YALE UNIVERSITY SCHOOL OF FORESTRY

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TROPICAL WOODS

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

Subscription price $1.50 for two semiannual numbers. Remittances should be made payable to TROPICAL WOODS. All communications should be addressed to the Editor, 205 Prospect Street, New Haven 11, Connecticut, U. S. A.

Manuscripts on all phases of tropical forestry and tropical woods and trees will be considered for publication. Manuscripts should be typed double-spaced throughout on one side of paper. Drawings, done in black ink, or photographs, should be mounted on stiff cardboard and the desired reduction plainly indicated. Figures should be planned so that after reduction they occupy the entire width of a page (4 inches) and any portion of the height (6 inches). Economy of space is important; therefore, the editor cannot accept loose figures or those so mounted as to leave large unused spaces on the printed page. Figures should be numbered consecutively. Legends for figures should be typewritten and included with the manuscript. All legends for one group of figures should form a single paragraph. In cases where magnifications are stated, they should apply to the reduced figures.

In general, *style should follow the most recent number of* TROPICAL WOODS especially as regards punctuation, literature citation, capitalization, use of italics, and references to literature and illustrations. Main divisions are indicated by centered headings; subdivisions by italicized marginal captions. Footnotes should be minimized. The editors alone retain the right to accept or reject manuscripts.

TROPICAL WOODS

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GUIDE TO INSTITUTIONAL WOOD COLLECTIONS

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Preliminary to embarking on studies in systematic wood anatomy, the researcher is often faced with the problem of amassing the raw materials. He may collect wood samples for study himself, or as is commonly the case, he communicates with institutions maintaining wood collections. To these he makes known his desiderata and requests small samples which can be used for study. All too frequently he is confronted with the fact, that sufficient, accurately identified materials for an exhaustive study are not to be had from those collections with which he is familiar. As a result, studies are sometimes fragmentary and inconclusive for want of more complete research materials. It is considered likely, that had the researcher been aware of other collections of wood, he might have been able to secure additional materials resulting in a more complete work. It was with the above thoughts in mind that the writer set out to prepare this guide to the institutional wood collections of the world.

A tentative questionnaire was prepared and offered for criticism to Professor I. W. Bailey of Harvard University, Dr. B. Francis Kukachka of the U. S. Forest Products Laboratory, Professor Carl de Zeeuw of the College of Forestry, New York State University, Dr. L. Chalk of the University of Oxford and Professor Oswald Tippo of Yale University. For their kindness in reviewing this questionnaire, the writer would like to express his thanks and appreciation.

Employing the suggestions of these wood anatomists, a revised questionnaire was written and sent to all the wood collections then known to the writer. Attached was an address list of the collections to which questionnaires were mailed. Recipients were requested to supply the writer with the names of other collections not included in the list. In this way over 80 institutions housing collections of wood were approached, and returns received from most. The questions asked were as follows:

1. Complete name and address of the institution in which the wood collection is housed.
2. If your wood collection has a special name, please state it.
3. Date (year) of foundation of the collection.
4. Name of curator, or individual directly in charge of the collections, his official title, and his area of research.
5. Other personnel connected with the collection, their titles, and areas of research.
6. Number of specimens, and number of genera if easily accessible.
7. Regions, countries, or taxonomic groups in which your wood collection specializes.
8. Is a herbarium of voucher specimens connected with the wood collection? If so, how extensive is the herbarium? If not, do you have any record of herbarium collections (deposited elsewhere) that may have been made at the time the wood was taken?
9. About what proportion of the wood collection is authenticated with herbarium vouchers?
10. List any major special collections, i.e., Desch's Malayan Woods, Gamble's Indian woods, etc.
11. Are any periodicals dealing wholly or in part with woods published by your institution? If so, name them.
12. Are small samples suitable for sectioning available to qualified individuals?

13. Do you maintain a microscope slide collection of woods? If so, are these available on loan to qualified individuals?
14. Are duplicate wood samples available for exchange or distribution? What woods are desired in return?
15. Are you familiar with any institutional wood collections other than those listed on the attached sheet? If so, please indicate names and addresses.
16. Please record below any other information of value regarding your wood collection.

In an effort to be concise, the items in the original questionnaire are somewhat abbreviated in the presentation below as follows: Items 1 and 3 are incorporated in the address; item 2 is listed under *Foundation;* item 4 under *Curator* and item 5 under *Staff members. Collection* corresponds with item 6; *Specialization* with item 7. *Voucher material* incorporates items 8 and 9. Corresponding with *Important collections* is item 10; *Periodical or serial works* is under item 11; item 12 is considered under *Samples for sectioning.* Question 13 is answered under *Microscope slides* and item 14 is stated as *Exchange.* Under *Remarks* item 16 is listed. Where answers were negative or were omitted, the statement is left out in the index.

There are several points which should be mentioned regarding the construction of the guide which follows: 1) Answers to the questionnaire were fragmentary in a number of cases. 2) Questions were misconstrued by some recipients. 3) It is likely that wood collections exist that are not considered here. 4) It may be that inaccuracies have crept in to this report. Therefore, it is hoped that users of this guide will bring to the attention of the writer, any particulars that may help in making a future revised edition more exhaustive and accurate.

