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TROPICAL WOODS

A technical magazine devoted to the furtherance of knowledge of tropical woods and forests and to the promotion of forestry in the Tropics.

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TROPICAL WOODS

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RAY VOLUMES IN HARDWOODS

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Introduction

The revival of interest in rays in connection with the shrinkage of hardwoods has drawn attention to the lack of data on the proportion of the wood occupied by the rays in different species. Apart from some studies of variation in individual species associated with growing conditions and position in the tree, there appears to have been very little interest in the subject since the paper by J. E. Myer published in 1922. As this was entirely limited to woods from temperate North America, it was thought that it would be useful to make further observations covering tropical hardwoods. During the course of this investigation it was observed that the higher ray volumes tended to occur in woods with rays many cells wide and vice versa and it was decided to pursue this line of investigation at first within a single family, so as to reduce the complications resulting from differences in size and shape of ray cell. The Meliaceae was chosen for this purpose, as a natural group with many species and with rays varying from 1 to 6 or more cells wide. A positive relation was found in this group and the study was then extended to cover all hardwoods.

The investigation therefore falls into two parts, firstly a general survey of ray proportions in the dicotyledons, and secondly a study of the relation between ray width and ray volume.

Materials and Methods

The proportion of ray to other tissues was measured on transverse section with a Shand Recording Micrometer, which records separately the total of ray and of other tissue crossed in a straight-line traverse. The total width of ray tissue traversed expressed as percentage of the whole traverse is thus equivalent to the percentage of the ray tissue by volume.

It was found by experiment, as could be predicted, that traverses on tangential sections gave the same results as on transverse sections and tangential sections were used in a few instances where the transverse sections presented special difficulties or to check individual results that were unexpected. The traverses were made under a 1/6 objective and number 4 eyepiece, so that the hairline in the eyepiece could be easily and accurately aligned on the edge of the ray.

The traverses were normally tangential, but it was found advisable to make them oblique where banded parenchyma was present as the rays tend to be wider within the bands and a tangential traverse might not include a proper proportion of parenchyma. Subject to such safeguards, a traverse of about 5 mm. was found to give a sufficiently accurate representation of the section, but lengths of 6 to 8 mm. were used whenever possible.

To obtain a random selection of the species of the dicotyledons, slides were picked out at approximately equal intervals from the Imperial Forestry Institute collection of some 13,000 slides, avoiding genera already covered by Myer, and with a slight bias towards the inclusion of as many families as possible; very small stems were ignored. Two hundred and forty species from 87 families were measured.

For the study of the Meliaceae, further slides were selected bringing the total for this family to 68, the slides being chosen so as to provide an adequate number to represent each size of ray. The classification of the rays according to number of cells wide presented some difficulty. The classification adopted was based on the maximum width of the largest rays, disregarding the occasional extra-large ray. To have used the mean number of cells wide would have greatly increased the work involved without any very certain gain.

Results

The percentage of ray tissue in the dicotyledons.—The values obtained for the individual species were grouped into classes according to the proportion of ray tissues; the means of these classes are shown in columns 2 and 3 of table 1. Myer's figures for the same groups are shown in the fourth column and the author's and Myer's figures have been combined in the fifth column. These distributions are compared graphically in fig. 1 which illustrates the very close agreement between the two independent sets of observations.

Table 1. Distribution of Ray Proportions in the Dicotyledons

RAY TISSUE Percentage of total	CHALK (240 species)		MYER (53 species)	TOTAL (293 species)
	Number of species	Per cent of species	Per cent of species	Per cent of species
0—8	9	3.7	5.7	4.1
9—16	82	34.2	49.0	36.8
17—24	87	36.3	30.2	35.2
25—32	39	16.2	13.2	15.8
33—40	14	5.9	0.0	4.7
41—48	6	2.5	1.0	2.4
49—56	2	0.8		0.7
57—64	1	0.4		0.3

The most frequent proportion was about 16 per cent, and 72 per cent of the species fell within the limits of 9 to 24 per cent inclusive. It may be of interest to note that percentages of 40 and over were recorded in species of *Acanthosyris* (Santalaceae), *Aegeciras* (Myrsinaceae), *Anisoptera* (Dipterocarpaceae), *Aporosa* and *Baccaurea* (Euphorbiaceae), *Pellacalyx* (Rhizophoraceae), *Tamarix* (Tamaricaceae), *Tetramerista* (Tetrameristicaceae), and *Vitis* (Ampelidaceae). The lowest percentages (less than 9 per cent) were found in species of *Acanthopanax* (Araliaceae), *Brachylaena* (Compositae) and *Albizzia*, *Aubrevillea*, *Enterolobium*, *Parkia* and *Pithecolobium* of the Mimosaceae.

Relation between ray volume and ray width.—Sixty-eight species of the Meliaceae were grouped according to the

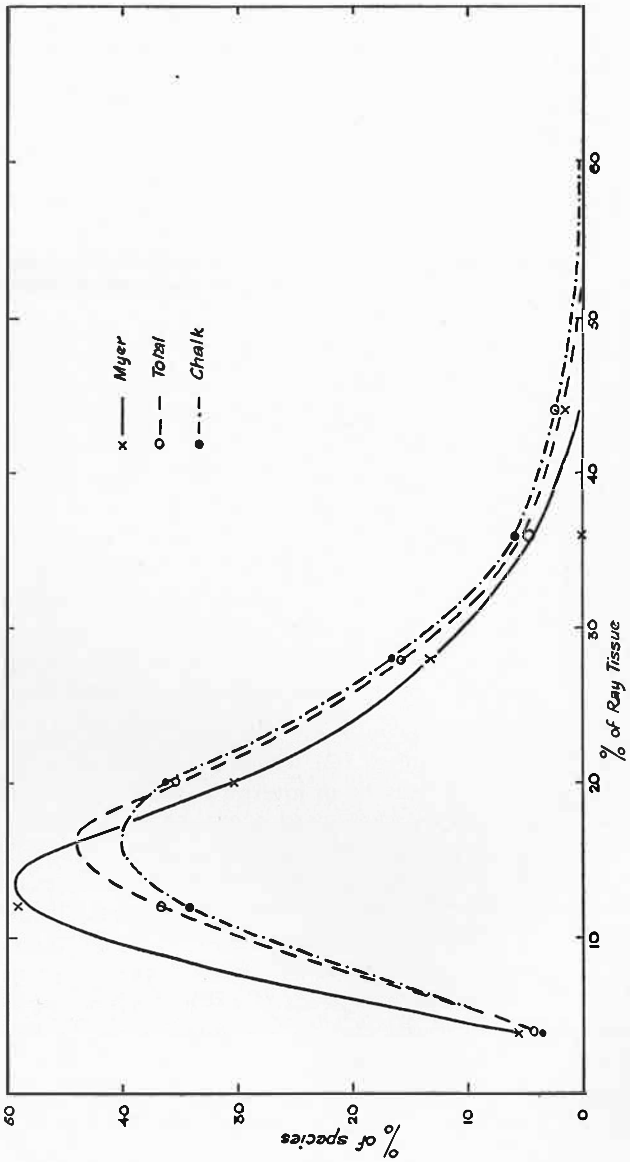

Fig. 1. Distribution of ray volumes.

number of cells wide of their largest rays. The mean percentage of ray tissue for each ray class is shown in table 2. It will be seen that there is a steady increase in the proportion of the wood occupied by the rays with increase in number of cells wide. This is shown graphically in fig. 2.

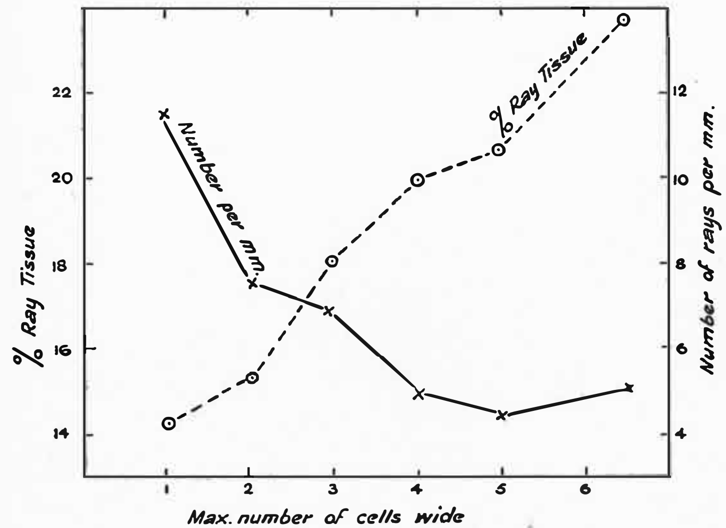

Fig. 2. Proportion, number and width of rays in the Meliaceae.

This figure also shows a negative correlation with ray number; increase in number of cells wide being accompanied by a decrease in ray number. Figures for the latter are included in table 2. The decrease in number tends to flatten out in the groups with larger rays. Mean width, on the other hand, increases throughout the range; the mean widths of the "1–seriate" to "6– and 7–seriate" groups were 13.0, 20.7, 31.2, 42.0, 47.2, and 51.3 microns respectively for a slightly smaller set of species than those used for table 2.

A similar increase in ray proportions with wider rays is discernible in the dicotyledons as a whole, though there tends to be a much greater range of variation for each size

Table 2. PERCENTAGE OF RAY TISSUE IN RELATION TO RAY WIDTH IN THE MELIACEAE

MAXIMUM RAY WIDTH	NUMBER OF SAMPLES	RAY TISSUE PER CENT	RAY NUMBER PER MM.
1—seriate	9	14.2	11.5
2—seriate	13	15.3	7.5
3— seriate	11	18.1	5.9
4—seriate	12	19.9	4.9
5—seriate	14	20.6	4.3
6— and 7—seriate	9	23.6	4.8

of ray owing to the large differences in cell size that occur in different groups. The figures for the whole range of samples representing the dicotyledons, excluding the special additional Meliaceae, are given below in table 3.

An arbitrarily smoothed curve for these figures is given in fig. 3. Except for the low value for 6–seriate rays, the figures are very consistent. The corresponding curve for the Meliaceae has been included in the same figure for compari-

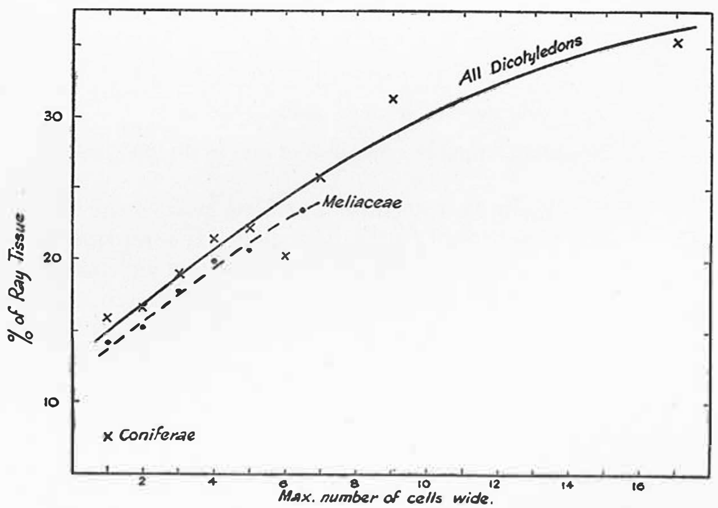

Fig. 3. Relation between ray volume and ray width.

son and it will be seen that it shows lower values for each ray size than the corresponding means for all the dicotyledons. The mean value for the 38 conifers measured by Myer is 7.8 per cent. This has been shown in the figure, for comparison with the uniseriate hardwoods.

Table 3. PERCENTAGE OF RAY TISSUE IN RELATION TO RAY SIZE IN THE DICOTYLEDONS

MAXIMUM RAY SIZE	NUMBER OF SAMPLES	RAY TISSUE PER CENT
1—seriate	29	16.0
2—seriate	50	16.8
3—seriate	49	19.2
4—seriate	36	21.4
5—seriate	22	22.2
6—seriate	12	20.1
7—seriate	8	25.7
8— to 10—seriate	8	31.6
11—seriate and over (mean 16—seriate)	12	33.6

These data show incidentally that the most common type of ray tissue is one with the largest rays 2— or 3—seriate; these two groups include about 44 per cent of the species investigated. Woods with wholly uniseriate rays represent about 13 per cent of the whole.

DISCUSSION

The distribution curve obtained for the varying percentages of ray tissue throughout the dicotyledons (fig. 1) is very similar to that for Myer's North American hardwoods and there is little to suggest that the inclusion of a large number of tropical species in the author's data has made any significant difference. The temperate species in the author's data were, however, separated from the tropical in an attempt to elucidate this point further, but there were not sufficient with which to construct a satisfactory curve for the temperate woods. For the most common ray sizes 2— to 5—seriate, for which there were enough species to give a representative average, there was very little difference (about

1 per cent) between the two sets of figures and the differences were not consistently in the same direction. It may well be, though, that any difference that may exist between temperate and tropical species would be masked by the influence of other factors, such as cell size, unless a very large number of species were examined, and it might be more profitable to limit study of this point to genera that have both temperate and tropical representatives.

The relation between the width of the rays and the proportion of ray tissue was rather unexpected. It might be assumed that in woods with small rays, the smallness of the rays would be compensated for by their greater number. It is clear that in general this is not so, even though individual species with uniseriate rays may have up to 25 to 30 per cent of ray tissue. This relation may, perhaps, supply a clue to the contradictory results obtained by different investigators attempting to explain the differential shrinkage of wood. In the large-rayed woods, such as *Quercus* and *Cardwellia*, in which the influence of rays on shrinkage has been most clearly demonstrated (Clarke, 1930; Lindsay and Chalk, 1954; McIntosh, 1954) a quarter to a third or more of the tissues may consist of rays, and, unless these rays shrink in exactly the same way as the longitudinal tissues, it seems highly probable that they must exert some influence on shrinkage as a whole. At the other end of the scale, in hardwoods with wholly uniseriate rays these occupy on the average only about 16 per cent of the tissues and may be as low as 6 per cent. In the conifers the rays occupy 3 to 11 per cent of the tissues with an average of 8 per cent. It is particularly in these latter woods that investigators have found that the rays have no influence on shrinkage (Ritter and Mitchell, 1952).

Reference has already been made to the great differences in size of cell that occur in different woods. As this is a character that tends to be characteristic of families, there is often a tendency for certain families to have characteristically high or low ray volumes, both in relation to the size of the rays and absolutely. It has been shown that the species of

the Meliaceae, for example, have slightly smaller ray volumes than the average for each ray size. The Mimosaceae, having homogeneous rays with very small cells, averaged only about 11.4 per cent with rays 2– to 3–seriate and the Caesalpiniaceae and Papilionaceae 16 and 17 per cent, respectively in the relatively small number of species selected for this investigation. Some of the lowest values observed, e.g., 5.3, 6.6, 6.8, and 7.4 per cent, occurred in the Mimosaceae in woods with 3–, 2–, 2– and 3–seriate rays respectively. The Moraceae also has small ray cells and averages about 16 per cent for woods with 3– to 8–seriate rays, and the Rutaceae also tends to have low ray volumes. The Rubiaceae, on the other hand, with markedly heterogeneous rays, tends to have high ray volumes, for example, 20 to 33 per cent for woods with 2– to 5–seriate rays.

Summary

1. The proportion of ray tissue was measured in 240 hardwood species, most of which were tropical. The range was 5.3 to 59.3 per cent and the most common amount was about 16 per cent; 72 per cent of the species had between 9 and 24 per cent.

2. No difference was observed between tropical and temperate woods.

3. There is a positive correlation between percentage of ray tissue and maximum ray width measured in number of cells.

4. Certain families, e.g., the Leguminosae, Moraceae and Rutaceae, have characteristically low proportions of ray tissue.

5. It is suggested that the proportion of ray tissue may determine the extent to which rays affect differential shrinkage.

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TAXONOMIC NOTES ON NEOTROPICAL TREES

By José Cuatrecasas[1]

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The following are descriptions of new species or varieties of South American forest trees, chiefly from Colombia. They belong to the families Anacardiaceae, Aquifoliaceae, Bombacaceae, Flacourtiaceae, Metteniusaceae, Olacaceae and Sabiaceae.

Metteniusa tessmanniana (Sleumer) Sleumer var. **fragrantissima** Cuatr., var. nov.—Folia oblongo-elliptica utrinque attenuata, supra glabra subtus juventute minutissime puberula demum glabra. Flores albi fragrantissimi.

Type.—Frontera Colombo-ecuadoriana: selva higrófila del río San Miguel (río Sucumbíos) margen derecha del río (Ecuador), entre los afluentes Churruyaco y Bermeja, 400–350 m. altitud, 12 diciembre 1940, *J. Cuatrecasas* 11021 (holotype, F).

The genus *Metteniusa* has been illustrated and described in detail by Karsten (Fl. Columb. 1: 79. *t. 39.* 1858–1861) on the basis of *M. edulis* which he collected in the Sierra Nevada de Santa Marta, Colombia. In 1925, Pittier published a new genus in the Olacaceae: *Aveledoa* with *A. nucifera* which is found in the rain forest of Rio Limon in the Valle de la Cruz, Venezuela, at 1000 m. altitude, as the only species. Sleumer, in 1936, published another species of *Aveledoa*, *A. tessmanniana*, collected by Tessmann at the famous Pongo de Manseriche, Peru. According to the original descriptions (Sleumer had not seen Pittier's material), the difference between the two species is small, and Sleumer based the separation of the two species essentially on the glabrous ovary of the Venezuelan plant. In a later publication (Notizbl. 13: 359. 1936), Sleumer identified *Aveledoa* with *Metteniusa* and presented a key for the three species, at the same time expressing some doubt about the specific value of these taxa. However, with the material at hand today, it is not possible to arrive at another conclusion. I compared my plant with Pittier's type of *A. nucifera*, and it seems to be specifically different, even though the differences are small. Tessmann's material has not been available to me for comparison, but my specimens from the river Sucumbíos agree with the descriptions and explanations given by Sleumer for his *M. tessmanniana* except for a few characters which I consider of varietal category.

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The locality in the Putumayo drainage, where I found my plant, is between the heretofore known localities for the genus; this fact indicates a wider distribution of the species, although scattered, throughout the western part of the Amazonian basin.

The genus *Metteniusa*, characterized by its relatively large flowers (3–4 cm.) with curled ramentaceous-hirsute petals coherent in the tube one third to one fourth of their length; by its arrow-shaped, large, linear, bifid and reflexed anthers; by the single pendant ovule in the ovary and by its drupaceous monosperm fruit, has an uncertain position in the present classification. Pittier included it in the Olacaceae mentioning its close connection to Opiliaceae. Sleumer classified it first as belonging to Opiliaceae (Nat. Pflanzenfam. 2 Aufl. 16b: 35. 1935), but changed this later to include it in Icacinaceae (Notizbl. 12: 150. 1934). In the first edition of *Pflanzenfamilien* (Nachträge 1: 226. 1897) Engler had already treated *Metteniusa* as one of the Icacinaceae. But, in his very accurate and exhaustive study of the Icacinaceae (Jour. Arnold Arboretum 21: 485. 1940), Howard gives very positive reasons for not admitting *Metteniusa* into this family. My opinion at this time is that the status of this genus originally given by Karsten is adequate: family Metteniusaceae.

Mauria peruviana Cuatr., sp. nov.—Arbor parva ramis terminalibus plus minusve flexuosis griseis rugulosis glabris.

Folia simplicia alterna petiolata coriacea glabra. Petiolus 8–17 mm. longus supra planus basi incrassatus rectus vel paulo flexuosus. Lamina oblonga elliptico-lanceolata vel sublanceolato-elliptica basi obtuse cuneata apicem versus modice angustata apice acuta vel subacuta vel obtusa, margine integra plana vel anguste revoluta, 6–13 cm. longa 1.8–5.5 cm. lata; supra in sicco pallido-viridis nervo medio secundariisque prominulis reliquis venulis reticulatis minus conspicuis; subtus costa elevata crassiuscula striolataque, nervis secundariis 9–14 utroque latere prominentibus subpatulis vel ascendentibus conspicue ramosis, nervulis laxe anastomosatis bene prominulis.

Inflorescentiae anguste thyrsoideae axillares et terminales quam folia breviores 4–9 cm. longae axi crassiusculo plus minus flexuoso striato griseo glabro, ramis 1–18 mm. longis flores sessiles solitarios vel glomeratos ferentibus. Bracteae late ovatae acutae 1–2 mm. longae margine ciliatae. Calyx expansus 3.5 mm. diamitens lobis rotundatis margine ciliatis ceterus glaber. Petala 5 libera albida elliptico-oblonga acutiuscula crassiuscula papillosa 4 mm. longa 2 mm. lata. Stamina 10 extra marginem disci inserta filamentis crassiusculis 1.5–2 mm. longis, antheris oblongo-ellipticis 1 mm. longis basifixis. Discus crassus 10-crenatus circa 1 mm. altus. Ovarium parvum oblongum sulcatum stylo columnari crasso brevi apice stigmate trilobato. Fructus elliptico-oblongus 10–44 mm. longus 6–7 mm. latus.

Type.—PERU: Huallaga, Chaglla, 3100 m. altitude, *A. Weberbauer 6692* (holotype, F); same locality 3000 m. altitude, *A. Weberbauer 6687* (paratype, F); Tambillo, 8000 feet altitude, dense shrub of stream banks, flowers yellowish, *F. Macbride 3582* (paratype, F); Panao, 10,000 feet altitude, tree 10–30 feet high in woods on northern slope, *F. Macbride & Featherstone 2211; H. Ruíz & J. Pavón 3300 (ex* Madrid Bot. Gard.—F); Huanuco, Pampayacu, *Sawada 21* and *23* (F); Huanuco, Pillao, 2800 m. altitude, in low forests, leaves leathery dark green, flower mixture: white, red and green (color of a peach) February 14, 1946, *F. Woytkowsky 34059*.

M. peruviana has been confused with *M. simplicifolia* H.B.K., which probably comes from Colombia. Careful examination of fragments (leaves) of the type and abundant material which I collected in Colombia, shows that the Peruvian trees, formerly attributed to the H.B.K. species, are different. *M. peruviana* differs essentially in its longer sublanceolate acute or obtuse leaves; in the strongly prominent nerves on the underside of the leaves; in its completely glabrous inflorescences and sessile flowers; and in the sessile or subsessile fruits. The Colombian and Ecuadorian plants have more or less pedicellate flowers and hirsutulous inflorescence branchlets. The short leaves are ovate and elliptic or obovate, with small, obtusely prominent, and more closely parallel secondary nerves, and immersed, obsolete or subobsolete venation.

Ilex macarenensis Cuatr., sp. nov.—Arbor parva vel magna ramis terminalibus paulo angulosis glabris griseo-brunneis.

Folia chartacea simplicia alterna petiolo 7–12 mm. longo angusto rigido glabro nigrescenti. Lamina elliptico-lanceolata basi attenuato-cuneata apice angustata acuteque cuspidata margine integerrima, 5–9.5 cm. longa 2–3.5 cm. lata, utrinque glaberrima; supra in sicco nigrescens vel fusco grisea subnitidula costa filiforme impressa nervis secundariis tenuissimis reliquis subobsoletis; subtus in sicco brunnescenti-tabacina dense minuteque papillosa, costa elevata discolori (nigricanti) nitidaque, nervis secundariis tenuibus prominulis inter sese remotis marginem versus arcuato-anastomosantibus nervulis tertiis tenuiter prominulis laxe reticulatis.

Flores solitarii vel cymuli sessiles pauciflori, axillares vel caulinares, interdum in ramulis hornotinis brevem corymbum vel fasciculum formantes. Bracteolae ovato-acutae brevissimae. Pedicelli in sicco nigrescentes 5–8 mm. longi rigidi glabri vel minutissime hirsuti, apice incrassati. Calyx fructifer glaber expansus 2.5 mm. diamitens 4-lobatus lobis ovato-obtusis. Fructus immaturus globosus 5 mm. diam. glaber viridis, stigmate capitato breviter stylato. Pyrenis 4 rubescens 3 mm. longis.

Type.—Colombia: Meta, cordillera La Macarena, extremo nordeste, macizo Renjifo, cumbre y alrededores 1300–1900 m. altitud, arbolito 6 m., frutos verdes, 6–20 enero 1951, *J. M. Idrobo & R. E. Schultes 1154* (holotype, US); same locality, Pico Renjifo 1650 m. altitude, dense humid forest near summit, large tree, January 25, 1950, *W. R. Philipson, J. M. Idrobo & R. Jaramillo 2269;* same locality, 1700 m. forest at summit, small tree 4 m. high, fruits green, frequent, January 21, 1950, *W. R. Philipson, J. M. Idrobo & R. Jaramillo 2171* (paratypes, US).

I. macarenensis is close to *I. umbellata* Kl. and *I. inundata* Poepp. differing from these in its thinner, smaller, lanceolate, acutely cuspidate leaves, which have conspicuous nerves beneath though not very prominent, and in the usually solitary flowers and the globose young fruit which is abruptly separated from the short style supporting a semi-globose stigma.

Ilex danielis Killip et Cuatr., sp. nov.—Arbor parva ramis terminalibus flexuosis plusminusve striatis rugosisque griseis glabris.

Folia alterna simplicia rigide coriacea. Petiolus 2–6 mm. longus crassiusculus glaber. Lamina obovato-elliptica basi obtuse attenuata apice rotundata vel obtusissima subitissime breviter acuteque apiculata, margine laevis plusminusve revoluta, 4–7 cm. longa 1.7–3.5 cm. lata, utrinque glabra; supra costa anguste impressa nervis secundariis paulo notatis ceteris obsoletis; subtus costa crassiuscule eminenti nervis secundariis 4–6 utroque latere patulis prominulis ad marginem arcuato-anastomosatis, reliquis nervulis laxe reticulatis paulo prominulis vel subobsoletis.

Pedunculi fructiferi solitarii, vel pauci fasciculati in puncto insertionis tuberculato, erecti minutissime pubescenti-hirtuli 5–10 mm. longi. Calyx fructiferus 3 mm. diam. glaber 5–6-lobatus lobis triangularibus deinde obtusatis. Drupa depresso-rotundata 6 mm. diamitens glabra stigmate semigloboso 5–6-lobato; pyrenis 5–6 circa 3.8–4 mm. longis. Raro tetrameri.

Type.—Colombia: Antioquia, San Vincente, 3 a 4 m., flor blanca pequeñísima, agosto 1952, *H. Daniel 4381* (holotype, US).

I. danielis is closely related to *I. guianensis* (Aubl.) Ktze. from which it differs in its thicker, coriaceous, obovate-elliptic or elliptic-obovate leaves (usually abruptly acute and subspiny at the apex); in the 5–6-lobate calyx (exceptionally 4-lobate) and in the mostly solitary fruits.

Pachira cardonae Cuatr., sp. nov.—Arbor mediocris ramis ultimis divaricatis griseis glabris paulo rugosis peridermato-scariosis.

Folia alterna 5–7-palmato-composita. Petiolus 5–8 cm. longus rigidulus rectus vel flexuosus basi apiceque incrassatus, striatus scarioso-squamatus. Foliola articulata praecipue 7 coriacea petiolulata, petiolulo 6–10 mm. longo semitereti supra plano subsulcato superficie plus minus scariosa et lepidoto-punctata; lamina lanceolata utrinque acuta margine integerrima 6.5–14 cm. longa 1–3.4 cm. lata, supra viridi glabra subtus pallidiori cum lepidibus minutis subfimbriatis rubescentibus dense punctata, costa supra filiformi subtus crassiuscule prominenti, nervis secundariis supra paulo notatis subtus prominulis patulis numerosis ad marginem arcuato-anastomosatis, venulis minoribus reticulatis.

Flores magni solitarii pedicello robusto glabro 2–3 cm. longo 5 cm. crasso. Calyx tubulosus apice breviter 5-lobatus lobis rotundatis 2 mm. altis, 2.5 cm. longus 8 mm. diamitens, intus villoso-sericeus extus copiose lepidoto-pustulata. Petala 5 libera anguste linearia acuta 25–28 cm. longa 5–6 mm. lata, viridi-lutescentia, tomentella pilis minutis stellatis tecta. Tubus stamineus in specimine 8.5 cm. longus strigoso-pubescens extremo in fasciculos glabros inaequales (15 cm. longos) 4–5-ramificatos superne in 140–150 filamenta capillaria flexuosa glabra solutos productus; antheris ellipticis circa 2 mm. longis supra basim insertis. Ovarium prismatico-oblongum dense strigosum cum stylum circa 25 cm. longum hirsutum sursum glabrescentem productum.

Type.—VENEZUELA: Guyana venezolana, Alto Caroní alrededores de Salto Hacha, lat. norte 6° 15′, long. oeste 62° 51′, orilla del río Carrao, 350 m. altitud, marzo 1954, *F. Cardona 2852* (holotype, US).

Pachira cardonae is characterized by its acute, lanceolate leaflets which are glabrous above and abundantly reddish lepidote-punctate beneath; by secondary nerves being rather close together and slightly prominent; by the strigose-tomentose ovary; by the long, pubescent staminal tube; by the united filaments (± 150) usually in five irregularly, several-times ramified fascicles; by the thick, short peduncle about the same length as the cylindric, lobate, glabrous scale-spotted calyx; and by the long, linear, tomentose petals. These features differentiate this species well from related ones: *P. aquatica* Aubl. and *P. minor* (Sims) Hemsl.

Quararibea ciroana Cuatr., sp. nov.—Arbor grandis trunco ad 50 cm. diamitenti ligno robusto. Ramulis terminalibus flexuosis, ochraceo-lepidotis.

Folia simplicia alterna rigide coriacea. Petiolus 1.5 cm. longus crassiusculus subteres dense ochraceo-lepidotus. Lamina elliptico-lanceolata basi paulo attenuata obtusiuscula apice angustata acuta, margine integra subplana, 8–20 cm. longa, 3–6.5 cm. lata; supra in sicco plumbeo-viridis visu glabra, sed sparsis squamulis margine stellatis adpressis praedita, nervio medio secundariisque conspicuis, reticulo nervulorum paulo notato; subtus in sicco ochracea dense adpresseque stellato-lepidota costa eminenti nervis secundariis minus prominentibus arcuato-ascendentibus prope marginem evanescenti-anastomosatis, reticulo nervulorum laxo subimmerso paulo conspicuo.

Flores in ramulis hornotinis solitarii oppositifolii pedunculo rigido crassiusculo ochraceo-lepidoto circa 1 cm. longo plerumque 2 bracteolis minutis munito. Calyx tubuloso-conicus coriaceus circa 1.5 cm. longus margine inaequaliter 4-lobatus dentibus rotundatis vel obtusis 2–3 mm. longis, intus dense villoso-sericeus, extus levissime striolatus dense adpresseque ochraceo-lepidotus. Petala membranacea obovato-linearia apice rotundata basim versus sine sensum in unguem angustata, circa 2.5 cm. longa 0.5 cm. lata, supra pilosa subtus densius pubescentia pilis gracilibus stellatis tecta. Columna staminarum crassa petala subaequilonga levissime puberula, apice 5-dentatus, lobis 1 mm. longis, infra apicem in quoque lobo 3 antheris bilocularibus loculis ellipticis 1–1.2 mm. longis instructis. Stylus dense stellato-pubescens apice ampliatus. Calyx fructiferus cupuliformis coriaceus rigidus circa 1.5 cm. altus, intus villosus extus lepidotus.

Type.—COLOMBIA: Departamento El Valle, municipio de Palmira, 1500 m. altitude, tall tree, trunk 50 cm. diameter, flowers white, wood hard, used for construction, April 20, 1936, *G. M. Duque-Jaramillo 553* (holotype, US; isotype, F).

Q. ciroana is a very characteristic species with its narrow, rigid, coriaceous leaves and its compressed lepidote indument covering branchlets, leaves and calyces. This indument is formed by small, round, fimbriate scales. The name honors the memory of Dr. Ciro Molina Garcés, a great personality and benefactor of agronomic and botanical studies in Colombia.

Hasseltiopsis mucronata Cuatr., sp. nov.—Arbor 10 m. alta ramis teretibus laevibus fuscis terminationibus minute pulverulento-tomentellis.

Folia alterna simplicia chartacea. Petiolus 2–4 cm. longus rigidus patulus minutissime puberulus supra leviter sulcatus. Lamina ovato oblonga basi rotundata vel obtusissima supra petiolum biglandulosa ad apicem attenuata longeque cuspidata acutissima, margine crenato-serrata dentibus 3–10 mm. distantibus ad 1 mm. altis acutis vel subobtusis, subtus glandulosis, 9–16 cm. longa 5–9 cm. lata; supra in sicco brunneo-olivacea, nitidula glabra nervis principalibus prominulis notatis, reticulo venulorum conspicue prominulo; subtus subnitida prospectu glabra sed minutissimis pilis supra nervationem praedita, basi quintuplinervia, tribus nervis principalibus prominentibusque ascendentibus ad apicem arcuato anastomosatis duobus nervis basilaribus extremis angustioribus cum margine parallelis ascendentibus, nervis secundiis angustis bene prominentibus transversis parallelis, lateralibus arcuato-ascendentibus anastomosantibusque reliquis nervulis minuto reticulo prominulo dispositis.

Inflorescentiae terminales thyrsoideo-paniculatae 12–14 cm. longa 9–14 cm. lata basi foliosa (foliis quam sterilibus minoribus) rhachi robusta minute griseo-tomentosa ramis ramulisque rigidis patulis minutissime tomentosis bracteolis minutis triangularibus 0.6 mm. longis. Pedicelli teneres 4–6 mm. longi. Sepala 4–5 elliptico-oblonga rarius subovato-oblonga apice obtusiuscula albida utrinque dense minuteque tomentosa 4–4.5 mm. longa 1.5–2.5 mm. lata. Petala 4–5, alba tomentosa, 4–4.5 mm. longa 1.2–1.5 mm. lata. Stamina numerosa libera perianthium non attingentia filamentis capillaribus flexuosis inferiore parte pubescenti-archnoideis, antheris minutis sub-globosis connectivo unguiculato-mucronato. Ovarium tomentosum globosum 2 mm. altum, in stylum 2 mm. longum crassiusculum tomentellum, sursum glabrum excepto, productum. Capsula globosa, pericarpio tenue coriaceo fragile, pallide roseo-ochracea ruguloso reticulata adpresse tomentulosa 4 nervis prominulis meridianis percursa, circa 10 mm. diamitens; semen unicum.

Type.–Colombia: Departamento El Valle, río Calima (región del Chocó) entre La Esperanza y Bellavista, 10 m. altitud, arbolito 4 m. corola blanca, frutos esféricos blanco ocráceo verdosos, hoja membranosa, rígida, verde medio, 8 marzo 1944, *J. Cuatrecasas 16807* (holotype, F; isotype F); Departamento Valle, Cordillera Occidental, hoya del río Anchicayá, lado derecho bajando a La Planta bosques 200–350 m. altitud, arbolito 10 m., hoja herbáceo-coriácea verde gris, brillante, frutos ocráceo rosado claros, 27 septiembre 1943, *J. Cuatrecasas 15212* (paratype, F).

Hasseltiopsis mucronata is very close to *H. albomicans* Sleumer (from Boyaca), from which it differs by its larger, more ovate-oblong and long acuminate leaves, which have a less prominent and more acute dentation and a very small pubescence on the nervation beneath (pulverulent) and which are prominently reticulate-veined above. *H. mucronata* has a smaller inflorescence with a more robust axis and rigid branches, and its flowers are usually tetramerous, each with 4 carpels. The most singular character of the new species is the mucronate anthers; their connective has an apical acute appendix usually curved like a claw. The closely related Central American species *H. dioica* (Benth.) Sleumer differs from the Colombian plant, not only in the above-mentioned features, but also in its narrower leaves and smaller fruits.

Homalium mituense Cuatr., sp. nov.–Arbor mediocris ramis terminalibus griseis vel fuscis rugosis glabrisque hornotinis parce puberulis.

Folia subcoriacea simplicia alterna. Petiolus 5–8 mm. longus crassiusculus fuscus pubescens. Lamina ovato-elliptica basi rotundata apice angustata acuminataque, margine profunde grosseque serrata dentibus obtusis, 6–11 cm. longa 3.5–5.5 cm. lata; supra viridis subnitida sparse pilosa nervis principalibus notatis, magis pilosis, venulis laxum reticulum prominulum formantibus; subtus pallidior, tenuiter mollique pubescens pilis longis tenuibus patentibusque copiose praedita, costa rufescenti crassiuscula, nervis lateralibus 7–8 utroque latere angustis prominentibus rubrisque arcuato-ascendentibus, reliquis nervulis angustum reticulum prominulum formantibus.

Inflorescentiae axillares simplice racemosae vel subsimplices folia non attingentes, 6–9 cm. longae, axi recto vel subflexuosi tenui anguloso hispidulo-pubescenti. Pedunculi teneres 1–4 mm. longi unum florem sessilem interdum duum ferenti, bracteolis lanceolatis acutissimis puberulis 1–2 mm.

longis ad apicem muniti. Post-anthesi calycis tubo circa 3 mm. longo subsemigloboso-conoideo breviter pubescenti basi in brevissimum pedem contracto, laciniis 6 flavo-albis oblongis minute pubescentibus 2—2.5 mm. longis 1 mm. latis, apice paulo angustatis acutiusculis; petalis 6 albis crassiusculis ovato-oblongis apice obtusiusculis basi non contractis utrinque minute pubescentibus, 3—4 mm. longis 1.8—2 mm. latis. Stamina tria unumquoque petalum opposita, filamentis glabris petala subaequilongis, antheris globosis sulcatis rubris. Glandulae ellipticae velutinae eburnae 1—1.5 mm. longae. Ovarium semigloboso-conicum villoso-hirtum. Styli liberi glabri, basi incrassata puberula excepta.

