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TROPICAL WOODS

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THE WOODS AND FLORA OF THE FLORIDA KEYS. WOOD ANATOMY AND PHYLOGENY OF BATIDACEAE[1]

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The earliest mention of the plants we now know as *Batis maritima* L. was probably that of Hans Sloane, who, in 1696, described them as "Kali fruticosum, coniferum, flore albo." The name *Batis,* however, was first established by Patrick Browne in 1756. In 1763 Jacquin added the specific epithet *maritima* and essentially utilized Browne's description. The family Batidaceae was erected by Martius in 1835 as the Batideae. Although three species of *Batis (B. americana, B. hermaphrodita, B. maritima)* and five synonyms *(B. auranti-aca, B. californica, B. fruticosa, B. spinosa,* and *B. vermicu-lata)* are listed in *Index Kewensis* (Hooker and Jackson, 1893), *Batis maritima* remained the only valid name until van Royen, in 1956, described a new species from New Guinea, which he designated *Batis argillicola.*

To the present day the affinities of the family have remained obscure. Indeed, *Batis maritima* has been allied by various authors to no fewer than thirteen other groups, namely the Empetraceae, Polygonaceae, Plantaginaceae, Cynocrambaceae, Podostemonaceae, Urticaceae, Buxaceae, Salicaceae, Juglandaceae, Julianiaceae, Fagaceae, Hamamelidaceae, and even the Coniferae.

[1]The field work necessary for this series was supported by a grant from the National Science Foundation.

[2]The author wishes to express her appreciation to Professors Oswald Tippo and William L. Stern and Dr. George K. Brizicky for their suggestion of the problem and kind help with it, to Dr. P. van Royen and Mr. Peter H. Raven for providing wood samples, and to Professor Theodore Delevoryas for his help with the photography.

Van Royen (1956) and van Heel (1958), the only authors who have considered the new species, *Batis argillicola*, believe that the family belongs among the Centrospermae. The taxonomic history of *Batis maritima* and the systematic positions assigned to it have been considered by Uphof (1930). Most taxonomists have placed the species either in the Centrospermae or among the amentiferous groups. It has sometimes been put in a separate order, the Batidales. Thus Dammer (1893) considers the species to be most closely related to the Amaranthaceae but also related to the Chenopodiaceae (both members of the Centrospermae). Similarly Wettstein in his first and second editions of *Handbuch der systematischen Botanik* (1908 and 1911) mentions *Batis maritima* in the treatment of Amaranthaceae. Hallier (1905), Bessey (1915), and Hutchinson (1926) regard Batidaceae as having "centrospermeous" affinities. In the third edition of *Handbuch der systematischen Botanik* (1924), however, Wettstein puts the species in a separate order, the Batidales, which he places between the Salicales and Urticales. Engler and Diels (1936) put this order between the Juglandales and the Fagales, adding that it is a completely isolated taxon.

The Batidaceae have been assigned to these various positions primarily on the basis of gross morphology and structure of the flower, relatively little work having been done on the stem anatomy. Solereder (1908) and Metcalfe and Chalk (1950) describe the morphology of *Batis maritima*. Van Heel (1958) has studied the structure of the stem in *Batis argillicola*. The present investigation was undertaken in the hope of establishing more definitely the systematic position of the family by a detailed study of the wood anatomy. The results of these investigations, coupled with information already in the literature, have been interpreted and brought to bear on the solution of this problem.

Materials and Methods

Specimens examined[3].—FLORIDA KEYS: Big Pine Key, wet salina area, fleshy undershrub, branches reclinate, rooting at nodes, base usually woody, fleshy opposite leaves, 21 June 1956, *W. L. Stern & G. K. Brizicky 176;* No Name Key, along beach, low shrub with succulent leaves and fruits, and woody base, 6 July 1956, *W. L. Stern & G. K. Brizicky 399;* Key Largo, between Key Largo town and Tavernier, cut-over land on coral near sea, low sprawling shrub, bark on older stems with papery or corky longitudinal ribs, leaves very fleshy, 18 March 1958, *W. L. Stern & K. L. Chambers 209;* same locality, 19 March 1958, *W. L. Stern & K. L. Chambers 217.* CALIFORNIA: Orange County, borders of salt marsh just north of Surfside, plant spreading and rooting when covered by soil, with *Salicornia, Distichlis, Monanthochloe*, 5 July 1958, *P. H. Raven 13559.*

Batidaceae are a family of low, spreading or prostrate shrubs which grow in salty coastal regions. The range of *Batis maritima* includes the tropical and subtropical New World and the Hawaiian Islands. It may be found from California south to the Galapagos Islands on the west coast of the Americas and from North Carolina to Brazil and in the West Indies on the east coast of the Western Hemisphere. *Batis argillicola* has been found only in southern New Guinea.

Woody cylinders ordinarily do not exceed 2 cm. in diameter. It is interesting to note in this connection that Raven's specimen was by far the smallest in diameter, approximately 6 mm. Yet Raven states that it represented the typical size of a mature plant, and was, indeed, collected from a rather larger than average size plant. Approximate stem (wood) diameters for the Florida Keys samples are as follows: *Stern & Brizicky 176*, 9 mm.; *Stern & Brizicky 399*, 13 mm.; *Stern & Chambers 209*, 11 mm.; *Stern & Chambers 217*, 13 mm.

[3]All wood specimens and vouchers are housed in the Samuel J. Record Memorial Collection of the Yale School of Forestry. The manner of citation follows W. L. Stern and K. L. Chambers *in* The citation of wood specimens in anatomical research. *Taxon* (in press).

Methods.—Slides were prepared according to the method described by Wetmore (1932). The dried specimens were boiled to remove the air, dehydrated, infiltrated with celloidin, and stored in glycerin-alcohol. Transverse, radial, and tangential sections were cut on a Reichert sliding microtome, stained with Heidenhain's iron-alum haematoxylin, and mounted in Canada balsam. Macerations of the wood were prepared using Jeffrey's maceration fluid as outlined by Johansen (1940).

Wood characters were analyzed following the outline of Tippo (1941). From the macerations of each specimen, the lengths of one hundred vessel elements were measured according to the suggestions of Chalk and Chattaway (1934). Measurements were also made of the lengths of one hundred fiber-tracheids and of the tangential diameters in cross section of one hundred vessels. Results and statistical analyses, as recommended by Rendle and Clark (1934a, 1934b), may be found in table 2. Terminology used in this paper is that proposed by the Committee on Nomenclature of the International Association of Wood Anatomists (1957).

Description of the Morphology

The fleshy linear leaves of *Batis* are simple and opposite. Stipules are present but are early deciduous. The flowers of *Batis maritima* are arranged in axillary sessile spikes, and although Dammer (1893) reports finding one exceptional case in which the plant was monoecious, it is ordinarily dioecious. Dammer's unusual specimen may have been a representative of *Batis argillicola*, a species of monoecious plants with solitary unisexual flowers borne on brachyblasts. The male flowers are axillary or terminal and female flowers are terminal.

The elongate male inflorescence of *Batis maritima* is composed of ten to thirty pairs of staminate flowers, each subtended by a scale-like persistent bract. The flowers of *Batis argillicola* are subtended by leaves. According to van Tieghem (1903) the male flowers are naked, although Torrey (1850) and others state that there is a two-lipped, campanulate, membranous calyx. Johnson (1935) considers this structure to be a two-parted "perianth." In following its development in the bud he found that initially there are two primordia, which meet and appear almost to fuse near the apex of the young stamens. In the course of their development the stamens break through the perianth, which then resembles a two-lipped calyx. Recent investigations (van Heel, 1958) indicate that this structure may be three- or four-parted. Van Royen (1956) refers to the calyx in *Batis argillicola* as a spathella, originally developed from two bracteoles, which he considers a two-lobed perianth. The lobes are crested and have basal appendages similar to those found on the leaves. In the same species van Heel (1958) agrees that the spathella is homologous to bracteoles since there is a gradual transition in shape from the lowest leaves on the brachyblast to the spathella segments. Stipules also gradually diminish in size as the inflorescence is approached. However, the vascular pattern in the spathella differs from that in the leaves. Therefore, if we interpret sepals as modified leaves, we cannot consider the spathella segments as sepalar in nature. Apparently only certain characteristics of the spathella are leaf-like.

The male flower contains four stamens with two-celled anthers attached to the filament at their centers, opening lengthwise and introrsely. In *Batis argillicola* these may be didynamous. Four additional structures are present, which have been variously interpreted as staminodes by Johnson, as colorless scales of an extra-staminal disc by van Tieghem, as petals by Torrey, and as tepals by van Royen. These are whitish, papery, spatulate processes, clawed at the base and alternating with the stamens. Although Torrey states that they are vascularized, van Tieghem disagrees. Johnson found no trace of vascularization even at the base of the stalk, and states furthermore, that cutinization of the outer wall of the organ would seem to be evidence against staminal origin. Van Tieghem cites the diagonal placement of these scales as evidence that they represent neither staminodes nor perianth parts, and refers to them as flattened emergences. However, the use of this criterion is unclear to the author, since the statement was not elaborated. In *Batis argillicola*, according to van Heel, the tepals usually do have a vascular strand, although it and that of the stamens are not connected to the corresponding tissue in the brachyblast. Nevertheless, since the tepals are inserted slightly below the stamens, and since no forms transitional between the two structures have been found, van Heel does not justify their being considered staminal in nature. Dammer (1892) reports one exceptional case in which he found a flower with five stamens and five staminodes. No other mention of this condition is found in the literature. He also describes (1893) a rudimentary pistil, as does Baillon (1888). However, van Tieghem believes that Dammer mistook the pointed receptacle for the pistil, and asserts that no rudimentary pistil is present in the male flower, an idea with which Johnson concurs. Van Tieghem summarizes the structure of the male flower by saying that it is morphologically naked, reduced to a four-merous androecium, but that it can be considered to be formed from two, two-merous whorls, that is, diplostemonous. Unfortunately, he does not explain this conclusion nor state from what he believes it to be reduced.

The female inflorescence of *Batis maritima* is a fleshy, ovoid spike of four to twelve naked flowers, each subtended by a small deciduous bract. The ovaries are superior, coherent, and fused at the base to the spike axis. The capitate, sessile stigma exhibits two pubescent lateral lobes which are fan-shaped. According to van Tieghem the four-loculed ovary has diagonal chambers, and has been derived by fusion of two, one-loculed carpels with the development of a thicker false septum in each chamber. Each locule contains a single basal hyponastic, anatropous ovule with two integuments and no endosperm. The embryo is straight. The fruit consists of four distinct nutlets held together by the fusion of the ovary to the axis.

Similar but solitary female flowers occur in *Batis argillicola*. Evidence of their bicarpellary nature is provided by the presence of two median vascular bundles and two lateral ones which are double. The ovary is one-loculed at the base, but becomes immediately four-loculed by the union of false septum and carpel margins. Ovules are anatropous, the young

ones sometimes slightly campylotropous, and sub-marginal. Only the inner of the two integuments forms the micropyle. The fruit is a drupe consisting of four hard nuts embedded in parenchyma.

Description of the Wood Anatomy

The wood of *Batis maritima* has fiber-tracheids with thin to thick walls and minute bordered pits. A slight tendency toward storied structure appears in these elements. Vessels (fig. 1) are distributed primarily as solitary pores and pore chains, as may be seen from table 1. The wood is diffuse-

Table 1. Pore Distribution

Specimen	Solitary pores per cent	Pore clusters per cent	Pore chains per cent
Stern & Brizicky 176	46	6 (3–5)[4]	48 (2–7)
Stern & Brizicky 399	47	10 (3–4)	43 (2–4)
Stern & Chambers 209	47	6 (4–5)	47 (2–8)
Stern & Chambers 217	53	9 (3–5)	38 (2–6)
Raven 13559	50	3 (3–6)	47 (2–7)

[4]Numbers in parentheses refer to the number of pores in each group.

porous. In transverse section the outlines of the vessels appear angular, and the walls are thick (up to 6.8μ). The diameters of the vessel elements range from 10μ to 71μ, with a mean of 37μ. These measurements may be found in table 2.

Many thin-walled empty tyloses with simple pits are present in the vessels. However, these are few in individual vessel members, usually one to three, and rarely occlude the lumen. The perforation plates are simple. End walls of vessel elements are oblique to transverse, the maximum inclination making an angle of 60° (fig. 2). The sparse intervascular pitting is alternate, the small pits (average 4.5μ in diameter) being circular with elongate apertures. Vessel–parenchyma pitting is similar in size, shape, and arrangement. No gum deposits were noted in the vessels. Tabulations of length of the elements may be found in table 2. A mean value of 125μ and a range of 32μ to 357μ was found.

Table 2. Dimensions of Tracheary Elements

Specimen	Range in μ	Most frequent range in μ	Mean in μ	Standard deviation in μ
		Fiber-tracheid length		
Stern & Brizicky 176	100–500	308–412	340±8.5	85±6.0
Stern & Brizicky 399	228–464	316–371	342±5.4	54±3.8
Stern & Chambers 209	200–540	352–460	397±7.4	74±5.2
Stern & Chambers 217	104–504	220–340	287±2.2	22±1.6
Raven 13559	108–520	312–412	356±7.9	79±5.6
		Grand mean	344±17.0	38±11.7
		Vessel element length		
Stern & Brizicky 176	44–152	76–100	94±2.0	20±1.4
Stern & Brizicky 399	85–357	200–243	225±5.4	54±3.8
Stern & Chambers 209	72–184	92–152	115±2.6	26±1.8
Stern & Chambers 217	32–120	60–92	78±0.4	4±0.3
Raven 13559	56–156	92–132	112±0.7	7±0.5
		Grand mean	125±26.3	58±18.1
		Vessel diameter		
Stern & Brizicky 176	14–49	26–37	31±0.9	9±0.7
Stern & Brizicky 399	10–71	40–58	48±1.3	13±13.3
Stern & Chambers 209	17–66	32–51	40±1.1	11±0.8
Stern & Chambers 217	13–56	31–41	33±0.1	0.9±0.1
Raven 13559	15–60	31–52	35±0.9	10±0.7
		Grand mean	37±3.1	7±2.1

The vascular rays (fig. 2) of the species are abundant, averaging 6.75 per mm. measured across a tangential section. They are Heterogeneous Type II A according to Kribs' classification (1935). As may be seen from table 3, the rays varied from 1 to 8 cells wide; the uniseriate rays ranged from 1 to 7 cells high, and the multiseriate rays ranged from 3 to more than 72 cells high. Pitting in walls of ray cells is

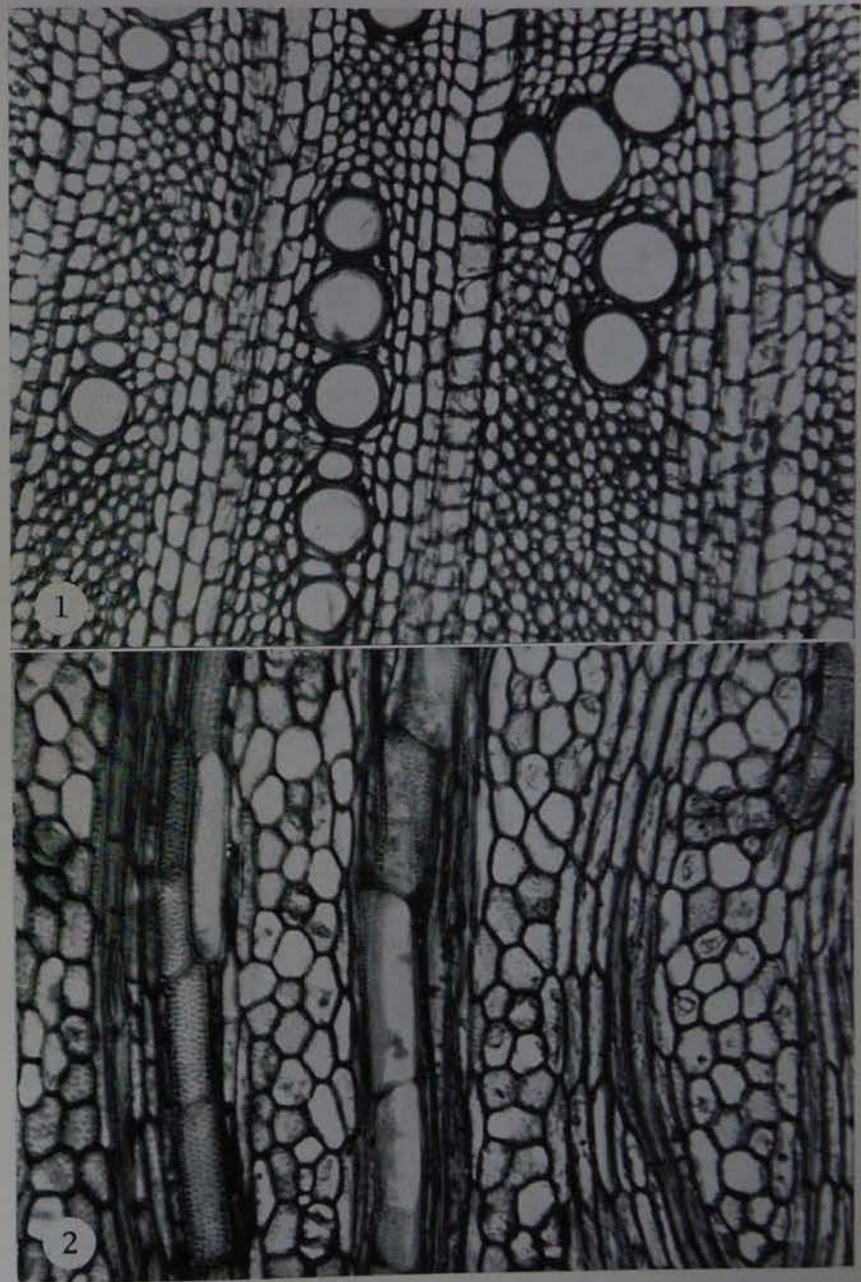

Fig. 1–2. *Batis maritima* xylem. Fig. 1. Transverse section showing pore chains, radial multiples, and solitary pores. Crystalliferous ray parenchyma is present as is vasicentric axial parenchyma. × 144.—Fig. 2. Tangential section illustrating storied fusiform axial parenchyma cells, crystalliferous ray parenchyma, and slightly oblique end

Table 3. Dimensions of Wood Rays (Number of Cells)

	Width		Height			
			Uniseriate		Multiseriate	
Specimen	Range	Most Frequent Range	Range	Most Frequent Range	Range	Most Frequent Range
Stern & Brizicky 176	1–6	3–5	2–7	3–5	3–35	15–25
Stern & Brizicky 399	1–7	3–5	1–6	2–4	4–37	15–28
Stern & Chambers 209	1–5	3–4	2–4	2	3–41	20–30
Stern & Chambers 217	1–8	3–6	2–4	3–4	3–52	20–30
Raven 13559	1–8	3–6	2–4	2	2–72+	20–40

abundant and pits are large, varying from 5.1μ to 6.4μ. No intercellular canals, laticifers, or oil cells are present. Irregularly shaped crystals, however, are evident in some cells, one to each cell (fig. 3). Sheath cells are also present.

The abundant axial xylem parenchyma is vasicentric (fig. 1), and the cells are fusiform in the tangential section (fig. 2). Parenchyma is found in distinct zones to such an extent that a cross-section of the stem exhibits rings to the naked eye. These rings are caused by alternating zones of parenchyma and fiber-tracheids. Many minute simple pits are found on the walls of the axial parenchyma cells. The elements are storied (fig. 2).

Van Royen states that the wood of *Batis argillicola* is similar to that of *Batis maritima* as described by Solereder in the German edition of *Systematic anatomy of the dicotyledons* and by Metcalfe and Chalk. There are, however, several distinctions: no small bundles are present in *B. argillicola* opposite the lateral surfaces of the stem, as described by van Tieghem for *B. maritima;* solitary stone cells are not present in the bark of *B. argillicola*, and crystals are lacking in the pith, cortex, and phloem; all ray cells are procumbent in *B. argillicola*, and the "vessels" are no longer than 200μ.

Discussion

The author believes that the comparative morphology and wood anatomy indicate that Batidaceae are most closely allied to Centrospermae and Salicaceae. This is in agreement with the views of most modern systematists. From an analysis of all information available in the literature on the Batidaceae plus a study of those characters of the wood of *Batis maritima* discussed previously, the writer concludes that the family is probably less closely related to the Salicaceae than to the Centrospermae.

Salicaceae and Batidaceae comprise woody plants with simple, stipulate leaves and rubiaceous stomata (Metcalfe and Chalk, 1950). Both families contain dioecious plants with naked flowers (if one accepts van Tieghem's analysis of *Batis maritima*). The ovary of both is bicarpellary. The staminate flower of the Salicaceae consists of two or more stamens, while that of the Batidaceae consists of two diplostemonous cycles. The pistils of both families have sessile stigmas and anatropous ovules. A trace of endosperm is present in the seeds of Salicaceae but it is entirely lacking in the Batidaceae. Both have straight embryos. Anatomical characters which are identical in the two families are as follows: vessel elements with simple perforation plates, and alternate intervascular pitting.

In the Centrospermae, the Amaranthaceae and Chenopodiaceae are the two families to which the Batidaceae have usually been allied. The three families are quite similar in habit as well as in gross morphology and anatomy. The leaves of Batidaceae are opposite and fleshy; those of Amaranthaceae and Chenopodiaceae may be opposite or alternate, and in some cases also fleshy. Nodes are unilacunar. In all three families inflorescences may be spicate and petals are lacking in the flowers. Moreover, in *Amaranthus*, *Acnida*, and *Acanthochiton* (Amaranthaceae) and in *Sarcobatus* and the tribe Atripliceae (Chenopodiaceae), some of the flowers are completely naked, as is the case in the Batidaceae. In all three families petaloid outgrowths are situated on the receptacle. The Chenopodiaceae and Batidaceae have bicarpellary ovaries. All three families have ovules with two integuments. Ovules are basal in the Amaranthaceae and Chenopodiaceae and appear basal, at least, in the Batidaceae. Van Royen calls them "basilateral" in *Batis argillicola*, and

van Heel remarks that although they look basal in that species, they are actually submarginal.

Evidences of possible relationship are also found in the secondary xylem. All three families have vessels with simple perforation plates and alternate intervascular pitting. The axial wood parenchyma is always paratracheal, and sometimes cells are fusiform. In the Chenopodiaceae storied structure is characteristic. A tendency toward this is found in the fiber-tracheids and axial wood parenchyma of the Batidaceae. Both groups have sheath cells associated with the multiseriate rays. A comparison of the characters of the Batidaceae, Centrospermae, and Salicaceae may be found in table 4.

Table 4. A Comparison of Batidaceae, Centrospermae, and Salicaceae

	BATIDACEAE	CENTROSPERMAE	SALICACEAE
		General morphology	
Leaves opposite	+	+	—
Rubiaceous stomata	+	rare	+
Stipules	+	rare	+
Unisexual flowers	+	some	+
Two-merous floral parts	+	some	+
Perianth lacking	+	rare	+
Stigma sessile	+	—	+
Anatropous ovules	+	some	+
Solitary ovules	+	+	—
Straight embryo	+	rare	+
Endosperm	—	+	trace
Two integuments	+	+	—
Micropyle formed by inner integument	+	some	—
		Stem anatomy	
Unilacunar node	+	+	—
Paratracheal parenchyma	+	+	—
Fusiform parenchyma cells	+	+	—
Multiseriate rays	+	+	—
Sheath cells in rays	+	+	—
Storied structure	+	+	—

The Centrospermae are usually considered a natural group with campylotropous ovules, curved embryos, and abundant endosperm, characters in which they differ from the

Batidaceae. However, it is felt that since exceptions to these conditions are found within Centrospermae, a relationship to the Batidaceae cannot be overruled on these bases. Orthotropous ovules are present in some Chenopodiaceae. Anatropous ovules, as in the Batidaceae, are found in the Nyctaginaceae, Aizoaceae, and Caryophyllaceae. Straight embryos appear in the Nyctaginaceae and Caryophyllaceae (in the latter, very nearly straight). Similarly, anomalous secondary growth is usual in the Centrospermae and absent in the Batidaceae. However, it is also lacking in some genera of the Phytolaccaceae, Gyrostemonaceae, and Chenopodiaceae.

There is no fossil record of the Batidaceae. Pollen analysis has yielded no conclusive evidence of the affinities of the family; however, there does seem to be a resemblance between pollen of *Batis maritima* and that of the Polygonaceae and Gyrostemonaceae according to Erdtman (1952). Pollen grains of *Batis argillicola* are similar.

Gibbs (1954 and 1958) and Bate-Smith and Metcalfe (1957) have carried out a number of phytochemical tests. Results of these for various species in the Salicaceae, Centrospermae, and Batidaceae are listed below. (Gibbs' data for the latter family are recorded by van Heel.) Leucoanthocyanin test: *Batis argillicola*, negative; Centrospermae, 7 species negative, 4 species positive; Salicaceae, 1 species negative, 7 species positive. Test for cyanogenetic glycosides: Batidaceae, negative; Centrospermae, 1 species negative, 1 species positive; Salicaceae, not known. HCl/Methanol test: Batidaceae, negative; Centrospermae, Salicaceae not known. Mäule's test: Batidaceae, ++ to +++; Centrospermae, 2 species +, 7 species ++ to ++++; Salicaceae, 9 species + to ++. Syringin test: Batidaceae, negative; Centrospermae, not known; Salicaceae, 5 species positive.

In the opinion of the author the Batidaceae are more closely related to the Amaranthaceae and Chenopodiaceae of the Centrospermae than to any other living plant groups. The evidence must be considered inconclusive, however, since the family also shows many similarities to the Salicaceae. The suggestion is offered that the Batidaceae constitute a phylogenetically isolated family, and that Batidaceae, Salicaceae, and Centrospermae may have evolved from a common, petaliferous ancestor. The relationship of Salicaceae to Centrospermae is, of course, a problem in itself, and beyond the scope of this discussion. The Batidaceae are considered to be an advanced, reduced group and not primitively simple. It seems that on the basis of present knowledge the family should be placed in its own order, the Batidales, and classified near the Centrospermae.

Summary

The family Batidaceae, with two species, *Batis maritima* L. and *Batis argillicola* van Royen, has been assigned many positions in so-called phylogenetic classifications of plants, but most often it has been placed near the Salicaceae or in the Centrospermae. A study of the wood anatomy of *Batis maritima* was undertaken in an effort to help determine the true relationships of the genus.

Evidence from the flower morphology does not indicate definitely whether the Batidaceae are more closely related to the Salicaceae or to the Centrospermae. Certain anatomical features, however, point to a relationship between the Batidaceae and Centrospermae, specifically the Amaranthaceae and Chenopodiaceae. Nevertheless, it is believed that it is an isolated, reduced family, and should be placed in an order by itself, the Batidales, this order to be considered allied to the Centrospermae.

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PROSPECTS FOR FOREST LAND MANAGEMENT IN PANAMA

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Introduction

The forests of Panama are potentially the country's most important natural resource. Garver (1947) estimated that roughly 5.2 million hectares, or 70 per cent of the land area of Panama, should be classified as commercial forest land; that is, land capable of growing timber of commercial quantity and quality, and either now or prospectively available for commercial use. The importance of these forests as such becomes evident with the realization that the bulk of the tropical forest soils in Panama, as elsewhere in the American tropics, is not suited to permanent agricultural cultivation. Tropical agriculturists in the past have been greatly misled by the assumption that the luxuriance of the tropical forest is a direct indication that the soils which support such forests are also suitable for agriculture. The forest land planted to bananas and sugar cane in tropical America, and then subsequently abandoned due to soil deterioration, bears witness to this fact (Lamb, 1954; Wardlaw, 1929). There is apparently little correlation between the soil fertility and the lushness of forest vegetation in the tropics (Lamb 1956; Popenoe, 1945; Richards, 1952). Although the leached, impoverished soils of the wet tropics may bear magnificent forests, the soil serves as little more than a substratum for the roots and a passageway for the nutrients which are taken up immediately as they are released from the rapidly decaying plant materials (Gill, 1958; Richards, 1952).

The present distribution of the forests in Panama is the result of the land use practices of the past. The forests that still exist today remain either because of their isolation, or because climatic conditions make clearing for agriculture impractical. For example, the extensive forests along the Atlantic slope of the central cordillera have been cut only

lightly, largely because the high rainfall in this area makes land clearing and subsequent cultivation difficult. The high altitude forests of the cordillera and the forests of Darién are also practically untouched because of their isolation and the resulting transportation difficulties. On the other hand, in the central provinces, and in Chiriquí and Panamá, the forests have nearly disappeared, although at one time the areas were largely dominated by forest cover. The marked dry season and accessibility of these areas are partly responsible for the decimation of the forest. It is in these places today that the bulk of the population lives, where most of the agriculture is concentrated and where the transportation system is highly developed.

Land Management

The felling of forests for shifting cultivation and the subsequent repeated indiscriminant use of fire to maintain the land free of woody plant cover, has resulted in the conversion of large areas of potentially productive land into sterile, impoverished savannas. Examples of this are seen around Penonomé and Santiago. The entire area from Cerro Campana to the Costa Rican border is rapidly being converted to grassland. Properly managed, this grassland could conceivably produce more cattle than could be profitably marketed in Panama; however, a large part of this area is sterile savanna and wasteland, bearing neither forest nor supporting crops of any kind. Bartlett (1956) has described the methods whereby tropical forest is changed to grassland and the latter reconverted to tropical forest. Fire plays an important part in these alternations. If properly managed, as noted below, fire may become a permanent part of an agricultural system in which crops alternate with forest. However, the uncontrolled and destructive fires which sweep freely over parts of Panama result only in large areas of ground unsuited for forests, crops or grazing, and which are characterized by a worthless growth of fire-resistant woody vegetation and coarse, unpalatable grass.

Productive forest returns very slowly to cleared land that has deteriorated under cultivation and burning unless artificial means are used to accelerate natural plant succession. By introducing valuable pioneer and successor species to the transitional plant association, the succession toward the climax can be accelerated (Food and Agriculture Organization, 1956; Lamb, 1954). Species for consideration in this regard include, *Cedrela mexicana* and *C. odorata* (Bascopé et al., 1957; Flinta, 1959), *Swietenia macrophylla* and *S. mahagoni* (Flinta, 1959; Lamb, 1954), *Cybistax donnell-smithii* (Lamb, 1951), *Cordia alliodora* (Flinta, 1959), and *Tectona grandis* (Food and Agriculture Organization, 1956). This appears now to be a most practical method of restoring productive capacity to abandoned agricultural land that has deteriorated beyond economic productivity. Certain other areas appear to be misused: Lands suitable for permanent grazing are endangered by overgrazing and burning; some of the land currently utilized as pasture could be better employed for crops. On an aerial inspection in sections of Chiriquí Province, the burning of rice straw was observed. Good agricultural practice would demand that it be returned to the soil to replenish the organic content. As a result of all these malpractices, many families in the central provinces of Veraguas, Los Santos, Herrera and Coclé are seeking to leave these areas because of the difficulties encountered in attaining a reasonable standard of living. The reasons given by these people are drought, poor soil and insufficient land area. Thus, the initial use of lands best suited to forest growth and their subsequent mismanagement as agricultural lands have given rise to wasted soils, essentially barren lands and a group of people dissatisfied with their present living and ready to migrate elsewhere, no doubt to repeat the poor practices that have brought about their present dissatisfaction.

The adequate and efficient employment of land in Panama hinges on an intelligent categorization of the land in an attempt to determine for what purpose it is best fitted. Soil classification and land use planning techniques now available provide the basis for improving land management practices in the tropics. The long range use of the soil resources of Panama depends on a program of land classification that

designates, according to soil quality, aspect and climate, the most productive uses to which the land can be permanently devoted. This work has been initiated by a small group of dedicated technicians in Panama, and its furtherance is vital to the future agricultural economy of the country. Land classification programs have not as yet progressed to the point where it is possible to say what proportion of the forest area in Panama would best be suited to permanent cultivation of agricultural crops and what proportion should be left as forest land. The magnitude of this problem is striking when one recalls that Garver estimates a forest area of 5.2 million hectares—70 per cent of the total land area! However, the present state of our knowledge of tropical land resource management indicates that a large portion of the land area of Panama should be maintained either under forest cover, or tree-type crops that protect the land from deterioration.

It may be that in some areas an alternation of crop plants with forest through the use of controlled burning will be desirable. Bartlett (1956) describes the process by which certain people of Indonesia and Africa maintain a shifting type of agriculture by rotating clean cultivation with tree crops. Employing this method, when the soil of plots used for cultivation of food crops has deteriorated following three or four years of use, and the encroachment of coarse grasses make further cultivation difficult, valuable fruit and timber trees are established and the land reverts to forest cover. Such a program ultimately results in a renewal of soil fertility and prepares the soil for a future cycle of cultivation. It appears that the Cuna Indians of the Upper Bayano and Chucunaque Rivers in Panama have a similar system of alternating clean cultivation of plantains, bananas, corn and rice with cacao and coffee. A few young mahogany trees have also been observed which obviously had been planted. This type of cultivation should be encouraged and intensified in other parts of Panama. It should be pointed out in connection with the above methods, that the use of fire is essential in the process of preparing the land for subsistence crops. However, the fire must be controlled to avoid destruction of the tree crops in adjacent areas. It has been just this control, this vital step, that has been lacking in the agricultural practices of the Panamanian farmer. The initiation of planned demonstration projects to indicate the proper use of fire in shifting agriculture and its adaptation to adequate land management procedures would help the Panamanian farmer to understand the conditions under which he should carry out his farming.

Watershed Protection

The effect of the forest on watershed areas in Panama needs immediate study. Several rivers on the Pacific slope of Panama are changing from a steady year-round flow, to alternate periods of flood and drought as their catchment basins are being denuded of forest by shifting cultivation and burning. The Chiriquí Viejo River in Chiriquí provides a pertinent example. Observations here over a period of 25 years by a lay observer, indicate that since the headwaters have been gradually denuded, the minimum dry season flow has decreased to only 50 per cent of the former dry season minimum. During periods of high rainfall the maximum crest of floods has more than doubled.

Watersheds which, because of their importance to irrigation projects, hydroelectric developments and Panama Canal operation, require immediate control, are those of the Chiriquí Viejo, Chiriquí, San Pablo and Chagres Rivers. It is much less costly to protect existing vegetation on critical watersheds than to re-establish it after destruction. The remaining vegetation on the rivers mentioned should be protected and experiments set up to determine the effect of timber removal on a controlled basis from watershed areas. Thus, in the future these forests can be managed for maximum production of both water and timber. Few data are currently available on the exact effect of vegetation on water flow under conditions in Panama.

Tree Crops

The importance of tree crops to the economy of Panama will become more evident as integrated land management

plans develop. The increasing realization that silvicultural methods can be applied in the humid tropics, and that clean cultivation and horticultural methods are not the only workable practices for land use, is a change taking place in tropical agriculture in the Orient (Pendelton *in* Popenoe, 1945). Furthermore, Bartlett (1956) suggests that permanent land use in the tropics is likely to utilize woody plants almost exclusively, and that this land use will resemble forestry in its procedures. In Panama such tree crops as the following might logically fit in with suitable land management plans: cacao, *Theobroma cacao;* African oil palm, *Elaeis guineensis;* coffee, *Coffea* spp.; and rubber, *Hevea brasiliensis*. These may be grown in combination with important tropical timber trees as mahogany, *Swietenia macrophylla;* Spanish cedar, *Cedrela* spp.; primavera, *Cybistax donnell-smithii;* teak, *Tectona grandis*, and others. The forest environment also produces conditions suitable for the growth of small understory plants of commercial value: ipecac, *Cephaelis ipecacuanha;* rotenone-producing genera, *Derris*, *Lonchocarpus* and *Tephrosia;* vanilla, *Vanilla fragrans* (*V. planifolia*); and sarsaparilla, *Smilax* spp.

Timber Crops

Wood utilization and forest land management in the American tropics still have a long way to go before the tremendous potential of the forest resources can be realized. The complex mixture of species found in most of the forests of Panama creates a serious obstacle to efficient forest management at present levels of wood utilization. Logging operations now extract only scattered trees of the more valuable species such as mahogany and Spanish cedar. This type of operation leaves the forest relatively intact so far as vegetative cover is concerned, but depleted of the most desirable trees with no provision made for their replacement.

