sapwood is white or grayish white. The grain is straight to very irregular.

The pores in the sapwood are at the limit of vision without a lens, but in the heartwood the pores appear as fine yellow dots as they are filled with a yellowish powder. This powder is a lapachol compound which turns red when brought into contact with an alkali. It is characteristic of several species of this genus including *T. guayacan* and *T. heterotricha* (16, 39, 99). On longitudinal surfaces of the heartwood the pores appear as yellow lines. The pores themselves have no definite arrangement but they are surrounded by parenchyma which under a lens can be seen to stretch out tangentially in wings, often connecting several pores. Narrow, darker zones in which the pores are less numerous mark off distinct but not sharply defined growth layers. The rays are very fine and inconspicuous on all surfaces, but are arranged in stories which form very fine "ripple marks" on tangential surfaces.

The specific gravity based on green volume and oven-dry weight averages 0.92 (0.86-0.96). The average weight per cubic foot is 75 pounds when green and 69 pounds at 12 percent moisture content.

The wood from a log of an undetermined species of *Tabebuia* from Brazil, identified in the field as Pau d'Arco, also was tested under this project. Its average specific gravity based on volume when green and weight when oven dry was 0.83 (0.80-0.85). Weight per cubic foot when green was 79 pounds and at 12 percent moisture content it was 65 pounds. The heartwood of this wood was chestnut brown in color. The pores, which were individually not visible without a lens, were filled with tyloses (not yellowish powder). They were isolated or arranged in short wavy tangential lines connected by parenchyma. Alternating lighter and darker growth zones were present due to variations in concentration of the pores. The rays were fine and inconspicuous on all surfaces. "Ripple marks" due to storied rays were present but obscure.

Bethabara exhibited a rapid rate of drying during air seasoning in spite of its high density, and the wood is rated easy to season. Slight warping took the form of crook and twist, and end and surface checking was slight, as was casehardening. Material from one log of Pau d'Arco *(Tabebuia* sp.) was rated moderately difficult to season with a minimum of degrade.

Test material of Bethabara for this study came from two sources: Surinam and Brazil. Although some differences may be noted in the accompanying table, they are of relatively minor importance and the data from both sources have been combined to obtain average values for the species. This species is much denser and stronger than any domestic wood. Even when compared with other tropical woods of comparable high density unseasoned Bethabara exhibits superior strength properties in every respect and is outstanding in its ability to resist shock.

As shown in the table, the unseasoned wood is appreciably stronger, but less stiff, than Greenheart in static bending. It surpasses Greenheart by a considerable margin in elastic resilience, shock resistance, hardness, bearing strength, and shear and is at least comparable to Greenheart in other respects. Bethabara is substantially heavier and stronger in all properties of the unseasoned wood except shear than the related Guayacan *(T. guayacan* and *T. heterotricha)* (99), and as shown in the accompanying table, it also exceeds in most respects the values determined for Pau d'Arco *(Tabebuia* sp.) from Brazil, although data for the latter are based upon tests of only a single log.

Upon air drying, the wood improved slightly in most of its properties although in no case was the proportionate increase as great as that commonly exhibited by domestic hardwoods. Decreases occurred on drying in work to maximum load, shear, and particularly in cleavage resistance and tension perpendicular to the grain. Loss of strength in the two latter properties is probably attributable in part to the effects of seasoning checks. There was no change in bearing strength associated with seasoning.

The air-dry wood is outstanding among other woods of comparable high density for its hardness and toughness. Work to maximum load, elastic resilience, and compression across the grain are about average on this basis of comparison, and the remaining properties are somewhat below average. The accompanying table shows that Bethabara and Greenheart are similar in static-bending properties including work to maximum load, and also in crushing strength and shear. Bethabara is appreciably harder than Greenheart and superior in compression across the grain, but falls well below Greenheart in tension across the grain.

As in the green condition, the air-dry wood of Bethabara is distinctly superior to Guayacan *(T. guayacan* and *T. heterotricha)* in static-bending strength and stiffness, crushing strength, and hardness. These species are comparable in compression across the grain and shock resistance as measured by work to maximum load, but Bethabara is surpassed

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		Static Bending: Fiber Stress at Proportional Limit	Static Bending: Modulus of Rupture	Static Bending: Modulus of Elasticity	Static Bending: Work to Proportional Limit	Static Bending: Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Bethabara (*Tabebuia serratifolia*)	Brazil	1	Green	32.0	1.07	0.94	13,080	21,690	2,530	4.82	33.3
			Air Dry[1]	12.6			13,900	22,500	2,640	4.10*	18.9*
	Surinam	2	Green	30.3	1.05	0.91	15,370	23,430	3,320	4.28	21.8
			Air Dry[1]	12.0			19,420	28,210	3,640	5.86	25.1
	Average	3	Green	31.2	1.06	0.92	14,220	22,560	2,920	4.55	27.6
			Air Dry[1]	12.3			16,660	25,360	3,140	4.98	22.0*
Pau d'Arco (*Tabebuia* sp.)	Brazil	1	Green	51.9	0.94	0.83	13,340	21,290	2,540	3.94	17.0
			Air Dry[1]	12.3			15,240	25,100	2,760	4.77	23.9
Greenheart[2] (*Ocotea Rodiaei*)	Britsh Guiana		Green	42.7	1.06	0.88	13,250	19,550	2,970	3.31	13.4
			Air Dry[1]	14.8			16,200*	25,500*	3,700*	4.02*	22.0*
White Oak[3] (*Quercus alba*)	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
			Air Dry	12			8,200	15,200	1,780	2.27	14.8

Species	Condition	Compression Parallel to Grain: Fiber Stress at Proportional Limit	Compression Parallel to Grain: Maximum Crushing Strength	Compression Parallel to Grain: Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Bethabara (*Tabebuia serratifolia*)											
Brazil	Green	7,430	9,420	2,580	2750	3350	2500	1480	2340	690	366.7
	Air Dry[1]	6,840*	11,770	2,940	3110	3720	2470*	500*	2060*	440*	
Surinam	Green	10,350	11,280	3,640	2510	2780	2090	1200	1900	540	441.0
	Air Dry[1]	11,170	14,250	3,570*	3260	3640	2140	500*	2070	310*	
Average	Green	8,890	10,350	3,110	2630	3060	2300	1340	2120	620	403.8
	Air Dry[1]	9,000	13,010	3,260	3180	3680	2300	500*	2060*	380*	
Pau d'Arco (*Tabebuia* sp.)											
Brazil	Green	9,140	10,730	2,730	2410	2520	1780	1130	1970	500	317.9
	Air Dry[1]	9,570	12,200	2,700*	3070	3160	2160	530*	2140	280*	
Greenheart[2] (*Ocotea Rodiaei*)											
British Guiana	Green	7,580	10,160	3,580	2260	2320	2040	1070	1730	610	—
	Air Dry[1]	10,000*	12,920*	4,160*	2140*	2630*	1970*	1020*	1830*	—	—
White Oak[3] (*Quercus alba*)											
United States	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[4]
	Air Dry	4,760	7,440	—	1520	1360	1320	800	2000	450	

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[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] Kynoch and Norton (54).

[3] U. S. Dept. Agr. Tech. Bul. 479 (64).

[4] Value obtained for plank material received from the New York Naval Shipyard.

by these lighter related species in shear, cleavage, and tension across the grain. The properties of air-dry Bethabara are closely matched by the data for Pau d'Arco as shown in the table. The chief differences appear to be the lesser stiffness and side hardness values for Brazilian Pau d'Arco.

The following table provides a comparison of the relative strength properties of Bethabara and White Oak in the green and air-dry conditions. In each case White Oak has been arbitrarily assigned a value of 100.

	Specific gravity	Bending strength	Stiffness	Shock resistance	Crushing strength
Green	153	272	234	238	291
Air Dry		167	176	149	175

	Side hardness	Shear	Bearing strength	Cleavage resistance
Green	289	170	278	148
Air Dry	270	103	174	85

Bethabara exhibits relatively low shrinkage in proportion to its high density. Volumetric shrinkage of 13.2 percent is approximately that which might be anticipated for a domestic wood only half as dense as Bethabara. Shrinkage values of 6.6 percent radially, 8.0 percent tangentially, and 13.2 percent volumetrically are all less than corresponding values for White Oak. The slightly less dense Pau d'Arco of Brazil is characterized by shrinkage comparable to that of Black Walnut as shown in the tabulation.

The wood is reputed to be highly resistant to decay (25, 68, 77). This reputation is borne out by results of this study. Wood exposed to both a white-rot and a brown-rot fungus proved to be very durable. Thorough agreement is shown with material of *Tabebuia* sp. which also rated very durable to both a white-rot and a brown-rot fungus. Bethabara ties used in poorly drained soil in Brazil lasted 10 to 12 years and those placed in well-drained soil lasted 18 to 20 years (41). Bethabara is susceptible to marine-borer attack despite its hardness and density. Although exposure tests at Wrightsville, North Carolina revealed only light marine-borer activity in specimens representing both Brazil and Surinam material after 6 months' immersion, the small test specimens showed moderate to fairly heavy damage at the end of the first year (11). This confirms the rating by Edmondson (23) who classed *Tabebuia serratifolia* among species showing little resistance to marine-borer activity in Hawaii. Amos has reported the silica content of this species as only 0.01 percent (1). Pau d'Arco *(Tabebuia conspicua)* (which may be the same wood referred to in this report by this vernacular name) was also included in Edmondson's tests and was rated moderately resistant to marine-borer attack (23).

Species and Source	Shrinkage (percent) Radial	Tangential	Longitudinal	Volumetric
Bethabara				
(Tabebuia serratifolia)				
Brazil	6.5	7.9	0.18	12.8
Surinam	6.6	8.0	0.14	13.5
Average	6.6	8.0	0.16	13.2
Pau d'Arco				
(Tabebuia sp.)				
Brazil	4.9	7.3	0.08	11.5
White Oak[1]				
(Quercus alba)				
United States	5.3	9.0	—	15.8
Black Walnut[1]				
(Juglans nigra)				
United States	5.2	7.1	—	11.3

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

Largely because of its density, Bethabara proved moderately difficult to machine, although cutting edges seemed to retain their keenness. Surfaces resulting from sawing and planing were very smooth in the case of straight-grained material. Interlocked grain, which is often present in this species, would probably not yield such smooth surfaces, especially in planing. The single log of *Tabebuia* sp. exhibited interlocked grain and planed surfaces were somewhat torn. The yellowish powder in the wood often so fills the air during sawing operations that it becomes a considerable nuisance. No ill effects were noted although it has been reported that the wood sometimes gives rise to a mild form of dermatitis (77).

Both *T. serratifolia* and *T. guayacan* (16) are members of the *Lapacho* group of the genus *Tabebuia*. The latter is the principal species of the group in Central America, while *T. serratifolia* is the most important in its range from central Brazil to Colombia (77). Both timbers are valued for their strength, toughness, resilience, and resistance to insects and decay. Bethabara finds use in Brazil for railway crossties, fence and house posts, and bridge construction.

Fanshawe (25) reports that in British Guiana the wood is used for bridge construction, house framing, and railway crossties. Specialty uses include tool handles, walking sticks, fishing rods, and archery bows. Some logs are highly figured and veneers have been used for decorative work both in England and the United States (43).

Record and Hess (77) state that the closely related species, *T. ipe*, of northeastern Argentina and Paraguay is used extensively in those countries for general construction, carpentry, cabinet work, turnery, and vehicles. Between four and five million board feet are thus used annually. In the northern portion of its range lumber of this species is not differentiated in the trade from that of *T. serratifolia*.

References: 1, 11, 16, 23, 25, 39, 41, 43, 44, 68, 73, 77, 86, 90, 99, 102.

BANAK

Virola surinamensis (Rol.) Warb.
(= *Myristica surinamensis* Roland)

The tree and wood of the species here described are also known as Cuajo and Camaticaro in Venezuela; Carjuco and Wild Mustard in Trinidad; Baboen and Moonba in Surinam; Becuiba and Ucuúba in Brazil.

In Brazil, Banak is found in the northernmost part of the state of Amazonas and the coastal region of Pará, including the whole Amazon estuary, the northern part of Marhanão and northern Ceará. It is extremely abundant in the low inundable islands of the estuary, where it represents the majority of the larger trees. It also grows in southern Venezuela, the Guianas, Trinidad, and the Lesser Antilles. Banak is a medium sized to large tree, attaining under favorable conditions a height of at least 125 feet and diameter of 2-3 feet.

Two other well-known species of *Virola*, also called Banak in the trade, are *V. sebifera* Aubl. and *V. Koschnyi* Warb. (= *V. merendonis* Pittier). The former is found in Brazil and the latter in Central America from British Honduras and Guatemala to Panama. The woods of these three species are said to be very much alike. The fruit of another well-known species of the family to which Banak belongs, namely the nutmeg family (Myristicaceae), furnishes the spices nutmeg and mace (32).

The freshly cut heartwood and sapwood are of about the same color, namely cream or tan, and are difficult to distinguish. Slight differences in color, however, indicate that the sapwood is only ¼ to ½ inch wide. On drying and exposure to air and light the heartwood becomes darker ranging from pinkish to deep reddish brown. Its luster is low. The wood has no characteristic odor or taste when dry. The grain is straight and the texture is coarse.

The average specific gravity of the wood, based on oven-dry weight and green volume, is 0.42 (0.40-0.44). Weight per cubic foot in the green condition averages 51 pounds and at 12 percent moisture content it averages 32 pounds.

The wood is reported to dry readily without warping or checking (77). Banak is rated as easy to season on the basis of the present study. Only slight degrade in the form of warping and casehardening resulted from rapid drying.

In comparison with other moderately light woods, unseasoned Banak is below average in all strength properties, but its stiffness is exceptionally high. Banak is particularly deficient in compressive and tensile strength perpendicular to the grain.

The accompanying table includes data from another source on *Virola Koschnyi* of Central American origin for comparison with these results for *Virola surinamensis* from Brazil. The Central American material was slightly heavier

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		Static Bending: Fiber Stress at Proportional Limit	Static Bending: Modulus of Rupture	Static Bending: Modulus of Elasticity	Static Bending: Work to Proportional Limit	Static Bending: Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Banak *(Virola surinamensis)*	Brazil	2	Green	93.8	0.50	0.42	3,580	5,600	1,640	0.46	4.1
			Air Dry[1]	11.4			6,900	10,950	2,040	1.40	10.0
Banak[2] *(Virola Koschnyi)*	Central America	1	Green	75	0.51	0.44	—	6,200	1,470	—	5.3
			Air Dry	12			—	10,800	1,720	—	8.1
Mahogany[3] *(Swietenia macrophylla)*	Central America		Green	79.6	0.51	0.45	5,500	8,960	1,340	1.13	9.1
			Air Dry[1]	11.4			7,960	11,460	1,500	2.08	7.5
Yellow Poplar[4] *(Liriodendron tulipifera)*	United States		Green	64	0.43	0.38	3,400	5,400	1,090	0.62	5.4
			Air Dry	12			6,100	9,200	1,500	1.43	6.8

Species	Condition	Compression Parallel to Grain: Fiber Stress at Proportional Limit	Compression Parallel to Grain: Maximum Crushing Strength	Compression Parallel to Grain: Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Banak *(Virola surinamensis)* Brazil	Green	1,740	2,390	1,900	430	320	200	260	720	180	60.6
	Air Dry[1]	3,330	5,140	2,130	560	510	270	360	980	200	
Banak[2] *(Virola Koschnyi)* Central America	Green	—	3,050	—	590	440	—	—	660	240	—
	Air Dry[1]	—	5,720	—	950	640	—	—	1300	240	
Mahogany[3] *(Swietenia macrophylla)* Central America	Green	3,080	4,340	1,520	820	740	680	740	1240	330	88.2
	Air Dry[1]	5,080	6,780	1,500*	970	800	1090	740	1230	340	
Yellow Poplar[4] *(Liriodendron tulipifera)* United States	Green	1,930	2,420	—	390	340	330	450	740	220	—
	Air Dry	3,550	5,290	—	560	450	580	520	1100	280	

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[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] Dept. Sci. and Indus. Research (Gt. Britain), Forest Products Research Bul. 28 (1a).

[3] Heck (38); Kynoch and Norton (54); unpublished Yale results for plank material received from the New York Naval Shipyard.

[4] U. S. Dept. Agr. Tech. Bul. 479 (64).

and correspondingly stronger in most properties of the unseasoned wood, although not as high as *V. surinamensis* in modulus of elasticity. The table also permits direct comparison to be made with Yellow Poplar, and the similarity between Banak and Yellow Poplar is evident. The only important differences in the unseasoned condition appear to be the much greater stiffness of Banak and the appreciable superiority of Yellow Poplar in compression and tension across the grain. Banak is surpassed by Mahogany in every property except modulus of elasticity.

Upon air drying, Banak improved substantially in all properties, exceeding the proportionate increase in strength generally shown by domestic hardwoods in all properties except modulus of elasticity, end hardness, compression perpendicular to the grain, and shear.

In comparison with other species of like density, air-dry Banak is in a more favorable position than the green wood. In addition to its outstandingly high stiffness, Banak is above average in work to maximum load, and very close to the average anticipated on the basis of its specific gravity in bending strength, crushing strength, tension across the grain, and shear. It is below average in other respects. The air-dry properties of the Brazilian material of this study are shown in the accompanying table to lie generally below those determined for *Virola Koschnyi*, although *V. surinamensis* appears to be considerably stiffer, and slightly superior in static-bending strength and work to maximum load.

Air-dry Banak is similar to Yellow Poplar in many respects, exceeding the latter by a relatively small margin in most static-bending properties—stiffness excepted. In the latter the superiority shown by Banak in the green condition was retained. Again, however, Yellow Poplar is shown to advantage in compression and tension perpendicular to the grain. The superiority of air-dry Mahogany over Banak is particularly evident in hardness, transverse compression and tension, shear, and cleavage values, although Banak retained its advantage in stiffness shown earlier for the green condition.

Banak exhibits unusually high shrinkage, especially in the tangential direction. Radial shrinkage of 5.3 percent, tangential shrinkage of 12.4 percent, and volumetric shrinkage of 17.6 percent are all greater, and the tangential and volumetric particularly so, than corresponding values for Yellow Poplar of approximately the same density. Previously, attention had been called to the unusually high tangential shrinkage of a closely related species, *Virola Koschnyi*, that was noted in connection with kiln-drying studies (27).

	SHRINKAGE (percent)			
Species and Source	Radial	Tangential	Longitudinal	Volumetric
Banak				
(Virola surinamensis)				
Brazil	5.3	12.4	0.00	17.6
Yellow Poplar[1]				
(Liriodendron tulipifera)				
United States	4.0	7.1	—	12.3

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

The wood is reputed to be low in resistance to decay (77). Recently completed durability tests confirm this, in that wood of Banak was non-durable when exposed to both a white-rot and a brown-rot fungus. Similar results were obtained by Scheffer and Duncan (82) in both soil and pure culture tests involving white-rot fungal attack of Chalviande (*Virola* sp.). The wood is also reputed to be subject to the attack of pinworms, actually small beetles, during logging operations (77). It is necessary to saw logs into lumber shortly after felling in order to avoid damage. Spraying logs with a suitable insecticide is also recommended. Even after drying, Banak is susceptible to attack by powder-post beetles and should be kept under surveillance if storage is prolonged.

Because of its low density Banak works easily. The wood is straight grained and satisfactory results are obtainable in sawing and planing, although fibers occasionally tear out in planing (31). Care is required in boring if torn grain is to be avoided. The wood can be nailed and screwed easily without splitting, it is readily glued, and takes a good finish (25, 77). In machining tests conducted at the Forest Products

Laboratory, Banak was found to compare with 25 domestic hardwoods as follows, based on percent of defect-free pieces: above average in shaping and sanding; average in planing; and below average in turning, boring, and mortising (15).

Uses for the wood have been limited in the past. Record and Hess (77) report its use as veneer and solid lumber for general utility purposes. Fanshawe (25) states that the wood is used locally in British Guiana for match boxes, coffins, and interior construction. It is also regarded as suitable for general carpentry, packing cases, plywood, and slack cooperage. Its similarity in many respects to Yellow Poplar suggests the possible use of Banak as lumber core stock for veneered panels, although the high ratio of tangential to radial shrinkage may require that special attention be given to segregation of plain and quarter-sawn stock.

The seeds of Banak, and related species, are rich in oil used for making candles and soap. Large quantities of Ucuhuba seeds, as they are called, are exported yearly from Pará (77).

References: 1a, 15, 25, 27, 31, 32, 34, 59, 68, 73, 77, 82.

ACAPÚ *Vouacapoua americana* Aubl.

The name Acapú is applied to this species of timber in Brazil. Other common names are Bruinhart and Wakapoe in Surinam, and Wacapou in French Guiana. In English literature it is sometimes referred to as Brownheart or Partridge Wood.

Acapú occurs sparingly in British Guiana, but is fairly common in Surinam and French Guiana. It attains its best development in the state of Pará, Brazil (22, 77) where it is very important locally as a timber tree (17). This species inhabits the primary forests of the higher lands close to the rivers. It does not occur in the state of Amazonas although the name Acapú is sometimes applied there to other species.

The tree is tall with a bole 50 to 75 feet in length and up to 36 inches in diameter, but usually not over 24 inches. The trunk is unbuttressed.

The freshly cut heartwood is dark olive to dark chocolate in color, whereas the sapwood, which is from ¾ inch to 1¼ inches wide, is cream colored. The dry heartwood is dark brown with numerous fine lighter colored lines, or reddish brown eventually turning almost black (44). The dry wood lacks distinctive odor or taste.

The grain is usually straight and the texture uniformly coarse. The pore openings themselves are not visible on the end surface without a lens, but the pore locations are made distinct by a surrounding layer of light colored parenchyma which give the appearance of very pale brown spots on the end surface, and of similarly colored lines on longitudinal surfaces. The pores are arranged in no definite pattern but the parenchyma around them often extends laterally connecting several pores in short tangential or echelon rows. The pores are mostly open although some contain small quantities of amber colored gum. Faint growth layers marked by fine lines of parenchyma and slight variations in the porosity of the wood are apparent. The rays are fine and inconspicuous on all surfaces.

Average specific gravity based upon oven-dry weight and green volume is 0.79 (0.73-0.85). Weight per cubic foot in the green condition averages 73 pounds and at 12 percent moisture content is 59 pounds.

Acapú is moderately difficult to air season. Material observed in this study dried at a moderate rate with slight warping in the form of cup and twist. A portion of the stock developed slight end and surface checking and was also slightly casehardened.