Type.—COLOMBIA: Comisaría Vaupés, orilla del río Vaupés, entre Mitú y Mirití, 200 m. altitud, arbol, sépalos blanco-amarillentos, pétalos blancos, anteras rojas, glándulas crema, 20 septiembre 1939, *J. Cuatrecasas 6908* (holotype, US); other specimen: Vaupés, Mitú selva marginal del río Vaupés, 200 m. altitud, 12 septiembre 1939, *Pérez Arbeláez & J. Cuatrecasas 6745* (US).

Homalium mituense belongs to the same group as *H. trichocladum* Blake from Santo Domingo and *H. anzoateguiensis* Steyerm. from Venezuela. The Vaupés plant differs from *H. trichocladum* in the lack of barbellate tufts at the axils of the nerves beneath, and in its smaller flowers (sepals and petals). It differs from *H. anzoateguiensis* also in the absence of barbellate nerve axils and in the smaller sepals and petals which are oblong (not lanceolate) and contracted at their bases. Furthermore, the latter has a densely pubescent ovary, whereas *H. mituense* has rather long, slender and sparser hair on the ovary.

Neosprucea montana Cuatr., sp. nov.—Arbor ramis terminalibus brunneis minute lenticellatis primum puberulis denique glabratis.

Folia alterna simplicia subchartacea. Petiolus 1—2 cm. longus rigidus supra canaliculatus, sparse strigulosus. Lamina trinervia ovata vel ovato-oblonga basi obtusa apicem attenuata cuspidataque vel acuta, margine repando dentata dentibus vulgo 1.5—2 cm. distantibus obtuse triangularibus subtus glandulosis, 6—13 cm. longis 3—6.5 cm. latis; supra atroviridis glabra nervis principalibus conspicuis impressis reliquis parum notatis; subtus pallidior, tribus nerviis principalibus crassiusculis basi in angulo acuto, arcuato ascendentibus sub apicem tenuissimis convergentibus, nervis secundariis transversis parallelis angustis prominentibusque, reliquis venulis reticulatis paulo elevatis, prospectu glabra sed nervis primariis minute sparseque pilis strigosis munitis.

Inflorescentiae racemosae axillares folia valde breviores, 5—6 cm. longae axi subrecto ramisque minute tomentosis. Ramuli brevis uniflori. Pedicelli subteneres rigidi 13—18 mm. longi minute pubescentes. Alabastra globosa 6—7 mm. diamitentia minute puberula. Sepala 4 valvata crassiuscula ovato-elliptica apice acuta puberula, subanthesi 7 mm. longa 4 mm. lata. Petala 4 extus tomentello-pubescentia intus sursum pubescentia. Stamina crebra filamentis complanatis tenuis parce hirtis 1.2—1.8 mm. longis, antheris linearibus 2.5—3 mm. longis connectivo hirto. Ovarium subglobosum 3 mm. diam. glabrum 5 placentis. Stylus crassus circa 3 mm. longus. Receptaculum intra stamina hirsutum.

Type.—COLOMBIA: Departamento Norte de Santander, región del Sarare, Quebrada del Sararito, 1930—1950 m. altitud, en bosques de montaña, 22 octubre 1941, *J. Cuatrecasas, R. E. Schultes & E. Smith 12581* (holotype, F).

N. montana differs from *N. sararensis* in its smaller ovate leaves which have a more distant spreading dentation; in the smaller and more slender inflorescences; in longer pedicels; in the size of the flowers and stamens; and in the hirsute stamens.

Neosprucea sararensis Cuatr., sp. nov.—Arbor mediocris ramis terminalibus teretibus brunneis sparse lenticellatis glabris vel juvenilibus minute puberulis.

Folia subcoriacea simplicia alterna. Petiolus 2—3 cm. longus crassiusculus rigidus teres junioribus minute strigosus denique glaber. Lamina subelliptica utrinque attenuata basi angustata obtusiuscula apicem versus attenuata apice cuspidata, margine grosse remoteque serrata dentibus subtus glandulosis usque ad 2 mm. altis; 17–23 cm. longa, 7–9.5 cm. lata supra viridis glabra nervis principalibus valde notatis planis nervis transversis minute subprominulis; subtus tantum tribus nervis principalibus ad basim conniventibus in angulo acuto, ascendentibus ad apicem convergentibus crassis valde eminentibus, nervis secundariis filiformibus prominentibus transversis subparallelis sed lateralibus paulo ascendentibus et proper marginem curvato-anastomosatis, venulis minutum reticulum subprominulum formantibus, tantum nervis parce strigoso puberulis reliqua glabra.

Inflorescentiae anguste paniculatae axillares 16 cm. longae axi robusto sursum tomentello inferiore parte (pedunculo 6 cm. longo) terete glabrescenti; ramulis alternis remotis crassiusculis circa 1 cm. longis pubescentibus saepe trifloris; pedicello 12–14 mm. longo crassiusculo tomentoso-pubescenti, cum pedunculo circa 5 mm. longo articulato. Sepala 4 viridia, basi cum receptaculo connata, ovata obtusiuscula subite acuminata 9–10 mm. longa 5–6 mm. lata, crassa extus adpresse tomentosa intus parte media glabra excepta minute tomentulosa. Petala oblongo-elliptica vel obovato-elliptica apice subrotundata vel subacuta, crassiuscula alba extus dense tomentello-villosa intus sursum minute tomentosa, 10–11 mm. longa 5.5–6.5 mm. lata. Stamina creberrima libera filamento filiformi glabro 3–4 mm. longo, antheris linearibus glaberrimis 2 mm. longis apice oblique dehiscentibus. Ovarium sessile globosum glabrum 4 mm. latum, 9 placentis parietalibus convergentibus multiovulatis. Stylus filiformis crassiusculus 3 mm. longus. Receptaculum inter stamina longe setosum.

Type.—COLOMBIA: Cordillera Oriental, Departamento Norte de Santander, región del Sarare; hoya del río Margua, Quebrada del Sararito entre Miranda y Alto de la Aurora, 950–1087 m. altitud, 23 noviembre 1941, *J. Cuatrecasas 13400* (holotype, US).

Neosprucea sararensis is close to *N. grandiflora* (Spruce) Sleumer, having slightly narrower, somewhat lanceolate leaves and differing chiefly in its three principal nerves which are connivent at the base (and diverge) in a very acute angle; in its longer petioles; in its pedicellate flowers; in its slightly larger sepals and petals; in the short anthers and long filaments; and in its multicarpellate ovary. In one of the ovaries examined I found paracarpic convergent placentation with 9 placentas.

I doubt very much that the Mutis plant (2232), attributed by Sleumer (Notizbl. 13: 363. 1936) to *N. grandiflora*, belongs to this species. This collection, which I have not examined, collected probably in the Magdalena Valley, may well represent an undescribed species.

Neosprucea sucumbiensis Cuatr., sp. nov.—Arbor parva ramis terminalibus teretibus griseis rugulosis glabris, hornotinis pubescentibus.

Folia chartacea alterna simplicia. Petiolus 2–3 cm. longus crassus hirtulo-tomentosus. Lamina oblongo-elliptica basi rotundata vel obtusissima apice subite acuminata margine repando serrata dentibus patulis subtus glandulosis circa 2 mm. altus, maxima vidi 31 cm. longa 13.5 lata; supra pallide viridis glabra tribus nervis principalibus notatis, nervis transversis minute elevatis conspicuisque; subtus molliter pubescens tribus nervis principalibus crassis valde elevatis hirtulo-tomentellis basi breviter conniventibus et angulum acutum formantibus, sed duobus lateralibus sunt ascendentibus cum marginibus subparallelis, nerviis secundariis filiformibus prominentibus transversis, marginalibus arcuatis anastomosantibus, venulis minoribus bene prominulis reticulatis.

Inflorescentia terminalis paniculata 10–12 cm. longa basi foliosa axi crasso tereti subvelutino-tomentoso ramis parcis brevibus vel brevissimis saepe trifloris dense tomentosi. Pedicelli crassi 5 mm. longi hirsuto-tomentosi. Sepala 4 crassa ovato-oblonga apice subite acutata utrinque dense tomentoso-sericea 16–18 mm. longa 7–9 mm. lata. Petala crassa pallido-lilacina ovato-oblonga apicem versus paulo attenuata acutiuscula utrinque dense tomentoso-sericea, 18–

20 mm. longa circa 8 mm. lata. Stamina creberrima filamentis capillaribus hirtis 4—5 mm. longis, antheris anguste linearibus 8—9 mm. longis graciliter hirtis; stamina exteriora sterilia: staminodia angustissime capillaria flexuosa 14—16 mm. longa. Ovarium sessile rotundatum glabrum 5 mm. diamitente, 5 placentis parietalibus convergentibus multiovulatis. Stylus filiformibus 7 mm. longus. Receptaculum intra stamina valde hirsuto-setosum.

Type.—COLOMBIA: Comisaría del Putumayo; selve higrófila del río san Miguel o Sucumbíos, en el afluente izquierda Quebrada de la Hormiga, 290 m. altitud, diciembre 1940, *J. Cuatrecasas 11147* (holotype, US).

Neosprucea sucumbiensis is very different from all other described species of this genus; it has the largest flowers, and leaves which are broadly oblong, rounded and abruptly acuminate at the tip and sparsely but softly pubescent on the underside. Because of its large flowers and hirtous anthers, it is close to the Ecuadorian *N. pedicellata* Little, but it differs from it, not only in the aforementioned characters, but also in its longer anthers, petals and sepals and in the longer hirtous filaments.

The genus *Neosprucea* Sleumer (= *Spruceanthus* Sleumer, Notizbl. 13: 362. 1936, a later homonym), was created on the basis of *Banara grandiflora* Spruce from Amazonian Peru. In 1948, E. L. Little published a second species, *N. pedicellata*, found by him in the forests of Ecuador. The five species can be distinguished with the following key:

1. Stamens glabrous.
   2. Flowers sessile or subsessile. Calyx about 7 mm. long. Filaments 2 mm. long, anthers 5 mm. long. Leaf glabrous.. *N. grandiflora* (Spruce) Sleumer
   2. Pedicels 12—14 mm. long. Calyx 9—10 mm. long. Filaments 3—4 mm. long, anthers 2 mm. long. Leaf subglabrous beneath.. *N. sararensis* Cuatr.
1. Stamens hirsute.
   3. Flowers less than 10 mm. long. Filaments 1.2—1.8 mm. long, anthers 2.5—3 mm. long. Pedicels 13—18 mm. long. Leaf subglabrous beneath.. *N. montana* Cuatr.

   3. Flowers 14—20 mm. long.
      4. Pedicels short (5 mm. long). Leaf soft pubescent beneath. Filaments 4—5 mm. long, anthers 8—9 mm. Sepals 16—18 mm. long.. *N. sucumbiensis* Cuatr.
      4. Pedicels 25—30 mm. long. Leaf subglabrous. Filaments 2 mm. long, anthers 5 mm. long. Sepals 15—16 mm. long.. *N. pedicellata* Little

Prockia orinocensis Cuatr., sp. nov.—Arbuscula ramis terminalibus pallido-griseis puberulis denique glabris.

Folia alterna simplicia subchartacea. Petiolus 7—12 mm. longus fuscus pubescens. Lamina elliptico-oblonga basi obtusa symmetrica vel inaequilatera, apicem versus angustata acuta margine argute serrata, 10—15 cm. longa 4.5—6 cm. lata; supra viridis nitida sparse strigosa nervis medio et lateralibus magis strigosis planis sed conspicuis reticulo venulorum minute prominulo; subtus grisaceo-viridula molliter pubescens, costa eminenti, nervis secundariis 7—8 utroque latere angustis prominentisque sericeis arcuato ascendentibus ad marginem cum nervulis anastomosatis, venulis bene prominulis reticulatis.

Inflorescentia terminalis paniculata ramulis tomentellis. Pedicelli 7—10 mm. longi crassiusculi hirsuto—tomentelli. Sepala 3 crassiuscula ovata vel rotundato-ovata apice subite acutata intus villosa extus villoso-tomentosa 8—9 mm. longa 5—6 mm. lata. Petala 3 obovato-oblonga obtusiuscula vel acutiuscula extus villoso-tomentosa intus subglabra circa 9 mm. longa 4—6 mm. lata. Stamina creberrima filamentis capillaribus glabris antheris globoso-ellipticis minutis. Ovarium ellipticum glabrum 5-loculare multiovulatum, stylo crassiusculo recto 5 mm. longo. Receptaculum inter stamina hirsutum.

Type.—COLOMBIA: Llanos orientales, orillas del Orinoco en Puerto Carreño, 23 octubre 1938, *J. Cuatrecasas 4009* (holotype, F).

The shape of the penninervate leaves, elliptic-oblong, obtuse at the base (never cordate), attenuate below the tip, with acutely serrate edges, and the sparse soft pubescence of the leaves differentiate *P. orinocensis* from all other known species of this genus. The leaves are pennatinervate and only the two lateral basal nerves in acute angle make a slightly trinervate base. The flowers are a little shorter than in *P. morifolia*.

Heisteria barbata Cuatr., sp. nov.—Arbor mediocris ramis terminalibus fuscis glabrisque.

Folia subcoriacea simplicia alterna glaberrima. Petiolus 4—7 mm. longus subteres supra paulo sulcatus. Lamina in sicco viridi-brunnescens ovata vel ovato-oblonga basi obtusa vel obtuse lateque cuneata apice subite angustato-cuspidata margine integerrima, 6.5—10.5 cm. longa, 3.5—5 cm. lata; supra nitida costa nervis secundariis filiformibus prominulis, nervulis reticulatis paulo elevatis; subtus costa crassiuscula prominenti nervis lateralibus 6—8 utroque latere angustis eminentibus curvato-ascendentibus marginem versus arcuato anastomosatis, venulis minoribus reticulum prominulum conspicuumque formantibus.

Flores in fasciculis umbellatis circa 12, axillares glomerati pedicellis 3—4 mm. longis gracilibus erectis vel flexuosis glabris. Calyx glaber expansus 2 mm. diamitens 5-lobatus lobis brevibus acutis. Petala 5 crassiuscula viridi-flavescentia libera oblonga apice acuta extus glabra intus supra medium dense barbata. Stamina 10, quinque petala opposita filamento cum petalum dimidia parte coalito, quinque alterna longiora libera; filamentis 2 mm. longis, glabris; antheris subglobosis. Ovarium in discum crassum immersum rotundato-depressum 1 mm. diam. paulo sulcatum, triloculare loculis uniovulatis ovulis anatropis pendulis. Stylus brevis crassiusculus striatus stigmate trilobato brevi. Fructus ignotus.

Type.—Peru: Departamento Loreto, Mishuyacu, near Iquitos, altitude 100 m. forest tree 12 m. high, flowers yellow-green, December 1929, *G. Klug 684* (holotype, F).

Heisteria barbata is characterized by its petals which are abundantly hirsute on the upper part of the inner side; by the stamens of which 5 are opposite and concrescent to the petals (the lower half), and by the thick disk united with the ovary. The general appearance reminds one of *H. calo-*

neura Sleumer, but it differs essentially from this in the above-mentioned characters.

Meliosma boliviensis Cuatr., sp. nov.—Arbor parva ramulis terminalibus badiis tomentellis.

Folia simplicia alterna coriacea. Petiolus 2.5—4 cm. longus subteres brunneo-tomentosus basi incrassatus. Lamina obovato-oblonga basi attenuata cuneata apice rotundata vel obtusa margine integra sublaevi, interdum sparsissimis minutis dentibus mucroniformibus, 15—35 cm. longa, 5—13 cm. lata; supra juvenilis villoso-puberulis adulta glabrescenti, in sicco tabacina, costa depressa villosula, nervis secundariis filiformibus conspicuis venulis minutum reticulum prominulum formantibus; subtus sparse hirtulo-villosa costa crassa elevata striata hirsutulo-tomentella, nervis secundariis 22—24 utroque latere valde eminentibus villosulis patulo-ascendentibus marginem versus arcuatis ad marginem decurrenti-anastomosantibus, nervis tertiis transversis filiforme prominentibus cum venulis minoribus prominulisque in laxum reticulum anastomosatis.

Inflorescentia in panicula thyrsoidea valde composita magna terminalis tantum basi foliosa, in specimine 45 cm. longa 25 cm. lata, axi anguloso ramulisque hirsutulo-tomentellis, inferne uno vel duobus foliis ad 13 cm. longis superne bracteis valde brevibus deciduis munitis. Flores subsessiles in ramulis terminalibus dense glomerati. Alabastra globosa, 1.5 mm. diamitentia. Pedicelli 0.1—0.3 mm. longi tomentello-hirtuli, una bracteola ovata margine ciliata 0.5 mm. longa ad calycem adpressa. Calyx 5 sepalis concavis orbiculatis margine ciliatis dorso glabris, interioribus 1 mm. diam., exterioribus paulo brevioribus basim magis angustatis. Petala exteriora 3 cochleata crassiuscula glabra tantum margine sparse ciliolata, 1.3 mm. diamitentia. Petala interiora squamosa linearia 0.5 mm. longa. Stamina fertilia duo, antheris latis lobulis subglobosis rubris 0.4 mm. latis connectivo evoluto crassoque, filamento crassiusculo circa 0.6 mm. longo. Staminodia squamiformia emarginato-lobulata circa 0.3 mm. longa, 0.7 mm. lata. Ovarium glabrum pyriforme

0.8 mm. longum biloculare loculis biovulatis. Annulus disci receptaculi valde brevis.

Type.—Bolivia: .Valle de Tipuana, hacienda Casana, 1400 m. altitud, 6 octubre 1922, *O. Buchtien 7616* (holotype, US 1399780; isotype US 1399781).

M. boliviensis is characterized by its large obovate-oblong scattered-pilose leaves, which are many-nerved and have a minute reticulum on the upper sides; by its hispidulous indumentum beneath; by its large inflorescences, and its small glomerate flowers.

The following new combinations are given to transfer taxa described as *Mayna* to *Carpotroche*. In the opinion of the writer this genus deserves recognition for its typical winged, dehiscent, thicker-shelled fruits.

Carpotroche linguifolia (Schultes) Cuatr., comb. nov.
Mayna linguifolia R. E. Schultes. Caldasia 3: 439. 1945.

Carpotroche longifolia (Poeppig) Benth. var. **heliocarpa** (Schultes) Cuatr., comb. nov.
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THE XYLEM ANATOMY OF *ORTHOPTERYGIUM* (JULIANIACEAE)

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Introduction

Orthopterygium Hemsley is one of the two genera which comprise the family Julianiaceae. The other genus is *Juliania* Schlechtendal. There are five species in the family: *J. adstringens* Schlechtendal *(Amphipterygium adstringens* Schiede), *J. mollis* Hemsley *(Amphipterygium molle* Hemsley & Rose), *J. amplifolia* Hemsley & Rose *(Amphipterygium amplifolium* Hemsley & Rose), *J. glauca* Hemsley & Rose *(Amphipterygium glaucum* Hemsley & Rose), and *Orthopterygium huaucui* Hemsley *(Juliania huaucui* A. Gray, *Amphipterygium huaucui* Hemsley & Rose). The *Juliania* species are found mainly in Mexico (Record and Hess, 1943) although *J. adstringens* has also been found in Guatemala (Standley and Steyermark, 1949) and in Honduras (reported by Stern, 1952). *Orthopterygium huaucui* has been found only in Peru (Macbride, 1936).

The natural affinities of Julianiaceae among the flowering plants have been subject to controversy since the genus *Juliania* (then *Hypopterygium)* was described by von Schlechtendal in 1843. Other aspects of this controversy relate to Hemsley's (1908) separation of the family into two genera.

There appears to be a difference of opinion between anatomists and taxonomists as to the relationships of Julianiaceae. Most workers who have studied the anatomy of the woods of this family tend to place it in close proximity to the Anacardiaceae. Others who have studied the family, solely from the exomorphic point of view, favor placing it nearer to the Juglandaceae or other families. A notable exception to this occurs in the Bentham and Hooker (1862–1867) system, where the genus *Juliania* was placed in the

Anacardiaceae. However, when Hemsley (1908) created the family Julianiaceae he considered its relationship to be closer to Juglandaceae and the "Cupuliferae." Fritsch (1908) disputed Hemsley's views on anatomical grounds and demonstrated that no clear-cut line of demarcation existed between Julianiaceae and Anacardiaceae. Fritsch suggested that the presence of resin-containing canals in the phloem and pith of both families is one of the chief points of resemblance. Hallier (1908) concluded that *Juliania* is an obvious link between Juglandaceae and Anacardiaceae and placed this genus in the family Terebinthaceae after having placed it in the Juglandaceae as a result of previous work. Hallier concluded that Jadin (1894) must have been working with incorrectly named material when he drew the conclusion that the resin canals of *Juliania* appear only in the pith. Solereder (1908) stated that *Juliania* should probably be included in the Simarubaceae since it only had resin canals in its branches. This has since been shown to be incorrect by subsequent investigators (Kramer, 1939; Heimsch, 1942; Stern, 1952) who have observed resin canals in the wood of the main axis. I. W. Bailey, as quoted by Copeland and Doyel (1940), is of the opinion that the structural similarities between the xylem and secretory canals of Julianiaceae and those of Anacardiaceae are such that the genera of the Julianiaceae might well be included in the Anacardiaceae, and that the Juglandaceae are anatomically unlike either of these families. Copeland and Doyel (1940) conclude that the Anacardiaceae and Julianiaceae are very closely related and that, although Juglandaceae are not derived from Anacardiaceae, a collateral relationship between them remains a possibility. Heimsch (1942) concludes that Julianiaceae and Anacardiaceae are closely related but the Juglandaceae are distinctly separate from both. Engler and Diels (1936) place the family Julianiaceae in the order Julianiales, next to the order Juglandales. Wettstein (1935) places both Julianiaceae and Juglandaceae under the order Juglandales. Metcalfe and Chalk (1950) locate Julianiaceae next to Anacardiaceae and Gundersen (1950) places Julianiaceae in the order Rutales

along with Burseraceae, Anacardiaceae, Coriariaceae, Cneoraceae, Simarubaceae, Rutaceae, and Meliaceae.

Stern (1952), on the basis of a study of the secondary xylem of the woods of the Julianiaceae, suggests that this group is most closely related to Anacardiaceae and its relatives. In addition, this worker reports that his findings with regard to the anatomy of the xylem do not present any obvious bases for separation of the Julianiaceae into two genera as was done by Hemsley (1908), since no significant differences were found among the woods of the different species. Of the species studied by Stern, however, only one, *Juliania adstringens*, was represented by mature wood. Wood of the other species was available only in the form of twig specimens. This meant that many of his observations and interpretations had to be qualified to take the age of the wood into consideration. Rendle and Clarke (1934a) emphasize the point that the elements of successive growth rings are progressively larger from the pith outward in young wood, so that measurements on young wood often vary from those on mature wood of the same species and even of the same plant. Barghoorn (1941), as a result of his studies on the rays of dicotyledonous woods, has stated that the variations of ray structure which occur normally during ontogeny render the height and width of rays of doubtful value in the identification of woods.

The present study was undertaken in the hope that the results would contribute to more complete knowledge of the wood anatomy of *Orthopterygium huaucui*. In this way it may be possible to ascertain more closely the affinities of Julianiaceae and the validity of the present subdivision of this taxon into two genera.

Materials and Methods

The specimens of *Orthopterygium huaucui* studied in this investigation were collected by the Reverend J. Soukup from a single tree located in the valley of the Chillon River, between Lima and Canta in western Peru. The cross-sectional diameter was approximately 1.4 centimeters, including the bark. The material was collected in 1951 and stored in a solution of formalin, acetic acid and alcohol.

The procedures used in preparing the material for microscopic study are essentially those outlined by Wetmore (1932). Samples were infiltrated with celloidin and stored in glycerin-alcohol for several days preparatory to sectioning. Transverse, radial, and tangential sections were cut on a Spencer sliding microtome. These sections were stained with Heidenhain's iron-alum haematoxylin and safranin, cleared in xylol, and mounted on slides in Canada balsam. Macerations were made with Jeffrey's macerating fluid using a modification of Jeffrey's technique as outlined by Johansen (1940) which involved the use of tertiary butyl alcohol as a dehydrating agent. The macerations were stained with safranin.

The diagnostic characters believed most appropriate to the present study were selected from those listed by Tippo (1941). In measuring the length of vessel members, the suggestion of Chalk and Chattaway (1934) regarding the use of total length (tip-to-tip) was followed. In diffuse-porous woods this length approximates very closely the length of the parenchyma strands and probably that of the fusiform cambial initials. The total lengths of 100 vessel members were measured from macerations. The tangential diameters of 100 vessels were measured from mounted transverse sections. Lengths of 100 fibrous tracheary elements were measured from macerations. According to Tippo (1938) such measurements cannot be made with sufficient accuracy from sectioned material.

The advice of Rendle and Clarke (1934a, b) was followed in calculating and reporting sizes of fibrous and vessel elements. Vertical xylem parenchyma and vascular rays are classified here as outlined by Kribs (1935, 1937). The size classes of Chattaway (1932) are employed in general descriptions of vessel diameters and vessel element lengths. Other descriptive terms used in reporting results are those recommended by the Committee on Nomenclature of the International Association of Wood Anatomists (1933).

In order to compare and evaluate possible effects of age on vessel diameter, vessel element length, and fiber length, measurements were made from sections prepared by W. L. Stern of young and mature wood of *Juliania adstringens*, and young wood of *Orthopterygium huaucui*. Further measurements were also made from macerations prepared by Stern of mature wood of *Juliania adstringens*, and from sections and macerations of young wood of *Orthopterygium huaucui* prepared by the present author in connection with this study. These measurements were analyzed and compared following statistical methods outlined by Bliss and Calhoun (1954).

Description of the Xylem

The growth rings in the xylem of the specimen studied are so indistinct as to make any estimate of the age of the material impossible. Since the only gradation in diameter of vessel members is that associated with the development of the young wood from the pith outward, this wood may be classed as diffuse-porous. Although both vertical and horizontal secretory canals are present in the bark (fig. 1), and vertical secretory canals and secretory cells are present in the pith (fig. 2), no secretory canals were observed in the xylem. The presence of secretory canals in the bark and pith and the absence of secretory canals from the young wood of *Juliania* spp. was reported by Stern (1952).

Fibrous tracheary elements (fig. 3) are nearly all septate and consist of both fiber-tracheids, containing small bordered pits, and libriform wood fibers, containing small simple pits. The two types of elements appear to be almost equally distributed in the wood. All fibers are thin-walled with lumens considerably broader than the thickness of the walls (fig. 4). Fiber length averages approximately 430μ, with most fibers between 310 and 530μ in length (table 1).

In transverse section vessel elements appear mainly as solitary pores, with a smaller proportion in multiples of 2 to 4 or clusters of 3 to 6 (table 1). Pore clusters were frequently observed to be associated in short tangential bands.

Table 1. DIMENSIONS OF TRACHEARY ELEMENTS, PORE ARRANGEMENT, AND RAY SIZE IN *Orthopterygium huaucui*

DIMENSIONS OF TRACHEARY ELEMENTS IN μ

	RANGE	MOST FREQUENT RANGE	MEAN AND STANDARD ERROR	STANDARD DEVIATION AND STANDARD ERROR
Fibrous element length	210—630	310—530	429.46±9.82	92.03±6.97
Vessel element length	135—375	160—290	242.70±4.56	45.60±3.24
Vessel diameter	25—130	30—95	71.26±2.73	27.31±1.94

PORE DISTRIBUTION (IN PER CENT)

Solitary	45
Multiples	32
Clusters	23

AVERAGE NUMBER OF PORES IN EACH GROUPING

Multiples	2
Clusters	4

SIZE OF VASCULAR RAYS (NUMBER OF CELLS)

Range in width	1—4
Range in height	
Uniseriate rays	1—18
Multiseriate rays	3—29

Pores are angular in cross-section in the young wood, gradually tending to become rounder in the older wood as vessel diameter increases. Vessel elements are thin-walled, averaging less than 3.5μ in thickness. Length of these elements ranges from 135 to 375μ, averaging approximately 240μ, with most of the elements between 160 and 290μ in length. Diameters range from 25 to 130μ, averaging about 70μ (table 1). A few thin-walled tyloses were observed in vessel elements (fig. 4). End walls are both transverse and oblique (30° to 45°). Perforation plates are mostly simple (fig. 5), but reticulate perforation plates are not uncommon (fig. 5, 6). Intervascular pitting is mostly alternate and frequently opposite (fig. 5, 8). Considerable transitional pitting was evident (fig. 8), especially in vessel elements near the pith where the pitting may approach scalariform.

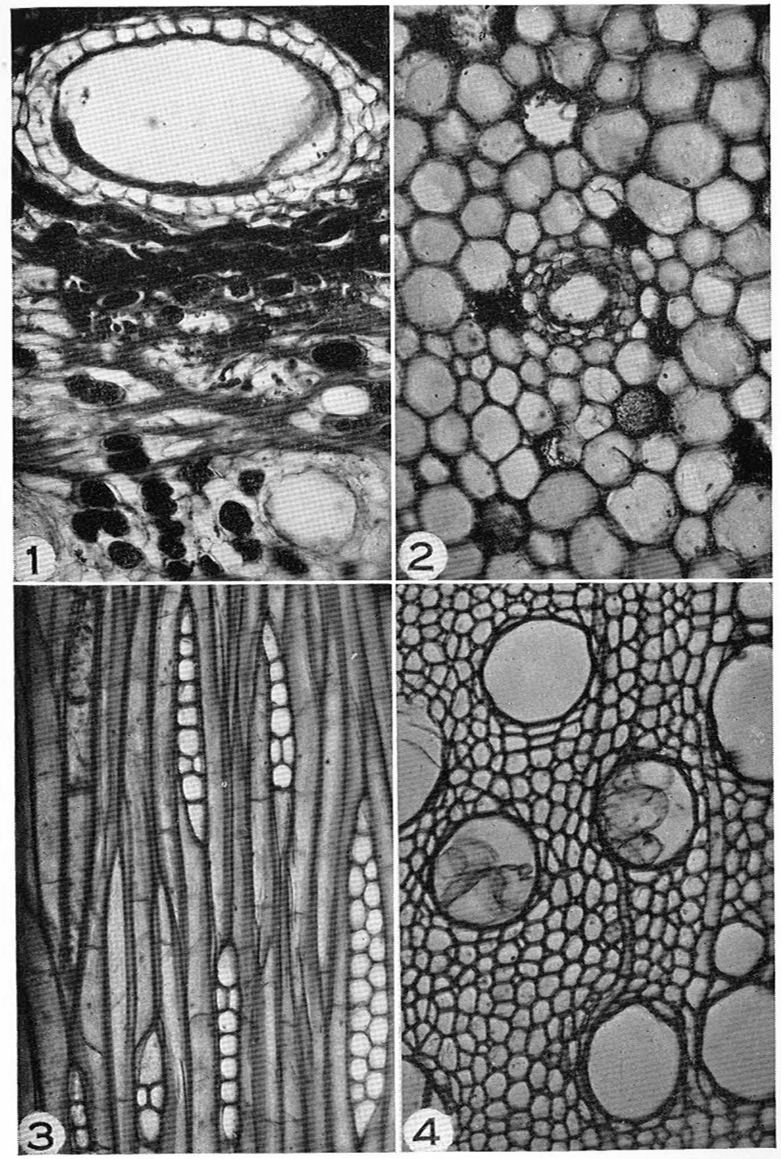

Fig. 1—4. *Orthopterygium huaucui.* ×200.—Fig. 1. Cross-section showing vertical secretory canals in the bark.—Fig. 2. Cross-section showing vertical secretory canal and secretory cells in the pith.—Fig. 3. Tangential section showing uniseriate and multiseriate rays and septate fibers.—Fig. 4. Cross-section showing tyloses in vessel elements.

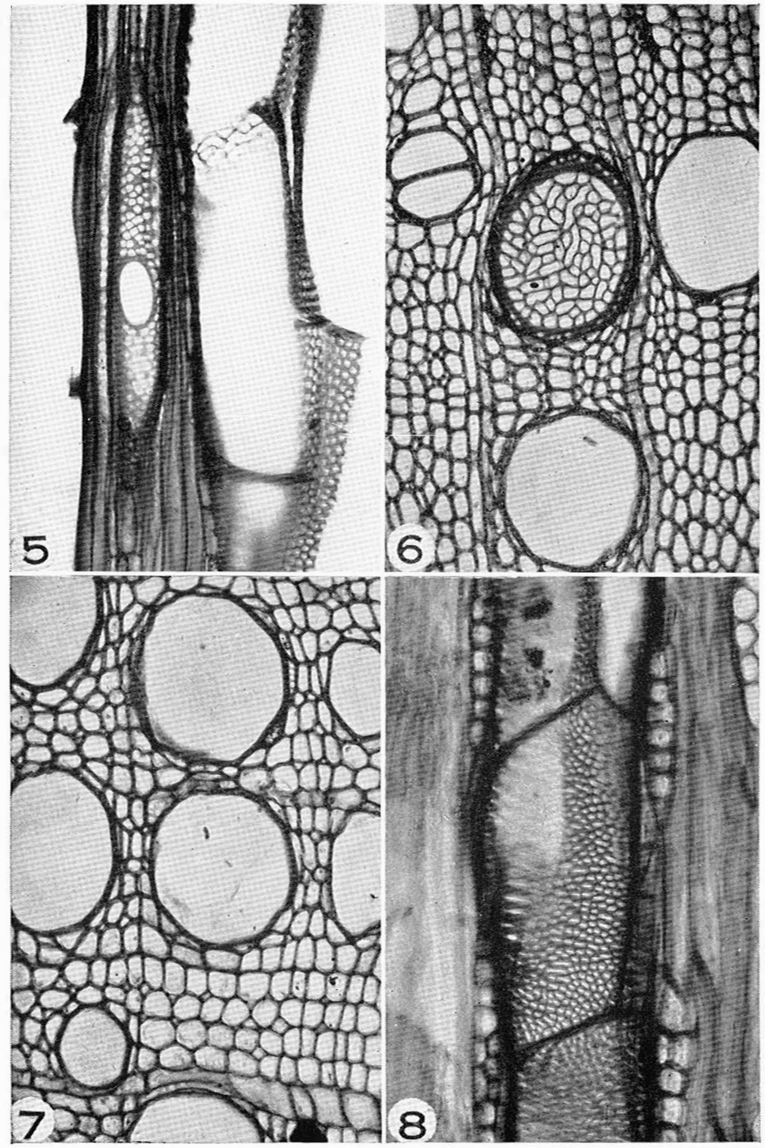

Fig. 5—8. *Orthopterygium huaucui.* ×200.—Fig. 5. Radial section showing reticulate and simple perforation plates and alternate intervascular pitting.—Fig. 6. Cross-section showing reticulate perforation plate.—Fig. 7. Cross-section showing vasicentric parenchyma.—Fig. 8. Tangential section showing opposite and transitional intervascular pitting.

Vascular rays (fig. 3) are entirely of the type designated by Kribs (1935) as heterogeneous IIB. Uniseriate rays range from 1 to 18 cells in height with most of them falling within the range of 3 to 10 cells. Multiseriate rays are mostly 2 cells wide and between 4 and 12 cells high, although rays up to 4 cells wide and 29 cells high were observed (table 1).

Longitudinal parenchymatous elements (fig. 7) are sparse, occurring in assocation with scattered vessel elements (vasicentric).

Statistical Comparison of Sizes of Tracheary Elements

In an effort to determine significant points of similarity and difference in sizes of tracheary elements observed in Julianiaceae, measurements of tangential diameters of vessel members, lengths of vessel members, and lengths of fibers were analyzed statistically using methods based on analysis of variance and "Student's" t test as described by Bliss and Calhoun (1954).

Measurements of tangential diameters of vessels located within 1 millimeter of the pith were made by means of a fixed ocular micrometer from prepared slides of *Juliania adstringens* from two different sources[1] and of *Orthopterygium huaucui*.[2] Similar measurements were made from slides of *Orthopterygium huaucui* prepared for the present study. The analysis was based on 50 measurements from each source. Results of the statistical analysis of the four groups showed that the within-group variances were slightly heterogeneous and the differences between group means were significant at the 1 per cent level of probability. This indicated that the null hypothesis, that all samples were from the same population of measurements, was untenable and that significant fundamental differences existed among the groups. When the two groups of measurements from *Orthoptergyium huaucui* specimens were combined and

[1]Preparations of W. L. Stern; collections of Hinton 4812, and Rose and Hay 5341.

[2]Preparations of W. L. Stern; collection of Macbride 2866.

compared with the combined two groups of measurements from *Juliania adstringens* specimens, it was found that mean vessel diameters of the two species were significantly different at the 1 per cent level of probability. A further breakdown of the analysis showed that the means of the two groups of *Orthopterygium huaucui* measurements were significantly different at the 1 per cent level of probability, although the means of the two groups of *Juliania adstringens* measurements were significantly different at the 5 per cent level of probability.

Tangential diameters of 50 vessels from the portion of the specimens under investigation *(Orthopterygium huaucui)* within 1 millimeter of the bark were compared statistically with similar measurements from prepared slides of mature wood of *Juliania adstringens*.[3] Neither the means nor the variances of the two groups of measurements differed sufficiently to reject the null hypothesis that both groups of measurements were from the same normal population.

Measurements of tangential diameter of 50 vessels from the portion of the specimen of *Orthopterygium huaucui* under consideration within 1 millimeter of the pith were compared with similar measurements made on 50 vessels from the portion of the same specimen within 1 millimeter of the bark. Results of statistical analysis showed that both the variance and the mean diameter of the vessels nearer the bark were significantly larger than those of the vessels near the pith.