Technological developments in the utilization of mixed tropical hardwoods for the production of paper pulp, fiber board and chip board offer hope of improvement in the utilization of these woods (Hall, 1947; Glesinger, 1949; Lamb, 1956). The disposal of a larger proportion of the raw material available will make it possible to initiate more intensive forest management practices to maintain and increase the productive capacity of the forest. If a forest similar to that which now exists is to be maintained, the most satisfactory method of cutting will probably be the group selection system, with natural regeneration or direct seeding to care for the reproduction. If utilization practices require the extraction predominantly of one species, then perhaps it will be best to clear cut in blocks and replant with the species desired. Such questions as stand composition, rates of growth and density of stocking, remain to be determined. The silvicultural characteristics, and the physical and mechanical properties of the woods of many of the forest tree species in Panama are as yet unknown.

It might be of interest to examine the possibilities of timber production in two of the provinces of Panama as examples of conditions which exist in the forests.

Darién Province.—The province of Darién, where over 90 per cent of the land is now covered with forest, provides an example of the type of resource problem facing Panama. A recent reconnaissance soil survey (Smith et al., 1954) indicates that the land area of this province suitable for permanent cultivation is approximately 10 per cent of the total land area of 1.5 million hectares. The undesirable physical and chemical characteristics of the so-called upland soils limit the area suitable for cultivation in Darién to the friable alluvial soils of the river basins. These constitute only a small percentage of the total area. An ecological survey of the same region resulted in the recommendation that clearing land for agriculture should not be allowed to progress into areas of rough topography and low fertility, because such terrain would not yield an adequate return for the effort required (Holdridge and Budowski, 1957). However, future developments are unpredictable due to the extension of a preliminary route survey for the Inter-American Highway through Darién to form the connecting link between Panama and Colombia (Pan American Highway Congress, 1957). As a result, considerable speculation is already taking place regarding the use of the land that will

be opened up by this project. The construction of modern highways has a drastic effect on the tropical landscape which encompasses not only the area actually disturbed by the construction, but also the land opened up to commercial development. Road construction in other parts of Panama and Central America has resulted in complete destruction of the forests. Therefore, if orderly development of the natural resources of Darién is to be accomplished, effective plans will have to be developed and suitable controls established before the pressure of land speculation becomes too great to control.

Darién is most favorably situated for the establishment of an integrated forest industry to produce pulp and paper, fiber board, chip board, veneer, plywood and sawn lumber, because of the existing extensive forest resources and the natural water transportation routes. The present forest cover should be protected as a source of raw material for future industrial developments wherever the land is unsuited to agriculture. Important woods available for utilization in large quantities in Darién are mangrove, *Rhizophora mangle*, and cativo, *Prioria copaifera*. These species occur in almost pure stands in tidal and fresh water swamps, respectively. The volume of mangrove available has not been estimated, but the cativo forests of Darién contain some 500,000,000 board feet of commercial timber according to one estimate (Lamb, 1953). The most abundant tree in a large part of the upland forest is quipo, *Cavanillesia platanifolia*, which produces a wood similar to that of balsa, *Ochroma lagopus*. The volume of quipo in the Chucunaque River Valley of Darién has been estimated at 1,250,000,000 cubic feet. This figure would probably be doubled if all of Darién were included (Lamb, 1958). This wood was shipped to England during World War II to be used as a substitute for balsa. Preliminary trials indicate that by itself quipo is not suitable for pulp and paper because of the high portion of fiber that is lost in the screening process (T. Ford, personal correspondence). However, it is possible that this difficulty might be overcome by mixing quipo pulp with that of other species. Other uses apparently have not been studied, but applications in the insulation and acoustical fields seem to be worth investigating. Other woods of interest, although more scattered in occurrence, are mahogany, *Swietenia macrophylla;* Spanish cedar, *Cedrela* spp.; nazareno, *Peltogyne* sp.; tachuelo *Zanthoxylum* sp.; cedro espino, *Bombacopsis quinata;* and espavé, *Anacardium excelsum.*

Production of mahogany from the forests of Panama in recent years has averaged approximately 3,000,000 board feet annually, largely extracted from Darién. One-third of this production is utilized locally, and the other two-thirds is exported. At this rate of cutting the remaining stands of mahogany can be expected to last approximately 20 years (Lamb, 1953, 1954). The timber now being cut is an accumulation of mature and over-mature trees that have been developing over a period of several hundred years. Since 40 to 50 years are required for planted mahogany to reach commercial size, the natural growing stock remaining in Panama does not provide a basis for continuous supply at present levels of production. However, restrictive measures do not seem advisable since such a large proportion of the existing trees are over-mature and defective, and subject to rapid deterioration if left standing. A planting program, which does not now exist, is essential if Panama is to have mahogany in the future.

Bocas del Toro Province.–The forests of this province are considerably different from those of Darién largely because of the higher rainfall. There are nearly pure forests of orey, *Campnosperma panamensis,* in the coastal swamps, and of cativo in the swamps along the rivers. The upland forests are a more complex mixture of species than occurs in the drier forests of Darién. This area is now being studied to determine the feasibility of setting up a pulp and paper industry to utilize the available wood.

Of particular interest in this area are the secondary forests that have sprung up in abandoned banana plantations. One of the most abundant species in this secondary vegetation is the valuable timber tree *Cordia alliodora.* It would be of considerable value in formulating management plans for the forests of this area to have data on stocking, and of natural reproduction and growth for this species in Panama. The establishment of experimental plots to study these points would be a worthwhile project.

Government Forestry

The bulk of the forest land in Panama remains in the public domain. However, no long-range plan exists for the orderly development of this natural resource which may well hold the answer to the future well being of the country. The effect of misdirected efforts to extract the utmost contribution to the economy of the country from these land resources is evident in many places. In certain areas of national development and growth, the responsibility for leadership and direction lies in the hands of public officials. It appears that the people of Panama have reason to expect more enlightened leadership in the field of natural resource development than they have had in the past. For example, an attempt has been made to require the forestry section of the Inter-American Cooperative Agricultural Service to dedicate its major effort to a program of providing a tree to plant for every school child in Panama. There is no question of the value of such a program from the educational and public relations standpoints, but emphasis on such tree planting shows a complete lack of understanding of the tremendous problem facing Panama in developing a program for the rational use of the country's forests.

The forestry staff in the government organization of Panama now consists of one forester and a secretary. The minimum personnel requirement needed to initiate a forestry program in this Central American republic is estimated to be seven technicians, including one administrative officer, four forest inspectors, one nursery technician, and one technician trained in public relations and education. This staff would need to be supplemented with office personnel and laborers. Such a technical group would have to be expanded rapidly as experience is developed, if an adequate job of forest resource administration is to be accomplished. This organization could be financed by an increase in the stumpage fee for the timber now being cut on public land. Present logging operations in Panama pay only a small fraction of what would be considered a reasonable stumpage fee, based on accepted methods of stumpage appraisal. For example, mahogany concession holders presently pay only $2.00 per thousand board feet for stumpage. In other mahogany-producing countries the stumpage fee ranges from $10.00 to $40.00 per thousand board feet. The new fiscal code, not yet in effect in Panama, specifies that mahogany shall be assessed at 10 per cent of the gross value of the product. If properly applied, this plan may improve the situation.

Conclusions

Central and South America, including Mexico, embrace the greatest wood-surplus region on the face of the earth, according to a recent report of the Forestry Division of the Food and Agriculture Organization (1946). However, in proportion to total area and total volume of wood available, these forests probably make the smallest economic contribution of all the major forest areas of the world. The greatest obstacle to the development of these forests is the low value per unit of area because of the lack of established markets under existing methods of utilization. If integrated forest industries can be founded, based on sound forest management, regular markets can be developed. Problems of forest management will become vital, and it is likely that such problems will find their solutions only through planned experimentation carried out under industrial auspices as the industries themselves develop. Progress in both of these fields appears to be behind that being made in many parts of tropical Africa and Asia. Many aspects of financing, marketing and technology remain to be worked out. However, an integrated type of development, utilizing a mixture of species to produce a variety of products, appears to offer the most promising means of extracting a significant economic contribution from the complex tropical forest. Such a contribution will create additional forest values and will justify

forest management practices to maintain and increase forest productivity.

The problems of forest management in Panama are intimately associated with the agricultural practices. Both of these are in turn closely related to the general questions of resource management. It is evident that the problems of resource management will become increasingly acute with increasing population growth, improved communications and growing transportation systems such as the projected Darién link represents. These are coupled with the strong urge of all underdeveloped nations to attain a better standard of living.

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Fig. 1. *Wimmeria Sternii* Lundell, sp. nov. Isotype Y.

A NEW SPECIES OF *WIMMERIA* (CELASTRACEAE) FROM PANAMA

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Wimmeria Sternii Lundell, sp. nov.—Arbor glabra, 40 cm. diam. Folia parva, 3–8 mm. longe petiolata, chartacea, lanceolata, 3.5–7.5 cm. longa, 1.2–2.3 cm. lata, acuminata, serrulata. Cymae ad 1.5 cm. longae.

Tree, 40 cm. in diameter, entirely glabrous; branchlets slender, reddish. Leaves small, chartaceous, slender petiolate, slightly paler on lower surface of blade. Petioles 3 to 8 mm. long, with conspicuous medial ridge on upper surface. Leaf blades lanceolate, 3.5 to 7.5 cm. long, 1.2 to 2.3 cm. wide, the apex acuminate, base acute to acuminate, costa prominent on both surfaces, veins inconspicuous, margin serrulate. Cymes (in bud) up to 1.5 cm. long, the peduncles slender, 1- to 7-flowered, usually 3-flowered. Pedicels slender, jointed at base. Flowers and fruits unknown.

PANAMA: Province of Chiriquí, in cloud forest, alt. 4500 ft., foothills of Volcán Barú, northwest of El Hato, tree, 16 in. diameter, known locally as "ratón rojo," June 6, 1957, *William L. Stern & Kenton L. Chambers* 57 (TYPE, LL; ISOTYPE, Y. fig. 1).

W. Sternii appears to be related to *W. concolor* Schl. & Cham., a shrub of Mexico. This is the southernmost representative of the genus.

A CRITICAL NEW *BURSERA* FROM COSTA RICA

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This unusual member of the Burseraceae has been studied at various times for several years by the authors and by Paul C. Standley, for whom we name it. It has changed generic designations three times in our notes, partly because of the morphology of the flowers and the unusual epiphytic habit of the plant. Burseras are most often to be found as terrestrial plants in mesophytic or xerophytic habitats. The habitat of the present species is a wet rain forest area where the annual rainfall amounts to 3,800 mm. or usually more. It has occurred to us that epiphytism in this species may have developed in response to these wet conditions, for the relatively dry tree tops remove the plant from the constantly moist ground.

Bursera standleyana L. Wms. & J. Cuatr. sp. nov.— Arbor magna ramis terminalibus viridibus striatis minute lenticellatis glabris. Folia alterna imparipinnata vel paripinnata bijuga vel unijuga 30–40 cm. longa. Petiolus ambitu subteres striolatus rigidus mediocris basi paulo incrassatus glaber circa 10–12 cm. longus. Internodia rhachidis striata glabra 5–6 cm. longa. Petioluli graciles striolati glabri 1.4–3.5 cm. longi. Foliola chartacea utrinque nitida et glaberrima, ovato-elliptica vel oblongo-elliptica basi rotundata, ad apicem paulo attenuata subrotundata vel obtusa et subite acuteque triangulari-acuminata, margine integerrima, 9–18 cm. longa, 4–11.5 cm. lata, acumine acuto 8–12 mm. longo basi 5–10 mm. lato; supra nitidissima, nervo medio secundariisque conspicuis venulis in reticulum gracile prominulum productis; subtus costa prominenti sed tenui nervis secundariis irregularibus filiformibus prominentibus 7–8 utroque latere ascendentibus prope marginem arcuatis anastomosantibus venulis reticulum prominentem valde conspicuum

gracilem formantibus. Inflorescentiae femineae axillares subterminales anguste thyrsoideae 8–9 cm. longae, laxe multiflorae axi ramulis pedicellisque tenuibus striolatis glaberrimis, bracteolis anguste ovatis acutis vel lanceolatis glabris 0.5–1.5 mm. longis. Pedicelli graciles 1–2 mm. longi. Sepala 3, ovata, basi brevissime coalita, circa 0.7 mm. longa, 0.8–0.9 mm. lata, glabra. Petala 3, valvata, alba, oblongo-ovata, apice acutata incurva crassiuscula glabra, intus papillosa, 1.8–2 mm. longa, 0.9–1.2 mm. lata, decidua. Stamina 6, sterilia 1 mm. longa, filamento 0.3 mm. longo, anthera lanceolato-oblonga, 0.7 mm. longa, complanata, vacua. Discus crassiusculus, amplus, glaber. Ovarium ovato-oblongum, glabrum, 1 mm. longum in stylum brevem (0.2–0.3 mm.) productum. Stigmata tria, capitata. Ovarium triloculare, loculis biovulatis. Drupa 6–8 mm. longa, 3–4 mm. lata, ovoideo-trigona, basi paulo angustata obtusaque apice attenuata subobtusa, exocarpio laevi glabro subnitido carnosulo 0.5–0.7 mm. crasso in sicco coriaceo, maturitate in 3 valvis dehiscenti. Endocarpium corneum tenue, trinucularium, nuculis duobus rudimentariis anguste oblongis 2–3 mm. longis una tantum evoluta fertilique. Nucula fertilis oblongo-ovata subtrigona, apice acutiuscula, 4.5–6 mm. longa, circa 2.5–3 mm. lata, monosperma. Semina oblongo-ovata, paulo compressa, testa crassiuscula embryo recto cotyledonibus foliaceis lobatis contortuplicatis.

COSTA RICA: Province of Puntarenas, Esquinas forest, region between Río Esquinas and Palmar Sur, alt. 30 m., very large hemi-epiphytic trees, flowers white, fragrant, February 26, 1951, *Allen 5966* (HOLOTYPE, US no. 2085776. fig. 1); same locality, epiphytic tree with red, peeling bark, *Allen 6271;* same locality, very large hemi-epiphytic trees, the branches to 30–40 feet in length and 6 inches in diameter, *Allen 5884;* same locality, epiphytic tree growing in the top of *Anacardium excelsum*, May 30, 1950, *Allen 5547*.

As mentioned above, the generic classification of *Bursera standleyana* has been difficult. The genus *Bursera* generally has tetramerous or pentamerous flowers, while those of *B. standleyana* are trimerous. *Bursera standleyana* is related to

B. simaruba, from which it is distinguished by its epiphytic habit, and by the thinly chartaceous, large, green, shining, glabrous leaflets which are prominently reticulate and long petiolulate.

The specimens of *Bursera simaruba* from the Antilles and Colombia which we have seen have pentamerous flowers. This is true also of most Mexican material. However, a few Mexican collections, and some from Costa Rica, show trimerous flowers. Apparently the trimerous flowers observed were feminine, which may indicate a possible sexual dimorphism. There is a possibility also that among the mass of material determined as *Bursera simaruba* there is more than one species.

NOTES ON THE DISTRIBUTION OF *GOMORTEGA*

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Gomortega nitida Ruiz & Pavón, the queule, is the sole member of the Gomortegaceae. The species is highly restricted in range and is confined to a part of coastal Chile. Apparently the trees were once abundant within this range (fig. 1) but their numbers have diminished alarmingly in recent years. The account to follow represents an attempt to define the present and past distribution of queule as indicated by first-hand observations, correspondence and the literature. The authors have been unable to visit all of the area which was probably once occupied by this species, and regret that many of the conclusions must be tentative pending further exploration.

In their description of *Gomortega nitida*, Ruiz and Pavón (1798) mention that it grows in woods throughout Concepción and in other provinces. Furthermore, they suspect that a second species of the genus grows in the Arauco Mountains and extends to Valdivia. No other species has come to light since the time Ruiz and Pavón. Gay (1849) merely states that the queule occurs in forests of the provinces of Maule and Concepción. R. A. Philippi (1868) gives Concepción and Arauco provinces as localities, and states further that the range of queule is incorporated in the *Araucaria* country and extends south to the Río Queule. In his *Elementos de botánica* (1869) he remarks that the queule grows from Nuble to the Río Queule. F. Philippi (1876) relates, that in a visit to the Río Queule, no queules were seen, nor did the inhabitants of the region know of such a tree. A recent report (correspondence) from Professor Hugo Gunckel L., Director of the Instituto de Botánica de Universidad de Chile, appears to confirm this observation for he states that, "Apparently in the coastal region of the northern part of the province of Valdivia and the southern part of Cautin the Queule has never existed, at least in historic times. I cannot understand how the port of Queule received its name. I think we should look for the origin of the name, not in the name of the tree but in some other indian word which sounds very like queule but with an entirely different meaning; for example, 'Kauluñ,' meaning flame of fire." It is entirely possible also, that some of the early botanists took for granted the existence of the tree in the region without actually seeing any merely because of the place names.

Reiche (1896) records queule from Tomé (Concepción province) and from Collipulli (Malleco province). He cites personal communication with F. Philippi who says that certain fruits seen by him and collected in the coast range of Valdivia, could only have come from *Gomortega*. Reiche also records the remarks of R. Bonn: Queule inhabits a limited region near Tomé and occurs between 500 and 600 m. above sea level. Bonn states that it is a constituent part of the forest associated with *Fagus dombeyi* Mirb. [*Nothofagus dombeyi* (Mirb.) Blume] and several Myrtaceae. Reiche (1907) mentions that the queule extends north to 35° 30′ in the vicinity of Chanco, Maule province, and reaches south to 40° 20′ in Valdivia province. Espinosa Bustos (1948) collected specimens from the northeast of Tomé at about 100 m. elevation, and also at Coyén near Tomé at 120 m. altitude. Two herbarium specimens of queule in the S. J. Record Memorial Collection of the Yale School of Forestry *(L. Rossovsky s. n.)* were collected near Tomé, in a high mixed forest at 600 m. altitude, and near Copiulemu (Concepción province) in a mixed forest of poor appearance at 800 m. altitude.

All of the trees observed by the senior author were confined to the coastal area, principally in the environs of Concepción and farther north. These observations show that the queule grows naturally on very rough, rocky land, unfit for agriculture, and generally where there is abundant moisture. In the hills north of Concepción it is found in eroded gullies from quite close to sea level up to 150 to 200 m. above sea level. Queule has actually been seen by the senior author planted as an ornamental in the city of Concepción, on the Tumbes Peninsula north of Talcahuano, along the coast on this peninsula, west and a little north of Concepción, and in the hills just off the public road between Penco and Tomé. A station at Quillón (Concepción province), 20 miles from the sea, has just been noted by students from "El Vergel." The authors have reliable information that the queule is abundant in the region of Coelemu in the extreme north of Concepción province, and also that there are a fair number of trees in an area west of Cañete, in the province of Arauco. This latter locality seems to be about the center of the area where the tree was formerly distributed. The authors have been unable to obtain information on the present occurrence of queule south of the station at Cañete.

From the above reports, it seems that the queule was once more widespread than at present. Espinosa Bustos (1948) implores the people of Chile to protect this interesting endemic from extinction. He cites its destruction during land clearing, its use for charcoal and firewod and its supplantation by exotic species. It is possible therefore, that because of these practices, the queule no longer grows naturally over all of its former range, but that it still may be found in isolated localities especially where the land is unfit for agriculture. It can be stated, that the original range of the queule extended from the Río Itata in the north, possibly to the Río Queule in the south, although the latter limit seems dubious. This range covers only three degrees of latitude, a distance of about 200 miles. Our own observations and recent information indicate that the greatest concentration of individuals of *Gomortega nitida* exists in the northern portion of its presumed former range, mostly in the coastal areas of Concepción and Arauco provinces.

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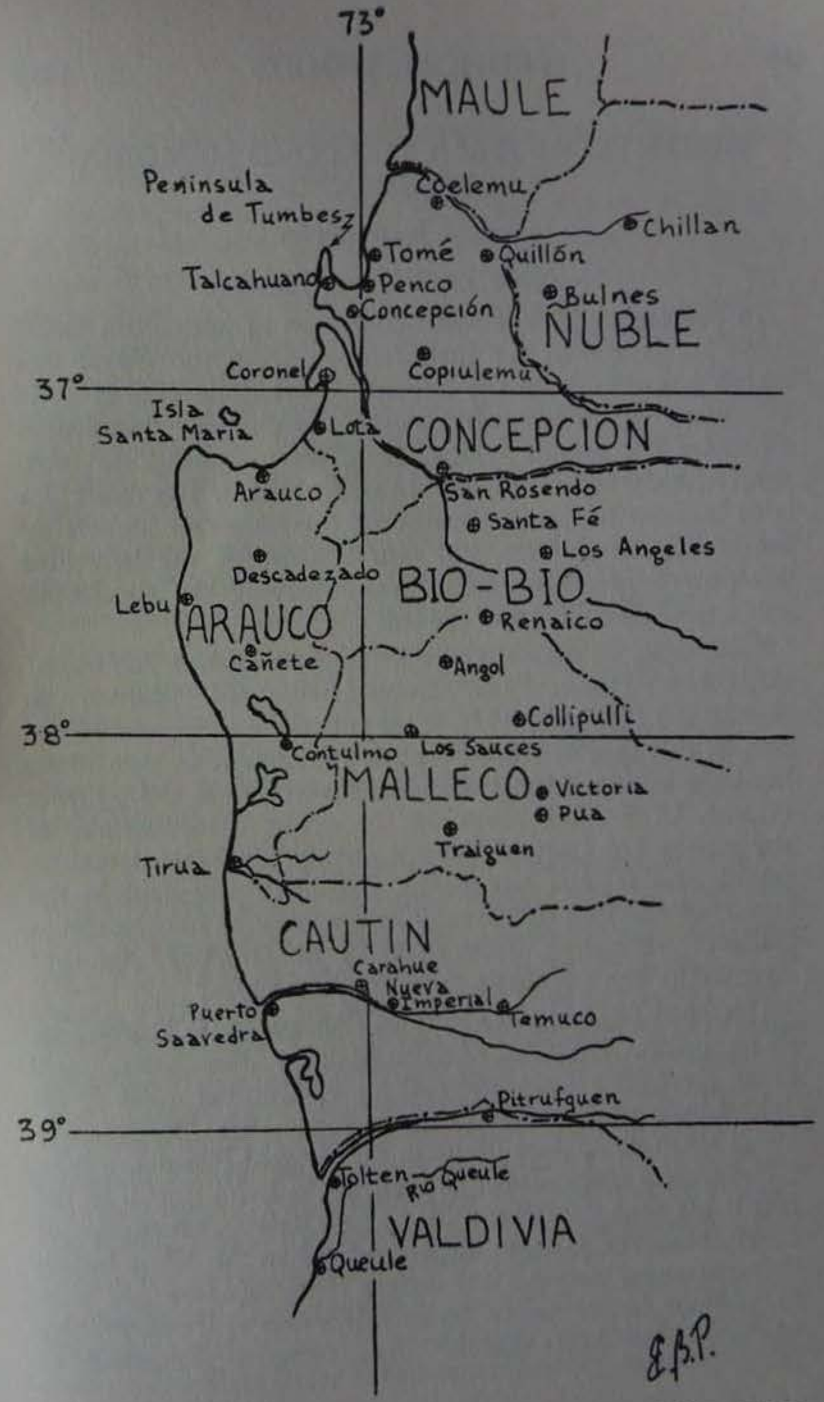

Fig. 1. Map of coastal Chile covering the range of *Gomortega*

NOTES FROM THE S. J. RECORD MEMORIAL COLLECTION. III.

GEORGE K. BRIZICKY

NOTABLE TREES FROM PANAMA

In November 1958, a small collection of herbarium specimens was received for identification from the Naval Research Laboratory in the Panama Canal Zone (Canal Zone Corrosion Laboratory). These specimens constituted vouchers for woods which, after seven-month-long tests, exhibited marked resistance to marine borers. The collection is of interest not only because of the resistance shown by the associated timbers, but also because of the heretofor unreported common names accompanying the specimens, and a new distributional record.

CARINIANA PYRIFORMIS Miers (Lecythidaceae) "chibugá." DARIÉN: NEAR PANAMANIAN-COLOMBIAN BORDER, *A. Adrian s. n.*, October 1958. This collection is apparently the first of this species from Panama. Previously, *C. pyriformis* has been known from Colombia. However, in 1927, Pittier (Contr. U. S. Natl. Herb. 26: 2) wrote, "More species of the genera (of Lecythidaceae) already represented will be found, and at least one genus, *Cariniana*, abundant in the forests of the Sinu and Atrato valleys, is likely to exist also in Darién." According to the collector, the fruits of "chibugá" are used by the Indians to make smoking pipes.

COLUBRINA GLANDULOSA Perkins (Rhamnaceae) "carbonero de munición." CANAL ZONE: MADDEN DAM AREA, *Canal Zone Corrosion Laboratory s. n.*, 14 October 1958. I. M. Johnston, who discovered this species in 1945 (Sargentia 8: 190. 1949) on San José Island in the Gulf of Panama, writes, "The species ranges from Panama to Peru and Brazil. In the past it has been confused with *C. rufa* Reiss. That species of Brazil, however, is more closely related to the West Indian *C. ferruginosa* Brong., and differs from our tree not only in its much larger rufous flowers, but also in its very hairy leaves lacking basal glands." According to Johnston, *C. rufa* of Standley's *Flora of the Panama Canal Zone* (Contr. U. S. Natl. Herb. 27: 248. 1928) is *C. glandulosa*.

Another interesting observation regarding the distribution of *Colubrina* lies in the fact that R. C. Foster, in his *A catalogue of the ferns and flowering plants of Bolivia* (Contr. Gray Herb. 184: 1958), does not mention the occurrence of the genus in Bolivia. Probably it has not been reported from that country. However, in the herbarium of the S. J. Record Memorial Collection there is a specimen of *C. glandulosa* collected in "Provinz Velasco, Am Fusse des Serrania Ricardo Franco" by *Eberhard Schmidt 57*, 14 September 1951.

LAFOËNSIA PUNICIFOLIA DC. (Lythraceae) "amarillo negro." CANAL ZONE: MADDEN SADDLE DAM ROAD, *Canal Zone Corrosion Laboratory s. n.*, 15 October 1958.

POUTERIA CHIRICANA (Standl.) Baehni (Sapotaceae) "níspero de monte" (det. A. Cronquist). CANAL ZONE: MADDEN SADDLE DAM ROAD, *Canal Zone Corrosion Laboratory s. n.*, 15 October 1958. This species is only known from a few collections in the provinces of Bocas del Toro and Chiriquí.

VALIDATION OF *Meliosma longipetiolata*

In *The rain forests of Golfo Dulce*, P. H. Allen (1956. Univ. Florida Press. Gainesville) mentioned the following species of *Meliosma* (Sabiaceae): *M. allenii* Standl. & L. O. Wms., *M. anisophylla* Standl. & L. O. Wms., and *M. longipetiolata* Standl. & L. O. Wms. In the process of identifying a species of *Meliosma* collected in 1957 by W. L. Stern and K. L. Chambers in Panama, the author found that only one of these species, *M. allenii*, has been validly published. The others lack Latin diagnoses. To avoid future confusion arising through the use of an invalid binomial, Dr. Louis O. Williams has kindly loaned the type material of *M. longipetiolata* upon which the Latin diagnosis below is based.

Meliosma longipetiolata Standl. & L. O. Wms. ex Brizicky.—Arbor ca. 12-metralis ramulis crassis, fistulosis, basi subteretibus, apicem versus verisimiliter subtri- vel subpentagonis, in sicco bruneolis, lenticellatis, pilis minutissimis glandulosis parce pilosis, ceteroqui glabris. Folia simplicia, alterna, membranacea, petiolata; petioli subtereti, 5.5–7.5 cm. longi, minutissime partim gladuloso pilosi; laminae integrae, ellipticae, 16–22 cm. longae et 6–8 cm. latae, apice breviter acuminatae, basi acutae, in sicco brunnescentes, supra praesertim ad costam et nervos laterales minutissime plerumque glanduloso pilosae costa nervisque lateralibus plus minusve impressis, venis vix conspicuis, subtus ad costam, nerves laterales venasque minutissime parce, praesertim glanduloso, pilosae costa crassiuscula prominente, nervis lateralibus utrobique 18–22, angulo semirecto abeuntibus, rectiusculis, gracilibus prope marginem arcuato conjunctis, venis prominulis, laxe reticulatis, vix conspicuis. Panicula axillaris, pyramidalis, 12.5 cm. longa et 6 cm. lata, subsessilis pedunculo 0.4 cm. longo, multiflora, dense adpresse pilosula ramis ramulisque crassiusculis, floribus parvis, sessilibus, congestis. Sepala 5 subaequalia, suborbicularia vel triangulari-suborbicularia, apice rotundata, 0.08–0.1 cm. longa et 0.1–0.12 cm. lata, margine scarioso minutissime plerumque glanduloso ciliata, extus parce adpresse pilosula. Petala 3 exteriora majora, carnosula, viridi-flava (Allen!), in sicco nigrescentia, late-ovata vel triangulari-suborbicularia, apice rotundata vel obtusissima, basi paulo contracta, glabra, 0.25–0.3 cm. longa et 0.2–0.25 cm. lata, marginibus angustissime scariosis; petala 2 interiora minora, membranacea, anguste lanceolato-linearia, apice longe attenuata, ca. 0.22 cm. longa et 0.04–0.06 cm. lata. Stamina 2 fertilia, petalis interioribus opposita, filamentis anguste linearibus 0.15 cm. longis et 0.03–0.04 cm. latis, basi latioribus et hoc loco petalis adnatis. Staminodia 3, petalis exterioribus opposita, 0.14–0.15 cm. longa et 0.1 cm. lata. Discus hypogynus minutissimus, membranaceus, irregulariter 5-dentatus. Ovarium ovatum, 0.12–0.14 cm. longum, glabrum, in stylum 0.06–0.08 longum sensim attenuatum, 2-loculare, loculis 2-ovulatis. Fructus ignotus.

Species *Meliosmae allenii* Standl. & L. O. Wms. multo affinis sed ab ea differt foliis minoribus, ellipticis nervis

Fig. 1. *Meliosma longipetiolata* Standl. & L. O. Wms. ex Brizicky. Type US.

lateralibus numerosioribus et sepalis plerumque glanduloso ciliatis.

COSTA RICA: Province of Puntarenas, occasional in lowland forest near Palmar Norte, 1951, *P. H. Allen 5248* (TYPE US; fig. 1).

M. longipetiolata seems closely related to *M. allenii* Standl. & L. O. Wms. According to the original description of the latter species (Ceiba 1: 238. 1950 under *Meliosma maxima* Standl. & L. O. Wms.) it has obovate-oblong leaves with about 15 lateral nerves on each side of the blade. This agrees with *Stern & Chambers 145* from Panama which has been identified as *M. allenii* (Trop. Woods 109: 77. 1958). However, the photograph of *M. allenii* in Allen (1956. plate 33) shows leaves with more numerous lateral nerves (about 22 or more pairs) than was mentioned in the original description. These leaves bear greater resemblance to our new species than to *M. allenii*. Since there seems to be no question that *Stern & Chambers 145* represents *M. allenii*, an additional distinguishing characteristic by which the two related species may be separated is to be found in the ciliation of the sepals. In *M. longipetiolata* sepalar trichomes are chiefly glandular, whereas in *M. allenii* these are almost completely eglandular.

Centrolobium (Leguminosae)

On plate XXIX of S. J. Record and C. D. Mell's *Timbers of tropical America* (1924. Yale Univ. Press. New Haven), Pittier's photograph, "Fruits of Amarillo de Guayaquil *(Centrolobium patinense)*" is reproduced. In fact, the fruits shown are not those of *C. patinense*, but belong to *C. yavizanum* Pittier. The latter is known from Darién, Panama and from Colombia, and was not mentioned in the text of the above volume. As the error has been overlooked and subsequently was transferred into *Index Londinensis* (Suppl. 1: 205. 1941), it is thought desirable to publish this correction.

SURVEY OF AFRICAN WOODS. IV.[1]

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Maesopsis eminii Engl. Musizi Rhamnaceae

The species is known in the trade by the name musizi. Local names for the species include bu-ay-wray (Liberia); manasati (Ivory Coast); igilogbon (southern Nigeria); essenge (Cameroons); muhongera, musizi (Uganda); muhunya (Kenya); muhumula, nsira (Tanganyika); (Eggeling and Harris, 1939; Dalziel, 1937).

The tree attains heights of 90–120 feet or more and diameters up to 4 feet at maturity. The bole is straight and reasonably cylindrical, clear of branches for a length of 30–80 feet, and with occasional buttresses which are short and blunt (Eggeling and Harris, 1939; Wimbush, 1950). The species occurs in western, central, and eastern Africa along the equator. Its range extends from Liberia eastward through the Ivory Coast, Ghana, southern Nigeria, Cameroons, Belgian Congo, to Uganda and Tanganyika. The largest trees occur in East Africa and decrease in size as one goes westward. It is most commonly found in forests bordering the grassland where it thrives on dry sandy soil. Plantations have been established in the Belgian Congo and Uganda with good results.

The heartwood is olive-brown when freshly cut becoming russet upon exposure (Cooper and Record, 1931). The sapwood is nearly white, 1–2 inches wide, and sharply delineated from the heartwood (Department of Scientific and Industrial Research, 1956). The wood is odorless and tasteless when dry and has a high satiny luster. The texture is medium and the grain slightly interlocked. The growth rings

[1]This is the concluding article of the series on African woods. Readers are directed to *Tropical Woods* 105: 13–38, for Part I with tables and introduction, and to 106: 65–97, for Part II and to 107: 92–128 for Part III.

are absent or poorly defined. The pores are visible, variable in abundance but never crowded, open, and generally solitary but occasionally aliform confluent, uniting 2 or more pores. The rays are fine and visible to the naked eye on the end and tangential surfaces but inconspicuous on the radial surface.

The wood is moderately light in weight averaging 30 pounds per cubic foot air dry (Cooper and Record, 1931). The specific gravity (oven-dry weight, air-dry volume) is 0.43.

The wood air-seasons and kiln-seasons rapidly with some tendency to split particularly in thicker sizes (Wimbush, 1950). Jay (1947) reports that there is a tendency for splitting, warping and collapse to occur.

The results of mechanical tests on green and air-dry material are reported in table 1. Musizi is approximately of the same specific gravity as yellow poplar *(Liriodendron tulipifera)* but is generally somewhat stronger in most strength properties.

The unseasoned wood of musizi is superior to yellow poplar in all static bending properties and impact strength. It is 50 per cent superior in impact strength and in total work in static bending. The same margin of superiority exists in endwise compression, hardness and cleavage. In shearing strength parallel to the grain, musizi is 30 per cent stronger than yellow poplar.

Upon drying from the green to the air-dry condition, musizi exhibits moderate increases in modulus of rupture in static bending, end hardness and shear. Maximum crushing strength increases 60 per cent. Static bending properties of stiffness, work to maximum load and total work increase slightly. Impact strength and cleavage undergo moderate reductions upon drying.

In the air-dry condition, musizi is superior to yellow poplar in all strength properties except stiffness in static bending and cleavage. Although the total work value in static bending for musizi is 40 per cent greater than for yellow poplar, the former is only slightly stronger in impact strength. The greatest difference between the two woods in the seasoned state is in hardness, musizi being twice as hard on the end surface and 1.5 times as hard on the side-grain surfaces. Musizi is 20 per cent stronger in maximum crushing strength and approximately equal in cleavage to yellow poplar.

The wood appears to possess good dimensional stability as is indicated by the dimensional change between 90 per cent and 60 per cent relative humidity. The equilibrium moisture contents at these two relative humidities are 18 per cent and 12 per cent respectively (Forest Products Research Laboratory, 1954); the dimensional change occurring between 60 per cent and 90 per cent relative humidity is 1.5 per cent tangentially and 1.0 per cent radially based upon the dimension at 60 per cent relative humidity. These values are only slightly higher than comparable values of 1.3 per cent and 0.8 per cent for teak. Musizi is therefore classified as a wood with small dimensional change.

The results of decay resistance tests conducted in England (Findlay, 1938) are reported in table 3. After exposure to white-rot and brown-rot fungi for periods of 4 and 8 months, specimens exhibited appreciable weight loss due to decay, particularly when exposed to the former. The wood is therefore classified as not resistant to decay. It is not resistant to damage by termites and should be treated with a preservative when used under conditions where biological deterioration is a hazard (Eggeling and Harris, 1939). The wood is reported as easily treated with preservatives.

The wood is soft and works fairly readily with machine and hand tools (Eggeling and Harris, 1939). Irregularities of grain may result in grain pick-up in planing. Good surfaces are produced if the wood is adequately supported in sawing, drilling and mortising, and in planing if a cutting angle of 20° is employed. The wood nails well and finishes satisfactorily with the usual finishes, but careful preparation and grain filling are required before varnishing or painting.