In the preparation of this work, certain editorial liberties were taken mainly to effect consistency among the individual statements. Extraneous material was eliminated, and some phrases were shortened to economize on space. The writer trusts that no important data have been omitted.

Grateful appreciation is offered to all who were so kind as to lend their cooperation in completing the questionnaires used to prepare the guide.

AMSTERDAM: The Royal Tropical Institute, Mauritskade 64, Amsterdam-O, **Netherlands.**

Foundation: 1913.
Curator: A. T. J. Bianchi, Scientific collaborator of the Tropical Products Department (Identification).
Collection: About 10,000 specimens.
Specialization: Southeast Asia, Surinam, tropics in general.
Voucher material: Vouchers deposited elsewhere; about 30 per cent.
Important collections: Koorders (Java); Stahel (Surinam).
Samples for sectioning: Available occasionally by special request.
Exchange: Yes, but limited; wanted, authentic samples of tropical woods.

BANGKOK: Section of Wood Technology, Forest Products Division, Royal Forest Department, Bangkok, **Thailand.**

Foundation: 1953.
Curator: Mr. T. Sriburi, Officer-in-charge.
Collection: 2476 specimens; 187 genera.
Specialization: Thailand.
Voucher material: Yes, at the Section of Botany, Forest Products Research Division; 50 per cent.
Samples for sectioning: Yes.
Exchange: Yes; wanted, any commercial woods.

BELÉM: Instituto Agronômico do Norte, Belém, Pará, **Brazil.**

Foundation: Herbarium, 1945; wood collection, recently.
Curator: João Murça Pires, Chefe da Secção de Botânica (Amazonian region).
Staff members: Humberto Marinho Koury, Assistant (Amazonia); George Alexander Black, Assistant (Amazonia); Ricardo de Lemos Fróes, Asssitant (Amazonia); Adolopho Ducke, Collaborator (Amazonia).
Collection: 1,500 specimens.
Specialization: Amazonian species.
Voucher material: Yes, 80,000 specimens; 100 per cent.
Periodical or serial works: Boletim Técnico do Instituto Agronômico do Norte.
Samples for sectioning: Yes.
Microscope slides: Yes.
Exchange: Yes; wanted, South American woods.

BOGOR: Balai Penjelidikan Kehutanan Indonesia (Forest Research Institute), Bogor, **Indonesia.**

Foundation: 1915.
Curator: Oey Djoen Seng, Section of Investigation of Physical and Mechanical Properties of Wood and Wood Identification.
Collection: 32,000 specimens; 690 genera; 3800 species.
Specialization: Indonesia.
Voucher material: Yes, 42,975 sheets. The herbarium is housed separately and is under the Botanical Division headed by Dr. A. J. G. H. Kostermans; 100 per cent.
Periodical or serial works: Before 1940, *Publication of the Forest Research Institute (Mededelingen van het Bosbouwproefstation).*
Samples for sectioning: Very restricted.
Exchange: Very restricted; none are desired in return (A great deal of the duplicate stock of wood samples was damaged or lost during the Pacific war).

BRISBANE: Botanic Museum and Herbarium, Botanic Gardens, Brisbane, Queensland, **Australia.**

Foundation: 1880.
Curator: S. L. Everist, Government Botanist.
Staff members: L. S. Smith, Botanist (Taxonomy of rain forest trees).
Collection: About 2,000 specimens.
Specialization: Queensland, New Guinea.
Voucher material: Yes, included in general herbarium of 500,000 specimens; about 75 per cent.
Important collections: Queensland Woods (Colonial and Indian Exhibition 1886, Colonial International Exhibition, Melbourne 1888); New Guinea Forests Collections.
Samples for sectioning: Only in exceptional cases.

BRISBANE: Reference Collection of Queensland Timbers, Forest Products Research Branch, Sub-Department of Forestry, 68 George Street, Brisbane, **Australia.**

Foundation: 1922.
Curator: C. J. J. Watson, Investigations Officer (Timber utilisation, Queensland).
Staff members: W. J. Smith, Technical Assistant (Timber utilisation, Forest Products Research Branch).
Collection: About 3,800 specimens; 170 genera.
Specialization: Queensland trees attaining utilisable sizes.
Periodical or serial works: Annual Report.
Microscope slides: Yes, but not for loan.

CAMBRIDGE: Harvard University Herbarium, 22 Divinity Avenue, Cambridge 38, Massachusetts, **U.S.A.**

Foundation: 1880's.
Curator: Acting Curator, Dr. I. W. BAILEY, Professor of Plant Anatomy Emeritus (Plant morphology and anatomy).
Collection: About 25,000.
Specialization: General.
Voucher material: In Herbarium of the Arnold Aboretum.
Periodical or serial works: Journal of the Arnold Aboretum.
Samples for sectioning: Not at present.
Microscope slides: Yes; not at present.
Exchange: Not at present.

CARACAS: Instituto Botanico, Apartado 2156, Ministerio Agricultura y Cria, Caracas, **Venezuela.**

Foundation: 1938.
Collection: 255 genera.
Specialization: Venezuela.
Samples for sectioning: Yes.
Remarks: The collection formed the basis for *Maderas de Venezuela* by Harry Corothie, Caracas, 1948.