Measurements of the length of 50 fibers from macerated material taken from within 1 millimeter of the pith of the *Orthopterygium huaucui* specimen were compared with 50 similar measurements from macerated material taken from within 1 millimeter of the bark. Neither the means nor the variances of the two groups of measurements differed sufficiently to reject the null hypothesis that both groups of measurements were from the same normal population.

[3]Preparations of W. L. Stern; collection of Leavenworth 1497a.

Lengths of 50 vessel elements within 1 millimeter of the pith of the *Orthopterygium huaucui* specimens were compared with those of 50 vessel elements within 1 millimeter of the bark. Measurements were made from sections in both instances, with both the length of elements and distance from bark or pith being determined by means of a filar ocular micrometer. The two groups of measurements did not differ significantly in variance, but their means showed a difference that was significant at the 1 per cent level of probability.

Discussion

Comparison of the xylem anatomy of the specimen of *Orthopterygium huaucui* under investigation, with that observed in other prepared slides of this species and *Juliania adstringens*, as well as with descriptions of the species of the Julianiaceae reported by Stern (1952), appears to support his contention that there is little anatomical basis for separation of the Julianiaceae into two genera. The structure of the xylem of *Orthopterygium huaucui* as observed in the material at hand does not differ appreciably from that reported by Stern. The observed differences seem to be largely due to variation among individual samples of a given species and to the effects of age on the material being studied. This latter effect is probably of particular importance since the observed differences are mostly in sizes of elements rather than in basic structure. The absence of secretory canals from the xylem of the material under consideration may well be due to the effect of age on structure, since Stern (1952) observed secretory canals only in the mature wood of Julianiaceae and did not see these structures in any immature specimens. The importance of the effect of age on wood structure has been mentioned by deBruyne (1952) and others who point out particularly the variation that may be expected in vessel diameter and ray size.

Comparison of measurements made on the material at hand with measurements reported by Stern, for younger wood of *Orthopterygium huaucui* and *Juliania* spp. and mature wood of *Juliania adstringens*, suggests that increase in size of wood elements with age does not proceed at the same rate for all elements of the same wood. This is apparent in that the vessel diameters in the portion of the present specimens of *Orthopterygium huaucui* nearer the bark differ significantly from vessel diameters in the portion nearer the pith but do not differ significantly from vessel diameters reported by Stern for mature wood of *Juliania adstringens*. However, fiber lengths in the portion of the present *Orthopterygium huaucui* material nearer the bark do not differ significantly from fiber lengths in the portion of this same material nearer the pith and are only half as great as fiber lengths reported by Stern for those in mature wood of *Juliania adstringens*. Vessel elements in *Orthopterygium huaucui* (J. Soukup) show a significant increase in length with age. Vessel elements in the portion of this material nearer the bark measured from sections approach in length the vessel element lengths reported by Stern for sectioned mature material of *Juliania adstringens*. Further indication of the differences in rate of development of wood elements to their mature size is given by the height of vascular rays, in which respect the present *Orthopterygium huaucui* material is very closely comparable to the twig specimens of *O. huaucui* studied by Stern but apparently much different from the mature wood of *Juliania adstringens* observed by that investigator.

The fact that the present specimen is intermediate in both age and ontogenetic development between the twig material of *Orthopterygium huaucui* and *Juliania* spp. and the mature material of *Juliania adstringens* observed by Stern, may well be the reason for the above-mentioned apparent variations in sizes of wood elements. *Orthopterygium huaucui* (J. Soukup) is much closer in its stage of development to the twig material than to the mature material. Therefore, if this variation in rate of development of wood elements actually exists, only those age changes which take place most rapidly and which are most pronounced might be expected to be apparent. Thus the changes in vessel diameter and vessel element length appear to have taken place quite rapidly with the result that these dimensions have attained

approximately the values to be expected in mature wood. On the other hand, fiber length and ray height have apparently changed very little from the values shown in young wood.

This variability in development of individual types of wood elements might also explain the absence of intercellular canals in the xylem of the *Orthopterygium huaucui* material under study. The presence of such canals would be expected in the mature wood of this species if it is as closely related to *Juliania* as other features would lead one to believe. Stern pointed out that these intercellular canals were observed in the wood of only the mature specimens of *Juliania* and did not appear in any of the young specimens. It would therefore be reasonable to expect that absence of intercellular canals in the xylem of the present material is due to the age of the wood rather than to any fundamental difference between *Orthopterygium* and *Juliania*.

The effect of variation among individual samples must not be overlooked in any discussion of changes in wood elements with age as contrasted to fundamental structural differences among species and genera. The fact that individual specimens of both *Orthopterygium* and *Juliania* showed fully as much variation within the species as among species serves to emphasize this point. Thus, any apparent slight differences between the woods of the two genera *Juliania* and *Orthopterygium* could very well be due to variation in sampling.

The fact that the present material is so similar structurally to that previously reported by Stern for the same and other species of the family serves to support the contention of that author, and the many previous investigators mentioned in the INTRODUCTION, that the family Julianiaceae is most closely related to the Anacardiaceae and its relatives and is not closely related to the Juglandaceae as claimed by certain other botanists. Tippo (1938), in describing the woods of the Juglandaceae, lists several structural features that are also possessed by the woods of the Julianiaceae. Among these are: the arrangement of vessels in multiples and clusters as well as solitary; diffuse-porous woods (some of the Juglandaceae are ring-porous); vessels angular to round; simple perforation plates (some of the Juglandaceae have scalariform perforation plates); and vascular rays mostly heterogeneous IIB. However, there are other structural features of Julianiaceae that are not reported as being similar for the woods of the Juglandaceae. Among these are the conspicuous intercellular canals, septate fibers, distinct libriform fibers, sparse vasicentric vertical xylem parenchyma, three types of intervascular pitting (alternate, opposite, and transitional), and reticulate perforation plates. On the other hand, the woods of the Anacardiaceae do show structural features which, although shared with Julianiaceae, do not occur in Juglandaceae.

Summary

The form and size of the xylem elements in *Orthopterygium huaucui* observed in this study support the contention of Stern (1952) that anatomical evidence does not justify the separation of the Julianiaceae into two genera. The observations also agree with the statements of many investigators that the woods of Julianiaceae are structurally like those of Anacardiaceae but differ in several important features from juglandaceous woods.

A significant effect of age on both vessel diameter and vessel element length in immature wood was observed. This effect was not evident with respect to length of fibrous tracheary elements or development of intercellular canals in the xylem, indicating that there may be a considerable difference in the rate at which various structural elements of the wood attain their mature size and form. Comparison of prepared slides of *Juliania adstringens* and *Orthopterygium huaucui* showed that variation in vessel diameter among samples of young wood of the same species was as significant as that among samples of young wood of different species. This indicates that apparent differences among species at the same stage of development may be due largely to sampling variation.

It is expected on the basis of this study that examination of the mature wood of *Orthopterygium huaucui* would disclose enough similarity to the wood of *Julania* to warrant serious attention to a reconsideration of Hemsley's (1908) division of the family into two genera. Such an investigation would appear to be the next logical step in clarifying the classification of the Julianiaceae.

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POSSIBILITIES OF TIMBER INDUSTRIAL DEVELOPMENT IN THE AMAZON VALLEY

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One of the significant effects of political conditions in the Far East during the postwar period has been an intensification of interest by the colonial powers in the development of territories closer to The West. The timber industry has received generously of this interest. The forests of the near tropics still retain their established rôle of log suppliers to export markets, but the picture is changing. The French are bringing pulp and plywood from their African territories; the Dutch have a large modern plywood plant in Suriname; and the British a two million sterling investment in a new milling enterprise in Georgetown, British Guiana. Independent investment has been no less active. Mexico has

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a hardboard plant, and is considering pulp and paper, as is also Peru, and there is a considerable awakening of interest throughout practically all the tropical belt of Central and South America in the possibilities of forest enterprise. Yet, the world's most extensive forest stretching unbroken over more than two million square miles of the Amazon plain remains remote and unapproached by the flurry of interest in its lesser neighbors.

The reason for the lack of interest is not readily apparent in this land of paradox. The Amazon lies squarely astride the equator but climate cannot even start to explain why this vast area, after three centuries of opportunity for colonization, remains one of the empty spaces of the earth. Java, similarly located on the equator, is at the other extreme; the most densely populated. The Amazon, in fact, enjoys one of the healthiest and most comfortable tropical climates of the world; one which offers no bar to successful colonization from the crowded areas of the world.

One sixth of the water reaching the seas from the land masses of the world runs down the Amazon River from the eighty inches of rain that falls on its millions of acres. But the popular legend that it is a "rainy-season inland sea" as unsuited for settlement as any other sea, is as ill-founded as most Amazon legends. Less than one per cent of the land is covered in the annual spillover of the main river and its tributaries. The area is indeed flat—as characteristically flat as is the American midwest. But the runoff has carved and eroded a riverine system of roughly parallel tributaries, 100 to 200 miles apart, and some 100 to 300 feet below the parent plain level. The annual floods merely border the rivers and lap the foothills of the otherwise undisturbed *planalto* (high plain). However, the scale is so vast, that even a mere one per cent flooded area may retreat the terra firma (firm or dry unflooded land) fifty or even a hundred miles from the dry-season margin of the river. These conditions are accompanied by transport difficulty in a land depending upon only water and flying boat communication. A farmer's choice is continuous isolation on the

terra firma, or a place on "main street" where he may farm for half the year and fish for the remainder.

The soils are loamy clays, devoid of stone and arable. Yet apart from maize and manioc (which alike are processed by primitive methods for a low return of flour), the Amazon imports more than half the food it eats. The forests yield fruits and game, and the rivers teem with fish. The Amazonian says with pride in his land, "God is a Brazilian. There is no need to starve in the Amazon." Yet that is in effect what he does! In such a climate he needs little of clothing and shelter, and a lesser supply of food for bodily heat and energy. But his diet is so deficient in all but carbohydrate, that he averages only thirty-eight years before his lack of resistance makes him fall prey to what he could readily throw off as a minor ailment were he properly fed.

Economically the modern Amazon had a good start, with its monopoly of raw rubber, around the turn of the century. The two main cities still show evidences of their former glory when they were indeed two of the most fabulously wealthy in the world. Rubber is still the whole basis of economy. The *cabocle*, the man of the forest, still makes a twenty mile hike collecting from 150 wild rubber trees in the jungle as his antecedents did in the last century. Still in the manner of his forefathers he continues to trade rubber at the motor launch of the itinerant hawker. This barter exchange keeps him permanently in debt and obligated to remain at his isolated calling. Here he is cut off from human contact, from medicine, education and other amenities. The recently constituted Amazon Valorization Commission is making a belated attempt to switch from the wild rubber economy to a plantation basis. But the scourge of epidemic rubber diseases is still unsolved, and synthetic rubber is now an established reality. Continued concentration on rubber has perforce to overlook the fact that the misery of the Amazonian has always been proportionate to the extent that preoccupation with rubber diverted him from growing food.

The trader has ever been "king of the Amazon." A new economy will not easily evolve in which sufficiency of locally grown food can force relaxation of the hold from which he has derived his power, prestige and his very considerable fortune. Nature has favored him on every side in developing this condition. The *cabocle*—of mixed white and Indian blood—is by nature a man of the river and the jungle, and is not readily disposed to agriculture. He easily fits into a "collection economy" where he functions as the foundation collector of such forest products as rubber, nuts, and log timber, which the trader rafts down the rivers.

The fundamental reason however, why the enormous Amazon remains in its little state of suspended feudalism and why there has been no frontier rush for new land in our overcrowded world, has been the essential poverty of the soils themselves. Sustained high temperature and high rainfall together have so leached out the sandstone-derived soil that the only chemical material of any value in agriculture lies in the leaf litter. This, the jungle reuses with extraordinary economy and with little addition from the great depths plumbed by its big trees. As few as one, two or three agricultural crops following clearing and burning of the jungle, exhausts the slender resources of nutrients stored in the top few inches of soil by the thrifty forest. The *cabocle* does not easily take to a shifting system of agriculture which demands the labor necessary to clear and prepare a new area of jungle annually for what will, in any case, be a poor return.

Only in the *varzea*, or margin of the river annually flooded, does the soil provide the opportunity for sustained agriculture. Vast quantities of suspended fertilizing material are carried off the higher reaches of the rivers and deposited on the flood plains. But the length of the season when these soils are available, the restriction of choice of crops suited to these conditions, and the annual uncertainty as to the exact height of the flood crest, all add up to great difficulty in efficient regulation of land use in the *varzeas*.

For permanent development to replace what up to now has been merely a partial ransacking of the native storehouse, a basis must be provided other than that of the traditional type of initial or colonial development. The Amazon shows no promise of producing the agricultural surpluses which served the initial establishment of the United States of America, Australia, New Zealand or even of southern Brazil, Argentina and certain other parts of South America. Diamonds and a variety of other minerals occur in this area. The Bethlehem Steel Company is at present extending a railway line into Serra do Navio to tap one of the richest mountains of manganese in the world. Oil has been found in Peruvian Amazonia and is sought, and predicted in the Brazilian Amazon. Tree crops like rubber, nuts, citrus fruits, etc., may eventually be grown in wide-scale plantations free from disease. The *varzea* can grow jute, of which Brazil's coffee export business has great need, and rice which now the Amazon imports to a great extent. It is probable that the extension of coffee growing will eventually spread from the Paulista plateau beyond Cuiaba, its present limit of interest, to tap the volcanic soils on the rim of the Amazon some two thousand miles south of the main river. Pockets of rich soils of different geological origin from the Tertiary and Quaternary plain are known to exist on the terra firma nearer the Amazon. These will probably play an important role for the Amazon itself.

None of these possibilities does more than start to spot the vast expanse of the Amazon. In fact, they are made still more difficult by the distances that would separate them. Real development or settlement of the Amazon must concern the great bulk of the area remote from these exceptional opportunities. The asset offered as a basis for such development is the forest.

There has been something of a logging and lumbering industry in the Amazon, which often has been expected to blossom into something of worth. The so-called precious woods have long been known to world markets—mahogany, *Swietenia macrophylla* King; Spanish cedar, *Cedrela* spp.; andiroba, *Carapa guianensis* Aubl.; freijo, *Cordia goeldiana* Huber; the louros, Lauraceae; etc.—as have some of the structural hardwoods—massaranduba, *Mimusops* spp.; itauba, *Mezilaurus itauba* (Meissn.) Taub.; acapú, *Vouacapoua americana* Aubl.; and so forth. Even so, the industry has functioned merely as another unit in the "collection commerce," and has suffered all the difficulties inherent in high-grading dependence on an export market.

No power other than manpower is available for extraction of logs to water. While "floaters" can be rafted, there is obvious difficulty in the organization of barges for "sinkers," especially at great distance from the mills, without means of communication other than by launch.

Extraction involves hand rolling of thirteen foot logs to water, along swathes cut eighteen feet wide directly though the jungle to the river. Although logs may, in exceptional cases, be rolled distances of more than a mile, in general, logging operations have only skimmed the river banks for acceptable species and quality. Where good quality forest may exist just five miles from the back door of the mill, log supplies may be coming from many hundreds of miles upstream. It serves no useful purpose to describe the kind of industry in existence today, because it is a poor criterion for a future which now seems to be realizable in view of significant developments affecting the Amazon forests—at least of Brazilian Amazonia.

First, a market is opening in the fast growing south and northeast which has not previously been available. Brazil's big cities—Rio de Janeiro, São Paulo, Recife, Salvador—have been adequately provided with constructional hardwoods and cabinet woods from local forests. But the speed of development, the rate at which the forests have disappeared before coffee-culture, the deforestation for firewood from which Brazil draws over eighty-five per cent of its power, have brought the era of easy local supply to an end. At Recife, for example, logs may travel 750 miles to the mill by motor lorry on unmade roads. Even in the Paraná pine belt, haulage distances are up to 300 miles largely on earth roads. The three forests from which Rio de Janeiro and São Paulo have drawn their supplies are estimated to have five, ten, and thirty years of life, respectively, at the present rate of cutting. Prices have risen faster even than Brazil's normal inflation, and buyers are now actively and insistently seeking Amazon supplies for practically everything from crossties to veneer logs at hitherto unheard of prices. Cedar prices, for example, rose more than sixty per cent in one season. Amazon supplies to a southern market are no longer a mere future possibility. The continuation of the extraordinary rate of development that has characterized the south, as measured by its dependence on timber supplies in hardwood, now depends on the Amazon's capabilities, still to be proved.

A Technical Assistance Forestry Mission of the Food and Agricultural Organization of United Nations is currently working on this problem at the request of the Brazilian Government, under the aegis of the Amazon Valorization Commission. In a report published by F.A.O. in 1953, the Mission indicated that it saw no technical reason why a wood utilization industry could not be developed to the extent of the available markets. However, the Mission also stated, that before new investment could be attracted, certain basic requirements need to be met.

The key to the situation is the demonstration that an assured and cheap supply of logs is obtainable through mechanization, and that there is no technical difficulty inherent in Amazon logging of greater moment than is normal under tropical conditions. The Amazon forests are flat; despite legend to the contrary they are open and easily penetrated except for the tangle of vines and undergrowth characteristic of the immediate margins of the rivers. Because of the topography and forest character, road construction is exceptionally cheap. Despite the high rainfall, the soils dry very quickly. The magnificent system of waterways is of evident advantage. On the unfavorable side, although 20,000 board feet an acre may be about average for these forests, the percentage of this represented by merchantable species is low. Despite the fact that a 6 × 6 truck could drive, for example, to every cedar stump, it is the exceptional forest that would give more than a tree to two acres, of this or any other single valuable species. At present only a handful of the many hundreds of species is merchantable. The precious woods will necessarily form the initial basis of mechanical extraction. How many additional species growing in association with the precious woods can economically be made merchantable in the future, remains to be seen.

This aspect of economic botany is the second major project of the F.A.O. Mission. An interpretation is being made of the aerial photographs of certain limited areas strategically favorable to industrial establishment. At the same time the project calls for the training of Brazilian technicians to continue this as the foundation of a permanent mapping and estimation-interpretation service. Very significant advances have been made in the technique of aerial survey interpretation and estimation of tropical forests in the last decade, largely as a result of the work of the Central Bureau of Aerial Survey, Suriname. The Amazon work has been fortunate in having included within its personnel, the technician responsible for the forestry aspects of the Suriname work. Preliminary indications are, that data of great value can be gained from the Amazon photographs, similar to those already obtained in Suriname.

The overall technical problem of the Amazon, which is present to an even greater extent here than is general in the tropics, because of the poverty of these forests, is to secure the utilization of the greatest number of species and of the greatest volume per unit of area served by a road construction. Were the topography broken, or the undergrowth of normal density and clearing cost, the Amazon timber stand would be a very doubtful economic proposition for mechanical working, other than in exceptional cases. However, the ease of working the Amazon region, the value of the species which are marketable, and the excellent form of the trees of all species, makes for optimism. That which must begin as high-grading, can later develop into real forest exploitation.

Genuine forest utilization cannot develop until the local economy itself expands to the point where it is able to absorb and pay for the big volume of second grade material which is the inevitable accompaniment to exploitation for export. As mechanization establishes itself, the need for increased intensity of exploitation and increased local sales are two ends of the one problem. Mechanized high-grading for export can reduce costs to a fraction of the present prices and be a highly profitable starting point. Nevertheless, a truly economic exploitation would involve high quality and regular supplies of well cut and conditioned lumber, veneer and logs for foreign export. A lower quality, but of considerably greater volume would be required for Brazil's coastal market. A healthy local outlet is essential to the other two.

In view of the recent advances made in the techniques of pulping mixed tropical hardwoods, clear-cutting for pulp at once suggests itself. Raw material, if acceptable within a wide range of species, can be delivered at points favorable to other requirements of a pulp industry at very low prices. This possibility is already being examined.

However, actual development of the Amazon is not obtainable by mere demonstration of the economy of technical method. If industry, rather than agriculture, is accepted as the sound basis for Amazon colonization, there arises at once the necessity to safeguard the investment on every side—human, political, and social. The old order will need to give way to a new. A new colonization will have to be developed; the techniques of its establishment clearly demonstrated and determined, and the lessons of previous failures turned to profit. Above all, the Amazon first needs an agriculture sufficient for its needs, to eliminate its dependence on outside and uncertain sources of food.

Finally, though industry may, when necessary draw supplies from upriver to alleviate local difficulty, the risks that are involved in a too exhaustive exploitation in the vicinity of the industry, must be clearly recognized. Local population pressure is the ubiquitous tropical problem in even the best regulated shifting agricultural system. The weak soils of the Amazon offer more than normal risk. Already there are significant examples of complete destruction which serve as a warning of what can happen if colonization demands too intensive land utilization. Until soil science offers some other solution to the problem of leached soils, rehabilitation by rotation allowing for regrowth of the jungle, continues to be the only means available to renew fertility in the soil. The jungle is primarily the creation of the climate, but for its re-establishment it still requires that sufficient nutrients be left in the soil after deforestation and use. As population pressure shortens the periods between successive reuse, the odds turn against the chance that the jungle can return to its former state in the face of leaching and the erosion that even on these flat lands can decide the issue. Natural balance in the Amazon has been demonstrated to be slender indeed, and the risk is ever present, that what has been popularly characterized as a "green desert" may easily be turned into a real desert.

THE DEVELOPMENT OF THE GROWTH RING IN WOOD OF *QUERCUS INFECTORIA* AND *PISTACIA LENTISCUS* IN THE HILL REGION OF ISRAEL

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INTRODUCTION

In recent years several investigations have been made in Italy on growth ring development (Maugini, 1949; Messeri, 1948; Minervini, 1948; Paolis, 1948, 1949, 1950). When the author first became interested in this subject, only one woody plant species had been investigated from this point of view (Oppenheimer, 1945) in the eastern Mediterranean region. This led the author to examine this aspect of the

growth cycle of trees and shrubs growing in the maquis[1] of Israel. The growth ring development in some of these, *Quercus ithaburensis* (Decne.) Boiss., *Quercus calliprinos* Webb, *Crataegus azarolus* L., *Pistacia atlantica* Desf., *Pistacia palaestina* Boiss., and *Ceratonia siliqua* L., has already been summarized in a previous paper (Fahn, 1953). The present paper adds two more species to the number of trees and shrubs already examined.

MATERIAL AND METHODS

Two specimens of *Quercus infectoria* Oliv., a deciduous tree, and three specimens of *Pistacia lentiscus* L., an evergreen shrub, have been examined. Both of these grow in the hills near Jerusalem. Chips of the outermost wood were removed with a chisel at ten intervals during the period from July 8, 1951 to October 3, 1952. Samples of *Quercus infectoria* were taken from a trunk, 10–12 centimeters in diameter, at chest height, and from twigs which were 2–3 centimeters in diameter. Twigs were 2.5 meters above the ground. In *Pistacia lentiscus*, the samples were taken from the main stem 30, 40, and 100 centimeters above the base, in the first, second and third specimens respectively. The diameter of the stems at these points was between 5 and 6 centimeters.

After boiling the chips in water for 15 to 30 minutes, they were cut transversely with a sliding microtome. The sections were then mounted in glycerine and examined unstained or after staining with *réactif genèvois* (alcoholic solution of Congo red and chrysoidin). Some of the sections were stained with safranin and mounted in Canada balsam.

OBSERVATIONS

Quercus infectoria Oliv.

Wood structure.—The wood is ring-porous; vessels are 18–250μ in diameter, solitary and in radial or oblique rows; lumens mostly radially or obliquely elongated, seldom

[1]The characteristic Mediterranean formation of densely growing high shrubs and small trees.

rounded; perforation of the vessel members simple; end walls of the members in the spring wood are horizontal or slightly oblique, while those of the summer wood are oblique to very oblique. The length of the elements was found to vary from 200—600μ; the elements of the spring vessels being mostly shorter than those of the summer wood; intervascular pitting alternate; tyloses present. Parenchyma is apotracheal appearing as irregular uniseriate more or less tangential bands, and partly diffuse. Chambered crystals occur in the parenchyma. The rays are homogeneous and of two distinct sizes: uni- and multiseriate. Multiseriate rays were found to be 24—40 cells wide and 3000—10,000μ high; uniseriate rays are 50—550μ high. Thirteen to sixteen uniseriate rays have been found in a millimeter. The large rays are commonly compound. Fibers are 850—1560μ long; the walls of some were moderately thick but the majority of the fibers are very thick-walled. Vasicentric tracheids were 400—820μ long.

Development of the annual ring.—(1) The cambium started to divide in the second half of March and cross-sections of samples taken on March 24 showed one row of newly formed vessels (fig. 1). All the fibers of the new ring were as yet unlignified. (2) Activity of the cambium began simultaneously in trunks and branches; (3) the unfolding of leaf buds commenced in the first half or middle of March, i. e., somewhat before the cambium started to divide; (4) spring wood was formed from the end of March to the beginning of May and (5) the cambium entered dormancy at the end of August. In late summer, incomplete false rings sometimes occurred. In a sample taken from the trunk of one tree, a false ring was observed while in course of formation on October 21, 1951. In another tree a very narrow additional growth was observed in a sample taken from a branch on September 6, 1951.

Pistacia lentiscus L.

Wood structure.—The wood is ring-porous; vessels are 15—120μ in diameter, solitary, in radial multiples of 2—4 and in more or less radial groups of many; perforation plates of

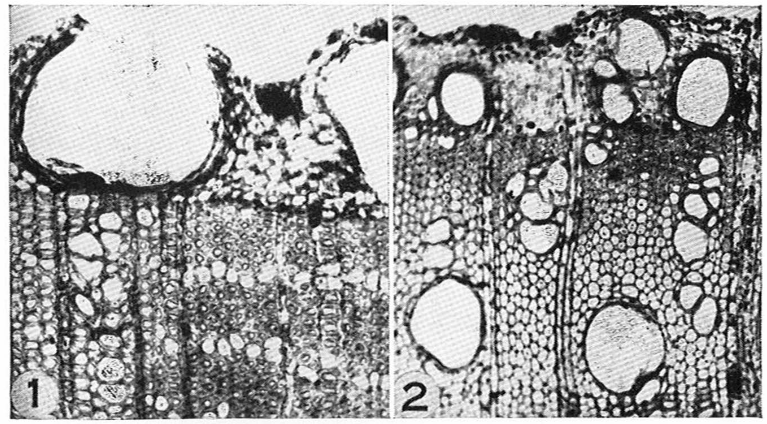

Fig. 1—2. Fig. 1. *Quercus infectoria*, cross-section, outermost wood at onset of cambial activity showing appearance of newly formed wood (March 24, 1952). ×115.—Fig. 2. *Pistacia lentiscus*, cross-section as above (April 9, 1952). ×115.

vessel members are simple; end walls are horizontal or slightly oblique in the vessel elements of the spring wood, and oblique to very oblique in the elements of the summer wood; the length of the elements was found to vary from 100–360μ, the elements in the spring vessels generally being the shorter ones; some of the vessel elements were "tailed," and tyloses were present. Alternate intervascular pitting was observed in the spring vessels, and in the summer vessels spiral thickenings were seen. Vasicentric parenchyma was found to be rather scanty in the summer wood. The vascular rays are heterogeneous, 2–3 cells wide, their height varying from 150–380μ. Seven to ten rays in a millimeter were usually found, and crystals were present in the upright cells on the upper and lower margins of the rays. Intercellular canals occur in the rays. Fibers are 250–680μ long, thin-walled in the spring wood, becoming moderately thick to thick-walled in the summer wood; all exhibit gelatinous inner layers.

Development of the annual ring.—(1) The cambium started to divide at the beginning of April, and in the samples taken on April 9, generally one new row of spring vessels was found (fig. 2). At this time the fibers among the vessels were, for the most part, not yet lignified. (2) Inflorescences began to appear in the first half of February, i. e., about two months before the cambium started to divide. The unfolding of the leaf buds commenced at the beginning of April, at the time when cambial activity started; (3) spring wood was formed during April and May and (4) the cambium entered its period of dormancy sometime between October and the beginning of November. On October 31, 1951 the cambium was found to be dormant in two of the three specimens examined, but was still active in the third one. On October 3, 1952 the cambium of one specimen had already become dormant, while the two others were still active. (5) Examination of some of the samples seemed to indicate that false rings may be formed in *Pistacia lentiscus*. However, owing to the extremely eccentric structure of the ring, it was very difficult to decide whether the narrow "unfinished" ring of the sample was false, or only the narrowest part of an ordinary ring. Further investigation should give clearer results.

Conclusions

In *Quercus infectoria*, cambial activity started at the end of March, simultaneously with the other two species of *Quercus* growing in the Israel maquis (*Q. ithaburensis* and *Q. calliprinos*). Furthermore, the time of commencement of cambial action in *Q. infectoria* corresponded to that in almost all of the tree species previously investigated by the author (Fahn, 1953; fig. 3). In *Pistacia lentiscus*, on the other hand, the cambium started to divide later than in the two

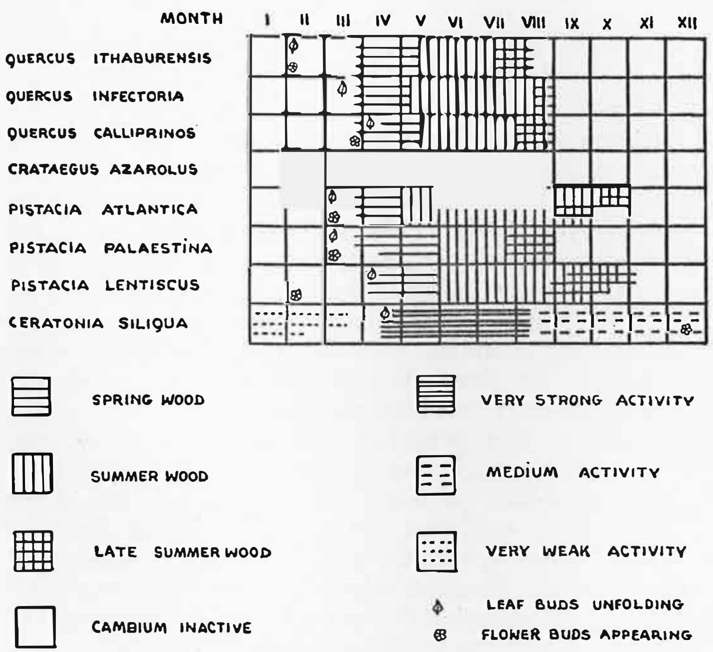

Fig. 3. Illustration depicting the development of the annual wood ring in *Quercus infectoria* and *Pistacia lentiscus* as compared with species previously investigated.

other species of *Pistacia* growing in Israel (*P. atlantica* and *P. palaestina*; Fahn, 1953). In these two species, the initial divisions of the cambium were noted at the end of March, while in *P. lentiscus* cambial activity was not observed until the beginning of April.

In *Quercus infectoria* the cambium remained active for five months, thus resembling the other two species of *Quercus* in this respect. However, in *Pistacia lentiscus*, as in *P. atlantica*, cambial activity lasted from six to seven months, whereas the cambium only showed activity for five months in *P. palaestina* (fig. 3).

A comparison of the course of the development of the growth ring with relevant climatic data (fig. 4) shows the following: in the species examined here, the cambium commenced division when the mean minimum temperature was about 10°C., and the mean maximum about 18°C. High activity of the cambium was seen to continue until sometime in May, when the mean minimum temperature reached about 15°C., and the mean maximum about 27°C. After this time, cambial activity decreased until in *Quercus infectoria* it ceased by the end of August and in *Pistacia lentiscus* by the end of October. From these observations and data it appears that cessation of cambial activity does not reflect the effect of temperature, but rather is related to the prolonged drought period which generally continues from May to October.

Summary

The anatomy of the wood and the development of the growth ring in *Quercus infectoria* and *Pistacia lentiscus* were examined and described. It was found that both are ring-porous, show pores in solitary and radial arrangements, simple perforation plates and alternate intervascular pitting. However, *P. lentiscus* exhibited paratracheal parenchyma, heterogeneous vascular rays and intercellular canals in the rays, whereas *Q. infectoria* was characterized by apotracheal parenchyma, homogeneous vascular rays, and lacked any radial intercellular canals.

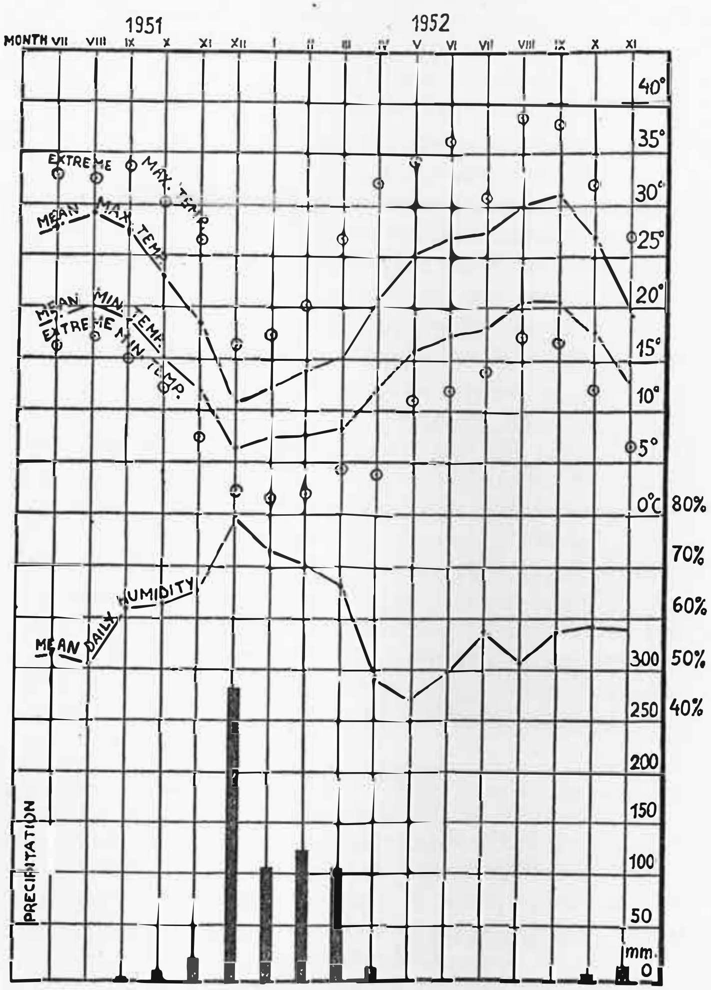

Fig. 4. Climatological data, Jerusalem; July, 1951 to November, 1952. (from Annual Weather Summary. 1951, 1952. Meteorological Service. Israel).

Observations on the rhythm of cambial activity yielded the following information: the vascular cambium began dividing at the end of March in *Quercus infectoria*, and at the beginning of April in *Pistacia lentiscus*. In *Q. infectoria* the growth ring was completed by the end of August; in *P. lentiscus* by the end of October or beginning of November.

From comparison of cambial activity in *Quercus infectoria* and *Pistacia lentiscus* with climatological data (fig. 4), it seems likely that cessation of cambial activity is brought on by the protracted dry period from May to October, rather than by the temperature.

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FOREST BUFFEN HARKNESS BROWN

1873–1954

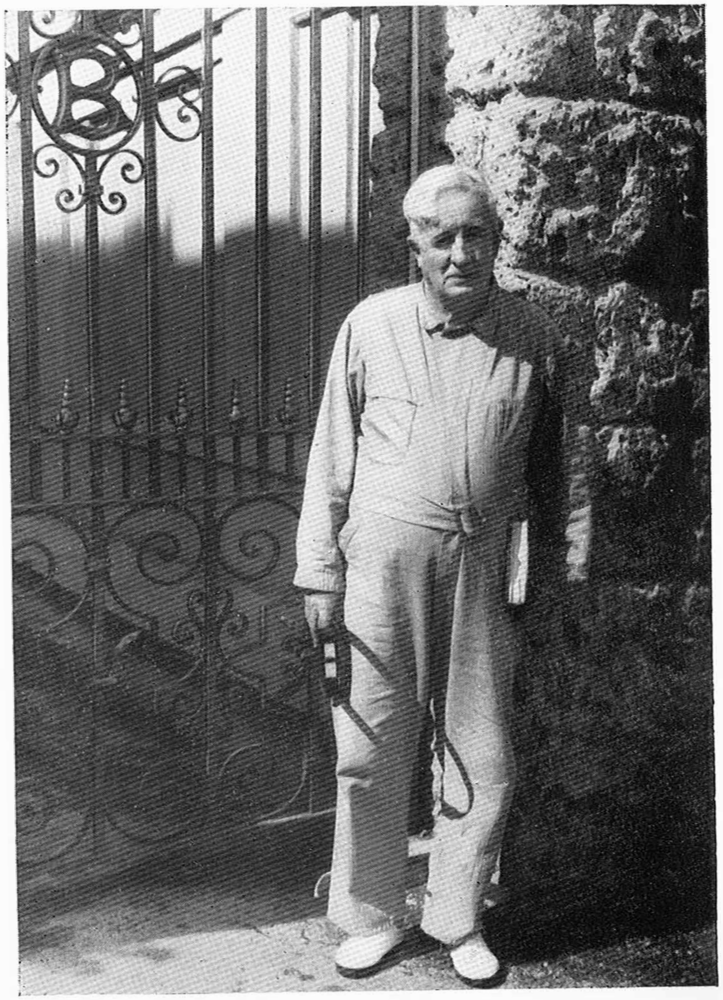
By Elizabeth D. W. Brown
Dayton, Ohio

Forest Buffen Harkness Brown died April 16, 1954 in Honolulu, Territory of Hawaii. He was born in Rushville, New York on December 11, 1873, the only son of Hiram and Alice Jane Harkness Brown. The latter was a direct descendant of Elder William Brewster. Reared in Ypsilanti, Michigan, where he was taken when three years of age, he received his early education in the Michigan State Normal College. At the University of Michigan in 1902, Brown received his A.B. degree, and his M.S. degree in 1903. He majored in botany for both degrees.