Musizi is suitable for millwork and general indoor construction as a softwood substitute (Jay, 1947; Organisation for European Economic Co-operation, 1951). It may prove suitable for exterior use if treated with a preservative.

Mansonia altissima A. Chev. Mansonia Sterculiaceae

Local names (Dalziel, 1937) for this species include bete (Ivory Coast); aprono, pruno (Ghana); afun, odo, urodo (southern Nigeria).

The tree attains a maximum height of 100 feet at maturity and an average diameter of 2 feet (Department of Scientific and Industrial Research, 1956). The bole is clear and straight and buttressed at the base (Vigne, 1933). The species occurs in the deciduous forest type of the Ivory Coast, Ghana, and southern Nigeria.

Sapwood is white in color, 1–1½ inches wide, and sharply delineated from the grayish-brown heartwood (Department of Scientific and Industrial Research, 1956; Vigne, 1933). The heartwood often has a purple cast (Jay, 1947) and resembles American black walnut. Luster is low to medium; the wood lacks a distinct taste or odor (Kribs, 1950). The grain is straight and the texture is medium. Growth rings are distinct due to concentric bands of terminal parenchyma. Pores are barely visible to the naked eye, numerous, evenly distributed, and solitary or in radial groups of 2–8. The parenchyma is terminal, forming concentric bands 1–2 cells wide, and diffuse-in-aggregates, forming numerous, broken tangential lines between the rays. Rays are not distinct to the naked eye on the cross section and are inconspicuous on the radial surface. Ripple marks are distinct and regular and all elements are storied.

The weight per cubic foot air-dry averages 38 pounds (Jay, 1947), which is a specific gravity (oven-dry weight, air-dry volume) of 0.53. Harrar (1941) reports the average specific gravity based on oven-dry weight and volume as 0.71.

The wood air-seasons readily with a slight tendency to split and distort (Department of Scientific and Industrial Research, 1956). Kiln-seasoning proceeds rapidly with some extension of splits and splitting at knots. The British Forest

Products Research Laboratory (1945) suggests a kiln schedule similar to that recommended for American black walnut and sugar maple.

The results of mechanical tests on green and air-dry material are reported in table 1. In the seasoned condition, mansonia may be compared to yellow birch *(Betula alleghaniensis)* in most strength properties.

The unseasoned wood of mansonia is superior to yellow birch in maximum bending strength (modulus of rupture) but inferior in total work in bending and impact strength. In all other strength categories, mansonia is far superior to yellow birch.

In drying from the green condition to 12 per cent moisture content, mansonia undergoes moderate increases in strength with the exception of total work in static bending and cleavage. Total work exhibits a slight decrease (approximately 10 per cent) upon drying from the green to air-dry condition. Cleavage decreases approximately 25–30 per cent of the value for the unseasoned wood.

In the air-dry condition, mansonia is equal to yellow birch in maximum bending strength, although, it is slightly inferior in stiffness and work to maximum load in static bending. However, it is 25 per cent inferior in total work and 20 per cent inferior in impact strength. Mansonia is considerably less resistant to splitting than yellow birch, but equally strong in endwise crushing, hardness and shear.

Mansonia is suggested as a possible substitute for well-known bending woods such as oak, beech and walnut (Department of Scientific and Industrial Research, 1956). But the steam-bending properties of the wood vary considerably and as a result, it is not generally recommended except for moderate radii of curvature. Steam-bending tests conducted in England demonstrated that the material could be bent to radii of curvature of 10 inches per inch of thickness when supported, and 15½ inches when not supported by a steel tension strap.

Green to oven-dry shrinkage values for mansonia are reported in table 2. The shrinkage of the wood—volumetric

11.5, tangential 6.4 and radial 4.6 per cent—is less than that for the majority of domestic hardwoods of equal density. The reported values are comparable to those for quaking aspen, black cherry and American chestnut, these species being of a lower density than mansonia.

Results of decay resistance tests conducted in England (Findlay, 1938) are reported in table 3. After 8 months exposure to the action of wood-destroying fungi, mansonia exhibited negligible weight loss due to decay. The species is therefore classed as very resistant to decay. However, logs are susceptible to pinhole borer and longhorn beetle attack, the damage usually being confined to the sapwood (Department of Scientific and Industrial Research, 1956). Reports from Nigeria indicate that the species is resistant to termite attack. The wood is resistant to impregnation of preservatives by the open tank process.

Mansonia works very easily with hand and machine tools and has little dulling effect on cutting edges (Department of Scientific and Industrial Research, 1956). It offers less resistance to cutting than black walnut and does not tend to char when worked on the end-grain. A dust is produced in sawing which is irritating to the mucous membranes of some individuals. The wood has good nailing, screwing and gluing properties, and takes the usual stains and finishes very well (Jay, 1947).

Mansonia is used in Nigeria for carpentry and in railway coach construction (Forest Products Research Laboratory, 1945). The better-colored portions of the wood may be used as a substitute for black walnut (Jay, 1947), and have found a market for use in piano cases, furniture, shop woodwork and camera bodies. It combines the desirable qualities of strength, dimensional stability, durability and ease of working with a pleasing appearance.

Mimusops heckelii Hutch. & Dalz. Makoré Sapotaceae

This species is identified in the English timber trade as makoré. It is also known as (Dalziel, 1937) wosime (Sierra Leone); babu, bagwain, butusu, dimori, diutu, (Ivory Coast);

abaku, makoré, makwe, opepe (Ghana); and aganokwe (southern Nigeria).

The tree attains a height of 120–150 feet. The bole is long, clear, cylindrical and free from buttresses with an average diameter at maturity of 4 feet (Department of Scientific and Industrial Research, 1956). Makoré is found sparsely distributed throughout the moist high forest zone of Sierra Leone, Ivory Coast, Ghana and Nigeria (Forest Products Research Laboratory, 1952a).

The wood is pinkish- to reddish-brown in color, medium-textured, straight-grained to slightly roey, lacking in a distinctive taste or odor, and has a medium to high luster (Kribs, 1950). It bears a superficial resemblance to mahogany, and is sometimes called cherry mahogany. Straight-grained stock presents a plain appearance; however, the presence of interlocked grain produces a mottle (broken stripe figure), handsomely marked with irregular veins of darker color (Forest Products Research Laboratory, 1952a), of a nature seldom met in mahogany. Makoré can be distinguished from mahogany by its distinct reddish cast and finer texture. Growth rings are indistinct; pores are visible without a lens, not numerous, arranged in definite irregular radial lines, and solitary or in radial groups from 2–6 (Kribs, 1950). Vessels contain a brownish "gum" and tyloses. Parenchyma is distinct without a lens, apotracheal in closely spaced tangential bands 2–4 cells wide, and the cell cavities contain a reddish "gum." Rays are distinct with a lens on cross-section, inconspicuous on the radial surface, and the cell cavities contain a red "gum."

The wood is somewhat heavier on the average than central American mahogany (*Swietenia* spp.) ranging from 40–53 pounds per cubic foot when green (Forest Products Research Laboratory, 1952a). It has an average density of 40 pounds per cubic foot air-dry (Rendle, 1938) which is a specific gravity of 0.56 (oven-dry weight and air-dry volume).

The wood dries slowly but is by no means refractory. There is a tendency for splitting to develop around knots and end-splitting to occur. Degrade in other forms is low, but a mild kiln schedule is suggested (Clifford, 1953; Department of Scientific and Industrial Research, 1956).

The results of mechanical tests conducted in Great Britain on air-dry material are reported in table 1. The strength properties of makoré are often compared to Honduras mahogany (*Swietenia macrophylla*) since both are commonly used as furniture woods.

In the air-dry condition, makoré is equal to Honduras mahogany in bending (modulus of rupture), stiffness and maximum crushing strength. Makoré is 50 per cent harder on the end grain, 100 per cent harder on the side grain and 60 per cent more resistant to splitting than mahogany. However, it has a higher specific gravity on the average which is not reflected in increased bending and crushing strength.

The heartwood bends well after steaming but the sapwood tends to buckle and rupture when bent to any appreciable extent (Forest Products Research Laboratory, 1952a). The species is classed as a moderately good bending wood (Department of Scientific and Industrial Research, 1956) and will take bends of radii down to 12 inches per inch of thickness when supported, and 18 inches per inch of thickness when unsupported.

The shrinkage of makoré from green to oven-dry is reported in table 2. The values—volumetric 13.7, tangential 7.8 and radial 5.3 per cent—are similar to those for white ash (*Fraxinus americana*) and approximately twice the values for Honduras mahogany. In going from 90 per cent relative humidity (19 per cent equilibrium moisture content) to 60 per cent relative humidity (13 per cent equilibrium moisture content), the dimensional change is 1.8 per cent tangentially and 1.1 per cent radially of the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). Comparable values for Honduras mahogany are 1.3 and 1.0 per cent. Both species are classified as undergoing small dimensional change.

Makoré is highly resistant to decay; specimens under test in soil in Ghana showed only slight decay after 12 years.

The sapwood is susceptible to powder-post beetle attack, otherwise the wood is very resistant to insect attack including termites (Jay, 1947). The heartwood is impermeable to preservative treatment and the sapwood moderately resistant to treatment; nevertheless, satisfactory creosote penetration into the sapwood can be accomplished either under pressure or by the open tank process (Forest Products Research Laboratory, 1952a).

The wood can be worked with moderate ease by hand and machine tools but rapid blunting of cutting edges is common (Forest Products Research Laboratory, 1952a). The difficulty of working and the blunting effect, increase as the moisture content of the wood decreases. Green material can be satisfactorily cut with a wide tooth pitch at a fast, uniform rate of feed. Material below 20 per cent moisture content should be cut with a carbide-tipped saw. A cutting angle of 20° is necessary to avoid tearing quarter-sawn stock in planing. The wood tends to char in boring and to split in nailing. It has good screwing and gluing properties, slices with ease, and stains and finishes very well with little grain filler required (Department of Scientific and Industrial Research, 1956; Jay, 1947; Kinloch and Miller, 1949). A good dust-collecting system is required as the wood produces a dust irritating to the nose and throat.

Being a timber of exceptional beauty, makoré finds its greatest use in decorative work. Its ease of slicing renders it an ideal veneering wood. It compares favorably with mahogany for furniture and high-class decorative work either in the form of lumber or veneer. It is also used for superior millwork and interior woodwork (Forest Products Research Laboratory, 1952a). Veneered wood of this species in the form of panels was used in the main lounge gallery and book shop of R. M. S. Queen Mary (Forest Products Research Laboratory, 1945; Jay, 1947). Makoré finds lesser use for exterior doors, benches, sills, thresholds and flooring, drain boards and textile rollers. It has been used in small quantities for plywood manufacture.

Abura

Mitragyna spp. Rubiaceae

There are three principal species of this genus: *M. inermis* O. Ktze. (*M. africana* Korth.), *M. ciliata* Aubr. & Pelleg. and *M. stipulosa* O. Ktze. (*M. macrophylla* Hiern). These species are discussed by Dalziel (1937) and by Aubréville and Pellegrin (1936). The latter two species are the only ones which are described in the light of their technological characteristics. An initial survey of the literature concerning the genus *Mitragyna* failed to produce an authoritative reference to *M. ciliata*, which was first recognized and described as such in 1936 by Aubréville and Pellegrin. Previous literature referred to *M. stipulosa* as the only commercial species of this genus. Since it is pointed out in British literature (Forest Products Research Laboratory, 1945), that *M. stipulosa* does not occur in the dense rain forests which furnish the timber of abura for the export trade, it seems a reasonable assumption that a goodly portion of the export shipments of *Mitragyna* timber consists of *M. ciliata*.

The common names applied to the two species are: *Mitragyna ciliata* (Jay, 1947): subaha (Ghana); bahia (French West Africa); elilom (Cameroons); elebom (Gabon); maza, vuku (Belgian Congo). *Mitragyna stipulosa* (Chalk et al., 1933; Dalziel, 1937): baya, subaha (Ghana); kwo-kwo, agouwa, popo (western Africa); mukonja malambia (Cameroons); mvuku, vukus (Belgian Congo); bahia (Ivory Coast); abura, eben, (Nigeria).

The differences between the two species are primarily in the flowers (Aubréville and Pellegrin, 1936). Both species are medium to large trees attaining heights of over 100 feet and a diameter of 3–5 feet (Chalk et al., 1933; Department of Scientific and Industrial Research, 1956). The bole is clear and cylindrical to a height of 60 feet, free of buttresses and usually with only a slight butt swell. The distribution of the species are not clearly stated in the literature. Chalk et al. (1933) report the distribution of *M. stipulosa* in western tropical Africa from Sierra Leone, through the Ivory Coast, Ghana, Nigeria, Belgian Congo, southward as far as northern Rhodesia and eastward to Uganda. However, *The*

Handbook of Empire Timbers (Forest Products Research Laboratory, 1945) reports that *M. stipulosa* occurs outside the dense rain forest zone which supplies timber for the export market. Jay (1947) reports the distribution of *M. ciliata* in the rain forest zone of Ghana, Ivory Coast, Gabon and the Belgian Congo. The occurrence of trees of this genus outside this range is probably represented by *M. stipulosa*.

The literature describing the characteristics and properties of the wood is somewhat confused, especially as regards the particular species involved. Early descriptions (Chalk et al., 1933; Imperial Institute, 1926, 1926a) contain considerable valuable information which probably resulted from studies on material shipped in international trade and now known to be *M. ciliata*, but then assigned to *M. stipulosa*. To avoid further confusion, the following description of the wood will apply to *Mitragyna* spp. This should not result in any inaccuracy, since there is little difference between the two species (Aubréville and Pellegrin, 1936).

The wood of abura is pale grayish yellow, yellowish brown with a pinkish cast, or grayish pink sometimes with darker streaks (Kribs, 1950). The sapwood is usually not differentiated from the heartwood (Aubréville and Pellegrin, 1936). The wood has a low luster and lacks a distinct taste or odor (Cooper and Record, 1931). The texture is medium but apparently quite variable (Jay, 1947); the grain is ordinarily straight, and the wood lacks pronounced figure. Growth rings are inconspicuous; pores barely visible without a lens, numerous, evenly distributed, solitary or in radial groups of 2–5, and open; parenchyma indistinct without a lens, diffuse or in short, broken tangential lines between the rays; rays not distinct on the cross-section without a lens but distinct on the radial surface, lumina of ray cells are filled with reddish "gum" (Chalk et al., 1933).

The wood is moderately heavy ranging from 29–43 pounds per cubic foot air-dry and averaging about 36 pounds per cubic foot (Chalk et al., 1933; Jay, 1947; Kribs, 1950). Chalk reports the average specific gravity as 0.46, with a range of 0.38–0.54 based on oven-dry weight and green volume. Determinations at the Imperial Institute in Great Britain (1926) established the specific gravity range of 0.45–0.53 with an average of 0.50 based on oven-dry weight and air-dry volume of the material tested.

The wood air-seasons rapidly with little degrade (Department of Scientific and Industrial Research, 1956), and no degrade may be expected in kiln-seasoning even under rapid drying conditions. The British Forest Products Research Laboratory (1945) reports that abura dries well under high temperature drying schedules applicable for balsa (non-aircraft), western red cedar, pines and spruces.

Abura compares favorably with domestic hardwoods of equal specific gravity in most strength categories. However, it lacks the toughness (impact resistance) of many domestic hardwoods of similar specific gravity. The mechanical properties of abura are quite similar to those of American elm *(Ulmus americana)* with the exception of impact strength, in which elm exceeds abura by 50–60 per cent.

In the green condition, abura exceeds American elm in bending strength, compression parallel to the grain, compression perpendicular to the grain, hardness and cleavage. The impact strength of elm is considerably greater.

Upon drying from the green to the air-dry condition, abura exhibits appreciable increases in most strength categories. Bending strength, maximum crushing strength and hardness on the end grain, exhibited increases ranging from 50 to 75 per cent of green strength values. Work to maximum load and total work in static bending showed slight increases, but impact strength decreased slightly.

With the exception of work values, impact strength and shearing strength, the air-dry strength values of abura equal or exceed the air-dry strength values of American elm. Abura is a reasonably hard wood as compared with domestic woods of the same specific gravity.

The shrinkage of abura is typical of the shrinkage of many domestic hardwoods of equal density (table 2). Tangenital shrinkage of 10.4 per cent is approximately twice the radial shrinkage. However, since abura does not exhibit marked interlocked grain, its shrinkage should not produce undue distortion. This is borne out by its ability to season without degrade.

The durability of abura is not impressive. The wood is susceptible to wood-destroying fungi and attack by termites (Department of Scientific and Industrial Research, 1956; Forest Products Research Laboratory, 1945) and pinhole borers (Imperial Institute, 1926a). However, the wood is especially resistant to acids, particularly sulfuric acid (Marshall, 1941), which has permitted its use in battery and accumulator boxes (Jay, 1947). The wood is moderately resistant to preservative treatment but the large proportion of sapwood enables satisfactory retention to be obtained (Department of Scientific and Industrial Research, 1956).

The working qualities of the timber are excellent (Imperial Institute, 1926). Straight-grained material saws, planes and bores easily resulting in smooth clean surfaces. Nails and screws can be driven easily, hold firmly and do not cause splitting. The wood glues well, stains very well and finishes well but requires several applications of finish.

Because the wood is easily worked with simple tools, it finds many local uses. In various parts of western Africa, it is used for canoes, paddles, drums, barrels, boxes, house posts, roofing, planking and doors (Dalziel, 1937). In Freetown, Liberia, floors laid of abura are still in service after 100 years. It is recommended for carpentry and joinery, laboratory fittings, battery boxes, flooring and plywood fabrication, the last-named in the form of rotary-cut veneers (Forest Products Research Laboratory, 1945; Jay, 1947). The wood has found application in the building trade for joinery, decorative moldings and other interior work (Department of Scientific and Industrial Research, 1956).

Ocotea bullata E. Mey. ex Meissn. Stinkwood Lauraceae

The species is also known as stinkhout, Cape laurel, and umnukane in South Africa (Chalk et al., 1935). Stinkwood is closely related botanically to East African camphorwood

(*Ocotea usambarensis* Engl.), but the tree and wood are appreciably different in their commercial aspect.

The tree is from 60–80 feet high with a clean straight bole 3–5 feet in diameter (Chalk et al., 1935). The species occurs in the Union of South Africa predominantly in the forested country of the Cape Peninsula northward to Natal and eastern Transvaal. It is generally found on moist, well drained sites in the vicinity of streams at altitudes above 200 feet. Experimental plantations established directly from seed and from transplanted seedlings have met some success (Phillips, 1924).

The wood varies in color from an even straw color through various shades of gray-brown to almost black (Chalk et al., 1935). The straw-colored wood does not appreciably darken upon exposure but the brown wood darkens noticeably under oil and exposure. When green, the wood has a characteristic unpleasant smell which fades upon exposure. The grain is generally interlocked producing an attractive ribbon figure on the quartered surface. The texture is moderately fine and the wood very lustrous. Growth rings are usually distinct on the end surface; pores are individually distinct to the naked eye, moderately numerous, evenly distributed and mostly solitary or in radial pairs (sometimes in radial groups of 3–5). Vessels are distinctly visible on the longitudinal surfaces. Axial parenchyma is barely visible with a lens, forming narrow sheaths around the pores. The rays are fine, distinct to the naked eye on the end surface, barely visible on the tangential surface and inconspicuous on the radial surface.

The wood is moderately hard and heavy to very heavy varying in specific gravity according to color. The light-colored portions of the wood have an average specific gravity of 0.67 (oven-dry weight and volume) with a range from 0.59–0.76 (Scott, 1926). The black portions of the wood have an average specific gravity of 0.80 (0.72–1.0).

The dark portions of the wood air-season and kiln-season rather poorly with a marked tendency to distort and honeycomb (Scott, 1936). The light-colored wood dries more rapidly and with a much lesser tendency toward degrade. To dry from 83 per cent to 12 per cent moisture content, pieces 1⅛ inches thick (probably dark-colored material) required at least 50 days but more commonly require 90 days (Scott, 1945). Pieces 2¼ inches thick required 250 days to dry from 85 per cent to 12 per cent moisture content. Scott (1936) suggests a combination of air-seasoning and kiln-seasoning to minimize the tendency toward degrade.

The results of mechanical tests on air-dry material are reported in table 1. The wood is stronger in proportion to its specific gravity than East African camphorwood. Stinkwood compares favorably with domestic hardwoods of similar specific gravity.

The seasoned wood of stinkwood may be compared to that of rock elm *(Ulmus thomasii)* of somewhat greater specific gravity. In static properties, stinkwood is superior in fiber stress at the proportional limit (11,780 p.s.i.), modulus of rupture and stiffness. It is somewhat superior in maximum crushing strength but slightly inferior in shearing strength and hardness.

The shrinkage of the wood is exceptionally large being 8.0 per cent tangentially and 4.2 per cent radially in drying from green to 10 per cent moisture content (Scott, 1945). The value for volumetric shrinkage from green to oven-dry is 22 per cent (Scott, 1926). These values are in the order of those for blue gum *(Eucalyptus globulus)* and are associated with the tendency of the wood to distort and collapse in drying.

The species is considered as durable (Scott, 1927) in service but no details are given as to its specific resistance to various agents of biological deterioration. Its resistance to decay is probably similar to that of East African camphorwood since both species possess the aromatic oil of camphor.

Scott (1936) reports that the wood works well by machine or hand but is hard and severe on tools, and is inclined to exhibit some irregular tearing. The best surface appears to be obtained by scraping and an excellent finish is easily

secured in this manner. Apparently the wood is easily worked but has a blunting effect on cutting edges and exhibits grain pick-up. Smooth surfaces are obtained by sanding.

In spite of its obvious drawbacks, stinkwood is reported to be one of the most prized furniture woods (Scott, 1936) and is largely used for furniture, paneling, framing and high-class millwork. Supplies of the wood are becoming increasingly scarce and it brings a greater price than any other furniture wood. There is no report of the species being exported from Africa.

Ocotea usambarensis Engl. East African Camphorwood
Lauraceae

The species is known as East African camphor, East African camphorwood, and Ibean camphor (Empire Forestry Association, 1932; Forest Products Research Laboratory, 1945).

The tree is the largest of the indigenous trees of Kenya attaining a height up to 120 feet and a diameter of 5–7 feet, and occasionally as great as 10 feet (Department of Scientific and Industrial Research, 1956; Empire Forestry Association, 1932). The species occurs in Kenya, where it is confined to the wet forests on the eastern slopes of the Aberdares and Mount Kenya at altitudes of 7–8 thousand feet.

The wood is a light yellowish-brown when first cut, darkening to a deep brown upon exposure (Department of Scientific and Industrial Research, 1956). A distinct scent of camphor is present even in the seasoned wood. The grain is interlocked and the texture is medium (Empire Forestry Association, 1932). Growth rings are indistinct. The pores are visible without a lens on the end surface, numerous, evenly distributed and solitary or in radial groups of 2–5. Paratracheal parenchyma is barely visible with a lens on the cross-section. The rays are very fine, numerous, visible with a lens on the cross-section, conspicuous on the radial surface and visible with a lens on the tangential surface (Yw 16524).

The wood is moderately heavy, averaging 37 pounds per cubic foot air-dry (Department of Scientific and Industrial Research, 1956), which is a specific gravity (based on oven-dry weight, air-dry volume) of 0.53. The weight per cubic foot when air-dry ranges from 32–40 pounds (Empire Forestry Association, 1932), a specific gravity range from 0.46–0.57 (oven-dry weight, air-dry volume).

The wood air-seasons satisfactorily but rather slowly with some tendency to distort (Department of Scientific and Industrial Research, 1956; Forest Products Research Laboratory, 1945). It also kiln-dries very well, although tending to retain water pockets in the interior. Checking and splitting are slight, and defects initially present show little tendency to extend. The British Forest Products Research Laboratory (1945) suggests a schedule having high temperatures and relative humidities which is intended for use with woods that dry very slowly but show little tendency to warp.

Results of mechanical tests on green and air-dry material are presented in table 1. The values reported from two different sources are not averaged because of the difference between specific gravity and strength values, the lighter material having greater strength. East African camphorwood is quite similar to American beech *(Fagus grandifolia)* in most strength categories.

Unseasoned camphorwood of approximately the same specific gravity as American beech is superior to the latter in maximum bending strength (modulus of rupture) and stiffness in bending, but only 60 per cent as great in total work in bending and impact strength (toughness, 106 in.lb./specimen). It is 25 per cent stronger in maximum crushing strength parallel to the grain but not quite as hard nor as strong in shear parallel to the grain and only 90 per cent as resistant to splitting.

Upon drying from the green to the air-dry condition, camphorwood exhibits appreciable increases in maximum bending strength and crushing strength. Increases in all other properties except total work in bending are moderate.

Upon drying, total work in bending decreases about 20 per cent while impact strength increases by the same amount.

In the air-dry condition, camphorwood is inferior to American beech in all bending properties. It is slightly inferior in maximum bending strength (modulus of rupture) and stiffness, but only 50 per cent as great as American beech in total work in bending. The impact strength (toughness, 131 in.lb./specimen) of camphorwood relative to American beech increases from 60 per cent in the green condition to 75 per cent in the seasoned condition. Camphorwood is 20 per cent stronger than beech in maximum crushing strength but appreciably inferior in hardness and cleavage, and slightly inferior in shearing strength parallel to the grain.

Tests at the British Forest Products Research Laboratory (Department of Scientific and Industrial Research, 1956) indicate that camphorwood is a moderately good bending species. Steamed material was bent to radii of curvature of 14 inches per inch of thickness when supported with a steel tension strap, and 27 inches per inch of thickness when unsupported.

The shrinkage values for camphorwood—volumetric 9.0, tangential 6.0 and radial 3.0 per cent—from the green to oven-dry condition are reported in table 2. The values are somewhat higher than comparable values for teak. The dimensional change between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 14 per cent and 11 per cent respectively) is 0.9 per cent tangentially and 0.5 per cent radially expressed as a per cent of the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). Comparable values for teak are 1.3 per cent tangentially and 0.8 per cent radially. In the category of dimensional stability, camphorwood is superior to teak, and both are classed as woods with small dimensional change.

Results of decay tests on material from Uganda are reported in table 3. After 4 months exposure, specimens exhibited only slight losses in weight due to decay and the wood is therefore classified as very resistant to decay by fungi (Findlay, 1938). The heartwood absorbs very little preservative even when treated under pressure, but the sapwood can be treated by the open tank process or under pressure with satisfactory retention (Department of Scientific and Industrial Research, 1956).

The wood is worked readily and easily with hand and machine tools and has very little dulling effect on cutting edges (Department of Scientific and Industrial Research, 1956). Straight-grain material may produce a fibrous surface in sawing if dulled tools are used. The presence of interlocked grain may cause grain pick-up in planing unless a cutting angle of less than 20° is used. The wood takes nails and screws well, glues satisfactorily, stains readily and gives good results with paint and varnish.

The species is used in railway construction and furniture and for paneling in Kenya (Forest Products Research Laboratory, 1945). It is said to be suitable for high quality joinery and interior fittings (Organisation for European Economic Co-operation, 1951). It is believed unlikely that this species will find a market in the United Kingdom for general construction and joinery (Department of Scientific and Industrial Research, 1956). However, it is considered suitable for plywood core stock and can be sliced for use in decorative paneling due to its attractive figure.

Olea hochstetteri Baker East African Olive Oleaceae

Local names (Wimbush, 1950) include musharagi, oltoliondo, murakoiwa, masaieta and muthat (Kenya).

The tree attains a maximum height of 90 feet and a diameter of 3 feet at maturity (Wimbush, 1950). The bole is seldom absolutely straight or clear for more than 30 feet. The species is found in the coniferous forests and rain forests of Kenya at elevations from 6–9 thousand feet.

The sapwood is pinkish white when freshly cut, turning to a light brown upon exposure, and about 1–2 inches wide (Wimbush, 1950). The heartwood is light brown with irregular dark gray veins or streaks of varying width which

give the wood a strikingly handsome appearance. The grain is interlocked and the texture very fine (Department of Scientific and Industrial Research, 1956; Forest Products Research Laboratory, 1945).

The wood is exceedingly heavy, averaging 55 pounds per cubic foot at 15 per cent moisture content (Department of Scientific and Industrial Research, 1956; Forest Products Research Laboratory, 1945) with a range of 54–59 pounds per cubic foot air-dry (Wimbush, 1950). The specific gravity is 0.77 (oven-dry weight, air-dry volume) with a range of 0.77–0.84.

The wood is somewhat refractory and dries rather slowly (Department of Scientific and Industrial Research, 1956). Inch thick flooring stock was dried under cover in Nairobi, Kenya in 4–5 months (Wimbush, 1950). In kiln-seasoning, close humidity control must be maintained in the early stages of drying to prevent checking and splitting. Toward the end of the drying run, a very slow rate of moisture movement delays the completion of the seasoning. The British Forest Products Research Laboratory (1945) suggests a kiln schedule designed for woods that dry slowly but are not particularly prone to warp.

The results of mechanical tests of material in the green and air-dry condition are reported in table 1. In all strength properties except work in static bending and impact strength, East African olive is comparable to pignut hickory *(Carya glabra)* but is somewhat denser.

The unseasoned wood of East African olive is superior to pignut hickory in the static bending properties of modulus of rupture and stiffness, but is only 40 per cent as great in total work in static bending and 65 per cent as resistant to impact loads. It is appreciably stronger in maximum crushing strength and shearing strength parallel to the grain. It is approximately as hard as black locust *(Robinia pseudoacacia)* and more resistant to splitting than common domestic hardwoods. In this last category, it is about twice as resistant to splitting as slippery elm *(Ulmus rubra)*.

Upon drying from the green condition to 12 per cent moisture content, the wood undergoes appreciable increases in most strength properties. Total work in static bending increases approximately 20 per cent, but impact strength remains essentially the same. However, cleavage in both the radial and tangential plane decreases appreciably.

In the air-dry condition, East African olive is similar to pignut hickory of comparable specific gravity in most mechanical properties. It is equal to pignut hickory in the static bending properties of modulus of rupture and stiffness but only one half as great in total work. In the property of impact resistance, it is 80 per cent as strong as pignut hickory, the latter undergoing a moderate decrease in impact strength upon drying, while East African olive remains the same in this category upon drying. The wood of East African olive is 10 per cent stronger than pignut hickory in maximum crushing strength parallel to the grain and superior to pignut hickory in shearing strength parallel to the grain. It is almost as hard as live oak *(Quercus virginiana)* when air-dry and about as resistant to splitting as the ashes *(Fraxinus* spp.). In the last-named category, East African olive is much less resistant to splitting in the radial plane than in the tangential plane.

The wood is classified as moderate in steam-bending characteristics (Department of Scientific and Industrial Research, 1956). Steamed material may be bent to radii of curvature of 13 inches per inch of thickness when supported by a steel tension strap, and 30 inches when unsupported.

Shrinkage values from the green to the oven-dry condition for East African olive are reported in table 2. The values–volumetric 14.9, tangential 10.2 and radial 5.2 per cent–compare favorably to white oak *(Quercus alba)* although the olive exhibits somewhat greater tangential shrinkage than the oak.

The results of decay tests on the wood are reported in table 3. The values indicate that the wood is moderately resistant to decay by wood-destroying fungi (Findlay, 1938). The weight loss due to 4 months exposure to fungi

causing brown rots was negligible. The results of 4 months exposure to fungi causing white rots indicates only moderate resistance to this group of fungi.

The wood is difficult to work with hand tools and offers fairly high resistance to cutting by machine tools (Department of Scientific and Industrial Research, 1956), but apparently it has no undue blunting effects on cutting edges. The wood vibrates if not held firmly when machining. In planing, the pressure exerted by the rolls should be increased and a cutting angle of 20° employed. In most operations, a smooth, clean surface is produced. The wood turns well and finishes satisfactorily.

Colored portions of the wood are used for high-grade flooring and paneling (Department of Scientific and Industrial Research, 1956; Forest Products Research Laboratory, 1945). Less decorative pieces are used for railway car work, car bodies, wheel spokes, platform barrows and tool handles. It has found limited use in England for flooring and decorative work.

Parinari excelsa Sab. Mubura Rosaceae

The species is known as mubura in England (Forest Products Research Laboratory, 1951a). Local names (Dalziel, 1937) include mampata, gulih (Senegal); mampataz, kuranako (Portuguese Guinea); kura, shuge (French Guinea); suge, kura (Sierra Leone); kpar (Liberia); esagko (southern Nigeria).

The tree attains a maximum height of 150 feet with a diameter up to 5 feet (Forest Products Research Laboratory, 1951a). The sizes of the average trees are appreciably smaller. The bole is straight and cylindrical for 90 feet (Department of Scientific and Industrial Research, 1956). The species is widely distributed throughout the rain forest of western, central and eastern Africa, occurring gregariously at elevations between 3- and 6-thousand feet. Its range extends through Senegal, Portuguese Guinea, French Guinea, Liberia, Sierra Leone, Ivory Coast, Ghana, Nigeria and eastward to Uganda.

The sapwood is yellowish-white in color and has a honey-like or beeswax-like smell when freshly cut (Forest Products Research Laboratory, 1951a). The heartwood is a dull pinkish- or reddish-brown color. The wood is odorless and tasteless when dry, medium textured, and irregularly-grained (Cooper and Record, 1931). Growth rings are not distinct. The pores are large and visible to the naked eye, rather few in number, and tend to be diagonally arranged. Axial parenchyma occurs in fairly regular concentric lines less than one pore-width apart and is visible to the naked eye. The rays are very fine and scarcely visible to the naked eye on the end and tangential surfaces, and inconspicuous on the radial surface.

The wood is very heavy, ranging in weight when air-dry from 43–55 pounds per cubic foot with an average of 46 pounds per cubic foot (Department of Scientific and Industrial Research, 1956). The specific gravity (oven-dry weight, air-dry volume) varies between 0.61 and 0.79, with an average of 0.66.

The wood is very difficult to kiln-season from the green condition. Drying is very slow and there is a marked susceptibility to degrade in the form of checking and splitting. Distortion is often a problem in drying thicker material and may necessitate air-drying prior to kiln-drying. The British Forest Products Research Laboratory (1951a) recommends a high humidity kiln schedule particularly for material thicker than 1½ inches.

The results of mechanical tests on air-dry material are reported in table 1. In most strength categories, mubura compares favorably with yellow birch *(Betula alleghaniensis)*. Notable exceptions where mubura is inferior are, work in static bending and impact strength. Mubura is similar to yellow birch in the static bending properties of modulus of rupture and stiffness. It is definitely inferior to yellow birch in work to maximum load and total work in static bending. Mubura is only 60 per cent as resistant to shock loads as is yellow birch, but considerably harder on the end and side grain and stronger in endwise compression and shear.

Mubura is very resistant to splitting in the tangential plane but only moderately resistant in the radial plane.

The species is classed as a moderately good steam-bending wood (Forest Products Research Laboratory, 1951a). Steamed pieces were bent to radii of curvature of 13 inches per inch of thickness when supported at the ends by a steel tension strap and 32 inches per inch of thickness when unsupported. Unsteamed thin laminae were bent to a radius of curvature of 52 inches per inch of thickness.

The green to oven-dry shrinkage values for mubura are reported in table 2. The values—volumetric 15.5, tangential 10.0 and radial 6.0 per cent—are comparable to those for white oak of equal density. The dimensional change between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 20 per cent and 13 per cent respectively) is 3.0 per cent tangentially and 2.0 per cent radially expressed as a per cent of the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). These values are among the highest for Empire timbers investigated at the British Forest Products Research Laboratory.

The wood is classed as moderately resistant to decay although experience has shown in Uganda that in tropical climates the wood is perishable in contact with the ground. In Sierra Leone, it is reputed to be resistant to marine borer attack. It is moderately resistant to preservative treatment by the open tank process (Forest Products Research Laboratory, 1951a).

The wood works with some difficulty, causing rapid blunting of cutting edges due to its high silica content (Forest Products Research Laboratory, 1951a). The use of tungsten carbide-tipped saws on material below 20 per cent moisture content is strongly recommended. The conversion of logs in the green condition can be accomplished without so severe a blunting effect on cutting edges and steel saws give fairly reasonable outputs. The irregular grain may pick up in planing but generally good surfaces are obtainable. The wood tends to split in nailing.