CHICAGO: Chicago Natural History Museum, Roosevelt Road and Lake Shore Drive, Chicago 5, Illinois, **U.S.A.**

Foundation: About 1896.
Curator: DR. JOHN W. THIERET, Curator of Economic Botany.
Staff members: Mr. ARCHIE F. WILSON, Associate (Wood anatomy).
Collection: About 18,300 (not including duplicates and unidentified specimens).
Specialization: United States, tropical and subtropical America.
Voucher material: Yes; perhaps 65 per cent.
Important collections: Krukoff (Brazil); Ll. Williams (Mexico, Peru, Venezuela); Acosta-Solis (Ecuador); Cuatrecasas (Colombia); H. H. Smith (U.S.A.); New York State College of Forestry (U.S.A.).
Periodical or serial works: Field Museum of Natural History Publications, Botanical Series; Field Museum of Natural History Handbook.
Samples for sectioning: Yes (recipient is requested to prepare one slide for the Museum).
Microscope slides: Yes; yes.
Exchange: Yes; desired, Old World woods.

COLLEGE: Forest Products Research Institute, College, Laguna, **Philippines.**

Foundation: 1954 (Most of the collection consists of duplicates of the original and authentic wood collections of the Philippine Bureau of Forestry which started its collection in 1901. These duplicates were salvaged from the fires set in the Forestry Campus in 1945.)

Curator: Prof. EUGENIO DE LA CRUZ, Chief, Forest Products Research Institute.
Staff members: FRANCISCO N. TAMOLANG, Chief, Wood Technology Section (Wood anatomy); Dr. FELIPE M. SALVOSA, Dendrologist (Taxonomy); MARTIN LAGRIMAS, Senior Forester (Industrial investigation).
Collection: 10,526 specimens; 162 families; 663 genera; 1917 species.
Specialization: Principally Philippines, some foreign.
Voucher material: Present collections have vouchers in six copies kept in the Herbarium of the Forest Products Research Institute; old collections (duplicates) had vouchers deposited with the former Bureau of Science. Most of these were mentioned in E. D. Merrill's *Enumeration of Philippine flowering plants.* All were burned during World War II. About 80 per cent of present samples are authenticated.
Samples for sectioning: Yes, upon request and with the approval of the Chief, Forest Products Research Institute.
Microscope slides: Yes, upon request and with the approval of the Chief, Forest Products Research Institute. Slides may be loaned to qualified individuals for scientific purposes only.
Exchange: Yes, limited duplicates; wanted, any authenticated commercial woods from the country of the exchanging institution.
Remarks: A checklist is being prepared by the Institute to up-date the present collection with the current changes in scientific and official common names.

DEHRA DUN: Forest Research Institute and Colleges, Post Office New Forest, Dehra Dun, **India.**

Foundation: 1836 (by Dr. Griffith).
Curator: Dr. K. A. CHOWDHURY, Wood Technologist (Wood anatomy, pure and applied, including classification and identification of timbers, study of its variation from morphological as well as genetical point of view; structure and properties of timbers, fossil woods and archaeological plant remains; identification of seeds, leaves, roots based on anatomical structure).
Staff members: Mr. S. S. GHOSH, Assistant Wood Technologist (as above).
Collection: 14,337 specimens; 1,664 genera.
Specialization: Mostly Indian zone, i.e., India, Pakistan, Burma and Ceylon; mostly tropical families.
Voucher material: Yes; 25 per cent of the specimens comprising the early collections are not accompanied by vouchers; the herbarium attached to this Institute contains 300,000 sheets. Some of the herbarium specimens have also been deposited in the Kew herbarium; about 75 per cent.

Important collections: Brandis, Gamble, Chowdhury (India, s. l.).
Samples for sectioning: Yes, when possible.
Microscope slides: Yes; not normally loaned to individuals.
Exchange: Yes, some duplicate wood samples; the woods required in return depend on the problem in hand.
Remarks: A fairly large collection of × 10 and × 110 photomicrographs of various woods is available.

† DELFT: Forest Products Research Institute T. N. O., Postbus 49, Delft, Netherlands.
Foundation: 1939.
Curator: Miss S. M. JUTTE, Wood anatomist (Structure and properties of normal and abnormal wood).
Collection: 4,015 samples; 340 genera.
Specialization: Surinam, Indonesia, New Guinea, Siam, Amazon region of Brazil.
Voucher material: The herbarium from our New Guinea and Siamese samples is deposited at the University of Leiden; that from Surinam samples is deposited with the University of Utrecht; about 75 per cent.
Important collections: Stahel (Surinam); Lam (Siam, New Guinea); Krukoff (Brazil).
Periodical or serial work: Houtbladen (Leaflets), circulars.
Samples for sectioning: Yes, to a certain extent.
Exchange: Yes; wanted, woods from Africa, southeast Asia, Japan.
Remarks: Our collection includes the samples of Dr. J. Ph. Pfeiffer.

† DURHAM: School of Forestry, Duke University, Durham, North Carolina, U.S.A.
Foundation: 1936.
Curator: Dr. E. S. HARRAR, Professor of Wood Technology (Anatomy, forest products technology).
Collection: 6,327 specimens; 937 genera; 139 families.
Specialization: North America, Philippines, Australia, Indo-Malayan region.
Voucher material: Most American species backed by herbarium material in the Duke University Herbarium; Queensland Australia woods backed by vouchers in Brisbane; 30 per cent.
Samples for sectioning: In many instances, yes.
Microsope slides: Yes.
Exchange: Yes, in limited numbers only; wanted, conifers of the world.