While a student at the University of Michigan he did extensive botanical and forestry surveys of various counties in Michigan, compiling notes, maps and photographs. These have been placed in the library of the museum at the University of Michigan. Also, he was a member of the University's forestry camp at Roscommon, Michigan. After graduation he was appointed a member of the forest survey team at Broken Bow, Oklahoma, under the auspices of the Bureau of Forestry, United States Department of Agriculture.

Forest Brown became an instructor in the Michigan State Normal College and also instructed in plant anatomy in the botany department of Ohio State University at Columbus. In addition to his teaching at Ohio State University, he was in charge of the University's botanical garden from 1911 to 1916 and carried on a heavy botanical research program in the cave regions of Hocking County, Ohio.

In 1918 he received his Ph.D. degree from Yale University. His thesis, *The secondary xylem of Hawaiian trees*, was based on a detailed microscopic study of sections of Hawaiian woods which he prepared. During World War I, while working for his Ph.D. degree, Dr. Brown assisted in the identification of wood used for airplanes by the United States Government. From 1918 to 1919, as a Fellow at Yale



Forest B. H. Brown at the courtyard gate of the Bishop Museum. Photo by Olaf H. Selling in the late 1940's.

University, he continued his research on an anatomical key to the species of *Tecoma*.

Susequently, Brown was appointed Botanist at the Bernice Pauhi Bishop Museum in Honolulu, T. H. From 1920 to 1922 he served as Botanist on the Bayard Dominick Expedition from the B. P. Bishop Museum to the Marquesas Islands. The results of his studies in the Marquesas were published in three volumes as the *Flora of southeastern Polynesia*. This monumental publication will always be regarded as the most lucid, reliable and exhaustive analysis of the flora in this area.

During World War II he acted as consultant and adviser to servicemen, some of whom were sons of old friends, who wished to do botanical work while stationed in the Pacific area. Dr. Brown continued to fill the position as Botanist at the B. P. Bishop Museum until he was forced to retire because of increasing physical disability. Despite his failing health, he continued research work for many years, retaining his contacts with the Museum. His last contribution to research was a study of the Cucurbitaceae with special reference to the ancient Hawaiian lagenarias as bearing on the migration of the Polynesians in the Pacific.

A Fellow of the American Association for the Advancement of Science, Brown was also a retired member of the Botanical Society of America. Brown was a charter member of the University of Hawaii chapter of Sigma Xi, the Hawaiian Academy of Science and the Hawaiian Botanical Society. When at Yale, he was affiliated with that university's Sigma Xi chapter. As a charter member, Brown had been active in the International Association of Wood Anatomists since its inception in 1930.

Forest B. H. Brown was married August 20, 1918 in New Haven, Connecticut to Elizabeth Dorothy Wuist, also a botanist. Mrs. Brown is an alumna of the University of Michigan (Ph.D., 1912). She alone survives him.

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YALE WOOD SPECIMENS DISTRIBUTED FOR INVESTIGATION[1]

In the past, this journal has published reports on the status of the Yale Wood Collections. The reports included lists of accessions, as well as wood specimens distributed for scientific investigations. Although at this time such detailed reports will not be undertaken, the editor feels that it may be of interest to include in this issue of *Tropical Woods* a list of specimens recently sent to various individuals and institutions throughout the world. The period covered is that from March 1, 1954 to March 1, 1955. It is intended that this practice be continued at irregular intervals in the future.

Bignoniaceae. Robert A. Claus, Department of Botany, University of Illinois, Urbana, Illinois: *Adenocalymma, Arrabidaea, Callichlamys, Campsis, Ceratophytum, Crescentia, Cydista, Enallagma, Ferdinandia, Macrodiscus, Melloa, Mussatia, Parmentiera, Petastoma, Pithecoctenium, Pleonotoma, Saldanhaea, Schlegelia, Spathodea, Tecoma, Tecomaria, Tynanthus.*

Combretaceae. Peter J. Jacobs, 135 Rock Ave., Gillingham, Kent, England: *Terminalia* species.

Cupressaceae. Pál Greguss, Institutum Botanicum, Universitatis, Szeged, Hungary: *Juniperus macropoda;* Sir Edward Salisbury, Royal Botanic Gardens, Kew, Richmond, Surrey, England: *Chamaecyparis, Cupressus, Thuja.*

Leguminosae. K. A. Chowdhury, Office of Wood Technologist, Forest Research Institute, P. O. New Forest (Dehra Dun), U.P., India: *Adenanthera, Aeschynomene, Caesalpinia, Calliandra, Colvillea, Haematoxylon, Inga, Leucaena, Robinia, Sesbania.*

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[1]Compiled by Mary E. Record, Assistant to the Editor.

Magnoliaceae. James E. Canright, Department of Botany, Indiana University, Bloomington, Indiana: *Magnolia, Manglietia, Michelia, Talauma.*

Pinaceae. Everett Ellis, School of Forestry, University of Idaho, Moscow, Idaho: *Abies* species; Raymond H. Hudson, 34 Arnold Ave., Coventry, England: *Larix, Picea.*

Podocarpaceae. Pál Greguss, Institutum Botanicum, Universitatis, Szeged, Hungary: *Podocarpus* species, *Saxegothaea;* Sir Edward Salisbury, Royal Botanic Gardens, Kew, England: *Saxegothaea.*

Tetracentraceae. Arthur H. Blickle (Thomas K. Wilson), Department of Botany, Ohio University, Athens, Ohio: *Tetracentron sinense.*

Thymelaeaceae. K. Ramesh Rao, Office of Wood Technologist, Forest Research Institute, P. O. New Forest (Dehra Dun), U. P., India: *Aquilaria, Dirca.*

Trochodendraceae. Arthur H. Blickle (Thomas K. Wilson), Department of Botany, Ohio University, Athens, Ohio: *Trochodendron aralioides.*

Miscellaneous. Harry R. Muegel (Cecile F. Simon), Department of Botany, University of Cincinnati, Cincinnati, Ohio: Miscellaneous woods within the range of *The new Britton and Brown illustrated flora* . . .

CURRENT LITERATURE

Chang, Ying-Pe. *Anatomy of common North American pulpwood barks.* Tappi Monograph Series. No. 14: 1-249. *fig.* 151. *tab.* 5. *graphs* 2. Published by Tech. Assoc. Pulp and Paper Indus. New York. 1954.

Extract of Author's Summary

The following twenty species were selected for this study—conifers: (1) *Abies balsamea* (L.) Mill., (2) *Larix occidentalis* Nutt., (3) *Picea engelmannii* Parry, (4) *Picea mariana* (Mill.) B.S.P., (5) *Pinus banksiana* Lamb., (6) *P. contorta* Dougl., (7) *P. elliottii* Engelm., and (8) *Tsuga canadensis* (L.) Carr.; dicotyledons: (9) *Acer saccharum* Marsh., (10) *Alnus rubra* Bong., (11) *Betula alleghaniensis* Britton, (12) *B. papyrifera* Marsh., (13) *Quercus alba* L., (14) *Q. rubra* L., (15) *Liquidambar styraciflua* L., (16) *Nyssa sylvatica* Marsh., (17) *Platanus occidentalis* L., (18) *Populus tremuloides* Michx., (19) *Salix nigra* Marsh., and (20) *Ulmus americana* L. Besides the above-listed twenty species, barks from an additional thirty-seven closely related species, mainly common North American hardwoods, were also examined for the purpose of comparison.

Material used for this study included the fresh specimens, cut at breast height, of at least three ordinary-sized trees for each of the twenty species. Young branches on the same trees were also collected. In addition to the fresh barks, dried specimens collected from various localities were also used.

For each of the twenty species a description was given under the following subjects: (1) a brief introduction, (2) general features, and (3) anatomical structure, including a brief account of young bark and full description of mature bark.

In addition to the composition and arrangement of tissue elements in a given bark, the shape and size of cells, their cell walls and contents, and their transformation including deformation, expansion, "lignification," "sclerification," and "redifferentiation" were all noticed. The mean length and standard deviation of sieve cells, sieve tube elements, and phloem fibers were computed for each species.

On a comparative basis, the significance of tissues and tissue elements of the barks studied was discussed. The chemical contents in the bark cells are just as specific and constant as the structure of cells in different species. Features of diagnostic value in the structure of coniferous and dicotyledonous barks were enumerated in separate tables. The basic differences in these two groups of barks were also compared. The pattern of bark structure in different species shows a definite range of variation and constant end products of the transformation of tissue elements. The distinctions between barks of different genera are quite clear. In many cases they are even agreeable with the taxonomic classification of a subgenus or section, as is demonstrated in the subgenera *Haploxylon* and *Diploxylon* of *Pinus;* the series *Castatae* Reg. and *Albae* Reg. of *Betula;* and the subgenera *Erythrobalanus* Spach and *Lepidobalanus* Endl. of *Quercus*, etc.

The effect of bark structure on the thickness of bark was discussed, as well as the relationship between the structure of the secondary xylem and that of the secondary phloem, especially with respect to their characteristics as pulping material. Some other problems related to bark structure in the field of chemical studies and silvicultural relations were mentioned briefly.

Chang, Ying-Pe. *Bark structure of North American conifers.* U. S. Dept. Agr. Tech. Bull. No. 1095: 1-86. *fig.* 37. *tab.* 1. Published by the Government Printing Office, Washington, D. C. $.35. 1954.

EXTRACT OF AUTHOR'S SUMMARY

This study, which was a 1951–1952 project of the U. S. Forest Products Laboratory, dealt with the comparative anatomy of North American coniferous barks. Material used for this study included old specimens from the collection of the U. S. Forest Products Laboratory and fresh material cut at breast height and from young branches on the same trees and sent to the Laboratory by various forest experiment stations of the U. S. Forest Service. All together, fifty-seven timber species distributed in fifteen genera of North American conifers were examined.

Using the modern accepted terms in plant anatomy, full descriptions of the bark of representative species in each genus are given in this bulletin. Supplementary summaries of the characteristics and differences among the important species in each genus follow each description. The comparison table and artificial keys to families and genera presented in this bulletin are based upon both the gross features and the microscopic structures of diagnostic value. Recognizing the limitations of bark identification by structure alone, the author briefly reports supplementary random preliminary chemical tests, especially on the coloration of bark extracts.

The significances of various tissues and the characteristics of bark in each genus of North American conifers are discussed. In general, their family and generic characteristics are quite distinct, constant, and rather naturally classified according to the suggested scheme. Somewhat overlapping diagnostic features are encountered only in the barks of Cupressoideae. The important structural correlations of wood and bark are summarized, primarily on the basis of comparisons between secondary xylem and secondary phloem of the conifers studied.

The relation of bark structure to other research problems in the field of forest products is briefly discussed. Some general suggestions are offered in regard to bark utilization and desirable chemical, physical, and pure anatomical studies.

Both of Dr. Chang's works as reviewed here are valuable contributions to our knowledge of the detailed bark structure of native forest trees. The works are significant not only from the botanical—especially taxonomic—aspect, but also from the point of view of forest products and forest industry. The many excellent photomicrographs and several drawings perfectly illustrate the detailed and accurate descriptions. The tables of diagnostic features as well as the artificial keys to genera based on microscopic (also macroscopic for conifers) bark structure present a good review of the material under study. At the same time these keys are useful for separating genera of North American conifers and some common hardwoods on the basis of their bark structure. The resulting deductions of the author are circumspect; the sources of cited literature, abundant.—*George K. Brizicky*, School of Forestry, Yale University, New Haven, Connecticut.

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TROPICAL WOODS

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CONTENTS

TROPICAL WOODS

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A REVIEW OF CHANGES IN THE TERMINOLOGY OF WOOD ANATOMY

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INTRODUCTION

When the Committee on Nomenclature of the International Association of Wood Anatomists published its *Glossary of Terms used in describing Woods* in 1933, the study of wood anatomy was in a very active phase and there was an urgent need to introduce some measure of uniformity into the spate of new terms and old terms used in new ways that were appearing in publications of that period. A measure of the success achieved by the Committee is the fact that the *Glossary* it produced has remained the accepted standard for over 20 years, and it is remarkable that nearly all the innovations then proposed, such as included and extended pit apertures, pore multiples and chains, aliform and confluent parenchyma, pit-pairs, etc., have become firmly established. Nevertheless, since the *Glossary* was published, further research has, of course, suggested changes and there have been occasional attempts to improve on the solutions then attempted for the more intractable problems. The International Association of Wood Anatomists is now proposing to prepare a revised version of the *Glossary* in English, as a preliminary to an illustrated version in several languages, and it is, therefore, an appropriate time to consider the changes that have taken place. Before discussing these in detail, however, it may be mentioned that possibly the most important trend in wood description has been recognition of the variation inherent in a species and the importance of basing descriptions on as many samples of a species as possible (Bailey and Faull, 1934). The old idea that the International Association of Wood Anatomists should emulate the systematic botanists and establish a single "type" wood specimen for each species has, it is to be hoped, been finally buried.

Rays

In the gymnosperms several new types of pitting between the ray parenchyma cells and the vertical tracheids have been distinguished, for example: "cupressoid" (Gothan, 1905), "pinoid" (Phillips, 1941) and "taxodioid" (Kräusel et al., 1917). Record's "piciform" has been changed to "piceoid" by Phillips (1941) on etymological grounds. "Indentures" (Kräusel et al.) in the horizontal walls of the ray cells are now well recognized as a diagnostic character, and the occurrence of "nodules" instead of pitting in the end-walls of ray and vertical parenchyma has also risen to some prominence as a character (Bannan, 1954; Barghoorn, 1941; Phillips, 1941).

In the hardwoods the most troublesome problem connected with rays has undoubtedly been the use of the terms "heterogeneous" and "homogeneous." In the *Glossary* the former was defined as, "A xylem ray composed of cells of different morphological types" and a homogeneous ray as, "A xylem ray composed of radially elongated cells." The basic weakness of these definitions is that they do not provide for the ray composed entirely of upright cells, such as the uniseriates accompanying markedly heterogeneous multiseriate rays, or the multiseriate rays in many shrubs and dwarfed species (Barghoorn, 1941). Kribs (1935) demonstrated a phylogenetic trend towards the elimination of either the uniseriate or the multiseriate rays together with a parallel reduction of the upright cells. He emphasized the importance of considering both multiseriate and uniseriate rays in any wood in which both occur, and established a series of heterogeneous and homogeneous types that appear to have a phylogenetic significance. One of the characters of his basic hetereogeneous type (Heterogeneous Type I) is the presence of numerous uniseriates composed entirely of square or upright cells. The linguistically obvious solution

of calling such rays "homogeneous" is thus peculiarly inappropriate. Kribs suggested using the term "homocellular" and "heterocellular" for individual rays, but for some reason limited "homocellular" to rays in which all the cells are elongated, and so missed the neat solution possible by including under "homocellular" all rays composed of a single type of cell, whether of upright cells or of procumbent cells.

At least two attempts have been made to define the terms "homogeneous" and "heterogeneous" on an entirely different basis. Chattaway (1949) suggested that pitting, cell contents and staining reactions can be used to demonstrate functional differences between different rows of ray cells, a well-known example being the pitting of the marginal ray cells of *Populus* where they cross a vessel. Such rays may be functionally heterogeneous though at present classified morphologically as homogeneous. Others, morphologically heterogeneous, appear to be functionally homogeneous. She proposed that the terms should be re-defined using the features that indicate these functional differences.

Reinders-Gouwentak (1950), on the other hand, has suggested using "homogeneous" and "heterogeneous" as synonymous with Janssonius' "*einfach*" and "*zusammengesetzt*," including under "homogeneous" any ray composed of only one tier or story, and as "heterogeneous" any ray composed of two or more stories, regardless of whether the rays are homocellular or heterocellular.

Metcalfe and Chalk (1950) used Kribs' types, but avoided the terms "heterogeneous" and "homogeneous" altogether as applied to individual rays, giving a description instead.

Another ray character that has attracted some attention is the feature known as "tile cells." As defined in the *Glossary* these cells have three essential characters: lack of contents, shape (including being of the same height as the procumbent cells), and occurrence (scattered among the procumbent cells). Chattaway (1933) studied these rays in the small botanical group of the Malvales in which they occur, and found a gradation between two extreme types, one of which, her "*Pterospermum* Type," technically does not fall within the *Glossary* definition, as the height of the upright cells is greater than that of the procumbents. She concluded that the most important characteristic of the tile cell, separating it from the ordinary upright cell, is its occurrence in rows alternating with the procumbent cells. It has been objected, however, that her "*Pterospermum* Type" cell lacks the extremely narrow radial width that gave rise to the name "tile cell."

Vertical Parenchyma

Interest in the recognition and classification of types of parenchyma was stimulated by the development of various punched card systems for identifying wood (Pfeiffer and Varossieau, 1946; Varossieau and Kukachka, 1951) and the need for more precise and more detailed headings. This has led to a critical revision of some of the existing terms and to the recognition of some new types. "Metatracheal" may be taken as an example of the former category. This term had fallen into disrepute owing to use in different senses by different authors. To replace it in the sense of independent of the pores–the alternative to "paratracheal"–the term "apotracheal" was suggested by the author (1937) and appears to have been widely accepted. Various terms have been suggested to replace "metatracheal" as the banded alternative to "diffuse," e. g. "tangential" by Hess (1950) and "banded" by Bailey and Howard (1941), but the term was retained in this sense by Pfeiffer and Varossieau (1946). The meeting of the International Association of Wood Anatomists (1951) in Stockholm in 1950 expressed itself in favor of "banded apotracheal."

It has been found desirable to distinguish between two types of diffuse parenchyma: (1) isolated cells scattered among the fibers, and (2) short, irregular, 1-seriate bands from ray to ray. The most generally acceptable solution for this appears to be to retain "diffuse" to include both these types and to subdivide it into "scattered" and "diffuse-in-aggregates," as suggested by Bailey and Howard (1941).

Among the terms for paratracheal parenchyma "vasicentric" is the only one that has attracted comment. Criticism has been on the score that, defined as a sheath, "vasicentric" cannot be applied to a few cells around a vessel that do not form a continuous sheath. It seems to be generally accepted that "scanty paratracheal" would be a satisfactory term for this latter type. A form of paratracheal parenchyma that was not distinguished in the *Glossary* is that associated with only one side of a vessel. Almost always occurring on the side away from the pith, it has been described as "adaxial," but, as this position is not quite invariable, the term "unilaterally paratracheal," as suggested by Hess (1950), appears preferable. This can be subdivided into "unilaterally aliform" and "unilaterally confluent," but not, of course, into "unilaterally vasicentric." The literal meaning of "unilateral," however, may suggest parenchyma on one only of the radial "sides" of a vessel, for example a single wing of aliform parenchyma. It has been suggested that it might be better to retain "abaxial" and "adaxial." Against this must be placed the convenience of a single term and the fact that it is not always possible in a section or small sample to determine which are the abaxial and adaxial sides.

The discovery by Chowdhury (1947) that so-called "terminal" parenchyma is often formed at the beginning of the season's growth, and not at the end, led him to suggest the term "initial" for this type. This seems to have been generally accepted, but a need has been felt for a single term to include both "terminal" and "initial," particularly for cases where the distinction between the two is difficult. The term "marginal" has been suggested for this purpose by Hess (1950).

Milanez (1932) has suggested the terms, holo-, hemi-, and merocrystalliferous for parenchyma strands composed wholly, half, or less than half, of chambered crystals.

Vessels

The terminology for vessels has remained remarkably stable. Woodworth (1935) has coined the term "fibriform vessel member" for the unusual type of vessel member found in the Passifloraceae, and Chalk (1933) has suggested differentiating between the "foraminate" and "reticulate" forms of multiperforate plates such as are found in the Bignoniaceae. Otherwise there appear to be no changes to record.

Fibers

Fibers have been the subject of two interesting discussions. The more important of these has been concerned with what constitutes a fiber-tracheid. As is well-known, there is a complete series from the type of cell that everyone would accept as a tracheid to the typical libriform wood fiber with simple, slit-like pits and considerable elongation. In between these extremes lie various intermediate forms, which, because they combine the elongation and pointed ends of the libriform fiber with the bordered pits of the tracheid, have been termed "fiber-tracheids." Opinions differ, however, as to just where in the series "fiber-tracheids" become "libriform wood fibers." This must be an arbitrary division and give rise to a number of borderline cases wherever it is drawn, as there does not appear to be any natural break in the series.

In the *Glossary* a libriform wood fiber was defined as, "Elongated, commonly thick-walled cell with simple pits. (Usually distinctly longer than the cambial initial as inferred from length of vessel members and parenchyma strands)."

A fiber-tracheid was defined as, "A fiber-like tracheid, commonly thick-walled with small lumen, pointed ends and small bordered pits having lenticular to slit-like apertures" and this contrasts with the definition of the "libriform wood fiber" particularly in respect to the lack of elongation and the presence of bordered pits. The importance of lack of elongation is emphasized by a note indicating that the term "fiber-tracheid" is intended to be applicable also to the late wood tracheids of gymnosperms. In fact, however, most of the dicotyledonous cells with bordered pits, for which this term appears to have been intended, are at least 50 per cent longer than the cambial initials from which they are derived. In practice these definitions tend to depend almost entirely on whether the pits are bordered or not, as the amount of elongation cannot be easily judged from sections, and the main practical difficulty lies in the decision as to when vestigial borders should cease to be classed as borders.

Reinders (1935) objected strongly to these definitions on the grounds that they place the distinction too high in the series and destroy the significance of the resemblance to tracheids in the lower group by including with them types that are essentially fiber-like. He has maintained that the fiber-tracheid, as defined by Janssonius, is of much greater taxonomic significance, being characteristic of whole families. Janssonius' definitions are, however, rather long and cumbersome, depending on a complex of characters, of which the most important appear to be, for the fiber-tracheid: bordered pits between fibers equally numerous on radial and tangential walls and with borders of about the same size as the pitting between vessels (or equal to the narrow width of scalariform pitting where this occurs), bordered pits to vessels common and similar to the intervascular pitting, and starch and septa absent.

Bailey (1936), who was a member of the Committee responsible for the *Glossary* definition, claimed (1) that one of the merits of this was that it separated off the specialized fiber—simple pits being "characteristic features of bast fibers, cortical fibers, pericyclic fibers and sclerenchymatous elements in general; whereas the pits of tracheary elements typically are bordered." The choice between these two conceptions seems therefore to depend on whether it is held to be more important to isolate the unspecialized end of the series or the specialized end. Reinders' argument that the unspecialized forms, as defined by Janssonius, are characteristic of natural groups, though true enough, can be countered by a similar claim for the more highly specialized fibers, as indeed appears to be implicit in Reinders' comments on the fibers in storied woods (1951). Logically it would therefore seem desirable to turn these intermediate forms, which spoil the groups at either of the ends of the sequence, into a neutral zone, with or without a name clearly indicating its intermediate character. The concept of the fiber-tracheid being intermediate between tracheids and libriform fibers has tended to conceal the fact that in the hardwoods fiber-tracheids and libriform fibers are all sufficiently specialized to have become primarily mechanical tissue and have probably ceased to play an effective part in the conducting system. It might, therefore be better to regard them all as "fibers," as opposed to tracheids, and to describe rather than give names to the differences in detail, as was done by Metcalfe and Chalk (1950) or to make three subdivisions, the two extremes retaining the names "fiber-tracheids" and "libriform wood fibers."

Another aspect of fibers that has aroused some discussion has been the definition of a "crystalliferous fiber," a term that was not included in the *Glossary*. The matter was raised in 1938 by Milanez, who questioned the correct application of this term by Chattaway in a paper on the Sterculiaceae (1937) and by Marco (1935) with reference to the Gynotrocheae. The point at issue was essentially whether elongation or septation is the definitive character of a crystalliferous fiber (as opposed to a crystalliferous parenchyma strand). The subsequent discussion made it clear that in a true crystalliferous fiber the crystals are separated by septa and not walls, but that intermediate forms may occur in which the cells resemble fibers in length and pitting, but contain crystals separated by walls, as in parenchyma strands.

Miscellaneous

Intercellular spaces.—Stern (1954) has recently proposed a simple classification of the various features concerned. He divides "intercellular spaces" into two categories: (1) Non-secretory (interstitial), and (2) Secretory. For the secretory spaces he follows the suggestion of Webber (1938) and separates cavities from canals; both of these groups are then subdivided according to contents, e. g. (a) Gum canal (duct) and (b) Resin canal (duct).

Latex trace.—This term has been used by Eggeling and Harris (1939) to describe the ribbon-like strands of tissue

containing latex tubes that run radially outwards at the internodes of certain latex-bearing trees (notably *Alstonia* spp. and *Dyera* spp.), and which have their origin in the traces from the leaves and axial buds. These have been called "latex passages" by Desch (1941), but this term seems suitable only for the empty passages left in dry timber after the original tissues have shrunk and been torn away.

Terms of size.—Numerical definitions for terms of size have been standardized by the International Association of Wood Anatomists for the lengths of vessel members and fibers (1937) and for vessel diameter and ray width (1939).

Conclusion

It was mentioned in the Introduction that the International Association of Wood Anatomists is planning to issue a revised version of the *Glossary*. One of the preliminary steps suggested at the Paris meetings of the Association last year was to issue to members for comment a compilation of the English terms and definitions recently prepared by the author for another purpose. It is hoped that the present article will make easier the discussion of general problems, such as what terms should, or should not be included, and will make clear the reasons for many of the changes and innovations that have been suggested.

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LINEAR RELATION OF FIBRILLAR ANGLE TO TRACHEID LENGTH, AND GENETIC CONTROL OF TRACHEID LENGTH IN SLASH PINE

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Introduction

Dimensions of conifer tracheids are important in that they provide a basis for comparison of various anatomical areas within trees and between trees, for estimation of strength and shrinkage properties of wood and pulp, and for the study of physiological development of trees. Sanio (1872) showed that in the main stems and branches of conifers, tracheids increase in size centrifugally until some constant size is reached; also the size increases from the base of the stem upward to a maximum at some height, then decreases toward the tip.

Although Sanio's laws were developed for *Pinus sylvestris* L., they are generally applicable to other conifers, with slight modifications in older wood (Bailey and Shepard, 1915; Kribs, 1928; Bethel, 1941; Liang, 1948; Bisset and Dadswell, 1949; Anderson, 1951; Bisset, Dadswell and Wardrop, 1951; Wardrop, 1954). It has been shown that a relationship exists between tracheid dimensions, and strength and shrinkage properties of wood (Gerry, 1915, 1916; Pew and Knechtges, 1939). More recent attempts have been made to correlate these properties with fibrillar angles, or angles of micellar orientation, in the secondary walls of late wood tracheids (Pillow and Luxford, 1937; Pillow, Chidester and Bray, 1941; Koehler, 1946; Cockrell, 1946).

Xylary cells are believed to attain their ultimate size before the secondary cell wall is laid down (Brown, Panshin and Forsaith, 1949; Kerr and Bailey, 1934). The formation of the secondary wall precludes further enlargement of the cell. It is reasonable to assume therefore, that the manner in which cellulose fibrils are formed is influenced by the size of the tracheid at the time of deposition. This view is shared by Preston (1948) and Wardrop (1951). Wardrop (1951) stated that "it is probable that the spiral organization of the entire secondary wall is determined by the cell length." Preston reduced this relation to the formula: $L = a + b \cot \theta$, where a and b are constants, L, the cell length, and θ, the angle of fibrillar orientation. However, it was found in this investigation that Preston's formula does not apply to slash pine (*Pinus elliottii* Engelm.).

Direct measurements of angles of fibrillar orientation in tracheids can be obtained only by methods involving high magnifications and complex staining or lighting techniques. Fibrillar angles may be determined indirectly from the direction of elongation of pit apertures and orientation of cleavage planes (Bailey and Vestal, 1937; Brown, Panshin and Forsaith, 1949). The establishment of a direct linear relationship between fibrillar angle and tracheid length would permit the use of less complex length measurements to calculate fibrillar angle, and would greatly reduce the time and equipment necessary to examine any property which appears to be a function of fibrillar orientation.

Slash pine was chosen for this investigation because its type of growth produces relatively wide growth rings with the late wood sharply delineated from early wood, and because of the availability of parent trees with progeny from controlled crosses. This study therefore falls into two parts, (1) the linear relation of fibrillar angle to tracheid length, and (2) genetic control of tracheid length.

Materials and Methods

Wood samples for the first part of the study were obtained from six slash pine trees, 21 to 23 years of age, located on a dry site on the Olustee Experimental Forest, Olustee, Florida, in the area known as the "Pecan Orchard." Disks were removed from one tree at 1, 3, 6, 12, 18 and 24-foot levels above the ground. One disk was removed at the 3-foot level from each of the other five trees. The material was immediately killed and fixed in a formalin-acetic acid-alcohol mixture. Samples of late wood from all growth rings were macerated in separate vials in Jeffrey's macerating fluid (equal parts of 10 per cent nitric acid and 10 per cent chromic acid) at room temperature. The resulting material was washed to obtain gray-white tracheids. A uniform sample of unstained tracheids from each growth ring was mounted directly from water into a drop of glycerin on a slide and a cover slip applied.

Both tracheid length and fibrillar angle measurements were taken using polarized light. A polarizing attachment was constructed for use with a photographic enlarger. Slides were placed between the two crossed polarizing filters and projected at 5× enlargement onto bromide printing paper. The resulting pictures showed black tracheids sharply differentiated on a white background (fig. 1). Forty intact tracheids were measured at random from each finished photograph with an expanded length measuring scale. The number to be measured was determined from a prior statistical estimation of variation within growth rings.

The above photographic process is versatile and requires no special skill to obtain optimum prints. An extraordinarily wide latitude is permissible in both exposure and developing times, the former ranging from 20 to 90 seconds and the latter from 60 seconds to 10 minutes or longer. This may be explained by the fact that virtually no light is transmitted by the enlarger except in planes which are rotated by the cellulosic components of the tracheid walls, and these image patterns are developed completely.

Fibrillar angles in the tracheids were determined from the direction of elongation of pit apertures and orientation of cleavage planes (fig. 2). The angles were measured directly under a microscope by use of a protractor eyepiece and a polarizing attachment modified by mounting the analyzer in the body of the microscope. Ten angles were measured at random from each slide.

For the inheritance study seven slash pine parent trees (G3, G4, G6, G8, G9, G10 and G11) and 44 eight-year-old progeny from controlled and open-pollinated crosses were used. The parent trees were growing in northern Florida and southern Georgia; the progeny were located in a plantation on the Olustee Experimental Forest. Using the maceration and photographic techniques described above, the average tracheid lengths in the fourth and sixth growth rings from the pith in the parent trees at the 4.5-foot level, and the seventh growth ring in the progeny at the 1-foot level were obtained. These heights and growth rings were selected because wood samples were available from a previous investigation of the genetic control of oleoresin yield and viscosity in slash pines in which the same trees had been employed (Mergen, Hoekstra and Echols, 1955). A conversion factor for reducing the level in the parent trees to that of the progeny was computed from a highly significant regres-

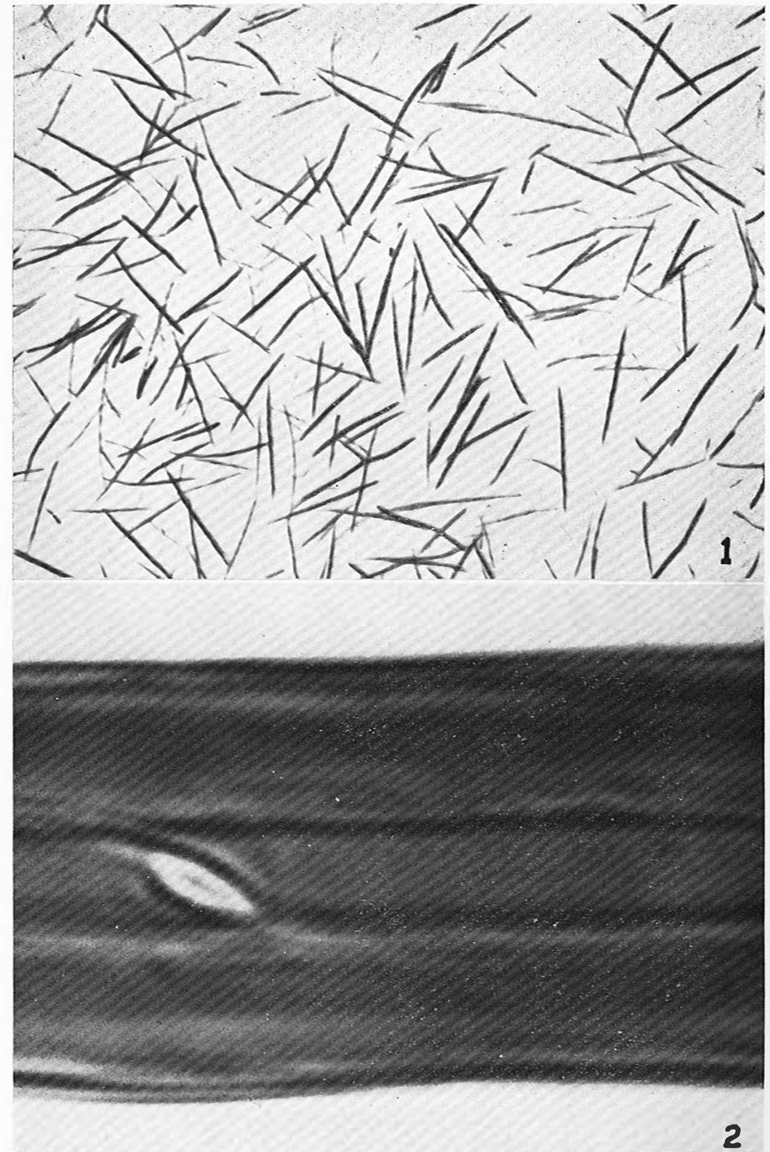

Fig. 1—2. *Pinus elliottii* Engelm. Fig. 1. Late wood tracheids under polarized light. ×5.—Fig. 2. Portion of late wood tracheid with elongated pit aperture indicating fibrillar orientation. ×1850.

sion of tracheid lengths at the 1, 3 and 6-foot levels in an average slash pine tree (fig. 3).

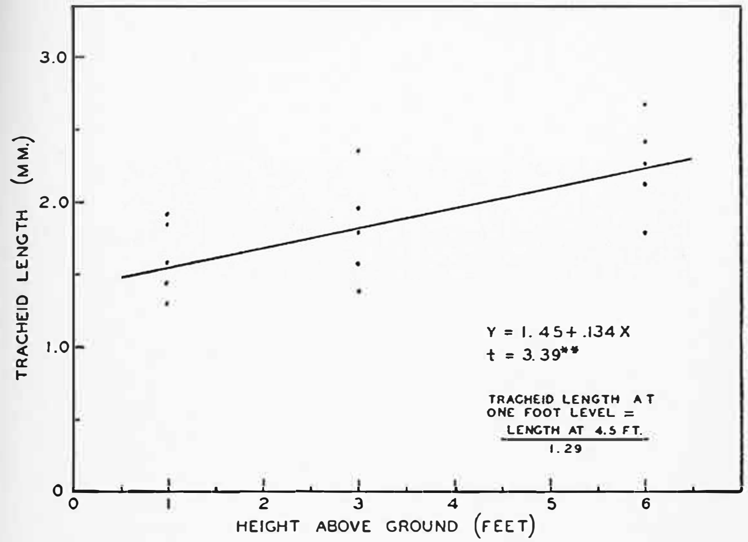

Fig. 3. Regression of tracheid length on height above ground. Dots at each level represent growth rings 3, 4, 5, 6 and 7 from the pith. Conversion factor for reducing 4.5 foot level to 1 foot is given. (** = exceeds mean square error 1 per cent level of significance.)

Results

Relation of fibrillar angle to tracheid length.—Individual fibrillar angle measurements ranged from 2 degrees in some tracheids in latest formed growth rings to 52 degrees maximum in the second growth ring from the pith at 3 feet above the ground. Lengths fell between 1.0 mm. and 5.5 mm. The relation of fibrillar angle to tracheid length is shown in figure 4, based on all heights measured, where each dot represents 10 pairs of measurements. A regression line was fitted using tracheid length as the independent variable and fibrillar angle as the dependent variable. The slope for the regression was very highly significant, considerably exceed-

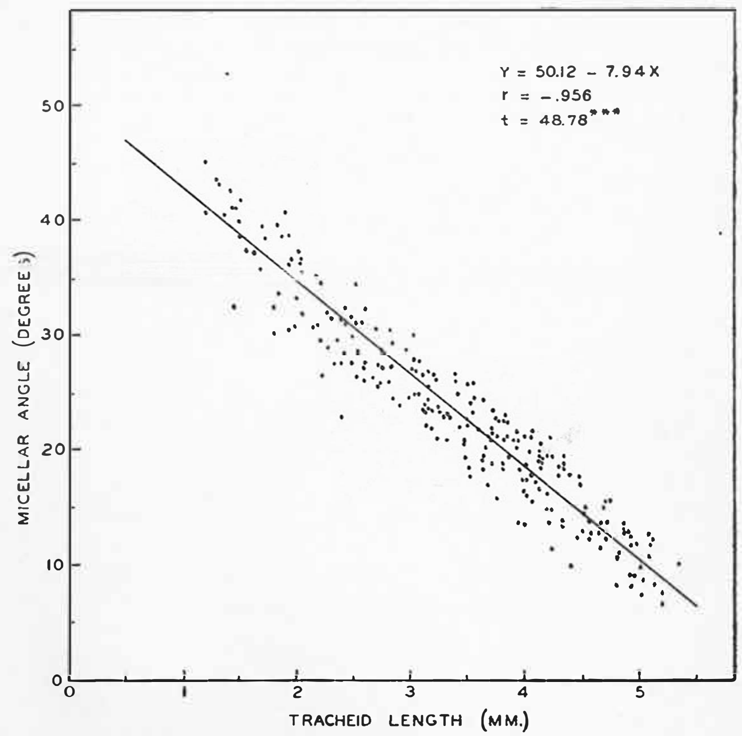

Fig. 4. Regression of micellar angle on tracheid length in slash pine based on 2240 pairs of measurements. (*** = exceeds mean square error 0.1 per cent level of significance.)

ing the mean square error at the 0.1 per cent level of significance. From the correlation coefficient, 91 per cent of the variation in fibrillar angle is completely associated with tracheid length, with only 9 per cent of variation attributable to independent causes.