Petersia africana Welw. Essia Lecythidaceae

This species is known as essia in the United Kingdom (Jay, 1947). Local names (Dalziel, 1937) are tifei (Sierra Leone); abale, abimpe (Ivory Coast); esia-kokobin, essia (Ghana); akashun, okpewe, onunun (Nigeria).

The tree grows up to 120 feet or more and ranges from 2–3½ feet or more in diameter (Forest Products Research Laboratory, 1951). The bole is clear, free from buttresses and generally cylindrical but sometimes shallowly fluted [Wood (London), 1948]. Essia occurs throughout west Africa from French Guinea, Sierra Leone, Liberia, Ivory Coast, Ghana and Nigeria, to the Belgian Congo and Angola. It is sparsely distributed through the dry high forests in a frequency from 100–200 trees per square mile (Forest Products Research Laboratory, 1951).

The sapwood is a creamy color, 3 or more inches wide, and sharply delineated from the pinkish-brown heartwood which is often veined or mottled with a dark red-brown shade [Wood (London), 1948]. The wood is coarse-textured with straight to somewhat interlocked grain, sometimes irregular and tortuous (Kinloch and Miller, 1949). Pores are visible without a lens on a cleanly cut cross-section and are generally occluded with tyloses. Rays are also visible without a lens and vary appreciably in width and distribution.

The wood is very heavy, averaging 44 pounds per cubic foot air-dry (Department of Scientific and Industrial Research, 1956) with a specific gravity of 0.63 (oven-dry weight, air-dry volume).

Essia dries very slowly and is subject to degrade in the form of checks, splits and distortion. In most cases, seasoning degrade is serious and almost unavoidable making it improbable that the wood can be satisfactorily kiln-seasoned from the green condition. The British Forest Products Research Laboratory (1951) suggests a kiln schedule having high humidities at each stage of drying in order to provide slow drying conditions.

The results of mechanical tests on air-dry material are reported in table 1. In some strength categories, essia may be compared to shagbark hickory *(Carya ovata)*.

In the air-dry condition, essia is equal to shagbark hickory in bending strength (modulus of rupture) and stiffness but notably inferior in work to maximum load, total work and impact strength. It is 65 per cent as resistant to impact loads as is shagbark hickory but considerably more resistant than seasoned white oak. It is 10–15 per cent superior to shagbark hickory in maximum crushing strength but about 90 per cent as strong in shear parallel to the grain. Essia is approximately 50 per cent harder and more resistant to splitting than white oak *(Quercus alba)*.

The results of steam-bending tests conducted at the British Forest Products Research Laboratory (1951) indicate that the species possessed poor steam-bending qualities. Steamed material accepted bends of radii of curvature of 36 inches per inch of thickness when supported by a steel tension strap, and 27 inches per inch of thickness when unsupported (Department of Scientific and Industrial Research, 1956).

The shrinkage values from green to oven-dry are given in table 2. These values—volumetric 25.2, tangential 14.0 and radial 13.0 per cent—far exceed comparable values for domestic hardwoods. The exceptionally high shrinkage values are partly reflected in the dimensional change values for essia going from 90 per cent relative humidity to 60 per cent relative humidity (equilibrium moisture contents of 20 per cent and 12 per cent respectively). The changes in dimension (expressed as a per cent of the dimension at 60 per cent relative humidity) occurring between the two relative humidities are 3.0 per cent tangentially and 2.0 per cent radially (Forest Products Research Laboratory, 1954). Comparable values for domestic white oak are 2.8 per cent and 1.3 per cent. Essia is therefore classified as a wood with large dimensional change.

The wood is classified as resistant to moderately resistant to decay by fungi and resistant to termite attack (Forest Products Research Laboratory, 1951). The heartwood is resistant to impregnation of wood preservatives but the sapwood is absorbent when the open tank process is employed.

The timber is hard to work with hand tools and machine tools but is not reported to cause undue blunting of cutting edges (Forest Products Research Laboratory, 1951). Saw-tooth vibration is common unless a small pitch and a moderate hook are employed. Spring-set circular ripsaws with 66 teeth having a 15° hook perform best on the timber. The material planes to a smooth surface when a 20° cutting angle is used. It tends to char in boring and requires prebored nail holes to prevent splitting and excessive nail bending. The wood finishes and stains well but requires a filler. Care must be taken in staining heartwood and sapwood in order to produce a uniform color. Peeling tests at the British laboratory indicated that essia is unsuitable for veneering (Jay, 1947).

The species is essentially of local importance (Jay, 1947; Marshall, 1941) for heavy mine construction and for railway sleepers. Its working qualities render it unsuitable for extensive machining.

Piptadeniastrum africanum (Hook.f.) Brenan[2] Dahoma
Leguminosae

The species is also called (Chalk et al., 1933; Dalziel, 1937) beli, mbeli-guli (Sierra Leone); gaw (Liberia); gbon, habé, dabbema, kuangua-iniama (Ivory Coast); dabbema, dahoma, odani (Ghana); agboin, ekhimi, ikkimi, eya, onitoto (Nigeria); edundu (Cameroons); mpewere (Uganda). Trade names for the species are dabbema (Ivory Coast); dahoma (Ghana); agboin or ekhimi (Nigeria).

Dahoma is a tall forest tree 120 feet in height and 3–4 feet in diameter (Department of Scientific and Industrial Research, 1956), easily recognized by its large plank-like buttresses extending about 15 feet up the bole and outwards

[2]The name of this species, formerly and commonly known as *Piptadenia africana* Hook. f., has lately been altered as indicated, by Brenan (1955). A recent anatomical study (Brazier, 1958) of the woods of *Piptadenia sensu lato* tends to support Brenan's conclusions.

for about the same distance (Chalk et al., 1933; Dalziel, 1937). The bole is straight and cylindrical above the buttresses and clear of branches to a height from 30–50 feet above the ground (Forest Products Research Laboratory, 1952). It is found in the mixed deciduous, evergreen, and fringing forests usually near the edges of waterways, reaching its maximum growth in moist evergreen forests and on monsoon forest sites. It occurs in Senegal, Sierra Leone, Liberia, Ivory Coast, Ghana, northern Nigeria and the Cameroons, and eastward to eastern Uganda. In Ghana and Nigeria, concentrations of 200–300 mature trees per square mile are not infrequent.

The sapwood is whitish to grayish-red in color, approximately 2 inches wide, and sharply delineated from the light brown to golden-brown heartwood (Chalk et al., 1933; Dalziel, 1937; Jay, 1947). The luster is high and satiny. The wood has no distinct taste but exhibits a disagreeable odor when freshly cut (Kribs, 1950). The grain is generally interlocked producing a prominent stripe on the quarter which on a well-planed surface has a pleasing appearance (Forest Products Research Laboratory, 1952). The texture is medium and growth rings are indistinct. The pores are distinct to the naked eye, evenly distributed or in slight echelon, and solitary or in radial groups of 2–4. The lumina of the pores are filled with a yellowish "gum." Axial parenchyma is distinct with a lens and surrounds the pores having short to long wings which occasionally extend to form fine concentric lines of terminal parenchyma and confluent tangential lines including a few pores. The parenchyma may also be scattered appearing as individual cells among the pores (diffuse). Rays are visible to the naked eye as fine white lines on the end surface and inconspicuous on the radial surface.

The wood is heavy, ranging from 39–49 pounds per cubic foot air-dry with an average of 43 pounds per cubic foot (Department of Scientific and Industrial Research, 1956). Specific gravity (oven-dry weight and air-dry volume) varies between 0.56–0.70, averaging 0.61.

The seasoning characteristics of the wood are variable. It seasons slowly, often with a marked tendency to collapse and distort (Forest Products Research Laboratory, 1952). Collapse cannot be effectively removed by reconditioning treatment (Department of Scientific and Industrial Research, 1956). A kiln schedule similar to that recommended for white oak *(Quercus alba)* is suggested for dahoma.

Results of mechanical tests conducted on air-dry material at the British Forest Products Laboratory are reported in table 1. One group of tests was conducted on material at 8 per cent moisture content which probably explains the greater strength values even though the specific gravity is approximately the same for both groups.

Dahoma compares closely with white oak in most strength properties. At 12 per cent moisture content, it is 85 per cent as strong as white oak in bending (fiber stress at proportional limit 9400 p.s.i.; Imperial Institute, 1923), 15 per cent stronger in maximum crushing strength, and 15–20 per cent harder. The reported value for shearing strength (determined at 8 per cent moisture content) indicates that dahoma compares favorably with white oak in this category also. Impact tests conducted in France indicate that the wood tends to be brittle and has low resistance to impact loads (Forest Products Research Laboratory, 1945).

Bending tests carried out in England on material in the green condition indicate that the wood possesses moderately good bending properties (Department of Scientific and Industrial Research, 1956). Steamed wood can be bent to radii of curvature of 14.5 inches per inch of thickness when supported with a steel tension strap, and 29 inches per inch of thickness when unsupported.

The shrinkage values—volumetric 16.4, tangential 10.2 and radial 5.8 per cent—for dahoma (table 2) are similar to those for American beech *(Fagus grandifolia)* and white oak. The dimensional change between 90 per cent relative humidity (20 per cent equilibrium moisture content) and 60 per cent relative humidity (12 per cent equilibrium moisture content) is 2.8 per cent tangentially and 1.5 per cent radially

of the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). These values are almost identical to those for white oak and twice as great as those for teak *(Tectona grandis)*. The appreciable shrinkage of the wood combined with the presence of interlocked grain may explain the tendency of the wood to distort during drying.

Dahoma exhibits moderate resistance to decay when in contact with the soil (Forest Products Research Laboratory, 1945, 1952). The sapwood is susceptible to attack by powder-post beetles. Reports from Nigeria state that the wood is resistant to termites but indications from South Africa are that it cannot resist severe termite attack more than 3 years. Impregnation with creosote results in penetration into the vessels but not the fibers. The sapwood is reported to be moderately resistant to preservative treatment (Department of Scientific and Industrial Research, 1956). Lateral penetration occurs through the inclined grain; nevertheless, the species is considered resistant to preservative treatment.

The wood works fairly readily with hand and power tools (Department of Scientific and Industrial Research, 1956; Forest Products Research Laboratory, 1952). Blunting of cutting edges is moderate to appreciable. Sawing produces fibrous surfaces and an irritating dust (Imperial Institute, 1923). Appreciable grain pick-up in planing is encountered which can be reduced by using a 10° cutting angle. The wood bores, nails and screws well without splitting, but gluing properties are poor. Staining and finishing are readily accomplished when a grain-filler is used.

Dahoma is recommended for construction, heavy work benches and as a substitute for *Quercus robur* (Forest Products Research Laboratory, 1952). In western Africa, the wood is used for rough construction, canoes, furniture and railway ties. Dalziel (1937) suggests that its fire-resistant qualities may be worth testing.

Pterocarpus angolensis DC. Muninga Leguminosae

Local names for muninga include (Chalk et al., 1932) mutete, munhaneca (Angola); imbilo, thondo (Mozambique); mulambi (Northern Rhodesia); umvagaz, umvangazi (Southern Rhodesia); mlombwa (Nyasaland); and moroto (Transvaal). The species is commonly known as bloodwood in the Rhodesian states and Nyasaland (Organisation for European Economic Co-operation, 1951).

The tree is relatively small, attaining a height of 70 feet with a clear bole 12–25 feet in length and a diameter of 2 feet (Department of Scientific and Industrial Research, 1956). It occurs as a scattered tree in the forests of Angola, Belgian Congo, Tanganyika, Kenya, Portuguese East Africa, and southward in east Africa to the Transvaal (Chalk et al., 1932).

The wood bears a superficial resemblance to other species of *Pterocarpus* such as Andaman and Burma padauk *(P. dalbergioides;* Department of Scientific and Industrial Research, 1956). The sapwood is white to light yellow, 1–2 inches wide, and sharply defined from the darker heartwood (Chalk et al., 1932). The heartwood is golden- to red-brown in color with streaks of brick-red or dark brown. The grain is straight to interlocked, texture is coarse, and planed surfaces are lusterless. Growth rings are indistinct; pores variable in size, distinct to the unaided eye, irregularly distributed, mostly solitary, sometimes in radial groups from 2–4 and visible on longitudinal surfaces as deep grooves; axial parenchyma is abundant, visible to the naked eye, aliform and confluent in wavy tangential bands joining several pores; rays are fine, not visible to the naked eye on transverse or longitudinal surfaces; ripple marks are present, 140 to the inch (Yw 36388).

The weight of the seasoned wood is quite variable, ranging from 30–49 pounds per cubic foot with an average air-dry weight of 39 pounds per cubic foot (Chalk et al., 1932; Department of Scientific and Industrial Research, 1956). Specific gravity (oven-dry weight, air-dry volume) ranges from 0.43–0.70, averaging about 0.56.

The wood seasons rather slowly, particularly thicker pieces of quartered material (Department of Scientific and Industrial Research, 1956). Due to the low shrinkage exhibited by this species, there is little tendency toward degrade in the form of splitting or distortion.

The results of mechanical tests on seasoned and unseasoned material are reported in table 1. In several strength categories, particularly for the air-dry material, the values given are averages of only a small number of tests (Forest Products Research Laboratory, 1945). Muninga is considerably stronger in some strength categories than domestic hardwoods of comparable specific gravity such as American elm *(Ulmus americana)* and black cherry *(Prunus serotina)*.

In the unseasoned condition, the wood compares quite favorably with teak *(Tectona grandis);* however, upon drying, erratic strength changes result in generally inferior strength properties as compared with teak. The unseasoned wood of muninga is equally as strong as teak in bending but inferior in stiffness. The values of modulus of rupture are almost identical for both woods, and the value of total work in bending for muninga is about 25 per cent greater, however, stiffness (modulus of elasticity) is only 70 per cent that for teak. However, muninga is 20 per cent more resistant to impact, about equally as strong in maximum crushing strength and resistance to indentation (hardness), and 10 per cent stronger in cleavage.

Upon drying to the air-dry condition, teak exhibits moderate increases in all strength properties with the exception of total work in bending and impact strength which undergo a marked decrease. However, muninga exhibits only a slight increase in the modulus of rupture in bending and moderate to considerable increases in maximum crushing and shearing strength. The values for modulus of elasticity in bending, total work in bending, impact strength, hardness and cleavage show decreases upon drying to air-dry moisture content.

In the air-dry condition, muninga is superior to teak in total work in bending, impact and shearing strength. It is

90 per cent as strong in bending (modulus of rupture), 60 per cent as stiff (modulus of elasticity) and 87 per cent as strong in maximum crushing strength. It is superior (by 10 per cent) in side hardness and somewhat inferior in end hardness. Values for resistance to cleavage are not complete but indicate that muninga may be 70–80 per cent as strong in this respect as teak.

The green to oven-dry shrinkage values–volumetric 3.4, tangential 1.8 and radial 1.6 per cent–in table 2 indicate the superiority of muninga over teak in dimensional stability. From 90 per cent relative humidity to 60 per cent relative humidity (equilibrium moisture contents of 13 per cent and 10 per cent respectively), muninga underwent a 0.5 per cent radial and 0.6 per cent tangential dimensional change, based on per cent of dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). Comparable values for teak are 0.8 per cent radially and 1.3 per cent tangentially. The values for muninga are among the three lowest values for all species of British Empire woods tested at the British Forest Products Research Laboratory.

Tests on the decay resistance of muninga for Tanganyika were conducted in England (Findlay, 1938) and are reported in table 3. After 4 months exposure to the decay action of both white- and brown-rot fungi, the specimens showed negligible decay by brown rots and only slight decay by white rots. On the basis of these tests, the wood is classed as very resistant to decay. The sapwood is susceptible, however, to powder-post beetle attack. The heartwood is classed as resistant to impregnation and the sapwood is considered moderately resistant to preservative treatment (Department of Scientific and Industrial Research, 1956).

The wood works well with hand and machine tools but has a moderate dulling effect on cutting edges (Department of Scientific and Industrial Research, 1956). The straight-grained material machines well but figured material may show grain pick-up in planing. The wood gives excellent results in nailing and screwing and is suitable for gluing. Finishes are easily applied.

In Africa, muninga is employed in the building and furniture industries, for pick handles, yokes and for mining purposes (Forest Products Research Laboratory, 1945). In England, very handsome furniture has been made from it and a room in the Forest Products Research Laboratory is framed and paneled with lumber and veneer. It is suitable as a flooring wood under conditions of light traffic (Department of Scientific and Industrial Research, 1956). Muninga should prove suitable as a substitute for teak for even the most exacting purposes for which teak is used. It is comparable in strength and durability and superior in dimensional stability to teak.

Pterocarpus soyauxii Taub. Barwood Leguminosae

The species is known in the United Kingdom as barwood, redwood, Gabon padouk and African coral wood (Dalziel. 1937). Local names are akume, uhie, ukpa, boko (Nigeria); bo, muenge (Cameroons); padouk, corail (Belgian Congo; Jay, 1947).

The tree attains a height of 75–100 feet with a diameter of 2–3 feet (Jay, 1947; Dalziel, 1937). It is considerably larger than the related species, muninga *(P. angolensis)*. The species is found in Ghana, Nigeria, Cameroons and the Belgian Congo.

The sapwood is thick, commonly 4–8 inches wide (Department of Scientific and Industrial Research, 1956); white when freshly cut, turning to a brownish yellow; the heartwood red, becoming darker on drying, and sharply delineated from the light-colored sapwood (Dalziel, 1937). The freshly cut wood has a faintly aromatic odor. Grain is interlocked, texture medium and the luster medium to high (Kribs, 1950). Growth rings are indistinct. Pores are distinct without a lens, not numerous, unevenly distributed, solitary and in radial groups of 2–10, and the cavities of the cells contain a red "gum." Axial parenchyma is visible without a lens, aliform with short to long wings, confluent forming closely spaced, wavy, tangential bands, and apotracheal in short tangential lines or bands several cells wide. Rays are not visible without a lens on the end surface, inconspicuous on the radial surface, lumina with red "gum"; ripple marks distinct and regular. The wood of *P. angolensis* may be distinguished from that of *P. soyauxii* by the radial grouping of pores from 2–4 in number, whereas *P. soyauxii* contains radial groups of vessels from 2–10 in number.

The wood is very heavy, ranging between 39 and 49 pounds per cubic foot air-dry (Department of Scientific and Industrial Research, 1956; Kribs, 1950); no average density is reported. The specific gravity (oven-dry weight, air-dry volume), ranges from 0.56 to 0.70. The wood of barwood is somewhat heavier on the average than that of muninga.

Jay (1947) reports that the wood is not very liable to warp. Barwood exhibits seasoning characteristics similar to those of muninga.

Strength properties of barwood are not reported but the wood is similar to muninga and somewhat heavier, probably equally as strong or somewhat stronger than muninga in mechanical properties.

The green to oven-dry shrinkage values—volumetric 8.5, tangential 4.4 and radial 3.8 per cent—for barwood are given in table 2. The total shrinkage of the wood is somewhat greater than that of teak.

The wood works easily (Jay, 1947), but the presence of interlocked grain may result in grain pick-up on quartered surfaces in planing.

Barwood is used in western Africa for essentially the same purposes as is muninga; namely, tool handles, paddles, oars, agricultural implements, furniture and cabinet-making (Jay, 1947). Howard (1951) states that the two woods (muninga and barwood) "have been produced without distinction." In practice, the smaller material of trade consignments has been shipped under the name barwood or camwood (the latter name is usually reserved for *Baphia nitida)* and the larger sizes under the name padauk.

Sarcocephalus diderrichii De Wild. &. Dur. Opepe Rubiaceae

The standard trade names are opepe in the British territories and bilinga in the French colonies (Organisation for European Economic Co-operation, 1951). Local names for the species include (Dalziel, 1937) badi, dunkake (French Guinea); doe-yah (Liberia); bedo, nguebe, bosuma, groussou, (Ivory Coast); kussia, kisia, bosima (Ghana); opepe, owoso, odosi (southern Nigeria); ikaka (Cameroons); bonkangu, maza, bonkese (Belgian Congo); gulo-maza (Angola).

The tree attains a large size, up to 160 feet in height and 6 feet in diameter (Department of Scientific and Industrial Research, 1956). The bole is straight and clear of branches for a length of 80–100 feet. It is widely distributed in French Guinea, Liberia, the Ivory Coast and Ghana, Nigeria, Cameroons, Angola and Belgian Congo (Organisation for European Economic Co-operation, 1951). It is found most abundantly on wetter sites in the high forests where it attains frequencies of 100 mature trees per 1000 acres (Marshall, 1941).

The sapwood is whitish to orange-yellow or occasionally reddish in color (Jay, 1947; Wood, 1936). The heartwood is a rich golden-yellow when freshly cut, which darkens to deep gold or orange upon exposure (Jay, 1947). The grain is straight to interlocked, the latter producing a very handsome figure on the quartered surface (Dalziel, 1937; Department of Scientific and Industrial Research, 1956; Kribs, 1950). The texture is medium and the luster medium to high. The freshly cut wood is faintly fragrant and with a slightly bitter taste. Growth rings are indistinct. Pores are distinct to the naked eye, not numerous and irregularly distributed. Lumina of the pores contain a yellow or reddish "gum" which makes them appear as reddish streaks on the longitudinal surfaces. Axial parenchyma is indistinct to the naked eye and occurs between the pores in aggregates forming broken, short, tangential lines. The lumina of parenchyma cells contain a yellowish "gum." The rays are barely visible to the naked eye on the end surface and inconspicuous on the radial surface.

The density of the wood averages approximately 47 pounds per cubic foot air-dry (Organisation for European Economic Co-operation, 1951). The specific gravity (oven-dry weight, air-dry volume) ranges from 0.61–0.70 with an average of 0.67.

The wood air-seasons fairly rapidly with a marked tendency to split and check (Department of Scientific and Industrial Research, 1956). Distortion is not appreciable during air-seasoning. Quarter-sawn material kiln-seasons fairly quickly, but flat-sawn material may prove refractory and develop checks and splits in drying. In thick sizes, the wood dries slowly with a tendency to split. The British Forest Products Research Laboratory (1945) suggests a kiln schedule similar to that recommended for black walnut *(Juglans nigra)* and sugar maple *(Acer saccharum)*.

The results of mechanical tests on green and air-dry material are reported in table 1. Opepe is superior in strength to most domestic hardwoods of equal specific gravity.

The unseasoned wood of opepe is comparable to black locust *(Robinia pseudoacacia)* in the static bending properties of modulus of rupture and stiffness. In work to maximum load and total work in static bending, it is notably inferior to black locust and it is only 75 per cent as strong in impact bending as the latter. The wood of opepe is essentially as strong as black locust in maximum crushing strength, hardness, shear and cleavage.

Upon drying from the green to the air-dry condition, opepe undergoes moderate increases in the static bending properties of modulus of rupture and stiffness, a slight increase in work to maximum load and a slight decrease in total work. Impact strength decreases slightly and cleavage strength falls off appreciably. Maximum crushing strength, hardness and shearing strength undergo moderate increases upon drying to 12 per cent moisture content.

At 12 per cent moisture content, opepe is very similar to yellow birch *(Betula alleghaniensis)* in the static bending properties of modulus of rupture and stiffness. Although both species are approximately equal in specific gravity,

the values of work to maximum load and total work for opepe are only one-half of those for yellow birch. The same relationship is also found between the two species in regard to impact strength. Opepe is 20–25 per cent stronger in maximum crushing strength, 40 per cent harder on the end grain, 30 per cent harder on the side grain and 15 per cent stronger in shear than yellow birch. However, it is only one-half as resistant to splitting.

Opepe is classified as a very poor bending species (Department of Scientific and Industrial Research, 1956). Unsteamed thin laminae can be bent to a radius of curvature of 78 inches per inch of thickness.

The shrinkage of the wood from the green to the oven-dry condition is reported in table 2. The shrinkage values of opepe—volumetric 11.7, tangential 7.6 and radial 4.4 per cent—are smaller than for the majority of domestic hardwoods of equal specific gravity and are somewhat greater than those for black cherry *(Prunus serotina)*. The dimensional change occurring between 90 per cent relative humidity (equilibrium moisture content of 18 per cent) and 60 per cent relative humidity (equilibrium moisture content of 12 per cent) is 1.8 per cent tangentially and 0.9 per cent radially of the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). The radial dimensional change is comparable to that of teak (0.8 per cent). The tangential dimensional change is considerably greater than the 1.3 per cent value for teak, but opepe is still classified as a wood with small dimensional change.

The results of decay resistance tests on material from Nigeria are reported in table 3. After 8 months exposure to wood-destroying fungi, specimens exhibited negligible weight loss when exposed to fungi causing brown rot (Findlay, 1938). Slight weight loss due to decay was exhibited after 8 months exposure to fungi causing white rot. The species is classified as very resistant to decay by fungi, but is slightly susceptible to pinhole borer attack (Department of Scientific and Industrial Research, 1956). Opepe is claimed to be resistant to termites in western Africa (Department of

Scientific and Industrial Research, 1956). The wood can be satisfactorily impregnated with creosote under pressure but is apparently too resistant to impregnation to give satisfactory results in the open tank process. It is classed as moderately resistant to preservative treatment.

Investigations of the working properties of opepe conducted at the British Forest Products Research Laboratory (Department of Scientific and Industrial Research, 1956) indicate that the wood works with moderate ease in most hand and machine tool operations and has a slight dulling effect on cutting edges. The resistance to cutting varies with density but averages about 25 per cent greater than medium-grade African mahogany. Flat-sawn material planes to a smooth finish but quarter-sawn stock may show grain pick-up in planing. A reduction of the cutting angle to 10° should produce a smooth quarter surface. Good results are produced in all other operations but the wood tends to split in nailing. It takes screws well, glues well, and stains and finishes satisfactorily when moderate amounts of grain filler are used.

Opepe is used in western Africa for canoes, mortars, planks, tables and bridges (Forest Products Research Laboratory, 1945). It is suitable for exterior uses such as harbor work, piles, planking and heavy construction (Department of Scientific and Industrial Research, 1956; Organisation for European Economic Co-operation, 1951). Other recommended uses are flooring, framing of railway passenger coaches and crossarms.

Scottellia kamerunensis Gilg Odoko Flacourtiaceae

The species is commonly known in the trade under the name odoko (Jay, 1947). Local names include (Dalziel, 1937) mehr-chu, ne-mor-ba-de (Liberia); aburuhi (Ivory Coast); lakpa (Ghana); emwenfuohai (southern Nigeria).

The tree is of medium size, attaining a height of 100 feet at maturity and a diameter of 1–2 feet (Department of Scientific and Industrial Research, 1956). The bole is long and straight but seldom cylindrical. The species occurs in

western Africa from Liberia through the Ivory Coast, and from Ghana to southern Nigeria (Department of Scientific and Industrial Research, 1956). It is found on wetter sites where locally it may attain a frequency up to 300 mature trees per 1000 acres (Marshall, 1941).

The wood is pale yellow throughout with little or no distinction between heartwood and sapwood (Cooper and Record, 1931). It is odorless and tasteless when dry, fairly lustrous, medium-textured and straight-grained (Cooper and Record, 1931; Kribs, 1950). The growth rings are not distinct. The pores, not visible to the naked eye, are numerous, evenly distributed, and solitary or in radial groups of 2–3. Axial parenchyma is apparently absent. The rays are visible on the end surface and conspicuous on the radial surface, producing a "silver grain."

The wood weighs 39 pounds per cubic foot air-dry (Department of Scientific and Industrial Research, 1956) which corresponds to a specific gravity of 0.56 based on oven-dry weight and air-dry volume. Cooper and Record (1931) report specific gravity values (oven-dry weight and volume) of 0.66 and 0.70 for two groups of material of the species.

The wood seasons rapidly but exhibits a marked tendency to split and check during air-seasoning with an occasional occurrence of blue-stain (Department of Scientific and Industrial Research, 1956). In kiln-seasoning, the wood tends to split and distortion is slight. The British Forest Products Research Laboratory (1945) recommends a kiln schedule similar to that recommended for sugar maple (*Acer saccharum*) and black walnut (*Juglans nigra*).

The results of mechanical tests on green and air-dry material are reported in table 1. In the green condition, odoko exhibits unusually high static bending strength and strength in compression parallel to the grain, compared to domestic woods of equal specific gravity.

The unseasoned wood is equal to pignut hickory (*Carya glabra*) in the static bending properties of modulus of rupture and stiffness. It is notably inferior to pignut hickory in work to maximum load and total work in bending and toughness. In compression parallel to the grain, it is superior to pignut hickory but slightly inferior in shear. Odoko is comparable to white oak *(Quercus alba)* in shearing strength, hardness and resistance to splitting.

Upon drying from the green to the air-dry condition, odoko undergoes moderate increases in most strength categories. Slight decreases in work to maximum load in static bending and toughness occur. Total work in static bending decreases 25 per cent and cleavage in the radial plane decreases by one third.

In the air-dry condition, odoko is comparable to white oak in all properties except total work in bending, toughness and cleavage, although of lesser specific gravity. In static bending properties it is superior in modulus of rupture and stiffness, but considerably inferior in work to maximum load and total work. It is superior to white oak in maximum crushing strength and end hardness but slightly inferior in shearing strength parallel to the grain and resistance to splitting.

The wood is classified as having very poor steam bending properties (Department of Scientific and Industrial Research, 1956; Forest Products Research Laboratory, 1945). It can be bent to radii of curvature of 30 inches per inch of thickness when supported with a steel tension strap and 60 inches per inch of thickness when unsupported after steaming.

The green to oven-dry shrinkage values—volumetric 13.0, tangential 9.0 and radial 4.4 per cent—for odoko are reported in table 2. These values are comparable to those for slippery elm *(Ulmus rubra)* which is a less dense wood. The dimensional change between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 21 per cent and 13 per cent respectively) is almost identical to white oak, being 2.8 per cent tangentially and 1.5 per cent radially for odoko and 2.8 per cent tangentially and 1.3 per cent radially for white oak (Forest Products Research Laboratory, 1954). Therefore, odoko is classified as a wood of medium dimensional change.

The results of decay resistance tests conducted in England (Findlay, 1938) are reported in table 3. After 4 months exposure to wood-destroying fungi, specimens exhibited slight deterioration when exposed to fungi causing brown rot but considerable deterioration when exposed to fungi causing white rot. The wood is therefore classified as non-resistant to decay by fungi and it is also not resistant to termites. Odoko is readily impregnated with creosote under pressure (Department of Scientific and Industrial Research, 1956).

The wood works readily and with moderate ease in all operations with hand and machine tools (Department of Scientific and Industrial Research, 1956). Excellent finishes are obtained in planing and molding except that the true radial surface tends to flake in planing. There is some chipping-out at tool exits and the wood tends to split in nailing. It takes screws and glue very well and reacts desirably to finishing treatments. The wood has been investigated for suitability for peeler stock (Cox, 1940). Logs that were obtained for the study had extensive radial splits and the veneer tended to break up into short strips as it came off the lathe. Large and numerous rays cause splitting of thin veneers during and after drying.

The Organisation for European Economic Co-operation (1951) suggests that odoko may prove suitable for general utility purposes such as domestic woodenware, turnery and table tops. It is also suggested as a substitute for American beech *(Fagus grandifolia)* and American sycamore *(Platanus occidentalis)*. The susceptibility of the wood to discoloration by blue-stain fungi limits its applicability. If this drawback could be overcome odoko may prove more useful for domestic uses (Department of Scientific and Industrial Research, 1956).

Sterculia oblonga Mast. Yellow sterculia Sterculiaceae

The species is known locally (Dalziel, 1937) as ebenebe, kokoniko, orodo, okoko (southern Nigeria); bongele, ekonge (Cameroons).

Mature trees attain heights of 80–120 feet and diameters of 2–3½ feet (Forest Products Research Laboratory, 1952b). The bole is straight and cylindrical and clear of branches for a length of 50–70 feet. The trunk is sharply buttressed to a height of 12 feet. Yellow sterculia occurs throughout the high forest zone of Nigeria and the Cameroons but is more frequent in the deciduous forests than in the rain forests. In the deciduous forests, trees 3 feet or more in diameter are found in frequencies of 150 per square mile.

The wood is creamy yellow to light yellowish-brown in color (Forest Products Research Laboratory, 1952b). Sapwood is 4–8 inches wide but not differentiated from the heartwood (Department of Scientific and Industrial Research, 1956). The freshly-cut wood has a strong disagreeable odor which fades upon drying. The grain is slightly interlocked and the texture is coarse.

The wood is very heavy having an average weight per cubic foot air-dry of 49 pounds (43–52 pounds); (Department of Scientific and Industrial Research, 1956). Specific gravity (oven-dry weight, air-dry volume) averages 0.70 (0.61–0.74).

The timber seasons slowly with a marked tendency for surface checking to develop and for splits to extend. Collapse and cupping may also be encountered. The British Forest Products Research Laboratory (1952b) suggests a kiln schedule similar to that recommended for white oak *(Quercus alba)*.

Numerical strength data are not available for yellow sterculia; however, the air-dry wood is comparable to brown sterculia *(Sterculia rhinopetala)* in static bending strength, impact strength and maximum crushing strength (Forest Products Research Laboratory, 1952b). It is somewhat inferior in side hardness and shear and comparable in cleavage. It is equal to or slightly superior to white oak in strength, both woods being of similar specific gravity.

Tests of the steam-bending properties of yellow sterculia indicate that it is a moderately good steam-bending species (Forest Products Research Laboratory, 1952b). Steamed wood can be bent to radii of curvature of 17 inches per inch of thickness when supported with a steel tension strap and 18 inches per inch of thickness when unsupported. However, the wood is prone to distort severely during bending.

The green to oven-dry shrinkage values for yellow sterculia—volumetric 19.1, tangential 13.0 and radial 7.0 per cent—are somewhat greater than comparable values for shagbark *(Carya ovata)* and mockernut *(Carya tomentosa)* hickories of equal specific gravity. The dimensional change occurring between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 18.5 per cent and 11.5 per cent respectively) is 3.0 per cent tangentially and 1.3 per cent radially of the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). These values are comparable to those for white oak (tangential 2.8 per cent and radial 1.3 per cent).

The wood is non-resistant to decay by fungi (Forest Products Research Laboratory, 1952b). Rapid conversion of logs is necessary to prevent pinhole borer attack. The wood is also liable to become stained if there is any delay in extraction and conversion. The heartwood is extremely resistant to impregnation with creosote but the sapwood is permeable and may be treated satisfactorily under pressure and by the open tank process.

The wood works readily with machine tools but is rather difficult to work by hand (Forest Products Research Laboratory, 1952b). There is a moderate blunting effect on cutting edges which must be kept sharp in order to minimize the development of fibrous surfaces. In planing, a sharp cutting edge and a 20° cutting angle produce smooth surfaces. Fibrous surfaces are almost invariably produced in all other operations. The wood nails satisfactorily with a slight tendency to split. Stains and finishes give satisfactory results when a small amount of filler is used.

Yellow sterculia is used in Africa for general construction and flooring (Organisation for European Economic Co-operation, 1951). It may prove suitable as a substitute for white oak in service where decay resistance is not critical such as agricultural implements, flooring and inexpensive furniture in which a light-colored wood may be desired.

Sterculia rhinopetala K. Schum. Brown sterculia
Sterculiaceae

Brown sterculia is also known locally (Dalziel, 1937) as awabima, awasea, pokodom (Ghana); aye, oro, otutu (southern Nigeria).

Jay (1947) reports that brown sterculia is a large tree, 2–3 feet in diameter, and has a straight, clean bole with sharp buttresses which extend approximately 10 feet up the bole. It is found principally in the rain forests of Ghana and southern Nigeria where it is frequent in certain localities.

The color of the heartwood varies between pale and deep reddish-brown. The sapwood is straw-colored, generally 1½–2½ inches wide, and sharply delineated from the darker heartwood. The grain is commonly interlocked and the texture coarse (Department of Scientific and Industrial Research, 1956).

Brown sterculia wood is heavy, weighing between 33–64 pounds per cubic foot with an average weight of 51 pounds (Department of Scientific and Industrial Research, 1956). The specific gravity averages 0.73 (0.47–0.92) based on oven-dry weight and air-dry volume.

The wood seasons slowly from the green condition and requires care to avoid the development of cupping and the extension of splits (Department of Scientific and Industrial Research, 1956; Jay, 1947). Appreciable checking may be encountered and slight collapse is frequent.

The results of mechanical tests on air-dry material are reported in table 1. Brown sterculia compares very favorably in strength properties with domestic woods of equal specific gravity. The seasoned wood of brown sterculia is superior to domestic white oak *(Quercus alba)* of similar specific gravity in most strength categories. It exceeds white oak in the static bending properties of modulus of rupture and elasticity, work to maximum load and total work. In the

property of total work, it exceeds white oak by 30 per cent. Brown sterculia is 10 per cent stronger in impact strength than white oak. It is stronger in maximum crushing strength, shear, and cleavage and harder on the side grain than white oak.