† FLORENCE: Istituto Botanico dell'Università, Erbario Centrale Italiano ed Erbario Coloniale di Firenze, Via Lamarmora 4, Firenze, Italy.
Foundation: 1842 (Same as that of the Museum and Herbarium of the Institute).

Curator: Prof. Dr. A. CHIARUGI, Director of the Botanical Institute of the University of Florence (Cytology, genetics, taxonomy, paleobotany, plant ecology and geography); Prof. Dr. R. E. G. PICHI-SERMOLLI, Curator of the Herbarium and Museum of the Botanical Institute of the University of Florence, Assistant of the Herbarium (Taxonomy, plant ecology and geography, anatomy).
Staff members: Prof. Dr. A. MESSERI, Istituto Botanico dell'Università, Messina (Anatomy, plant ecology and geography).
Collection: About 2000 specimens.
Specialization: Chiefly Italy, Greece, Egypt, Libya, India, Canary Islands, Ethiopia, Eritrea, Somaliland, Australia, Borneo.
Voucher material: Yes; vouchers present for the collections of Beccari, Pichi-Sermolli and Corti; 10 per cent.
Important collections: Beccari (Borneo); Orphanides (Greece); Fiori, Senni and Pichi-Sermolli (Ethiopia, Eritrea, Somaliland); Corti (Libya).
Periodical or serial works: Atlante Micrografico dei Legni dell'Africa Orientale Italiana (Discontinued).
Samples for sectioning: Yes, for some specimens only.

FLORENCE: Istituto Nazionale del Legno, Piazza T. A. Edison 11, Firenze, Italy.
Foundation: 1954.
Curator: Dr. LICIA DEMI, Wood Anatomist (Anatomy and systematics of wood).
Staff members: Dr. FRANCO PALLI (Wood preservation).
Collection: About 2,000 specimens; about 650 genera.
Specialization: Italy, South America, Japan, East Africa, North America, French Colonies, Central America, Philippines.
Samples for sectioning: Yes.
Microscope slides: Yes; yes.
Exchange: Available, Italian woods; wanted, woods imported into Italy.
Remarks: The National Institute of Wood was founded in 1954 with the aim of promoting and coordinating research in the field of wood utilization. The wood samples are those of the personal collection of the Director, Prof. Guglielmo Giordano.

† FRANKFURT AM MAIN: Botanisch-Paläobotanische Abteilung, Forschungs-Institut Senckenberg, Senckenberg-Anlage 25, Frankfurt am Main, Germany.
Foundation: 1920.
Curator: Prof. Dr. R. KRÄUSEL, Abteilungs-Leiter, Prof. an der Universität (Plant geography, paleobotany, recent and fossil woods).
Collection: About 3000 specimens.

Specialization: Europe, south and east Asia, conifers, Fagaceae, Dipterocarpaceae; fossil conifers and dicotyledons of diverse origin.
Periodical or serial works: Senckenbergiana.
Samples for sectioning: Yes.
Microscope slides: Yes.
Exchange: Yes, as far as material is available.

FREIBURG: Forstbotanisches Institut der Universität Freiburg, Bertoldstrasse 17, Freiburg i. Br., **Germany.**
Curator: Dr. W. Liese.
Collection: 100 specimens.
Specialization: Central European woods.
Samples for sectioning: Yes.
Microscope slides: Yes.
Exchange: Yes.

GEMBLOUX: Collection J. Louis et C. Donis, Institut agronomique de l'Etat, Gembloux, **Belgium.**
Foundation: 1938.
Curator: Professor J. Fouarge, Institut agronomique de l'Etat; Director, Laboratoire forestier.
Staff members: A. Mottet, Forest Engineer (Pulp and paper).
Collection: 150 species; 100 genera.
Specialization: Belgian Congo; tropical and subtropical woods.
Voucher material: Yes, at the Botanical Garden, Brussels; 100 per cent.
Important collections: Woods of São Paulo, Brazil.
Samples for sectioning: Yes.
Microscope slides: Yes.
Exchange: Available, woods of the C. Donis Collection; wanted, Japanese and Central American woods.

GEORGETOWN: Forest Department, Georgetown, Demerara, **British Guiana.**
Foundation: 1908.
Curator: Conservator of Forests.
Collection: Over 835 species; 415 genera.
Specialization: British Guiana.
Voucher material: Yes; 100 per cent.
Samples for sectioning: Yes.
Exchange: Yes.

HAVANA: Escuela Forestal, Ministerio de Agricultura, La Habana, **Cuba.**
Foundation: 1935.
Curator: Ingeniero Alberto J. Fors, Jefe de la Sección de Montes.
Collection: 1,700 specimens.
Specialization: Miscellaneous.

Voucher material: No, records maintained of those deposited elsewhere; 10 per cent.
Samples for sectioning: Yes, of some species.
Exchange: Yes; wanted, miscellaneous woods.