Regression lines were fitted to individual series of measurements taken from all growth rings at the various levels in one tree and the 3-foot level in five additional trees (fig. 5). A very highly significant relation was found between fibrillar angle and tracheid length at each level.

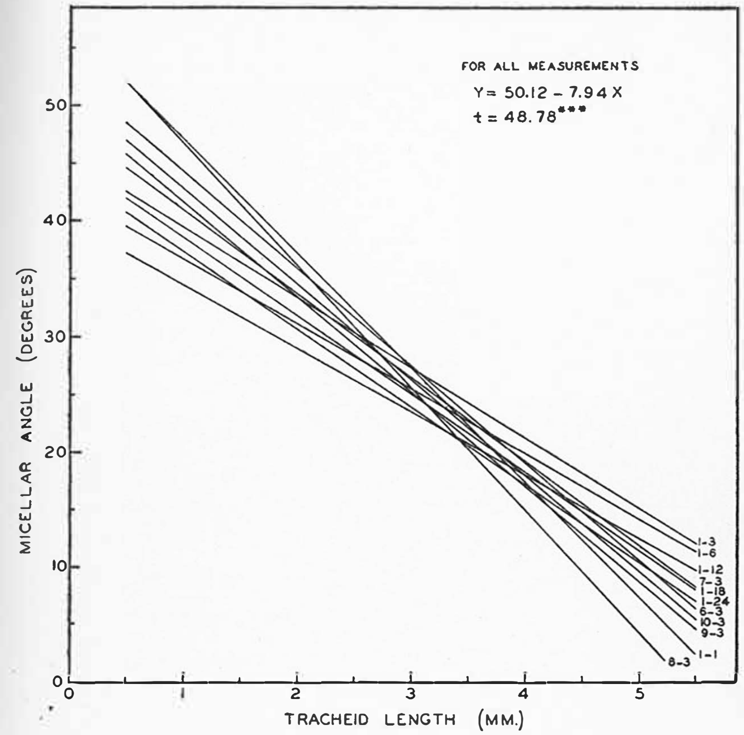

Fig. 5. Regression lines of fibrillar angle on tracheid length for six levels in one tree and one level in five additional trees. Each line exceeds mean square error 0.1 per cent level of significance.

The following formula was derived for computing the angle of fibrillar orientation in secondary walls of slash pine tracheids where tracheid length is known:

$$\theta = 50.12 - 7.94L$$

where θ = fibrillar angle in degrees, and L = tracheid length in millimeters.

Genetic control of tracheid length.—Average tracheid lengths in growth rings 4 and 6 from parent trees G3, G4, G6, G8, G9, G10 and G11, and tracheid lengths for ring 7 in the F_1 generations are diagrammed in figure 6. Twenty-

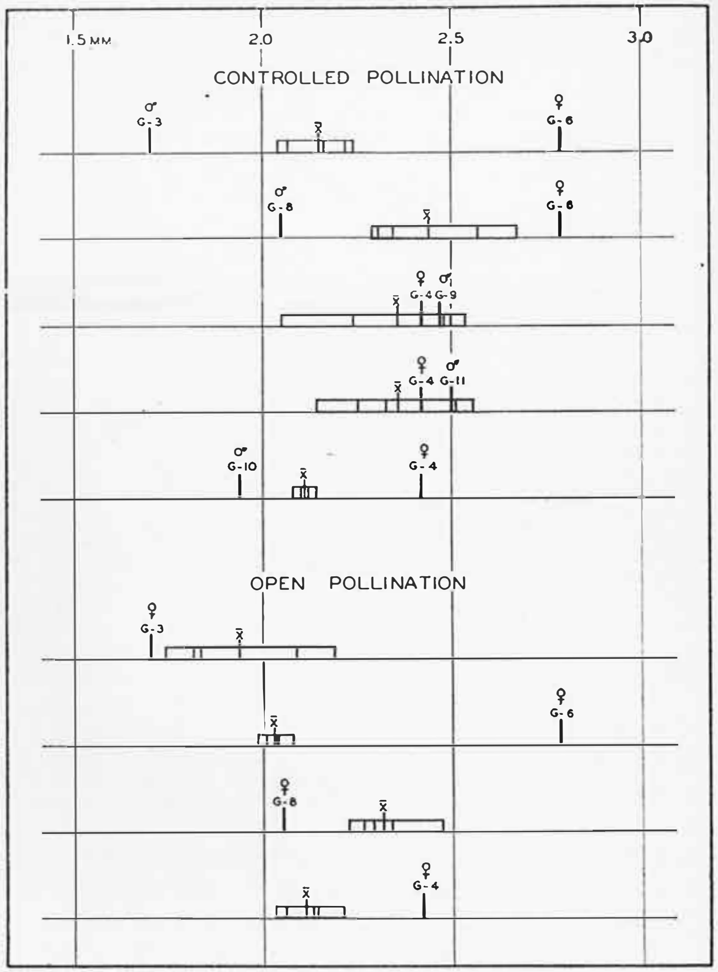

Fig. 6. Inheritance pattern for tracheid length in slash pine. Range in tracheid length for progeny is indicated by horizontal bars. ($\bar{x}$ = average for progeny.)

five of the F_1 progeny are from control-pollinated crosses between the above parents, and nineteen are from open-pollinated crosses.

The inheritance pattern strongly indicates that the multiple gene hypothesis of East (1910) is applicable to tracheid length in slash pine. The F_1 generation appears as a blend of both parents, as is typical of quantitative characters. The mean tracheid length of the F_1 progeny is approximately intermediate between the parents. When more than one male was crossed with the same female, the mean tracheid length in their progeny varied with the male parent. Progeny of the male with shorter tracheids also had a shorter mean tracheid length.

Where trees with longer tracheids were open-pollinated, the average length of progeny tracheids was lower than that of the female parent. Trees with shorter tracheids had open-pollinated progeny with average tracheids longer than those of the female parents. This demonstrates the equalizing effect of open-pollination in producing average progeny from parental deviates.

Discussion

The establishment of a direct relation of fibrillar angle to tracheid length lends support to the theory that orientation of fibrils, or micelles, depends upon length of the cell. By using the derived formula, fibrillar angles in slash pine tracheids can be determined from relatively simple length measurements. Further study is necessary to determine whether or not the basic formula, $\theta = a - bL$, can be applied to other species of pine.

No direct relation was found between tracheid length and ring width. The general trend was a regular increase in tracheid length outward from ring to ring at the same level and upward from the 1-foot to the 12-foot level; from 12 to 24 feet the average tracheid length remained rather constant in any one growth ring. Wide rings did not produce proportionately longer tracheids than did narrow rings. The greatest increase in length occurred at the transition from early wood to late wood within each growth ring.

A wide variation in the tracheid length at comparable points in slash pines was found to occur in parent trees as well as in those selected at random in the forest (fig. 6). Wardrop (1951) and Wardrop and Dadswell (1953) have shown that where tracheid length of the first growth ring of conifers was large, the tracheid length continued to be greater in subsequent growth rings than in a specimen in which the tracheid length of the first growth ring was small. They suggested breeding for long initial tracheid length. Results of this investigation indicate that such a breeding program would be genetically sound. Tracheid lengths follow a consistent pattern that appears to be rigidly controlled by the genotype. The effect of genes controlling length appears to be cumulative rather than dominant or recessive. Further breeding work and the use of a larger number of trees is necessary to definitely establish the effect of the independent genes which govern tracheid length.

Summary

A study of slash pine tracheids resulted in these findings:

1. A direct linear relation exists between fibrillar angle and tracheid length. This relation was reduced to the formula: $\theta = 50.12 - 7.94L$, where θ = fibrillar angle in degrees, and L = tracheid length in millimeters.

2. The relation holds for late wood of all growth rings from pith to bark and at all levels of height above the ground from 1 foot to 24 feet.

3. No direct relation was found between tracheid length and ring width.

4. Tracheid length appears to be under rigid genetic control. The inheritance pattern indicates that tracheid length is governed by a multiple gene series.

5. Open-pollination resulted in an equalizing effect which tended to produce progeny with average tracheid length.

6. Breeding for long tracheid length should be genetically feasible.

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UTILIZATION OF SOME OF THE WOODS IN ALTO PARAGUAY

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Paraguay is probably known to most people as an important source of the famous tanwood quebracho, the axe-breaker, which grows in the Chaco (the area west of the Río Paraguay). Here we are concerned with some of the lesser known woods of Alto Paraguay, which lies between the Río Paraguay and Río Paraná.

The Primavera colony was settled in Alto Paraguay in 1941 by the Society of Brothers. The Society was founded in Germany after World War I, when a number of people set out to live together as brothers, working and helping one another, sharing what they had and giving up their private possessions—a way of life that is in sharp contrast to the greed in the world today. More and more people joined the group and eventually a settlement was begun on the land near Fulda, Germany. Slowly the work prospered and contacts were made with friends throughout the country and abroad. A number of English people came to the continent and joined the group so that when the community was dissolved in 1937 by the Nazis, a new home was found in Wiltshire, England. People of various nationalities continued to come so that when World War II broke out there were many aliens in the group who were threatened with internment—a situation which meant the disintegration of the community. Eventually a new home was found in Paraguay and in ten ships most of the 300 members crossed the ocean to South America.

Primavera is a 20,000-acre ranch about equally divided between forest and grassland. The best timber had been exploited previously, yet much remained. Two sawmills were set up to provide lumber, with metal and woodworking shops. In one village a wood-turning shop was established. Two old steam engines were imported for power. Some of the forest had to be cleared to provide land for cultivation and to supply firewood, the only fuel available in a country that has no coal. A wood-gas plant is now in the process of being erected with a larger engine so that a more adequate source of electricity can be established. There is an ever-increasing need for power as well as a necessity to conserve the forest.

The forest is quite mixed, though the principal timber trees are yvyra-pita, *Peltophorum dubium* (Spreng.) Taub.; cedro, *Cedrela fissilis* Vell.; lapacho, *Tabebuia ipe* (Mart.) Standl.; urunde'y, *Astronium urundeuva* Engl.; curupa'y, *Piptadenia macrocarpa* Benth.; kirandy, *Aspidosperma quirandi* Hassl.; yvyra-ro, *Pterogyne nitens* Tul., and timbo, *Enterolobium contortisiliquum* (Well.) Morong. The main woodland is confined to the higher ground which has a superficial sandy soil and a ferruginous clayey subsoil. Trees are felled—with the axe—and are carted to the nearest sawmill. Here lumber is manufactured for sale. It then has to be transported fifty miles by truck to the nearest port, Puerto Rosario on the Río Paraguay, or prepared for use in the colony itself.

In Paraguay, iron, cement, etc., are always in short supply, so that wood is a very important item. Most of the houses (ranchos) are made of wood. In their construction urunde'y posts are first erected to support the round wood rafters of mbavy *(Casearia gossypiospermum* Briq.). Laths consist of strips of bamboo *(Guadua angustifolia* Kunth) held fast with lianas (e. g., *Adenocalymma marginatum* P. DC.). No deep foundations are dug, but the walls are simply erected under the roof supported on urunde'y beams which are laid in the ground. For these walls a wattle is made with cocotero palm strips *(Acrocomia totai* Mart.), and smeared with the red ferruginous clay which is later whitewashed. "Wattle and daub" is a method used throughout the tropics for constructing walls. Laths (wattles) are tied cross-ways with lianas to make a framework, and wet clay is smeared on and allowed to harden. The roof is thatched with grass *(Andropogon lateralis* Nees) dipped in red clay. Where sawmills are at hand, yvyra-pita boards, beams, rafters, and

laths are utilized. This is a heavy wood and tends to split, but is one of the most common trees. Furniture is made mainly from cedro, a lighter wood which is more easily worked, or peterivy, *Cordia trichotoma* (Vell.) Vell. *ex* Steud.

For many years wood-turning has been an important industry in the community. Bowls, cups, plates, beakers, candlesticks, lampshades, smoking sets, chess pieces and other items are manufactured. In Paraguay, the great variety of woods offers many opportunities. Nearly forty species have been tested and an assortment of wood samples was made available for visitors who often came to the shop maintained in Asunción.

The very mixed type of forest, with liana and thorny undergrowth, makes the transport of logs by alsa-primas—carts with two nine-foot wheels drawn by six or more oxen—a difficult job, especially in wet weather (fig. 1). One often encounters abandoned logs in the field where a cart bogged down. At the sawmill, logs are unloaded on a slightly sloping bank above a track of wooden rails.

Fig. 1. An alsa-prima used in Alto Paraguay for extracting logs from the forest.

After rough trimming with an axe to produce a plane surface for the frame-saw rollers, logs are rolled by hand or hooks onto a trolley and pushed to a hoist. Logs up to six meters in length are lifted and lowered on to the saw trolley which runs at right angles to the bank track. Logs are broken down by a vertical frame-saw and cut in the mill with pendulum, band and circular saws.

Preparation of lumber for the turning shop was a problem from the very beginning twelve years ago. Most of the woods are much harder than what had been used previously and it was thought that only peterevy and yvyra-ro could be used. Many mistakes were made. Wood dried outside was almost useless due to the formation of hair cracks; it was so hard that a piece of planer steel sharpened to 75° would immediately be blunted with the production of sparks. After many disappointments and losses under these pioneer conditions, it was discovered that the only way to use the hard woods was to saw each tree with special saws, set up according to the grain and peculiarities of shape. All raw materials had to be pre-turned. A log of urundey-para (*Astronium fraxinifolium* Schott) might have rich chocolate brown markings on one side only, and a four inch set up would be arranged to take it out–the remainder would be used for building.

Drying of pre-turned goods also presented difficulties and some woods were particularly notorious with regard to cracking and warping. Lapacho, or tayi, *Tabebuia ipe* (Mart.) Standl., was ideal for drying and often a pre-turned 6 by 2 inch piece, dried in a heated cupboard for several months would show, at most, a 2–3 mm. variation in circumference, with and across the grain. Others such as arayacan (*Eugenia* sp.) were completely useless. Some very beautifully figured woods are nursed through this stage by first boiling in water and then carefully drying for the first month or two. For some jobs air-dried planks three to four inches thick are needed. These are stacked in a simple shed to protect them from the wind. Without close coöperation between the sawmill and turning shop, lumber designated for turning would be very expensive.

The actual turning of the wood presented many difficulties and faced with a lack of tools, large files were used. Some breakages caused accidents but eventually high speed tool steel was smithed into suitable implements. This allowed turning at high speed with a modicum of sharpening.

As has been said, lapacho is the most favored wood from an artistic and sales point of view, but it has one objection–its irritating dust, which is very fine and penetrates the nose, lungs and skin. In the hot summer months when shirts or aspirators are uncomfortable, penetration is quite painful. The pain is increased when one ventures into the sun. Effects last half an hour or so unless the dye is washed out with soap. During this process one's color changes from yellow-green to bright red. This phenomenon, it is thought, is due to the yellow crystals of the dyestuff called lapachol. Extractions have yielded up to three per cent of these crystals and it is hoped to investigate possible uses more fully.

The rebuilding of the three villages consumes the greatest amount of timber produced. Most of the present structures must be replaced as they were rapidly and unsatisfactorily erected fourteen years ago. At present, there are about 700 people in the three villages, about half of whom are children. A sister community exists in Rifton, New York.

FOREST TYPE MAPPING WITH THE HELP OF AERIAL PHOTOGRAPHS IN THE TROPICS

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Vast areas of the tropical regions are covered with virgin forests, about which much has been written. As yet, however, exact data concerning them are scanty, mainly because of the inaccessibility of these nearly unpopulated areas, and the lack of good topographical maps. Different observers have evaluated tropical forests from highly valuable to worthless. What their true value is, or will be in the near future, is not yet known.

Until now only a few of the hundreds of tree species growing in tropical forests have been utilized commercially. The introduction of modern management to selected parts of these forests in an effort to increase the yield is needed to encourage large capital investments. It is here that forestry research can play its part, but with a different orientation than has been the case up to the present. Future management should require that research aim at securing the utilization of groups of tree species known to be growing in concentration, rather than the present practice of directing forest exploration to the location of single promising species based on laboratory examination. To orient this urgently needed research, the first necessity is the preparation of forest inventories. For this work the preliminary essential is the procurement of topographical maps.

With the development of aerial survey techniques we are in a much better position to learn something about the extension and location of forests. The forester now has an excellent tool which enables him to collect data about forest composition in a reasonably short time. It is no mean task to construct good topographical maps of areas partially or wholly covered by virgin tropical forests from vertical aerial photographs. During the preparation of such maps the photogrammetrist and the photo-interpreter must deal directly with one of the main characteristics of the tropical forest: the tropical rain forest is evergreen.

The rain forest as a whole never loses all its leaves at any time, and in consequence it is never possible, from the air, to see through the tree crowns to the ground. The evidence from which a map of the earth's surface must be drawn therefore, is the variation in the unbroken canopy of tree leaves, some tens of meters above the ground and not necessarily following its contours. Only in exceptional cases does the ground surface become visible on photographs as

seen by the occurrence of bare ground or rocks, open savanna, shifting cultivation, little settlements, etc. Lakes, rivers and creeks to about 15 meters in width are clearly visible, but the smaller creeks are mostly hidden by the tree crowns.

The first essential of a good topographical map is that it present a clear picture of the drainage system in the region being mapped. As long as one can see the surface of the rivers and creeks on the photographs, no difficulty is met in mapping them. However, when creeks are hidden by tree crowns, in most cases it is very difficult to locate them from the stereoscopic view of the pictures. It is here that evidence from the vegetation is the key to the topographic interpretation. Even in hilly country where the differences in elevation show most of the low places, inexperienced photo-interpreters have nevertheless often allowed the creek to run over the watersheds, by overlooking changes in vegetation. In flat country, with no or very slight differences in elevation, the location of creeks can be found only by vegetational studies supported by proper field checking.

Figure 1 shows a small creek with a border of alluvial marsh land on either side supporting a different type of vegetation than the surrounding dry land. These strips of marsh land can mostly be mapped correctly, as shown in figure 2, and the creek given its location in the middle. In contrast, figure 3 illustrates a low watershed with low tree vegetation, which can easily be mistaken for a strip of marsh land with a creek running through it.

The next major requirement of the topographical map is that it locate the borders of dry land, marsh land, and swampland. It has been proven in Dutch Guiana (Surinam) that all these borders can be drawn from aerial pictures. The same has been true (up to now) in the Amazon Valley. But only rarely are the borders sharply defined. Nevertheless, it is possible on the photographs to see and to delineate the zones (sometimes 100 meters, sometimes 500 meters in width) in which the vegetation changes from one type to another (fig. 6).

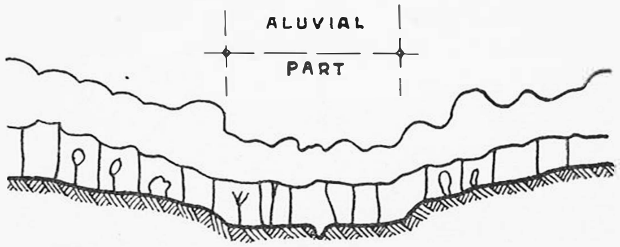


FIG. 1

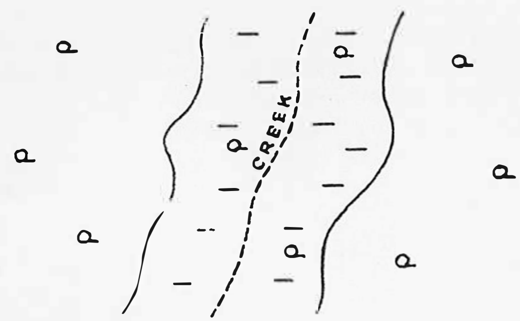


FIG. 2

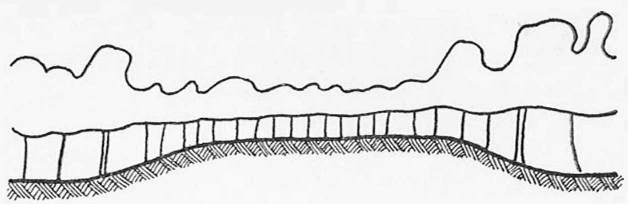


FIG. 3

For the complete topographical map the inclusion of contour lines is an established technique in temperate regions. However, drawing contour lines from aerial pictures of areas covered by an unbroken canopy of tropical forest is very difficult and in some cases simply impossible. In the flat, or nearly flat parts, slight differences (from 5 to 10 meters) in elevation of the ground are mostly completely hidden by the differences in heights of tree vegetation (fig. 3). Sometimes they are strongly exaggerated (fig. 4).

During forest sampling in Dutch Guiana and in the Amazon Valley it has been the procedure to estimate, as accurately as is practicable, the total tree height of the individual trees comprising the upper and understories. From the data thus obtained the average height of the upperstory trees may vary from 25 to 40 meters. The variation in average height of the understory trees is much less—from 19 to 25 meters. Figure 17 shows three main types of forest canopies: *a* low (savanna, catinga) forest with a smooth surface, *b* true high forest with coarse surface and *c* marsh or semi-savanna forest with smooth surface and some scattered bigger crowns.

As far as could be ascertained the height of the smooth surface of the canopies of the types *a* and *c* is the same. If in these two kinds of canopies it is possible to distinguish single tree crowns, it can thus be deduced, that (on a photo scale of 1: 40,000) the average height of the canopy is 20 to 25 meters. If it is not possible to distinguish single crowns the interpreter must be extremely cautious for the evidence may denote low scrubby forest. The smooth surface denoted in *a* or *c* may have nearly the same height as the understory beneath the big crowns of the true high forest in *b*. If the photogrammetrist is able to move the floating dot of his tracing instrument over the smooth surface of the lower

Fig. 1—3. Fig. 1. Profile of small creek with strip of marsh forest.—Fig. 2. Aerial view of profile in fig. 1. showing stream which is actually invisible from the air.—Fig. 3. Profile of a low watershed surrounded by a low forest type. On aerial photographs, this can easily be mistaken for a marsh forest traversed by a creek.

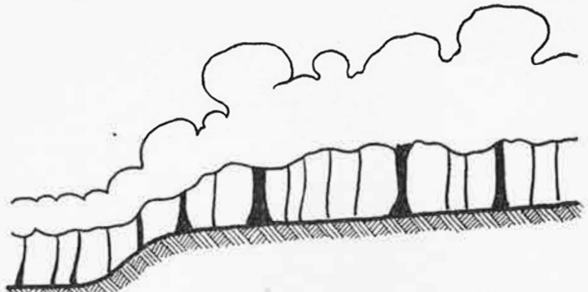


FIG. 4

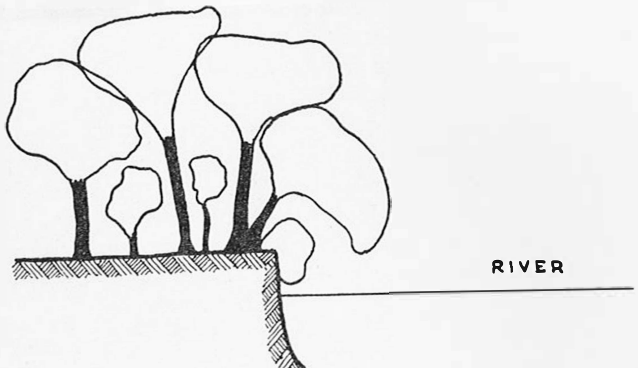


FIG. 5

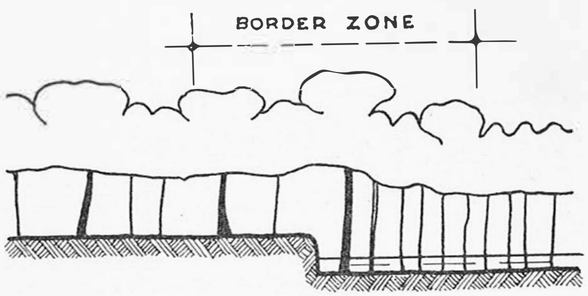


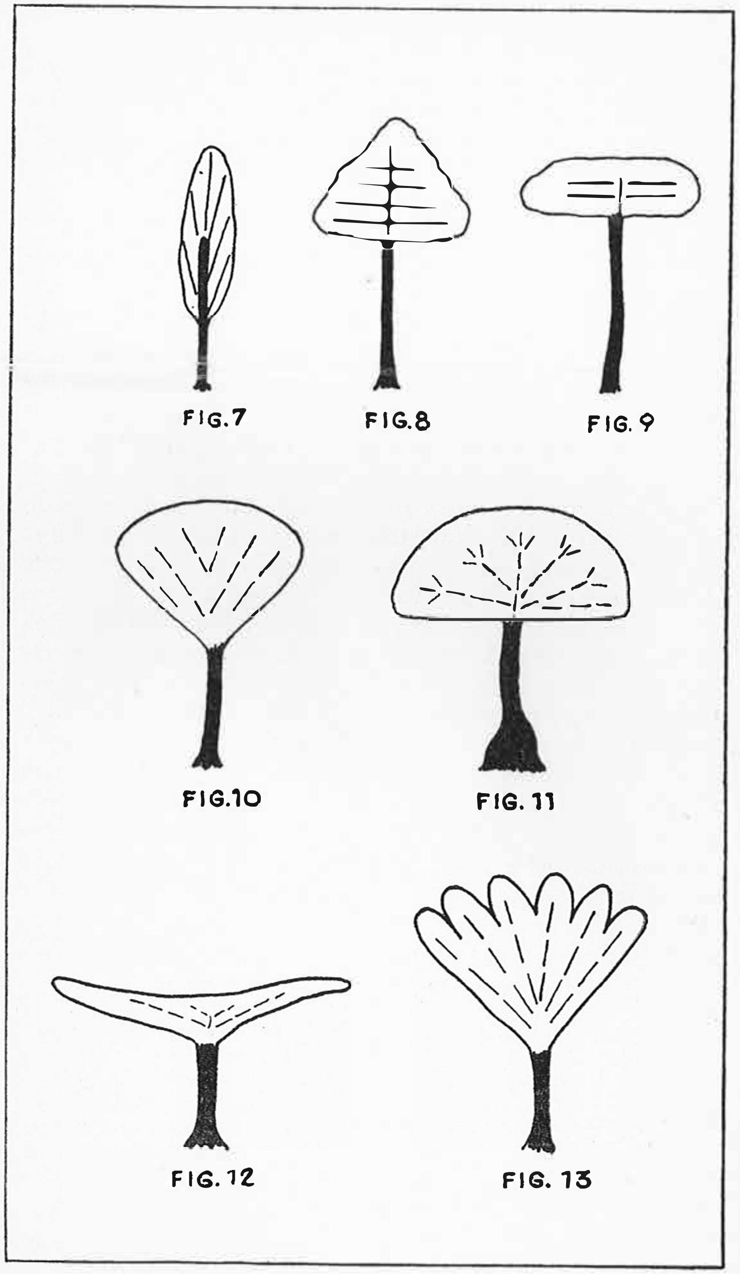
FIG. 6

forest and over the vegetation seen in the openings among the big trees of the high forest, then it is possible for him to draw reasonably correct contour lines from these kinds of pictures.

The general approach to the problem in the tropics is in essence the same as in the evergreen forests of the northwestern United States (Dodge, 1954) except that we cannot use crown diameter curves for correcting the heights of the trees, due to the multitude of tree species growing in tropical forests.

After long consideration it is still impossible for the writer to give a positive answer to the question of whether an improvement in the accuracy of topographical interpretation would be secured by employing larger scale photography in forested country of this kind. When detailed maps of river parts with waterfalls must be constructed, large scale photographs (1: 10,000) are needed to map correctly the exposed rocks in the water. If the borders of rivers are to be more accurately mapped, consideration must be given to the fact that on the photographs the real borders of rivers are never seen, only the border produced by trees overhanging the river margin (fig. 5). Where the vegetation is hanging in the water, at least 5 meters, and sometimes much more, on both sides of a stream may be overlooked. In Dutch Guiana the opportunity was available to work with photographs of both 1: 40,000 and 1: 20,000. Only in one instance was a substantial improvement in accuracy obtained in areas completely covered by tree vegetation. On the pictures scaled 1: 20,000 it was possible to distinguish a palm tree *(Maximiliania maripa)* which grows only on dry and semi-

Fig. 4—6. Fig. 4. Profile of rolling land where taller trees are aggregated on the higher land. This causes strongly exaggerated differences between the higher and lower land as viewed stereoscopically from aerial photographs.—Fig. 5. Profile of river border showing how overhanging trees may obscure the bank when viewed on aerial photographs.—Fig. 6. Profile of the transition from dry land to swampland. Although forest types may differ according to the land, the variation shown here is not strictly coincidental with the change in land.



dry soil. It was possible in this instance to draw the border between dry land and swampland more correctly (Suriname, 1953a). If larger scale photographs mean only bigger tree crowns on the photographs, with no additional detail to help in outlining more topographical distinctions from *under* the trees, it is probable that such larger scale photography will confuse the photogrammetrist and photo-interpreter, more than it will aid him.

With the topographical map it is possible to proceed with type mapping. The maps will have already delineated the extension and location of the main forest formations: dry land forest, marsh land and swampland forest. The experienced technician can add, by pure photo-interpretation, savanna (catinga) forest and secondary forest. However, further detail only results from field work. The intensity of field checks will depend to a great extent on the degree to which the interpreter can stratify variation in forest types on the topographical map from photo-examination. This is very difficult, and even impossible, if the forester is not familiar with the forests under survey. The main reason is that he sees an image of a very small part of the complex vegetation-form under study. Nevertheless the initial and continuing attempt to stratify the photo-evidence is an essential feature of the work, for it is never practicable to exam-

Fig. 7—13. Fig. 7. Profile of *candle* type crown. Example: *Tabebuia aquatilis*. This type appears as a small circular white spot on aerial photographs.—Fig. 8. *Conifer* crown type. Examples: *Virola* sp., some *Eschweilera* spp. On aerial photographs the *conifer* type crown appears. as a sharp-edged, whitish image.—Fig. 9. *Table* crown type. Example: *Cordia* sp. This type is very difficult to recognize from aerial photographs as crowns are mostly loose.—Fig. 10. *Parachute* crown type. Examples: *Sclerolobium* sp., *Dicorynia* sp., *Qualea* sp.—Fig. 11. *Umbrella* crown type. Example: *Ceiba pentandra*.—Fig. 12. *Disk* crown type. Example: *Parkia* sp. The disk type is easily identified from the ground, but is difficult to spot from the air. This is due to the very small leaves of the species. Occasionally this type is distinct on pictures and appears as a hazy whitish spot.—Fig. 13. *Broom* type crown. Examples: Some *Eschweilera* spp. and sometimes *Goupia glabra*. This type is difficult to identify and occurs as a black dotted image on aerial pictures.

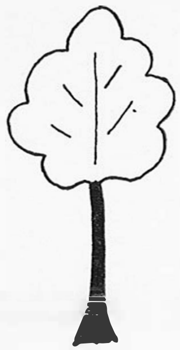


FIG. 14

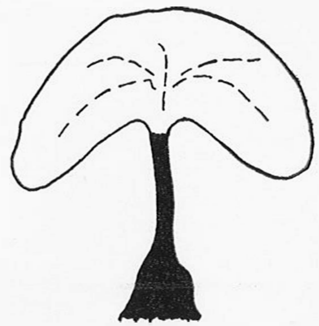


FIG. 15

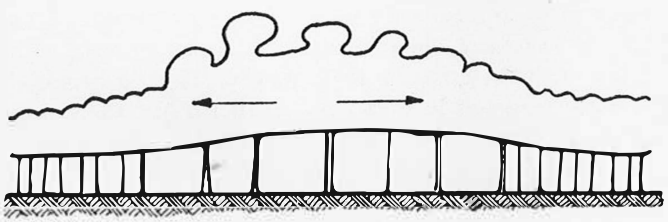


FIG. 16

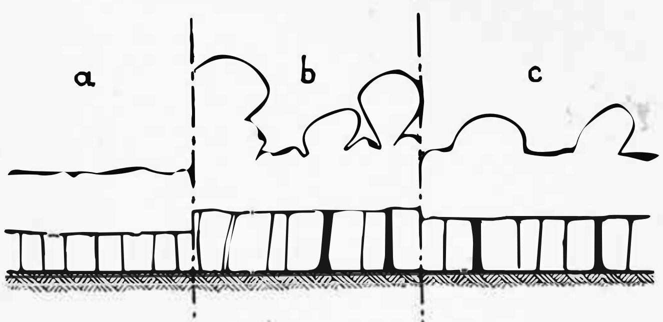


FIG. 17

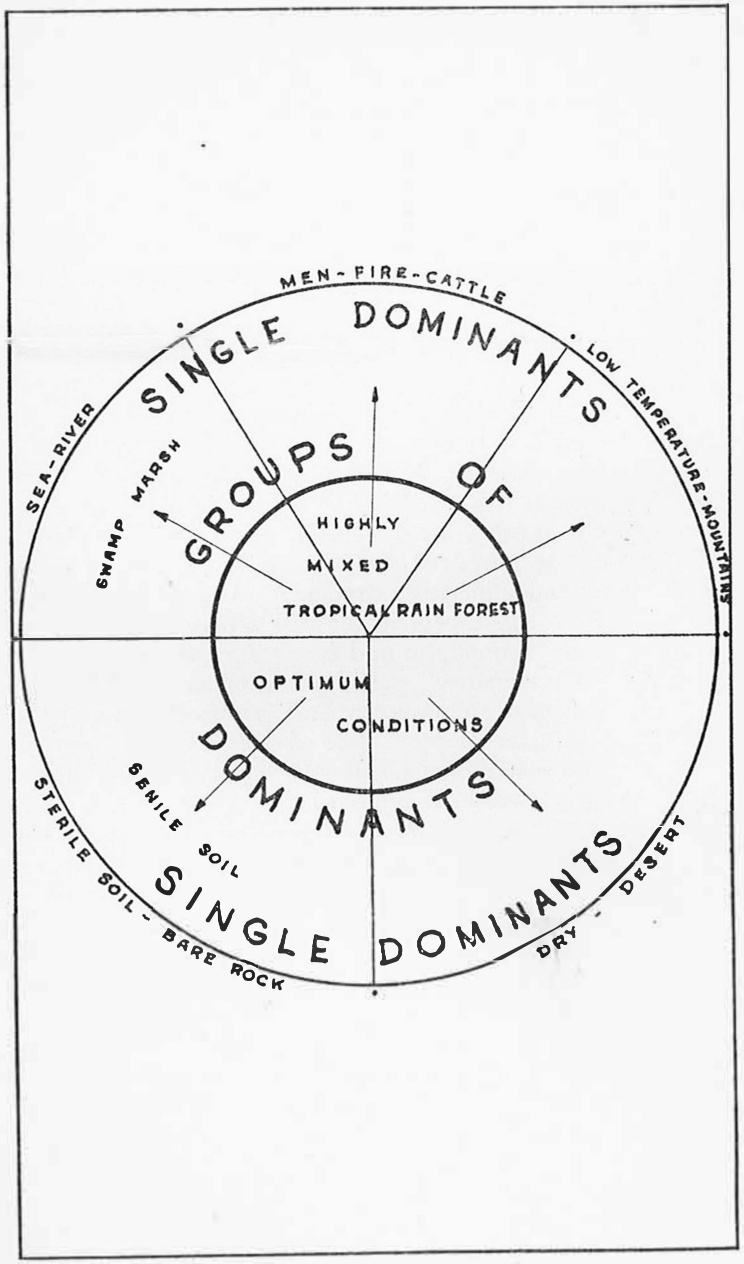
ine on the ground more than a very small percentage of what in tropical forests is a very complex form of vegetation.

Richards' (1952) three-strata structure for rain forests has been found entirely applicable for the purpose of photo-interpretation of the types under consideration; namely: *a.* the upper layer of big trees, *b.* the second layer of smaller trees and *c.* the small trees and saplings.

During sampling in Dutch Guiana from 1949 to 1953 only the trees from 25 centimeters in diameter (10 inches) and over at breast height or just above the buttresses, were measured (in the similar work being carried out at present in the Amazon Valley the same procedure is being followed). At the same time, trees are noted whose full crowns extend free above their asssociates. It is practically certain that these trees will appear with their full crowns exposed on the aerial photographs and they are designated as the upperstory trees. The rest of the measured trees are called understory trees. This upper and understory are identical with the *a* and *b* strata of Richards, except in the case where because of an opening in the canopy, an odd *b* stratum tree falls into the free crown "upperstory" classification, or an odd *a* stratum tree does not have a completely free crown. Because of the minimum diameter adopted, none of the *c* stratum trees will be measured or enumerated, and only very few, if any, of the *b* stratum trees will be overlooked.

In Dutch Guiana, of a total of 140—170 measured trees per hectare, an average of 30 fell into the upperstory classifica-

Fig. 14—17. Fig. 14. Profile of *cauliflower* crown type. Example: *Mora* spp.—Fig. 15. *Drooping* crown type. Example: *Parinari* spp. Only in the low forest is it possible to identify this species from aerial pictures.—Fig. 16. Profile of a high forest changing to a less mixed or pure forest. This transition in most cases means a change to a lower, poorer forest. The latter has the appearance of a degenerated high forest.—Fig. 17. Profile showing three different kinds of forest: *a.* low forest (savanna, catinga) with smooth crown surface, *b.* true high forest with a coarse crown surface, and *c.* marsh or semi-savanna forest with smooth crown surface and scattered protruding crowns. The heights of the smooth crown surfaces of *a* and *c*, and of the vegetation between the big crowns of *b*, are nearly the same.



tion. The main forest type now being studied in the Amazon Valley shows only around 20 trees in the upperstory of a total of 100–200 measured trees per hectare. However, the average height of the Amazon upperstory trees is 8–10 meters more than those in the Surinam types. This tends to explain the difference in numbers. When the forest canopy is of even height (which means mostly low) we can distinguish more single tree crowns in the upperstory than in the coarse forest canopies of the high forest. In the latter, the large crowns of the high trees hide most of what is growing nearby.