Brown sterculia is classed as a moderately good steam-bending wood. Steamed material has been found to accept bends of radii 12 inches per inch of thickness when supported by a steel tension strap and 14 inches when unsupported (Department of Scientific and Industrial Research, 1956).

The dimensional change occurring between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 21 per cent and 13 per cent respectively) is 3.0 per cent tangentially and 1.3 per cent radially of the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). Comparable values of 2.8 per cent and 1.3 per cent for white oak are not widely different from those for brown sterculia.

The wood is moderately resistant to decay by fungi (Jay, 1947) and extremely resistant to preservative treatment (Department of Scientific and Industrial Research, 1956).

Brown sterculia works without undue difficulty but produces extremely fibrous surfaces and exhibits a marked tendency to spring (Jay, 1947). Difficulty in working may be experienced with denser pieces (Department of Scientific and Industrial Research, 1956). Interlocked grain is satisfactorily worked when conventional processes for dealing with this characteristic are employed. The wood tends to split in nailing. Peeling tests conducted in England revealed that the wood is difficult to cut and causes rapid blunting of the cutting edges of the knives. It is however, capable of taking a good finish.

It has been used in western Africa for furniture manufacture (Jay, 1947) and may prove suitable for general construction (Organisation for European Economic Co-operation, 1951). The close relationship in strength properties and dimensional stability among brown sterculia, white oak and ash *(Fraxinus* spp.), suggests that brown sterculia may be found satisfactory as a substitute for white oak in boat frames and under-water structural members and for ash in agricultural implements (Department of Scientific and Industrial Research, 1956).

Tarrietia utilis Sprague Nyankom Sterculiaceae

The trade names for this species include (Forest Products Research Laboratory, 1952a; Jay, 1947) niangon (United Kingdom); yawe, red cedar (Sierra Leone); niangon (Ivory Coast); ogoué (Cameroons); rezogoue (Gabon). Other names of local importance include (Dalziel, 1937) yauwi, yaw (Sierra Leone); de-orh (Liberia); niangon, (Ivory Coast); nyankom, nyangwen, nyangwune (Ghana).

The tree attains a maximum height of 130 feet at maturity with an average of 100 feet (Forest Products Research Laboratory, 1952a). The diameter of mature trees ranges from 2–3 feet. The bole is clear up to 65 feet above the ground and occasionally as high as 105 feet. On well-drained sites, the bole is cylindrical and of good form, but on swampy sites the tree develops a twisted, irregular shape. The species occurs in the rain forests of Sierra Leone, Liberia, the Ivory Coast, and in the southwestern region of Ghana. It is not recorded in Nigeria but is found further eastward in the Cameroons and Gabon. Nyankom is found in an average frequency of 200–300 mature trees per square mile, and under especially favorable conditions, up to 1200 mature trees may occur in a square mile.

The heartwood is light to dark red-brown in color and bears a superficial resemblance to African mahogany (Jay, 1947). The sapwood is grayish in color and about 3 inches wide (Forest Products Research Laboratory, 1952a). The wood is odorless and tasteless, medium-textured, with straight to interlocked grain, and a high, satiny luster (Cooper and Record, 1931; Kribs, 1950). Growth rings are fairly distinct due to an increase in fiber density and the presence of axial parenchyma at the margins of the seasonal increments. Pores are distinct to the naked eye, not numerous, evenly distributed, and solitary or in radial groups of 2–3. The lumina of the pores contain a red "gum." Axial parenchyma is distinct with a lens on a moist surface, vasicentric in sheaths 2–4 cells wide, aliform with short wings, and confluent connecting 2–3 pores. The parenchyma also appears in an apotracheal, diffuse-in-aggregates manner forming broken, tangential lines of irregular distribution between the rays and occasionally continuous tangential lines of terminal parenchyma. The lumina of parenchyma cells contain a red "gum" and occasionally crystals. The rays are visible on all surfaces, producing a "silver grain" on the radial surface. Ripple marks are present but not distinct, and fibers and axial parenchyma are storied (Kribs, 1950).

The wood weighs 32–47 pounds per cubic foot air-dry (Department of Scientific and Industrial Research, 1956) which corresponds to a specific gravity range (oven-dry weight, air-dry volume) of 0.46–0.67.

Nyankom seasons moderately slowly but well, with little tendency to degrade (Forest Products Research Laboratory, 1952a). Some pieces may tend to twist upon drying. Slight end-splitting and surface checking may develop and some collapse may occur in a few boards. The British Forest Products Laboratory (1952a) suggests a kiln schedule similar to that recommended for black walnut *(Juglans nigra)* and sugar maple *(Acer saccharum)*.

The results of mechanical tests on air-dry material are reported in table 1. Nyankom is very similar to American sycamore *(Platanus occidentalis)* in density and most strength properties. In the air-dry condition nyankom is superior to American sycamore in the static bending properties of fiber stress at the proportional limit and modulus of rupture. However, it is somewhat inferior in properties of stiffness and work to maximum load in bending. Total work in static bending and impact strength are not reported for nyankom. Nyankom is slightly stronger than American sycamore in maximum crushing strength and compression perpendicular to the grain but inferior in shear and end hardness and approximately equal in resistance to splitting. However, in no strength property is the difference between the two woods appreciable.

Tests conducted in England indicate that nyankom possesses moderately good steam-bending properties (Forest Products Research Laboratory, 1952a). Steamed material was bent to radii of curvature of 18 inches per inch of thickness when supported with a steel tension strap and 30 inches per inch of thickness when unsupported. Thin, unsteamed laminae were bent to a radius of curvature of 59 inches per inch of thickness.

The shrinkage from the green to the oven-dry condition of nyankom is reported in table 2. The values–volumetric 13.6, tangential 9.0 and radial 5.0 per cent–are quite similar to American elm *(Ulmus americana)* of approximately the same specific gravity. The dimensional change occurring between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 20 per cent and 13 per cent respectively) is 2.5 per cent tangentially and 1.3 per cent radially based on the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). Comparable values of 2.4 per cent and 1.3 per cent for an unspecified species of the American red oak group, are almost identical to those for nyankom. Nyankom is therefore classified as a wood of medium dimensional change.

The wood is reported as having fairly high resistance to fungi which cause brown rots and moderately resistant to "dry-rot" fungi (Forest Products Research Laboratory, 1952a). However, for some unstated reason, the wood is classified as not resistant to decay by fungi. It is considered as moderately resistant to termites in Ghana. The wood is classed as extremely resistant to penetration with creosote.

Nyankom works readily and easily with hand and machine tools, good surfaces being readily obtainable in all operation (Forest Products Research Laboratory, 1952a; Imperial Institute, 1926). There is some conflict in the reports of working properties which may be due to differences in the quality of material investigated. The wood saws easily with comparatively little blunting effect on cutting edges. The British Forest Products Research Laboratory (1952a) reports that narrow-pitch saws produce a fine sawdust which

tends to cause overheating when trapped in the saw-cut. Wide-pitch saws produce a coarser sawdust and prevent overheating in sawing. Good surfaces are produced in planing when a 15° cutting angle is employed. The wood bores cleanly, takes nails and screws easily and holds them firmly. Gluing properties are good and strong joints can be obtained. The wood finishes well but a grain filler is required (Imperial Institute, 1926).

Although it lacks the dimensional stability of the African mahoganies *(Khaya* spp.) nyankom is considered suitable for similar uses (Jay, 1947). It is recommended (Organisation for European Economic Co-operation, 1951) for building joinery, both interior and exterior, cabinet-making, mouldings, plywood, fine luxury flooring and boat building (hulls and decks).

Terminalia ivorensis A. Chev. Idigbo Combretaceae

This species is known in trade as idigbo (United Kingdom), baji (Sierra Leone), framire (Ivory Coast), emeri (Ghana) and black afara (Nigeria; Forest Products Research Laboratory, 1952). Local names are bagyi, bajii, bassi (Sierra Leone); baye (Liberia); onidjo, buna (Ivory Coast); emri, emil, frameri (Ghana); idigbó, ebi, epepe (southern Nigeria; Dalziel, 1937).

Idigbo is a tall, deciduous tree, attaining a height of 100–120 feet with a diameter of 3–4 feet (Dalziel, 1937; Department of Scientific and Industrial Research, 1956). The bole is straight, cylindrical, and clear of branches for a length of 70 feet with shallow buttresses often extending far along the bole (Forest Products Research Laboratory, 1952). The black bark has given rise to the Nigerian name "black afara" which distinguishes the tree from the white-barked "white afara," *Terminalia superba.* The tree occurs in a high forest belt of French Guinea, Sierra Leone, Liberia, the Ivory Coast and Ghana, Nigeria, and the Cameroons. It is found in both the rain forest type and the more moist deciduous forest as a scattered tree, and is rarely but occasionally found in gregarious stands on abandoned farm land.

The average frequency is 50 trees per square mile of which one half may be of exploitable size.

The wood is yellow to light yellowish-brown with no clear distinction between the heartwood and the narrow band of sapwood (Forest Products Research Laboratory, 1952). The grain is commonly straight but occasionally wavy or somewhat interlocked; the texture is medium to coarse. Occasionally a zone of low-density wood commonly containing compression failures ("thundershakes") occurs near the center of the log. This zone, termed brittleheart, can usually be distinguished by a pinkish coloration which develops in it after exposure to light for a day or two. Growth rings are unusually distinct for a tropical timber and produce an appearance on a flatsawn surface somewhat similar to plain oak. The wood contains a yellow coloring matter which when wet will stain fabrics.

Idigbo is moderately heavy exhibiting an extremely wide variation in density probably due to the varying amount of "brittleheart" in the wood. The density varies between 23 and 47 pounds per cubic foot, though more commonly 30–39 pounds per cubic foot, in the air-dry condition, a specific gravity variation based on oven-dry weight and air-dry volume of 0.33–0.67. The average density of the wood when seasoned is approximately 34 pounds per cubic foot (Department of Scientific and Industrial Research, 1956), a specific gravity of 0.49 based on oven-dry weight and air-dry volume.

The British Forest Products Research Laboratory (Department of Scientific and Industrial Research, 1956) reports that the timber seasons rapidly and well. Little or no checking should develop during drying and distortion of all forms is very small. Some degrade in the form of splitting may develop in the zone of "brittleheart" and in the vicinity of knots. For lumber sizes up to 1½ inches thick, a moderately high temperature schedule such as is used for American basswood *(Tilia americana)* and non-aircraft Sitka spruce *(Picea sitchensis)* can be employed.

The results of mechanical tests on green and air-dry material are reported in table 1. The unseasoned wood of idigbo is superior in most strength categories to domestic hardwoods of comparable specific gravity such as sweetgum *(Liquidambar styraciflua)* and American sycamore *(Platanus occidentalis)*. It is notably inferior to sweetgum and American sycamore in total work in static bending, impact strength (toughness 98 in.-lb. per specimen; Armstrong, 1953), and resistance to splitting. In the static bending property of modulus of rupture and the properties of maximum crushing strength, hardness and shear, idigbo is considerably superior to sweetgum and American sycamore.

Upon drying to the air-dry condition, the strength properties of idigbo exhibit a somewhat erratic behavior. Bending, crushing, and shearing strength undergo moderate increases. Cleavage shows no significant change. However, side hardness and toughness exhibit appreciable decreases upon drying.

In the air-dry condition, idigbo may be compared with black cherry *(Prunus serotina)* in most strength properties. Idigbo is somewhat inferior to black cherry in the static bending properties of modulus of rupture, stiffness, work to maximum load and total work. The difference between the two species in values for modulus of rupture and stiffness is very slight; however, the work values in static bending for idigbo are only 70–75 per cent of those for black cherry. The lower work values for idigbo in static bending are reflected in the property of impact strength (toughness 78 in.-lb. per specimen; Armstrong, 1953), idigbo being only 65 per cent as strong as black cherry. It is 90 per cent as strong in maximum crushing strength, 70–75 per cent as hard, and slightly inferior in shearing strength and cleavage.

Idigbo is considered as a very poor steam-bending species (Department of Scientific and Industrial Research, 1956). Solid beams can be bent to radii of curvature of 32 inches per inch of thickness when supported with a steel tension strap, and 44 inches per inch of thickness when unsupported.

The green to oven-dry shrinkage values are reported in table 2. The shrinkage values for idigbo—volumetric 14.2, tangential 6.2 and radial 4.6 per cent—may be compared with American sycamore and yellow-poplar *(Liriodendron tulipifera);* the two domestic species are, however, somewhat denser. The dimensional change occurring between 90 per cent relative humidity (18 per cent equilibrium moisture content) and 60 per cent relative humidity (12 per cent equilibrium moisture content) is 0.78 per cent tangentially and 0.5 per cent radially of the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). These values, which are among the lowest of all the British timbers tested in England, appear inconsistent with the comparatively high shrinkage values reported for the species.

The results of decay resistance tests conducted in England (Findlay, 1938) are reported in table 3. Specimens of idigbo were subjected to the action of five wood-destroying fungi for a period of 8 months. The wood showed no measurable deterioration by brown-rot fungi. Exposure to the two white-rot fungi, *Polyporus versicolor* and *P. sanguineus,* resulted in only slight decay. The logs are susceptible to pinhole borer attack and powder-post beetle damage. Reports from Nigeria (Department of Scientific and Industrial Research, 1956; Forest Products Research Laboratory, 1945) indicate that the wood is also liable to termite infestation. The wood is extremely resistant to impregnation with creosote, penetration occurring in the vessels only.

The wood works easily with hand and machine tools with a slight dulling effect on cutting edges (Department of Scientific and Industrial Research, 1956; Forest Products Research Laboratory, 1952). The presence of interlocked grain may result in picking up on the quartered surface which can be overcome in planing with a cutting angle of 20°. The wood tends to crumble on end grain working and some charring in boring may be experienced because chips do not clear effectively. It has fairly good screwing and gluing properties, but tends to split when nailed. Staining and finishing properties are good but a grain filler is required.

Idigbo is reported (Forest Products Research Laboratory, 1952) as being one of the most useful light hardwoods available. It combines good seasoning, strength and working properties with durability and stability. Its only drawback is the presence of brittleheart which can be minimized by inspection and grading. Its principal use is in furniture, generally in the form of veneer for linings, backing and corestock. It is also used as a face veneer in cheap furniture to take advantage of its resemblance to satinwood or plain oak when suitably stained (Forest Products Research Laboratory, 1945). The wood contains tannins and hence will become stained in contact with iron (Department of Scientific and Industrial Research, 1956). It has moderate wearing resistance and may be suitable as a flooring material where traffic is moderate.

Terminalia superba Engl. & Diels Afara Combretaceae

This species is well known in international trade as afara (United Kingdom), limbo (France and French West Africa); limba (Belgium, Belgian Congo and Angola); and korina (a trade-marked name used in United States; Gerry, 1950). Common names of local importance are ka-ronko (Sierra Leone); frake, bale, fram (Ivory Coast); fram, frameri, farayen, afara (Ghana); afara, eji, eghoin, edo, ojiloko (Nigeria); bokome, djombe, mukonja (Cameroons; Dalziel, 1937).

Afara is a tall tree, frequently from 100–150 feet in height with a diameter of 3–5, and occasionally up to 6, feet (Department of Scientific and Industrial Research, 1956; Record, 1929). The bole is straight, cylindrical, and clear to a height of 90 feet, with slight taper and wing-like buttresses which reach a height of 15–20 feet. The tree occurs in the mixed deciduous forests of Sierra Leone, Liberia, Ivory Coast, Ghana, Nigeria, Belgian Congo and the Cameroons. It is abundant in the Belgian Congo where it makes up as much as 60 per cent of the stands on alluvial plains and in mountain valleys (Record, 1929). In southern Nigeria, it is frequently gregarious, particularly in forests bordering on the limits of the rain forest (Chalk et al., 1933). Jay (1947) reports the establishment of plantations of afara (mixed with other species) which appear to be succeeding in western Africa.

The wood is light yellowish-brown in color with no distinct demarcation between heartwood and sapwood (Jay, 1947). A common phenomenon in the wood of this species is the occurrence of dark walnut-brown zones, in the center of logs, often marked with darker brown and black striations which give the wood a striking appearance similar to English walnut (Dalziel, 1937). The darker colored wood is suited for veneering, cabinet work and pattern making. Therefore, the wood is divided into two groups depending upon the proportion of the log containing the dark coloration. "Limba clair" is the term applied when the dark colored wood occupies one-third or less of the log diameter; "limba noir," when the dark colored wood is extensive enough to show on the sides of squared logs (Jay, 1947). Brittleheart is occasionally encountered in some logs (Department of Scientific and Industrial Research, 1956).

The wood lacks a distinct taste or odor (Kribs, 1950). Grain is straight to somewhat wavy or irregular; the wavy grain often yields highly figured veneers (Jay, 1947). The luster is high and satiny, enhancing the decorative value of the wood. Growth rings are distinct; vessels indistinct, numerous, evenly distributed, solitary or in radial groups of 2–3, open or occluded with a yellow "gum"; axial parenchyma is distinct without a lens, vasicentric, aliform with short to long wings, aliform-confluent forming wavy tangential bands and occasionally terminal. Rays are not visible on either the transverse or tangential surface, and are inconspicuous on the radial surface. The lumina of ray cells are filled with a yellow "gum" (Kribs, 1950).

The wood is moderately heavy averaging approximately 34 pounds per cubic foot (specific gravity 0.50 based on

oven-dry weight and air-dry volume) in the air-dry condition (Department of Scientific and Industrial Research, 1956). The range in weight is generally 25–49 pounds per cubic foot which corresponds to a specific gravity range of 0.36–0.70 based on oven-dry weight and air-dry volume.

The seasoning-properties of the wood have not been fully investigated. Air-seasoning requires the use of thick stickers (1 inch) to avoid decay and discoloration (Jay, 1947). The wood is believed to kiln-season similarly to idigbo *(Terminalia ivorensis)*; that is, with ease and little tendency toward degrade. A kiln schedule identical to that recommended for American basswood *(Tilia americana)* and non-aircraft Sitka spruce *(Picea sitchensis)* is suggested (Forest Products Research Laboratory, 1945).

Strength data compiled from mechanical tests are limited; green values are not reported in the literature. Only the results of tests in bending, compression, shear and side hardness on air-dry material are available and shown in table 1.

In the seasoned condition, the wood is somewhat weaker in bending (fiber stress at the proportional limit 6,230 p.s.i.; Imperial Institute, 1923) than domestic hardwoods of similar density. Afara is similar in strength to American chestnut *(Castanea dentata)* in bending, crushing (fiber stress at the proportional limit 4,570 p.s.i.; Imperial Institute, 1923) and shear but has twice the side hardness of chestnut. Tests in France that are reported by the British Forest Products Laboratory (1945) indicate that the light colored wood is fairly resistant to shock loads but the dark colored wood tends to be brittle. The dark colored wood may be similar to the brittleheart found in idigbo *(Terminalia ivorensis)*.

The shrinkage of afara–radial 5.1, tangential 8.1 and volumetric 14.4 per cent–is similar to that of American elm *(Ulmus americana)* and approximately 50–75 per cent greater than for idigbo. Since the wood is commonly straight-grained, the tendency to warp during drying is very slight. The dimensional change from 90 per cent relative humidity (equilibrium moisture content 18 per cent) to 60 per cent relative humidity (equilibrium moisture content 12 per cent) is 1.3 per cent tangentially and 1.0 per cent radially based on per cent of dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). The tangential value is the same as for teak *(Tectona grandis)*, but the radial value is slightly higher than the 0.8 per cent value for teak.

Results of decay studies in Great Britain (Findlay, 1938) indicate that afara is particularly susceptible to deterioration by white-rot organisms, but moderately resistant to deterioration by brown-rot fungi. Weight losses due to decay by two white-rot fungi amounted to 25–30 per cent in 4 months. Therefore, the species is classed as non-resistant to decay. Logs are susceptible to sap stain and the heartwood is usually found to be unsound when the trees are felled (Department of Scientific and Industrial Research, 1956; Forest Products Research Laboratory, 1945). Both the heartwood and sapwood of downed trees are liable to damage by pinhole borers; the sapwood is also susceptible to powder-post beetle infestation. Observations of preservative treatment in Nigeria indicate that the wood is resistant to penetration of creosote by the open tank process but less resistant to treatment with aqueous solutions.

The general working properties of the wood are good. The straight-grained wood machines easily without the problem of grain pick-up. Occasionally irregular grain can be satisfactorily machined employing a cutting angle of less than 20°. The wood holds nails and screws firmly although some tendency to split may be experienced. Afara has very satisfactory veneer-cutting qualities by either the rotary or slicing methods, it finishes well when a grain filler is used, and has good gluing properties (Department of Scientific and Industrial Research, 1956; Imperial Institute, 1923).

In western Africa, afara is used for furniture, school furnishings, shop fittings and joinery (Jay, 1947). Afara is gaining popularity in international trade as a light colored decorative wood commonly in the form of veneer for furniture and paneling (Organisation for European Economic Co-operation, 1953). In England it has been used as a substitute for teak and in the manufacture of switch boards (Forest Products Research Laboratory, 1945). The French recommend afara for use in interior and exterior joinery, door frames and as peeler stock.

Triplochiton scleroxylon K. Schum. Obeche Sterculiaceae

In export trade (Jay, 1947), the species is also known as African whitewood (United Kingdom), and as ayous and samba (France). Names of local importance include (Dalziel, 1937; Organisation for European Economic Co-operation, 1951) ayous, ejoung, nkom, bush maple (Cameroons); owawa and African whitewood (Ghana); cofa, hafa, bamba, samba, serama, wawa (Ivory Coast); arere, obeche, African maple, bush maple, soft satin-wood (Nigeria).

This species is a large tree, often 125–150 feet in height and from 5–7 feet in diameter above the buttresses (Gerry and Miller, 1954; Record, 1929a). The bole is long and cylindrical above the fluted base but generally hollow in the larger trees. Buttresses are typically plank-like and form rather sharp angles with the axis of the tree. The species is common to tropical west Africa, predominantly along waterways in the deciduous forests between the savanna of the interior and the monsoon forest toward the coast. It occurs in French Guinea, Liberia, Ivory Coast, Ghana, Nigeria, Cameroons and Spanish Guinea.

The wood is creamy to yellow or yellow-brown when freshly cut with little differentiation between heartwood and sapwood (Gerry and Miller, 1954; Kribs, 1950). Exposure to air does not produce any color variation. The wood has a high luster often described as satiny and is lacking in any distinctive odor or taste. The texture is medium. The grain may be straight but is more commonly interlocked producing a roe or striped appearance on quartered stock. Growth rings are indistinct to distinct; pores distinct without a lens, sparse and irregularly distributed; axial parenchyma is visible on a smooth surface, apotracheal, forming closely spaced uniseriate tangential lines or a fine reticulum with the rays; wood rays are visible as fine whitish lines on the cross section, distinct on the radial surface being lighter than the background; ripple marks present, distinct with lens, 80–90 per inch.

The wood is soft and light in weight, ranging from 22½ to 25 pounds per cubic foot air-dry with an average weight of 24 pounds per cubic foot (Department of Scientific and Industrial Research, 1956; Record, 1929a). The range in specific gravity (oven-dry weight, air-dry volume) is from 0.32–0.36, the average being approximately 0.34.

The heartwood has a low moisture content in the living tree and dries readily developing little or no defect (Record, 1929a). The wood shows little tendency to check, warp, or split during drying and exhibits good dimensional stability (Forest Products Research Laboratory, 1945). However, slight distortion and splitting about knots may be encountered (Department of Scientific and Industrial Research, 1956). A moderately high temperature schedule is recommended similar to that suggested for western red cedar *(Thuja plicata)*, non-aircraft Douglas-fir *(Pseudotsuga menziesii)* and western white pine *(Pinus monticola)*. Kiln-seasoning is decidedly to be preferred because of the stain and decay hazard encountered in air-seasoning.

The results of mechanical tests of green and air-dry material are reported in table 1. Obeche compares favorably with yellow buckeye *(Aesculus octandra)* in most strength categories. In the green condition obeche is superior to yellow buckeye in most static bending properties, impact strength, compressive strength parallel to the grain and hardness. Values of modulus of rupture, work to maximum load and total work are somewhat greater for obeche, but it is only 70 per cent as stiff in bending as yellow buckeye. Obeche is 30 per cent more resistant to impact loads (toughness, 96 in.-lb. per specimen; Armstrong, 1953), 40 per cent stronger in compression parallel to the grain, and 30 per cent harder than yellow buckeye. Both woods are approximately equal in shearing strength and cleavage resistance in the green condition.

In drying from the green to the air-dry condition, obeche exhibits small to moderate increases in strength with the exception of total work in bending and impact strength. Shearing strength parallel to the grain increases approximately 50 per cent. Stiffness, hardness and cleavage increase slightly upon drying. Total work in bending and impact strength decrease 30 per cent and 25 per cent respectively upon drying (toughness, 59 in.-lb. per specimen; Armstrong, 1953).

The seasoned wood of obeche is similar to yellow buckeye in modulus of rupture, shearing strength and cleavage. It is superior to yellow buckeye in work to maximum load and total work in bending, but only 70 per cent as stiff. Yellow buckeye is slightly stronger in compression parallel to the grain but only 70 per cent as hard.

Tests carried out on two consignments of obeche suggested that the wood may be suitable for bending to moderate radii of curvature. Steamed material may be bent to radii of curvature of 18 inches per inch of thickness when supported by a steel tension strap, and 17 inches per inch of thickness when unsupported (Department of Scientific and Industrial Research, 1956).

The shrinkage values—volumetric 7.8, tangential 5.1 and radial 2.5 per cent—for obeche from green to oven-dry are similar to comparable values for teak (table 2). The dimensional change occurring between 90 per cent relative humidity and 60 per cent relative humidity (equilibrium moisture contents of 19 per cent and 12 per cent respectively) is 1.25 per cent tangentially and 0.8 per cent radially expressed as a per cent of the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). Comparable values for teak are practically identical being 1.3 per cent tangentially and 0.8 per cent radially.

Decay resistance tests were conducted at the British Forest Products Research Laboratory (Findlay, 1938). Specimens were exposed to 4 wood-destroying fungi for periods of 4 and 8 months. The data collected in these tests are reported in table 3. Results indicate that obeche has a marked susceptibility to decay by both white-rot and brown-rot fungi and the species is therefore classified as non-resistant to decay. The wood is also susceptible to discoloration by blue-stain fungi and attack by pinhole borers, powder-post beetles and termites. Wood from the center of the tree (probably heartwood) is resistant to preservative treatment with creosote but the outer wood (probably sapwood) is more readily treated (Department of Scientific and Industrial Research, 1956; Forest Products Research Laboratory, 1945).

The wood works readily and easily with hand and machine tools with no undue dulling effect on cutting edges (Department of Scientific and Industrial Research, 1956). The tendency to crumble in cutting, especially on the end grain, can be largely overcome by maintaining sharp cutting edges. Interlocked grain causes grain pick-up on quartered surface in planing which may be minimized by reducing the cutting angles. The wood takes nails and screws readily but nailed joints do not stand up well in rough usage. Obeche takes stains of water, oil, or spirit bases well, but its coarse texture requires considerable grain filler (Clifford, 1953; Wood 1938). It finishes nicely with a satiny sheen.

Obeche is used locally for dugout canoes, shingles, doors, shelves, dishes, platters and house construction (Dalziel, 1937). Presently, it is used commercially for interior joinery, framing, furniture, shop fitting, veneer (substituting for yellow poplar) and vehicle bodies (Gerry and Miller, 1954). It is recommended for containers, woodworking, furniture core stock and interior millwork (Wood, 1938). Obeche was tested in 1952 by the Bureau of Ships at the Philadelphia Naval Shipyard for use as pattern stock because of its low shrinkage (Gerry and Miller, 1954).

Turraeanthus africana (Welw.) Pellegr. Avodiré
Meliaceae

In export trade (Forest Products Research Laboratory, 1945; Miller, 1951), the species is also known as olon (United Kingdom), African satinwood and white mahogany (United States). Local names for the species include blimah-

pu (Liberia); avodiré, agboue, hague (Ivory Coast); apeya, appayia, wansewa (Ghana); apaya (Nigeria); engan (Cameroons) and songo (Belgian Congo; Dalziel, 1937; Jay, 1947).

The tree is of medium size, ranging in height from 60–100 feet with a diameter from 3–4 feet (Miller, 1951). The bole is generally crooked but clear to a height from 25–50 feet, rarely over 65 feet. The species occurs in Liberia, Ivory Coast, Ghana, Nigeria, Cameroons, Gabon and the Belgian Congo. It is most common in the eastern regions of the Ivory Coast and is rather scattered elsewhere in its range. It is found as an understory species on moist sites bordering streams and lakes below altitudes of 2500 feet. Avodiré attains its best development in foothills from 50–100 miles inland from the coast. It is not uniformly distributed but localized in almost pure groups.

The wood is creamy white to pale yellow occasionally darkening to a golden yellow with no distinction between heartwood and sapwood (Forest Products Research Laboratory, 1951). A distinct taste and odor are lacking and the luster is satiny (Record, 1931). The grain is sometimes straight but more commonly wavy and irregularly interlocked. The texture is fine to medium and very uniform. The quartered surfaces commonly have a very pronounced stripe, curl, or mottled figure suggesting satinwood (Miller, 1951). Growth rings are indistinct; pores barely visible without a lens, evenly distributed, solitary and in radial groups of 2–4, and the pore openings contain a yellowish "gum." The axial parenchyma, although not visible with hand lens, is paratracheal. The rays are barely visible without lens on the cross-section and inconspicuous on the radial section (Kribs, 1950).

The wood is moderately heavy ranging from 31–37 pounds per cubic foot with an average of 35 pounds per cubic foot air-dry. Specific gravity (air-dry volume; Miller, 1951) varies between 0.45 and 0.60 with an average of 0.50.

The wood seasons fairly rapidly with some tendency towards cup and twist (Forest Products Research Laboratory, 1951). Existing splits may extend in drying, and splitting in or around knots may occur. A kiln schedule recommended for black walnut *(Juglan nigra)* and sugar maple *(Acer saccharum)* is suggested for avodiré by the British Forest Products Research Laboratory (1945).

Mechanical test data for avodiré are given in table 1 but only the results of tests on air-dry material are reported. The air-dry strength properties of avodiré are similar to those of seasoned black cherry *(Prunus serotina)*. In the air-dry condition, avodiré exhibits bending properties nearly equal to those of black cherry. The modulus of rupture of avodiré is somewhat greater, but both species are equally as stiff in bending. Work to maximum load and total work values are 10 per cent less than those for black cherry which is reflected in the 15 per cent lower impact resistance of avodiré. It is slightly superior to black cherry in maximum crushing strength, shearing strength and resistance to splitting, but both species are approximately equal in side and end hardness.

Steamed solid beams can be bent to a radius of curvature of 36 inches per inch of thickness when supported by a steel tension strap, and 38 inches when unsupported (Forest Products Research Laboratory, 1951). Unsteamed laminae will take bends of 57 inches per inch of thickness; the species is therefore classed as a very poor bending wood.

Shrinkage data for avodiré are reported in table 2. The shrinkage of the wood–volumetric 10.6, tangential 6.2 and radial 4.0 per cent–is of the same magnitude as yellow poplar *(Liriodendron tulipifera)*, although yellow poplar weighs only 60 per cent as much as air-dry avodiré. The dimensional change between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 18 per cent and 12 per cent respectively) is 1.8 per cent tangentially and 1.0 per cent radially based on dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). These values are considerably less than comparable values of 2.8 per cent and 1.3 per cent for white oak *(Quercus alba)*.

The wood is extremely perishable and should not be used in a situation where decay is a hazard (Forest Products Research Laboratory, 1951). The logs are susceptible to insect attack and therefore should be converted into lumber as quickly as possible (Miller, 1951). Heartwood is extremely resistant to impregnation but the sapwood can be impregnated easily under pressure or by the open tank process.

The wood works easily with hand or machine tools with a slight dulling effect on cutting edges (Forest Products Research Laboratory, 1951). A 15° cutting angle should be used in planing to avoid tearing of the irregular grain on quarter surfaces (Miller, 1951). Preboring for nails is required to prevent splitting; screwing and gluing properties are good. The wood tends to stain unevenly but its finishing properties are excellent.

Avodiré is most commonly used in the form of veneer (Forest Products Research Laboratory, 1951). Such veneer is usually sliced, as the poor log form makes peeling difficult. It is well suited for superior joinery and cabinet work particularly where a wood of light color is desired. In England, it has been employed in marine woodwork, millwork and railway coach construction.

Juniperus procera Hochst. African pencil cedar
Cupressaceae

The English trade name for the species is African pencil cedar (Wimbush, 1950). Common names (Chalk et al., 1932) include pencil cedar, East African cedar, Uganda juniper and East African juniper. Local names are mutarakwa, mukuu (Kenya); tolokyo (Uganda).

The average height of the mature trees ranges between 80 and 120 feet although 150 feet is not uncommon (Chalk et al., 1932). The bole is usually deeply fluted at the base, clear of branches for lengths of 60 feet, and may be as much as 10 feet in diameter, but generally only 4–5 feet (Department of Scientific and Industrial Research, 1957). The species occurs in Ethiopia, Kenya, Uganda and Tanganyika. It is commonly found in association with podo *(Podocarpus* spp.) on extensive areas of the mountain slopes between 6- and 9-thousand feet in altitude. Eggeling and Harris (1939) report that the cedar forests are probably the most important in all of eastern Africa.

The sapwood is white in color, ½–1½ inches wide, and sharply defined from the red heartwood (Chalk et al., 1932; Department of Scientific and Industrial Research, 1957). The appearance of the wood is very similar to that of the common northeastern American species, *J. virginiana* (eastern redcedar). The grain is straight and the texture is fine. The wood has the characteristic cedar-like aroma. Growth rings are distinct to indistinct on the end surface and sometimes distinct on the longitudinal surfaces. The rays are invisible to the naked eye on the end surface and conspicuous on the radial surface. Compression wood is an oft-encountered defect with African pencil cedar and is common to much of the material (Department of Scientific and Industrial Research, 1938; Phillips, 1940).

The wood is moderately heavy in weight, averaging 36 pounds (32–38 pounds) per cubic foot air-dry (Department of Scientific and Industrial Research, 1957; Forest Products Research Laboratory, 1945; Wimbush, 1950). The specific gravity (oven-dry weight, air-dry volume) averages 0.50 (0.44–0.53).

African pencil cedar exhibits a marked tendency toward surface-checking in seasoning which necessitates mild drying conditions in the early stages of seasoning (Department of Scientific and Industrial Research, 1957; Wimbush, 1950). In kiln-drying, rapid drying conditions may cause end-splitting. The presence of compression wood causes excessive longitudinal shrinkage, which when localized in a single piece, may produce serious warping. The British Forest Products Research Laboratory (1945) suggests a high-humidity kiln schedule during the initial stages of drying, the initial low temperature being progressively increased as drying proceeds beyond the point of maximum checking hazard.

The results of mechanical tests on green material are reported in table 1. African pencil cedar, in the green condition is superior in strength to domestic softwoods of equal specific gravity.

The unseasoned wood of African pencil cedar is appreciably superior in mechanical strength to Douglas-fir (coast form) of 10 per cent lower specific gravity. In static bending properties, it exceeds Douglas-fir *(Pseudotsuga menziesii)* by almost 40 per cent in modulus of rupture and 65 per cent in work to maximum load. However, it is somewhat inferior in stiffness and total work. It is 50 per cent stronger in maximum crushing strength, twice as hard on the end and side surface, and notably superior in cleavage.

The green to oven-dry shrinkage values for African pencil cedar are reported in table 2. These values—volumetric 9.4, tangential 5.6 and radial 4.0 per cent—are greater than those for eastern redcedar *(Juniperus virginiana)* in proportion to the greater specific gravity of African pencil cedar.

The heartwood is very durable in the ground and extremely resistant to termites (Wimbush, 1950). The wood is also very resistant to impregnation with oils.

The British Forest Products Research Laboratory (Department of Scientific and Industrial Research, 1957) reports that the wood works easily in all operations with hand and machine tools. In general, the dulling effect on cutting edges is very slight but occasional pieces may be somewhat abrasive. An excellent surface is readily obtainable when cutting edges are kept sharp. In boring, mortising and end cutting, the wood must be well supported in order to prevent chipping. Splitting is often encountered in nailing and screwing. The wood forms strong glue joints and stains and finishes very well.