HAVANA: Estación Experimental Agronómica, Santiago de las Vegas, Habana, **Cuba.**
Foundation: About 1918 (by Dr. J. T. Roig).
Curator: Jefe del Departamento de Botánica Económica.
Collection: 600 specimens; 176 genera.
Specialization: Native Cuban or naturalized species.
Voucher material: Part of the collection is authenticated by vouchers from the Roig herbarium; 50 per cent.
Microscope slides: Only Meliaceae.
Remarks: The collection is mainly used for teaching purposes in the Escuela Forestal.

HONOLULU: Bernice P. Bishop Museum, Honolulu 17, **Hawaii.**
Foundation: 1889.
Curator: Mr. Edwin H. Bryan, Jr., Curator of all Museum collections.
Staff members: Miss Marie C. Neal, Botanist in charge of Museum herbarium.
Specialization: Polynesia, Melanesia, Micronesia, Malaysia.
Voucher material: The herbarium includes over 150,000 specimens; probably a small part.
Periodical or serial works: Bulletin of the Bernice P. Bishop Museum.
Samples for sectioning: From time to time, the Museum sends sets of named wood specimens to the School of Forestry, Yale University, duplicates of which are kept by the Museum.
Exchange: The Museum sends the bulk of its material to Yale, keeping only a 2-inch section.

KEPONG: Forest Research Institute, Kepong, **Federation of Malaya.**
Foundation: 1918.
Curator: P. K. Balan Menon, Wood Technologist (Malaya, North Borneo, Sarawak and Brunei).
Collection: 6,796 specimens; 320 genera.
Specialization: Malaya, North Borneo, Sarawak, Brunei; collection confined exclusively to timber-producing species.
Voucher material: Yes, originally correlated by herbarium sheets deposited in the Forest Research Institute (Kepong), but some of these were destroyed when the Institute building was looted in 1942; 100 per cent.
Periodical or serial works: Malayan Forester; Malayan Forest Records; Research Pamphlets; Trade Leaflets.
Samples for sectioning: Yes.
Microscope slides: Yes; yes.

† **KEW:** Museums of Economic Botany, Royal Botanic Gardens, Kew, Richmond, Surrey, **England.**

Foundation: 1847 (first Museum of Economic Botany).

Curator: Dr. F. N. Howes, Keeper of Museums (Economic botany); Dr. C. R. Metcalfe, Keeper of Jodrell Laboratory (Wood structure).

Staff members: Mr. S. G. Harrison, Senior Scientific Officer (Economic botany); Miss B. J. Youngman, Scientific Officer (Economic botany); Dr. M. Stant, Scientific Officer (Wood structure, Jodrell Laboratory); Mr. Richardson, Scientific Assistant (Wood structure, Jodrell Laboratory).

Collection: Between 16,000 and 20,000 specimens.

Specialization: World-wide.

Voucher material: There is no herbarium of voucher specimens connected with the wood collection. Some of the wood samples have corresponding herbarium specimens which are kept in the Kew herbarium, or have been deposited in other well-known herbaria; 5–10 per cent).

Important collections: Gamble (India); Desch (Malaya); regional sets of various other countries, e.g., Ceylon, tropical Africa, Australia, North Borneo, West Indies, Argentina, British Guiana, Suriname, etc.

Periodical or serial works: Kew Bulletin.

Microscope slides: A collection of microscope slides of timbers and other parts of plants (excluding flowers) is maintained at the Jodrell Laboratory, and is arranged mainly on a taxonomic basis. At the present time, the slide collection consists of approximately 6000 timber slides, 4600 slides of twigs and leaf petioles of dicotyledons, and 2300 slides of monocotyledons. The slide collection is growing steadily and continuously. The slide collection was used in preparing the two volumes entitled *Anatomy of the dicotyledons* by Metcalfe and Chalk, and is now being used in the preparation of a similar book on monocotyledons.

It is not a regular practice to send microscope slides on loan, but in exceptional circumstances this might be done if the slides are required for research work that is really important, and no alternative source of material is available.

Exchange: Normally little material is available for exchange.

Remarks: From time to time there is reason to question the identity of some of the older specimens, especially those received during the last century.

† **LAE:** Division of Botany, Department of Forests, Lae, **Territory of New Guinea.**

Foundation: 1944.

Curator: J. S. Womersley, Chief, Division of Botany (Southwest Pacific).

Collection: About 4000 specimens.

Specialization: New Guinea.

Voucher material: Yes; 100 per cent.

Samples for sectioning: Yes.

Microscope slides: Yes, duplicates of those in C. S. I. R. O., Division of Forest Products, Melbourne, Australia.

Exchange: Only by special request.

LENINGRAD: V. L. Komarov Botanical Institute of the Academy of Sciences of the U. S. S. R., Professor Popov Street 2, Leningrad 22, **U. S. S. R.**

Foundation: 1823.

Curator: Andrei Andreievitch Nikitin, Senior Scientific Worker (Wood anatomy of foliage trees).

Staff members: Evgenia Vikentievna Budkevicz, Junior Scientific Worker (Coniferous wood anatomy).

Collection: 7,932 specimens; 983 genera.

Specialization: General.

Samples for sectioning: Yes.

Exchange: Yes, at times; desired, coniferous woods.

† **LISBON:** Laboratório de Histologia e Tecnologia de Madeiras da Junta de Investigações do Ultramar, Jardim do Ultramar, Belém-Lisboa, **Portugal.**

Foundation: 1947.