In measurements that have been made in Surinam and the Amazon Valley, the crown diameters range from 2 or 3 meters to 49 meters (the largest measured up to now). Comparing this with the data given by Ferree (1953), where the crown diameters of northern hardwoods (sawtimber forests) vary only from 5 to 35 feet (about 1.5 to 11 meters), it will be clear that the problem here of estimating the exact number of trees per hectare (1 hectare = 2.471 acres) from aerial photographs is much more complicated. And as a consequence, the same will be true for the gross volume.

In Dutch Guiana a close relationship was found between the crown diameter and the d.b.h. of the upperstory trees. There is a relationship between the volume of the upperstory and the gross volume of the forest, but up to July, 1953 the data were insufficient to determine the mathematical correlation (Suriname, 1953b). Unfortunately these relationships are of little practical value at present, for as yet there is not much interest in the gross volume of the tropical forests. Present interest is focused only on the few marketable species, and this makes inventory work still more difficult. At this point one of the other characteristics of the tropical forest must be considered: in tropical rain forests a multitude of tree species are present.

After studying aerial photographs of several millions of hectares from Dutch Guiana and the Amazon Valley, it can

Fig. 18. Transition from highly mixed tropical rain forest to pure stands through alterations in growing conditions.

be said that the highly mixed dry land forest is the most common and widespread. Only comparatively small areas of pure or substantially pure forests were found. These were mostly swamp and marsh forests, with a few patches on dry land. When mixed forests give way (slowly or abruptly) to less mixed forests, the reason for the change in composition is generally obvious. To understand this, the reader should consult figure 18. When the characteristic highly mixed tropical rain forest growing under optimum conditions is placed in the middle of this diagram and the conditions of ground-water level, soil, rainfall and temperature are altered, a change in forest composition results which ranges through "Groups of Dominants" to compositions with "Single Dominants." For the sector "Sea–River," the facts are well-known: when the dry land forests change to marsh forests (temporarily waterlogged soil) or to swamp forests (more or less permanently waterlogged soil) the forest composition becomes simpler and it is then that pure forest stands often occur. The same is true for the sectors "Low–Mountains" and "Dry–Desert." In both these instances the mixed forest can give way to forests of simpler composition.

For the section "Men–Fire–Cattle" the situation is more complicated. If the mixed dry land forest has been cut, burned or left alone for a long period it may perhaps revert to the original forest type via successions of simpler composition. Constant burning and cattle grazing can easily turn it into a kind of savanna with poor tree growth (as *Curatella americana)* or into a pure forest of a tree species resistant to fire and cattle grazing. Perhaps the least known is the sector "Sterile soil–Bare rock," which was encountered in Dutch Guiana and must also be dealt with very intensively in the Amazon Valley. The change is always obvious where the soil varies from clay, sandy clay or loam to brown and pure white sand. On white sand in Dutch Guiana two kinds of pure forests were found: *Eperua falcata* and *Dimorphandra conjugata.* The latter formed a thick layer of leaves on the ground and was even seen growing under nearly swamp conditions mixed with *Euterpe* on white sand. Similar con-

ditions exist in South Borneo, where there are patches of pure *Agathis borneensis, Dacrydium* and a kind of "heath" forest (Richards, 1952) growing on white sand in the lowlands. On rocky places, especially where the soil was covered with hard crusts or ironstone, the forest became very poor and was sometimes replaced by a thick layer of vines.

The less mixed and pure forests of the tropics are well-known and their composition has been fairly well described. The reason for this is that although the places where these types occur may be relatively inaccessible, it is possible to reach a reasonably good qualitative description, during short botanical expeditions. For the highly mixed dry land forest this is impossible, and any description has necessarily to be based on numerous quantitive observations: the so-called samples.

With aerial photographs at hand, sampling can be most effective. It is possible to locate the place of the sample and study the image of its canopy on the photograph. After six years of combined sampling and photo-study the writer reached the following major conclusions which may be of general interest:

(a) The pure and less mixed forests are easy to map from aerial photographs—each has its own special canopy image. When forest tree species which grow in these types of forests also occur in the adjacent high dry land forests, they are on an average mostly taller than in the pure or less mixed forests. In the purer type they may appear in the upperstory, even though they always, or mostly, grow in the understory of the high dry land forest. These forests often have the appearance of a degenerated high dry land forest (fig. 16).

(b) Indicating single trees from pictures is very difficult and highly speculative if the interpreter is not thoroughly familiar with the vegetation-form in which they appear. Until now it has been impossible to give reliable rules in this regard. When standing under a tree, one cannot see the sky through the thick layer of tree leaves; most probably the crown of that tree will appear as a white or a nearly white spot on a panchromatic photograph. Reddish leaves give mostly dark images, but there are many exceptions. In the author's experience, the form of the crown is a better indicator of species than the white or gray tone of the photograph. Tree crowns can be grouped to some extent into a number of main forms which in some instances typify single species, but in general identify a group of species of a special crown form (fig. 7–15).

(c) By grouping the trees from the samples of the high dry land forest into upper and understory trees it appeared that there were specific understory or "tolerant" trees. The only time these appeared in the upperstory was near (or in) a gap in the forest canopy caused by fallen upperstory trees. Data illustrating the prevalence of certain tree species in the forest strata are presented in table 1 (from Suriname, 1953a).

Table 1. Stratification of Some Forest Tree Species in Dutch Guiana

SPECIES	NUMBER OF TREES MEASURED ON 445 HA. SAMPLES (TOTAL AREA ABOUT 900,000 HA.)	NUMBER OF TREES IN UPPERSTORY	PERCENTAGE IN UPPERSTORY
	UNDERSTORY TREES		
Eschweilera longipes	3622	177	4.6
Eschweilera corrugata	3657	306	8.5
Tetragastris sp.	1592	89	5.6
Eperua falcata	6992	535	7.7
Swartzia spp.	2782	212	7.3
	UPPERSTORY TREES		
Dicorynia paraensis	2892	1317	45.5
Sclerolobium melinonii	972	549	56.5
Couratari spp.	1170	608	59.9
Goupia glabra	1935	788	40.7
Qualea rosea and *Q. albiflora*	689	349	50.6
Other *Qualea* spp.	768	496	52.8
Ocotea rubra	595	322	54.1

These data are comparable to those for the Amazon forests under study (unpublished). This knowledge facilitates

to a great extent attempts to recognize tree species from pictures, but makes type-mapping and inventory work very difficult when the dominants, or trees of economic interest, are found in the understory.

(d) For the different mixed forests studied in Dutch Guiana and the Amazon Valley (up to the present) characteristic compositions have been found to be constant over wide areas, showing distinct groups of dominant tree species. In Dutch Guiana the writer's observations were in agreement with Gonggryp and Burger (1948), that the really lush tropical rain forest did not occur in Surinam except perhaps in a few limited cases in the more mountainous areas. The same is perhaps true for the Amazon Valley. In the author's opinion it is better to follow Beard (1944) and call these forests (mostly growing on senile soils) "Evergreen Seasonal Forests" (in fig. 18, this designation would be placed just outside the inner circle).

(e) The question of climax composition of tropical forests has engaged the attention of many ecologists: are there sufficient young trees of the species which dominate and give the forests their typical composition, to maintain their character and composition? As long as it is not possible to determine the actual age of individual trees of the tropical forests, there is little, other than the evidence of diameter class representation, from which to suggest an answer to this question. Table 2 shows the frequency of certain dominant tree species as arranged according to diameters.

Table 3 presents data similar to that in table 2 employing the same species. However, these data are for another closely related forest type in which the species are only partly dominant.

These data show very clearly that the greatest number of trees is found in the smallest (youngest) diameter class. It is of course impossible to say that these diameter frequencies prove that there are enough young trees to replace the old ones. It can be said at most, that it is very likely, particularly as no evidence to the contrary was ever found in field study.

Table 2. Diameter Class Frequencies of Trees

DIAMETER IN CM.	UPPERSTORY TREES				UNDERSTORY TREES				PARTLY UPPER- AND UNDERSTORY TREES	
	1[1]	2	3	4	5	6	7	8	9	10
25— 34	78	207	79	151	455	547	166	129	120	247
35— 44	61	166	59	81	192	146	52	50	68	115
45— 54	56	99	26	38	127	48	13	21	58	61
55— 64	33	91	23	25	78	24	6	8	52	30
65— 74	37	59	20	5	29	7		4	27	7
75— 84	33	24	18	2	14	3			21	9
85— 94	32	15	24		11	1			10	2
95—104	13	6	13		3	1			2	1
105—114	7	2	5		2				2	1
115—124	8	5	4						3	
125—134	3		1							
135—144			1		1					
145—154			1							

Table 3. Diameter Class Frequencies of Trees

DIAMETER IN CM.	UPPERSTORY TREES				UNDERSTORY TREES				PARTLY UPPER- AND UNDERSTORY TREES	
	1	2	3	4	5	6	7	8	9	10
25— 34	91	135	9	28	419	229	89	27	33	74
35— 44	29	96	3	4	210	51	11	9	20	33
45— 54	25	50	1	5	67	6	2	3	7	4
55— 64	16	22	2		15	1	2	4	4	1
65— 74	14	12	1		10	1			3	
75— 84	5	4	1		3	1				
85— 94	6		1		1	1				
95—104	4	1				1				
105—114						1				

[1]To simplify tables 2 and 3, tree species are designated by number.

It is admitted that this picture of the diameter class frequencies is not complete; trees with diameters of 15—24 centimeters d.b.h. and saplings have not been enumerated for practical reasons. In the present Amazon work, Dr. R. Froes, botanist at the Instituto Agronomico do Norte in Belém, whose botanical work in the Amazon has had a 20 year background, is in charge of the purely botanical part of the inventory. He has been training his personnel so that in the near future it will be feasible to start counting the smaller

trees. It will be possible then, to include these countings with others employed in the usual forest sampling procedure.

Summary

Technically, the construction of topographical maps only by ground survey in tropics covered with dense forests, has become definitely obsolete. Aerial survey has largely replaced ground survey in these regions. Nevertheless the necessity of making forest inventories of small areas without the help of aerial photographs is still common practice in the tropics. The study of the possibilities of replacing forest inventories, at least in part by pure photo-interpretation, is in its infancy.

The Forest Service of Dutch Guiana has adopted the following system: detailed topographical maps are first prepared from aerial pictures. These are used as the bases for forest type maps made by photo-interpretation and ground reconnaissance sampling. The forest type maps are then used to carry out efficiently such detailed inventory as is necessary.

The Superintendencia do Plano de Valocizacão Economica da Amazonia has initiated the inventory and forest research work of the Amazon forests. In this work they are assisted by the Food and Agriculture Organization of the United Nations with a team of technicians. This team has at its disposition numerous trimetrogon-aerial-photographs, taken during World War II by flyers from the United States of America. By using these pictures to advantage, an attempt is being made to locate the valuable forests, where better (vertical) aerial survey work is most needed, and what kind of inventories have next to be done. Due to the very simple topography and the wide areas over which the forest types remain more or less constant in composition, the results of this work are very promising.

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ANOTHER METHOD FOR PREPARING HERBARIUM SPECIMENS OF *PICEA* AND *TSUGA*

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Herbarium specimens of spruce and hemlock usually consist of little more than naked twigs (sometimes with cones attached), accompanied by packets of loose needles. This is due, of course, to the well-known fact that the needles of these trees are deciduous when dry. Although several methods which might prevent the disarticulation of the needles have been suggested, all of them appear to allow room for improvement.

Sharp (1935) reported gluing a fresh specimen to an herbarium sheet, covering it with cheesecloth, and then pressing it. He indicated that he was able to retain about 60 per cent of the leaves by the use of this technique. He stated also that he had tried boiling specimens but with no success as far as retention of the leaves was concerned. Fosberg (1947) suggested that treatment with formaldehyde might prevent shedding of the needles from dried specimens of spruces and hemlocks. Johnson (1948) however, after experimenting with formaldehyde, reported that the treated specimens of

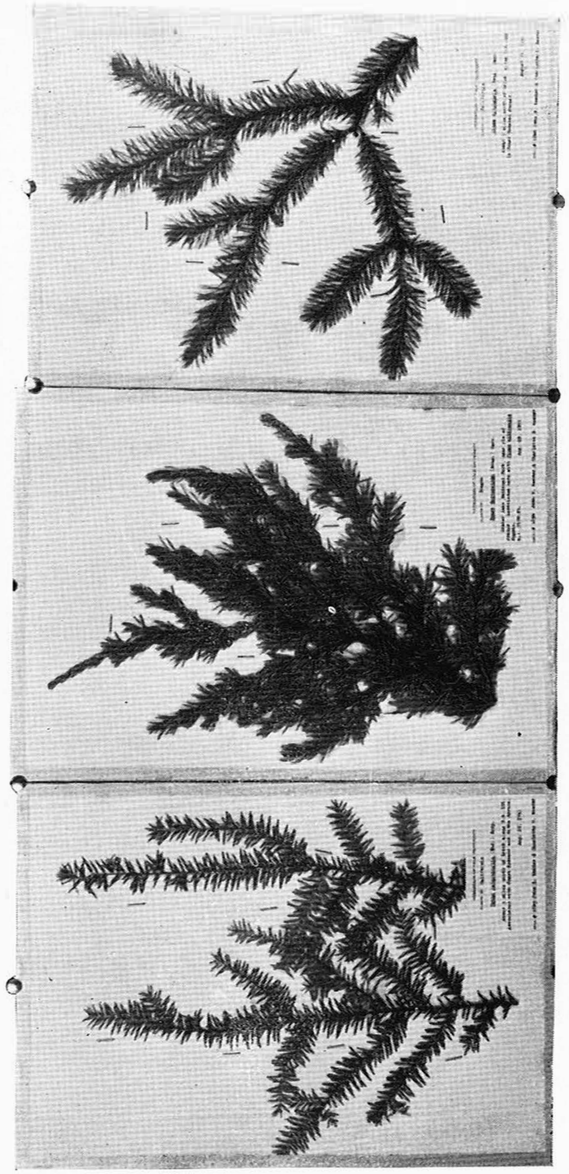

Fig. 1. Specimens of *Tsuga* and *Picea* prepared in 1951 according to the method described here. From left to right, *Tsuga heterophylla*, *T. Mertensiana*, *Picea sitchensis*. Note the numerous staples close to the specimens which are necessary in order to keep in permanent contact the celluloid, the specimen, and the cotton backing. Note also that the edges of the mounts are bound with masking tape.

these two genera lost their needles when dry quite as readily as the controls. Wherry (1949) indicated that covering the specimens with a plastic spray would prevent the leaves from falling. He remarked: "At last we have a means for keeping hemlock and spruce needles attached to the stem when pressed!" I have experimented with this method on material of native hemlock and have found it to be ineffective.

Although I have not tried it, the method suggested by Dr. Sharp appears to have some merit. Perhaps if a plastic adhesive were used, the technique would be even more effective. One disadvantage, it seems to me, is that it might be inconvenient to employ in the field.

What is most desired is a simple and effective technique, adaptable to field conditions, which will result in specimens as natural in appearance as is possible. In a short paper published a few years ago, Little (1952) implied that the problem is extremely simple of solution. All that is required is to place the fresh specimen in boiling water for a minute or more before pressing. He remarked: "For a few years I have successfully prepared herbarium specimens of *Picea* and *Tsuga* by this easy method." I have not seen specimens prepared by Dr. Little, but if he can prevent the disarticulation of the needles of spruce and hemlock merely by boiling, he is more fortunate than most of us. As pointed out earlier in this note, Dr. Sharp did not find the "hot-water treatment" to be of any value. On several occasions I have experimented with the method with little success. I found the treatment to have no effect upon hemlock, although a few needles are retained upon some spruces.

For several years I have been quite interested in a method for retaining needles on *Picea* and *Tsuga* dried specimens since I teach a course in dendrology, part of which is concerned with the conifers of North America. The usual herbarium specimens of spruce and hemlock are not only quite unsatisfactory for teaching purposes, but students are likely to find them rather amusing. Described below is a method which I have used for a few years in making acceptable specimens of these genera.

As the material is collected, it is placed in a plant press overnight in order to flatten it and remove some of the moisture. For each specimen a sheet of cotton about ½ inch thick is cut to fit a piece of cardboard the size of a regular herbarium sheet. Upon removal from the press, the specimen is placed upon the cotton, covered with a sheet of rather heavy celluloid, and the whole stapled securely together, using a heavy stapler. A sufficient number of staples must be used to hold the celluloid in permanent contact with the specimen and the cotton backing. When this is done properly, it is possible to retain all of the needles on specimens with flattened sprays, and most of them can be retained on any specimen. The edges of the mounts are allowed to remain open until the specimen inside has become thoroughly dry. Finally these edges are bound with masking tape.

This method was first used in preparing specimens of *Picea sitchensis*, *P. Engelmannii*, *Tsuga heterophylla*, and *T. Mertensiana* while I was on a collecting trip in the summer of 1951. The accompanying figure (fig. 1) shows three of these specimens as they appear today, almost four years later. Other specimens prepared in this manner which have been handled considerably by students for four years have suffered no loss of needles. Not only have these specimens retained their leaves beyond all expectations, but little or no discoloration has appeared during the drying process.

This method, while especially adapted to spruce and hemlock, might also be useful in preparing specimens of tropical woody plants which often shed their leaves and/or leaflets upon drying.

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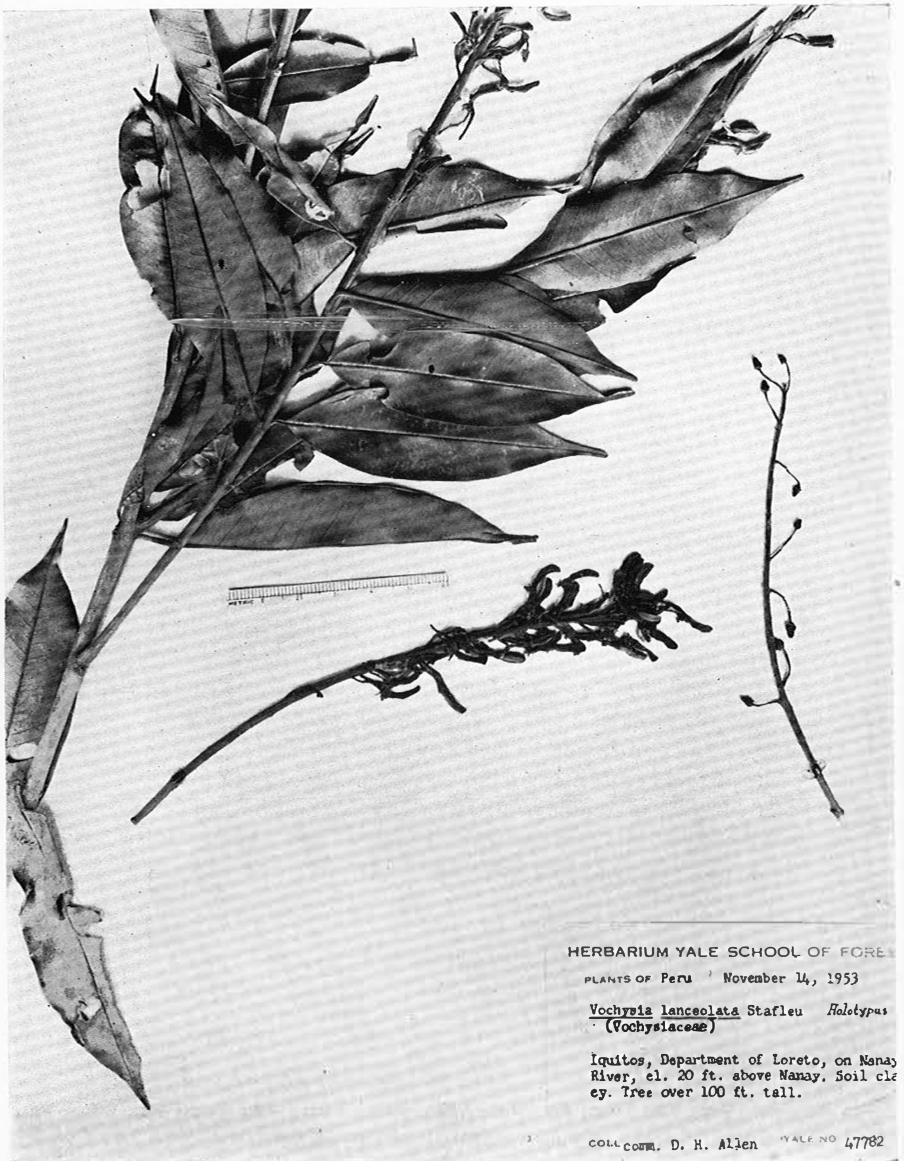

Fig. 1. *Vochysia lanceolata* Stafleu sp. nov.

VOCHYSIA LANCEOLATA SP. NOV.

F. A. Stafleu
International Bureau for Plant Taxonomy and Nomenclature, Utrecht, Netherlands

Vochysia sectio *Ciliantha* Stafleu, subsectio *Ferrugineae* Warming. A *V. vismiifolia* Spruce ex Warming stipulis incrassatis, foliis lanceolatis, longe acuminatis, floribus calcare longo modice incurvo, petalo intermedio stamen aequante, stigmate terminali parvo instructis differt.

Arbor magna. Ramuli juveniles, petioli, inflorescentia, foliorum pagina inferior indumento fusco-canescente instructi. Stipulae basi incrassatae, ovatae, acutae, circa 1.5 mm. longae.

Folia opposita, petiolo circa 7–8 mm. longo, lamina lanceolata, circa 7.5–9.5 cm. longa, circa 2–2.5 cm. lata, apice longe acuminata, basi obtusa, nervis supra haud conspicuis, lateralibus subtus modice prominentibus, majoribus utrinque 8–12 sub angulo circa 50°–60° e costa ortis a nervo limbali undulato margini proximo junctis, venulis subtus reticulatis.

Inflorescentia cylindrica, multiflora, cincinnis 2–3 floris, pedunculis circa 3–4 mm. longis, pedicellis 3–5.5 mm. longis; alabastra circa 7–9 mm. longa, haud recurva, obtusa, calcare circa 7–9 mm. longo, subcylindrico basi incurvo, apice nonnunquam modice recurvo, sub angulo nullo e pedicello orto, instructa.

Petala suboblonga, apice obtusa, intermedium circa 8 mm. longum, extus dense pilosum, lateralia circa 6–7 mm. longa.

Stamen pilosum, anthera circa 6 mm. longa, apice rotundata; filamento 1–2 mm. longo. Staminodia 0.5–1 mm. longa, ciliata. Stylus glaber, stigmate terminali parvo instructus.

Holotypus.—Peru: Nanay River near Iquitos; altitude 100 m., "quillo sisa," tree more than 100 feet high, on clayey soil about 20 feet above river; collector unknown (comm. *D. Allen*), flowering November 14, 1953; in herbarium U. (Duplicates, US. 2104976: Y. 47782 (fig. 1).

PHYSICAL AND MECHANICAL PROPERTIES OF THE WOODS OF *MANILKARA CUNEIFOLIA* AND *BAIKIAEA MINOR* FROM UGANDA

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Logs from five trees each of *Manilkara cuneifolia* Bak. and *Baikiaea minor* Oliv. were selected by the Forest Ecologist of the Forest Department, Uganda, East Africa, in the Maramagambo forest. These were dispatched to the Forest Products Institute, Pretoria, South Africa, for a report on the physical and mechanical properties of the timber.

Manilkara cuneifolia Bak.; Sapotaceae; other names: nkunya, mukunya, ngambo.

Characteristics and Properties

In general the logs must be considered difficult to saw and sawing on a framesaw can only be done at a very slow rate of feed. The difficulty in sawing is due to the extreme hardness of the timber and a tendency of the sawdust to clog the teeth of the saw.

Despite its high density, the timber seasons very well. None of the common seasoning defects such as warping, twisting, cupping and surface checking take place in the air-seasoned material. In kiln seasoning checking is severe, especially in the top boards, and the use of a mild schedule is therefore recommended.

Air-dry weight is 66 (61—71) pounds per cubic foot (table 1). It is one of the hardest woods handled at this Institute, having an average side hardness of 3,430 pounds (table 1). The wood is straight-grained with a fine even texture and is tasteless and odorless. The sapwood is pale pink giving way gradually to a deep pink to pinkish-red heartwood.

The dry wood saws cleanly but is most severe on the saw teeth. It planes to a fine surface without any tendency of the fibers to lift. It is most difficult to screw despite initial drill-

ing and generally is very severe on all tools. It must be considered as a very difficult wood to work.

Table 1. Specific Gravity and Shrinkage

Green weight (44.1 per cent m.c.)	76.7 (75—79) lb. per cu. ft.
Oven-dry weight	62.5 (58—68) lb. per cu. ft.
Air-dry weight (10 per cent m.c.)	66.0 (61—71) lb. per cu. ft.
Radial shrinkage (to 10 per cent m.c.)	3.7 (2.8—4.7) per cent
Tangential shrinkage (to 10 per cent m.c.)	5.1 (4.4—6.4) per cent
Longitudinal shrinkage	
outerwood	0.30 per cent
core	0.20 per cent
Volumetric shrinkage to oven-dry	14.7 (13—17) per cent

As seen in table 1, the small difference between the radial and tangential shrinkage probably accounts for the good seasoning qualities shown by this timber.

Table 2 reflects the mechanical properties of *Manilkara cuneifolia* adjusted to 12 per cent moisture content and using the standard methods.

Table 2. Mechanical Properties

PROPERTY	UNIT	NUMBER OF TESTS	VALUES AT 12 PER CENT MOISTURE CONTENT MAXIMUM	MINIMUM	MEAN
Density	lb. per cu. ft.	48	72.9	59.7	64.4
Modulus of rupture	p.s.i.	48	26,665	15,921	21,824
Fiber stress at P. L.	p.s.i.	47	16,384	7,235	11,634
Modulus of elasticity	p.s.i.	47	3,716,000	2,255,000	2,971,000
Maximum crushing strength in compression parallel to the grain	p.s.i.	35	13,158	8,401	11,422
Hardness					
end	lb.	49	4,569	2,713	3,686
side	lb.	49	4,424	2,458	3,430
Shear parallel to the grain	p.s.i.	35	3,517	1,469	2,294

As the figures in table 2 indicate, this timber is very heavy, strong and hard. There was little or no tendency to split during the performance of the Janka hardness test as quite often occurs when testing such dense material.

Macroscopic Structure

Growth rings are not clear, but occasionally apparent and poorly defined, due to a denser late wood band and closer parenchyma bands. Parenchyma is abundant, appearing as fine regular metatracheal bands, poorly visible to the naked eye but clear under a lens; more or less 50 bands to a centimeter and more numerous in the late wood. Pores are numerous, evenly distributed, visible to the naked eye, but not clearly defined, moderately small, in radial multiples of two to many and often staggered so as to create an echelon effect. The wood is difficult to cut so as to produce open pores. Some pores are filled with a whitish chalky deposit. Rays are numerous, minute but clear under a lens and one pore width apart.

Recommended Uses

Due to the generally defective nature of the logs, difficulty in sawing and working and its heavy weight, this wood is not suitable for joinery work, furniture, etc. A small quantity of parquet and strip flooring was manufactured which turned out very well, producing a very hard, heavy, attractive floor. However, the wood was very severe on the cutters. The wood is also reported to be resistant against marine borers. Specimens are on test in Durban Harbor, but the tests have not yet been of long enough duration to enable any conclusions to be drawn. The heartwood is also reputed to be resistant to termites and decay. Combined with its good seasoning characteristics, this wood should be suitable for railway ties, marine piling and heavy construction.

Baikiaea minor Oliv.; Leguminosae; other names: mcau, nkobakoba.

Characteristics and Properties

The logs sawed with great difficulty on a framesaw. The sawdust was inclined to clog the saw teeth causing heating and displacement of the saw blades. It was necessary to use a very slow rate of feed.

The timber seasons well. Boards 1⅛ inches thick air-seasoned for 4 months to 12 per cent moisture content showed no seasoning defects except for minor end splitting. Thicker material (2¼ inches), first air- and then kiln-seasoned, also dried well, although many of the boards containing the pith split down the center. There were, however, no signs of collapse, cupping or twisting in any of the boards.

The wood is moderately hard, works easily and well, both with machines and by hand. It nails well taking a thin gauge 1¼ inch nail two inches from the end with ease and lack of splitting. It mortises well but is inclined to be woolly.

Its air-dry weight is 50 (47—52) pounds per cubic foot (table 3). The grain is fairly straight and the texture moderately coarse. It is tasteless and when freshly cut, or when being worked, the wood has a green fig odor. The color is straw to pale straw yellow often with a pinkish tinge.

Table 3. Specific Gravity and Shrinkage

Green weight	66.4 (60—71) lb. per cu. ft.
Oven-dry weight	47.0 (44—49) lb. per cu. ft.
Air-dry weight (10 per cent m.c.)	50.0 (47—52) lb. per cu. ft.
Radial shrinkage to 10 per cent m.c.	2.1 (1.7—2.7) per cent
Tangential shrinkage to 10 per cent m.c.	4.0 (3.6—4.6) per cent
Longitudinal shrinkage	
outerwood	0.35 per cent
core	0.26 per cent
Volumetric shrinkage to oven-dry	10.7 (9.4—11.7) per cent

It will be noted (table 3) that this timber has a very low shrinkage which accounts for its good seasoning qualities.

The table below reflects the mechanical properties of *Baikiaea minor* adjusted to 12 per cent moisture content and using the standard methods.

Taken as a whole, the average mechanical properties (table 4) of the timber of *Baikiaea minor* compare with those of timbers of the same weight.

Table 4. Mechanical Properties

Property	Unit	Number of tests	Values at 12 per cent moisture content: Maximum	Minimum	Mean
Density	lb. per cu. ft.	55	55.4	45.3	50.3
Modulus of rupture	p.s.i.	55	22,823	12,397	17,035
Fiber stress at P. L.	p.s.i.	55	12,499	5,093	9,165
Modulus of elasticity	p.s.i.	54	3,649,000	1,883,000	2,615,000
Maximum crushing strength in compression parallel to the grain	p.s.i.	38	11,784	7,259	9,460
Hardness					
end	lb.	53	2,850	1,605	2,099
side	lb.	53	2,264	1,369	1,770
Shear parallel to the grain	p.s.i.	44	2,284	1,201	1,803

Macroscopic Structure

Growth rings are not clear but sometimes poorly defined by areas of fewer pores and fewer parenchyma bands in early wood which are preceded by closer parenchyma bands in the adjacent late wood. Parenchyma is abundant as fine regular metatracheal bands clear to the naked eye, more or less 40 bands to the centimeter and closer together in the late wood. Pores are few, clear to the naked eye, medium-sized, open, solitary or in radial multiples of two to many, and evenly distributed. They may be fewer in the denser late wood zone. Rays are numerous, minute but clear under a lens, often less than one pore width apart.

Recommended Uses

The weight, good seasoning qualities and ease with which it works make this wood useful for many purposes. It could be used for utility furniture, joinery and panelling, and flooring. It is suitable for heavy construction work and could also be used as sleeper stock if incised and impregnated with an approved preservative.

CRYSTALS IN WOODY TISSUES; PART I

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Introduction

The aim of this survey is to collect lists of woody species in which crystals occur, in order to assist in timber identification. Crystals are of very common occurrence; of such frequent occurrence indeed that at first sight it appears unlikely that they can be of any diagnostic significance. Further examination shows, however, that there are certain less common types of crystals, such as raphides and druses; also, certain arrangements of crystals, such as one large one accompanied by many smaller ones, that are less common; that certain crystal patterns are characteristic of certain families; and that these become valuable features to use in identifications. Silica and crystals usually occur in different genera and/or species, but Amos (1952) has shown, in a very comprehensive paper, that there are species in which both occur, sometimes even in the same cell.

Crystals have been observed or recorded in approximately 1000 genera of 160 families. The present lists are admittedly not complete, and never will be as long as new species are being discovered and described, but it is hoped that they will assist in identifying woods by bringing together a mass of information in a form that will make it available for quick and easy reference.

Materials and Data

Slides covering approximately 1000 genera from the collection of the Division of Forest Products, C. S. I. R. O., Melbourne, formed the basis of the examination. To the information thus collected was added that recorded by other workers, the main sources being Solereder (1908), Moll and Janssonius (1906–1936), and Metcalfe and Chalk (1950).

After collating the information in the last named, it was felt that it was not necessary to go more deeply into the literature as Metcalfe and Chalk have reviewed all the literature up to 1950. A glance at their comprehensive bibliography indicates how widely they have covered recent research, making it redundant to attempt individual recordings for such a survey as this.

As the following lists are intended to assist in the quick and easy identification of woods, the appearance and location of crystals is of more importance than their chemical formulae. No attempt has therefore been made to go into the chemical constitution of the crystals.

The following types of crystals are listed:

1. *Druses.* Spherical clusters, either attached to the cell wall by a peg or lying free in the cells (fig. 1).

2. *Raphides.* Bundles of long needle-shaped crystals, tending to fill the whole cell (fig. 2, 3).

3. *Elongated and rod-like.* Elongated crystals about four times as long as broad, with pointed or square ends; rod-like similar to the preceding in general shape, but only about twice as long as broad, and usually with square ends (fig. 4, 5 a and b).

4. *Acicular.* Needle-shaped crystals, often rather small, not bundled, but lying free in the cells and not filling them (fig. 5c).

5. *"Crystal sand."* A granular mass of very fine small crystals.

6. *Rhomboidal, square or diamond-shaped.* The most common of all crystal types, one or more per cell or compartment (fig. 1c, 3b).

Of these six classes, only the first five are treated in the present paper; the sixth, which covers an enormously wide range of genera will be treated by itself in a subsequent paper.

Crystals are commonly found in the rays or vertical parenchyma or in both; less frequently they are found in sep-

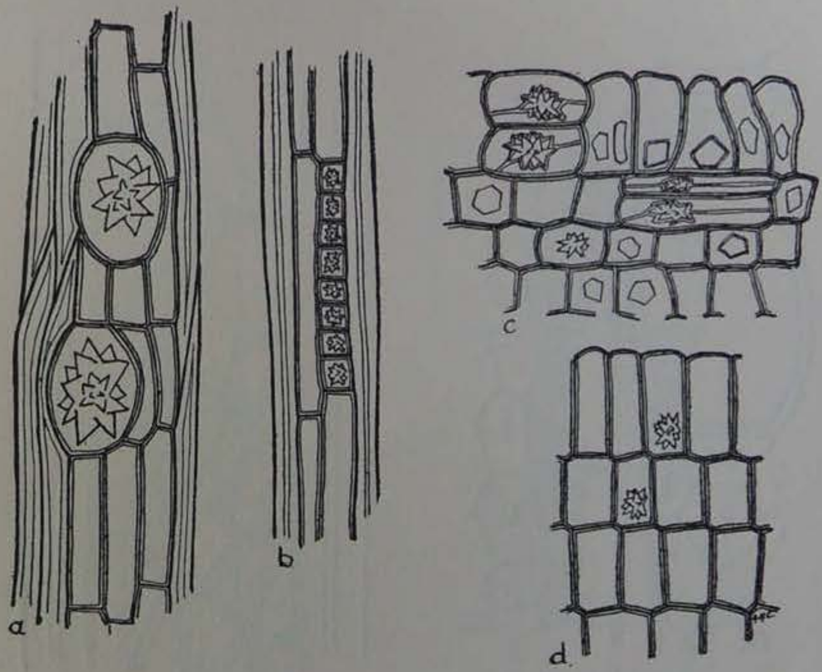

Fig. 1. Druses. *a.* enlarged parenchyma cells in *Terminalia catappa* L., *b.* subdivided parenchyma cells in *Garcinia gibbsae* S. Moore, *c.* enlarged and subdivided ray cells with druses and ordinary cells with druses and normal crystals in *Celtis paniculata* Planch., *d.* normal upright ray cells in *Pipturus argenteus* Wedd. ×300.

tate fibers and in the tyloses in vessels. In the accompanying lists the presence of crystals, their location in ray cells, (upright or procumbent), vertical parenchyma or septate fibers is indicated by a + sign in the appropriate column. Further columns indicate enlarged or subdivided (chambered) cells; brackets indicate that the crystals are few or sporadic in occurrence. Genera, and where possible species, not available for examination in which crystals have been recorded by other workers are given at the end of each list.