In Kenya the species has been used for many purposes including woodwork, paneling, flooring, shingles, fence posts and telephone poles (Wimbush, 1950). In England, it has been used for pencil manufacturing in place of eastern redcedar (Department of Scientific and Industrial Research, 1938; 1957; Forest Products Research Laboratory, 1945). Its strength, durability, low shrinkage and pleasing appearance would make it ideal for storage chests, and woodworking of all kinds. If material free from extensive compression wood could be obtained, the species might prove suitable for ship-planking.

Podocarpus spp. Podo, Yellowwood Podocarpaceae

The genus *Podocarpus* is represented in Africa by 10 species, 5 of which grow in tropical Africa and 5 in temperate South Africa (Chalk et al., 1932). Of these species, only 7 are of commercial importance (Chalk et al., 1935; Forest Products Research Laboratory, 1945): *P. elongatus* L'Herit., *P. falcatus* (Thunb.) R. Br., *P. gracilior* Pilg., *P. henkelii* Stapf, *P. milanjianus* Rendle, *P. thunbergii* Hook. (*P. latifolius* R. Br.), and *P. usambarensis* Pilg. (Dallimore and Jackson, 1948).

The common name applied to all the African species of *Podocarpus* is podo (Chalk et al., 1932; 1935); the South African species (*P. elongatus*, *P. falcatus* and *P. thunbergii*) are known collectively as yellowwood. In South Africa, *P. elongatus* is generally referred to as common yellowwood, *P. falcatus* as falcate yellowwood and *P. thunbergii* as real yellowwood or as upright yellowwood (Eckbo, 1922). *P. gracilior* and *P. milanjianus* are known locally as musengera in Kenya.

The trees vary considerably among species in growth habit. Individuals of *P. elongatus*, *P. henkelii*, *P. milanjianus* and *P. thunbergii* attain a height of 100 feet or more (Chalk et al., 1932; Eckbo, 1922; Forest Products Research Laboratory, 1945); trees of *P. falcatus* attain heights of 125–150 feet. Individuals of *P. usambarensis* may grow in height up to 250 feet (Dallimore and Jackson, 1948), but those of *P. gracilior* are generally only 60 feet or more in height (Forest Products Research Laboratory, 1945). The basal diameters of the bole are also variable from species to species. *P. elongatus* attains a bole diameter up to 10 feet, *P. falcatus* from 3–8 feet, *P. gracilior* up to 2½ feet, *P. henkelii* and *P. thunbergii* from 2–4 feet and *P. milanjianus* up to 3 feet. The boles are straight and cylindrical with very little taper, and clear of branches for a distance from 40–80 per cent of the tree height. Four species are found in east Africa: *P. henkelii* occurs in the mountain forests of Natal, Swaziland, Orange Free State and northern Transvaal on sites with deep moist soils (Chalk et al., 1935); *P. milanjianus* is found in

Uganda, Kenya, Tanganyika and Nyasaland on deep, moist soils at elevations up to 11-thousand feet (Dallimore and Jackson, 1948), at the higher elevations, it occurs as a low, dense shrub; *P. gracilior* is native to Ethiopia, Uganda, Tanganyika and Kenya where it occurs at elevations up to 8-thousand feet; *P. usambarensis* is restricted to Kenya and Tanganyika and grows in mountain meadows and in virgin forests at elevations from 2500 to over 6-thousand feet. The three remaining species are restricted to South Africa; *P. falcatus* and *P. thunbergii* are widely distributed in Cape Colony, Natal and the Transvaal. *P. elongatus* is much more limited in range, occurring in Robertson, western South Africa.

The woods of the 7 species are very similar, and the eastern African species are indiscriminately mixed for most practical commercial purposes. The color is a uniform light yellowish-brown with no clear distinction between heartwood and sapwood (Department of Scientific and Industrial Research, 1957). There is no distinct odor or taste (Chalk et al., 1932, 1935). The grain is straight and the texture fine; the woods are not resinous. Growth rings are distinct or indistinct on the end surface, sometimes visible on longitudinal surfaces, the early wood merging gradually into the late wood. Wood rays are very fine, just visible to the naked eye on the end surface in *P. falcatus*, *P. henkelii* and *P. thunbergii*, and visible with a lens on the end surface in the other species; rays are distinct on the radial surface in *P. falcatus*, *P. gracilior* and *P. milanjianus* but not in *P. henkelii* and *P. thunbergii*; resin ducts are absent.

The range in weight per cubic foot air-dry is from 27–48 pounds corresponding to a specific gravity range (oven-dry weight and air-dry volume) of 0.38–0.68. The average weight per cubic foot air-dry varies somewhat with the species, being 31 pounds for *P. falcatus*, 32 pounds for *P. elongatus*, *P. henkelii*, *P. gracilior*, *P. milanjianus* and *P. usambarensis*, and 33 pounds for *P. thunbergii* (Forest Products Research Laboratory, 1945; Scott, 1926). The average specific gravities (oven-dry weight, air-dry volume) for the three average densities are 0.43, 0.45 and 0.47, respectively.

Intensive experimental kiln-seasoning investigations were carried out in the Union of South Africa on the three native species (Eckbo, 1922). The results appear to be consistent with reports of the seasoning properties of the four east African species (Chalk et al., 1935; Department of Scientific and Industrial Research, 1957). *P. falcatus* boards 1⅛ inches thick were dried from an initial moisture content of 70 per cent to a final moisture content of 6.4 per cent in 19 days. An initial relative humidity of 86 per cent was used and progressively decreased to a final relative humidity after 19 days of 27 per cent. One-inch thick material of *P. elongatus* required only 14 days to dry from an initial moisture content of 67 per cent to a final moisture content of 5.2 per cent at the same range in relative humidity. A maximum dry-bulb temperature of 175° F. was used during the final stages in drying for *P. falcatus*, but only a 160° F. maximum dry-bulb temperature was used for *P. elongatus*. In tests on all three species *(P. elongatus, P. falcatus* and *P. thunbergii)*, little or no splitting or warping occurred even after resawing. The wood can be kiln-dried rapidly from the green condition with a slight to moderate tendency towards splitting, checking and warping. Care in piling should control warp satisfactorily. The British Forest Products Research Laboratory (Department of Scientific and Industrial Research, 1957) suggests a low-temperature schedule for species particularly prone to warp.

The results of mechanical tests on green and air-dry material are reported in table 1. The test material represents *P. gracilior, P. milanjianus* and *P. usambarensis* from east Africa (Forest Products Research Laboratory, 1945). There is no appreciable difference in strength among these three species, and since the woods of the 7 species are similar in structure and density, the data in table 1 are probably fairly representative of all 7 species.

The unseasoned wood of podo may be compared to that of baldcypress *(Taxodium distichum)* of equal specific

gravity. In static bending properties, podo is equal to baldcypress in maximum bending strength (modulus of rupture), superior in work to maximum load, but inferior in stiffness by 20 per cent and in total work by 25 per cent. Podo and baldcypress are equally strong in impact, strength and shearing strength parallel to the grain. Podo is 85 per cent as strong in maximum crushing strength but markedly superior in hardness and cleavage.

The increases in strength upon drying for podo are appreciable in all properties except work in bending, impact strength and cleavage. Maximum crushing strength and shearing strength increase 100 per cent over the green strength values. Work in bending and impact strength values exhibit erratic changes between green and air-dry values. Work to maximum load and height of 50-pound hammer drop increase slightly, but total work and toughness decrease appreciably. Values for cleavage in both the radial and tangential plane undergo no change upon drying from the green to air-dry condition.

In the air-dry condition, podo is comparable to baldcypress in static bending properties. It is slightly superior in maximum bending strength and work to maximum load but inferior in stiffness. Podo and baldcypress are essentially equal in total work in bending and impact strength. Podo exceeds baldcypress by 75 per cent in shearing strength parallel to the grain, 90 per cent in end hardness, and 60–65 per cent in side hardness. However, it is inferior to baldcypress in maximum crushing strength.

The three species of podo *(P. gracilior, P. milanjianus* and *P. usambarensis)* tested at the British Forest Products Research Laboratory (Department of Scientific and Industrial Research, 1957) have moderately good steam-bending properties. Steamed specimens of *P. gracilior* and *P. usambarensis* were bent to radii of curvature of 18 inches per inch of thickness when supported by a steel strap, and 20 inches per inch of thickness when unsupported. Comparable values for *P. milanjianus* of 10 inches and 16 inches indicate that this species is somewhat superior in wood bending properties.

The green to oven-dry shrinkage values—volumetric 11.4, tangential 7.8 and radial 3.8 per cent—for podo are presented in table 2. These values are similar to those for coast form Douglas-fir *(Pseudotsuga menziesii)* with a specific gravity (oven-dry weight and air-dry volume) of 0.49, podo being somewhat less dense.

The wood is classed as non-resistant to decay and is susceptible to longhorn beetle and pinhole borer attack (Department of Scientific and Industrial Research, 1957; Forest Products Research Laboratory, 1945). Impregnation with preservatives can be readily accomplished as the wood is permeable.

The wood is easily worked by hand and machine tools with little dulling effect on cutting edges (Department of Scientific and Industrial Research, 1957). Smooth, clean surfaces are produced in planing. Care must be taken to prevent chip-out at tool exits when cutting across the grain, boring and mortising. The wood has a tendency to split in nailing unless thin gauge nails are used, but it holds screws firmly. Gluing and finishing properties are generally good. The wood stains readily but not always uniformly.

The wood is used for railroad cross-ties (treated), truck bottoms, rough construction, boat building, flooring, millwork, furniture, paneling and framing (Chalk et al., 1935). Dallimore and Jackson (1948) state that *P. falcatus* is one of the most useful woods of South Africa.

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CURRENT LITERATURE

Fruits for southern Florida. *David Sturrock*, Southeastern Printing Co., Stuart, Florida. 1–196 including index and bibliography, with illustrations and 4 maps. 1959. $4.00.

This small book is a rewriting of the author's *Tropical fruits for southern Florida and Cuba*, published in 1940 and now out-of-print. Although dedicated to the homemakers of southern Florida and subtitled "A handbook for the homeowner," it contains much of interest to residents of other summer-rainfall areas bordering the tropics. The author is a professional horticulturist with long experience in Cuba and Florida, and the book is essentially a summary of his experience and his interests. One of the strongest of the latter is the uses to which the fruits may be put, and the book is unique in combining sound horticultural advice with practical ideas on home procedures for preparing the fruits in their most palatable form. Considerable effort has been made to provide data on the nutritional values of the fresh fruits, but here the author has had to rely on the literature rather than on his own experience, and the results are less successful. Frequent reference is made in the text to the work of Cardenas and Moreno on Cuban-grown fruits, and although the paper does not appear in the bibliography, I assume their 1923 paper *Las frutas de Cuba* is meant. The much more recent and detailed work of Navia, López et al. on the nutrient composition of Cuban foods of plant origin, published in *Food Research* in 1955 and 1957 is not mentioned, nor is any of the work of the INCAP group under Scrimshaw's direction in Guatemala. Many blanks in the table of food values could have been filled in from these, and many obsolete figures replaced.

After short chapters on climatic factors, cultural notes, "plant disorders," commercial and home plantings, and uses, the 120 fruits are described. The arrangement is first by family, in alphabetical order, and within the family by genus. Brief comments are made on each family, and for

each major species, there is a good description of the plant, and comments on special horticultural requirements, varieties, propagation techniques and nutritional values. Except for the unexplained omission of the pineapple, the coverage is remarkably complete. The author's wife has provided sketches of twigs and fruits of about a sixth of the species, and a brilliant color photograph of the jaboticaba serves as frontispiece. There are well-done maps of rainfall and temperature distribution in southern Florida, a less well-done aerial perspective drawing of the southern Florida peninsula showing the general land-use pattern and the Gulf Stream, and a sketchy and in part inaccurate map of the vegetation of the tropical and warm-temperate zones of the world.

The major defects of the book are the careless proofreading, especially of the index, and more serious yet, the abuse of scientific names. Spellings are inconsistent (e.g., *Dovyalis, Dovyalia; Cannabis, Canabis;* cainito, caimito) or always incorrect (e.g, *Musa cavandishii, Crytosperma, Antignon, Brysonima* and *Brysomina, Cocoloba)*. The acknowledgment page gives special thanks to Dr. Richard A. Howard, the authority on the genus *Coccoloba*, for his verification of the botanical nomenclature. Considering that *Coccoloba* is consistently misspelled, I suspect that Dr. Howard has not in fact had much chance to verify the nomenclature. E. A. Kabat's letter, *Acknowledgments in scientific papers*, Science 128 (3336): 1461–2. 1958, should be brought to attention of both author and publisher.–*Duncan Clement*, Atkins Garden and Research Laboratory, Cienfuegos, Cuba.

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CONTENTS

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

NUMBER 111 — OCTOBER, 1959

THE ANATOMY OF BARK. VII. SPECIES OF *EUGENIA (sens. lat.)*

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INTRODUCTION

Interest in the species of *Eugenia* from the New and Old Worlds has centered on the paradox that the genus, as at present comprised, splits easily into two very distinct groups on wood anatomy and pollen analysis (Pike 1956) as well as geographical distribution. However, taxonomists cannot agree as to their separation on floral morphology and seedling structure (Henderson, 1949). Dadswell and Ingle (1947) discussed the anatomical differences between the different species of *Eugenia* and followed Merrill and Perry (1938) in suggesting "that the genus *Eugenia* be restricted to the species of the New World and that the genus *Syzygium* be accepted to cover the majority of the species of the Old World."

Recently the bark of some species of *Eugenia* from both Old and New Worlds has been examined, and it is found that the same distinction between species exists in the phloem as in the wood. It is felt that this information may add another feature to the list on which a reclassification of the genus might be based.

[1]The author wishes to thank the following who have assisted by sending material: Dr. L. Chalk (Imperial Forestry Institute, Oxford), Mr. P. K. B. Menon (Forest Research Institute, Selangor, F.M.S.), Mr. B. J. Rendle (Forest Products Research Laboratory, Princes Risborough), Dr. W. L. Stern (Yale Forestry School), the Division of Wood Technology, Sydney, and the Department of Forestry, Queensland.

Material Examined

Eugenia "A"

E. anastomosans DC., 2, British Guiana and Surinam; *axillaris* (Sw.) Willd., 6, British Honduras and U.S.A.; *bahamensis* Kiaersk., 2, U.S.A.; *brasiliensis* Berg, 1, Argentine; *buxifolia* Willd., 1, U.S.A.; *cabanensis* Britt., 1, Cuba; *cisplatensis* Camb., 1, Argentine; *confusa* DC., 1, U.S.A.; *flavescens* DC., 1, Surinam; *flavifolia* Standl., 1, British Honduras; *florida* Merr., 2, Argentine and U.S.A.; *guabiju* Berg, 1, Argentine; *guatemalensis* Donn. Smith, 1, British Honduras; *ligustrina* Willd., 1, Cuba; *maestrensis* Urb., 1, Cuba; *monticola* (Sw.) DC., 2, Dominican Republic; *mucronata* Berg, 1, Dominican Republic; *myrtoides* Poir., 5, U.S.A.; *oerstediana* Berg, 1, Costa Rica; *origanoides* Berg, 1, British Honduras; *procera* (Sw.) Poir., 1, U.S.A.; *rariflora* Benth., 2, Fiji Islands; *retusa* Berg, 1, Argentine; *roraimana* Berg, 2, Colombia; *uniflora* L., 2, U.S.A. and Argentine; *wentii* Amsh., 1, Surinam; *whytei* Sprague, 1, Liberia; *winzerlingii* Standl., 1, British Honduras.

Eugenia "B" including *Syzygium*

E. albidiramea Merr., 1, North Borneo; *alcinae* Merr., 1, North Borneo; *angophoroides* F. Muell., 2, eastern Australia; *attenuata* Koord., 1, North Borneo; *bleeseri* Schwarz, 1, eastern Australia; *calcicola* Merr., 1, Philippines; *caryophyllata* Thunb., 1, East Indies; *clusiaefolia* A. Gray, 1, eastern Australia; *corniflora* F. Muell., 1, eastern Australia; *corynantha* F. Muell., 5, eastern Australia; *crebrinervis* C. T. White, 4, eastern Australia; *cryptophlebia* F. Muell., 2, eastern Australia; *cyanocarpa* (F. Muell.) Maid. & Betche, 4, eastern Australia; *duthieana* King, 1, Malaya; *erythrodoxa* C. T. White, 2, eastern Australia; *everettii* C. B. Rob., 1, Philippines; *filiformis* Wall., 1, Malaya; *francisii* Bail., 6, eastern Australia; *glauca* var. *pseudoglauca* King, 1, Malaya; *glaucicalyx* Merr., 2, Philippines; *grandis* Wight, 4, eastern Australia and Malaya; *grisea* C. B. Rob., 1, Philippines; *helferi* Duthie, 1, Malaya; *jambos* (L.) Alston, 2, Dominican Republic and U.S.A.; *kuranda* F. M. Bail., 1, eastern Aus-

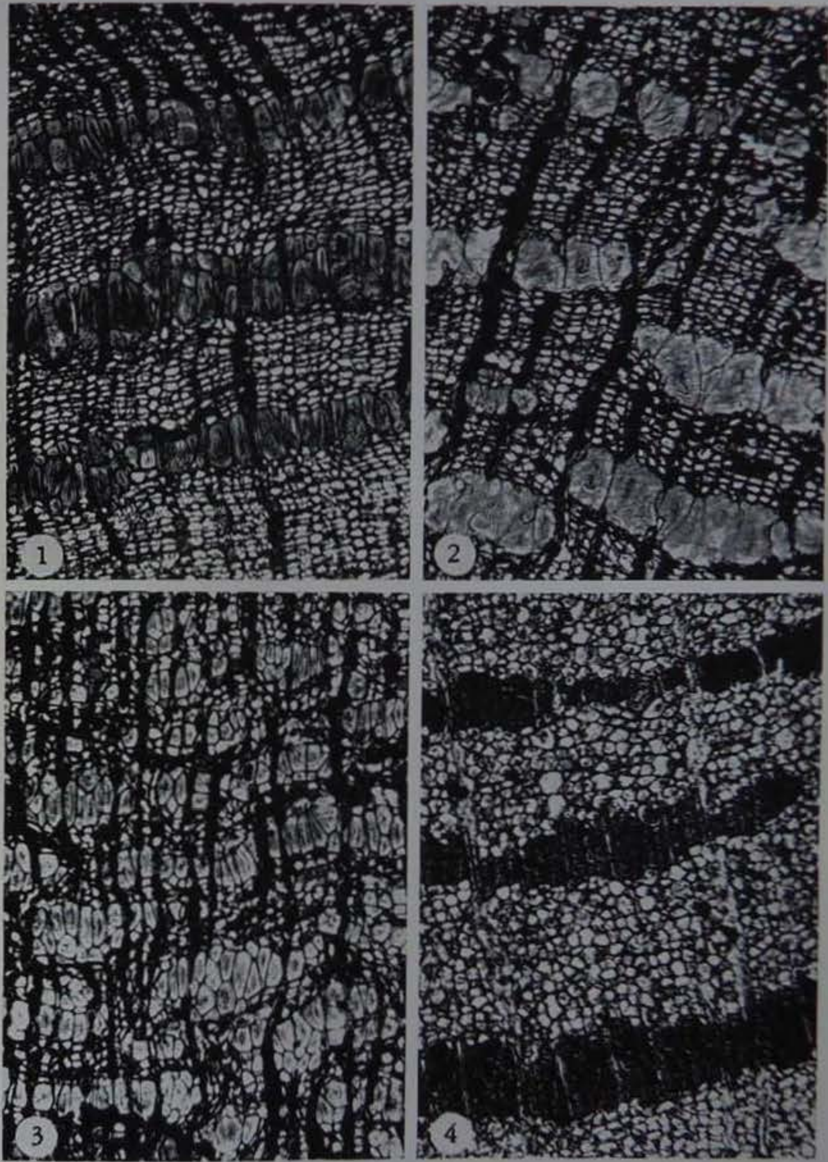

Fig. 1-4. Cross sections of phloem of *Eugenia* "A." × 85.—Fig. 1. *E. uniflora* L.—Fig. 2. *E. cabanensis* Britt.—Fig. 3. *E. anastomosans* DC.—Fig. 4. *E. confusa* DC.

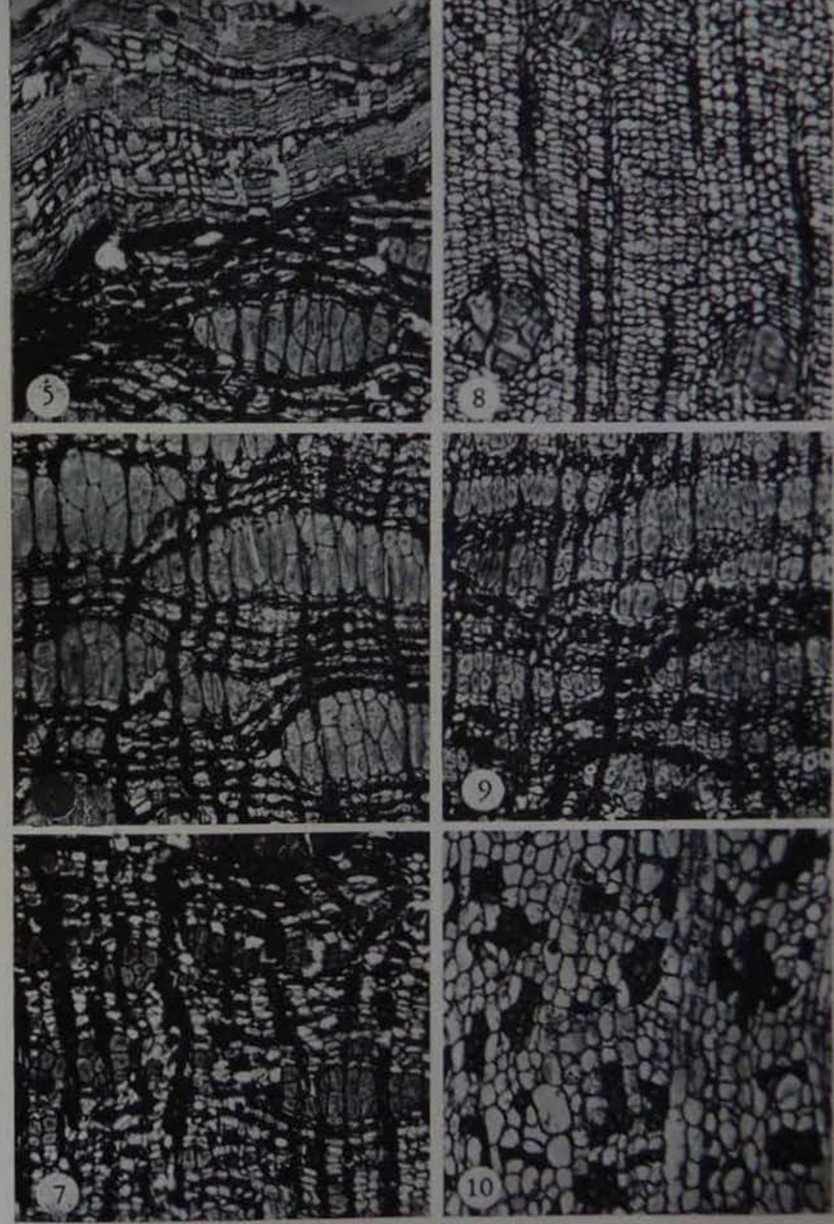

Fig. 5–10. Cross sections of phloem of *Eugenia* "A" and *Cleistocalyx* ×85.—Fig. 5 and 6. *E. origanoides* Berg.—Fig. 7. *E. procera* (Sw.) Poir.—Fig. 8. *E. retusa* Berg.—Fig. 9. *E. axillaris* (Sw.) Willd.—Fig. 10. *Cleistocalyx gustavioides* Bailey.

tralia; *luehmanni* F. Muell., 2, eastern Australia; *macrocarpa* Roxb., 1, Burma; *maire* A. Cunn., 2, New Zealand; *malaccense* (L.) Merr. & Perry, 1, New Guinea; *megalantha* C. B. Rob., 1, Philippines; *moorei* F. Muell., 3, eastern Australia; *S. multipetalum* Panch. ex. Brong. & Gris., 1, New Caledonia; *E. nitidissima* Merr., 1, Philippines; *S. nutans* K. Schum., 1, Melanesia; *E. oleosa* F. Muell., 1, Australia; *S. onesimum* Merr. & Perry, 1, British Solomon Islands; *E. palawanensis* C. B. Rob., 1, North Borneo; *S. paniculatum* Gaertn., 2, eastern Australia; *E. polita* King, 1, Malaya; *robertii* Merr., 1, Philippines; *S. rubiginosum* Merr. & Perry, 1, eastern Australia; *E. suborbicularis* Benth., 1, eastern Australia; *syzygioides* (Miq.) M. R. Hend., 3, Malaya; *thompsoni* Merr., 1, Guam Island; *tsoi* Merr. & Chun., 1, China; *valdevenosa* Duthie, 1, Malaya; *ventenatii* Benth., 2, eastern Australia; *wilsoni* F. Muell., 1, eastern Australia; *zeylanica* Wight, 1, Sarawak.

Acmena

A. accuminatissima (Blume) Merr. & Perry, 2, Malaya; *brachyandra* (Maid. & Betche) Merr. & Perry, 7, eastern Australia; *graveolens* (F. M. Bail.) L. S. Smith, 1, eastern Australia; *smithii* (Poir.) Merr. & Perry, 7, eastern Australia.

Cleistocalyx

C. gustavioides Bailey, 4, eastern Australia.

Anatomical Characteristics

Eugenia "A," as described by Ingle and Dadswell (1953) comprises those species of the genus which are characterized by the presence of vasicentric tracheids and fibre-tracheids and by solitary pores, apotracheal parenchyma and vessel-ray pitting which is similar to the intervessel type. The species which Ingle and Dadswell described under this heading included the New World species *E. axillaris*, *confusa*, *origanoides* and *uniflora*. To these species may now be added the wood of *E. bahamensis*, *brasiliensis*, *cisplaten-*

sis, *guatemalensis*, *rariflora*, *retusa* and *whytei*. In all these species wood typical of *Eugenia* "A" has been observed.

The main characteristics of the bark of most of the New World species examined is the presence of short fibres, under 1000μ except in *E. florida* (table 1) seen in cross sections as widely spaced groups, often with large radial diameter, often extending tangentially across many rays (fig. 1–10) sometimes in concentric bands *(E. cisplatensis, ligustrina* and *uniflora)*, rarely in uniseriate lines *(E. florida, guabiju)*. These fibre groups are separated by wide areas of phloem parenchyma and sieve tissue which commonly alter-

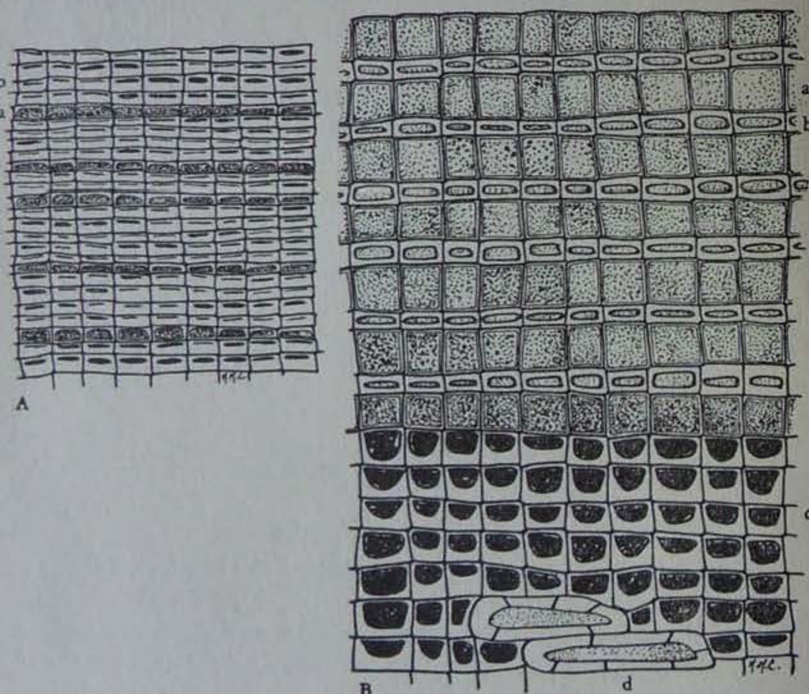

Fig. 11. A. *Eugenia monticola* (Sw.) DC. "A" type phellem, showing uniseriate suberised layer *a* alternating with multiseriate bands of sclerosed cells *b*. × 400.—B. *E. jambos* (L.) Alston "B" type of phellem showing alternating lines of suberised *a* and lignified *b* cells and phelloderm of adaxially thickened cells *c* and occasional stone cells *d*. × 400.

nate with lines of crystalliferous parenchyma containing twinned or occasionally multiple crystals. The rhytidome of these species usually consists of uniseriate lines of thin-walled tanniniferous cells with suberised walls, alternating with multiseriate bands of very thick-walled lignified cells (fig. 11.A). There is little phelloderm in most of these species and the peripheral parenchyma is unthickened except for clusters of enlarged stone cells.

The majority of the New World species examined exhibit these general characteristics, but *Eugenia bahamensis, cabanensis* (fig. 2), *cisplatensis, retusa* (fig. 8) and *uniflora* (fig. 1), while appearing very similar in cross section, differ from them in the details of their fibre structure. In these species there appear to be no true fibres, and what seem on a cross section of the phloem to be fibre bundles are seen

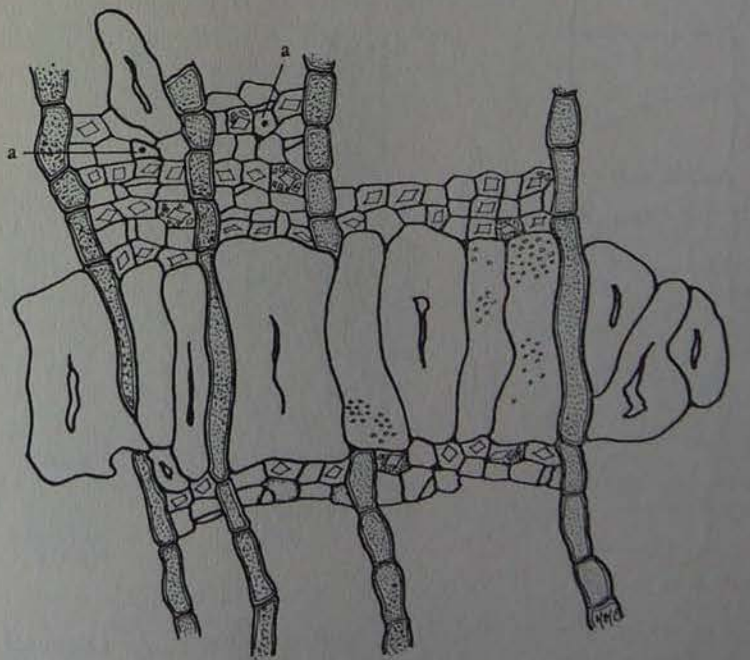

Fig. 12. *Eugenia bahamensis* Kiaersk. "A" type phloem with large stone cells in groups, and at a_1 small scattered fibrous cells. × 400.

in longitudinal section and in macerated material to consist of columnar groups of stone cells, each formed from a subdivided cambiform strand (fig. 12, 13). Among the parenchymatous ground tissue of the phloem very small fibres do occur (fig. 12a), but they are few in number compared with the columnar stone cells, and are usually formed from a cambiform mother cell after it has been subdivided into at least two daughter cells. Often only one of these cells has become thickened, and they have apparently not undergone any extension in length; consequently they cannot be described as true fibres, and although they differ markedly in appearance from the columnar groups of large stone cells (fig. 13) many intermediate stages between the two extremes can be found. These species are similar to

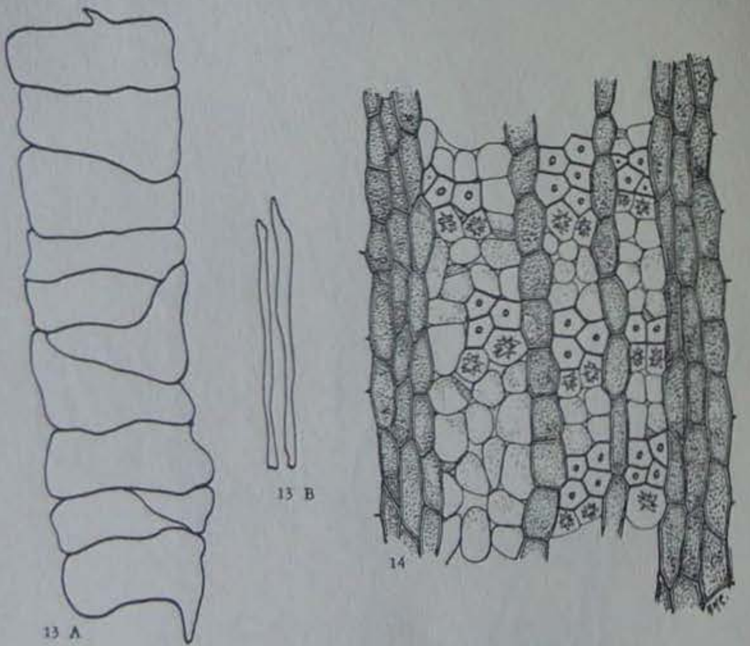

Fig. 13–14. Fig. 13. *Eugenia bahamensis* Kiaersk. A. Columnar strand of stone cells. × 300.—B. Small shorter fibrous cells, as seen in macerated material. × 300.—Fig. 14. *Eugenia moorei* F. Muell. "B" type of phloem showing scattered fibre groups with crystalliferous strands containing druses on the adaxial side. × 300.

the other New World species in the form of the crystals and in details of the rhytidome.

Ingle and Dadswell (1953) described as *Eugenia* "B" the Old World species of the genus which are characterized by the absence of vasicentric tracheids and fibre-tracheids and by the presence of pore multiples, paratracheal parenchyma and coarse, apparently simple to scalariform, vessel-ray pitting. In addition to these species, wood of the following species has now been examined: *Eugenia crytophlebia, cyanocarpa, duthieana, filiformis, glauca* var. *pseudoglauca, macrocarpa, malaccense, syzygioides* and *valdevenosa; Syzygium multipetalum, onesimum* and *polita.* The wood of these species is typical of *Eugenia* "B."