In a number of strength properties Acapú ranks appreciably above the heaviest well known domestic woods. When compared with other tropical species of similar high density, the unseasoned wood of Acapú is above average in compressive strength parallel to the grain, and in all static-bending properties except modulus of rupture. It is equal to the average in modulus of rupture, toughness, and in compression perpendicular to the grain, and below average in hardness, shear, cleavage resistance, and tension across the grain.

Species	Source	No. of Logs	Condition	Moisture Content	Specific Gravity		Static Bending: Fiber Stress at Proportional Limit	Modulus of Rupture	Modulus of Elasticity	Work to Proportional Limit	Work to Maximum Load
				percent	Oven-dry vol.	Green vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Acapú (*Vouacapoua americana*)	Surinam	3	Green	47.9	0.91	0.79	12,450	15,850	2,620	3.44	14.5
			Air Dry[1]	12.7			13,720	21,640	2,530*	4.23	17.0
Greenheart[2] (*Ocotea Rodiaei*)	British Guiana		Green	42.7	1.06	0.88	13,250	19,550	2,970	3.31	13.4
			Air Dry[1]	14.8			16,200*	25,500*	3,700*	4.02*	22.0*
White Oak[3] (*Quercus alba*)	United States		Green	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
			Air Dry	12			8,200	15,200	1,780	2.27	14.8

Species	Condition	Compression Parallel to Grain: Fiber Stress at Proportional Limit	Maximum Crushing Strength	Modulus of Elasticity	Hardness		Compression Perpendicular to Grain	Tension Perpendicular to Grain	Shear	Cleavage	Toughness
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	End lb.	Side lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Acapú (*Vouacapoua americana*)											
Surinam	Green	7,280	9,170	2,750	1580	1610	1860	860	1510	380	202.6
	Air Dry[1]	9,590	11,480	2,740*	1600	1730	1220*	550*	1890	335*	
Greenheart[2] (*Ocotea Rodiaei*)											
British Guiana	Green	7,580	10,160	3,580	2260	2320	2040	1070	1730	610	—
	Air Dry[1]	10,000*	12,920*	4,160*	2140*	2630*	1970*	1020*	1830*	—	
White Oak[3] (*Quercus alba*)											
United States	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9[4]
	Air Dry	4,760	7,440	—	1520	1360	1320	800	2000	450	

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[1] Air-dry values adjusted to 12 percent moisture content except where designated (*) in which case the actual moisture content at time of testing (col. 5) applies.

[2] Kynoch and Norton (54).

[3] U. S. Dept. Agr. Tech. Bul. 479 (64).

[4] Value obtained for plank material received from the New York Naval Shipyard.

The comparison made in the accompanying table shows that in the green condiiton Acapú is surpassed by the heavier Greenheart in every property except work to proportional limit and shock resistance. The greatest differences between these species are shown in hardness, cleavage, bending strength, and stiffness.

Upon air drying, the wood showed slight increases in most properties, but only in work to maximum load in static bending (denoting shock resistance) was the proportionate increase as great as that commonly exhibited by domestic hardwoods. Modulus of elasticity decreased slightly, cleavage resistance was reduced somewhat more, and substantial decreases occurred in compression and tension perpendicular to the grain.

The air-dry wood is about average in most static-bending and compression parallel to the grain properties as compared with other tropical woods of similar density. It is above average in elastic resilience but below the average in shock resistance, hardness, shear, and cleavage resistance, and especially low in compression and tension across the grain. The unfavorable position of Acapú in comparison with Greenheart that was shown for the green wood is maintained when these species are compared in the air-dry condition. Except for elastic resilience and shear strength in which these woods are approximately equivalent, Acapú is clearly deficient to Greenheart. The greatest differences appear in hardness, stiffness, and compression and tension across the grain. In the air-dry condition, Acapú is much stronger and stiffer than White Oak in bending and compression parallel to the grain. Acapú surpasses Oak by a substantial margin in shock resistance and side hardness, but is exceeded by White Oak in compression and tension across the grain, shear, and cleavage resistance.

A convenient comparison between Acapú and White Oak in both the green and air-dry conditions is presented in the following tabulation in which White Oak has been assigned a rating of 100.

	Specific gravity	Bending strength	Stiffness	Shock resistance	Crushing strength
Green	132	191	209	125	258
Air Dry		142	142	115	155

	Side hardness	Shear	Bearing strength	Cleavage resistance
Green	152	121	224	90
Air Dry	127	95	92	74

Shrinkage of Acapú is low in relation to its density. As shown in the accompanying tabulation, radial shrinkage is 4.9 percent, tangential shrinkage is 6.9 percent, and volumetric shrinkage is 13.0 percent, all less than corresponding values for White Oak. Radial and tangential shrinkage values compare closely with published values for Black Locust, although the independently determined volumetric shrinkage value of Acapú is substantially greater than that found for Black Locust.

Species and Source	SHRINKAGE (percent)			
	Radial	Tangential	Longitudinal	Volumetric
Acapú *(Vouacapoua americana)* Surinam	4·9	6.9	0.12	13.0
White Oak[1] *(Quercus alba)* United States	5·3	9.0	—	15.8
Black Locust[1] *(Robinia pseudoacacia)* United States	4·4	6.9	—	9.8

[1] U. S. Dept. Agr. Tech. Bul. 479 (64).

The wood is reputed to be highly resistant to decay and insect attack (17, 22, 68, 77). In this study, the heartwood proved to be very durable upon exposure to both a white-rot and a brown-rot fungus. Acapú ties placed in poorly drained soil in Brazil lasted 6 to 8 years and ties in well-drained soil remained sound 18 to 20 years (41). Acapú heartwood is included high among the list of woods that are immune or very resistant to the dry-wood termite of the West Indies and the wood is superior to Mahogany in this respect (107). Data relating to the marine-borer resistance of Acapú are contradictory. Edmondson, on the basis of tests conducted in Hawaiian waters, has classed this wood among those species showing little resistance to marine-borer attack (23). In contrast, two series of tests on Acapú from Surinam that have been conducted at Wrightsville, North Carolina as a part of the present investigation have indicated a high degree of resistance. In the first of these tests Acapú showed no evidence of attack after 16 months' exposure and only moderate damage after 33 months. In the same series, Greenheart was moderately damaged in 16 months and destroyed in 30 months. A second series of exposures of Acapú has continued only through 12 months, and during this period only light marine-borer activity was noted (10, 11). This high degree of resistance cannot be attributed to silica in the wood as chemical analyses of specimens from the same logs showed a total ash content of 0.51 percent and a silica content of only 0.002 percent (98).

The wood is moderately difficult to work because of its density, but smooth surfaces were obtained in sawing and planing. The relatively coarse grain caused some difficulty in boring as torn grain was difficult to avoid. Heartwood is highly resistant to moisture absorption.

Acapú is one of the most important commercial woods in the state of Pará, Brazil, as well as in Surinam and French Guiana. In the latter two countries the wood is highly regarded commercially for heavy durable construction, but is becoming increasingly scarce in areas that are presently accessible. Acapú is exported from Pará to northeastern Brazil and in small quantities to southern Brazil and the United States. The timber is valued in Brazil for furniture, general construction, and for flooring, beams, and railway crossties (4). Record and Hess (77) report the wood is employed in French Guiana for furniture, carpentry, wheelwright work, and posts. Suggested uses include cabinetmaking and all kinds of civil and naval construction. Pfeiffer (68) states that in Surinam the attractive color and grain and working qualities recommend the timber for general utilization. Because of its scarcity and high price, however, the wood is best adapted in that country for cabinet work, interior trim, and parquet flooring.

References: 4, 10, 11, 17, 22, 23, 40, 41, 44, 66, 68, 77, 79, 80, 81, 98, 107.

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Test Material

Tree No.	Species	Source	Tree height, feet	Diameter at stump, inches	Top diameter of test log, inches	Character	Remarks
350	*Ceiba pentandra*	Venezuela	95	31	26	Old growth	
463	" "	"	67	37	27	Old growth	
464	" "	"	98	31	24	Second growth	
382	*Cordia Goeldiana*	Brazil	110	16	14		Well drained site
383	" "	"	76	14	12		" " "
159	*Diplotropis purpurea*	Brazil			22		Upland forest, sandy soil, elevation 66 feet
500	" "	Surinam	95	26	22	Old growth	Lowland forest, flooded annually
505	" "	"	110	18	16	Second growth	High forest, flat terrain, sea level
506	" "	"	92	20	14	Second growth	" " "
372	*Enterolobium Schomburgkii*	Brazil			28		Upland forest, sandy soil, elevation 66 feet
381	" "	"			17		
511	" "	"	121	25	23	Old growth	Virgin forest, sandy soil, elevation 40 feet
512	" "	"	128	31	21	Old growth	" " "
155	*Eschweilera Blanchetiana*	Brazil	91	27	20	Old growth	Virgin upland forest, elevation 570 feet
393	" *odora*	"	102	22	18		Virgin forest, well drained site
394	" "	"	102	22	14		" " "
395	" "	"	98	20	17		" " "

TEST MATERIAL—*Continued*

Tree No.	Species	Source	Tree height, feet	Diameter at stump, inches	Top diameter of test log, inches	Character	Remarks
73	*Eschweilera subglandulosa*	Surinam	95	17	16	Old growth	Lowland forest, flooded annually
74	" "	"	82	20	18	Old growth	" " "
75	" "	"	89	18	18	Old growth	" " "
341	" *tenax*	Venezuela	66	25	17	Old growth	
342	" "	"	79	32	17	Old growth	
495	*Goupia glabra*	Surinam	66	28	22	Old growth	Lowland forest, flooded annually
496	" "	"	89	20	17	Old growth	" " "
374	" "	Brazil			30		Upland forest, sandy soil, elevation 66 feet
384	*Holopyxidium jarana*	Brazil	85	13	10		High forest, well drained site
385	" "	"	95	15	13		" " "
130	" *latifolium*	"	97	24	18	Old growth	Virgin upland forest, elevation 570 feet
121	*Hymenolobium excelsum*	Brazil	131		42		Upland forest
388	" "	"	125	41	36		Well drained site
389	" "	"	66	18	14		Site periodically inundated
386	*Lecythis paraensis*	Brazil	98	18	14		Well drained site
387	" "	"	121	22	21		" " "
147	" *usitata*	"	109	32	23	Old growth	Virgin upland forest, elevation 570 feet

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TEST MATERIAL—*Continued*

Tree No.	Species	Source	Tree height, feet	Diameter at stump, inches	Top diameter of test log, inches	Character	Remarks
230	*Licania buxifolia*	British Guiana	80	16	14		Wallaba forest on white sand flat
231	" "	" "	75	16	12		" " "
232	" "	" "	100	16	12		" " "
70	" *macrophylla*	Surinam	82	20	18	Old growth	Lowland forest, flooded annually
493	" "	"	82	18	15	Old growth	" " "
494	" "	"	85	28	20	Old growth	" " "
390	" "	Brazil	78	18	14		Site periodically inundated
391	" "	"	80	16	15		" " "
392	" "	"	66	13	10		" " "
243	*Licaria cayennensis*	Surinam	110		11	Old growth	Sandy soil, elevation 50 feet
227	" "	British Guiana	100	21	18		Greenheart forest on loam, hilly terrain
228	" "	" "	85	18	14		" " "
229	" "	" "	90	22	18		" " "
127	*Mezilaurus itauba*	Brazil	70	21	15	Old growth	Virgin upland forest, elevation 570 feet
491	" "	Peru	36		13		Sandy soil, elevation 430 feet
492	" "	"			18		
493P	" "	"			18		

TEST MATERIAL—*Continued*

Tree No.	Species	Source	Tree height, feet	Diameter at stump, inches	Top diameter of test log, inches	Character	Remarks
181	*Minquartia guianensis*	Costa Rica			18		
182	" "	" "			15		
183	" "	" "			15		
71	*Parinari campestris*	Surinam	92	25	18		Lowland forest, flooded annually
72	" "	"	85	27	22	Old growth	" " "
233	" *excelsa*	British Guiana	70	20	14		Rain forest on brown sand, hilly terrain
234	" "	" "	86	26	22		" " "
235	" "	" "	79	30	26		" " "
397	" *Rodolphi*	Brazil	108	30	21		Virgin forest, well drained site
398	" "	"	108	25	23		" " "
399	" "	"	105	20	17		" " "
467	*Pithecolobium Saman*	Venezuela	80	25	18		
468	" "	"	82	26	20		
V106	*Sapium biglandulosum*	Venezuela	103	35	19	Old growth	
V112	" "	"	87	20	16		
V147	" "	"	75	24	16	Old growth	
V108	*Spondias Mombin*	Venezuela	98	26	19	Old growth	
V117	" "	"	98	27	18	Old growth	
V121	" "	"	79	26	18		

TEST MATERIAL—*Continued*

Tree No.	Species	Source	Tree height, feet	Diameter at stump, inches	Top diameter of test log, inches	Character	Remarks
380	*Swietenia macrophylla*	Brazil			21		
401	" "	"	92	42	26	Old growth	Virgin high forest
497	*Tabebuia serratifolia*	Surinam	89	18	18	Old growth	Lowland forest
498	" "	"	98	28	20	Old growth	" "
396	" "	Brazil	105	14	12		Virgin forest, well drained site
134	*Tabebuia* sp.	Brazil	123	39	30	Old growth	Virgin upland forest, elevation 570 feet
513	*Virola surinamensis*	Brazil	112	28	23	Old growth	Virgin forest, periodically inundated, elevation 40 feet
514	" "	"	125	20	19	Old growth	" " "
350	*Vouacapoua americana*	Surinam	100	20	16	Old growth	Sandy soil, broken terrain, elevation 33 feet
499	" "	"	95	28	16	Old growth	Lowland forest, flooded annually
507	" "	"	79	24	16	Second growth	High forest, flat terrain, elevation 66 feet

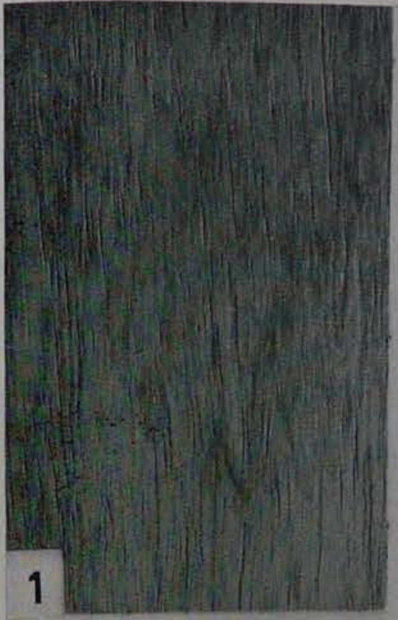
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FIGURE 1.	*Enterolobium Schomburgkii*	Tangential, 1⅓ ×
FIGURE 2.	*Hymenolobium excelsum*	Radial, 1⅓ ×
FIGURE 3.	*Pithecolobium saman*	Tangential, 1⅓ ×
FIGURE 4.	*Parinari excelsa*	Radial, 1⅓ ×

FIGURE 5. *Holopyxidium jarana* Radial, 1⅓ ×
FIGURE 6. *Lecythis paraensis* Tangential, 1⅓ ×
FIGURE 7. *Diplotropis purpurea* Tangential, 1⅓ ×
FIGURE 8. *Tabebuia serratifolia* Tangential, 1⅓ ×

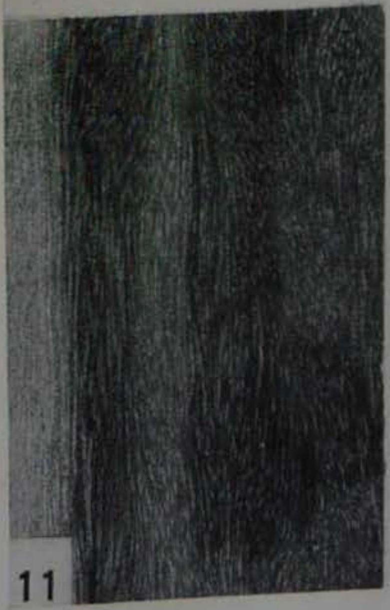

FIGURE 9.	*Cordia Goeldiana*	Tangential, 1⅓ ×
FIGURE 10.	*Swietenia macrophylla*	Tangential, 1⅓ ×
FIGURE 11.	*Mezilaurus itauba*	Radial, 1⅓ ×
FIGURE 12.	*Vouacapoua americana*	Tangential, 1⅓ ×

M.M. Chattaway

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YALE UNIVERSITY SCHOOL OF FORESTRY

TROPICAL WOODS

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TROPICAL WOODS

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COMPARATIVE ANATOMY OF XYLEM AND PHYLOGENY OF LAURACEAE

By William L. Stern
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Introduction

Members of the laurel family (Lauraceae) are perhaps among the first recorded plants. Kostermans (1952) states that members of the genera *Cinnamomum* [Burm.] Boehm. and *Persea* [Plum.] Boehm. were known to the Chinese emperor Chen-Nung in 2800 B. C. According to this authority, the Egyptians were acquainted with cinnamon as far back as 1700 B. C. A hieroglyphic prescription employing this material as one of its constituents has been noted on the wall of the temple of Edsu (1580-1350 B. C.). Moldenke and Moldenke, in *Plants of the Bible* (1952), make numerous references to members of the Lauraceae familiar to the ancient Hebrews. David selected the sweet bay *(Laurus nobilis* L.) as the symbol of prosperity presumably because of its evergreen leaves and their spicy, invigorating aroma. The cassia mentioned in *Exodus* is the cassia-bark tree, *Cinnamomum cassia* Bl. It is well known that the Greeks and Romans prized the sweet bay so highly that wreaths of it were used as adornments for priests, poets, heroes and others to whom honor was due. Some writers of this period ascribed strange powers to the sweet bay. The Roman emperor Tiberius (A. D. 14-37), being afraid of electrical storms, would don a coronet of this laurel and hide beneath his bed until the storm had passed.

Lauraceae are perhaps best known for their spices. Cinnamon is obtained from the bark of *Cinnamomum zeylanicum* Bl., a native of Ceylon and India. Cassia bark from *C. cassia* has been pulverized and used to a great extent as a bakery confection. An oily distillate from the same source is used to a limited degree in perfumery. Linaloe, derived from *Aniba rosaeodora* Ducke or bois de rose, is used in the compounding of synthetic perfumes. Natural camphor, once extensively used in manufacturing celluloid and other nitrocellulose derivatives, is prepared from *Cinnamomum camphora* (L.) Sieb. Camphor is also a common element in medicinal inhalants, astringents and insect repellents. The leaves and bark of *Sassafras albidum* (Nutt.) Nees and *Lindera benzoin* (L.) Bl. have been used locally in the preparation of medicinal teas. The bark of the former yields an oil used in flavoring carbonated beverages and dentifrices. *Ocotea rodiei* (Rob. Schomb.) Mez[1] probably represents the most important timber tree among the laurels, although Record and Hess (1943) state, "The woods of all the trees (in Lauraceae) are suitable for industrial purposes, but comparatively few are known to commerce." The wood of *O. rodiei*, commercially known as Demerara greenheart, or just greenheart, is noted for its great strength and resistance to decay and marine borers. South African stinkwood, *Ocotea bullata* (Burch.) E. Mey, is highly prized as a decorative cabinet wood. The avocado or alligator pear is the fruit of *Persea americana* Mill. Schery (1952) remarks that the expanding avocado industry in California and Florida already is rivalling citrus production in these regions. Most Lauraceae are characterized by possessing some kind of oil in the plant body. Among those most commonly found are cinneol, borneol and eugenol (Kraemer, 1916).

Lauraceae are nearly all tropical or subtropical with the exception of *Umbellularia* Nutt., which grows on the Pacific Coast probably from northern Baja California (Standley, 1922) to Oregon; *Sassafras albidum*, which occurs in the eastern United States, ranges from Ontario to Florida;

---

[1] The specific epithet was originally spelled *rodioei* by Robert Schomburgk (1844); however when Mez (1889) changed the genus from *Nectandra* to *Ocotea*, he also altered the spelling of the specific epithet. According to the *International code of botanical nomenclature* (1952) Section 14, Article 82, Note 2 and Article 82o, the spelling of the specific epithet as given by Mez, *rodiei*, is correct.

Lindera benzoin, ranging from Maine and Ontario to Florida and Texas; and *L. mellissaefolia* (Walt.) Bl., found from North Carolina to Florida. Native species of *Litsea* Lam., *Persea*, *Ocotea* Aubl., *Nectandra* Roxb., *Licaria* Aubl., and *Cassytha* [Osbeck] L. inhabit subtropical regions in southeastern United States.

Most lauraceous species are indigenous to southeastern Asia, Central and South America. The continental African species are few and include representatives of *Cryptocarya* R. Br. in extratropical South Africa, *Hypodaphnis* Stapf in West Africa, *Ocotea* and *Cassytha* in tropical and South Africa (Stapf, 1913). Both *Ravensara* Sonn. and *Potameia* Dupetit-Th. occur on Madagascar. Australia, the islands of the East Indies and the Malay Peninsula are fairly rich in laurels, with species of *Eusideroxylon* T. *et* B., *Cassytha*, *Cryptocarya*, *Endiandra* R. Br., *Cinnamomum*, *Litsea* and *Lindera* being prominent. *Laurus nobilis* encircles the Mediterranean Sea.

Most statements regarding descriptive features of laurels should be qualified in consideration of the variation within the family. Yet as a family, Lauraceae are reasonably well delineated. Lauraceae are mostly evergreen trees and shrubs (*Cassytha* is a parasitic, dodder-like twiner), which possess aromatic bark, foliage, flowers and fruits. Plants are usually monoecious, some dioecious. Leaves for the most part are alternate, a few species showing opposite or subopposite phyllotaxy. The leaves are entire, simple, pinnately-veined, often punctate, coriaceous, and estipulate.

Inflorescences are most often axillary or subterminal, paniculate, spicate, racemose or pseudo-umbellate (Allen, 1938). The flowers are usually bisexual, unisexual flowers being uncommon. The small yellowish-green or whitish flowers are actinomorphic, trimerous with a perianth of six basally-connate tepals which may be persistent or caducous. The floral tube usually persists as a cupule beneath the fruit.

The perigynous androecium commonly consists of four whorls of three stamens adnate to the perianth tube. The innermost cycle of stamens is often reduced to a whorl of staminodia and further reduction in functional stamens is not uncommon. Filaments are ordinarily free, and may bear a basal pair of sessile, glandular protuberances. Anthers are basifixed, two to four-celled, and dehisce upwards by means of flap-like valves. Although anthers of the two outer whorls dehisce introrsely, the inner whorls may dehisce extrorsely.