In many examples it is difficult to distinguish between rod-like and elongated crystals, and as the two types often

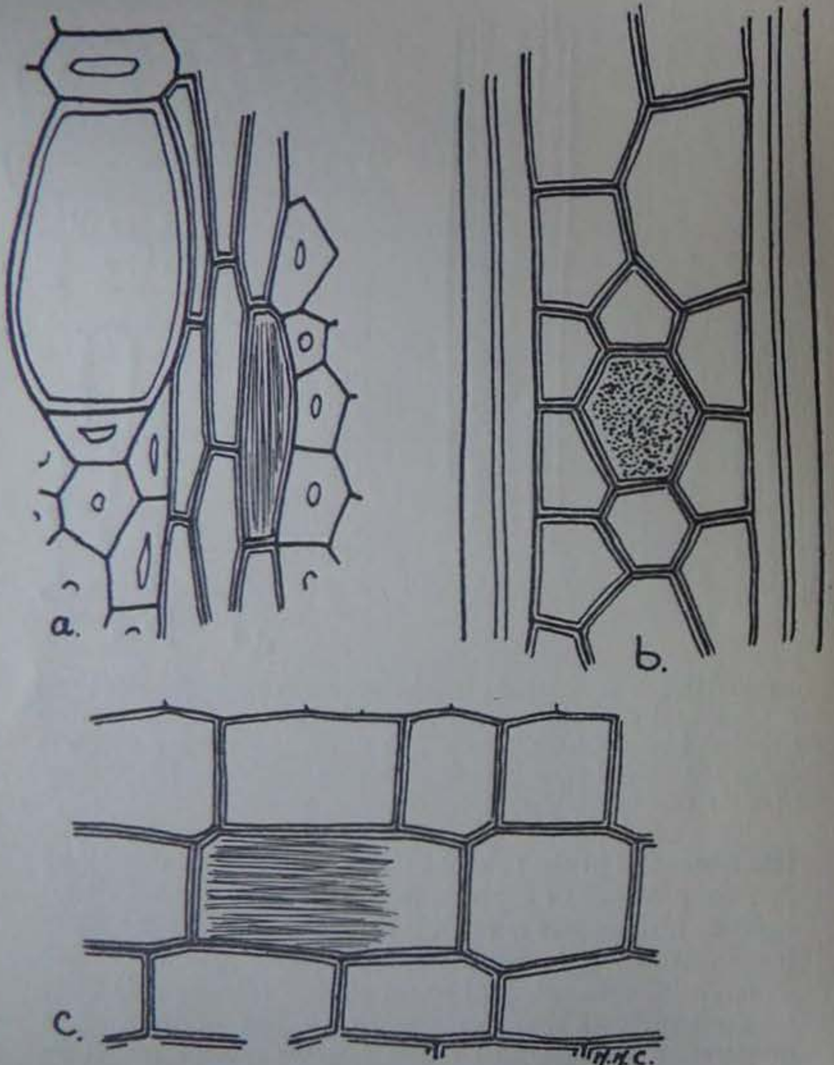

Fig. 2. Raphides in ray cells. *Tetramerista glabra* Miq. *a.* Cross-section, *b.* tangential section, *c.* radial section. ×435.

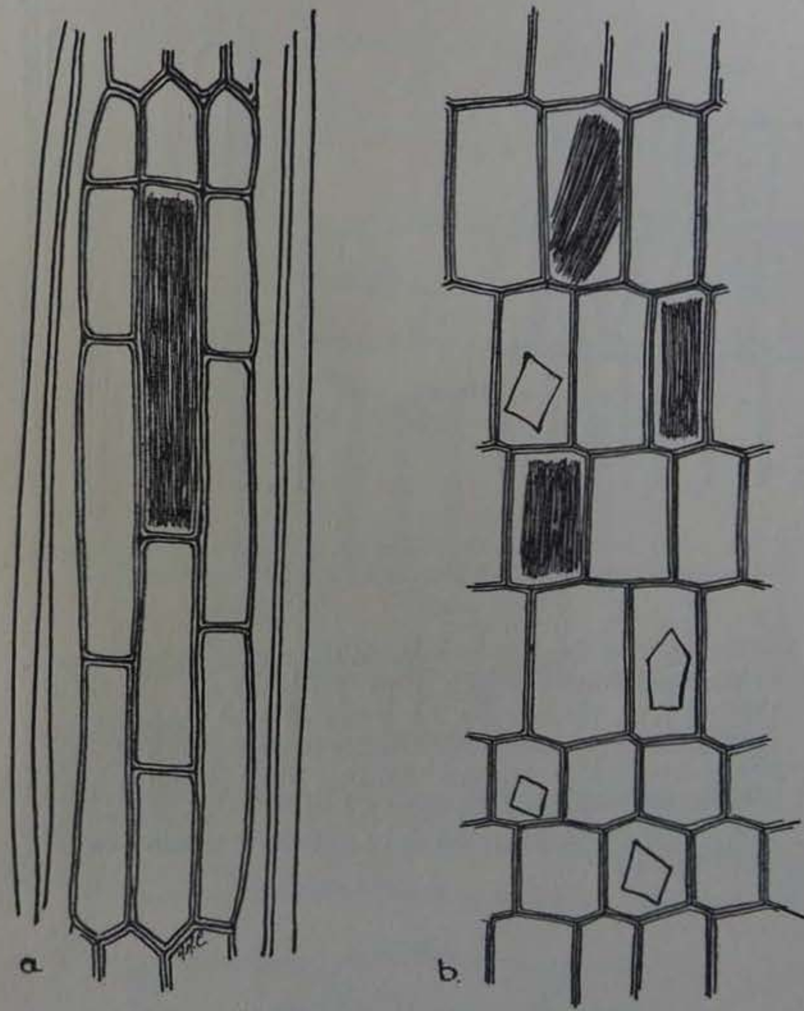

Fig. 3. Raphides. *a.* parenchyma in *Morinda citrifolia* L., *b.* raphides and normal crystals in ray cells of *Phyllanthus paniculatus* Oliv. ×400.

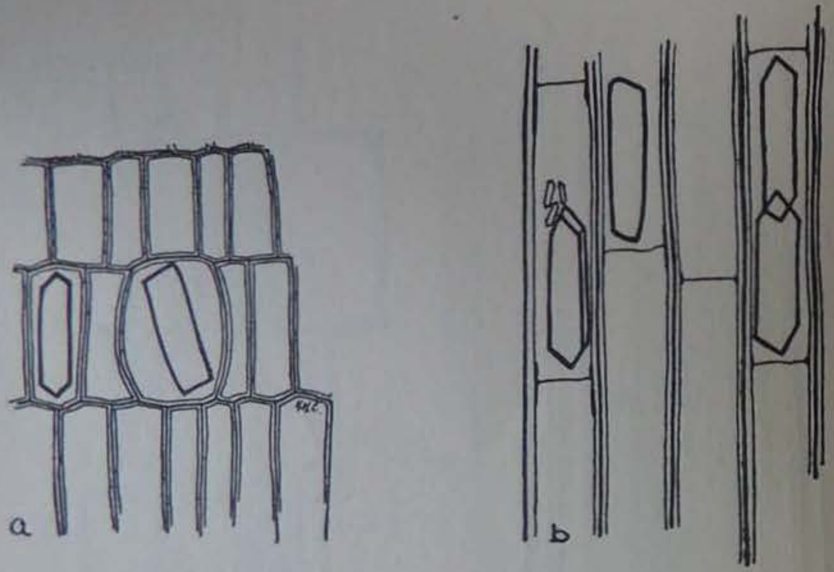

Fig. 4. Elongated crystals. *Glochidion* sp. *a.* in normal and enlarged ray cells, *b.* in septate fibers. ×400.

occur together they are included in the one list, appropriate columns indicating which type predominates. Acicular crystals may occasionally be confused with rod-like or elongated, but the ones listed here are all very small and very fine and pointed or tapered (fig. 5c). They are often very difficult to observe except under a fairly high power objective. Nevertheless they seem to be sufficiently distinct to be listed separately.

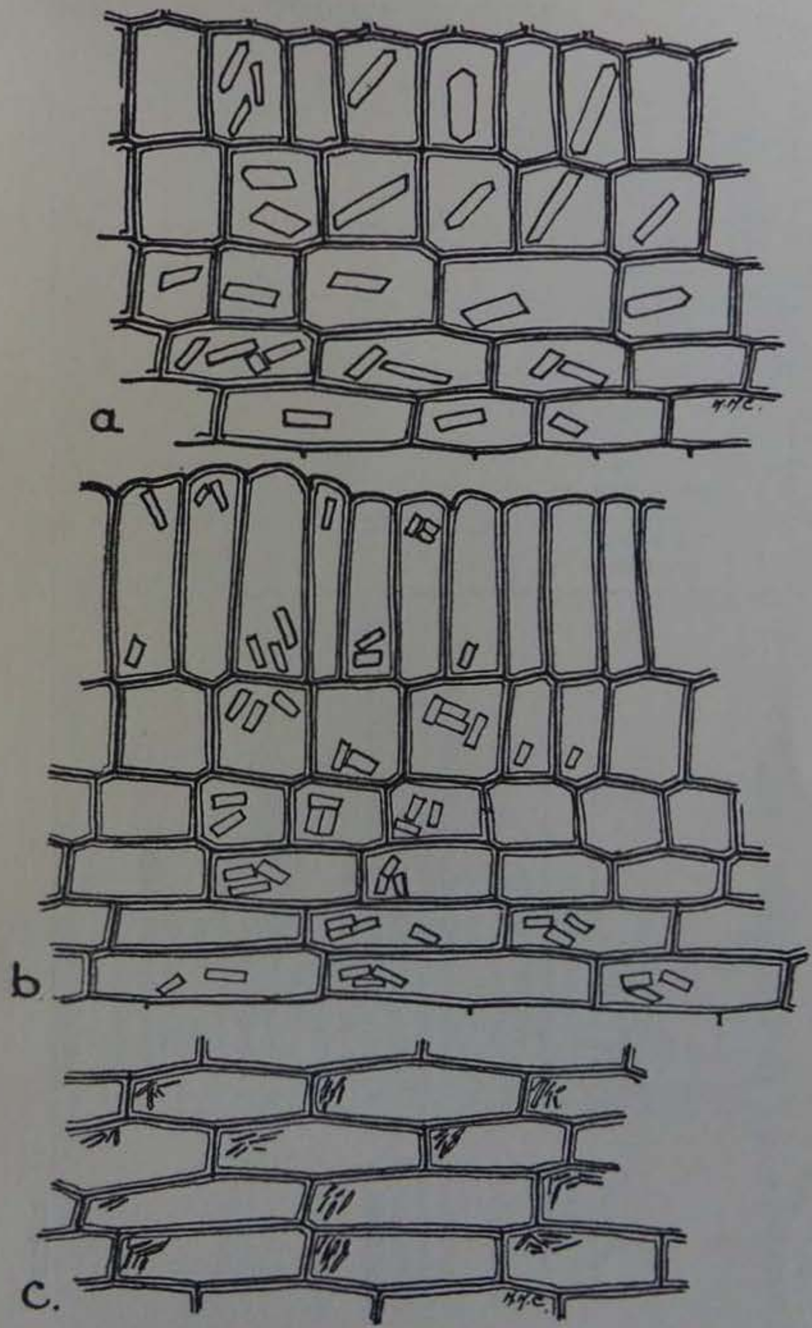

Fig. 5. Elongated, rod-like and acicular crystals. *a.* in ray cells of *Ligustrum* sp., *b.* in ray cells of *Cryptocarya* sp., *c.* in ray cells of *Gmelina fasciculiflora* Benth. ×600.

Table 1. List of Species Showing Druses

Family	Species	Distribution: Rays — Upright or square cells	Rays — Procumbent cells	Rays — Cells subdivided	Rays — Cells enlarged	Parenchyma — Ordinary cells	Parenchyma — Cells subdivided	Parenchyma — Cells enlarged
Anacardiaceae	*Rhus taitensis* Guill.	+		+				
Betulaceae	*Betula davurica* Pallo	+						
	B. grossa Sieb. & Zucc.	+						
Bombacaceae	*Adansonia gregorii* F. Muell.	+	+					
	Ochroma lagopus Sw.	+						
Burseraceae	*Haplolobus floribundus* (K. Schum.) H. J. Lam	+	+					
Cactaceae	*Pereskia guamacho* Weber	+	+					
Cochlospermaceae	*Cochlospermum gillivraei* Benth.						+	
Combretaceae	*Combretum verticillatum* Engl. & Diels							+
	Terminalia canaliculata Exell							+
	T. catappa L.							+[1]
	T. complanata K. Schum.							+
	T. hypargyrea Laut. & Schum.							+
	T. longispicata V. Sloot.							+
	T. microcarpa Decne.							+
	T. papuana Exell							+
	T. sepikana Diels							+
	T. sericocarpa F. Muell.							+
	T. sogarensis Bak.							+
	T. solomonensis Exell							+
	T. steenisiana Exell							+

[1]See fig. 1a

Table 1. List of Species Showing Druses—*Continued*

Family	Species	Distribution: Rays — Upright or square cells	Rays — Procumbent cells	Rays — Cells subdivided	Rays — Cells enlarged	Parenchyma — Ordinary cells	Parenchyma — Cells subdivided	Parenchyma — Cells enlarged
Corylaceae	*Carpinus macrostachya* (Oliv.) Koidz.		+					
	Ostrya japonica Willd.		(+)					
Dipterocarpaceae	*Hopea sangal* Korth.	+						
	Vatica papuana Dyer	(+)	(+)					
	V. rassak Bl.	(+)	(+)					
	V. stapfiana V. Sloot, *ex* K. Heyne	(+)	(+)					
Euphorbiaceae	*Macaranga involucrata* Baill.	+						
	M. tanarius (L.) Muell. Arg.	+						
	M. ricinoides Muell.	+						
	Mallotus floribundus Muell.	+						
	Manihot glaziovii Muell.			+				+
	Phyllanthus paniculatus Oliv.	+						
	Sapium ellipticum Pax		+					
Guttiferae	*Garcinia assuga* Lauterb.							+
	G. dioica Bl.		+					+
	G. gibbsae S. Moore[2]							+
	G. neglecta Vieill.		+					+
	G. platyphylla Sm.							+
	G. puat Guill.		+					+
	G. uniflora King							+
Leguminosae	*Gleditsia triacanthos* L.		+					

[2]See fig. 1b

Table 1. List of Species Showing Druses—*Continued*

FAMILY	SPECIES	DISTRIBUTION: RAYS: Upright or square cells	RAYS: Procumbent cells	RAYS: Cells subdivided	RAYS: Cells enlarged	PARENCHYMA: Ordinary cells	PARENCHYMA: Cells subdivided	PARENCHYMA: Cells enlarged
Malvaceae	*Cienfuegosia hakeaefolia* Hochr.	+						
	Hibiscus heterophyllus Vent.						+	
	H. similis Bl.	+						
	H. tiliaceus L.	+						
	H. tricuspis Banks	+				+		
	Malvaviscus grandiflora H. B. K.	(+)						
Meliaceae	*Cedrela toona* Roxb.		+	+			+	
	Entandrophragma candollei Harms					+		
	Toona sureni Merr.						+	
Myrtaceae	*Eugenia zollingeriana* Koord. & Valet.						+	
Quiinaceae	*Quiina crugeriana* Griseb.						+	
Rhamnaceae	*Ceanothus incanus* Torr. & Gray		+					
	Colubrina ferruginea Brongn.	+		+				
	Rhamnus alaternus L.	+						
Rhizophoraceae	*Crossostylis grandiflora* Brongn. & Griseb.		+					
Rosaceae	*Prunus chicasa* Michx.		(+)					
	P. avium L.		(+)		+			
	P. domestica L.		(+)					
	P. emarginata Walp.						+	
	P. padus L.					(+)		
	Pygeum africanum Hook. f.		+					

Table 1. List of Species Showing Druses—*Continued*

FAMILY	SPECIES	DISTRIBUTION: RAYS: Upright or square cells	RAYS: Procumbent cells	RAYS: Cells subdivided	RAYS: Cells enlarged	PARENCHYMA: Ordinary cells	PARENCHYMA: Cells subdivided	PARENCHYMA: Cells enlarged
Sterculiaceae	*Pterocymbium beccarii* K. Schum.	+						
	P. javanicum R. Br.	+						
	P. tinctorium Merr.	+						
	Sterculia ampla Bak. f .						+	
	S. coccinea Roxb.	+						
	S. conwentzii K. Schum.	+						
	S. laurifolia F. Muell.	+						
	S. urens Roxb.	+						
Ulmaceae	*Celtis labilis* C. K. Schneider	+		+				
	C. latifolia (Bl.) Planch.	+	+	+				
	C. luzonica Warb.	+						
	C. paniculata Planch.	+						
	C. philippinensis Blanco	+		+				
Urticaceae	*Boehmeria rugulosa* Wedd.	(+)						
	Pipturus argenteus Wedd.	+						
	P. incanus Wedd.	+						

Table 2. List of Species Showing Raphides

FAMILY	SPECIES	DISTRIBUTION: RAYS				DISTRIBUTION: PARENCHYMA		
		UPRIGHT OR SQUARE CELLS	PROCUMBENT CELLS	CELLS SUBDIVIDED	CELLS ENLARGED	ORDINARY CELLS	CELLS SUBDIVIDED	CELLS ENLARGED
Aizoaceae	*Carpobrotus aequilateralis* (Haw.) J. M. Black							+
Dilleniaceae	*Dillenia alata* Banks	+						
	D. castaneifolia Mart.	+						
	D. grandifolia Wall.	+			+			+
	D. indica L.		+			+		
	D. ingens Burtt	+			+			
	D. montana Diels	+						
	D. papuana Mart.	+						
	D. pulchella Jack	+						
	D. pentagyna Roxb.	+			+	+		
	D. reticulata King	+			+			
	D. salomonensis C. T. White	+						
	Hibbertia cuneiformis Sm.					+		
Euphorbiaceae	*Phyllanthus paniculatus* Oliv.[3]	+						
Nyctaginaceae	*Pisonia aculeata* L.					+		
	P. grandis R. Br.					+		
	Torrubia longifolia (Heim.) Britt.					+		
	T. bracei Britt.					+		

[3]See fig. 2b

Table 2. List of Species Showing Raphides—*Continued*

FAMILY	SPECIES	DISTRIBUTION: RAYS				DISTRIBUTION: PARENCHYMA		
		UPRIGHT OR SQUARE CELLS	PROCUMBENT CELLS	CELLS SUBDIVIDED	CELLS ENLARGED	ORDINARY CELLS	CELLS SUBDIVIDED	CELLS ENLARGED
Rubiaceae	*Coelospermum paniculatum* F. Muell.							+
	C. reticulatum Benth.							+
	Cosmibuena grandiflora (Ruiz & Pav.) Rusby	+						
	Hamelia patens Jack	+						
	Morinda citrifolia L.[4]					+		
	M. tinctoria Roxb.					+		
	Plectronia coprosmoides F. Muell.		+					
Saurauiaceae	*Saurauia dufaurii* (F. Muell.) Diels							+
Theaceae	*Tetramerista crassifolia* Hallier		+		+			
	T. glabra Miq.[5]		+		+			
	T. montana Hallier		+		+			
Vitaceae	*Leea angulata* Korth.	+						

[4]See fig. 2a
[5]See fig. 3

Druses have also been recorded in the following:

Bombacaceae: *Bernoullia, Ceiba, Eriodendron anfractuosum* DC.

Bonnetiaceae: *Bonnetia* ("clustered crystals" of Metcalfe and Chalk, 1950)

Cactaceae: *Cereus, Dendrocereus, Leptocereus*

Caryocaraceae: *Caryocar*

Combretaceae: *Guiera, Terminalia javanica* Miq., *T. procera* Roxb.

Dipterocarpaceae: *Vateria*

Euphorbiaceae: *Acalypha caturus* Bl., *Macaranga tanarius* (L.) Muell. Arg.

Guttiferae: *Clusia, Garcinia globulosa* Ridl., *Pentaphalangium*

Loranthaceae: *Viscum capense* Thunb.

Malvaceae: *Althaea, Lavatera, Paritium, Thurberia, Sphaeralcea*

Meliaceae: *Cedrela febrifuga* Bl.

Myrtaceae: *Eugenia jambolana* H. J. Lam

Sterculiaceae: *Sterculia blumei* G. Don, *S. spangleri* R. Br.

Theaceae: *Camellia, Gordonia, Schima*

Urticaceae: *Urera alceaefolia* Gaud.

Raphides have also been recorded in the following:

Dilleniaceae: *Curatella, Davilla, Dillenia parviflora* Griff., *Doliocarpus, Tetracera, Wormia excelsa* Jack

Greyiaceae: *Greyia*

Marcgraviaceae: *Marcgravia, Souroubea*

Nyctaginaceae: *Bougainvillaea, Calpidia, Colignonia, Neea, Pisonia sylvestris* Teijsm. & Binn., *P. excelsa* Bl., *Rockia*

Phytolaccaceae: *Phytolacca dodecandra* L'Herit.

Rubiaceae: *Calycosia, Calycodendron, Craterispermum, Faramea, Gillespiea, Prismatomeris albidiflora* Thw., *Psychotria auriantiaca* Bl., *P. robusta* Bl., *P. viridiflora* Reinw., *Straussia*

Rutaceae: *Raputia*

Saurauiaceae: *Saurauia blumeana* Benn., *S. bracteosa* DC., *S. cauliflora* DC., *S. junghuni* Choisy, *S. leprosa* Korth., *S. micrantha* Bl., *S. nudiflora* DC., *S. pendula* Bl., *S. ramiflora* Koord. & Valet., *S. reinwardtiana* Bl., *S. squamulosa* Koord. & Valet., *S. trichocalyx* Koord. & Valet., *S. umbellata* Koord. & Valet.

Urticaceae: *Laportea*

Vitaceae: *Cissus, Leea sambucina* Willd., *Tetrastigma, Vitis*

Table 3. List of Species Showing Elongated or Rod-like Crystals

Family	Species	Distribution: Septate fibers	Upright ray cells	Procumbent ray cells	Parenchyma	Crystals elonagated	Crystals rod-like
Apocynaceae	*Rejoua anguinea* Hemsl.	+				+	
Bignoniaceae	*Radermachera fenicis* Merr.			+			+
Boraginaceae	*Cordia subcordata* Lam.		+		+	+	
Celastraceae	*Siphonodon pendulum* F. M. Baill.		+	+		+	
Combretaceae	*Anogeissus acuminata* Wall.		+	+	+	+	
	A. latifolia Wall.				+	+	+
	Terminalia belerica Roxb.				+	+	
	T. burserina F. Muell.				+	+	
	T. latialata C. T. White				+	+	
	T. superba Engl. & Diels				+	+	
Elaeocarpaceae	*Sloanea australis* F. Muell.			(+)		+	
Euphorbiaceae	*Glochidion capitatum* Sm.[6]	+	+			+	
	G. ferdinandi (Muell. Arg.) Pax & Hoffm.		(+)			+	
	G. globosum Sm.	+	+			+	
	G. harveyanum Domin.		+			+	
	G. novo-guineense K. Schum.	+	+			+	
	G. philippense Benth.		+			+	
	G. sericeum Hook. f.		+	+	+	+	
	Sauropus rhamnoides Bl.				+	+	
Lauraceae	*Cryptocarya angulata* C. T. White		+				+
	C. bowie Druce		+	+			+

[6] See fig. 4

Table 3. LIST OF SPECIES SHOWING ELONGATED OR ROD-LIKE CRYSTALS—*Continued*

		DISTRIBUTION					
FAMILY	SPECIES	SEPTATE FIBERS	UPRIGHT RAY CELLS	PROCUMBENT RAY CELLS	PARENCHYMA	CRYSTALS ELONAGATED	CRYSTALS ROD-LIKE
	C. cinnamomifolia Benth.[7]		+	+			+
	C. cunninghami Meissn.		+				+
	C. elliptica Schltr.		+	+			+
	C. foveolata C. T. White & Fr.			+			+
	C. glaucescens R. Br.		+				+
	C. mackinnoniana F. Muell.		+		+		+
	C. medicinalis C. T. White		+				+
	C. microneura Meissn.		+	+			+
	C. murrayi F. Muell.			+			+
	C. patentinervis F. Muell.		+				+
	C. pleurosperma C. T. White		+				+
	C. triplinervis R. Br.		+	+			+
	Dehaasia microcarpa Bl.		(+)	+			+
	Licaria polyphylla (Nees) Kosterm.			+			+
	Litsea dealbata Nees		+	+			+
	L. reticulata Boerl.		+	+			+
	L. sebifera Juss.			+			+
Monimiaceae	*Tetrasynandra laxiflora* Perkins		+	+			+
Myrsinaceae	*Aegiceras corniculatum* Blanco			+			+
Myrtaceae	*Psidium guajava* L.				+		+
	Rhodamnia cinerea Jack				+	+	

[7]See fig. 5b

Table 3. LIST OF SPECIES SHOWING ELONGATED OR ROD-LIKE CRYSTALS—*Continued*

		DISTRIBUTION					
FAMILY	SPECIES	SEPTATE FIBERS	UPRIGHT RAY CELLS	PROCUMBENT RAY CELLS	PARENCHYMA	CRYSTALS ELONAGATED	CRYSTALS ROD-LIKE
Oleaceae	*Ligustrum ovalifolium* Hassk.[8]		+	+			+
	L. stauntoni DC.		+	+			+
	Linociera insignis C. B. Clarke		+	+		+	+
	L. macrophylla Wall.		+	+		+	+
	Notelaea longifolia Vent.		+	+	+	+	+
	N. microcarpa R. Br.			+	+		+
	Olea paniculata R. Br.			+			+
Proteaceae	*Hakea leucoptera* R. Br.			+			+
	H. preissii Meissn.			+			+
Rosaceae	*Prunus avium* L.			+		+	
Rubiaceae	*Hymenodictyon excelsum* Wall.				+	+	
Thymelaeaceae	*Pimelea serpylifolia* R. Br.		+		+	+	
Verbenaceae	*Avicennia alba* Bl.		+	+	+		+
	A. lanata Ridl.		+	+	+		+
	A. marina (Forsk.) Vierh.		+	+	+		+
	A. nitida Jacq.		+	+	(+)		+
	Premna cyclophylla Miq.		+			+	
	Vitex glabrata R. Br.			+		+	+

[8]See fig. 5a

Elongated and rod-like crystals have been reported for the following:

Compositae: *Proustia*

Euphorbiaceae: *Glochidion arborescens* Bl., *G. borneense* Boerl., *G. cyrtostylum* Miq., *G. glomerulatum* Boerl., *G. kollmannianum* Sm., *G. lucidum* Bl., *G. macrocarpum* Bl., *G. molle* Bl., *G. obscurum* Hook. f., *G. ramiflorum* Forst., *G. rubrum* Bl., *G. zeylanicum* A. Juss., *Dehassia caesia* Bl., *Lindera gemmiflora* Boerl., *Litsea velutina* Boerl.

Monimiaceae: *Matthaea*

Phytolaccaceae: *Gallesia, Seguiera*

Rubiaceae: *Ixora javanica* DC., *I. longituba* Boerl., *I. odorata* (Bl.) Koord. & Valet.

Table 4. List of Species Showing Acicular Crystals

		Distribution		
Family	Species	Upright Ray Cells	Procumbent Ray Cells	Parenchyma
Lauraceae	*Actinodaphne hookeri* Meissn.		+	
	Cryptocarya cinnamomifolia Benth.		+	
	C. erythroxylon Maiden & Betche		+	
	C. glaucescens R. Br.		+	
	Iteadaphne confusa Bl.		+	
Verbenaceae	*Gmelina arborea* Roxb.		+	
	G. fasciculiflora Roxb.[9]		+	
	G. leichardtii F. Muell.		+	
	G. macrophylla Benth.		+	
	G. salomonensis Bakh.		+	
	Premna angolensis Guerke		+	
	P. maxima C. T. E. Fries		+	
	P. tomentosa Willd.		+	

[9]See fig. 5c

Acicular or "needle-like" crystals have also been recorded in the following:

Lauraceae: *Actinodaphne glabra* Bl., *A. procera* Nees, *A. sphaerocarpa* Nees, *Cinnamomum javanicum* Bl., *Litsea brachystachya* Boerl., *L. chinensis* L., *L. pubescens* Koord. & Valet., *L. sumatrana* Boerl., *L. velutina* Boerl., *Machilus rimosa* Bl.

Verbenaceae: *Gmelina villosa* Roxb., *Premna cyclophylla* Miq., *P. foetida* Reinw., *P. leucostoma* Miq., *P. rotundifolia* Koord. & Valet.

Table 5. List of Species Showing Crystal Sand

		Distribution		
Family	Species	Upright Ray Cells	Procumbent Ray Cells	Parenchyma
Boraginaceae	*Cordia alba* Roem. & Schult.	+	+	+
	C. dodecandra Sessé & Moc.	+		+
	C. myxa L.	+		+
	C. subcordata H. J. Lam	+		+
	Patagonula americana L.	+		+
Icacinaceae	*Gomphandra polymorpha* Wight		+	
Lauraceae	*Actinodaphne glomerata* Nees		+	
	A. cf. *pruinosa* Nees		+	
	A. sesquipedalis Hook. f.		+	
	Lindera communis Hemsl.	+	+	
Rubiaceae	*Anthocephalus cadamba* Roxb.	+		
	A. indicus A. Rich.	+		
	Hodgkinsonia ovatiflora F. Muell.		+	
	Mastixiodendron smithii Merr. & Perry		+	
	Neonauclea calycina Merr.	+		
	Randia fitzalani F. Muell.		+	
	Timonius rumphii DC.	+	+	
	T. timon (Spreng.) Merr.	+	+	
Sapotaceae	*Pouteria maclayeana* (F. Muell.) Baehni			+
	P. malaccensis (C. B. Clarke) Baehni			+

Crystal sand has also been recorded in the following:

Amarantaceae: *Bosea*

Boraginaceae: *Cordia suaveolens* Bl.

Icacinaceae: *Gomphandra javanica* Valet.

Rubiaceae: *Adina, Calycophyllum, Diplospora*

Sapotaceae: *Bumelia obtusifolia* Roem. & Schult., *Chrysophyllum roxburghii* G. Don, *Mastichodendron nitidum* Bl., *Palaquium javense* Burck, *P. ottolanderi* Koord. & Valet., *Sideroxylon nitidum* Bl.

Solanaceae: *Solanum*

Summary

This paper is the first part of a survey of the occurrence of crystals in woody tissues. Lists are given of genera and species in which the following types of crystals occur: 1. druses, 2. raphides, 3. elongated or rod-like, 4. acicular, 5. very fine, referred to as "crystal sand," 6. rhomboidal, square

or diamond shaped. The distribution of the crystals in rays and/or vertical parenchyma is indicated, together with the type of cells in which they occur.

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PROPERTIES AND USES OF TROPICAL WOODS, V

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This is the fifth in a series of reports covering studies of the properties of tropical American woods. These studies have been conducted at the Yale University, School of Forestry continuously since 1947 in cooperation with the Office of Naval Research and the Bureau of Ships, United States Navy Department.

The scope of this program of research has been defined and test procedures described in previous reports (19, 44, 103, 104). These earlier reports dealt with 85 species of Central American, West Indian, or South American origin and presented data relative to their density, green and air-dry strength properties, shrinkage, air-seasoning characteristics and decay resistance. In addition, information concerning the source of each timber, its availability and general characteristics was also presented. It has also been the practice in these reports to evaluate each wood with respect to its present or potential utilization.

This report presents similar data for 19 additional species, chiefly from South America, bringing to 104 the total number of species covered in the manner just described over the entire study. In addition, data on specific gravity, mechanical properties and shrinkage, secured from the study of limited test material of a second group of 22 species, are given in the APPENDIX.

Table 1 lists both groups of woods in alphabetic order by generic name. The same arrangement is followed for the 19 species covered in the section entitled SPECIES DESCRIPTIONS. Appendix table 1 contains detailed information relative to

Table 1. INDEX TO SPECIES COVERED IN REPORT

Santa Maria	*Calophyllum brasiliense* Camb. var. *rekoi* (Standl.) Standl.
Degame	*Calycophyllum candidissimum* (Vahl) DC.
Suradanni	*Hieronyma laxiflora* (Tulas.) Muell. Arg.
Bois Rouge	*Humiria balsamifera* (Aubl.) J. St. Hil.
Kirikawa	*Iryanthera lancifolia* Ducke
Marakaipo	*I. sagotiana* (Benth.) Warb.
Copaia	*Jacaranda copaia* (Aubl.) D. Don
Rokoroko	*Macoubea guianensis* Aubl.
Konoko	*Micropholis guyanensis* (A.DC.) Pierre
Mora	*Mora excelsa* Benth.
Yekoro	*Ocotea schomburgkiana* (Nees) Benth. & Hook. f.
Purpleheart	*Peltogyne venosa* (Vahl) Benth.
Caribbean Pine	*Pinus caribaea* Morel.
Mountain Gronfoeloe	*Qualea rosea* Aubl.
Jawaledan	*Sclerolobium melinonii* Harms
Bannia	*Swartzia bannia* Sandw.
Chewstick	*Symphonia globulifera* L. f.
Hill Dalli	*Virola melinonii* (Benoist) A. C. Smith
Quillo Sisa	*Vochysia lanceolata* Stafl.
	APPENDIX
	Aspidosperma desmanthum Benth.
	A. duckei Huber
	A. megalocarpon Muell. Arg.
	Astronium lecointei Ducke
	Catostemma sp.
	Copaifera reticulata Ducke
	Cordia trichotoma (Vell.) Vell. *ex* Steud.
	Dalbergia sp.
	Glycydendron amazonicum Ducke
	Hernandia sonora L.
	Hymenaea oblongifolia Huber
	H. parvifolia Huber
	Manilkara huberi (Ducke) Chev.
	Ormosia paraensis Ducke
	Osteophloeum platyspermum (A.DC.) Warb.
	Platymiscium pinnatum (Jacq.) Dugand
	P. trinitatis Benth.
	Quararibea guianensis Aubl.
	Rauwolfia pentaphylla Ducke
	Sacoglottis uchi Huber
	Sterculia apetala (Jacq.) Karst.
	Vitex orinocensis H. B. K.

the source and character of the trees from which the test material of this report was obtained. An index to the species covered in the five reports of this series appears in the concluding section.

MECHANICAL PROPERTIES

Table 2 presents in summary form average values of specific gravity and strength for 19 tropical American woods. Mechanical properties are shown for each species tested in both the green and the air-dry condition according to standard A. S. T. M. methods. Comparable data are also shown for a number of well-known domestic and tropical woods. In this, and subsequent tables in this section of the report, species are arranged in order of decreasing specific gravity (oven-dry weight, green volume). The mechanical properties of each of these species are discussed individually in the section on SPECIES DESCRIPTIONS. In those instances in which a species was represented by test material from more than one source, the values for each source are shown in that section of this report.

Additional data on specific gravity and strength properties, based on tests of one log each of 22 species, are given in appendix table 2. Average values based upon such a limited sample are, of course, only indicative of the characteristics of a species and cannot be considered suitable for exacting use. Nevertheless, they provide additional information that is useful in portraying the highly diversified nature of tropical American woods in general.

A review of the complete study covering 126 species of tropical American woods shows a range of specific gravity (oven-dry weight, green volume basis) from 0.24 to 1.03. Figure 1 is a frequency diagram showing the distribution by number of species over this range of specific gravity for these 126 tropical American species as well as for the 168 woods native to the United States for which comparable data are available.