The phloem of these species has rather long fibres, approximately 1–2 mm. in length (table 1), solitary or in small groups (fig. 14), or tangential lines (fig. 5–10), widely spaced among the surrounding ground tissue of the phloem, or forming a compact ground mass of fibres separated by only one or two rows of parenchyma, sieve tissue or crystalliferous parenchyma (fig. 15.A), or in elliptical

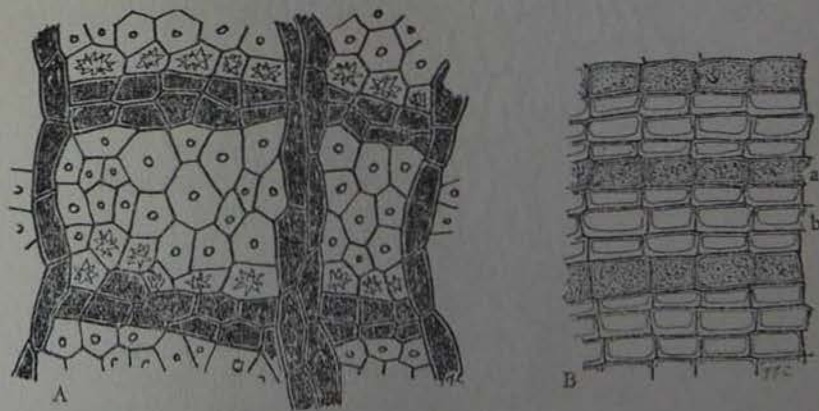

Fig. 15. *Eugenia albidiramea* Merr. A. "B" type phloem showing closely spaced compact fibrous phloem with crystalliferous strands containing druses on the adaxial side. × 400.—B. Phellem showing tanniniferous suberised cells *a* alternating with bands of lightly thickened lignified cells *b*. × 400.

bundles with large cross-sectioned fibres (fig. 16, 21). The crystalliferous tissue contains druses in most species, less frequent rhomboidal crystals, twinned crystals or many small multiple crystal masses. The crystalliferous tissue abuts adaxially on the fibre masses. In the older parts of the phloem, the phloem cells and parenchyma usually become heavily sclerosed, especially on the adaxial side (fig. 11.B). In some species this sclerosis extends throughout the whole of the phloem (fig. 20). The phellem consists most frequently of alternating lignified and suberised cell layers with little thickening (fig. 11.B), less commonly of up to 4 slightly

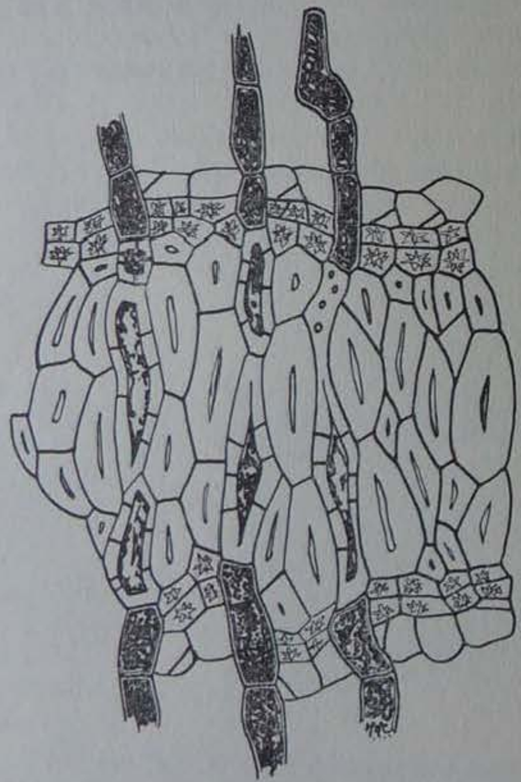

Fig. 16. *Syzygium rubiginosum* Merr. & Perry. "B" type phloem with large fibres and crystalliferous strands containing druses on both sides of the fibre bundles. × 400.

thickened lignified cells alternating with the suberised rows (fig. 15.B). A phelloderm of 1–6 cells with strong adaxial thickening (fig. 11.B) is usually present; stone cells with large tangential diameter occur in the outer phloem. The main distinguishing features of the two groups may be summed up as follows:

Eugenia "A": Fibres less than 1 mm. long or "columnar" stone cells; occasionally scattered and in groups, more often in widely spaced bundles crossing several rays tangentially, or in tangential bands; crystals twinned, rarely multiple and never druses; peripheral parenchyma cells thin-walled except for scattered groups of enlarged stone cells; phelloderm absent or unthickened; phellem commonly of uniseriate rows of cells with suberised walls alternating with bands 1–6 cells wide of heavily sclerosed cells.

Eugenia "B," including *Syzygium:* Fibres 1–2 mm. long, solitary or in scattered groups or bundles, sometimes closely spaced, crystals mainly druses, but sometimes solitary or in multiples; peripheral parenchyma cells and cells of phelloderm usually heavily sclerosed, especially on the adaxial walls; phellem usually of alternating rows of lignified and suberised cells without much heavy thickening of the lignified cells.

Three species of *Acmena* and one of *Cleistocalyx* were examined. They were very similar to *Eugenia* "B," especially to those species which have solitary or multiple crystals; no druses were observed.

Discussion

It would appear from this investigation that in general the features shown by the bark of the four genera, *Eugenia*, *Syzygium*, *Acmena* and *Cleistocalyx*, add to the evidence for a classsification such as that proposed by Ingle and Dadswell (1953) which was based on the wood anatomy. Examination of the list of species given on pages 2 and 3 of that work shows that all except two of the species listed as *Eugenia* "A" occur on the American continent or in the West Indies. The two exceptions are *Eugenia rariflora* from

Fiji and *Eugenia whytei* from Liberia, both of which show the characteristics of *Eugenia* "A." Examination of the wood of *E. rariflora* confirms this.

In a paper on *Jossinia reinwardtiana* Blume, Merrill (1950) gives *E. rariflora* as synonymous with *Jossinia reinwardtiana* and cites Diels (1921) as authority for separating *Jossinia* from *Eugenia* and relating it with *Acmena* and *Cleistocalyx* as worthy of generic rank. Both the bark and wood structure entirely support this suggestion. As the genus *Jossinia* covers tropical Africa as well as countries further east (Merrill, 1950), it is possible that *E. whytei* may belong to *Jossinia* rather than to *Eugenia*.

Ingle and Dadswell (1953) distinguish between the lengths of the wood fibres of the two groups, those of *Eugenia* "A" lying between 800μ and 1270μ, while those of *Eugenia* "B" are between 1100μ and 1900μ. A similar difference is to be found in the lengths of the phloem fibres, the majority of *Eugenia* "A" (excluding those with "columnar" stone cells) lying between 520μ and 997μ, and those for *Eugenia* "B" lying between 960μ and 1830μ, between 1230μ and 1660μ for *Acmena* and 1500μ for *Cleistocalyx*. This is shown in table 1. In addition to the importance of the bark as an aid to the classification of these involved genera, there are certain features of the barks which are of interest in themselves, even though they may not be of any taxonomic or diagnostic value.

Among the species of *Eugenia* "A" the main interest centers on the group of species with "columnar" stone cells. In these species there appear to be no true fibres, i.e., cells which are longer than the initials from which they have been formed. The fibrous elements in these species have all undergone thickening after the daughter cells of their cambium initials have subdivided at least once. The narrower elements of "fibrous" shape have undergone little or no radial or tangential expansion (fig. 13.B) and are usually solitary, occurring as single fibrous elements isolated vertically as well as radially and tangentially by other parenchyma cells. The "columnar" strands, on the other hand,

Table 1. Mean Lengths of Phloem Fibres in *Eugenia* (*sens. lat.*)

GENERA EXAMINED	RANGE OF LENGTHS IN μ 500–600	600–700	700–800	800–900	900–1000	1000–1100	1100–1200	1200–1300	1300–1400	1400–1500	1500–1600	1600–1700	1700–1800	1800+	NUMBER OF SPECIES EXAMINED
Eugenia "A"	3	2	6	7	1	—	—	1	—	—	—	—	—	—	20
Eugenia "B"	—	—	—	—	1	5	4	8	5	3	8	3	3	2	42
Acmena	—	—	—	—	—	—	—	2	—	1	—	1	—	—	4
Cleistocalyx	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1

are always found as whole strands, the cells of which have become enlarged radially and tangentially, and every cell of the strand has undergone sclerosis (fig. 13.A). Furthermore, superimposed strands show this structure through long vertical distances in the phloem. Stone cells on the other hand usually occur in "nests" or pockets of cells in the outer phloem, only a few cells of adjacent strands being sclerosed.

In *Eugenia* "B" the main feature of interest centers on the crystal strands which contain druses in all but 15 of the 47 species of *Eugenia* and *Syzygium* examined. In these 15 species the crystals are solitary or multiple, in the latter case a single large crystal is usually accompanied by a large number of very small ones. Sometimes the effect produced is very similar to that of a druse, but their true nature is clearly seen in macerated material, where the aggregations usually disintegrate, whereas the druses remain intact. In only two species, *Eugenia cryptophlebia* and *helferi* from eastern Australia, were solitary and multiple crystals and druses observed together. In the three *Acmena* species examined and in *Cleistocalyx gustavioides*, only solitary and multiple crystals were observed. In *Syzygium* druses were present except in *S. multipetalum*.

Fibre diameter is another feature that is variable within the different groups. In both "A" and "B," both large and small diameter fibres occur, but in *Eugenia* "A" the larger diameters predominate, whereas in *Eugenia* "B" the fibres are all of small diameter except in *Eugenia grandis* (fig. 21) and *everetii* (fig. 22). In the latter species bundles of large and small fibres are intermingled.

There is also considerable difference in the amount of lignification of the fibre walls. Throughout *Eugenia* "A" the fibres and columnar cells show a strong lignification even in the cambial region, but in *Eugenia* "B" lignification is often delayed until the fibres are quite mature. In sections stained in safranin and light green there is often a progressive colour change from green fibres near the cambium to red ones at the periphery.

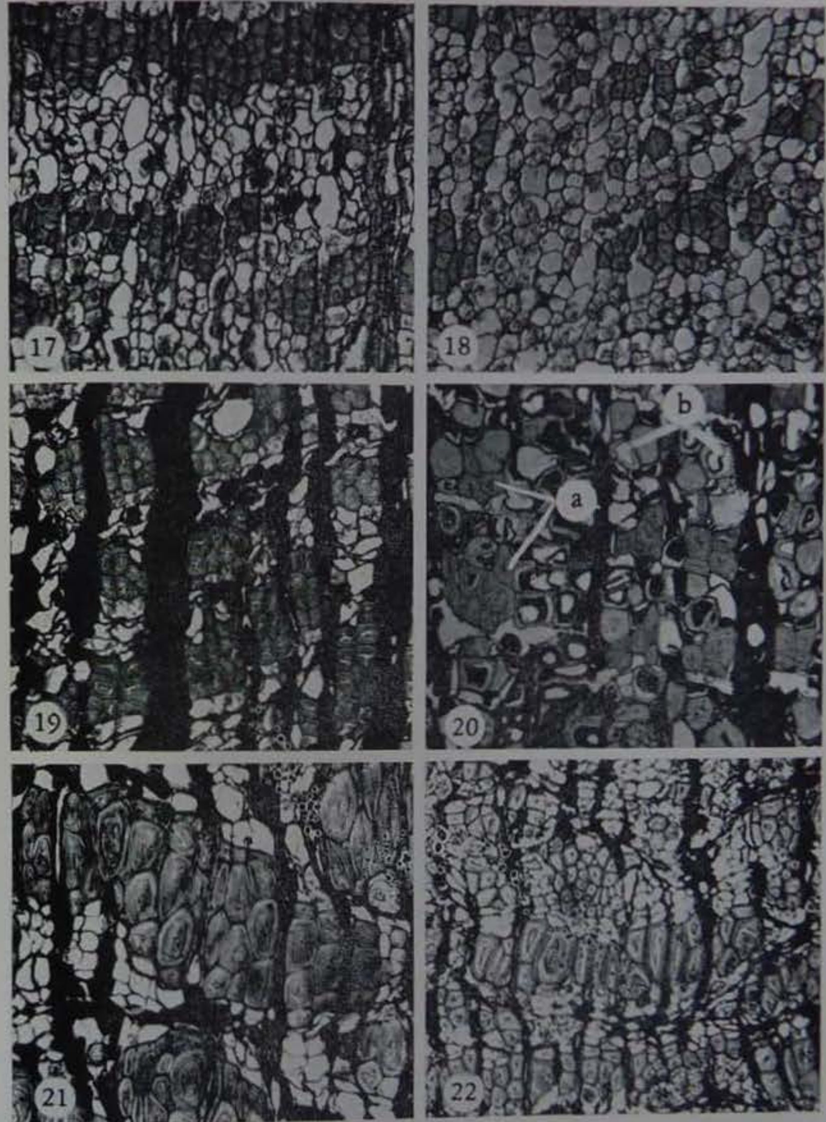

Fig. 17–22. Cross sections of the phloem of *Eugenia* "B" and *Syzygium* × 85.—Fig. 17. *E. moorei* F. Muell.—Fig. 18. *E. oleosa* F. Muell.—Fig. 19. *E. kuranda* F. M. Bail.—Fig. 20. *Syzygium onesimum* Merr. & Perry. (a) fibres, (b) sclerosed parenchyma.—Fig. 21. *E. grandis* Wight.—Fig. 22. *E. everetii* C. B. Rob.

Two species, one from each group, show certain features more characteristic of the other group. For example, *Eugenia florida* has small diameter scattered fibres which are similar in length to those of *Eugenia* "B" (avg. 1.287 mm. and 1.215 mm. for 50 fibres in each of two samples). In other features it is similar to the rest of *Eugenia* "A," having thin-walled parenchyma throughout the whole width of the phloem, no phelloderm and heavily sclerosed bands of lignified phellem cells; the crystals were twinned and multiple crystals, no druses were observed.

A group of species comprising *Eugenia duthieana, glauca* var. *pseudoglauca, grandis* (fig. 21), *palawanensis, rubiginosum* and *valdevenosa* differs from the majority of species of *Eugenia* "B" in having oval bundles of large diameter fibres in place of the closer or scattered arrangement of the rest of the group; in length the fibres lie within the expected length range of *Eugenia* "B"; the crystals are all druses, but surround the bundles instead of being only on the adaxial side. In other respects and in the details of the periderm these species are typical of *Eugenia* "B."

Summary

The bark of 82 species of *Acmena, Cleistocalyx* and *Eugenia (sens. lat.)* has been examined. The material came from both New and Old Worlds. The distinction between *Eugenia* "A" and *Eugenia* "B" already noted by Ingle and Dadswell (1953) on the basis of the wood structure, is upheld by certain features of the bark structure and adds weight to the theory already advanced that the *Eugenias* of the Old World should be grouped separately from those of the New World.

Some unusual details of the fibres of some of the species of *Eugenia* "A" are described and discussed.

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GUTTIFERAE FROM MIDDLE AMERICA

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The Guttiferae in Middle America are not very numerous, even so, generic delimitation is not always easy. The genera *Tovomita*, *Chrysochlamys* and *Tovomitopsis* are closely allied and a better understanding of the group may show them to be a single genus. The characters relied upon for generic delimitation are subject to variation. *Tovomita macrophylla*, described here, breaks further the lines of separation in these genera and as tropical American material accumulates more intermediates may be expected.

Chrysochlamys eclipes L. Wms. sp. nov.—Arbor parva usque ad 3 m. alta. Folia subcoriacea, oblongo-ovata vel late lanceolata, breviter acuminata; nervis lateralibus utroque latere 10–12. Inflorescentia subpaniculiformis vel subcorymbiformis. Sepala 5, carnosa, cochlearia, late ovata vel suborbicularia. Petala 5, carnosa, subcochlearia, ovata. Capsula carnosa, subpyriformis.

Small dioecious or polygamodioecious trees or shrubs 3–5 m. tall. Leaves subcoriaceous, opposite, equal in size, oblong-ovate to broadly oblanceolate, abruptly short acuminate, base not decurrent on the petiole, 15–25 cm. long and 7–10 cm. broad, with 10–12 pairs of subopposite lateral nerves. Inflorescence loose, terminal, subpaniculate or subcorymbose, to about 15 cm. long, pistillate and staminate inflorescences similar but the staminate more floriferous. Sepals 5, fleshy, cochlear, 2 outer sepals about 2.5–3 mm. long and nearly as broad, broadly ovate, acute; inner sepals 3–3.5 mm. long, suborbicular, one deeply retuse. Petals 5, fleshy, subcochlear, ovate, 4–5 mm. long and 2.5–3 mm. broad. Fruit subpyriform, to about 1.5 cm. long. Stigmas 5, sessile.

PANAMA: CANAL ZONE, Barro Colorado Island, corolla whitish, shrub 10 feet (tall), in moist forest, January 17, 1924, *Standley 31459* (TYPE US); CANAL ZONE, hills north of Frijoles, tree 15 feet (tall), wet forest, December 19, 1923, *Standley 27445* (US).

This species is closely related to *Chrysoclamys standleyana* from which it is distinguished by the more diffuse subpaniculate or subcorymbiform inflorescence. The leaves are longer petiolate than those of *C. standleyana* and terminate more abruptly on the petiole; they are also more coriaceous. The fruits described are from the second specimen cited (*Standley 27445*).

CHRYSOCHLAMYS STANDLEYANA L. Wms. nom. nov.

Chrysochlamys pauciflora Standl. in Ceiba 3: 214. 1953, non Steyerm. 1952.

A species described from Panama. The type specimen, as mentioned by Paul C. Standley, is not as complete as might be desired. It is related to the species described above. The type is in the Chicago Natural History Museum; a photograph is in the United States National Herbarium.

Tovomita macrophylla L. Wms. sp. nov.—Arbor terrestris usque ad 8 m. alta. Folia elliptica vel ovalia, acuta vel acuminata, coriacea, breviter petiolata; nervis lateralibus utroque 15–18. Inflorescentia terminalis, paniculiformis, densiflora. Sepala 3, cochlearia, suborbicularia. Petala 5–7, imbricata, ovalia, ovata vel obovata, obtusa, subaequalia. Capsula carnosa. Stigmata 5.

Small terrestrial trees up to 8 meters tall, probably dioecious or possibly polygamodioecious. Leaves opposite, equal in size, broadly elliptic to oval, acute or short acuminate, 25–40 cm. long and 11–17 cm. broad, coriaceous, with 15–18 pairs of prominent lateral nerves and a network of small secondary nerves; petiole thick, sulcate above, 2.5–4 cm. long. Inflorescence a dense, terminal, somewhat corymbiform panicle of yellow flowers; bracts subtending the divisions of the inflorescence cochlear, ovate, acute, 5–7 mm. long and nearly as broad, bracts under the ultimate division (the flower) similar, smaller, usually paired, point of dehiscence of the flower is immediately above these bracts. Male flowers to 3 cm. broad when expanded; sepals 3,

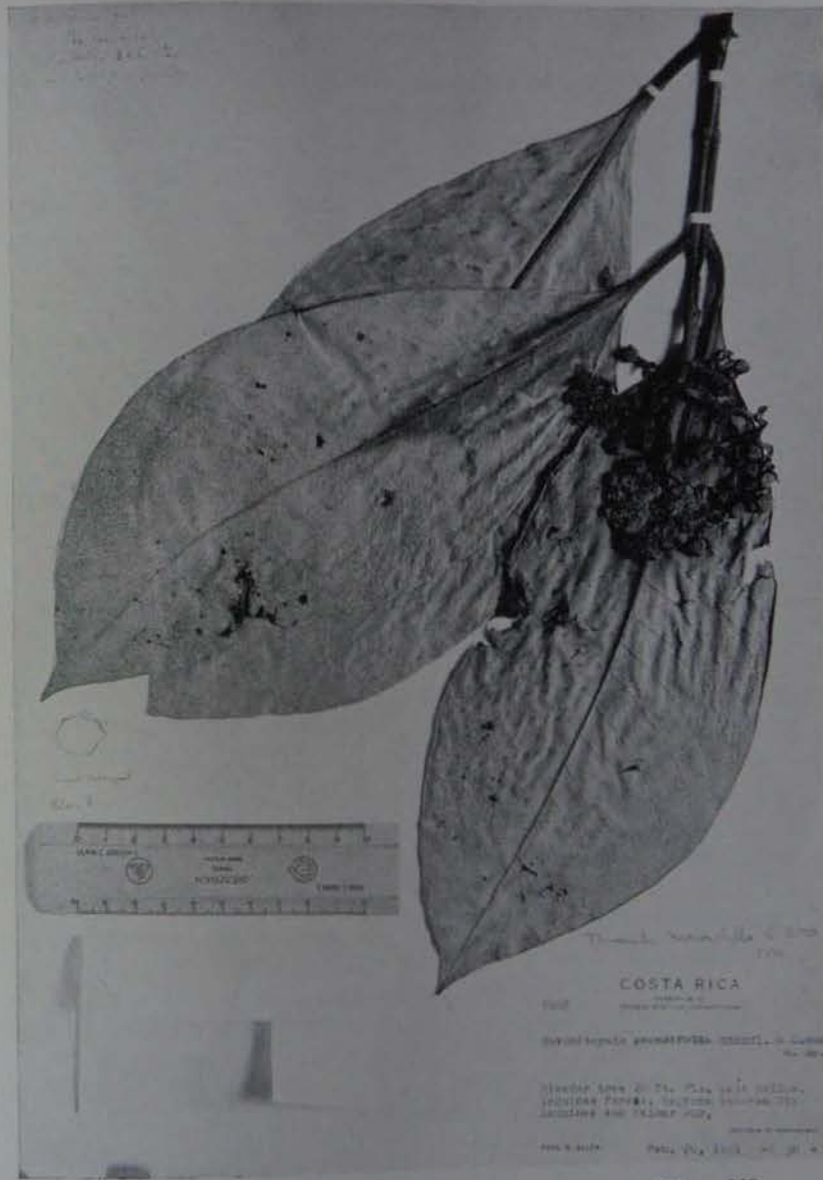

Fig. 1. *Tovomita macrophylla* L. Wms. sp. nov. Type US.

cochlear, suborbicular, fleshy-coriaceous, 5–9 mm. long and as broad, the inner two sepals nearly paired and subequal, the outer sepal smaller than the others and opposite the greater opening of the other two, broader than long; petals 5–7, imbricated, oval to ovate or obovate, obtuse, unequal to nearly equal in size, with many nearly parallel raised nerves, 7–12 mm. long and 5–8 mm. broad; stamens numerous, 5–7 mm. long, the filaments fleshy, free nearly to their bases, the anthers 2-celled, introrse, about 1.5 mm. long, smaller in diameter than the filament. Female flowers not known; fruit a fleshy capsule, red, ellipsoidal, strongly five-angled or -winged, 4–5 cm. long; stigmas 5, free, subsessile; each cell of the ovary one or usually 2-seeded; the seeds semilunate, subcylindrical, about 1.5 cm. long and 0.4–0.5 cm. in diameter, apparently with a fleshy aril-like covering, at least on the adaxial surface.

COSTA RICA: Province of Puntarenas, occasional in Esquinas forest, region between Río Esquinas and Palmar Sur de Osa, alt. 30 m., tree 20 feet tall, fruits red, January 16, 1951, *Allen 5771;* same locality, alt. 30 m., slender tree 20 feet, flowers pale yellow, February 26, 1951, *P. H. Allen 5968* (TYPE US; duplicates in Herb. Escuela Agrícola Panamericana and F. Fig. 1).

Tovomita macrophylla is not closely allied to any other described species of the genus known from Central or South America; nor is it allied to any species of *Clusia* or *Chrysochlamys.*

The number of sepals in this species is unusual; the outer one seems certainly to be a part of the floral envelope. The genus *Tovomita* (here considered to include *Tovomitopsis)* usually has two sepals, or four sepals in two pairs; each cell of the ovary should have but one ovule. The genus *Clusia* has four or six sepals and each cell of the ovary usually has two or more ovules. The genus *Chrysochlamys* has 5 sepals, with the outer two smaller; the ovary with one ovule in each cell. *Tovomita macrophylla* with three sepals and usually two seeds in the cells of the ovary would seem to belong to neither *Tovomita* nor *Clusia.*

The tropical American genera of the Guttiferae are badly in need of revision. The genus *Clusia* would seem to contain many elements or subgenera not more closely related one to another than are some of the allied genera which have been segregated one from another.

TOVOMITA NICARAGUENSIS (Oerst.) L. Wms. comb. nov.

Tovomitopsis nicaraguensis Oerst. in Ann. Sci. Nat. IV. Bot. 14: 266. 1846.

Chrysochlamys nicaraguensis Hemsl. in Biol. Cent. Am. Bot. 1: 87. 1879.

Tovomita nicaraguensis is assumed to be the commonest species of *Tovomita* in Middle America.

WOOD ANATOMY OF HELENIEAE (COMPOSITAE)

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INTRODUCTION

The Helenieae are a group of genera characteristic of the Southwestern United States and adjacent Mexico. They have been regarded as a definable group, although various taxonomists have implied that the genera are a series of groups best regarded as outliers of Heliantheae. If genera of Helenieae are to be included in Heliantheae, we must have much more documented knowledge before sound suggestions concerning relationships of the genera can be attempted. The present study may be considered an effort to contribute such data, as well as to illuminate the problems in interpretation which are brought forth by the variation patterns in wood anatomy of Helenieae.

Although not unique among groups of Compositae in the diversity of habitats which they occupy, Helenieae are especially interesting in this respect. Woody perennials occupy arid area sites in the western deserts and Great Basin; such genera include *Chrysactinia, Clappia, Dyssodia, Laphamia, Porophyllum,* and *Psilostrophe. Eriophyllum confertiflorum* and *E. lanatum* are characteristic of the California chaparral. *Baeria macrantha* occurs along maritime northern California, while *Eriophyllum staechadifolium* grows along the seacoast of central California. Three species, *Eriophyllum Nevinii* of the Channel Islands and *Perityle incana* and *Baeriopsis guadalupensis* of Guadalupe Island, are exclusively insular and are found near the coasts of these islands. *Flaveria linearis* occurs in Gulf Coast areas of the United States and Mexico.

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[1]This research was supported by a grant from the National Science Foundation, NSFG-5428. The writer wishes to express sincerest appreciation for this aid, which is permitting completion of studies on wood anatomy of Compositae and related families.

These habitats are strongly related to growth form among the woody perennial species of Helenieae. The desert or dry-country perennials are fruticose or suffruticose, and could all be termed "caudex-perennials" because they have a short woody stem which initiates new stems each year. *Eriophyllum lanatum* and *E. confertiflorum*, from somewhat moister regions, have this habit also, although *E. confertiflorum* may develop a woody stem up to an inch in diameter. *Flaveria linearis* is a small shrub. *Baeriopsis guadalupensis* is a diminutive shrub with succulent leaves, probably influenced by the salt spray sweeping the cliffs on Guadalupe Island where it grows. *Baeria macrantha* is a stoloniferous perennial, the older portions of whose stems develop a limited amount of secondary xylem. In Helenieae, the only true shrubs with indefinite secondary growth of stems are *Eriophyllum Nevinii*, *E. staechadifolium*, and *Perityle incana*. These species form shrubs with basal stem diameter up to two or three inches.

The growth forms of perennial Helenieae thus seem closely keyed to their respective climatic situations. The continued growth of insular and coastal perennials is probably linked with the relatively even temperature of these regions throughout the year, and possibly with the availability of moisture from fogs during the otherwise dry summer season. Perennial Helenieae in inland regions are probably adjusted to dry, hot summers by means of the "caudex-perennial" habit. These variations in habit and habitat are important in interpreting the variation pattern which occurs in wood anatomy of the group, for they seem to have exercised a strong influence on wood anatomy of particular species. Because of the pattern of specializations within Helenieae, it is difficult to select primitive or advanced genera either on the basis of gross morphology or of wood anatomy. The gamut between the most primitive and the most advanced is very small. Thus, although woody Helenieae are neither numerous nor important woody plants, the phylogenetic problems they pose are of considerable significance. Additional genera, such as *Hymenopappus*, *Chaenactis*, and *Baileya*, might have widened the scope of

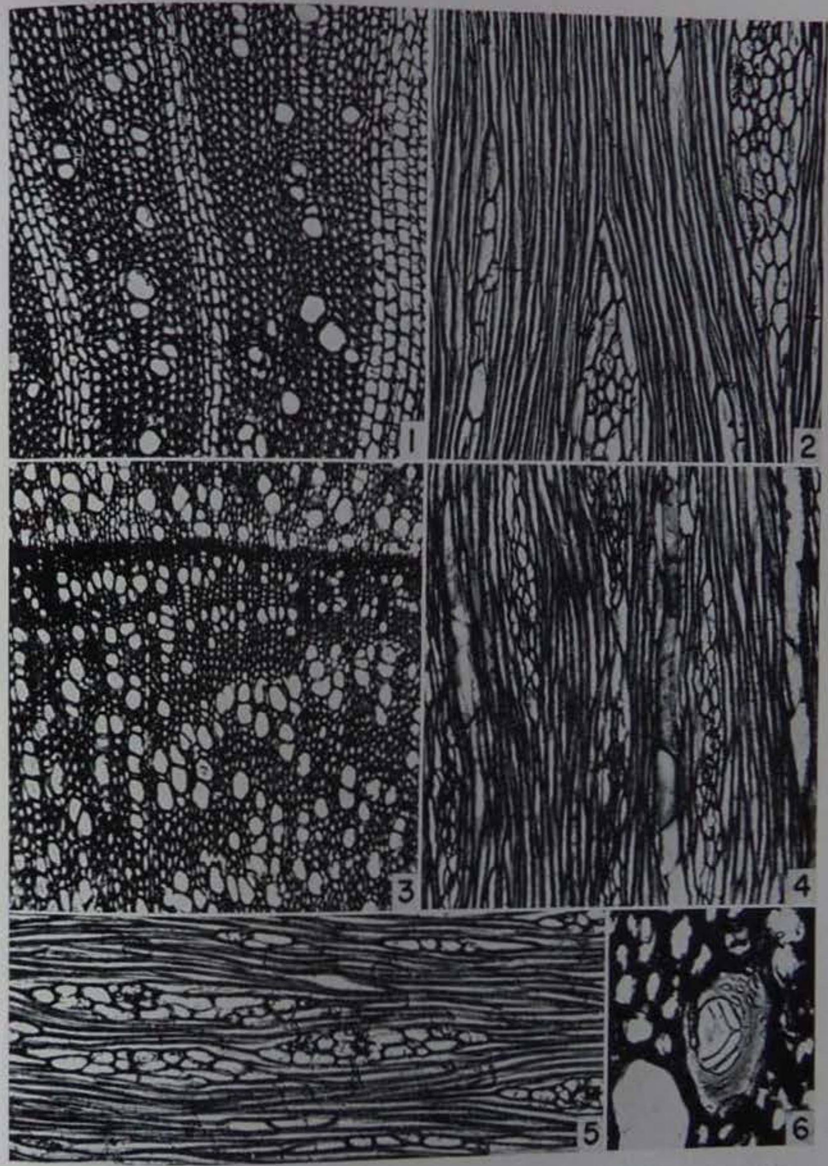

Fig. 1–6.—Fig. 1–2. *Perityle incana*.—Fig. 1. Transection, showing thin-walled fibers, lack of ring formation. × 80.—Fig. 2. Tangential section, showing type of rays. × 164.—Fig. 3. *Eriophyllum confertiflorum*. Transection, to illustrate rings, vessel grouping. × 64.—Fig. 4. *Eriophyllum staechadifolium*, tangential section, showing thin-walled nature of fibers, ray cells. × 77.—Fig. 5. *Eriophyllum Nevinii*. Tangential section to show multiseriate and uniseriate rays. × 77.—Fig. 6. *Eriophyllum confertiflorum*. Multiperforate perforation plate from transection. × 385.

this study if the writer had been willing to use samples from basal portions of these relatively short-lived plants. Such portions would probably not, however, have provided material truly comparable to that of the species selected, which comprise the most woody taxa in the tribe.

Materials and Acknowledgments

The majority of wood samples utilized in this study were collected by the writer or his colleagues in the field. In each case, a voucher specimen was prepared. The writer is indebted to the following individuals for materials of this nature: Mr. Edward K. Balls, Dr. Robert Ornduff, Dr. William L. Stern, and Dr. Stephen S. Tillett. Samples of wood of *Eriophyllum Nevinii* and *Psilostrophe Cooperi*, documented by the specimens indicated, were obtained from cultivated plants in the Rancho Santa Ana Botanic Garden, and the writer wishes to express his thanks to this institution both for these samples and for samples removed from herbarium specimens. These latter specimens, as well as specimens documenting field-collected samples, are all located in the Rancho Santa Ana Botanic Garden Herbarium. Special thanks are due Dr. Reid Moran of the San Diego Natural History Museum and appreciation is extended to the Scripps Institute of Oceanography for making possible the writer's visit to Guadalupe Island. The writer wishes to offer sincere gratitude to Mr. Alfred G. Diboll, who sectioned the woods used in this study. Finally, Dr. I. W. Bailey and Dr. William L. Stern have been of great service by reading the manuscript and offering many helpful suggestions.

Methods

All samples were taken from the most basal parts available of each species. The samples were softened in hydrofluoric acid and sectioned on a sliding microtome, or, in the case of some smaller samples, embedded in paraffin and sectioned on a rotary microtome. Safranin was used as a stain for woods sectioned on the sliding microtome, and staining of these sections was often intensified by the use of a tannic acid-ferric chloride mordant. Paraffin sections were stained with safranin and fast green following the use of this mordant. Slides upon which this study were based have been prepared in sets, and one set has been distributed to the Yale School of Forestry. In the accompanying photographs, all wood transections are oriented so that the most recently formed elements are above.

Anatomical Descriptions

Table 1 is a summary of the characters deemed most useful in comparing woods of Helenieae. Features which occur in only one or two species, or which are not suitable for summarization in the table, are described in the text. Additional features would have been added if they were significant in describing the variation pattern of helenioid woods. The reader will note that the characters used here are not those which have been found useful in surveys of dicotyledons as a whole. For example, the angle of the end wall may vary greatly within a single section, so that a generalization for such a species would be useless.

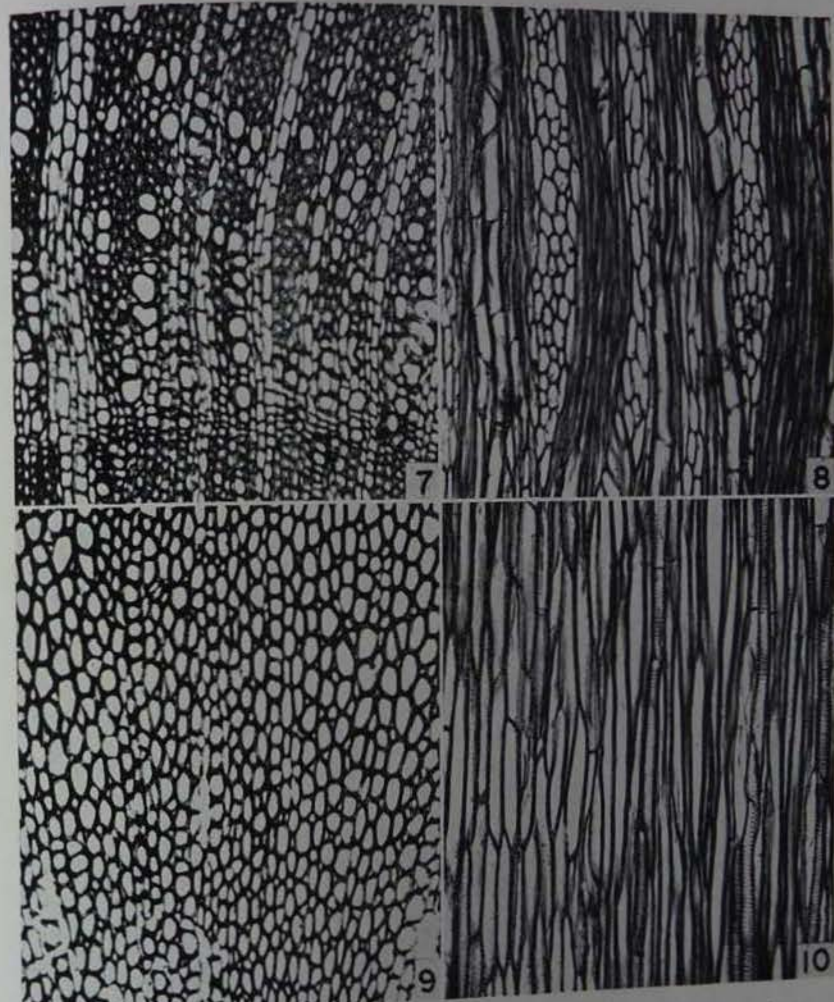

Fig. 7–10.—Fig. 7–8. *Baeriopsis guadalupensis.*—Fig. 7. Transection, showing a growth ring. × 80.—Fig. 8. Tangential section. × 80.—Fig. 9–10. *Baeria macrantha* var. *macrantha.*—Fig. 9. Transection, showing the virtually identical appearance of vessels and fibers as seen in this section; note rayless condition. × 160.—Fig. 10. Tangential section, showing portions of several vessels and (lower left) storied fibers. × 160.

Explanation of symbols in table 1:

c = cork
f = libriform fibers
g = grooves interconnecting two or more pit apertures
mv = more numerous vessels than at end of ring, concomitant with fewer fibers than at end of ring
nv = narrow vessels
p = axial parenchyma
s = striae (unrelated to pits) on vessel walls
tf = thin-walled fibers
ur = uniseriate rays
v = vessels
vt = vascular tracheids
wv = wide vessels
+ = presence of character
— = presence of character to a limited extent
blank space = total absence of character

GROWTH RINGS; RING POROSITY

In table 1, column 7 shows that most of the Helenieae studied possess growth rings. Stems of *Baeria macrantha* have perhaps only a single season's accumulation of secondary xylem before death, and may not show growth rings on this account. In species with growth rings, formation might be related more to water availability than to any other factor. This may account for the type of elements produced. Because of differences in types of seasonal progression in rainfall and temperature, growth rings in the various species are probably not truly comparable with each other, however, and this may account for the fact that the predominant elements at the beginning of a ring are not alike from species to species. In all instances in which growth rings are present, species may be regarded either as ring-porous or as having a ring-porous tendency. This is true because the variation in vessel diameter or the distribution of vessels, which makes for ring porosity, is associated with the presence of growth rings.