The pistil is solitary with the ovary superior and usually surrounded by the cup-like perianth tube. There is usually but a single, anatropous, pendulous ovule suspended from the ovary wall (parietal placentation). The style is single, terminated by an obtuse stigmatic surface which sometimes is bi- or trifurcated. Fruits are drupaceous or baccate and ordinarily subtended by the enlarged and frequently persistent perianth tube. The seed has a straight embyro and is exendospermous. The family comprises perhaps 40 genera and 3,000 species (Kostermans, 1952).

The relationships of Lauraceae to other families, and the delimitation of intrafamilial taxa, have been variously interpreted by taxonomists. Lindley (1853) places Lauraceae in his Daphnal Alliance (Daphnales) coexistent with Thymelaeaceae, Proteaceae and Cassythaceae (included in Lauraceae by later authors). He observes that the laurels resemble the "plume nutmegs" (Atherospermaceae, the genera of which are now placed in Monimiaceae) in the possession of valvular anthers, and Myristicaceae on account of their apetalous flowers and "sensible qualities." Lindley recognizes that the laurels, while resembling the barberries in anther characteristics, are far removed from that family by virtue of the latter family having polypetalous flowers, hypogynous stamens, and endospermous seeds. Brown (1810, in Lindley 1853) is said to have placed Lauraceae next to Myristicaceae, which were preceded by Proteaceae. In Bentham and Hooker's *Genera Plantarum* (1880-1883), the laurels (Laurineae) are placed in the daphnalean series, probably following Lindley. Also in this taxon are Proteaceae, Thymelaeaceae, Penaeaceae and Elaeagnaceae.

A. W. Eichler (1886) includes Lauraceae with such families as Berberidaceae, Myristicaceae, Magnoliaceae, Annonaceae and Ranunculaceae in the Polycarpicae. Pax, in Engler and Prantl's *Natürlichen Pflanzenfamilien* (1891), believes that Lauraceae form a connecting link between the Polycarpicae and Thymelineae. He also observes that laurels differ from monimiads in that the latter have acyclic floral parts, many ovaries, and frequently endospermous seeds. Warming (1895) asserts that Lauraceae show relationship with Polygonaceae since both taxa possess perigynous floral parts and similar gynoecia. In another place he states that Thymelaeaceae appear to be related to Lauraceae since the former also have a pendulous ovule, berry-like fruits and exendospermous seeds. From their general characters, Warming is of the opinion that the laurels should be grouped among the polycarps but in an isolated position because of their syncarpous gynoecium. Hallier, in his phyletic system of angiosperms (1912), implies relationship of Lauraceae to Calycanthaceae, Monimiaceae and, indirectly, Chloranthaceae. In this work, Annonales (separated from Ranales by presence of oil cells in leaves) consist of two sub-orders: Magnoliineae and Laurineae. The former is differentiated from the latter by the presence of a hypogynous perianth. Magnoliineae include Annonaceae, Myristicaceae, Canellaceae and Lactoridaceae; whereas Calycanthaceae, Monimiaceae, Chloranthaceae and Lauraceae constitute the Laurineae. The laurels are classed as Ranales in Engler and Diels (1936) along with thirteen other families. These include such families as Ranunculaceae, Berberidaceae, Nymphaeaceae, Magnoliaceae, Myristicaceae and Monimiaceae. Wettstein (1935) has added Lauraceae to the twenty-two other families in the huge and heterogeneous Polycarpicae in his *Handbuch*. The Lauraceae are placed within the order Laurales by Hutchinson (1926), together with Monimiaceae, Gomortegaceae, Hernandiaceae and Myristicaceae. Laurales, according to this author, are placed nearest to Annonales and Ranales. Johnson (1931) recognizes Lauraceae as belonging in Ranales with eighteen other families ranging in character from Trochodendraceae to Ceratophyllaceae and Hernandiaceae. Presumably with due regard to his dicta, Bessey (1915) has arranged Lauraceae in the order Ranales which includes Piperaceae, Annonaceae, Chloranthaceae, Cabombaceae, Myristicaceae, Leitneriaceae and Monimiaceae. A. B. Rendle (1925) puts the laurel family among the Ranales adjacent to the Monimiaceae and Ranunculaceae. Basing his conclusions on floral form, Gundersen (1943) placed Lauraceae in the "Magnolia Group" under the order Magnoliales which also included Magnoliaceae, Calycanthaceae and Menispermaceae. Ranales, Rosales, and Hamamelidales are also included in the "Magnolia Group." In 1950, this same author included Lauraceae within Magnoliales with seventeen other families such as Eupteleaceae, Myristicaceae, Degeneraceae, Annonaceae, Calycanthaceae, etc.

The laurels are considered as occupying familial rank by all of the above-mentioned writers except Hutchinson, who applies an ordinal designation. Both Lindley and Bentham and Hooker have placed Lauraceae in Daphnales in relation to Proteaceae and Thymelaeaceae. Eichler, Warming, and Wettstein have included Lauraceae in Polycarpicae. Engler and Diels, Johnson, Bessey and Rendle list Lauraceae in Ranales, while Gundersen places the family in Magnoliales. Hallier included Lauraceae under Annonales. Pax believes the laurels to bridge the gap between Polycarpicae and Thymelineae (Warming, 17th order of Choripetalae), and Warming has pointed to possible polygonaceous and thymelaeaceous affinities. Thus there appear to be two major views regarding the taxonomic placement of the Lauraceae: (1) that the laurels are related to the proteads and daphnads (Thymelaeaceae), and (2) that they have their closest affinities within the ranalian complex.

Anatomists and morphologists have also been concerned with the affinities of Lauraceae. In his comparative work on the woods of Myristicaceae, Garratt (1933b) says, ". . . a comparison of the anatomy of the secondary xylem of the several families under consideration lends definite support to the action of those systematic botanists who have placed the

Myristicaceae close to the Lauraceae, since the general similarity between the woods of these two families is outstanding." In a later work (Garratt, 1934), he states that while monimiaceous woods resemble those of Lauraceae, they are more like Myristicaceae. Certain genera of Monimiaceae are more Lauraceae-like than others.

Money and her co-workers (1950) in their work on Monimiaceae have indicated certain similarities among ranalian families. They note that Monimiaceae, Gomortegaceae, Lauraceae and Hernandiaceae are characterized by possessing oil cells and the unilacunar nodal condition. These workers further observe that the above-mentioned families, Austrobaileyaceae, Trimeniaceae, Amborellaceae, Chloranthaceae, Calycanthaceae and Lactoridaceae are also characterized by monocolpate or phylogenetically modified forms (dicolpate, polyporate, and acolpate) of such pollen. In conclusion, they assert that the first seven of these families ". . . are more or less closely related, and therefore form a natural grouping."

While recognizing the very provisional nature of his family tree for angiosperm seeds, Martin (1946) believes that his diagram ". . . may be instrumental in revising and improving current phylogenetic concepts." Lauraceae are tabulated here under the same category as the families Rhamnaceae, Lythraceae, Labiatae, Bignoniaceae, Betulaceae, Juglandaceae, and Fagaceae.

The subdivision of Lauraceae has been undertaken by several systematists, including Bentham and Hooker (1880-1883), Meissner (1864), Mez (1889) and Pax (1891). While the classifications of all four are based for the most part on floral structure, there are several important deviations among the systems. These variations can best be appreciated by perusal of table 1, which is a summary of the works mentioned above.

Plant anatomists have also made suggestions with regard to the internal classification of the family. Janssonius (1934)

Table 1. COMPARISON OF INTRAFAMILIAL SYSTEMS

Bentham and Hooker (1880-1883)	Meissner (1864)	Mez (1889)	Pax (1891)
Tribe I. Perseaceae	Suborder I. Laurineae	Suborder I. Laureae	Subfamily I. Persoideae
Cryptocarya	Tribe I. Perseaceae	Tribe I. Perseeae	Tribe I. Cinnamomeae
Ravensara	*Cinnamomum*	*Cryptocarya*	*Cinnamomum*
Apollonias	*Alseodaphne*	*Aiouea*	*Persea*
Beilschmiedia	*Phoebe*	*Aniba*	*Phoebe*
Dehaasia	*Persea*	*Persea*	*Ocotea*
Aiouea	*Haasia*[1]	*Ocotea*	*Umbellularia*
Potameia	*Beilschmiedia*	*Dicypellium*	*Nectandra*
Endiandra	*Apollonia*[2]	*Urbanodendron*	*Dicypellium*
Eusideroxylon	Tribe II. Cryptocaryeae	*Acrodiclidium*[3]	Tribe II. Eusideroxyleae
Cinnamomum	*Cryptocarya*	*Endlicheria*	*Eusideroxylon*
Persea	*Endinandra*	*Phoebe*	Tribe III. Litseeae
Dicypellium	*Aiouea*	*Nectandra*	*Sassafras*
Nectandra	*Acrodiclidium*[3]	Tribe II. Litseeae	*Actinodaphne*
Tribe II. Litseaceae	Tribe III. Oreodaphneae	*Litsea*	*Litsea*
Sassafras	*Dicypellium*	*Sassafras*	Subfamily II. Lauroideae
Actinodaphne	*Nectandra*	*Umbellularia*	Tribe I. Apollonieae
Litsea	*Sassafras*	*Benzoin*[4]	*Apollonias*
Umbellularia	Tribe IV. Litseaceae	Suborder II. Cassytheae	*Beilschmiedia*
Lindera	Subtribe I. Tetranthereae	*Cassytha*	*Dehaasia*
Laurus	*Actinodaphne*		*Aiouea*
Tribe III. Cassytheae	*Litsea*		*Micropora*[5]
Cassytha	Subtribe II. Daphnidieae		*Potameia*
	Laurus		Tribe II. Cryptocaryeae
	Lindera		*Cryptocarya*
	Suborder II. Gynocarpeae		*Ravensara*
	Suborder III. Cassytheae		Tribe III. Acrodiclidieae
			Endiandra
			Acrodiclidium[3]
			Tribe IV. Laureae
			Benzoin[4]
			Laurus
			Tribe V. Cassytheae
			Cassytha

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[1] *Hassia* = *Dehaasia*

[2] *Apollonia* = *Apollonias*

[3] *Acrodiclidium* = *Licaria*

[4] *Benzoin* = *Lindera*

[5] *Micropora* = *Hexapora*

has subdivided the 62 species and 3 varieties of 13 genera with which he dealt, into three groups based mostly upon wood anatomy. In "Group I" the species of *Beilschmiedia* Nees, *Cryptocarya, Endiandra* and *Lindera gemmiflora* Bl. are found. "Group II" contains the Javanese representatives of *Cinnamomum, Nothaphoebe* Bl. *(Alseodaphne* Nees and *Persea*[2]*), Machilus* Rumph. *(Persea*[2]*), Actinodaphne* Nees, *Litsea,* other linderas, *Phoebe* Nees, *Dehaasia* Bl., and *Iteadaphne* Bl. *(Lindera*[2]*). Hernandia peltata* Meissn. comprises Janssonius' "Group III." Using wood parenchyma distribution, Dadswell and Eckersley (1940) were able to divide the Australian laurels in their study into two groups. These correspond to Pax' subfamilies Lauroideae and Persoideae. In his study of Malayan timbers, Desch (1941) concurs in the findings of Dadswell and Eckersley with regard to the subdivision of Lauraceae.

According to both anatomists and taxonomists who have had experience with lauraceous species, great difficulties have been encountered in the delimitation of genera and species. Record and Hess (1943), Janssonius (1934), Kostermans (1952), Macbride (1931), Hooker (1885) and others have commented on the apparent artificiality of lauraceous genera. These workers have asserted that in many instances species assigned to the same genus often show differences greater than those between species in separate genera.

The writer has embarked on this study with what is hoped to be a full appreciation of the problems and difficulties involved. In the past, wood anatomy has frequently been helpful in resolving enigmatic relationships among plant families and sometimes within plant families. While such studies usually do not with certainty point to positive relations, they sometimes negate supposed kinships and suggest more reasonable affinities. It is the purpose of this work to employ the knowledge gained from a detailed study of selected laurel woods, together with information derived from other fields of botanical pursuit, to clarify and elucidate the phyletic relations between Lauraceae and other plant families. Comparative studies of this nature have been shown to produce the most useful results, for reliance on criteria from only one field of botanical endeavor often leads to fallacious and incomplete inferences. In the course of the investigation, an anatomical appraisal of some existing intrafamilial subdivisions will be made. Preliminary consideration will also be given to the circumscription of genera in anticipation of a more extensive survey.

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[2] According to Kostermans (1952) these are the valid generic names.

MATERIALS AND METHODS

The xylem of members of 29 lauraceous genera was studied. Two species of each genus were investigated except in the cases of *Aiouea* Aubl., *Alseodaphne, Apollonias* Nees, *Dicypellium* Nees, *Hypodaphnis, Laurus* L., *Phyllostemonodaphne* Kosterm., *Ravensara, Umbellularia,* and *Urbanodendron* Mez. *Dicypellium, Hypodaphnis, Phyllostemonodaphne, Umbellularia* and *Urbanodendron* are monotypic, and only one specimen of each of the other genera was procurable. Kostermans (1952) lists 33 genera as being valid and states that no more than 40 genera will persist under critical revision. Of these 33 genera, *Cassytha,* a parasitic, herbaceous twiner, was not considered in this investigation. Except for *Phyllostemonodaphne* and *Urbanodendron,* which were twig specimens, all other species were represented by old wood. Specimens of *Potameia, Systemonodaphne* Mez and *Hexapora* Hook f. were not obtainable. It is estimated that representatives of 90 per cent of the valid woody genera were available for this study. Table 2 is a list of the species investigated, followed by the name, number, or both of the collecting agency. In so far as possible, citation of author follows that employed in the works of Allen and Kostermans. In the few other situations, authorities were derived from those used in floras describing the species in question.

In preparation of sectioned material, permanent slides were made using the celloidin method, essentially as described by

Wetmore (1932). Woods were cut into convenient sizes, boiled and pumped to remove the air and softened in hydrofluoric acid where necessary. After prolonged washing with water, softened blocks were dehydrated in ethanol and embedded in a celloidin matrix. Embedded material was stored in a glycerine-ethanol solution prior to sectioning. Using a Reichert sliding microtome, transverse, radial and tangential sections were taken as thin as practicable, usually at 15μ. Sectioned material was stained in Heidenhain's iron-alum haematoxylin and counterstained with safranin. After dehydrating and clearing in xylol, sections were mounted in Canada balsam. Preparations of macerated woods were prepared using Jeffrey's macerating fluid (equal parts 10 per cent aqueous chromic and nitric acids). After thoroughly washing the pulp in water to remove the acids, the material was stained in aqueous safranin, dehydrated with tertiary butanol and mounted in Canada balsam. Photographs were taken of prepared materials with a Zeiss-Winkel attachment camera affixed to a Bausch and Lomb microscope model DDE.

Table 2. List of Species Investigated

Actinodaphne lancifolia (Sieb. *et* Zucc.) Meissn.	14584	Y*
A. reticulata Meissn.	21741	Y
Aiouea costaricensis (Mez) Kosterm.	38385	Y
Alseodaphne chinensis Hemsl.	21957	Y
Aniba kappleri Mez	44075	Y
A. ovalifolia Mez	32886	Y
Apollonias barbusana (Cav.) A. Braun	102-19	H
Beilschmiedia pendula (Sw.) Benth.	19314	Y
B. roxburghiana Nees	13118	Y
Cinnamomum camphora (L.) Sieb.	Conover	
C. porrectum (Roxb.) Kosterm.	34315	Y
Cryptocarya cordata All.	28621	Y
C. lancifolia A. C. Sm.	28361	Y
Dehaasia elliptica Ridl.	39000	Y
D. triandra Merr.	1973	Y
Dicypellium caryophyllatum Nees	23674	Y
Endiandra glauca R. Br.	102-36	H
E. trichotosa A. C. Sm.	6825	H
Endlicheria endlicheriopsis (Mez) Kosterm.	Stahel 38	H
E. sericea Nees	44223	Y
Eusideroxylon melagangai Sym.	Wilson	
E. zwageri T. *et* B.	39452	Y
Hypodaphnis zenkeri Stapf	36094	FHI
Laurus nobilis L.	40407	Y
Licaria cayennensis (Meissn.) Kosterm.	Stahel 10	H
L. rigida Kosterm.	Stahel 317	H
Lindera benzoin (L.) Bl.	Stern	
L. communis Hemsl.	21947	Y
Litsea elongata (Wall. *ex* Nees) Benth. *et* Hook.f.	21988	Y
L. mellifera A. C. Sm.	3493	H
Mezilaurus itauba (Meissn.) Taub.	Stahel 320	H
M. synandra (Mez) Kosterm.	22574	Y
Nectandra coriacea (Sw.) Gris.	Conover	
N. globosa (Aubl.) Mez	46858	Y
Neolitsea levinei Merr.	21995	Y
N. umbrosa (Wall.) Gamble	21964	Y
Ocotea cooperi All.	10277	Y
O. palmana Mez *et* J. D. Sm.	40827	Y
Persea americana Mill.	Conover	
P. schiedeana Nees	13278	Y
Phoebe amplifolia Mez *et* J. D. Sm.	43456	Y
P. mexicana Meissn.	34774	Y
Phyllostemonodaphne geminiflora (Meissn.) Kosterm.	5455-a	N
Ravensara crassifolia P. Dang.	12893	Y
Sassafras albidum (Nutt.) Nees	Stern	
S. tzumu (Hemsl.) Hemsl.	20560	Y
Umbellularia californica (Nees) Nutt.	40209	Y
Urbanodendron verrucosum Mez	1141	N

*Y—Yale University, School of Forestry, wood collection
H—Harvard University, Biological Laboratories, wood collection
FHI—Forest Herbarium Ibadan, Forest Department, Lagos, Nigeria
N—Herbarium, New York Botanical Garden

Anatomical features believed to be most appropriate for this study were selected from Tippo's (1941) list. The tangential diameters of 25 pores, selected randomly from each species, were measured from sectioned material. Following the suggestions of Chalk and Chattaway (1934) and the investigations of Bailey (1920), measurements of 25 vessel elements were taken from macerated materials. The "extreme body lengths" could thus be gauged. Bailey has shown that elongation of these elements over their fusiform cambial precursors is slight if any. Subsequently, Chalk and Chattaway (1934) asserted that "The phylogenetic significance of vessel member length is probably due to its relation to the length of the cambial initial . . ." In *Sassafras*, the only ring-porous wood in Lauraceae, only the lengths of the vessel elements from late wood were measured. Chalk and Chattaway (1935) have shown that because of their considerable lateral expansion, early wood vessel elements in ring-porous woods become foreshortened. The extremes and means of measurements for each species, genus, and the family as a whole are tabulated in the next section. In discussing relative vessel element sizes, classes suggested by Chalk (1936) for vessel element lengths, and by Chattaway (1932) for pore diameters, have been employed.

It is recognized by the author that measurements of so few elements can hardly be subjected to statistical treatment. Rendle and Clarke (1934) have said, "The diagnostic value of any feature depends on the extent to which it may vary in different samples of the same species." These investigators suggest that at least 100 vessel elements should be measured in order to produce statistically significant results. Thus the measurements that are included in this paper may only serve to indicate the general size of elements.

Bailey and Howard (1941) have employed a simplified system for the description of the vertical xylem parenchyma in Icacinaceae. According to these workers, present systems of classifying wood parenchyma distributions are confused and unsatisfactory. Since Sanio's (1863) description of metatracheal parenchyma (vessels linked with parenchyma) is the reverse of the present-day usage (bands of parenchyma divorced from contact with vessels), it should be abandoned for the term "banded-apotracheal." Other terms such as "diffuse-in-aggregates" and "initial" may be satisfactory simply for descriptive purposes but should be avoided in phylogenetic considerations at present. Kribs' (1937) work points to the primitiveness of "terminal" and "diffuse" parenchyma distributions; the derivation and relationship of the advanced types (vasicentric, aliform and confluent), however, is obscure. Hess (1950) presents an elaborate system for the classification of dicotyledonous xylem parenchyma. These categories may well serve the systematic anatomist. It is believed, however, that many of this worker's subdivisions are merely variations of basic parenchyma patterns.

A tentative list of phylogenetic specializations in xylem parenchyma has been set down by Bailey and Howard: (1) broad banded-apotracheal types arise from diffuse ones through various narrow banded-apotracheal types, (2) in many families, vasicentric, aliform and confluent types originate from banded types, and (3) through excessive reduction scanty paratracheal types may arise at various levels in the differentiation of both apotracheal and paratracheal types. Also, there are many complex types of parenchyma distribution which are transitional between typical apotracheal and purely paratracheal types. Because of the reasons cited above, and the diversity of distributional patterns in xylem parenchyma, these workers prefer to use a simple system describing the variations instead of naming them.

By slightly modifying Kribs' classification in the light of Bailey and Howard's suggestions, the following categories will be used to describe vertical xylem parenchyma in this paper.

APOTRACHEAL	PARATRACHEAL
Diffuse	Vasicentric
Banded	Aliform
Terminal	Confluent

The terms aliform and confluent are employed without intending to imply derivation of confluent from aliform. Bailey and Howard regard these as a mixture of types. Confluent, for example, would be viewed as a mixture of banded-apotracheal and vasicentric.

That the form and size of xylem rays are not constant throughout the plant axis has been emphasized by Barghoorn (1940, 1941a, 1941b). Because of this, conclusions regarding xylem ray structure should be drawn with great care. As

Barghoorn (1941a) has aptly stated, ". . . in phylogenetic studies, ray type designations should be used with considerable caution as an aid for determining the degree of specialization of the xylem. This is true because of the more or less extensive variation in ray structure which occurs during successive stages of secondary growth. Thus, ontogenetic stages in the same individual may represent different levels of phylogenetic modification . . ." The ray type designations employed here are those of Kribs (1935). It is questionable whether ray heights and widths are of any phylogenetic or systematic value because of their variation throughout the plant. A rough approximation of these values is listed under each species in the interests of completeness.

In describing the fibrous elements of the woods, great difficulty was encountered in some cases because of the minute dimensions of the pits. Bailey (1936) has defined fiber-tracheids as having bordered pits of smaller dimensions than those in the walls of the vessel elements in the same species. The term libriform wood fiber as used in this paper refers to a fiber cell with pits in which the border is lacking or indistinguishable.

Frost's (1930) categories for classifying scalariform perforation plates as to the number of bars, have been used here. All other descriptive terminology follows that recommended by the Committee on Nomenclature of the International Association of Wood Anatomists in the *Glossary of terms used in describing woods* (1933).