Table 2. MECHANICAL PROPERTIES OF TROPICAL AMERICAN WOODS IN THE GREEN AND AIR-DRY CONDITIONS

Species	Source	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	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[5]
			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
Bannia		Green	25.1	1.14	1.02	16,680	22,870	3,000	5.23	—	10,730	12,930	3,480	1890	3120	3160	810	2240	450	259.5
(*Swartzia bannia*)	Surinam	Air dry[1]	13.3			17,850	26,370	3,630	4.95*	15.6*	13,150	15,440	3,860	3200	4060	2920*	680*	2820	410*	
Greenheart[2]	British	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	—
(*Ocotea rodiei*)	Guiana	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*	—	
Mora (*Mora excelsa*)	Surinam, British	Green	60.0	0.97	0.78	9,040	12,630	2,330	2.04	13.5	4,800	6,400	2,660	1340	1450	1040	570	1400	380	228.5
	Guiana	Air dry[1]	11.6			13,040	22,100	2,960	3.22	18.5	6,320	11,840	3,840	2210	2300	1280	660	1900	380	
Caribbean Pine	British	Green	35.4	0.78	0.68	6,090	11,190	1,880	1.11	10.7	3,560	4,900	2,230	840	980	700	340	1170	240	250.7
(*Pinus caribaea*)	Honduras	Air dry[1]	13.1			9,850	16,690	2,240	2.43	17.3	4,960	8,540	3,010	1180	1240	1210	470	2090	340	
Degame (*Calycophyllum*		Green	—	0.78	0.67	7,330	14,290	1,930	1.52	18.6	3,660	6,200	2,260	1740	1630	1070	1070	1660	480	252.5
candidissimum)	Venezuela	Air dry[1]	14.2			12,430	22,300	2,270	3.97	27.0	5,180	9,670	2,560	2140	1940	1590	970*	2120	330*	
Purpleheart (*Peltogyne*		Green	70.7	0.77	0.67	9,360	13,690	2,000	2.49	14.8	4,520	7,020	2,370	1700	1810	1530	920	1640	440	224.2
venosa)	Surinam	Air dry[1]	13.0			12,770	19,220	2,270	4.05	17.6	8,440	10,320	2,500	2290	1860	1450*	640*	2220	340*	
Bois Rouge (*Humiria*		Green	62.7	0.78	0.66	7,820	11,720	2,060	1.69	10.0	4,060	5,810	2,470	1240	1320	870	880	1460	380	145.9
balsamifera)	Surinam	Air dry[1]	14.2			11,050	18,770	2,510	2.66	19.6	5,480	8,950	2,990	1870	1610	980	1000	2140	600	
Suradanni (*Hieronyma*		Green	82.6	0.75	0.65	6,510	10,680	1,880	1.30	8.3	3,300	4,960	2,100	1280	1220	760	740	1200	380	186.6
laxiflora)	Surinam	Air dry[1]	9.7			11,110	18,200	2,270	3.14	12.0	4,510	9,620	2,630	2140	1700	1160	670*	1720	280*	
Konoko (*Micropholis*		Green	36.5	0.75	0.65	8,190	13,630	2,470	1.53	10.9	4,770	6,610	3,180	1280	1130	710	650	1400	390	128.5
guyanensis)	Surinam	Air dry[1]	13.2			12,370	18,890	2,950	2.90	15.8	6,560	9,820	3,310	1890	1490	1160	790	2150	420	
Shagbark Hickory[3]	United	Green	60	0.78	0.64	5,900	11,000	1,570	1.28	23.7	3,430	4,580	—	—	—	1040	—	1520	—	—
(*Carya ovata*)	States	Air dry	12			10,700	20,200	2,160	3.01	25.8	—	9,210	—	—	—	2170	—	2430	—	
White Oak[3]	United	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[4]
(*Quercus alba*)	States	Air dry	12			8,200	15,200	1,780	2.27	14.8	4,760	7,440	—	1520	1360	1320	800	2000	450	
Chewstick (*Symphonia*	Surinam, British	Green	85.4	0.68	0.58	7,140	11,180	1,960	1.60	11.2	4,130	5,160	2,320	900	940	620	610	1140	320	157.0
globulifera)	Guiana	Air dry[1]	12.1			10,920	16,860	2,460	2.72	16.5*	4,840	8,820	2,860	1280	1120	800	350*	1420	220*	
Teak[4] (*Tectona*		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
grandis)	Burma	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*	
Marakaipo (*Iryanthera*		Green	52.6	0.68	0.57	5,990	9,190	1,960	1.05	—	3,090	4,430	2,620	670	710	400	500	970	270	104.1
sagotiana)	Surinam	Air dry[1]	12.6			11,320	15,710	2,620	2.86	9.8*	5,510	9,420	3,150	950	1010	740	300*	1400	200*	
Yellow Birch[3]	United	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	—
(*Betula lutea*)	States	Air dry	12			10,100	16,600	2,010	2.89	20.8	6,130	8,170	—	1480	1260	1190	920	1880	520	

Table 2—*Continued*

Table 2—*Continued*

Species	Source	Condition	Moisture content	Specific gravity oven-dry vol.	Specific gravity green vol.	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	Compression Parallel to Grain: Fiber stress at proportional limit	Compression Parallel to Grain: Maximum crushing strength	Compression Parallel to Grain: Modulus of elasticity	Hardness end	Hardness side	Compression perpendicular to grain	Tension perpendicular to grain	Shear	Cleavage	Toughness[5]
			per cent			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.	lb.	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
Mountain Gronfoeloe		Green	82.5	0.58	0.53	6,190	10,510	2,030	1.07	9.3	3,800	5,200	2,300	1030	930	560	480	1250	320	155.9
(Qualea rosea)	Surinam	Air dry[1]	12.8			9,720	14,610	2,200	2.41	12.5	5,940	7,570	2,650	1370	1050	860	430*	1800	250*	
Quillo Sisa *(Vochysia*		Green	117.9	0.61	0.52	5,440	8,530	1,600	1.07	8.5	3,300	3,960	1,890	890	800	580	500	960	280	137.8
lanceolata)	Peru	Air dry[1]	13.3			9,020	13,730	1,920	2.37	11.8	5,260	7,530	2,300	1450	1110	690	380*	1310	220*	
Santa Maria *(Calophyllum brasiliense*	British	Green	62.0	0.60	0.52	5,560	10,490	1,590	1.10	12.7	3,040	4,560	1,700	1010	890	570	580	1260	330	180.4
var. *rekoi)*	Honduras	Air dry[1]	13.1			9,000	14,640	1,830	2.50	16.1	4,860	6,910	2,010	1410	1150	890	520*	2080	330	
Black Walnut[3]	United	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	—
(Juglans nigra)	States	Air dry	12			10,500	14,600	1,680	3.70	10.7	5,780	7,580	—	1050	1010	1250	690	1360	320	
Kirikawa *(Iryanthera*	British	Green	74.5	0.58	0.49	4,840	7,570	1,680	0.75	7.5	2,640	3,260	2,210	610	580	400	400	900	230	98.6
lancifolia)	Guiana	Air dry[1]	11.6			8,480	12,650	2,180	1.86	10.2	5,120	6,970	2,430	1030	850	640	360*	1250	190*	
Jawaledan *(Sclerolobium*		Green	107.3	0.53	0.47	5,000	7,750	1,750	0.79	7.5	3,100	3,850	2,230	770	730	570	460	1060	260	159.4
melinonii)	Surinam	Air dry[1]	11.8			8,350	13,150	2,040	1.89	12.2	5,100	6,530	2,520	1040	730	650	500	1600	290	
Yekoro *(Ocotea*		Green	48.9	0.50	0.46	5,490	8,830	1,660	1.04	8.1	3,350	4,610	2,020	500	530	460	420	900	260	92.8
schomburgkiana)	Surinam	Air dry[1]	13.7			7,890	11,730	1,840	1.92	8.5	5,340	6,650	2,090	630	600	700	220*	870*	170*	
Mahogany[4] *(Swietenia*	Central	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
macrophylla)	America	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	
Hill Dalli *(Virola*		Green	49.5	0.49	0.42	4,150	6,340	1,740	0.57	4.6	2,520	3,100	2,220	490	400	250	360	730	190	52.5
melinonii)	Surinam	Air dry[1]	12.4			6,720	10,070	1,980	1.30	7.8	4,570	5,280	2,540	900	600	330	390	1220	230	
Chestnut[3] *(Castanea*	United	Green	122	0.45	0.40	3,100	5,600	930	0.59	7.0	2,080	2,470	—	530	420	380	440	800	240	—
dentata)	States	Air dry	12			6,100	8,600	1,230	1.78	6.5	3,780	5,320	—	720	540	760	460	1080	250	
Yellow Poplar[3] *(Liriodendron*	United	Green	64	0.43	0.38	3,400	5,400	1,090	0.62	5.4	1,930	2,420	—	390	340	330	450	740	220	—
tulipifera)	States	Air dry	12			6,100	9,200	1,500	1.43	6.8	3,550	5,290	—	560	450	580	520	1100	280	
Rokoroko *(Macoubea*		Green	91.3	0.41	0.37	3,830	6,120	1,170	0.69	7.1	2,210	2,630	1,370	400	370	310	300	760	220	67.4
guianensis)	Surinam	Air dry[1]	9.2			6,620	9,350	1,410	1.74	6.3*	4,160	5,100	1,550	600	480	450	350	810	230	
Copaia *(Jacaranda*		Green	98.2	0.36	0.32	2,440	4,580	1,160	0.30	3.3	1,420	1,980	1,220	350	280	150	180	510	120	53.7
copaia)	Surinam	Air dry[1]	9.2			5,290	7,040	1,310	1.22	4.7	3,080	4,120	1,490	520	350	250	210	640	160	

[1]Air-dry values adjusted to 12 per cent moisture content except where designated (*), in which case the actual moisture content at time of testing (col. 4) applies.
[2]Kynoch and Norton (62).
[3]Forest Products Laboratory, Madison, Wis.

[4]Trop. Woods 98 (104).
[5]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.

The data of table 2 and appendix table 2 support the validity of the generally accepted relationship between most strength properties and specific gravity. As stated in a previous report, however, tropical woods tested in the green condition "display a general superiority in bending strength, stiffness, crushing strength and a number of other properties over domestic woods of comparable density" (103). This superiority is less evident when the comparison is made at 12 per cent moisture content (103, 104).

The present data also add emphasis to the earlier observation (103) that air-dry strength of tropical woods in cleavage and tension perpendicular to the grain is commonly less than that in the green condition. Detailed discussion of the green and air-dry strength properties of individual species is presented under SPECIES DESCRIPTIONS.

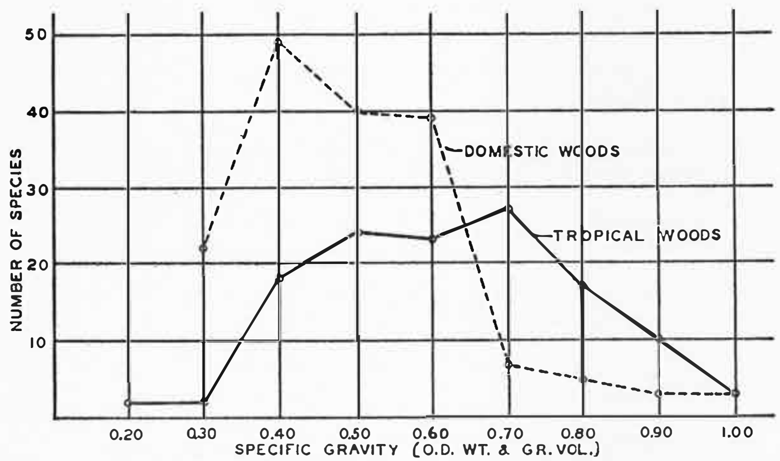

Fig. 1. Specific gravity distribution for the 126 tropical American species covered in this study, and for 168 domestic woods for which comparable data are available.

SHRINKAGE

Table 3 summarizes the results of standard A. S. T. M. shrinkage tests on 19 tropical American woods and, in addition, includes comparable data for several well-known domestic and tropical woods. Shown in the table are average values for independently determined radial, tangential, longitudinal and volumetric shrinkage from the green to oven-dry conditions. Similar data on 22 additional species, based on material from a single log of each, are presented in appendix table 3.

These additional data supplement previous work (103, 104) and show that, with few exceptions, tropical woods are characterized by lower shrinkage values than are domes-

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

Species	Source	No. of logs	Specific gravity green volume basis	SHRINKAGE (per cent) Radial	Tangential	Longitudinal	Volumetric
Bannia (*Swartzia bannia*)	Surinam	3	1.02	3.9	7.6	0.11	11.2
Mora (*Mora excelsa*)	Surinam, British Guiana	4+[2]	0.78	6.9	9.8	0.36	18.8
Caribbean Pine (*Pinus caribaea*)	British Honduras	3	0.68	6.3	7.8	0.01	12.9
Degame (*Calycophyllum candidissimum*)	Venezuela	2	0.67	4.8	8.6	0.19	13.2
Purpleheart (*Peltogyne venosa*)	Surinam	3	0.67	3.2	6.1	0.14	9.9
Bois Rouge (*Humiria balsamifera*)	Surinam	3	0.66	7.2	9.7	0.09	15.7
Suradanni (*Hieronyma laxiflora*)	Surinam	3	0.65	5.3	9.4	0.34	14.4
Konoko (*Micropholis guyanensis*)	Surinam	3	0.65	5.8	8.5	0.18	14.3
Shagbark Hickory[3] (*Carya ovata*)	United States		0.64	7.0	10.5	—	16.7
White Oak[3] (*Quercus alba*)	United States		0.60	5.3	9.0	—	15.8

Table 3—*Continued*

Species	Source	No. of logs	Specific gravity	SHRINKAGE (per cent)			
			green volume basis	Radial	Tangential	Longitudinal	Volumetric
Chewstick (*Symphonia globulifera*)	Surinam, British Guiana		0.58	5.7	9.7	0.15	15.6
Teak[4] (*Tectona grandis*)	Burma		0.58	2.3	4.2	—	6.8
Marakaipo (*Iryanthera sagotiana*)	Surinam	3	0.57	5.3	9.4	0.08	15.6
Mountain Gronfoeloe (*Qualea rosea*)	Surinam	3	0.53	4.4	8.4	0.08	11.4
Quillo Sisa (*Vochysia lanceolata*)	Peru	3	0.52	5.0	11.0	0.04	15.9
Santa Maria (*Calophyllum brasiliense* var. *rekoi*)	British Honduras	3	0.52	4.8	7.1	0.03	12.3
Black Walnut[3] (*Juglans nigra*)	United States		0.51	5.2	7.1	—	11.3
Kirikawa (*Iryanthera lancifolia*)	British Guiana	5	0.49	5.5	10.2	0.05	14.0
Jawaledan (*Sclerolobium melinonii*)	Surinam	3	0.47	4.4	8.9	0.16	12.3
Yekoro (*Ocotea schomburgkiana*)	Surinam	3	0.46	3.0	6.7	0.19	9.3
Mahogany (*Swietena macrophylla*)	Central America[3]		0.45	3.5	4.8	—	7.7
Hill Dalli (*Virola melinonii*)	Surinam	3	0.42	5.5	9.2	0.10	13.1
Chestnut[3] (*Castanea dentata*)	United States		0.40	3.4	6.7	—	11.6
Rokoroko (*Macoubea guianensis*)	Surinam	3	0.37	2.2	7.1	0.19	9.9
Butternut[3] (*Juglans cinerea*)	United States		0.36	3.3	6.1	—	10.3
Copaia (*Jacaranda copaia*)	Surinam	3	0.32	5.1	8.2	0.06	13.6

[1]Shrinkage values represent shrinkage from the 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, Wis.
[4]A Handbook of Empire Timbers (35).

tic woods of comparable density. Considered in their entirety, the 126 tropical American woods tested in the program fail to reveal any clear relationship between volumetric shrinkage and specific gravity. The wide dispersion of shrinkage values particularly when considered in combination with comparable data for domestic woods, strongly suggests that factors other than specific gravity are operative. Further investigation of this matter is contemplated.

Shrinkage characteristics of individual species are given in the section on Species Descriptions.

Decay Resistance

Table 4 presents the results of decay resistance tests on 19 tropical American woods involving a 4-month exposure of small heartwood specimens to pure cultures of typical white-rot (*Polyporus versicolor*) and brown-rot (*Poria monticola*) fungi. These tests follow the general pattern of those conducted at the U. S. Forest Products Laboratory by Scheffer and Duncan (84) and have been previously described in this series (19).

Two weight loss values—the average for the species and the maximum shown by an individual specimen—are given in table 4. Durability ratings based on these weight losses are also presented. The decay resistance of each species is discussed under Species Descriptions. The ratings referred to in that section are based on average weight loss only, and any variation indicated there, is that between logs rather than variation within the heartwood of a single log.

Seasoning Characteristics

Table 5 summarizes the air-seasoning characteristics of 18 of the species included in the main body of this report. Degame was not included in the seasoning phase of this study. These species are classified as to ease of seasoning in table 6. A number of domestic woods are included in this table for comparative purposes. The seasoning characteristics of individual species are discussed briefly under Species Descriptions.

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

				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	per cent		per cent		per cent		per cent	
Bannia (*Swartzia bannia*)	Surinam	3	1.02	0.4	A	0.8	A	0.3	A	0.7	A
Mora (*Mora excelsa*)	Surinam, British Guiana	4+[3]	0.78	23.4	B	55.9	D	4.1	A	33.7	C
Caribbean Pine (*Pinus caribaea*)	British Honduras	3	0.68	3.2	A	13.8	B	46.5	D	61.1	D
Degame (*Calycophyllum candidissimum*)	Venezuela	2	0.67	29.5	C	41.6	C	6.9	A	29.0	C
Purpleheart (*Peltogyne venosa*)	Surinam	3	0.67	15.1	B	32.2	C	7.7	A	32.2	C
Bois Rouge (*Humiria balsamifera*)	Surinam	3	0.66	5.1	A	14.6	B	24.0	B	41.9	C
Suradanni (*Hieronyma laxiflora*)	Surinam	3	0.65	2.1	A	18.2	B	1.4	A	12.1	B
Konoko (*Micropholis guyanensis*)	Surinam	3	0.65	25.4	C	44.1	C	4.0	A	36.5	C
Chewstick (*Symphonia globulifera*)	Surinam, British Guiana	7	0.58	17.1	B	39.4	C	12.3	B	38.9	C
Marakaipo (*Iryanthera sagotiana*)	Surinam	3	0.57	35.9	C	46.2	D	44.2	C	54.0	D
Mountain Gronfoeloe (*Qualea rosea*)	Surinam	3	0.53	2.2	A	8.0	A	24.1	B	45.5	D

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	per cent		per cent		per cent		per cent	
Quillo Sisa (*Vochysia lanceolata*)	Peru	3	0.52	4.7	A	24.1	B	45.6	D	54.0	D
Santa Maria (*Calophyllum brasiliense* var. *rekoi*)	British Honduras	3	0.52	30.3	C	62.4	D	32.6	C	48.6	D
Kirikawa (*Iryanthera lancifolia*)	British Guiana	5	0.49	54.8	D	72.8	D	54.8	D	61.1	D
Jawaledan (*Sclerolobium melinonii*)	Surinam	3	0.47	0.8	A	2.7	A	46.4	D	60.4	D
Yekoro (*Ocotea schomburgkiana*)	Surinam	3	0.46	4.9	A	15.9	B	22.3	B	44.1	C
Hill Dalli (*Virola melinonii*)	Surinam	3	0.42	38.1	C	50.5	D	48.1	D	61.3	D
Rokoroko (*Macoubea guianensis*)	Surinam	3	0.37	46.0	D	58.8	D	55.3	D	69.2	D
Copaia (*Jacaranda copaia*)	Surinam	3	0.32	41.6	C	81.5	D	4.7	A	50.2	D

[1]White rot—*Polyporus versicolor* (No. 720); Brown rot—*Poria monticola* (Madison No. 698, Davidson's No. 106).
[2]Resistance classes:
A—0–10 per cent decay; very durable.
B—11–24 per cent decay; durable.
C—25–44 per cent decay; moderately durable.
D—45 per cent or more 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	
Bannia (*Swartzia bannia*)	Surinam	3	1.02	Fast	B–C	A	A	C	B–C	B
Mora (*Mora excelsa*)	Surinam, British Guiana	4	0.78	Fast to moderate	C	A	A	B	B	A–B
Caribbean Pine (*Pinus caribaea*)	British Honduras	3	0.68	Fast	B–C	A	A–B	B	B	A
Purpleheart (*Peltogyne venosa*)	Surinam	3	0.67	Fast	C	A	B	B	B	B
Bois Rouge (*Humiria balsamifera*)	Surinam	3	0.66	Fast	B–C	A–B	B	B	B	B–C
Suradanni (*Hieronyma laxiflora*)	Surinam	3	0.65	Fast	C	A	A–B	B	C	A–B
Konoko (*Micropholis guyanensis*)	Surinam	3	0.65	Fast	B–C	A–B	A–B	C–D	C–D	B
Chewstick (*Symphonia globulifera*)	Surinam, British Guiana	7	0.58	Fast	B–C	A	B	B–C	C	A–B
Marakaipo (*Iryanthera sagotiana*)	Surinam	3	0.57	Fast	B	A	B	C	C	B–C
Mountain Gronfoeloe (*Qualea rosea*)	Surinam	3	0.53	Fast	C	A–B	C	B–C	B–C	B
Quillo Sisa (*Vochysia lanceolata*)	Peru	3	0.52	Fast to moderate	B–C	A–B	B–C	B	B	B–C

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	
Santa Maria (*Calophyllum brasiliense* var. *rekoi*)	British Honduras	3	0.52	Fast	B–C	A–B	B	B	B	A
Kirikawa (*Iryanthera lancifolia*)	British Guiana	5	0.49	Fast	B	A	B	B–C	B–C	B
Jawaledan (*Sclerolobium melinonii*)	Surinam	3	0.47	Fast	C	A–B	B	B	B	B
Yekoro (*Ocotea schomburgkiana*)	Surinam	3	0.46	Fast	B	A–B	A	B–C	B	B
Hill Dalli (*Virola melinonii*)	Surinam	3	0.42	Fast to moderate	B–C	A–B	B	B	B	B
Rokoroko (*Macoubea guianensis*)	Surinam	3	0.37	Fast	B–C	A	A–B	B	B	A–B
Copaia (*Jacaranda copaia*)	Surinam	3	0.32	Fast	A–B	A	A	B	B	A–B

[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 per cent moisture content.
Moderate: From 120 to 200 days to dry from green condition to 16 per cent moisture content.
Slow: Over 200 days from green condition to 16 per cent 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 per cent waste.
Moderate (C)—5–25 per cent waste.
Severe (D)—over 25 per cent waste.

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

Table 6. Classification of Tropical American Woods as to Their Ease of Seasoning

Species		Specific gravity green volume basis
	Group I (Easy to season)	
Jawaledan	*Sclerolobium melinonii*	0.47
Shortleaf Pine	*Pinus echinata*	0.46
Yekoro	*Ocotea schomburgkiana*	0.46
Yellow Poplar	*Liriodendron tulipifera*	0.38
Copaia	*Jacaranda copaia*	0.32
	Group II (Moderately difficult to season)	
Bannia	*Swartzia bannia*	1.02
Caribbean Pine	*Pinus caribaea*	0.68
Purpleheart	*Peltogyne venosa*	0.67
Bois Rouge	*Humiria balsamifera*	0.66
Suradanni	*Hieronyma laxiflora*	0.65
Konoko	*Micropholis guyanensis*	0.65
Chewstick	*Symphonia globulifera*	0.58
Marakaipo	*Iryanthera sagotiana*	0.57
Mountain Gronfoeloe	*Qualea rosea*	0.53
Quillo Sisa	*Vochysia lanceolata*	0.52
Santa Maria	*Calophyllum brasiliense* var. *rekoi*	0.52
Black Walnut	*Juglans nigra*	0.51
Kirikawa	*Iryanthera lancifolia*	0.49
Paper Birch	*Betula papyrifera*	0.48
Hill Dalli	*Virola melinonii*	0.42
Rokoroko	*Macoubea guianensis*	0.37
	Group III (Difficult to season)	
Mora	*Mora excelsa*	0.78
White Oak	*Quercus alba*	0.60

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 the main body of 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 in this

study. Additional recommendations are included in the individual species descriptions.

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.

- Bannia
- Bois Rouge
- Caribbean Pine
- Degame
- Mora
- Purpleheart
- Quillo Sisa
- Santa Maria
- Suradanni

BOATBUILDING

Uses for wood in boatbuilding are varied, and include 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.

Purpleheart

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

Caribbean Pine
Purpleheart
Yekoro

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 also desirable.

Caribbean Pine	Santa Maria
Mora	Suradanni
Purpleheart	

Keels and underwater 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.

Bannia	Purpleheart
Caribbean Pine	Santa Maria
Mora	Suradanni

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.

Bois Rouge	Mountain Gronfoeloe
Caribbean Pine	Quillo Sisa
Chewstick	Santa Maria
Konoko	Suradanni
Mora	

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.

Bannia	Mora
Caribbean Pine	Purpleheart
Chewstick	Suradanni

EXTERIOR USE

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

Caribbean Pine	Purpleheart
Chewstick	Yekoro
Mora	

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.

Bannia	Mora
Bois Rouge	Mountain Gronfoeloe
Caribbean Pine	Purpleheart
Chewstick	Quillo Sisa
Konoko	Santa Maria

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.

Bois Rouge	Mountain Gronfoeloe
Caribbean Pine	Purpleheart
Chewstick	Santa Maria
Mora	Suradanni

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.

Bannia	Marakaipo
Bois Rouge	Mountain Gronfoeloe
Chewstick	Purpleheart
Copaia	Quillo Sisa
Hill Dalli	Rokoroko
Jawaledan	Santa Maria
Kirikawa	Suradanni
Konoko	Yekoro

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.

Bannia	Purpleheart
Degame	Yekoro

MARINE PILING AND CONSTRUCTION

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

Caribbean Pine	Mora
Degame	Mountain Gronfoeloe
Konoko	Suradanni

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.

Caribbean Pine	Marakaipo
Chewstick	Mountain Gronfoeloe
Copaia	Purpleheart
Hill Dalli	Rokoroko
Jawaledan	Santa Maria
Kirikawa	Yekoro
Konoko	

PATTERNS

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

Yekoro

SPORTING AND ATHLETIC GOODS

The requirements for uses of this nature vary considerably. For example, in certain sporting and athletic goods, woods having the exceptional toughness of ash and hickory are needed; although 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.

Degame
Konoko
Purpleheart

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.

Bannia	Konoko
Degame	Purpleheart

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 paneling. The logs must also be large enough to make possible efficient veneer manufacture.

Utility

Caribbean Pine	Konoko
Chewstick	Mountain Gronfoeloe
Copaia	Rokoroko
Hill Dalli	

Decorative

Bois Rouge	Quillo Sisa
Jawaledan	Santa Maria
Konoko	Suradanni
Purpleheart	Yekoro

Species Descriptions

This section is devoted to descriptions of each of the species listed by common and scientific name in table 1 and for which experimental data have been summarized in tables 2–6. 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 experimental work. In the general description of the wood, color has been described from observations on test specimens as well as other samples from the Yale Wood Collection. Color terminology is based on Ridgway's, *Color standards and nomenclature*,[1] with certain modifications where apropos.

SANTA MARIA — *Calophyllum brasiliense* Camb. var. *rekoi* (Standl.) Standl.

Calophyllum brasiliense var. *rekoi* (fig. 2) is most commonly known as Santa Maria, and is also recognized by several other names throughout its range: leche de María, palo María, cedro cimarrón in Mexico; barillo, Marío, varío in Salvador; María in Honduras; krassa in Nicaragua; calaba in Panama; Marío in Guatemala; and jacareuba in Brazil.

Santa Maria occurs on the Atlantic and Pacific slopes, from Mexico (Nayarit, Michoacán, Oaxaca, Veracruz and Chiapas) to Panama (Chiriqui). Most species of this genus (one of the Guttiferae) occur in tropical Asia and Oceania; only a few are native to tropical America. In British Honduras it grows in the mixed rain forest on all types of soil. The logs tested for this report came from trees in British Honduras which grew at an elevation of approximately 60 feet. Trees may reach a diameter of 30 inches or more and a height of 110 feet. The specimens under study had clear stems of 41, 46 and 53 feet.

Heartwood varies from pink to reddish-brown and brown, sometimes with a purplish color. Sapwood is lighter, and is not sharply demarcated from the heartwood. Concentric lines resembling growth rings are sometimes indicated by terminal parenchyma. The grain is straight to interlocked, the latter producing an inconspicuous striped figure (fig. 13). Luster is medium and the texture moderately coarse. The wood is without distinctive taste or odor.

Specific gravity, based on oven-dry weight and green volume, is 0.52 (0.42–0.59) which resembles that of southern red oak. The average weight per cubic foot is 52 pounds in the green condition and 39 pounds when air dry.

Santa Maria is reputed to dry slowly with very little checking and splitting but with a tendency to warp (32).

[1]Ridgway, R. 1912. Color standards and nomenclature. Washington, D. C.

The material observed in the present study dried at a fast rate and was classified as moderately difficult to air season. Slight end and surface checking developed during the experimental seasoning study together with slight to moderate crook and slight twist. A moderate rate of drying during air-seasoning should keep degrade at a minimum. For kiln drying a mild, low-temperature schedule is recommended (35).

A number of previous strength determinations of Santa Maria are reported in the literature (3, 32, 41, 50), some of which are shown in the accompanying table. Of these, the most dependable from the standpoint of the number of trees represented are the data of the British Forest Products Research Laboratory (3) based on tests of seven trees from British Honduras. The close similarity in the results of that investigation and the current study lends support to the validity of the data reported here. The discussion that follows is based upon the results determined in the current study.

The unseasoned wood of Santa Maria equals or exceeds in strength most other woods of similar density in all properties except proportional limit stress in compression parallel and perpendicular to the grain. The unseasoned wood is notable for its relatively high bending strength and shock resistance. When compared with the appreciably heavier white oak, Santa Maria in the green condition is shown to be superior in static-bending strength, stiffness, shock resistance and crushing strength. The wood is equal to that of white oak in elastic resilience and shear, but is inferior to oak in hardness, compression and tension across the grain and cleavage resistance.

Upon air drying, the wood improved substantially in most properties but only in work to maximum load and shear was the proportionate increase in strength as great as that commonly shown by domestic hardwoods. Cleavage resistance remained unchanged and tensile strength across the grain decreased slightly.

In the air-dry condition, Santa Maria falls below the average of woods of its density class only in compressive

strength parallel to the grain. The air-dry wood is slightly superior to white oak in proportional limit stress in static bending, stiffness, elastic resilience, work to maximum load (shock resistance), proportional limit stress in compression parallel to the grain and shear. It is similarly exceeded by white oak in modulus of rupture, maximum crushing strength and hardness, and clearly inferior to oak in compression and tension perpendicular to the grain and in cleavage resistance.

Santa Maria exhibits the low ratio of shrinkage to specific gravity so characteristic of tropical woods. Volumetric shrinkage of 12.3 per cent, radial shrinkage of 4.8 per cent and tangential shrinkage of 7.1 per cent are quite comparable to values for black walnut as shown in the accompanying table. The only available data in the literature are not directly comparable as they are based on shrinkage of boards from the green condition to 11 per cent moisture content (32). In that study radial shrinkage was found to be 3.2 per cent and tangential shrinkage 5.4 per cent.

	Shrinkage (per cent)			
Species and source	Radial	Tangential	Longitudinal	Volumetric
Santa Maria				
(*Calophyllum brasiliense* var. *rekoi*)				
British Honduras	4.8	7.1	0.03	12.3
Black Walnut[1]				
(*Juglans nigra*)				
United States	5.2	7.1	—	11.3

[1]U. S. Dept. Agr. Tech. Bull. 479 (72).

The various species of *Calophyllum* are commonly rated as durable or moderately durable with respect to decay resistance (39, 63, 80). Reporting on the results of pure-culture decay resistance tests of *C. brasiliense* var. *rekoi*, Findlay rates the timber as resistant to decay (29). In the present study heartwood of Santa Maria was found to be moderately durable with respect to both white- and brown-rot fungi in pure-culture tests. Moderate resistance to termite and other insect attack has also been noted (8). Lamb

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
				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.
Santa Maria (*Calophyllum brasiliense* var. *rekoi*)	British Honduras	3	Green	62.0	0.60	0.52	5,560	10,490	1,590	1.10	12.7
			Air dry[1]	13.1			9,000	14,640	1,830	2.50	16.1
Santa Maria[2] (*Calophyllum* spp.)	British Honduras, Panama		Green	—	0.55	—	6,310	9,910	1,535	1.46	—
			Air dry	12			8,740	12,650	1,695	2.20	—
(*Calophyllum brasiliense*)[3]	Central America		Green	62	—	0.55	—	10,500	1,570	—	10.0
			Air dry	12			—	14,900	1,830	—	12.4
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

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	end	side					
		lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	lb.	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
Santa Maria (*Calophyllum brasiliense* var. *rekoi*)	Green	3,040	4,560	1,700	1010	890	570	580	1260	330	180.4
British Honduras	Air dry[1]	4,860	6,910	2,010	1410	1150	890	520*	2080	330	
Santa Maria[2] (*Calophyllum* spp.) British Honduras	Green	4,850	5,160	1,507	990	860	640	560	1060	320	—
Panama	Air dry	5,060	6,670	1,619	1370	870	1210	330	1480	340	
(*Calophyllum brasiliense*)[3]	Green	—	5,290	—	1170	1040	—	—	1310	390	—
Central America	Air dry	—	8,410	—	1680	1250	—	—	1900	410	
White Oak[4] (*Quercus alba*)	Green	3,090	3,560	—	1120	1060	830	770	1250	420	144.9
United States	Air dry	4,760	7,440	—	1520	1360	1320	800	2000	450	

[1] Air-dry values adjusted to 12 per cent moisture content except where designated (*), in which case the actual moisture content at time of testing (col. 5) applies.
[2] Trop. Woods 30: 9–16 (41).
[3] Dept. Sci. Ind. Res. (Great Britain), For. Prod. Res. Bull. No. 28 (3).
[4] U. S. Dept. Agr. Tech. Bull. 479 (72).

states that the wood is not resistant to marine borers (63). Although the sapwood takes preservative treatment readily by pressure impregnation or the hot- and cold-bath method, the heartwood is extremely resistant to impregnation under pressures as high as 140 lb. per sq. in. (32).

Santa Maria is fairly easy to work and has been compared with English oak in its resistance to cutting. Planing and molding operations generally yield smooth surfaces on straight-grained material but chipped or torn grain is fairly common on the quartered surface when interlocked grain is present. Tearing is most effectively controlled through the use of cutting angles of 20° or less. Although normally presenting no difficulty from the standpoint of dulling the cutting edges of tools, a pronounced blunting effect has been noted in the case of dark-streaked material containing deposits of calcium carbonate (32). In machining studies conducted at the Forest Products Laboratory in Madison, Wisconsin, Santa Maria was rated on the basis of surface quality as above the average of 25 domestic hardwoods in shaping, sanding and mortising, and below average in planing, turning and boring (15). The soft parenchyma layers which show a characteristic surface pattern on rotary-cut veneer are said to be associated with chipping or flaking during the peeling operation (80). Santa Maria poses no special problems in gluing, staining or finishing. The need for a filler is comparable to that of average African mahogany.

Santa Maria has been long and widely employed in the tropics for general construction, shipbuilding, shingles, furniture, cross ties, native house framing, bridge timbers, interior construction, flooring, general wheel-wright's work, heavy carts, saddle trees and, in general, wherever a fairly strong and moderately durable wood is desired. It is reported that untreated Santa Maria cross ties remained sound for only 3–4 years on a lightly traveled, poorly ballasted railroad in the interior of British Honduras but that the local abundance of the species made it economical to use due to low cost of production and replacement (37, 88). The wood

produces an attractively figured rotary-cut veneer but has not become widely accepted apparently because of the previously referred to tendency to flake during veneer-cutting operations. Burn (10) states that although the wood is often used for shingles, some form of preservative treatment is usually required. The results of trials carried on at Princes Risborough, England, indicate that the timber is unlikely to provide a satisfactory replacement for mahogany unless improved methods of seasoning are developed to overcome its tendency to warp and split.

References: 3, 5, 8, 10, 12, 15, 29, 32, 35, 37, 39, 41, 48, 50, 56, 57, 60, 63, 65, 74, 80, 81, 87, 88, 91, 94, 96, 102, 106, 109.

DEGAME *Calycophyllum candidissimum* (Vahl) DC.

Commonly known as lemonwood in domestic trade, degame is also called lancewood or degamme in the United States. In Cuba it is known as dagame. Other names used throughout its range follow: camarón or palo camarón in Mexico; madroño and salamo are generally used in Central America; chulub, ucá in Guatemala; alazano or guayabo alazano and harino are in use in Panama; urraco in Honduras; surrá in Costa Rica; araguato and betún in Venezuela; alazano, guayabo colorado and guayabo joveroso in Colombia.

Degame occurs in Cuba, and ranges from southern Mexico through Central America to Colombia and Venezuela. Other *Calycophyllum* species are of general occurrence throughout tropical America. It is also interesting to note, that quinine is derived from another member of the family to which *Calycophyllum* belongs (*Cinchona*–Rubiaceae). *Coffea*, also a member of the same family, produces the seed from which coffee is prepared. Degame may occur in pure stands and is commonly found along waterways. A small to medium-sized tree, degame is usually 40–50 feet high and may reach heights up to 90 feet and diameters to 30 inches. The trunks are usually straight and free of branches for half the total height of the tree.

The heartwood ranges from light brown to oatmeal color and is sometimes grayish. Sapwood is lighter in color and merges gradually with the heartwood. Growth rings are poorly delineated by concentric layers of darker colored fibers. Grain is straight to interlocked. An ill-defined stripe occurs in conjunction with the interlocked grain. Luster is low to medium and the texture is fine. The wood is odorless and tasteless.

Specific gravity, based on oven-dry weight and green volume, is 0.67 (0.65–0.71), comparable to that of pignut hickory. Air-dry weight is 51 pounds per cubic foot.

It is said that degame tends to warp when dried in small sizes such as those used for archery bow staves (61). The material tested in the present study was first sawn into 2¼-inch planks for seasoning in storage. Thus, air-seasoning characteristics based on 5/4-inch lumber are lacking for the wood. However, slight surface and end checking were noted in the plank stock. The U. S. Forest Products Laboratory recommends that degame be kiln dried using a low-temperature and mild-humidity schedule (61).

In the unseasoned condition the wood of degame equals or exceeds the average for woods of its density classs in nearly all strength properties. Its shock resistance, denoted by work to maximum load and toughness values, is exceptionally high. In comparison with persimmon, as shown in the accompanying table, unseasoned degame is superior in every property except compression across the grain, with notable differences in bending strength, stiffness, work to maximum load, crushing strength and hardness.

Upon air drying, the wood improved moderately in most properties, equalling or exceeding the average proportionate increase shown by most domestic hardwoods in modulus of rupture, elastic resilience and work to maximum load. A slight decrease was noted in tension perpendicular to the grain however, as was a substantial decrease in cleavage resistance.

The air-dry wood is above the average for woods of like density in bending strength, elastic resilience, shock resistance and shear. It is equal to the average in stiffness, crushing strength, hardness and tension across the grain, and below average only in proportional limit stress in compression parallel and perpendicular to the grain and in resistance to cleavage. The comparison with persimmon shown in the table indicates the superiority of degame in all static-bending properties, particularly in modulus of rupture and work to maximum load, as well as in maximum crushing strength. These two species are essentially equivalent in shear, but persimmon surpasses degame in hardness, compression and tension across the grain and cleavage resistance.

Shrinkage of degame is moderate for its weight. Volumetric shrinkage of 13.2 per cent is only about 70 per cent as great as that commonly shown by domestic hardwoods of similar high density. Radial and tangential shrinkage values of 4.8 and 8.6 per cent respectively, compare closely with values for pecan. Koehler (58) reports somewhat lower values for *Calycophyllum multiflorum.*

Species and source	Shrinkage (per cent)			
	Radial	Tangential	Longitudinal	Volumetric
Degame (*Calycophyllum candidissimum*)				
Venezuela	4.8	8.6	0.19	13.2
Pecan[1] (*Carya pecan*)				
United States	4.9	8.9	—	13.6

[1]U. S. Dept. Agr. Tech. Bull. 479 (72).

Degame is generally regarded as lacking appreciable resistance to decay (80). Pure-culture decay resistance tests showed the heartwood to be very durable when exposed to a brown-rot organism but only moderately durable with respect to deterioration by a white-rot fungus. The effect of the latter would, of course, limit the serviceability of the wood under use conditions involving exposure to decay. No specific data on marine-borer resistance are available but the wood is reputed to be highly resistant to such attack (78).