Curator: Eng. Manuel P. Ferreirinha, Research Officer (Wood anatomy).

Staff members: Drª. Maria Clara de Freitas, Assistant (Wood anatomy); Frederico Murta, Preparer of Wood Anatomy.

Collection: 350 species.

Specialization: Portuguese overseas territories, namely: Portuguese Guinea, Angola, Mozambique, Timor.

Voucher material: Yes, in the following herbaria: Centro de Botânica da Junta Investigações do Ultramar and Jardim e Museu Agrícola do Ultramar; about 30 per cent.

Periodical or serial works: Garcia de Orta.

Samples for sectioning: Yes.

Microscope slides: Yes, on loan or exchange.

Exchange: Available, samples 12.5 × 6 × 0.8 cm.; wanted, tropical woods especially from Africa, and species of *Eucalyptus.*

† **MADISON:** Forest Products Laboratory, Madison 5, Wisconsin, **U.S.A.**

Foundation: 1910.

Curator: Dr. B. Francis Kukachka, Forest Products Technologist (Identification of native and foreign woods especially Burseraceae, Sapotaceae and Quiinaceae).

Staff members: Dr. JEANETTE M. KRYN, Botanist (Identification of native and foreign woods).
Collection: 17,330 specimens; 1670 genera.
Specialization: U. S. A. and tropical America.
Voucher material: Yes, but limited to native species collected by Forest Service personnel; record kept of herbarium vouchers deposited elsewhere; about 75 per cent.
Periodical or serial works: Information Leaflets, Technical Notes, Technical Bulletins, Miscellaneous Publications and *Handbooks.*
Samples for sectioning: Yes.
Microscope slides: Yes, but not available on loan.
Exchange: Yes; wanted, authentic specimens.
Remarks: The major portion of our U. S. Collection consists of radial strips extending from bark to pith taken at various heights in the tree.

MELBOURNE: see **SOUTH MELBOURNE.**

MÉRIDA: Xiloteca-Facultad de Ciencias Forestales, Facultad de Ciencias Forestales, Universidad de los Andes, Mérida, **Venezuela.**

Foundation: 1952.
Curator: FEDERICO BASCOPÉ-VARGAS, Professor of Wood Anatomy; Alessandro Bernardi, Professor of Dendrology and Botany.
Collection: 320 specimens; about 240 genera.
Specialization: Venezuela.
Voucher material: Yes; 90 per cent.
Periodical or serial works: Boletín de la Facultad de Ciencias Forestales.
Samples for sectioning: Yes.
Microscope slides: Yes.
Exchange: Yes; desired, tropical woods particularly of the New World.

MEXICO, D. F.: Xiloteca, Instituto de Investigaciones Forestales, Edison 145, México (4), D. F., **México.**

Foundation: 1954.
Curator: OFELIA MANCERA VIGUERAS, Bióloga des Instituto Politécnico Nacional (Histology of wood).
Collection: 85 specimens; 38 genera.
Specialization: Mostly Pinaceae and tropical woods of Mexico.
Voucher material: Yes, in the herbarium of the Instituto; about 50 per cent.
Samples for sectioning: Yes.
Microscope slides: Yes; yes in exchange.
Exchange: Yes; wanted, samples of Pinaceae woods.

MUNICH: Botanische Staatssammlung, Menzinger Strasse 67, München 19, **Germany.**

Foundation: 1813.
Curator: Dr. HERMANN MERXMUELLER, Director.
Collection: 2,500 specimens.
Specialization: Martius (Brazil); Siebold and Zuccarini (Japan); old collections from Bavaria; Luetzelburg (Brazil); Sapindaceae (very important collection with many originals from Prof. Dr. L. Radlkofer; Palmae (originals from Martius).
Voucher material: Yes, associated with the herbarium of the Botanische Staatssammlung containing 1,500,000 sheets of phanerogams.
Important collections: Sapindaceae of Radlkofer.
Samples for sectioning: Only in special cases; write to the Director.

MUNICH: Ggbde. Forstbotanisches Institut, Amalienstrasse 52, München, **Germany.**

Specialization: Germany, Japan, Africa, South America and Java.
Important collections: Sample woods of the Chichibu University Forest, Tokyo University.
Samples for sectioning: Yes.
Microscope slides: Yes.
Exchange: Perhaps; wanted, woods of South Africa.

MUNICH: Institut für Holzforschung und Holztechnik der Universität München, Winzererstrasse 45, München 22, **Germany.**

Foundation: 1955.
Curator: Dr. EBERHARD SCHMIDT, In Charge of the Section (Biology, anatomy and pathology of wood).
Collection: 1833 specimens; 622 genera; 1267 species.
Voucher material: Herbarium vouchers for some South American and African specimens deposited at Munich, Berlin-Dahlem and Buenos Aires (Darwinion).
Periodical or serial works: Holz als Roh- und Werkstoff.
Samples for sectioning: Yes.
Microscope slides: Yes.
Exchange: Available in the future.

NATHANYA: Forest Research Station, Division of Wood Technology, Department of Forests, Ilanoth, P. O. B. 88, Nathanya, **Israel.**

Foundation: 1950.
Curator: MARTIN CHUDNOFF, Wood Technologist (Wood technology and utilization).
Collection: 927 specimens; 391 genera.
Voucher material: Yes, but restricted to woods of Israel; records are kept of herbarium specimens of woods received; 20 per cent.