Table 1. Characters of Wood Anatomy in Helenieae

SPECIES	COLLECTION	DIAMETER WIDEST VESSEL, μ	DIAMETER VESSELS, AVERAGE, μ	LENGTH VESSEL ELEMENTS, AVERAGE, μ	VESSELS PER GROUP, AVERAGE	HELICAL SCULPTURE ON VESSEL WALLS	VASCULAR TRACHEIDS	ELEMENTS DISTINGUISHING EARLY WOOD IN RINGS	STORIED ELEMENTS	MULTISERIATE RAY HEIGHT, AVERAGE, MM.	UNISERIATE RAY HEIGHT, AVERAGE, μ	RAY CELLS ISODIAMETRIC TO PROCUMBENT	RAY CELLS ISODIAMETRIC TO ERECT
Baeria macrantha (Gray) Gray var. *macrantha*	Ornduff 4709	24	19	234	5.33				f				
Baeria macrantha var. *pauciaristata* Gray	Ornduff 4140	26	23	228	3.85								
Baeriopsis guadalupensis Howell	Carlquist 468	38	29	118	3.05			p,tf,nv		.55	90	—	+
Chrysactinia mexicana Gray	Pringle 23-IV-1885	50	20	159	1±vt	s	+	wv	v,vt ±f,ur	.36	113		+
Clappia suaedifolia Gray	Norris 14-VI-1952	68	40	110	2.60	s	—	wv		.54		+	
Dyssodia Cooperi Gray	Balls & Everett 23209	76	39	151	2.24	g	—	wv					
Eriophyllum confertiflorum (DC.) Gray	Carlquist 489	73	39	121	3.68	g		nv,mv		.43	99	+	
Eriophyllum Nevinii Gray	Balls 20990	79	37	231	2.13	g				.52	120		+
Eriophyllum staechadifolium Lag.	Tillett 752	86	45	166	2.23	g				.56	117	+	+
Flaveria linearis Lag.	Stern & Chambers 260	51	33	180	1.70					1.5			+
Laphamia megacephala Wats.	Roos & Roos 6217	85	51	115	3.85	g	+	c		.88		+	+
Perityle incana Gray	Carlquist 440	78	47	278	1.53					1.06		+	+
Porophyllum gracile Benth.	Wolf 3052	65	39	156	2.10	g	—	mv,p					
Psilostrophe Cooperi (Gray) Greene	Campbell 14001	63	29	125	2.73	g	—	p,nv, tf		.91	49	+	—
Psilostrophe gnaphalodes DC.	Taylor 3-V-1944	66	34	133	7.73	g		nv,tf		.71	70		+

Experimental evidence on production of growth rings in Helenieae would be highly desirable, so that one could estimate the modifiability of xylem in this respect. The relatively uniform conditions for cultivation of *Eriophyllum Nevinii* might have caused the lack of rings in this sample. However, such a possibility is certainly ruled out in the case of *Perityle incana*, in which the highly seasonal (with respect to rainfall) climate of Guadalupe Island produced no perceptible growth rings. At the opposite extreme is *Laphamia megacephala*, in which each year's accumulation of secondary xylem is separated from the next by a band of thin-walled cork cells (fig. 22, below), resulting in a transectional appearance like that of some anomalous stems.

VESSELS

Diameter.—In table 1, a figure is given both for the largest vessel present and for the average diameter of a vessel. Both figures include the vessel wall. The two figures parallel each other, so that species with rather wide vessels reflect this tendency in both figures. However, the presence of numerous small vessels or vascular tracheids will tend to decrease the average figure. Because a species with vascular tracheids may also possess wide vessels, the writer does not consider that the average necessarily gives an accurate picture of vessel size. More elaborate statistical treatment does not seem to be justified, however, because the writer questions whether the samples of this study—like those of many studies in wood anatomy—are truly comparable statistically.

Vessels of *Baeria macrantha* are notable for their very narrow diameter. This is illustrated in fig. 9–10. Because vessels in this species are no wider than fibers, their identification in transection depended on a slight difference in staining which does not reproduce photographically in fig. 9.

The shape of vessels, as seen in transection, tends to be rounded. Somewhat angular vessels are present in some species, however, such as *Chrysactinia mexicana* (fig. 13). This condition is in no way related to primitively angular

vessels in unspecialized dicot woods. This fact has been acknowledged by Bailey (1957) for certain advanced families such as Compositae.

Element length.—As Bailey (1957) also notes, the presence of relatively long vessel elements does not necessarily suggest primitiveness within a family such as Compositae. Relatively long vessel elements occur in *Baeria macrantha* (fig. 10). This fact may be related to vertical elongation of cambial initials. Such elongation has resulted, in the case of ray initials, in the elimination of rays in this species. Even if this is a valid explanation in this species, the relatively long vessel elements of *Perityle incana* and *Eriophyllum Nevinii* must be explained differently. These two species, which have the best-developed woody stems in Helenieae, may have long vessel elements either on account of such woody development or because their insular habitat induces less specialization with regard to climate. These two species, as well as *E. staechadifolium*, also form fewer vessels per unit area of transection (fig. 1) than do the other Helenieae studied here. In this regard, it is interesting to note that the species of dry or desert habitats all have greater density of vessels and an average vessel-element length of less than 160μ. Although *Baeriopsis guadalupensis* (which has relatively short vessel elements and many vessels per unit area) grows on the same island as *Perityle incana*, the former must be regarded as a xerophyte or halophyte on account of the sunny cliff sites, bathed in salt spray, where it grows. *Perityle incana* occupies moister, shadier sites in canyons. Thus, the figure for average vessel-element length in Helenieae shows that within this tribe, element length bears a close relation to growth form or habitat and does not serve as an indicator of overall phylogenetic advancement.

Vascular tracheids.—The presence of vascular tracheids is a function of narrowing of vessels to the point where they lose perforation plates. Thus, a species in which vascular tracheids are present also contains a wide range of vessel widths from the maximum width to approximately the width of libriform fibers, or less. In Heleniceae, vascular tracheids appear to be characteristic of species from dry or desert habitats. On the basis of the writer's work (1957, 1958a) with other tribes of Compositae, a correlation between dry habitat and vascular tracheids would appear to be justified, for all species of those tribes with vascular tracheids either grow in arid regions or form vascular tracheids at the end of a growing season, possibly in response to decreasing water-availability. Within Helenieae, narrow vessels and vascular tracheids are most prominently represented in *Chrysactinia mexicana* (fig. 13, 14) and *Laphamia megacephala* (fig. 22). In these species, vascular tracheids and narrow vessels occur in patches in the secondary xylem. The distribution of these does not appear to be correlated with a seasonal pattern. Such bands of vascular tracheids and narrow vessels have been reported for other Compositae, such as *Flourensia cernua* and *Dubautia Menziesii* (Carlquist, 1958a).

Perforation plates.—Simple perforation plates, round to slightly oval, are characteristic of all Helenieae. In *Eriophyllum confertiflorum* (fig. 6), however, occasional multiperforate perforation plates are formed. Such plates have irregularly-placed bars, occasionally forked. Similar perforation plates, with more numerous forked bars, have been reported as occasional in *Flaveria linearis* (Carlquist, 1958b). Multiperforate plates of this sort are probably occasional in many Compositae, and have been described for several Heliantheae (Carlquist, 1958a).

Pitting.—Intervascular pitting consists of alternate pits with slit-like, usually obliquely-oriented apertures. In *Laphamia megacephala* and *Psilostrophe Cooperi*, especially on narrower vessels, certain vessel walls possess scalariform pitting. As in Mutisieae and Heliantheae, this cannot be interpreted as a primitive condition, but rather is a specialization, whatever the cause may be. Neither exceptionally large nor small pits were observed in any of the Helenieae studied, and diameter of pit cavities is typically about 5μ.

As table 1 shows, there are many species in which grooves interconnect two or more (usually two) pit apertures ad-

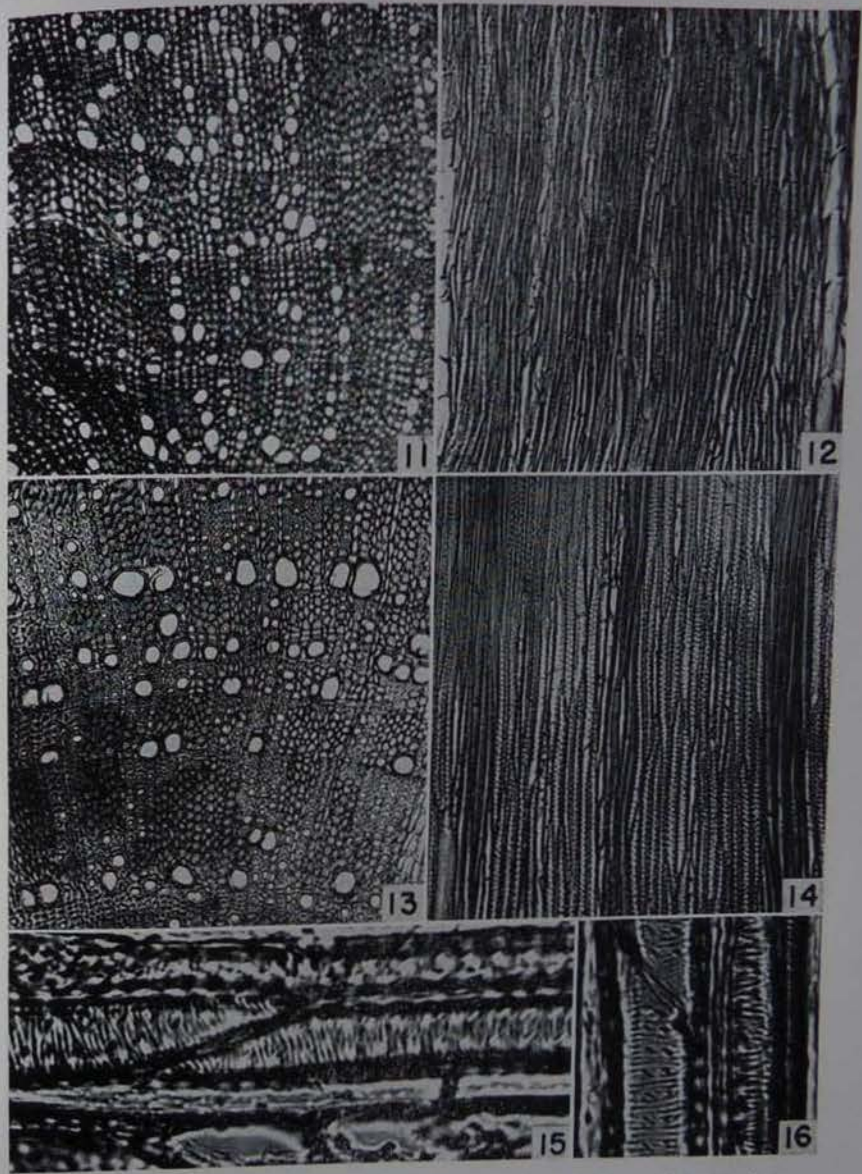

Fig. 11–16.—Fig. 11–12. *Porophyllum gracile.*—Fig. 11. Transection. × 67.—Fig. 12. Tangential section; note rayless condition in both sections. × 67.—Fig. 13–16. *Chrysactinia mexicana.*—Fig. 13. Transection. Zones of fibers appear slightly darker than the vessels and vascular tracheids. × 111.—Fig. 14. Tangential section, showing narrow vessels, vascular tracheids, and the near-rayless condition; a ray is present to the left of a strip of fibers (center). × 148.—Fig. 15–16. Vessels from tangential section to show helical sculpture; ray cells shown (below) in fig. 15. × 830.

jacent in a helix. A prominent instance of this condition was illustrated by the writer in *Pluchea odorata* (Carlquist, 1958b). Vessel walls of *Clappia suaedifolia* possess numerous fine striae, usually on walls with few pits adjacent to parenchyma cells, in occasional vessels. The striae on walls of almost all vessels and vascular tracheids in *Chrysactinia mexicana* (fig. 15–16) are much coarser. They are present on almost all surfaces of an element. These thickenings form helices much more numerous than the number of helices in which pits are arranged. Moreover (fig. 16), the pit apertures do not run confluent with, or parallel to, the thickenings. They are very similar to the vessel striations figured for *Eastwoodia elegans* by the writer (1958a). The formation of such striations appears to be a condition advanced over lack of sculpture, on account of the many other specialized features of the woods in which they occur. However, the writer is of the opinion that different types of sculpturing on vessel walls—such as (1) the grooves conecting pit apertures, and (2) the type of striations in *Chrysactinia*—may represent quite different phenomena with different origins. The current controversy (see Metcalfe and Chalk, 1950) over whether the presence of helical thickenings (or grooves) on vessel walls represents a primitive or advanced character may stem, at least in part, from the possibility that there are various types of vessel-wall sculpturing, and that these may have arisen independently, under quite different circumstances, in different groups. Webber (1936) has related abundance of helical thickenings to aridity in the dry-country plants with which she worked.

Grouping.—The figures given for this feature in table 1 show that a wide variation in number of vessels per group is present. Difficulty in distinguishing vascular tracheids, narrow vessels, and fibers in transection makes this figure unreliable where vascular tracheids and narrow vessels occur. Thus, the larger vessels in *Chrysactinia mexicana* (fig. 13) usually appear solitary, although they are in contact with numerous narrow vessels and vascular tracheids, so that a true figure for vessel groupings would be very high. *Baeria macrantha* (fig. 9) has vessels almost exclusively in long radial rows. Taxa in which radial arrangement of vessels was predominant or frequent include *Baeriopsis* (fig. 7), *Eriophyllum confertiflorum* (fig. 3), *Psilostrophe Cooperi* (fig. 19), and *P. gnaphalodes* (fig. 21). Variously clustered vessels are typical of the remaining taxa. One interesting modification is the occurrence of oblique, rarely truly tangential, bands of vessels in *Eriophyllum confertiflorum* (fig. 3, right half of photograph). The rather low figure for vessels per group in *Flaveria linearis* and *Perityle incana* is interesting in view of the relatively unspecialized (for Compositae) nature of woods in these species.

The figure for grouping of vessels may be considered, to some extent, an expression of the number of vessels per unit area. In any case, the high figure for vessels per group in most Helenieae would seem an indication of their specialization, in agreement with the dictum of Tippo (1946) that grouped vessels are more advanced than solitary ones.

LIBRIFORM FIBERS

The most interesting variation in libriform-fiber morphology in Helenieae is that of wall thickness. All of the mesophytic maritime Helenieae, including *Perityle incana* (fig. 1, 2), *Eriophyllum staechadifolium* (fig. 4), *E. Nevinii* (fig. 5), and *Baeria macrantha* (fig. 9, 10) possess relatively wide, thin-walled fibers. Thick-walled fibers are altogether absent in these species, as are growth rings. All other species have at least some thick-walled fibers, usually related to growth-ring phenomena. Thick-walled fibers are characteristic of late wood.

AXIAL PARENCHYMA

Although Heliantheae (Carlquist, 1958a) offer a number of instances in which bands of apotracheal parenchyma are present, few can be cited in Helenieae. The early wood in growth rings of *Baeriopsis* (fig. 7) shows parenchyma cells in fascicular areas to the exclusion of fibers, which occupy a similar position in late wood. Similar instances occur in *Porophyllum gracile* (fig. 11) and *Psilostrophe Cooperi* (fig. 19), although such parenchyma is much more limited.

Paratracheal parenchyma throughout the Helenieae studied is of the vasicentric scanty type. In only one instance, *Eriophyllum Nevinii*, could it be described as vasicentric abundant. In that species, parenchyma forms a sheath often two cell layers in width around vessels or vessel groups. In the remainder of the species investigated, parenchyma is limited to only a few cells, never more than a single layer thick, around vessels or vessel groups. Typical of an extreme condition is *Baeria macrantha* (fig. 9, 10) in which such parenchyma is present in the ratio of fewer than one strand per vessel. Kribs (1937) has interpreted abundant vasicentric parenchyma as derived from the scanty condition. The instance of abundant vasicentric parenchyma in *Eriophyllum Nevinii*—the most conspicuous such instance yet reported in Compositae—could probably be interpreted in this fashion.

RAYS

Size.—Table 1 shows dimensions of rays. Ray size is not a particularly important variable in Helenieae, because the species of this study all show rather short rays. Presence of erect cells at upper and lower tips of rays may render multiseriate rays difficult to distinguish precisely from surrounding thin-walled libriform fibers. The rays of *Flaveria linearis* deserve mention on account of their greater height.

Wall characteristics.—Rays in *Laphamia megacephala* (fig. 22) probably represent extensions of the original pith rays with little alteration. They are thin-walled, unlignified, and contain a few isolated cells converted into thick-walled sclereids. Ray cells of *Perityle incana* (fig. 2) and the species of *Eriophyllum* (fig. 4, 5) are relatively thin-walled, as are the fibers in these species, and section poorly on this account. Notably thick-walled lignified ray cells occur in *Psilostrophe gnaphalodes* (fig. 21). Other Helenieae are intermediate in this respect.

Cell shape.—Four species—*Baeriopsis guadalupensis* (fig. 8), *Eriophyllum staechadifolium* (fig. 4), *Perityle incana* (fig. 2), and *Psilostrophe Cooperi* (fig. 20)—were observed to have both procumbent and erect ray cells. Procumbent cells are uncommon in *Baeriopsis*, and erect cells are infrequent in *Psilostrophe Cooperi*. The species with isodiametric to procumbent cells exclusively or predominantly include *Clappia suaedifolia*, *Eriophyllum confertiflorum*, and *Psilostrophe Cooperi*. Procumbent cells, where present, are confined to the central portion of rays. Interestingly, *Psilostrophe gnaphalodes* and *Eriophyllum Nevinii* have ray cells isodiametric to erect in shape. Other species in which this condition occurs exclusively or predominantly include *Baeriopsis guadalupensis*, *Chrysactinia mexicana* (fig. 14), and *Flaveria linearis*.

Uniseriate rays.—In all of the taxa studied, uniseriate rays are infrequent, and are usually limited to one or two cells in height. In those species in which rays are present, few or no uniseriate rays were found in *Baeriopsis guadalupensis* (fig. 8), *Clappia suaedifolia*, *Flaveria linearis*, *Laphamia megacephala*, and *Perityle incana* (fig. 2).

Raylessness.—The tendency toward raylessness is very marked in Helenieae. Although Barghoorn (1941) lists only a handful of rayless species from the dicots at large, the Helenieae offer three species in which rays are completely absent: *Baeria macrantha* and its varieties (fig. 9, 10), *Dyssodia Cooperi* (fig. 17, 18), and *Porophyllum gracile* (fig. 11, 12). *Chrysactinia mexicana* (fig. 13, 14) is nearly rayless. Barghoorn's (1941) suggestion that raylessness results from ontogenetic and phylogenetic elongation of ray initials seems clearly borne out by *Chrysactinia mexicana*. The few rays present have cells nearly as long as vertical elements. The rayless condition is attained quite rapidly in *Baeria macrantha* (fig. 9; note termination of several rays), which has little secondary growth, despite the fact that prominent pith rays are present in the primary stem.

The high proportion of rayless or near-rayless genera in Helenieae is interesting and needs explanation. Certainly no direct relation to ecological factors can be postulated. The specialized nature of raylessness, as suggested by Barghoorn, seems to be supported by the assemblage of specialized characters in the rayless and near-rayless woods studied here. The high proportion of rayless helenioid woods might thus reflect the high degree of specialization in many other characters of these species. Although it is tempting to correlate raylessness in Helenieae with the herbaceous nature of the group, woods of some other herbaceous Compositae show no such rayless tendencies. Further considerations on the significance of raylessness should be based on a careful analysis of all instances in the dicotyledons. Such analysis should also include study of those species in which erect ray cells are present to the exclusion of procumbent cells. This condition is not infrequent in woods of herbaceous Compositae.

STORIED STRUCTURE

Storying of vertical elements does not play as important a role in woods of Helenieae as in other groups of Compositae. One species, *Chrysactinia mexicana*, showed consistently storied tracheary elements; fibers and uniseriate rays may or may not be storied. Rays in this species are composed of prominently erect cells, so that one or a pair may be of the same height as a vessel element; such uniseriate rays are most frequently storied. A certain amount of storied construction may appear in the fibers of *Baeria macrantha* (fig. 10), chiefly in places which have been derived from interfascicular areas, rendered fascicular by elongation of ray initials.

Presence of storied structure certainly would not seem a character induced by climatic conditions. Rather, it seems a true phylogenetic specialization. The high proportion of Heliantheae with storied structure in comparison with those of Helenieae would seem to indicate that a non-storied condition is basic to Helenieae. If *Chrysactinia* is correctly included in Helenieae, the occurrence of prominently storied structure would parallel the frequent occurrence of storied woods in many other woody Compositae of the western deserts. Specializations—perhaps over long periods of time—within such extreme habitats may account for the many advanced characters, including storied structure.

Other xerophytic genera of Compositae with a large number of advanced characters, including storied wood structure, include *Hecastocleis*, *Chrysothamnus*, and *Flourensia*.

RESINOUS DEPOSITS

Although none of the Helenieae studied have special secretory structures within the secondary xylem, deposition of resin-like substances in xylem cells is frequent. The observed occurrence of resin-like materials is as follows:

Large deposits in vessels, droplets in fibers, ray and axial parenchyma:
Baeriopsis guadalupensis, *Eriophyllum confertiflorum*, *E. staechadifolium*, *Perityle incana*.

Large deposits in vessels, deposits not seen in other cells: *Dyssodia Cooperi* (fig. 18, center), *Flaveria linearis*.

Small droplets in all cell types: *Baeria macrantha*, *Chrysactinia mexicana*, *Clappia suaedifolia*, *Laphamia megacephala*.

Small droplets in vessels and axial parenchyma: *Psilostrophe Cooperi*.

Small droplets in ray cells and axial parenchyma: *Eriophyllum Nevinii*.

Resin-like materials were not observed in *Psilostrophe gnaphalodes*. In wood of *Porophyllum gracile*, a portion of the transection showed all cells occluded with deposits—presumably on account of an injury—but normal deposition was absent. The only instance of intercellular deposits was in the rays of *Laphamia megacephala*, in which such deposits were carbonized. Differential resinous deposition might conceivably be usable taxonomically in Helenieae, but certainly deposition of these materials is quite general throughout the tribe.

TAXONOMIC CONCLUSIONS

Hoffmann (1890) recognized four subtribes within Helenieae; the genera included in the present study would be distributed among these as follows:

JAUMINAE: *Clappia*.

RIDDELLINAE: *Psilostrophe*.

HELENINAE: *Baeria*, *Baeriopsis*, *Eriophyllum*, *Flaveria*, *Laphamia*, *Perityle*.

TAGETININAE: *Chrysactinia*, *Dyssodia*, *Porophyllum*.

Other treatments might differ somewhat from this arrangement, but these subtribal divisions—which are typical of what may be offered—do not correlate readily with the differences among the woods, except for the relatively rayless nature of the genera of Tagetininae. This does not mean that the taxonomic system is incorrect. One can only conclude that members of a particular subtribe have not all followed the same trends of wood evolution. A basic pattern of wood anatomy seems to be present in Helenieae, and upon this basic pattern, variations have taken place. These variations have probably been related to rapid or sensitive adjustment (phylogenetically) to growth form, climate, and ecology. It is difficult, for example, to state on the basis of wood anatomy what the closest relatives of *Perityle incana* might be. Other insular or maritime species, such as *Eriophyllum staechadifolium*, show similar specialization, or lack of specialization.

Whatever the cause of distinctive specializations, or lack of specializations within species, they can be useful in making taxonomic distinctions. The three species of *Eriophyllum* studied, for example, show many points of similarity in respect to wood anatomy, and would probably have been referred to the same genus if the writer had been given unidentified samples. The different patterns of ray-cell shapes, however, serve to distinguish the three samples.

The genus *Chrysactinia* forms a rather distinctive element among the Helenieae studied with respect to the sum of its secondary xylem characters. The presence of storied structure, numerous small vessels and vascular tracheids, prominent helical striations on vessels, and almost random arrangement of fiber bands with relation to zones of vessels and vascular tracheids offer similarities to such genera (which occupy similar habitats) as *Chrysothamnus*, *Eastwoodia*, *Haplopappus*, and *Lepidospartum*. Are these similarities caused by parallel specializations in relation to habitat and growth form, or do they represent genuine affinities? Secretory cavities in involucral bracts—a chief character of Tagetininae—may be found in *Chrysothamnus* as well as *Chrysactinia*. Likewise, secretory cavities in terete leaves occur in *Chrysothamnus*, *Haplopappus*, and *Peucephyllum*, as well as in *Chrysactinia*. These genera of shrubby desert Compositae—currently treated under three different tribes—and their relatives need intensive investigation from every standpoint to determine which features are parallelisms and which are indicators of true relationship.

Aside from *Chrysactinia*, the Helenieae studied here show little or no storied wood structure. The presence of storied fibers in *Venegazia* (whereas even in *Chrysactinia*, fibers are often non-storied) and a tendency toward production of apotracheal parenchyma bands suggest that *Venegazia* (previously treated as helenioid) is in fact better placed in Heliantheae, subtribe Coreopsidinae. This interpretation was suggested by the writer (1958a) on the basis of wood characters and other features. Now that a survey of helenioid woods is available to lend greater perspective, the coreopsidinean position of *Venegazia* seems definitely more defensible.

Discussion and Summary

The fifteen species covered here include all the woody species of Helenieae, as well as a fairly comprehensive sampling of species with limited accumulation of secondary xylem. In this review of wood characters of the tribe, numerous comparisons with Heliantheae have been utilized on account of the supposed close relationships between genera of the two tribes. Helenieae, however, are worthy of separate consideration in this paper because of the great degree

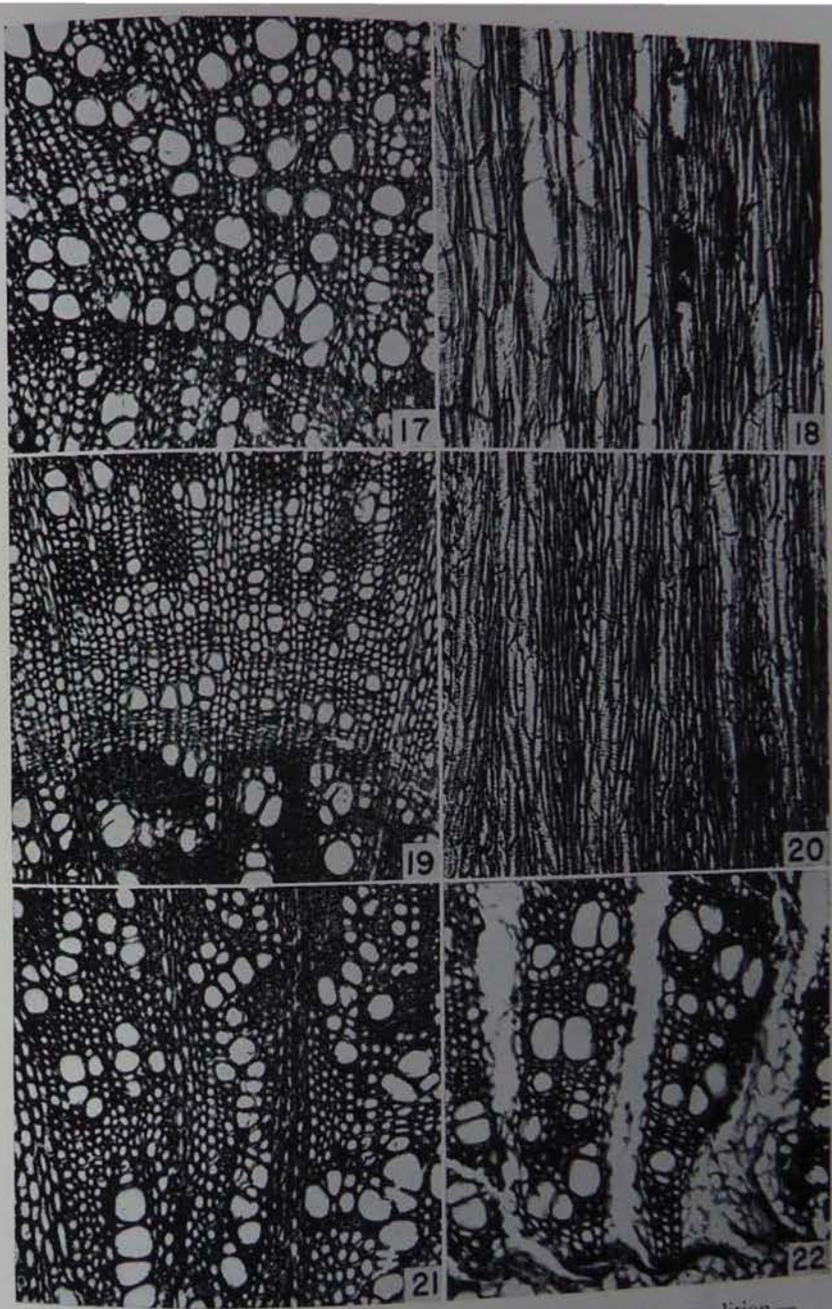

Fig. 17–22.—Fig. 17–18. *Dyssodia Cooperi*. Note rayless condition.—Fig. 17. Transection. $\times$ 85.—Fig. 18. Tangential section. $\times$ 85.—Fig. 19–20. *Psilostrophe Cooperi*.—Fig. 19. Transection, showing a growth ring. $\times$ 130.—Fig. 20. Tangential section; note shortness of vessel elements. $\times$ 130.—Fig. 21. *Psilostrophe gnaphalodes*. Transection. Note thick-walled nature of fibers, ray cells. $\times$ 95.—Fig. 22. *Laphamia megacephala*. Transection. All vertical elements other than fibers

to which wood anatomy apparently reflects adjustment to particular distinctive environmental conditions.

A basic pattern of wood structure in Helenieae appears to be represented by most characters of wood of *Eriophyllum staechadifolium*. One may question whether this species, a not unspecialized maritime shrub, is not itself specialized within Helenieae in respect to wood anatomy. However, *E. staechadifolium* possesses such relatively unspecialized features as diffuse-porosity, moderately long and wide vessel elements, absence of apotracheal parenchyma bands, non-storied structure, presence of both uniseriate and multiseriate rays, and presence of both erect and procumbent cells in rays. Such characters occur in Heliantheae such as *Verbesina vicina* and *Zexmenia frutescens* (Carlquist, 1958a).

The presence of relatively few (per unit area of transection), solitary, long vessel elements, wide, thin-walled fibers, and thin-walled ray cells are characteristic of maritime mesophytic species: *Baeria macrantha*, *Eriophyllum Nevinii*, *E. staechadifolium*, *Flaveria linearis*, and *Perityle incana*. These characteristics might be attributable either to adjustment to these ecological conditions or lack of specialization with relation to a more extreme environment. Such characters as listed for these species could conceivably be interpreted from the standpoint that these species have arisen from less woody ancestors, but there are no *a priori* reasons for such an interpretation.

Although the number of species is not large enough to warrant valid conclusions, dry-country or desert species of varied Helenieae all exhibit the same specializations: more or less marked ring-porosity, greater number of vessels per unit area of transection, large number of vessels per group, short (less than 160μ average) vessel elements, and presence of thick-walled fibers. On the basis of these Helenieae the writer can agree with the claim of Webber (1936) that shorter vessel elements are characteristic of desert shrubs, but her suggestions that vessels are of smaller diameter and rays are smaller and more numerous are not clearly demonstrated by desert or dry-country Helenieae. It is possible that different groups of dicotyledons which occupy arid habitats have undergone different specializations in wood anatomy.

The presence of storied structure (*Chrysactinia mexicana*, and, to a limited extent, *Baeria macrantha*) cannot be explained as an adaptation to climatic conditions. It certainly should be regarded as a specialization, in agreement with Bailey (1923). The same considerations apply to raylessness, in which regard the writer agrees with Barghoorn (1941). The high proportion of rayless woods in Helenieae is considered a highly specialized attribute, and further surveys are recommended to assess the significance of this character.

In comparison with other groups of Compositae, Helenieae are distinctive in their apparently rapid or sensitive adjustment (as reflected by changes in wood anatomy) to particular local environments. Environmentally modifiable characters cannot be delimited from heritable characters in all features of wood anatomy on the basis of the present study. Nevertheless, correlations between the distinctive habitats occupied by species of Helenieae and particular features of wood anatomy seem evident. This apparent correlation suggests that Helenieae are not a group, for example, like the genus *Bidens*. Studies on the wood anatomy of certain species of *Bidens* (Carlquist, 1958a, 1958b) show a sameness among these plants despite varied geographical and ecological locations. A sensitive or rapid specialization with relation to particular ecological conditions would explain why closely related species of Helenieae (e.g., *Eriophyllum confertiflorum* and *E. Nevinii*) show different features of wood anatomy. This would also explain why presumably related genera (e.g., *Baeria* and *Eriophyllum*) seemingly show little affinity on the basis of wood anatomy. In an earlier study (Carlquist, 1956) a small group of helenioid genera was shown to have undergone great diversification with respect to such characters as chromosome number and style anatomy. It is not surprising, therefore, that Helenieae as a whole show patterns of wood anatomy which do not follow larger taxonomic groupings such as subtribes.

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CURRENT LITERATURE

Indian woods. Their identification, properties and uses. Vol. I. Dilleniaceae to Elaeocarpaceae. *K. A. Chowdhury* and *S. S. Ghosh* with the assistance of *K. Ramesh Rao* and *S. K. Purkayastha*, Manager of Publications, Government of India, Delhi, India. i–liii, 1–304, including indices, bibliographies, illustrations and map. 1958 (about $6.00).

Among the first books to appear on the economic uses of trees and the structure and properties of their timbers, was Balfour's *The timber trees, timber and fancy woods, as also, the forests, of India and of eastern and southern Asia*, in 1862. Under the farsighted impetus of Dietrich Brandis, first Inspector-General of Forests in India, the importance of systematic anatomical studies of wood was emphasized in the Indian Forest Department. This resulted in a series of important works on the subject beginning in 1881 with Gamble's *A manual of Indian timbers*. Since that time, a succession of volumes on Indian woods has appeared including those by Troup in 1909, Pearson and Brown in 1932, and more recently, Trotter's *Common commercial timbers of India*. The present work, *Indian woods*, is thus the most recent and ambitious addition to this distinguished line of publications.

In their introduction, the authors state that, "The aim of the book is to give all up-to-date information on the secondary xylem or wood of the tree species that grow in the Indian sub-continent and which are represented in the Indian wood collection of the Forest Research Institute." An extensive introduction to this first volume covers discussions of the forest areas and climate of India, the general distribution of woody species, botanical classification and nomenclature, classification of woods, as well as the structural features, and mechanical and physical properties of woods in general.

In the body of the text, the families are arranged according to the system of Bentham and Hooker. For each family

a brief introduction includes the following topics: kinds of plants, size of family and world distribution; economic importance with emphasis on timber-producing species; species of particular importance in India. The generic section which follows treats such subjects as the size and distribution of the genera and certain notes on the systematic anatomy of the included woods. Important species are given a more detailed and lengthy consideration mentioning the common and trade names applied in India, the habit and general characteristics of the trees, and their distribution in India. A discussion of the wood is next with sections on general properties, gross structure (hand lens), strength properties, seasoning characteristics, natural durability and preservative treatment, working qualities, and supplies and uses. The specimens employed in the study are listed with the Forest Research Institute accesssion number, provenance and specific gravity for each sample. Each family section is terminated by an extensive and up-to-date bibliography. In this first volume, 20 families are handled in such a complete manner.

Volume I is concluded with several detailed and useful appendices: Mechanical properties of woods, Classification of woods according to anatomical structure, Classification of woods according to uses, and Latest changes in nomenclature of the species dealt with in the book. The two indices are very helpful and are classified according to scientific names, and trade and common names. An extensive section including 30 plates with 180 half-tone illustrations of cross sections of wood completes the volume.

One could hardly imagine a more exhaustive treatment of the subject than has been presented in this volume by Dr. Chowdhury and his co-workers. The plan of the book is simple, the paper satisfactory and the illustrations quite acceptable. Keys for identification might be desirable as well as a section on microscopic anatomy. One might also hope for more complete photographic coverage including illustrations of tangential sections of wood. It would also make the book more useable if the photographs accom-

panied the relevant textual material instead of being gathered at the end of the volume. However, Dr. Chowdhury has mentioned, that these additions, however desirable, would be beyond the limits of practicability. The present volume is the result of 25 years of accumulation of data and the work of the four authors and their many associates.—
William L. Stern.

Tropical Woods 110 was published May 12, 1959.