Anatomical Description of the Family

Growth rings (fig. 1, 2) are present in 82 per cent of the species under investigation; 18 per cent show no evidence of such increments. Among those species which manifest growth rings, 23 per cent exhibit indistinct rings. The occurrence of growth rings may vary within a species. Specimens of *Persea americana* were observed in which growth rings were present; others showed no sign of such zones. All woods except *Sassafras* are diffuse-porous (fig. 2), the pores being regularly distributed and of the same size throughout the growth ring. *Sassafras* species show decided ring-porosity (fig. 1). Pore arrangement is summarized in table 3. Here it is evident that solitary pores (fig. 1-6) are most numerous while pore clusters (fig. 6) are least abundant. Pore multiples (fig. 1, 2, 6) are frequent, but do not exceed the number of pores in solitary arrangement. The pores in aggregates vary from 2-9, mostly approximating the lower figure. No pore chains were observed. Most pores are somewhat angular in appearance though some show a marked tendency to be circular. Indeed, several species demonstrate well-formed circular pores. The number of pores in a square millimeter varies from 2-80 (few to very numerous). The thickness of the vessel wall ranges from 1-15μ; most show thicknesses between 2 and 6μ.

The ground-mass of the wood consists of fibrous elements that have pits differing from simple (fig. 7) through a series of vestigially bordered types, to those with unmistakable borders (fig. 12, 13). Thus, both fiber-tracheids and libriform wood fibers are present. None of the bordered pits in the fibrous elements is of the same magnitude as those in the vessel walls of the same species. Although tracheids have been reported in lauraceous woods (Metcalfe and Chalk, 1950), none was seen in the specimens examined. The bordered pits generally exhibit slit-like pit apertures (fig. 13) which extend beyond the confines of the border. In many cases, crossed apertures were observed. In table 3, one can see that 63 per cent of the species studied possess only fiber-tracheids, 29 per cent both fiber-tracheids and libriform wood fibers, and only 4 per cent libriform wood fibers exclusively. None of the species exhibited gelatinous fibers. The walls of the fibers vary from very thin (fig. 3) to very thick (fig. 12, 19). The lumen is practically obliterated in certain species. Septate fibrous elements are common in many species (fig. 11).

Table 3. SUMMARY OF PERTINENT ANATOMICAL FEATURES

	VESSELS							FIBERS	PARENCHYMA
	Pore distribution in per cent per group			Perforations					
					Bars per scalariform perforation				
	Solitary	Multiple	Cluster	sc = scalariform ss = simple + scalariform s = simple	m = many, 15+ i = intermediate, 5-15 f = few, 5 or fewer	Pore diameter — range in μ	Vessel element length — range in μ	f = fiber-tracheid lf = libriform wood fibers + fiber-tracheids l = libriform wood fiber s = septate	t = terminal ba = banded-apotracheal v = vasicentric a = aliform c = confluent
Actinodaphne lancifolia	80	19	1	ss	f-m	54- 95	394-666	lf	v
A. reticulata	90	10		ss	f-m	37- 87	218-490	f	v
Aiouea costaricensis	52	46	2	ss	f	68-177	422-804	f	v
Alseodaphne chinensis	90	8	2	ss	i	68-122	258-884	sf	v
Aniba kappleri	51	43	6	ss	f	68-122	394-762	slf	v
A. ovalifolia	42	57	1	ss	i	68-177	326-734	slf	v
Apollonias barbusana	74	23	3	s		41- 82	299-612	l	v
Beilschmiedia pendula	71	27	2	s		68-190	272-490	f	ba,c
B. roxburghiana	67	25	8	s		82-150	258-408	f	ba, v,a,c
Cinnamomum camphora	51	40	9	s		41- 95	150-462	f	t,v
C. porrectum	30	63	7	ss	i	68-136	204-639	slf	t,v
Cryptocarya cordata	84	13	3	s		68-122	218-422	lf	t,v
C. lancifolia	75	20	5	ss		82-136	258-680	f	ba,v
Dehaasia elliptica	37	60	3	ss	i	54-150	272-952	slf	v
D. triandra	60	30	10	ss	i	68-150	367-979	sf	v
Dicypellium caryophyllatum	63	30	7	ss	f	41- 95	354-884	slf	v
Endiandra glauca	68	25	7	s		68-150	204-544	f	v,a,c
E. trichotosa	35	55	10	s		54-122	231-639	f	v,a,c
Endlicheria endlicheriopsis	68	18	14	s		82-163	381-748	sf	v
E. sericea	70	26	4	ss	f-i	54-122	422-748	slf	v
Eusideroxylon melagangai	35	45	20	s		68-190	381-612	sf	v,a,c
E. zwageri	79	21		s		136-286	334-680	f	v,a,c
Hypodaphnis zenkeri	83	11	6	s		68-150	258-435	lf	v,a,c
Laurus nobilis	67	32	1	ss	f-i	27- 68	190-558	slf	v
Licaria cayennensis	42	50	8	s		82-218	354-952	f	v
L. rigida	72	25	3	s		54-150	381-843	slf	v
Lindera benzoin	57	43		ss	f-i	27- 54	264-462	f	v
L. communis	77	22	1	ss	f-i	41- 82	163-517	f	v
Litsea elongata	79	19	2	ss	f	54- 95	408-612	f, sf	v
L. mellifera	38	53	9	ss	f-i	54-150	476-680	f	v
Mezilaurus itauba	84	15	1	s		95-163	272-816	sf	v,a
M. synandra	69	29	2	s		68-204	245-571	sf	v
Nectandra coriacea	71	26	3	s		41- 68	299-612	slf	v
N. globosa	75	22	3	ss	f-i	54-150	367-612	slf	v
Neolitsea levinei	84	14	2	ss	f-m	41- 68	218-634	f	v
N. umbrosa	79	19	2	ss	f-m	41- 68	231-558	f, sf	v
Ocotea cooperi	76	24		ss	i	109-245	408-938	f	v
O. palmana	88	11	1	ss	i	82-177	612-1034	sf	v
Persea americana	84	15	1	ss	f-i	41-136	326-558	f, sf	v
P. schiedeana	83	16	1	ss	f-i	54-109	218-666	f	v
Phoebe amplifolia	80	13	7	ss	f-i	68-231	122-1224	sf	v
P. mexicana	75	22	3	ss	f-i	41-109	163-666	sf	v
Phyllostemonodaphne geminiflora	80	19	1	s				sf	v?
Ravensara crassifolia	86	9	5	s		95-163	394-653	f	ba,v
Sassafras albidum	84	15	1	ss	f	19-122	150-462	f	v
S. tzumu	63	30	7	ss	f	15-150	231-381	f	v
Umbellularia californica	58	37	5	ss	f	41- 95	150-422	sf	v
Urbanodendron verrucosum	63	35	2	ss	f			sf	v

The slope of the end walls in the vessel elements (fig. 9-11, 18) is highly variable and ranges from very steep (70°) in a few cases to almost transverse in several specimens. Most frequently, the angle of inclination is between 30° and 50°. Perforation plates are scalariform and simple (fig. 16, 17, table 3); both kinds occur in the majority of species (fig. 16). The number of bars in scalariform perforation plates varies from 1 to over 15. The borders on the scalariform apertures (fig. 16) are complete in most cases. Bizarre types of perforations (reticulate, vestigial bars, etc.) can be seen in several specimens. Vessel element lengths in the specimens surveyed range from 122-1224μ (extremely short to very long). The average range for the family is 294-667μ (moderately short to medium sized), the mean length being 493μ (medium sized). Tangential pore diameters vary from 15-286μ (extremely small to rather large), the average range for the family is 60-138μ (small to moderate sized), and the mean diameter is 101μ (moderate sized). Only elements from mature woods were employed in these calculations. Table 3 illustrates ranges in vessel element length and diameter on a species basis. The predominant type of intervascular pitting is alternate (fig. 11, 14, 15, 18). A few specimens show some transitional and opposite pitting together with the alternate type. The pit apertures are elongate or elliptical and limited by the border. Pit borders are variable in outline, round or elliptical (fig. 14) when the pits are loosely arranged, and polygonal (fig. 15) when crowded. Tyloses are present in the majority of specimens; their walls vary from thin to very thick and sclerotic (fig. 15, 19). Walls of sclerotic tyloses are often laminated and show ramiform pitting. In some cases the tyloses completely occlude the vessel lumen. Vessels may be plugged by a few large tyloses or by numerous small tyloses which present a honeycombed appearance in longitudinal aspect.

Vascular rays correspond to Kribs' heterogeneous type IIB in the majority of the woods surveyed (fig. 8, 9). In a few instances heterogeneous type IIA is exhibited and a single species evinces homogeneous type I rays. Rays are narrow and range from 1-6 cells wide; most are 1-4 cells in width. All specimens show uniseriate rays. These vary from 1-14 cells high; multiseriate rays from 3-66 cells in height. Walls of ray cells are mostly thin; a few specimens manifest thick-walled ray parenchyma. Table 3 contains a summary of axial xylem parenchyma distributions (fig. 3-6). It can be seen that all species possess paratracheal parenchyma; vasicentric is most commonly observed. Some species also exhibit aliform and confluent parenchyma. In addition to paratracheal parenchyma, some species display terminal and banded apotracheal distributions.

Secretory cells (fig. 6, 8-10) are an almost constant feature in the woods of the laurels under study, although a few specimens do not show this character. According to Janssonius (1934), these cells may contain oil or mucilage and apparently either compound can replace the other in the same cell. In the absence of chemical evidence, the cells will be referred to in this work simply as secretory cells as has been suggested by Stern (1954) for intercellular spaces. From observations in this investigation, it appears that secretory cells may have three dispositions in wood: as idioblasts among the fibers of the ground-mass, and among ray or axial parenchyma cells. Their occurrence is most common in the last two positions. Secretory cells are roughly barrel-shaped; that is, vertically elongated and widest at the middle (fig. 10). These cells are distinguished from other similar cells by their non-lignified thin walls (fig. 6) and sometimes by the presence of amorphous contents. In sections where the contents of the secretory cells were not removed during preparation, a yellow, unstained material remains.

Record (1928) reports storying in some species of Lauraceae, but none was observed in any of these studies. "Pith flecks" are common in some of the sections. The anatomical features described here are based solely on the specimens at hand. The reader should consider that some discrepancies may occur between these and other descriptions due to variations in the age and origin of the material studied.

Table 3 represents a summary of the most pertinent variable features among the xylem characters of the species investigated. Since many cases exist where two species of a genus differ in several points, each species studied will be described separately. This is more desirable than describing a genus as based on one or two species. Data on twig specimens are not recorded, nor are features already represented in table 3.

Actinodaphne lancifolia: Growth rings distinct; pores 10-21 in a square millimeter, angular to circular, tending to angularity; vessel wall thickness 1-4.5μ; tyloses absent; vessel element end wall inclination 10°-60°, mostly 45°; intervascular pits circular to polygonal, pitting alternate; vascular rays heterogeneous IIB, 1-3, mostly 2 cells wide, uniseriate rays 1-9, mostly 3-5 cells high, multiseriate 4-30, mostly 5-15 cells high; secretory cells in rays and axial parenchyma; pith flecks present.

Actinodaphne reticulata: Growth rings distinct; pores 27-42 in a square millimeter; angular to circular, tending to angularity; vessel wall thickness 1-3μ; tyloses absent; vessel element end wall inclination 40°-60°, mostly 50°; intervascular pits polygonal, pitting alternate; vascular rays heterogeneous IIB, 1-4, mostly 2-3 cells wide, uniseriate rays 1-5, mostly 3-4 cells high, multiseriate 4-43, mostly 10-30 cells high; secretory cells scarce in rays, axial parenchyma, and as idioblasts.

Aiouea costaricensis: Growth rings distinct; pores 6-12 in a square millimeter, angular to circular, tending to circularity; vessel wall thickness 1-4.5μ; tyloses absent; vessel element end wall inclination 20°-60°, mostly 50°; intervascular pits polygonal, pitting alternate, some opposite; vascular rays heterogenous IIB, 1-4, mostly 2-3 cells wide, uniseriate rays 1-5, mostly 2-4 cells high, multiseriate 4-28, mostly 10-20 cells high; secretory cells in rays and axial parenchyma.

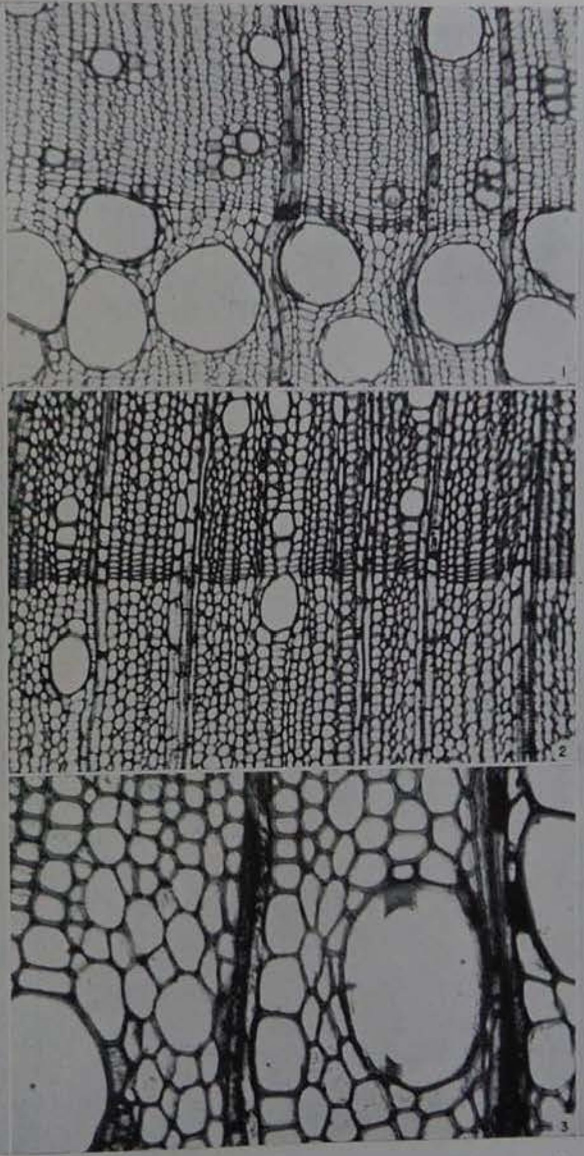

Fig. 1-3.—Fig. 1. *Sassafras albidum,* cross-section to show ring-porosity and pores in solitary and radial multiple arrangement. ×85.—Fig. 2. *Laurus nobilis,* cross-section showing diffuse-porosity and pores in solitary and radial multiple arrangements. ×85.—Fig. 3. Cross-section, *Persea schiedeana* illustrating paratracheal axial parenchyma, thin-walled fibers and circular pores. ×170.

Alseodaphne chinensis: Growth rings distinct; pores 7-14 in a square millimeter, angular to circular, tending to angularity; vessel wall thickness 2-4.5μ; tyloses thin-walled; vessel element end wall inclination 30°-60°, mostly 45°; intervascular pits polygonal, pitting alternate; vascular rays heterogeneous IIB, 1-4, mostly 2-3 cells wide, uniseriate rays 1-4, mostly 2-3 cells high, multiseriate 4-24, mostly 5-15 cells high; secretory cells in rays, axial parenchyma and as idioblasts.

Aniba kappleri: Growth rings distinct; pores 7-13 in a square millimeter, angular to circular, tending to angularity; vessel wall thickness 1.5-5μ; tyloses thick-walled; vessel element end wall inclination 10°-60°, mostly 30°; intervascular pits polygonal to circular, pitting alternate; vascular rays heterogeneous IIB, 1-3, mostly 2 cells wide, uniseriate rays 1-6, mostly 2-4 cells high, multiseriate 4-22, mostly 10-20 cells high; secretory cells mostly in rays, some in axial parenchyma and as idioblasts; pith flecks with sclerotic cells present.

Aniba ovalifolia: Growth rings absent; pores 4-15 in a square millimeter, angular to circular, tending to circularity; vessel wall thickness 3-4.5μ; vessel element end wall inclination 10°-45°, mostly 30°; tyloses thin-walled; intervascular pits polygonal to circular, pitting alternate with some opposite; vascular rays heterogeneous IIB, 1-4, mostly 2-3 cells wide, uniseriate rays 1-7, mostly 2-4 cells high, multiseriate 4-30, mostly 10-20 cells high; secretory cells in rays and axial parenchyma.

Apollonias barbusana: Growth rings absent; pores 23-29 in a square millimeter, angular to circular, tending to angularity; vessel walls unevenly thickened, 3-15μ; vessel element end wall inclination 20°-50°, mostly 30°; tyloses thin-walled; intervascular pits polygonal to circular, pitting alternate; vascular rays heterogeneous IIB, 1-3, mostly 2-3 cells wide, uniseriate rays 1-5, mostly 3-4 cells high, multiseriate 4-30, mostly 10-20 cells high; secretory cells in rays and axial parenchyma; sclerotic pith flecks present.

Beilschmiedia pendula: Growth rings absent; pores 7-13 in a square millimeter, angular to circular, tending to circularity; vessel wall thickness 1.5-6μ; vessel element end wall inclination 10°-50°, mostly 30°; tyloses thin-walled; intervascular pits polygonal, pitting alternate; vascular rays heterogeneous IIB, 1-3, mostly 1-2 cells wide, uniseriate rays especially numerous, 1-14, mostly 4-10 cells high, multiseriate 7-27, mostly 10-20 cells high; secretory cells in axial parenchyma.

Beilschmiedia roxburghiana: Growth rings absent; pores 8-16 in a square millimeter, mostly circular; vessel wall thickness 1-5μ; tyloses thin- and thick-walled; vessel element end wall inclination 10°-50°, mostly 25°; intervascular pits polygonal-circular, pitting alternate; vascular rays heterogeneous IIB, 1-6, mostly 3-4 cells wide, uniseriate rays numerous, 1-5, mostly 1-3 cells high, multiseriate 3-33, mostly 10-20 cells high; secretory cells in axial parenchyma; pith flecks present.

Cinnamomum camphora: Growth rings distinct; pores 17-35 in a square millimeter, angular to circular, tending to angularity; vessel wall thickness 2-4.5μ; tyloses thin-walled; vessel element end wall inclination 30°-50°, mostly 45°; intervascular pits circular-oval, pitting alternate; vascular rays heterogeneous IIB, 1-2 mostly 2 cells wide, uniseriate rays 1-6, mostly 2-3 cells high, multiseriate 3-16, mostly 7-13 cells high; secretory cells in rays and axial parenchyma.

Cinnamomum porrectum: Growth rings distinct; pores 11-19 in a square millimeter, angular to circular, tending to angularity; vessel wall thickness 3-4.5μ; tyloses mostly thin-walled; vessel element end wall inclination 10°-50°, mostly 40°; intervascular pits polygonal to circular, pitting alternate with some opposite; vascular rays heterogeneous IIB, 1-3, mostly 1-2 cells wide, uniseriate rays uncommon, 1-6, mostly 2-3 cells high, multiseriate rays 4-17, mostly 7-14 cells high; secretory cells in rays, axial parenchyma, and as idioblasts; sclerotic pith flecks present.

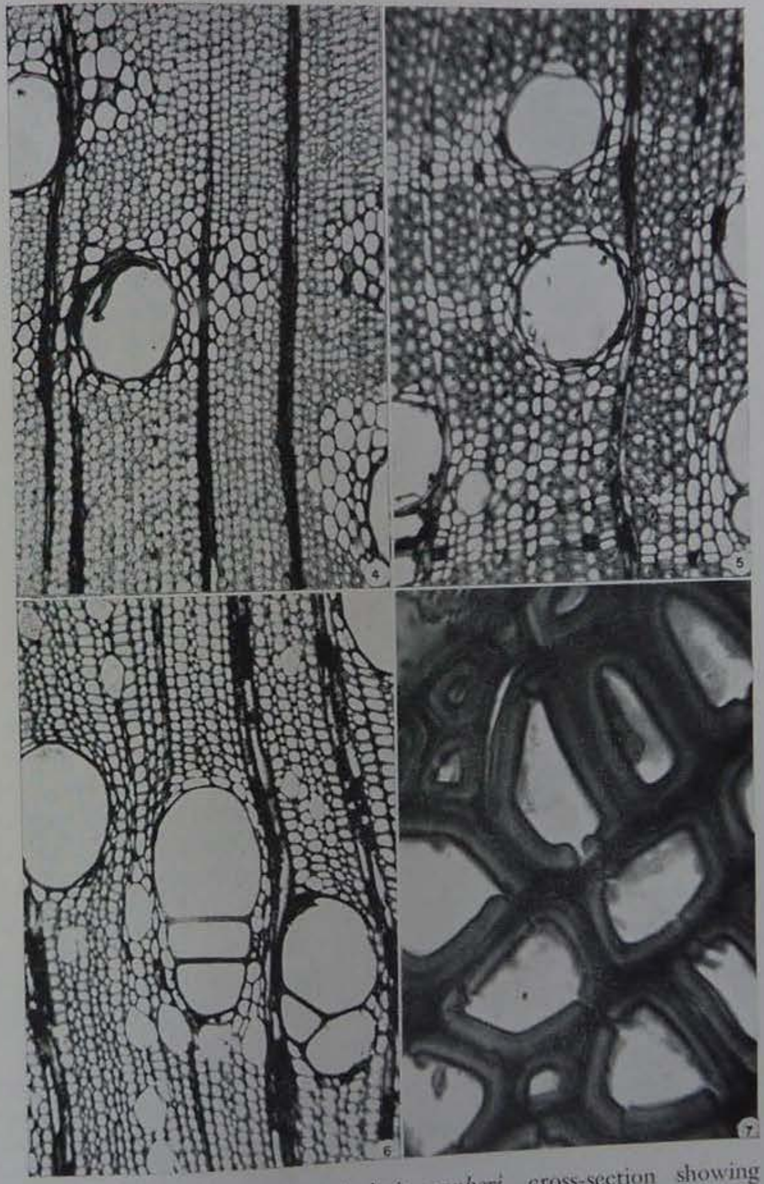

Fig. 4-7.—Fig. 4. *Hypodaphnis zenkeri,* cross-section showing solitary, circular pores and aliform axial parenchyma. ×85.—Fig. 5. *Beilschmiedia pendula,* cross-section exhibiting circular pores and confluent axial parenchyma. ×85.—Fig. 6. Cross-section, *Aniba ovalifolia,* showing pores in solitary, radial multiple and cluster arrangements, and conspicuous secretory cells. ×85.—Fig. 7. *Dehaasia elliptica,* cross-section illustrating libriform wood fibers and simple

Cryptocarya cordata: Growth rings distinct; pores 14-24 in a square millimeter, angular to circular, tending to angularity; vessel wall thickness 1.5-3μ; tyloses thin-walled; vessel element end wall inclination 20°-50°, mostly 40°; intervascular pits polygonal to circular, pitting alternate; vascular rays heterogeneous IIA, 1-3, mostly 1-2 cells wide, uniseriate rays 1-11, mostly 5-7 cells high, multiseriate rays 4-42, mostly 15-20 cells high; secretory cells scarce in rays and as idioblasts, common in axial parenchyma; pith flecks present.