Periodical or serial works: Ilanoth.
Samples for sectioning: Yes.
Microscope slides: Slides of native woods to be available in the future.
Exchange: Available, native woods; wanted, woods native to arid regions.

NEW HAVEN: The Samuel James Record Memorial Collection, School of Forestry, Yale University, New Haven 11, Connecticut, **U.S.A.**

Foundation: Original collection in 1901; burned in 1903; present collection in 1905.
Curator: Dr. WILLIAM L. STERN, Assistant Professor of Wood Anatomy (Xylem anatomy and phylogeny of Lauraceae, Julianiaceae, Gomortegaceae, Heteropyxidaceae; anatomy and taxonomy of the woody plants of the Florida Keys; secretory structures in wood).
Staff members: Dr. GEORGE K. BRIZICKY, Associate in Research in Wood Anatomy (Anatomy and taxonomy of *Centrolobium;* taxonomy of woody plants of Florida Keys; dendrology; forest pathology).
Collection: 50,200 specimens; 2680 genera.
Specialization: Tropical regions of world.
Voucher material: Yes; a herbarium of 25,000 sheets, containing mostly vouchers, is maintained as part of the Collection; records kept of vouchers deposited elsewhere; about 35 per cent.
Important collections: Koorders-Janssonius (Java); Forest Research Institute (Malaya); New York State College of Forestry (U. S. A.); Bernice P. Bishop Museum (Pacific Islands); Philippine Bureau of Forestry (Philippines); Williams (Peru, Mexico); Krukoff (Brazil, Bolivia, Africa, Sumatra); Pittier (Panama Canal Zone, Venezuela); Curran (Argentina, Brazil, Venezuela); Cooper (Liberia, Panama, Costa Rica); Whitford (Brazil, Colombia, Cuba); Dugand (Colombia); Hoehne (Brazil); Cuatrecasas (Colombia); A. C. Smith (Fiji, British Guiana); Sargent-Jesup (U. S. A.); Gamble (India); British Guiana Forest Department (British Guiana); Vigne (Gold Coast); Ducke (Brazil); Acosta-Solis (Ecuador); Lane-Poole (New Guinea); Stahel (Surinam); Desch (Malaya).
Periodical or serial works: Tropical Woods, Bulletin Yale School of Forestry.
Samples for sectioning: Yes; recipient is requested to prepare one slide for Yale collection.
Microscope slides: Yes; yes.
Exchange: Miscellaneous samples are occasionally available; wanted, preferably authentic samples of tropical woods.

NEW YORK: The Jesup Collection of Woods of North America, The American Museum of Natural History, Central Park West at 79th Street, New York 24, New York, **U.S.A.**

Foundation: 1890.
Curator: Dr. JACK MCCORMICK, In charge of vegetation studies (Regional vegetation of the Americas).
Collection: About 425 specimens.
Specialization: North America.
Voucher material: Yes, at the Museum and Arnold Aboretum Herbarium; 100 per cent.
Remarks: The collection consists of logs, mostly five feet long, taken from large individuals of each species. On most, the upper portion has been sawed to show radial, tangential and transverse facets.

NEW YORK: New York Botanical Garden, Bronx Park, New York 58, New York, **U.S.A.**

Foundation: 1944.
Curator: Dr. BASSETT MAGUIRE, Curator and Coordinator of Tropical Research (Tropical America).
Staff members: Dr. JOHN J. WURDACK, Assistant Curator; Dr. RICHARD S. COWAN, Assistant Curator; Mr. JOSEPH V. MONACHINO, Associate Custodian of the Herbarium.
Collection: About 1,000 specimens.
Specialization: General collections from the Guianas and Venezuela.
Voucher material: Yes; 100 per cent.
Important collections: Stahel (Surinam); Maguire and colleagues (Surinam, British Guiana and Venezuela).
Exchange: Some available for exchange.
Remarks: The Maguire et al. collections contain a rather high percentage of type material. Both shrubs and trees are represented.

NOGENT-SUR-MARNE: Centre Technique Forestier Tropical, 45bis, Avenue de la Belle-Gabrielle, Nogent-sur-Marne (Seine), **France.**

Foundation: 1937.
Curator: Monsieur DIDIER NORMAN, Chef de la Division d'Anatomie des Bois Tropicaux.
Staff members: Ingénieur ALAIN MARIAUX, Assistant de la Division d'Anatomie des Bois; other technical personnel employed at the Laboratiore d'Anatomie des Bois Tropicaux.
Collection: 10,117 samples; more than 1300 genera; about 150 families.
Specialization: Woods of the territories of the French Union; commercial woods of the tropics; Africa and Madagascar.
Voucher material: Yes, at the Muséum National d'Histoire Naturelle, Laboratoire de Phanérogamie in Paris; 50 per cent.