Cryptocarya lancifolia: Growth rings distinct; pores 12-21 in a square millimeter, angular to circular, tending to angularity; vessel wall thickness 2-4.5μ; tyloses thin-walled; vessel element end wall inclination 20°-50°, mostly 45°; intervascular pits polygonal to elongate, pitting alternate with some opposite and transitional; vascular rays heterogeneous IIB, 1-3, mostly 1-2 cells wide, uniseriate rays 1-6, mostly 3-4 cells high, multiseriate 4-33, mostly 9-15 cells high; secretory cells in rays and axial parenchyma.

Dehaasia elliptica: Growth rings indistinct; pores 9-19 in a square millimeter, circular; vessel wall thickness 3-4.5μ; tyloses thin-walled; vessel element end wall inclination 30°-60°, mostly 45°; intervascular pits polygonal to circular, pitting alternate; vascular rays heterogeneous IIB, 1-2, mostly 2 cells wide, uniseriate rays 1-9, mostly 4-8 cells high, multiseriate 5-34, mostly 10-20 cells high; secretory cells in axial parenchyma.

Dehaasia triandra: Growth rings distinct; pores 11-20 in a square millimeter, angular to circular, tending to angularity; vessel wall thickness 1.5-3μ; tyloses with thick and thin walls; vessel element end wall inclination 30°-60°, mostly 45°; intervascular pits polygonal to elongate, pitting alternate with some opposite and transitional; vascular rays heterogeneous IIB, 1-3, mostly 2 cells wide, uniseriate rays uncommon, 1-7, mostly 2-3 cells high, multiseriate 5-17, mostly 5-12 cells high; secretory cells absent; pith flecks present.

Dicypellium caryophyllatum: Growth rings distinct; pores 26-34 in a square millimeter, circular; vessel wall thickness

3-4.5μ; tyloses absent; vessel element end wall inclination 20°-50°, mostly 40°; intervascular pits polygonal to circular, pitting alternate; vascular rays heterogeneous IIB, 1-2, mostly 2 cells wide, uniseriate rays scarce, 1-4, mostly 2-3 cells high, multiseriate 5-30, mostly 8-16 cells high; secretory cells in rays; pith flecks present.

Endiandra glauca: Growth rings distinct; pores 6-16 in a square millimeter, circular; vessel wall thickness 3-4.5μ; tyloses thin-walled; vessel element end wall inclination 30°-50°, mostly 40°; intervascular pits polygonal to circular, pitting alternate; vascular rays heterogeneous IIB, 1-4, mostly 2-3 cells wide, uniseriate rays 1-7, mostly 2-3 cells high, multiseriate 3-24, mostly 8-16 cells high; secretory cells in rays, axial parenchyma, and as idioblasts.

Endiandra trichotosa: Growth rings absent; pores 3-8 in a square millimeter, angular to circular, tending to circularity; vessel wall thickness 3-4.5μ; tyloses absent; vessel element end wall inclination 20°-60°, mostly 45°; intervascular pits polygonal, pitting alternate; vascular rays heterogeneous IIB, 1-2, mostly 2 cells wide, uniseriate rays 1-14, mostly 2-4 cells high, multiseriate 6-27, mostly 9-15 cells high; secretory cells in axial parenchyma and as idioblasts.

Endlicheria endlicheriopsis: Growth rings distinct; pores 4-10 in a square millimeter, circular; vessel wall thickness 2-4.5μ; tyloses thin-walled; vessel element end wall inclination 30°-60°, mostly 45°; intervascular pits circular, pitting alternate; vascular rays heterogenous IIB, 1-3, mostly 2 cells wide, uniseriate rays 1-6, mostly 2-4 cells high, multiseriate 5-27, mostly 10-20 cells high; secretory cells in rays.

Endlicheria sericea: Growth rings indistinct; pores 12-20 in a square millimeter, angular to circular, tending to angularity; vessel wall thickness 1.5-3μ; tyloses thin-walled; vessel element end wall inclination 20°-60°, mostly 45°; intervascular pits polygonal to circular, pitting alternate; vascular rays heterogeneous IIB, 1-3, mostly 2 cells wide, uniseriate rays 1-7, mostly 2-4 cells high, multiseriate 4-66, mostly 15-25

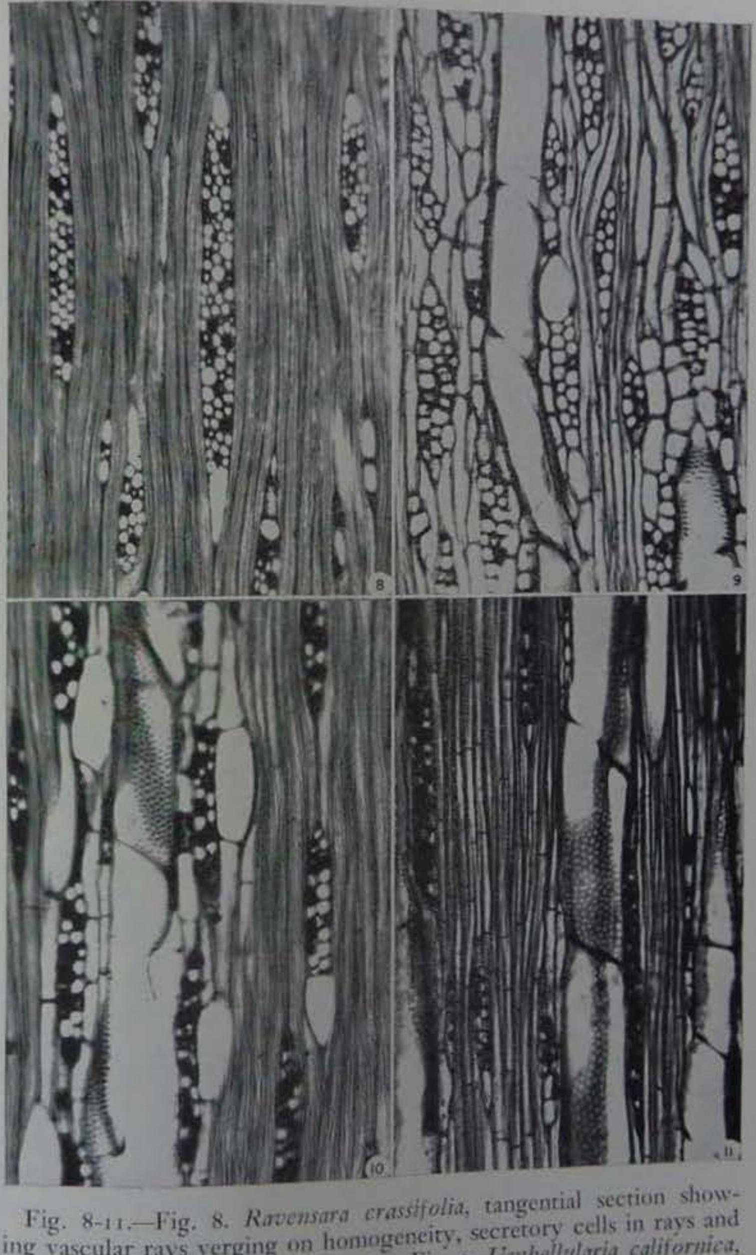

Fig. 8-11.—Fig. 8. *Ravensara crassifolia,* tangential section showing vascular rays verging on homogeneity, secretory cells in rays and thick-walled fibrous elements. ×85.—Fig. 9. *Umbellularia californica,* tangential section showing nearly homogenous rays, secretory cells and angular vessel element end walls. ×85.—Fig. 10. Tangential section, *Cinnamomum porrectum,* showing secretory cells in axial parenchyma *Dicypellium caryophyllatum,*

cells high; secretory cells in rays and axial parenchyma; pith flecks present.

Eusideroxylon melagangai: Growth rings indistinct; pores 3-13 in a square millimeter, circular; vessel wall thickness 3-6μ; tyloses thin-walled; vessel element end wall inclination 10°-45°, mostly 30°; intervascular pits polygonal to circular, pitting alternate; vascular rays heterogeneous IIB, 1-4, mostly 2-3 cells wide, uniseriate rays scarce, 1-6, mostly 2-3 cells high, multiseriate 5-33, mostly 15-25 cells high; secretory cells in rays and axial parenchyma.

Eusideroxylon zwageri: Growth rings indistinct; pores 2-8 in a square millimeter, circular; vessel wall thickness 8-9μ; tyloses thin to very thick-walled; vessel element end wall inclination 0°-30°, mostly 20°; intervascular pits circular, pitting alternate; vascular rays heterogeneous IIB, 1-4, mostly 2-3 cells wide, uniseriate rays 1-4, mostly 3-4 cells high, multiseriate 4-57, mostly 10-20 cells high; secretory cells in axial parenchyma.

Hypodaphnis zenkeri: Growth rings indistinct; pores 3-18 in a square millimeter, angular to circular, tending to circularity; vessel wall thickness 1.5-3μ; tyloses thin-walled; vessel element end wall inclination 0°-45°, mostly 40°; intervascular pits polygonal to circular, pitting alternate; vascular rays homogeneous I, 1-5, mostly 3-4 cells wide, uniseriate rays 1-9, mostly 4-7 cells high, multiseriate 4-34, mostly 15-25 cells high; secretory cells very scarce, occurring as idioblasts.

Laurus nobilis: Growth rings distinct; pores 20-38 in a square millimeter, angular to circular, tending to angularity; vessel wall thickness 1.5-3μ; tyloses thin-walled; vessel element end wall inclination 30°-75°, mostly 50°; intervascular pits circular, pitting alternate; vascular rays heterogeneous IIB, 1-4, mostly 2-3 cells wide, uniseriate rays 1-6, mostly 2-4 cells high, multiseriate 3-35, mostly 5-15 cells high; secretory cells scarce, occurring in rays and as idioblasts.

Licaria cayennensis: Growth rings absent; pores 2-9 in a square millimeter, circular; vessel wall thickness 4-11μ; tyloses very thick-walled; vessel element end wall inclination

20°-50°, mostly 45°; intervascular pits circular, pitting alternate; vascular rays heterogeneous IIB, 1-3, mostly 2 cells wide, uniseriate rays scarce, 2-5, mostly 2-3 cells high, multiseriate 5-30, mostly 15-25 cells high; secretory cells in rays and axial parenchyma.

Licaria rigida: Growth rings distinct; pores 8-20 in a square millimeter, angular to circular, tending to circularity; vessel wall thickness 1.5-4.5μ; tyloses thin-walled; vessel element end wall inclination 10°-50°, mostly 45°; intervascular pits polygonal to circular, pitting alternate; vascular rays heterogeneous IIB, 1-3, mostly 2 cells wide, uniseriate rays 2-13, mostly 3-8 cells high, multiseriate 4-33, mostly 15-25 cells high; secretory cells in rays, axial parenchyma, and as idioblasts.

Lindera benzoin: Growth rings distinct; pores 53-77 in a square millimeter, angular to circular, tending to circularity; vessel wall thickness 1.5-4.5μ; tyloses absent; vessel element end wall inclination 30°-60°, mostly 45°; intervascular pits circular to elliptical, pitting alternate; vascular rays heterogeneous IIB, 1-3, mostly 1-2 cells wide, uniseriate rays 1-14, mostly 3-8 cells high, multiseriate 5-48, mostly 10-20 cells high; secretory cells absent.

Lindera communis: Growth rings distinct; pores 33-56 in a square millimeter, angular to circular, tending to circularity; vessel wall thickness 1.5-2.5μ; tyloses thin-walled; vessel element end wall inclination 20°-50°, mostly 40°; intervascular pits polygonal, pitting alternate; vascular rays heterogeneous IIB, 1-3, mostly 2 cells wide, uniseriate rays 1-7, mostly 2-3 cells high, multiseriate 4-30, mostly 10-15 cells high; secretory cells in rays and axial parenchyma.

Litsea elongata: Growth rings distinct; pores 8-14 in a square millimeter, circular; vessel wall thickness 1.5-4.5μ; tyloses thin-walled; vessel element end wall inclination 20°-50°, mostly 40°; intervascular pits circular to elliptical, pitting alternate; vascular rays heterogeneous IIB, 1-4, mostly 2-3 cells wide, uniseriate rays 2-5, mostly 2-3 cells high, multiseriate 3-33, mostly 10-20 cells high; secretory cells scarce in rays, commoner in axial parenchyma.

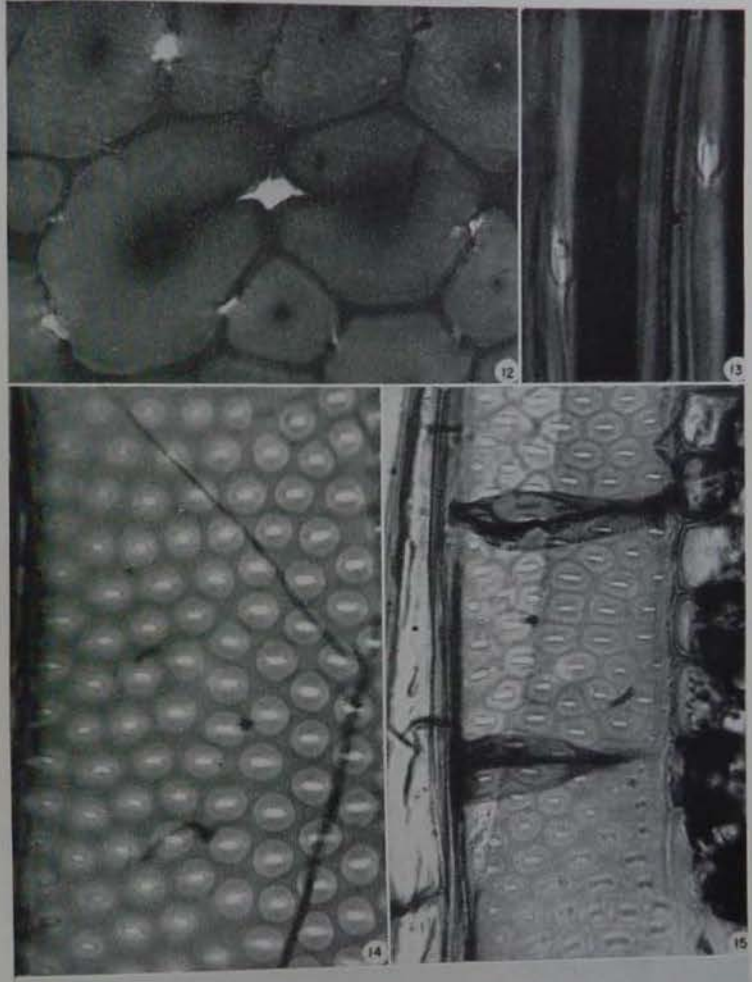

Fig. 12-15.—Fig. 12. *Eusideroxylon zwageri*, cross-section illustrating bordered pits in thick-walled fiber-tracheids. ×680.—Fig. 13. *Beilschmiedia pendula*, radial section showing bordered pits in fiber-tracheids. ×680.—Fig. 14. *Cryptocarya cordata*, tangential section illustrating alternate intervascular pitting, and circular pits with elliptical apertures. ×420.—Fig. 15. *Phoebe mexicana*, tangential section to show alternate and some opposite intervascular pitting, polygonal pits with elliptical apertures and tyloses. ×420.

Litsea mellifera: Growth rings indistinct; pores 27-44 in a square millimeter, angular to circular, tending to circularity; vessel wall thickness 1.5-4.0μ; tyloses thin-walled; vessel element end wall inclination 15°-50°, mostly 35°; intervascular pits polygonal to circular, pitting alternate; vascular rays heterogeneous IIB, tending to homogeneity, 1-5, mostly 3-4 cells wide, uniseriate 1-4, mostly 2-3 cells high, multiseriate 5-36, mostly 10-20 cells high; secretory cells in axial parenchyma.

Mezilaurus itauba: Growth rings indistinct; pores 8-13 in a square millimeter, angular to circular, tending to circularity; vessel wall thickness 4.5-7.5μ; tyloses thin-walled; vessel element end wall inclination 10°-45°, mostly 30°; intervascular pits circular, pitting alternate; vascular rays heterogeneous IIB, 1-4, mostly 2 cells wide, uniseriate rays scarce, 3-9, mostly 4-5 cells high, multiseriate 5-18, mostly 8-12 cells high; secretory cells scarce in rays, commoner in axial parenchyma.

Mezilaurus synandra: Growth rings indistinct; pores 5-9 in a square millimeter, angular to circular, tending to circularity; vessel wall thickness 1.5-3.0μ; tyloses thin-walled; vessel element end wall inclination 10°-45°, mostly 30°; intervascular pits circular, pitting alternate; vascular rays heterogeneous IIB tending to homogeneity, 1-4, mostly 2 cells wide, uniseriate rays scarce, 1-5, mostly 2-4 cells high, multiseriate 6-29, mostly 15-25 cells high; secretory cells in axial parenchyma.

Nectandra coriacea: Growth rings distinct; pores 48-80 in a square millimeter, angular to circular, tending to circularity; vessel wall thickness 1.5-4.5μ; tyloses thin-walled; vessel element end wall inclination 35°-50°, mostly 40°; intervascular pits circular, pitting alternate; vascular rays heterogeneous IIB, 1-3, mostly 2 cells wide, uniseriate rays 1-8, mostly 1-3 cells high, multiseriate 4-38, mostly 10-20 cells high; secretory cells absent.

Nectandra globosa: Growth rings absent; pores 7-13 in a square millimeter, angular to circular, tending to circularity;

vessel wall thickness 1.5-3.0μ; tyloses thin-walled; vessel element end wall inclination 20°-45°, mostly 30°; intervascular pits polygonal, pitting alternate; vascular rays heterogeneous IIB, 1-4, mostly 2-3 cells wide, uniseriate rays scarce, 1-3, mostly 2-3 cells high, multiseriate 4-29, mostly 15-25 cells high; secretory cells absent.

Neolitsea levinei: Growth rings distinct; pores 34-58 in a square millimeter, angular to circular, tending to angularity; vessel wall thickness 1.5-3.0μ; tyloses thin-walled; vessel element end wall inclination 35°-60°, mostly 45°; intervascular pits circular to elliptical; vascular rays heterogeneous IIB tending to IIA, 1-2 cells wide, uniseriate rays 1-8, mostly 3-4 cells high, multiseriate 3-23, mostly 5-15 cells high; secretory cells absent.

Neolitsea umbrosa: Growth rings distinct; pores 41-48 in a square millimeter, angular to circular, tending to angularity; vessel wall thickness 1.5-3.0μ; tyloses thin-walled; vessel element end wall inclination 30°-65°, mostly 50°; intervascular pits circular to elongate, pitting alternate, some opposite; vascular rays heterogeneous IIB tending to IIA, 1-3, mostly 1-2 cells wide, uniseriate rays 1-7, mostly 2-5 cells high, multiseriate 5-38, mostly 15-25 cells high; secretory cells numerous in axial parenchyma and as idioblasts.

Ocotea cooperi: Growth rings indistinct; pores 5-10 in a square millimeter, angular to circular, tending to circularity; vessel wall thickness 1-1.5μ; tyloses thin-walled; vessel element end wall inclination 30°-60°, mostly 45°; intervascular pits polygonal to circular, pitting alternate; vascular rays heterogeneous IIB, 1-3, mostly 2-3 cells wide, uniseriate rays 1-6, mostly 3-4 cells high, multiseriate 6-34, mostly 17-27 cells high; secretory cells in axial parenchyma.

Ocotea palmana: Growth rings distinct; pores 6-15 in a square millimeter, angular to circular, tending to circularity; vessel wall thickness 1-1.5μ; tyloses thin-walled; vessel element end wall inclination 35°-60°, mostly 45°; intervascular pits polygonal, pitting alternate; vascular rays heterogeneous IIB, 1-3, mostly 2 cells wide, uniseriate rays

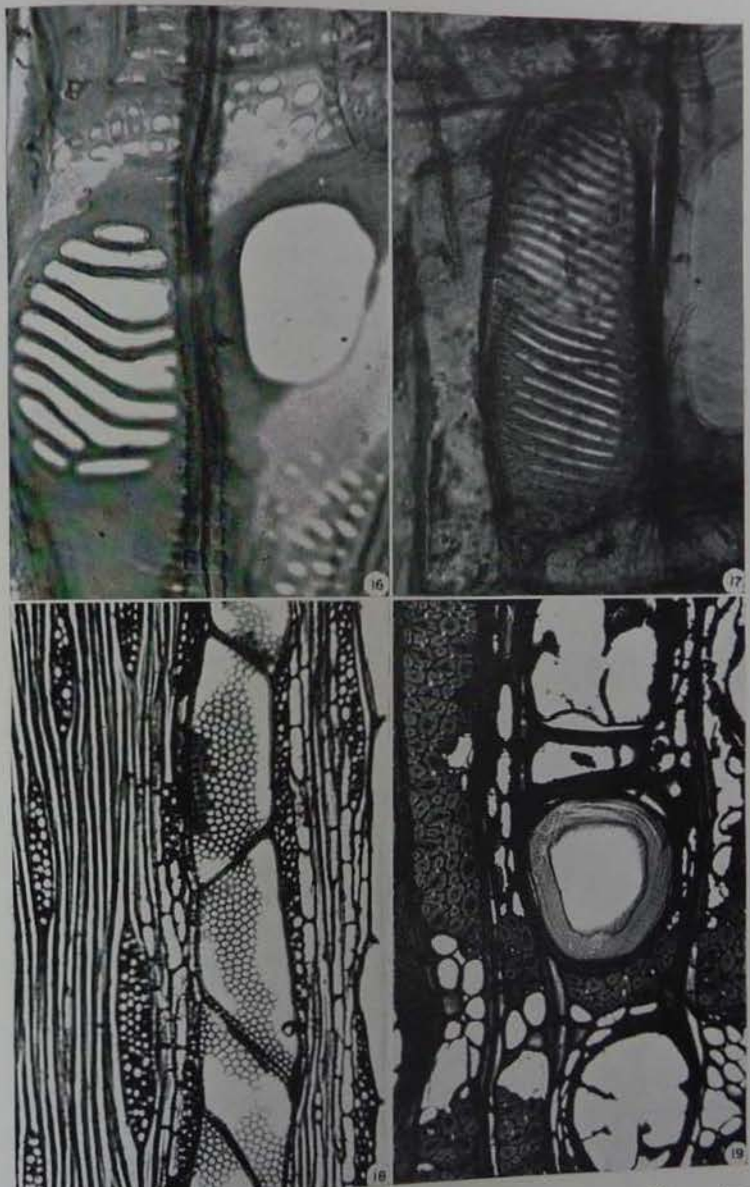

Fig. 16-19.—Fig. 16. Radial section, *Laurus nobilis*, illustrating adjacent simple and scalariform perforation plates. ×420.—Fig. 17. *Actinodaphne reticulata*, radial section showing many-barred scalariform perforation plate. ×420.—Fig. 18. Tangential section, *Hypodaphnis zenkeri*, to show vessel element end wall inclination, alternate intervascular pitting and homogeneous vascular rays. ×85.—Fig. 19. *Eusideroxylon zwageri*, cross-section showing thick-walled fibers, paratracheal axial parenchyma, and a sclerotic tylosis. ×85.

1-7, mostly 2-3 cells high, multiseriate 4-30, mostly 15-25 cells high; secretory cells scarce in axial parenchyma.

Persea americana: Growth rings distinct; pores 18-28 in a square millimeter, angular to circular, tending to circularity; vessel wall thickness 1.5-3.5μ; tyloses thin-walled; vessel element end wall inclination 20°-50°, mostly 40°; intervascular pits polygonal, pitting alternate, some opposite; vascular rays heterogeneous IIB, 1-4, mostly 3 cells wide, uniseriate rays 1-9, mostly 2-4 cells high, multiseriate 5-33, mostly 10-20 cells high; secretory cells in rays, axial parenchyma, and as idioblasts.

Persea schiedeana: Growth rings indistinct; pores 13-27 in a square millimeter, angular to circular, tending to angularity; vessel wall thickness 1.5-3.0μ; tyloses thin-walled; vessel element end wall inclination 20°-65°, mostly 45°; intervascular pits polygonal to circular, pitting alternate, some opposite; vascular rays heterogeneous IIB, 1-3, mostly 2-3 cells wide, uniseriate rays 1-7, mostly 2-3 cells high, multiseriate 5-23, mostly 10-20 cells high; secretory cells in rays, axial parenchyma, and as idioblasts; pith flecks present.

Phoebe amplifolia: Growth rings distinct; pores 2-5 in a square millimeter, angular to circular, tending to circularity; vessel wall thickness 1.5-3.5μ; tyloses thin-walled; vessel element end wall inclination 30°-50°, mostly 45°; intervascular pits polygonal to circular, pitting alternate, some opposite; vascular rays heterogeneous IIB, 1-4, mostly 2-3 cells wide, uniseriate rays 1-7, mostly 2-3 cells high, multiseriate 4-20, mostly 10-20 cells high; secretory cells in rays and axial parenchyma.

Phoebe mexicana: Growth rings distinct; pores 14-25 in a square millimeter, angular to circular, tending to circularity; vessel wall thickness 1-3μ; tyloses thin-walled; vessel element end wall inclination 30°-65°, mostly 45°; intervascular pits polygonal, pitting alternate, some opposite; vascular rays heterogeneous IIB, 1-3, mostly 2 cells wide, uniseriate rays scarce, 1-5, mostly 2-3 cells high, multiseriate 4-23, mostly 5-15 cells high; secretory cells in rays, axial parenchyma, and as idioblasts.

Ravensara crassifolia: Growth rings possibly present as marked by regular bands of parenchyma; pores 4-7 in a square millimeter, circular; vessel wall thickness 3-7.5μ; tyloses very thick-walled; vessel element end wall inclination 30°-50°, mostly 45°; intervascular pits polygonal, pitting alternate, some opposite; vascular rays heterogeneous IIB, 1-5, mostly 2-4 cells wide, uniseriate rays 1-4, mostly 1-2 cells high, multiseriate 4-57, mostly 10-30 cells high; secretory cells absent.

Sassafras albidum: Growth rings distinct; pores 30-61 in a square millimeter, small pores in late wood angular, large pores in early wood rounder; ring-porous; vessel wall thickness 1.5-4.5μ; tyloses thin-walled; vessel element end wall inclination 30°-70°, mostly 45°-60°; intervascular pits polygonal, pitting alternate, some opposite; vascular rays heterogeneous IIB, 1-5, mostly 2 cells wide, uniseriate rays numerous, 1-9, mostly 2-4 cells high, multiseriate 4-23, mostly 5-15 cells high; secretory cells in rays and axial parenchyma.

Sassafras tzumu: Growth rings distinct; pores 14-43 in a square millimeter, small pores in late wood angular, large early wood pores rounder; ring-porous; vessel wall thickness 1.5-4.5μ; tyloses thin-walled; vessel element end wall inclination 30°-70°, mostly 30°-50°; intervascular pits polygonal to circular, pitting alternate, some opposite; vascular rays heterogeneous IIB, 1-5, mostly 2-3 cells wide, uniseriate rays 1-5, mostly 2-3 cells high, multiseriate 4-29, mostly 10-20 cells high; secretory cells common in rays and axial parenchyma, less frequent as idioblasts.

Umbellularia californica: Growth rings distinct; pores 16-31 in a square millimeter, angular to circular, tending to angularity; vessel wall thickness 4.5-12μ; tyloses thin-walled; vessel element end wall inclination 20°-45°, mostly 35°; intervascular pits polygonal, pitting alternate; vascular rays heterogeneous IIB, tendency to homogeneity, 1-4, mostly 2-3 cells wide, uniseriate rays 1-4, mostly 2-3 cells high, multiseriate 3-17, mostly 5-15 cells high; secretory cells in rays, axial parenchyma, and as idioblasts.

Discussion

Anatomical considerations.—The Lauraceae possess a combination of anatomical features, which as far as can be determined, delimits this taxon from other families. Among these characteristics, the following are most significant: (1) vascular rays narrow, mostly 1- 3-seriate, heterogeneous IIB, (2) paratracheal parenchyma in all species, (3) alternate intervascular pitting, (4) secretory cells in the majority of species, and (5) diffuse-porosity in all but a single genus.

The several genera of laurels are not nearly so sharply defined as is the family, for species placed in the same genus on gross morphological characters may be anatomically dissimilar. *Endiandra trichotosa* shows no secretory cells in the rays, but these cells do occur in the rays of *E. glauca*. *Lindera communis* possesses secretory cells but none is seen in *L. benzoin*. *Cinnamomum camphora* has only simple perforations, while *C. porrectum* has both simple and scalariform perforation plates. Similar variations occur in species of *Cryptocarya*, *Nectandra*, *Endlicheria* and others. However it should be borne in mind that these few examples of anatomical differences are derived from studies on a relatively small portion of the total number of species in Lauraceae.

As has been intimated previously, anatomists have been aware of the hazy generic boundaries among the laurels. Janssonius (1934) states that sometimes differences among genera are of less magnitude than those among the species of a genus. He cites *Actinodaphne* as an example. In his descriptions of Malayan laurels, Desch (1941) mentions that "Considerable variation in anatomical structure exists within a species and between different species of the genus, so that no well-defined generic features can be discerned." Record and Hess (1945) have also observed that while species are often easily identified, generic determinations are difficult. Dadswell and Eckersley (1940) and Pearson and Brown (1932) have likewise noted discrepancies in the wood anatomy of species placed within the same genus.

Homogeneity within a taxon is an indication that the category is natural, whereas heterogeneity prompts doubt as to whether members of the taxon are genetically related. Because the species in certain lauraceous genera show large anatomical variations causing the genera to be ill-defined, some doubt can be raised regarding the naturalness of these taxa. Wood anatomists, working with other groups, have found that species are usually difficult to distinguish on the basis of anatomical features, yet genera are often distinct. The sharp anatomical differences among the species within certain genera of Lauraceae suggests the possibility of unnatural grouping.

In some random observations, Macbride (1931) has pointed to the artificiality of several lauraceous genera. He states that ". . . as he (Mez, 1889) himself indicated, the generic lines, especially as concerns *Persea*, *Phoebe*, *Nectandra* and *Ocotea*, are broken by species that in one or more essential characters do not entirely conform. As more species become known, more modifications will in all probability be disclosed and thereby prove more definitely that certain generic characters regarded as fundamental, such as the degree of development of staminodia and the position and relative position of anther cells, are themselves merely variable characters. The fact that there are no good concomitant characters of fruit or foliage, all species considered in the genera mentioned, suggests very strongly that the really natural limitations of the group or groups have even yet not been correctly defined." Hooker (1885) made observations similar to those of Macbride and wrote, "The species of this Order are very difficult of discrimination without fruits, and the genera are in some cases far from natural; the character of 2- and 4-celled anthers separating generically plants otherwise very nearly related." In a recent work, Sastri (1953) writes that the 2- and 4-celled anther condition divides the genus *Cinnamomum* between Persoideae (anthers 2-celled) and Lauroideae (anthers 4-celled). The genus *Cinnamomum* is placed in Lauroideae on the basis of its having 4-celled anthers. However, Sastri states that ". . . the anthers of all whorls of stamens in *Cinnamomum iners* are 2-locular . . ." He agrees with Hooker, saying that the number of

locules in the anther does not seem to be an adequate character to provide a basis for classification in this family.

Because of the heterogeneity of the anatomical features within genera, it is not possible to subdivide the family satisfactorily on anatomical grounds. Anatomical classifications have been constructed, but each suffers from faults arising from generic indistinctness. Both Desch (1941) and Dadswell and Eckersley (1940) employ parenchyma distribution as the basis for dividing the laurels studied by them. Their classifications coincide with Pax' subgroups Lauroideae and Persoideae. Species showing apotracheal parenchyma are placed in Lauroideae, and those having only paratracheal parenchyma are in Persoideae. Some species in Persoideae, according to Dadswell and Eckersley, exhibit scalariform perforation plates with a few bars. Presumably, species in Lauroideae have only simple perforation plates. These workers have placed species of *Beilschmiedia*, *Cryptocarya* and *Endiandra* in Lauroideae, and *Cinnamomum*, *Litsea* and *Persea* in Persoideae. In Desch's work, the same genera are included in Lauroideae; *Actinodaphne*, *Alseodaphne*, *Cinnamomum*, *Dehaasia*, *Litsea* and *Phoebe* are classified under Persoideae. Janssonius subdivides the laurels studied by him into three groups. The third group consists of *Hernandia peltata*, now usually considered under a separate family—Hernandiaceae. His divisions are based on the presence or absence of metatracheal (banded-apotracheal) wood parenchyma much as are those of the preceding workers. However, while Janssonius' groupings largely resemble those of Pax, he states, "*Die oben ergebene Einteilung stimmt nicht ueberein mit denjenigen von Bentham et Hooker, Genera Plantarum, III, 1, 147 und von Pax in Engler und Prantl, III, 1b, 112, welche beide Einteilungen auch voneinander sehr verschieden sind.*"

An attempt was made by the present author to employ the anatomical features described in this study in the construction of a classification of Lauraceae. The only significant features showing enough variability to permit the production of a system are the type of perforation plate and the parenchyma distribution. Difficulty was immediately encountered in placing those genera *(Cryptocarya, Cinnamomum, Endlicheria* and *Nectandra)* in which one species had only simple perforations and the other both simple and scalariform. Again, the variability of generic bounds is evident. Some interesting results were obtained when the anatomical features mentioned above were superimposed on the systems tabulated in the INTRODUCTION. Among the genera studied, those which show only simple perforation plates occur solely in Bentham and Hooker's tribe Perseaceae. These genera also occur in the subfamily Lauroideae of Pax, with the exception of *Eusideroxylon*, which falls under Persoideae. These same genera are listed only in part in the systems of Meissner and Mez. Genera studied which exhibit apotracheal parenchyma occur solely in the Perseaceae of Bentham and Hooker. In Pax' system all are in Lauroideae except *Cinnamomum*. The tribes Perseaceae and Cryptocaryeae of Meissner contain the apotracheal genera.

Referring again to the anatomical classification of Desch, and of Dadswell and Eckersley, we find that they have described the Malayan and Australian cinnamoma as lacking apotracheal parenchyma. The two species studied by the writer *(Cinnamomum camphora* and *C. porrectum)* evinced such parenchyma. Once again uncertainty of, or variability within generic bounds is shown. Dadswell and Eckersley intimate that species in Lauroideae have only simple perforation plates. Apparently the Australian laurels do not include species of *Dehaasia, Aiouea, Lindera* or *Laurus*. These genera have scalariform perforation plates and are placed by Pax under Lauroideae.

Present systems of classifying Lauraceae are founded mainly on stamen characteristics. Such features as the number of chambers in the anther, the presence or absence of sterile stamens, and the direction of anther dehiscence are among those employed in defining the subfamilial taxa. Some doubt might be raised regarding the desirability of using these features as indicators of relationship, since classifications based on them cannot be reconciled with anatomical

or other characters (see Macbride, 1931). It is entirely possible that 2-chambered and 4-chambered anthers have been developed independently in unrelated taxa within the laurels and that all laurels having 2- or 4-chambered anthers are not necessarily closely related. The same may also be true of the direction of dehiscence and reduction of fertile stamens. The characters heretofore employed in separating the genera may have arisen in several parallel series within the family. It is imperative, therefore, that to form a natural system of classification for Lauraceae, we employ characters other than those now in use. Macbride (1931) has emphasized this in his taxonomic observations quoted earlier in this paper. It is also important that any future studies in Lauraceae include a better representation of the species than surveyed in the past.

The wood anatomy of Lauraceae is indicative of a moderate stage of phyletic advancement. Some features show primitive propensities while others tend toward specialization. The following will serve to illustrate the gamut of evolutionary specialization as manifested in the xylem elements of the laurels: (1) predominantly alternate intervascular pitting but some transitional and opposite; (2) fiber-tracheids and libriform wood fibers; (3) oblique and transverse vessel element end walls; (4) mostly solitary pore arrangement but some multiples and clusters; (5) scalariform and simple perforation plates; (6) angular and circular pores; (7) vascular rays ranging from heterogeneous IIA through homogeneous I; (8) axial parenchyma which is mostly paratracheal but with some banded and terminal; (9) vessel elements ranging from "extremely short" to "very long" but which average "medium sized"; and (10) pores which vary from "extremely small" to "rather large," averaging "moderate sized." There are a few features in these woods of questionable phylogenetic import, but which nevertheless represent specializations of a sort. Among these are secretory cells and septa in some of the fibers.

Thus it appears that the woods of this family are transitional, rather than definitely phylogenetically advanced or primitive. In the opinion of the writer, however, most features are transitional or advanced. Supporting this contention is the presence in all woods of simple perforation plates, alternate intervascular pitting, pores in aggregate arrangements and paratracheal axial parenchyma.

The section to follow represents a brief anatomical description of families putatively related to Lauraceae as indicated in the Introduction. These descriptions were culled from the literature and do not represent any original work on the part of the author. The following works were consulted in summarizing these anatomical accounts: Benoist (1927), F. B. H. Brown (1922), Desch (1941), Garratt (1933a,b, 1934), Jolly (1917), Kanehira (1921), Kribs (1928), Lecomte (1925), McLaughlin (1933), Metcalfe and Chalk (1950), Pearson and Brown (1932), Record and Hess (1943), Reyes (1938), Solereder (1908), Tippo (1938) and Williams (1936). In perusing these publications, it was notable that only in very few cases were the fiber types named, although frequently notes on pitting were included. Exact specifications of ray types were not given in several of the original publications. In these cases only the general category (homogeneous or heterogeneous) is stated.

Annonaceae

Growth rings distinct or absent, sometimes indistinct. Woods diffuse-porous except in *Asimina*. Fiber-tracheids and libriform wood fibers present. Pores mostly solitary, some in radial multiples and clusters. Perforation plates simple. Vessel element end walls horizontal to slightly oblique. Intervascular pitting alternate with some opposite. Vessel element length 300-600μ. Vascular rays typically homogeneous I and II, some species showing heterogeneous types. Axial parenchyma mostly apotracheal, some showing paratracheal (vasicentric). Spiral thickenings occur in the vessels of *Asimina* and storying is present in 15 genera.

Berberidaceae

Growth rings present. Woods diffuse-porous with some ring-porous. Fibers sometimes septate, with simple pits. Pores

angular, mostly in groups, less often solitary; 25-50μ in tangential diameter. Perforation plates typically simple, some scalariform. Vessel element end walls slightly oblique. Intervascular pitting alternate. Vessel element length 150-350μ. Vascular rays predominantly homogeneous II, some heterogeneous. Axial parenchyma scarce to absent. Spiral thickenings in vessels of some; storied fibers in two genera.

Calycanthaceae

Growth rings present. Woods diffuse-porous, semi-ring-porous, and ring-porous. Fiber-tracheids present. Pores angular, mostly in radial multiples, some solitary and a few as clusters; tangential diameter 16-36μ, average 27μ. Perforations simple. Vessel element end wall inclination 10°-65°. Intervascular pitting alternate. Vessel element length 300-500μ. Vascular rays heterogenous I. Axial parenchyma paratracheal (scanty vasicentric), and apotracheal (diffuse). Spiral thickenings in vessels and vasicentric tracheids present in some.

Chloranthaceae

Growth rings indistinct or absent. Woods diffuse-porous. Fibers with bordered or simple pits. Pores mostly solitary, in radial multiples of 2-4 and a few as small clusters; tangential diameter small to medium sized. Perforation plates scalariform with many bars. Vessel element end walls very oblique. Intervascular pitting scalariform with some transitional. Vessel element length 800-2000μ. Vascular rays heterogeneous. Axial parenchyma mostly apotracheal and sparingly paratracheal.

Gomortegaceae

Fiber-tracheids present. Maximum tangential diameter of pores 30μ. Perforation plates exclusively scalariform with numerous bars. Vascular rays heterogeneous. Axial parenchyma scanty.

Hernandiaceae

Growth rings distinct or indistinct. Woods diffuse-porous or ring-porous. Fibers with simple pits, septate in part. Pores mostly solitary, some in radial multiples. Perforation plates predominantly simple with a few scalariform. Intervascular pitting is alternate. Vessel element length 300-700μ. Vascular rays homogeneous I and II, some slightly heterogeneous. Axial parenchyma paratracheal (vasicentric, aliform and confluent), and apotracheal (diffuse and terminal). Secretory cells present in axial parenchyma.

Lactoridaceae

Woods diffuse-porous. Fibers with bordered pits. Pores solitary and in radial multiples; mean tangential diameter less than 100μ. Perforation plates simple; intervascular pitting opposite-alternate. Vessel element length less than 300μ. Vascular rays composed entirely of upright cells (heterogeneous?). Axial parenchyma apotracheal (diffuse).

Magnoliaceae

Growth rings distinct, indistinct or absent. Woods diffuse-porous. Tracheids and fiber-tracheids present. Pores angular-oval and elliptical, mostly solitary and in radial multiples, a few as clusters; 25-200μ in tangential diameter. Perforation plates scalariform, rarely simple *(Magnolia acuminata)*. Vessel element end walls oblique. Intervascular pitting mostly scalariform, some transitional and opposite *(Liriodendron)*. Vascular rays heterogeneous IIA and B, sometimes homogeneous. Axial parenchyma apotracheal (banded, diffuse and terminal), some paratracheal (vasicentric). Secretory cells in rays; spiral thickenings in vessels of some.

Monimiaceae

Growth rings present or absent. Woods diffuse-porous. Fibers with simple or distinctly bordered pits, septate in part. Pores rounded to oval, sometimes angular, mostly solitary and in radial multiples; very small to medium sized. Perforation plates simple and scalariform. Vessel element end walls slightly to very oblique. Intervascular pitting scalariform to alternate, the latter occurring only in species with simple perforation plates. Vessel element length 300-500μ. Vascular rays weakly to distinctly heterogeneous. Axial parenchyma sparse, mostly apotracheal (diffuse and banded) and some paratracheal. Secretory cells sporadic in rays of some species; spiral thickenings in vessels of one species.

Myristicaceae

Growth rings present or absent. Woods diffuse-porous. Fibers with inconspicuously bordered pits or occasionally simple pits, sometimes septate. Pores oval to ovoid, solitary and in radial multiples; very small to rather large. Perforation plates simple and scalariform, the latter occurring in all woods. Vessel element end walls generally oblique, rarely transverse. Intervascular pitting alternate, occasionally opposite. Vessel elements very short to extremely long, mostly very long. Vascular rays mostly heterogenous, sometimes homogeneous. Axial parenchyma apotracheal (diffuse, banded and terminal), sometimes paratracheal (vasicentric) and apparently lacking in one species. Secretory cells common in vascular rays and axial parenchyma of several species.

Polygonaceae

Growth rings distinct, indistinct or absent. Woods ring-porous, semi-ring-porous or diffuse-porous. Fibers with simple or indistinctly bordered pits. Pores mostly solitary and in radial multiples, a few as clusters; tangential diameter 25-200μ. Perforation plates exclusively simple. Intervascular pitting alternate. Vessel element length 300-630μ. Vascular rays homogeneous I and III, sometimes heterogeneous. Axial parenchyma sparse, paratracheal and apotracheal (banded and diffuse). Some woods storied, and spirals are found in vessels of a few species.

Proteaceae

Growth rings distinct, indistinct or absent. Woods mostly diffuse-porous, a few are semi-ring-porous and ring-porous. Fibers mostly with bordered pits, some simple. Pores are round to angular, mostly solitary and in radial multiples of 2-4 and a few as clusters; tangential diameter 25-130μ. Perforation plates predominantly simple, a few with scalariform plates. Vessel element end walls oblique. Intervascular pitting alternate. Vessel element length 250-1000μ. Vascular rays mostly homogeneous, a few heterogeneous. Axial parenchyma apotracheal (in short, arcuate interradial bands and diffuse), paratracheal (aliform and confluent) and absent in one species. Spiral thickenings in vessels, vasicentric tracheids and local storying occur in some.

Thymelaeaceae

Growth rings distinct, indistinct or absent. Woods largely diffuse-porous, some semi-ring-porous, and ring-porous in *Dirca*. Fibers mostly with bordered pits, some simple. Pores oval to angular, mostly solitary and in radial multiples of 2-6, some as small clusters; tangential diameter 30-120μ. Perforation plates exclusively simple. Vessel element end walls transverse to slightly oblique. Intervascular pitting alternate. Vessel element length 150-535μ. Vascular rays heterogeneous and homogeneous I and III. Axial parenchyma mostly paratracheal (aliform and confluent), some apotracheal (banded, terminal and diffuse). Spiral thickenings in vessels, storied axial parenchyma and vascular rays, vasicentric tracheids, intraxylary phloem and vestured pitting occur in the family.

In attempting to draw comparisons between taxa, it is essential that we do not infer relationship based on a single common feature. It is a well-known phenomenon that similar characters can evolve in totally unrelated taxa. Therefore in presenting evidence regarding relationships among taxa, the worker must be certain that he has not overlooked possible cases of parallel evolution. When there are several comparable characteristics shared by two taxonomic categories, the chances are lessened that these features have arisen through the operation of parallel mechanisms. Another important factor worthy of consideration is that all elements in the plant may not have reached the same level of specialization. Money, Bailey and Swamy (1950) point out that in the xylem, the "Elimination of wood parenchyma or its reduction to scanty paratracheal or terminal may occur at any level of the structural specialization of vessels."

By comparing the wood structure of the families described above with that of Lauraceae, the following observations can be made: Myristicaceae, Monimiaceae and Hernandiaceae are comparable to Lauraceae in that all possess some libriform wood fibers. Myristicaceae, Monimiaceae and Lauraceae are further characterized by showing fibers with bordered pits as well as with simple pits. The four above-mentioned families are alike in having pores mostly in solitary and multiple arrangements. These taxa exhibit both scalariform and simple perforation plates. All show alternate intervascular pitting; Monimiaceae, Myristicaceae and Lauraceae also possess other types of intervascular pitting. Lauraceae, Monimiaceae, Myristicaceae and Hernandiaceae have at least some members with heterogeneous vascular rays and apotracheal parenchyma. The same families are further characterized by the possession of secretory cells in the xylem. No spiral thickenings have been reported in the vessels of any of these families excepting one species in the Monimiaceae. No storying has been observed in Lauraceae and none has been reported in the other three families.

The relative levels of specialization in the xylem of the aforementioned families can be stated without intending any implication of phylogenetic series. Myristicaceae and Monimiaceae appear to stand parallel with regard to modification in the xylem, the former perhaps a bit above the latter. Myristicaceous members do not exhibit any scalariform intervascular pitting and some species manifest homogeneous vascular rays. Lauraceae stand a step above these two families in presenting some pore clusters, one species with homogeneous vascular rays, and predominantly paratracheal parenchyma. The presence of only libriform wood fibers, mostly simple perforation plates, only alternate intervascular pitting and mostly homogeneous vascular rays signifies that Hernandiaceae are the most specialized among these families. However, pore distribution in the latter taxon is mostly solitary.

Polygonaceae, Proteaceae and Thymelaeaceae seem to be more highly specialized than the preceding families. All show clustered pores, predominantly simple perforations, only alternate intervascular pitting, mostly homogeneous vascular rays, and paratracheal parenchyma. In addition such special features as storying and spiral thickenings in vessels are of relatively frequent occurrence within these families. Vasicentric tracheids occur in Proteaceae and Thymelaeaceae. Intraxylary phloem is found in the daphnads.

Chloranthaceae and Magnoliaceae appear to be on a lower level of specialization than Lauraceae. Both evince mostly scalariform intervascular pitting, scalariform perforation plates, heterogeneous vascular rays and apotracheal parenchyma. Magnoliaceae are perhaps on a level slightly above Chloranthaceae since some members possess simple perforation plates as well as opposite intervascular pitting, homogeneous vascular rays, paratracheal parenchyma and secretory cells.

Lactoridaceae and Calycanthaceae are more specialized than Lauraceae in some respects, and less specialized in others. The fibers in Lactoridaceae and Calycanthaceae have only bordered pits and vascular rays are only heterogeneous. Axial parenchyma is solely apotracheal in the Lactoridaceae. On the other hand, perforation plates are exclusively simple in Lactoridaceae and Calycanthaceae. Intervascular pitting is entirely alternate in Calycanthaceae and paratracheal parenchyma is also present in this family. Of these two families, Calycanthaceae are the more specialized.

Annonaceae are more specialized than the laurels in two respects: only simple perforation plates are present and vascular rays are mostly homogeneous. However, some opposite pitting occurs and most of the axial parenchyma is apotracheal. Berberidaceous xylem is more highly modified than wood of either Lauraceae or Annonaceae. The fibers have simple pits exclusively, pores are mostly in aggregate arrangements, perforation plates are predominantly simple, intervascular pitting is entirely alternate, vascular rays are mostly homogeneous, and axial xylem parenchyma is extremely reduced, being scarce or absent in the majority of species.

Gametophytic and embryologic considerations.—Reference to several reviews dealing with angiosperm gametogenesis and embryogeny (Johansen, 1950; Maheshwari, 1950; Martin, 1946; and Schnarf, 1929) disclosed incomplete studies in all families under consideration. In cases where a given family was treated, only a few of the species were studied. Little or no mention was made of other families. Maheshwari (1950) lists twelve embryological characters which he considers of major taxonomic importance. However, due to the paucity of pertinent information, it was impossible to assemble a complete survey of any one of these characters throughout the families under consideration. Because of this, only the most sketchy comparisons are possible among these families.

Endosperm is present in Annonaceae, Berberidaceae, Chloranthaceae, Gomortegaceae, Lactoridaceae, Magnoliaceae, Monimiaceae, Myristicaceae, Polygonaceae and Thymelaeaceae. Only Proteaceae, Lauraceae and Hernandiaceae are exendospermous. Embryo sporophytes are notably small in Annonaceae, some Berberidaceae (*Achlys triphylla, Jeffersonia diphylla* and *Vancouveria hexandra)*, Chloranthaceae, Lactoridaceae, Magnoliaceae, Monimiaceae and Myristicaceae. In other Berberidaceae (*Berberis aquifolium, Caulophyllum thalictroides, Diphylleia cymosa, Nandina domestica* and *Podophyllum peltatum)*, Calycanthaceae, Lauraceae, Polygonaceae, Proteaceae and Thymelaeaceae the embryo is not conspicuously small. Indeed, the embryos of Calycanthaceae, Lauraceae and Gomortegaceae are described as being large (Lawrence, 1951).

Schroeder (1943) describes the embryo sac of *Persea americana* as developing from a single functioning chalazal megaspore which divides to form the "normal" eight-nucleate condition. According to Schnarf (1929), this same condition obtains in the Annonaceae, Berberidaceae, Chloranthaceae, Magnoliaceae, Proteaceae and Thymelaeacae as well as in the Lauraceae.

A single female archesporial cell has been reported by Schroeder (1943) to be present in the developing megasporangium of *Persea americana*. Schnarf (1929) specifies that this is also the condition in Annonaceae *(Annona cherimolia* and *Asimina triloba)*, Berberidaceae *(Mahonia* and *Jeffersonia diphylla* and usually *Podophyllum peltatum)*, Chloranthaceae *(Hedyosmum nutans* and *H. arborescens)*, Magnoliaceae, Polygonaceae, Proteaceae *(Stenocarpus sinuatus)* and Thymelaeaceae. No data were presented for the other families under consideration.

Basing his system on that of Schnarf (1929), Johansen (1950) presents an embryonomic classification of types and variations. Whether or not species belong to a given type and variation does not necessarily indicate that the species are related because ". . . when the laws of embryonomy for a given species have been determined, they serve to define this species from the embryological standpoint. Certain species from very diverse families may follow the identical embryonomic laws in a general manner and may therefore be grouped together as a Type." In general, the species of a genus tend to be homogeneous with regard to their embryonomic type. Types may differ, however, within a family.

Persea americana, *Peumus boldus* (Monimiaceae), Polygonaceae, *Grevillea banksii* and *G. robusta* (Proteaceae) and *Daphne kuisiana*, *D. pseudomezereum*, *D. mezereum* and *Thymelaea arvensis* (Thymelaeaceae) all exhibit variations of the Asterad Type. Members of the Berberidaceae and Magnoliaceae show the Onagrad Type. *Sassafras albidum* demonstrates the Piperad Type of embryonic development and *Hedyosmum nutans* (Chloranthaceae) the Chenopodiad Type. *Siparuna* in the Monimiaceae is described as being completely sterile. Embryonomical accounts of the other families are not available.

Palynological considerations.—Wodehouse (1936) recognizes that two main forms of pollen grains occur in spermatophytes. In the more primitive (found in most gymnosperms, monocotyledons and lower angiosperms) a distally monocolpate[3] (1-sulcate of Erdtman, 1952) grain is produced. Here the germinal furrow is on the side of the grain opposite its contact with the other microspores of the tetrad. Higher dicotyledons exhibit a three-furrowed or tricolpate pollen grain, which is restricted to these plants. The basic tricolpate form of the higher dicotyledons is often so profoundly modified as to be hardly recognizable. Erdtman (1952) observes that "Spores are usually aperturate, i. e., provided with apertures, less frequently nonaperturate." Accordingly, the pollen grains of plant families may be assigned to either category.

As Erdtman (1952), Money, Bailey and Swamy (1950) and Wodehouse (1935) have cautioned, discretion must be employed in using pollen morphology to compare taxa. As with other plant characters, similar modifications of pollen grains may have arisen through different evolutionary mechanisms. The pollen grains of closely related taxa usually are more or less of the same type, but striking exceptions occur (Erdtman, 1952).

Aperturate pollen grains have been shown to occur in the following plant families (sometimes aperturate and nonaperturate grains are exhibited by the same taxon): Annonaceae, Berberidaceae, Calycanthaceae, Chloranthaceae, Lactoridaceae, Magnoliaceae, Monimiaceae, Myristicaceae, Polygonaceae, Proteaceae and Thymelaeaceae. Pollen grains of the nonaperturate type are found in Annonaceae, Chloranthaceae, Gomortegaceae, Hernandiaceae, Lauraceae and Monimiaceae.

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[3] Wodehouse (1935) apparently assigns the adjective "colpate" to any elongated germinal furrow. Erdtman (1952) restricts the usage of "colpate" to fusiform, meridional furrows.

Gomortegaceae, Hernandiaceae and virtually all Lauraceae have nonaperturate pollen grains (Kasapligil, 1951, illustrates monocolpate pollen grains from *Umbellularia californica)*, and those of Monimiaceae are predominantly that way. It is interesting to note that all of the above families except Polygonaceae, Proteaceae and Thymelaeaceae are tabulated by Money, Bailey and Swamy (1950) under their category "Monocolpate and derived dicolpate, polyporate and acolpate pollen–ethereal oil cells present."

General exomorphic considerations.–The following discussion represents the results of a survey of taxonomic descriptions (Engler and Diels, 1936; Hutchinson, 1926; and Lawrence, 1951) involving the habit, leaf and gross floral characteristics of Lauraceae, and the thirteen families suggested as being related to the laurels. A moderate diversity of structure is present among these families, no one being strikingly similar to Lauraceae. Some differ considerably.

The families whose exomorphic characters are most like those of the laurels are Gomortegaceae, Hernandiaceae and Monimiaceae. The following traits are held in common among these taxa: (1) arborescent or shrubby habits, (2) simple, estipulate leaves, (3) mostly or entirely bisexual actinomorphic flowers, borne in branched inflorescences (some solitary in Monimiaceae), (4) valvate anthers (some Hernandiaceae and Monimiaceae also possess anthers which dehisce longitudinally), (5) a single, pendulous ovule in the solitary locule (some erect in Monimiaceae) and (6) oil cells present in the plant body. Several notable differences also occur among these families. The most important are: (1) opposite phyllotaxy in Gomortegaceae, Monimiaceae and a few Lauraceae, (2) inferior ovaries in Gomortegaceae and Hernandiaceae, (3) a presumably apetalous condition in Gomortegaceae, Lauraceae and some Monimiaceae, and (4) a 2- 3-loculate, syncarpous ovary in Gomortegaceae.

Annonaceae resemble Lauraceae in the common possession of alternate, simple, estipulate leaves, bisexual (in some annonads), actinomorphic flowers with a superior ovary and some trimerous parts, an apocarpous gynoecium and anatropous ovules. Differences are noted in the differentiated perianth whorls, the longitudinal dehiscence of the anthers, the several pistils and the 1-many ovules in Annonaceae.

Lactoridaceae, Polygonaceae and possibly Chloranthaceae (cf. Swamy, 1953) bear some resemblance to the laurels in their tripartite floral plans. Anther dehiscence in these three families is longitudinal, leaves are stipulate, and the ovary of Chloranthaceae is inferior. The flowers of Chloranthaceae are reduced in some genera to the unisexual condition. In others, only a single stamen, adnate to the ovary wall, is present.

Berberidaceae are like the laurels in having actinomorphic flowers with an undifferentiated perianth, a superior ovary and valvate anthers. However, the berberids also possess a syncarpous gynoecium, 8-12 perianth segments and few-many ovules in a locule.

Calycanthaceae, Magnoliaceae and Myristicaceae are more or less like Lauraceae in their woody nature, simple leaves, apocarpous superior ovaries, actinomorphic flowers, parietal placentation and single anatropous ovule in the locule. These families further resemble Lauraceae in that they may show a tripartite perianth whorl. Calycanthaceae differ from the laurels in that they are shrubs with opposite leaves and have flowers with numerous pistils and perianth segments. Furthermore, the pistils are attached to the wall of a "rosaceous receptacle." The leaves of Magnoliaceae are stipulate, the pistils, petals and stamens are numerous and the anthers dehisce longitudinally. Myristicaceae possess monadelphous stamens, basal ovules, unisexual flowers, and a peculiar arillate fruit.

Proteaceae and Thymelaeaceae bear some likenesses to Lauraceae in their predominantly woody habit, estipulate, alternate simple leaves, superior ovaries and pendulous ovules. The number of floral parts, dehiscence of anthers and the presence of zygomorphy in the flowers of some Proteaceae are at variance with the condition in the laurels.

Considerations involving floral morphology.—That the biseriate perianths of *Umbellularia californica* and *Persea americana* are in fact composed of a calyx and corolla has been averred by Kasapligil (1951) and Reece (1939) respectively. Kasapligil points to the three traces entering the members of the outer perianth cycle and the single trace which enters the segments of the inner whorl and says that "In many dicotyledons this is a common difference between the sepals and petals." "The fact that the perianth traces arise at two levels is in itself sufficient evidence that the perianth does not consist of a calyx alone" is stated by Reece for the avocado. In these species the perianth is complete and is composed of a tripartite calyx and corolla. In *Laurus nobilis*, however, the perianth is not differentiated into sepals and petals (Kasapligil). Here, the segments of the inner perianth whorl are smaller than those of the outer cycle, but the members of both series are supplied by three traces indicating a sepaloid nature. According to the above information, and in the absence of a more complete survey, it seems likely that both biseriate and uniseriate (reduced) perianths occur among the Lauraceae.

A floral tube is formed in *Persea americana* and *Umbellularia californica* due to the connation and adnation of the perianth segments at their bases. In these laurels the insertion of the androecium is perigynous, but adnation is limited to the bases of the filaments. The perianth traces in *Persea americana* are distinct in the floral tube. This is also the case in *Umbellularia californica* and indicates that the perigynous cup is appendicular in nature. In reference to the insertion of the floral parts in the Lauraceae, it is noteworthy that in *Hypodaphnis zenkeri* the ovary is definitely inferior.

Stamens in the two outer whorls of *Umbellularia californica* normally contain a single vascular bundle, whereas each of those in the third whorl is supplied by three traces. In cases where stamens possess a single strand in the filament, Kasapligil considers this condition as arising through fusion of a median and two lateral traces. He supports his conclusions with observations from teratological material. The filaments of stamens in *Laurus nobilis* are supplied by three vascular traces, but normally only the median trace reaches the anther portion. In *Persea americana*, the stamens are characterized by having three traces enter the filament. In *Umbellularia californica* and *Persea americana*, the fourth staminal cycle consists of 3 staminodia. Staminodia in the former species are supplied by a single vascular trace.

The normal condition in Lauraceae is for the gynoecium to consist of a single ovary which contains a solitary, pendulous ovule. There is evidence, based on teratological specimens of ovaries with 2 ovules and gynoecia of 2 ovaries, oblique placement of the stigma, and the inconstant position of the pistil in certain gynoecia (In *Persea americana* the pistil usually lies in the plane of a sepal; however, it is frequently located on the radius of a petal.), that the single pistil of the laurels has been reduced from an apocarpous multicarpellate ancestral condition (Kasapligil, 1951; Reece, 1939). Eames and MacDaniels (1947) point out that the three-trace carpel is most common in dicotyledons and that the one-trace carpel has been derived by reduction from the common arrangement. In *Umbellularia californica* a dorsal trace extends through the style to supply the stigma and a ventral trace supplies the ovule. Variations of this plan are common, and the six-trace type is most frequent—one dorsal, four lateral and one ventral trace. The two-trace condition is also found in *Laurus nobilis* and *Persea americana*. These two-trace carpels are probably reduced from three-trace carpels by fusion of the ventral traces.

The flowers of *Umbellularia californica* and *Persea americana* are bisexual as are those in most other Lauraceae. On the other hand, *Laurus nobilis*, *Sassafras albidum*, *Hypodaphnis zenkeri* and others bear unisexual flowers. In the staminate flowers of *Laurus*, Kasapligil has observed the vestigial vascular supply to the lost gynoecium. The pistillate flower is characterized by having staminodia.

It is interesting to note that the floral plan for *Laurus nobilis* is dimerous in contrast with the trimerous plan of most other laurels. Kasapligil assumes that this species may have been derived from a trimerous ancestor. Along this same line, provocative statements have also been forwarded by Swamy (1953) in his work on Chloranthaceae. He concludes that the flowers of this family have undergone reduction both in regard to the number of floral parts and vasculature. Furthermore this worker points to the trimerous stamens in *Chloranthus* and the tricornered gynoecium in *Hedyosmum*. Swamy then broaches the question: Could these facts be employed to suggest a basically trimerous plan of construction of the flower (in Chloranthaceae)? He further suggests a study of Lauraceae, Gomortegaceae and Hernandiaceae as possibly yielding useful data for a cogent explanation of the chloranthaceous condition.

The above discussion of the floral morphology in some members of Lauraceae shows that throughout the reproductive structures reduction has occurred (and may still be occurring). These modifications have involved the loss of parts as well as the fusion of parts. Further evidences for these reductions are supplied by Kasapligil in his numerous illustrations of transitions between the unmodified and modified conditions as they occur in the laurels studied by him.

In their comprehensive work on the morphology and relationships of the Monimiaceae, Money, Bailey and Swamy (1950) have set down four diverse trends of morphological specialization in the flowers of this family. Briefly these are: (1) modification of the receptacular concavity, (2) more or less extensive cohesion and adnation within the perianth, (3) variability in the form of stamens and staminodia, and (4) transitions between bisexuality and unisexuality. These trends, moderated somewhat, could just as well depict the lines of morphological specialization in lauraceous flowers. These investigators, in discussing the relationships of Monimiaceae to other families, have stated that "Utilizing *Hortonia* as a basis of comparison, it is evident that the flowers of the Laurelieae—in acquiring valvular dehiscence of their stamens and a modified orientation of their anatropous

ovule—have retained relatively free tepals; stamens with associated staminodes, which in turn may be variously modified in form and which may at times assume a glandular function; numerous transitions between bisexuality and unisexuality; and varied stages of increasing concavity and extension of the receptacle, particularly subsequent to anthesis. It should be emphasized in this connection that it is the stamens and associated staminodes of *Hortonia* and the Laurelieae—with concomitant valvular dehiscence in the Laurelieae—that provide the most cogent evidence of relationship between the Monimiaceae and the Gomortegaceae, Lauraceae and Hernandiaceae."

W. H. Brown (1938) has shown that the presence or absence of nectaries, together with their form and position in the flower, is often helpful in the resolution of taxonomic problems. He states that the nectaries in Laurales are modified stamens and that this is also the case in Berberidales and Ranunculales. If Laurales are derived from Magnoliales, ". . . it must have been from a group in which petals had not been differentiated from the sepals." In certain of the Monimiaceae and Myristicaceae the "torus cup" functions as a nectary. In other Monimiaceae, in Lauraceae and Hernandiaceae, the nectaries are modified stamens. It is of some importance to note in this connection that Brown does not mention Myristicaceae as having any nectaries formed from altered stamens. This worker continues his discussion by saying that the "honey glands" in the Laurales may be very similar to those of the Ranunculaceae. He states that the very peculiar nectaries of *Helleborus* have their exact counterpart in *Illigera* (Hernandiaceae). No pertinent information was presented by Brown on other families possibly allied to the laurels.

In a recent paper, Fahn (1953) attempts to present a phylogenetic trend based on the position of the nectary in the flower. In primitive families the nectaries are confined to the perianth. In phylogenetically more advanced families, the nectaries are found closer to the gynoecium, and finally are actually situated on the top of the ovary. The author most other laurels. Kasapligil assumes that this species may have been derived from a trimerous ancestor. Along this same line, provocative statements have also been forwarded by Swamy (1953) in his work on Chloranthaceae. He concludes that the flowers of this family have undergone reduction both in regard to the number of floral parts and vasculature. Furthermore this worker points to the trimerous stamens in *Chloranthus* and the tricornered gynoecium in *Hedyosmum*. Swamy then broaches the question: Could these facts be employed to suggest a basically trimerous plan of construction of the flower (in Chloranthaceae)? He further suggests a study of Lauraceae, Gomortegaceae and Hernandiaceae as possibly yielding useful data for a cogent explanation of the chloranthaceous condition.

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Considerations of nodal anatomy.—Kasapligil (1951) describes the nodal condition of *Umbellularia californica* and *Laurus nobilis* as unilacunar with a single, sometimes trilobed, vascular strand. A study of the early ontogeny of the node in these species reveals that three distinct traces emerge from the single foliar gap. After some secondary vascular tissues are produced, these three separate traces fuse laterally to form the single U- or V-shaped vascular bundle of the mature petiole.

The presumably primitive nodal situation in angiosperms is the trilacunar type, that is, three foliar gaps from which three traces diverge (Sinnott, 1914). Upon further modification, this condition is reduced or is expanded. Reduction occurs in the development of the unilacunar nodal type. Here, three distinct traces may depart, or only a single trace. The single trace can be produced by loss of the two lateral traces leaving the median trace, or the three traces may fuse. In any event, the result is a single foliar gap from which a single trace departs. The primitive trilacunar condition may be altered in the direction of amplification instead of reduction. When this follows, many gaps are formed, each giving rise to a single trace (multilacunar type).

Lauraceous nodes appear to be somewhat transitional in that the tripartite character of the leaf trace is still distinguishable. That "This method of origin of a 'single' petiolar vascular bundle may possibly represent a 'recapitulation' " is a view held by Kasapligil. In any case, the nodal anatomy of Lauraceae is clearly advanced over the trilacunar condition.

Table 4 represents a comparison of the nodal conditions in the thirteen families supposedly allied to Lauraceae (data

from Sinnott, 1914, except for Myristicaceae, Gomortegaceae, Annonaceae and Lactoridaceae, which are from Money, Bailey and Swamy, 1950).

Table 4. NODAL CONDITIONS IN LAURACEAE AND IN FAMILIES POSSIBLY RELATED TO LAURACEAE

Nodes trilacunar or multilacunar

Chloranthaceae
Proteaceae
Polygonaceae
Berberidaceae

Magnoliaceae
Calycanthaceae
Myristicaceae
Annonaceae

Nodes unilacunar

Lauraceae
Monimiaceae
Hernandiaceae

Gomortegaceae
Lactoridaceae
Thymelaeaceae

Phytochemical considerations.—The ability for certain groups of plants to synthesize given chemical compounds is attributable to the genetic constitution of the taxon. Some chemical substances, as starch, are of almost ubiquitous occurrence among embryogenic plants. Other materials, for instance mannoketoheptose (found in *Persea americana*), are very rare among embryophytes. Still other compounds are produced sporadically among the taxa of higher plants. The capacity of plants to manufacture given substances is in many cases the result of parallel evolution. The production of starch, glucose, chlorophyll, oxygen, etc., is common to many diverse and unrelated taxa of plants. In other cases, the faculty to produce a chemical substance is a true expression of genetic relationship, since it can be correlated with other features which denote affinity among taxa.

As is obvious on perusal of McNair's works (1929, 1930, 1931a,b, 1932a,b), many plant constituents are of such widespread occurrence as to yield little or no cogent data relevant to establishing relationships among familes of dicotyledons. On the contrary, the production and structure of alkaloids appears to demonstrate some striking tendencies and interrelationships among these taxa. For example, we find that well-defined alkaloids are produced in only 38 plant families and that ". . . it may safely be said that the remaining families will provide only an occasional alkaloid bearing plant" (Manske and Holmes, 1950). Furthermore, Biddle (as quoted in McNair, 1935) has stated that there appears to be ". . . an intimate connection between the properties on which the classification of plants is based and those which should naturally determine the classification of alkaloids." This does not mean that all plants which elaborate alkaloids are related. Rather, taxa which do not yield alkaloids, in the main do not give rise to others which are capable of forming these substances (Manske and Holmes). Alkaloid-producing families have arisen from similar taxa. Some alkaloids are structurally related and others are very different. The same alkaloid is rarely produced by different families of plants and certain alkaloids are often characteristic of a single family. It is of great interest that ". . . the structure of the alkaloids elaborated in various genera exhibit a degree of similarity of an order commensurate with the relationship of the genera from which they are derived" (Manske and Holmes).

A survey of the works of Henry (1949), Manske and Holmes (1950), McNair (1935) and Pictet (1904) reveals the production of alkaloids in Annonaceae, Hernandiaceae, Lauraceae, Berberidaceae, Calycanthaceae, Magnoliaceae and Monimiaceae. The other families with which this work is concerned (Gomortegaceae, Lactoridaceae, Myristicaceae, Polygonaceae, Proteaceae, Thymelaeaceae and Chloranthaceae) are not mentioned in these papers. Presumably such well-known families as Myristicaceae, Polygonaceae, Proteaceae, and Thymelaeaceae have been tested and found to be non-alkaloid yielding. Chloranthaceae, and especially Gomortegaceae and Lactoridaceae, are more poorly-known and probably were not even analyzed.

An analysis of the alkaloids produced in the above families shows that most are peculiar to the genus or family yielding them. Nevertheless, certain important interrelationships are

seen among alkaloids produced by these taxa: (1) laurotetanine is produced by several species of *Litsea* and "In view of the close relationship between boldine (produced by *Boldea fragrans* in Monimiaceae) and laurotetanine it is interesting to note that . . . a substance resembling boldine accompanies laurotetanine in *Litsea citrata*" (Henry, 1949), (2) bebeerine (pelosine) occurs in the bark of *Ocotea rodiei* and *Hernandia sonora* (Hernandiaceae) as shown by Pictet (1904) and (3) the alkaloids synthesized by Annonales and Laurales (both ordinal designations in the sense of Hutchinson, 1926), belong to the general group known as aporphine alkaloids. Thus, a close relationship is indicated betwen Lauraceae and Monimiaceae on the one hand and Lauraceae and Hernandiaceae (at least between certain genera) on the other. A more distant affinity between Laurales and Annonales is also suggested.

Paleobotanical considerations.—The identification of fossil angiosperms based on vegetative structures is in most cases only tentative. This is especially true in families whose foliage is little different from the foliage of other families. Leaves of many laurels, annonads, magnolias, etc. are difficult of discrimination in the living state and understandably more so in fossils. With the laurels in particular, the foliar organs show little variation among most of the living genera and species. As has been stressed previously, taxonomists are still in a quandary regarding the taxonomic limits of many present-day laurels, yet some paleobotanists attempt to distinguish fossil genera and species based only on leaf characters. Paleobotanical determinations founded solely on leaf impressions or compressions should be accepted with caution.

An extensive review of fossil floras (Berry, 1911, 1914, 1916, 1918, 1919a,b, 1921a,b, 1922, 1923, 1929, 1930, 1935; R. W. Brown, 1937; Chaney, 1925; Duigan, 1951; Edwards, 1931; Jeffrey and Chrysler, 1906; Knowlton, 1919, 1930; MacGinitie, 1941; Reid and Chandler, 1933; and Seward, 1926) has shown the presence of members of Lauraceae, Annonaceae, Magnoliaceae, Proteaceae, Monimiaceae, Polygonaceae, Myristicaceae and Berberidaceae in Mesozoic and

Cenozoic strata. In general we can divide these families into two groups: those recorded in Cretaceous and Tertiary rocks and those observed only in Tertiary deposits. Annonaceae, Lauraceae, Magnoliaceae and Proteaceae belong to the first category; Berberidaceae, Monimiaceae, Myristicaceae and Polygonaceae are in the second group.

Because the fossil record is so discontinuous and a great deal of further probing needs to be accomplished, it is not possible to say anything definite about the relative antiquity of the aforementioned families. We can state, however, that representatives of Annonaceae, Lauraceae, Magnoliaceae and Proteaceae are among the oldest recorded flowering plants. We might also hazard the suppositon that Berberidaceae, Monimiaceae, Myristicaceae and Polygonaceae arose at a later time than the first four families. The fossil record is hardly convincing on this point. It is also of interest that of the eight families for which fossil records were observed in the literature, references to supposed lauraceous plants were most numerous.

Miscellaneous considerations.–Of the fourteen families under consideration, Lactoridaceae and Gomortegaceae are most restricted in range. In the case of the former family, the degree of limitation is extreme, since this monotypic taxon is found only in the Juan Fernandez Islands of the southeast Pacific Ocean. The Gomortegaceae, another monotypic family, grows in Chile. Hernandiaceae, Lauraceae, Annonaceae, Monimiaceae and Myristicaceae are pantropical in distribution. The species of Monimiaceae, Thymelaeaceae and Proteaceae are predominantly Southern Hemisphere. Berberidaceae, Polygonaceae and Thymelaeaceae are largely temperate in distribution. Chloranthaceae is mostly paleotropical in range, with a single genus occurring in the New World Tropics.

The fossil distribution of some of these families was apparently different from the present range. Species of *Laurus*, *Cinnamomum*, *Litsea*, *Ocotea*, *Cryptocarya*, *Persea* and *Nectandra* supposedly grew in regions now temperate or polar. A fossil *Myristica* has been recorded from the southeastern United States. *Persoonia* (Proteaceae), which is now found only in New Zealand and Australia, has been recorded in the Cretaceous of New Jersey. It appears that since prehistoric times, the ranges of certain of these families have contracted or at least shifted. Good (1953) has stated that growing discontinuities or contractions in the ranges of plant taxa are indicative of venerableness. A more complete survey of fossil distributions would have to be available in order to forward any theories of expansion or condensation in the ranges of the families under discussion.

Karyological studies of the families being considered are too sparse to warrant any protracted analyses. No chromosome counts are available in the works consulted (Darlington and Ammal, 1945; Gaiser, 1926, 1930a,b,; Mezzetti-Bambacioni, 1940; and Tischler, 1927, 1931, 1937, 1938, 1950) for Lactoridaceae, Myristicaceae, Hernandiaceae or Gomortegaceae. Studies in Chloranthaceae, Calycanthaceae, Lauraceae and Monimiaceae were based on only a small percentage of the total number of species. It is deemed sufficient therefore to state that the haploid number in Lauraceae is 12 in most cases. A more detailed and extensive karyological investigation of this family might prove beneficial, for Mezzetti-Bambacioni (1940) has observed that $x = 12$ in Persoideae, and $x = 12, 18$, or 21 in Lauroideae.

Phylogenetic interrelationships.–In attempting to determine the origin and affinities of the Lauraceae, consideration has been given to the wood anatomy, palynology, floral morphology, nodal anatomy, external morphology, phytochemistry and paleobotany of the laurels and thirteen other families presumed by various workers to be more or less allied to this family. An evaluation of the information derived from these diverse disciplines indicates that certain families have a greater combination of characters in common with Lauraceae than do others. Some of these families are obviously not at all or only very distantly related to Lauraceae; others apparently have arisen from the same stock. While certain of the latter families show many similarities to

Lauraceae, no well-defined lines of development among these families is indicated. It is hardly possible to construct a tree of phylogeny on the evidence presented here. Transitional characters upon which such a scheme could logically be based may have been present in taxa now extinct. Instead of a main branch producing the laurels and their allies on the finer twigs, only the branchlets seem to have survived into the present. Thus we can only assume common derivation for these families and not a phylogenetic series.

The anatomy of the wood supports the contentions of those investigators who have placed Lauraceae in close proximity to Hernandiaceae, Myristicaceae and Monimiaceae. As based on anatomy this group of families, and possibly others, represents a closely related, natural taxon. Hutchinson (1926) recognized these affinities when he placed the above mentioned families in the taxon Laurales. The anatomical features which form a common bond among Lauraceae, Myristicaceae, Hernandiaceae and Monimiaceae are: (1) some members which have libriform wood fibers, (2) pores solitary and in radial multiples, (3) simple and scalariform perforation plates, (4) members with alternate intervascular pitting, (5) some species with heterogeneous vascular rays and others with rays tending to homogeneity or actually homogeneous, (6) the presence of apotracheal and paratracheal axial parenchyma and (7) secretory cells in the wood. Of these families, Monimiaceae seem to be most diverse anatomically. There are several distinct taxonomic elements in this taxon which have been resolved into separate families by Money, Bailey and Swamy (1950). It is difficult to state on anatomical grounds whether Myristicaceae, Monimiaceae or Hernandiaceae bear the greatest resemblance to Lauraceae. Each shows strong similarities in some features and variations in others. Of the four families, the wood of Hernandiaceae is certainly the most specialized, for it exhibits such advanced characters as ring-porosity, septate libriform wood fibers, mostly simple perforation plates, alternate intervascular pitting, vessel elements of medium length, mostly homogeneous vascular rays and paratracheal axial parenchyma. These indications of specialization are corroborated by the presence of an inferior ovary in this taxon. Certain of the Monimiaceae show primitive organization in the wood and are homoxylous; others have fibers with distinctly bordered pits, very small to medium pore diameters, very oblique vessel element end wall inclinations, scalariform intervascular pitting, decidedly heterogeneous vascular rays and mostly apotracheal axial parenchyma. Both Myristicaceae and Lauraceae show anatomical conditions intermediate between those of Monimiaceae and Hernandiaceae.

These four families possess wood characters that are in the main more specialized than those found in the primitive angiosperm families. The wood anatomy indicates therefore that these families are derived. Classifications which include these families among the taxa of primitive flowering plants (Engler and Diels, Wettstein, Bessey, Eichler, Gundersen, Johnson, Rendle, Warming and Potter) are not supported on anatomical grounds. The truth of these statements will be shown later in this section when the anatomical findings are supported by evidence from other botanical studies.

As indicated in a previous section, the anatomy of Polygonaceae, Proteaceae, and Thymelaeaceae does not point to any close relationships with Lauraceae. These families exhibit certain highly specialized features in the xylem such as spiral thickenings in the vessels, storied structure, vasicentric tracheids and even intraxylary phloem. Those characters held in common between these families and Lauraceae are most likely attributable to parallel development.

Findings germane to the origin and relationships of Lauraceae as founded on wood anatomy are supported in the main by evidence from other branches of botanical science. The following data uphold the conclusions of wood anatomy that Lauraceae are closely related to Monimiaceae and Hernandiaceae: (1) nonaperturate pollen grains are produced in these three families, (2) valvular anthers are common to these taxa as are nectaries which have been modified from stamens, (3) the nodal condition is unilacunar, (4) all are woody taxa, (5) leaves are simple and estipulate, (6) flowers are actinomorphic, mostly bisexual and borne on branched inflorescences, (7) a single pendulous ovule is ordinarily present in the single locule, and (8) related alkaloids are elaborated by Lauraceae and Monimiaceae, and Lauraceae and Hernandiaceae.

It is noteworthy that while wood anatomy supports the placement of Myristicaceae with Lauraceae, Monimiaceae, and Hernandiaceae, their position within this group is not warranted by other studies. Myristicaceae have trilacunar nodes, non-valvate stamens and have not been recorded as producing any alkaloids. The stamens in Myristicaceae are monadelphous, the ovules may be basal and the flowers are entirely unisexual. The pollen is distally monocolpate (1-sulcate) as in some Magnoliaceae. The similar features which occur in the xylem of Myristicaceae and of Lauraceae, Monimiaceae and Hernandiaceae may be due in part to parallel evolution and/or the presence of a common ancestor. This ancestor may have given rise to separate lines, one which produced Myristicaceae and possibly other families, and one which produced Lauraceae, Monimiaceae and Hernandiaceae. It is also possible that Myristicaceae and the other three families arose on the same stem, the former family branching off at a separate time to develop certain characters in a different manner from those in Lauraceae, Monimiaceae and Hernandiaceae.

Although the anatomical data on Gomortegaceae were insufficient to be of use in formulating conclusions as to the affinities of this family, other data do show that this family is also related to Lauraceae. Gomortegaceae have valvular anthers, unilacunar nodes, oil cells in the plant body, a woody habit, simple estipulate leaves, actinomorphic bisexual flowers and a single pendulous ovule in the locule.

As intimated in a previous section, according to wood anatomy the laurel family is not a primitive group but is moderately highly advanced and derived. Evidence in support of this is available from other branches of botanical endeavor. The number of stamens frequently shows much reduction in that entire whorls are reduced to staminodia. In some cases all the stamens have been lost, thus producing unisexual flowers. Valvular anthers are a specialized form. The number of perianth segments is small (typically 6) and may be reduced to 4 in some genera. Fusion has occurred among the petals, sepals and stamens to form a floral tube. Evidence is also available to show that the unicarpellate condition has been derived from a multicarpellate arrangement. Only a single ovule is present in the pistil. Lauraceae are characterized by unilacunar nodes which have arisen from the trilacunar type. Fusion of the triple vascular strand is seen in the stamens. The vascular supply to the ovary consists only of a dorsal and ventral trace, indicating fusion of 2 ventral traces. Thus it is obvious that many of the supposedly simple structures in Lauraceae are that way because of reduction and fusion, rather than because of actual primitiveness.

Although pertinent aspects in the fields of embryology, geobotany, paleobotany and karyology were reviewed, material relating to Lauraceae and its presumed relatives was sparse. The evidence that was uncovered proved too inconclusive to be of any great value in this report. Nevertheless it has been included with the hope that someone may be stimulated to expand upon it in the future.

The affinities of Lauraceae, as determined by wood anatomy and supported by evidence from several other fields of botanical study, lie most closely with the families Hernandiaceae, Monimiaceae and Gomortegaceae. It is suggested that these four families are nearly enough related to be classed under the designation Laurales as has been done by Hutchinson. These families show a number of advanced characters and should not be included with primitive dicotyledons. Lauraceae and their allies are probably descendants from some woody magnolialean taxon. We know from the work of Sinnott (1914) that the unilacunar nodal condition is derived from the trilacunar type. The former condition is present in Lauraceae and allies, and the latter in many magnolialean taxa. Oil cells are present in magnolialean families as in lauralean families. The apocarpous gynoecium is common to both taxa, as is the ability to produce alkaloids. Pollen grains in both groups are monocolpate, derived dicolpate, polyporate or acolpate.

SUMMARY

The constant occurrence of certain features in the xylem of Lauraceae implies that this family is natural and well-defined. Members of this family possess wood which exhibits the following characters: (1) diffuse-porosity, (2) mostly solitary pores with some multiples and clusters, (3) fiber-tracheids and libriform wood fibers which may be septate, (4) simple and scalariform perforation plates, (5) predominantly alternate intervascular pitting, (6) heterogeneous IIB vascular rays, (7) paratracheal axial parenchyma in all species, and (8) secretory cells.

While it is true that the xylem anatomy of Lauraceae serves well to characterize the family, the wood structure of subfamilial taxa is often very heterogeneous. This may indicate that taxonomic characters selected to circumscribe infrafamilial groups do not reflect close relationship within these taxa. Thus, unrelated plants may be combined under the same category. A re-evaluation by the taxonomist of characters employed in describing subfamilial groups is suggested.

Botanists have speculated on the affinities of the laurels, and at various times have suggested relationship to the following families: Annonaceae, Berberidaceae, Calycanthaceae, Chloranthaceae, Gomortegaceae, Hernandiaceae, Lactoridaceae, Magnoliaceae, Monimiaceae, Myristicaceae, Polygonaceae, Proteaceae and Thymelaeaceae. When the xylem anatomy of these families and Lauraceae is compared, it is apparent that the wood of Polygonaceae, Proteaceae and Thymelaeaceae is more specialized than Lauraceae. Among other specialized characters, these three families show storying, vasicentric tracheids and spiral thickenings in the vessels, none of which is observed in Lauraceae. Accordingly, studies in wood anatomy preclude any close relationship between these three families and Lauraceae.

The wood anatomy of Annonaceae, Berberidaceae, Calycanthaceae, Chloranthaceae, Lactoridaceae and Magnoliaceae is more or less similar to that in Lauraceae. Certain of these families, such as Annonaceae, contain members which show features more advanced than in Lauraceae. Others, such as Magnoliaceae and Chloranthaceae, manifest less specialized xylem than Lauraceae. Further comparisons indicate that the wood in Hernandiaceae, Monimiaceae and Myristicaceae resembles Lauraceae in a number of respects. These families all have some members with heterogeneous vascular rays, libriform wood fibers, alternate intervascular pitting, pores solitary and in radial multiples, and secretory cells. Both apotracheal and paratracheal axial xylem parenchyma are found in each of the above taxa. In addition, spiral thickenings in the vessels and storying are ordinarily absent from these families.

With one exception, findings based on wood anatomy are corroborated for the most part by comparative studies in other botanical fields. Anatomical investigations of Myristicaceae and Lauraceae have shown that the woods of the two groups are similar. However, in other respects, this family varies to a large extent from the laurels. It is suggested that the nutmeg family, Hernandiaceae, Monimiaceae and Lauraceae (and probably also Gomortegaceae, although accounts dealing with the wood anatomy of the latter are very sketchy) were derived from a common ancestor, but that Myristicaceae branched off at an early time from this line of development. Consequently, certain characters of Myristicaceae resemble those of Lauraceae, Monimiaceae and Hernandiaceae, while others differ considerably.

Several taxonomic systems include Lauraceae and its relatives in a taxon with primitive dicotyledons. Anatomical and other studies show that the features in Lauraceae, Her-

nandiaceae, and many Monimiaceae are not primitive, but specialized, and show evidences of fusion and reduction. On the basis of studies in several botanical fields, it appears that Lauraceae and their close relatives have arisen from woody magnolialean forebears, and represent a terminal group from which no extant taxa of plants have since developed.

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CURRENT LITERATURE

Aristeguieta, Leandro. *Clave y Descripcion de la Familia de los Arboles de Venezuela.* Tipografia la Nacion, Caracas, Venezuela. 1-307 pp. 1954.

This work, which is concerned with the forest trees of Venezuela, is divided into six parts, including the introduction which is Part I. The family key which is, in reality, a series of 11 keys makes up Part II. The first of these keys is to the 10 artificial groups into which the author has divided the 100 families treated. Following this there are keys to the families within each of the 10 groups.

The main part of the work, Part III, is entitled *Description of the families contained in the key*. In addition to the botanical description however, for each family treated there is the following information: distribution and importance of the family in the flora of Venezuela; a list of the genera with arborescent species; usually a key to the included genera; and finally a list of the common names of the genera treated.

Not all of the families included, of course, contain trees of great economic value. In order to call the attention of the user of this work to the most important families, the names of these have been printed in capitals, whereas the remainder are in lower case letters. This practice is followed also in the list of families which appears in the introduction.

The author states that in the construction of his family keys he has utilized vegetative characters wherever possible, since these are present at practically all times of the year. In some cases however, especially in attempting to separate closely related families, it has been necessary to resort to the characteristics of the flower and fruit. In the keys to the genera within each family it has been necessary to rely largely upon floral characters since the vegetative differences between genera within a family are frequently too slight to be of much value in identification. All of the keys are dichotomous.

The glossary, which is designated as Part IV, is somewhat lost near the middle of the volume. It would, perhaps, be more convenient to use had it been placed at the back of the book.

Part V of the work consists of an alphabetical list of the common names of the included genera (of which there are 570), along with the Latin equivalent and the name of the family to which each belongs. This list is an interesting one since it reveals that the same common name is often used for several different genera, and thus demonstrates once again the confusion that may arise when common names alone are relied upon.

Part VI is another list, but this one is arranged alphabetically according to the generic name. In addition to the common name and the family to which it belongs, the number of arborescent species in each genus is also given.

The work closes with a table of contents. There is no index, but none is needed since the families are arranged alphabetically. There are also lists of the genera arranged alphabetically by both the common and scientific name.

As has been indicated above, this volume contains much more information than the title might suggest. This work should be of interest both to tropical foresters and to botanists who desire a useful key to the more important genera of forest trees of the American tropics.——*John R. Reeder*, Plant Science Department, Yale University, New Haven, Connecticut.