Important collections: Woods cited in the following publications: *Atlas des bois de la Côte d'Ivoire* by D. Normand; *Ekop du Cameroun* by R. Letouzey and R. Mouranche; *Bois et Forêts de la Nouvelle-Calédonie* by P. Sarlin; *Propriétés physiques et mécaniques des bois tropicaux de l'Union Française* by P. Sallenave.
Periodical or serial works: Bois et Forêts des Tropiques.
Samples for sectioning: Yes.
Microscope slides: Duplicates may be exchanged.
Exchange: Available, samples 13 cm. × 6 cm. × 1 cm.

+ **OTTAWA:** Ottawa Laboratory, Forest Products Laboratories of Canada, Department of Northern Affairs and National Resources, Ottawa, Ontario, **Canada.**
Foundation: 1917.
Curator: Mr. J. D. Hale, Head of the Wood Structure Section (Wood anatomy and properties of wood).
Staff members: Mr. E. Perem, Forest Products Engineer (Wood anatomy and properties of wood); Mr. C. T. Keith, Forest Products Engineer (Wood anatomy and properties of wood).
Collection: About 1,800 specimens; 1,500–1,600 species.
Specialization: Timber species of present and possible commercial importance.
Samples for sectioning: Yes, but not authenticated.
Microscope slides: Yes; yes.
Exchange: Yes; Canadian commercial specimens, $.05 each or on exchange.

+ **OXFORD:** The Imperial Forestry Institute Wood Collection, Department of Forestry, Imperial Forestry Institute, University of Oxford, Oxford, **England.**
Foundation: 1924.
Curator: Dr. L. Chalk, Reader in Wood Anatomy in the University of Oxford (General and systematic wood anatomy of the dicotyledons).
Collection: 18,700 specimens; 2,115 genera.
Specialization: British Commonwealth.
Voucher material: The Forest Herbarium, Oxford, has between 80,000 and 90,000 sheets about half of which are African. Some of these are correlated with wood specimens in the collection. References to other herbaria are always kept when received; 48 per cent have references to herbarium sheets that are available somewhere.
Important collections: Desch (Malaya); Gamble (India); Vigne (Gold Coast); Fanshawe (British Guiana); Cooper (Panama, Liberia); Molfino (Argentina); Forest Department, Burma; Krukoff (Sumatra); Walker (British Solomon Islands); Wood (North Borneo).

Samples for sectioning: Yes.
Microscope slides: Yes.
Exchange: Available, limited sets; wanted, only material with herbarium backing.
Remarks: A large miscellaneous duplicate collection of slides is available for exchange.

PARAMARIBO: Landsbosbeheer Suriname (Surinam Forest Service), P. O. B. 436, Paramaribo, **Suriname.**
Foundation: 1948.
Curator: ir. I. A. de Hulster, Conservator of Forests.
Collection: 380 specimens; about 188 genera.
Specialization: Surinam.
Voucher material: Yes; also deposited at the Botanical Museum and Herbarium, Utrecht, Netherlands; 100 per cent.
Samples for sectioning: Yes.
Exchange: Yes, in small quantities.

+ **PRETORIA:** Forest Products Institute Wood Collection, Forest Products Institute, P. O. Box 727, Pretoria, **Union of South Africa.**
Foundation: 1899 by Conservator, Western Concervancy, continued in 1929 by Forest Products Institute.
Curator: Officer-in-Charge, Timber Mechanics Section (C. H. Banks, Professional Officer).
Staff members: L. M. Schwegmann, Professional Officer (Identification); D. Jackson, Professional Officer (Identification); G. J. van Staden, Technical Assistant (Indexing); W. F. J. van Vuuren, Technical Assistant (Indexing).
Collection: About 3,000 specimens.
Specialization: Africa.
Voucher material: No; records kept of deposition of herbarium vouchers.
Important collections: Large numbers of samples have been received from the following: Imperial Institute Collection; Technological Museum, Sydney; Forestry Commission, New South Wales, Sydney; Forest Branch, Victoria, British Columbia; Yale University; Forest Department, Brisbane; Joel Hugo (Mexico); Forest Commission, Melbourne; Research Institute, Dehra Dun; C. C. Robertson (Australia); Commonwealth Forestry Bureau, Australia; C. E. Legat (Australia); Tokyo University; Netherlands Embassy, Pretoria (Dutch Indies); Queensland Forest Service, Brisbane; New York State College of Forestry, Syracuse; Bureau of Forestry, Manila; Forest Products Laboratory, Canada; Forest Products Research Laboratory, Princes Risborough; Agriculture and Forestry, Tokyo; Professor Taccard, Zürich; Divisional Forest Officer, Northern Rhodesia; Forest

Department, Kenya; Conservator of Forests, Gold Coast; Director of Forestry, French West Africa; M. H. Scott (West Africa); South African Railways Administration (Gold Coast); O. B. Miller (Bechuanaland); Serviço Florestal, Secção Tecnologia, Brazil; E. E. Loock (Mexican pines); J. H. Ter Laak, Amsterdam; Conservator of Forests, Tanganyika; Chicago Natural History Museum; C. W. Scott, Santiago.

Samples for sectioning: Yes.
Microscope slides: Yes.
Exchange: Yes.
Remarks: The collection is housed in a building constructed entirely of locally-grown exotic and indigenous timbers.

PRINCES RISBOROUGH: Forest Products Research Laboratory, Princes Risborough, Aylesbury, Bucks, **England.**

Foundation: 1930.
Curator: Mr. B. J. Rendle, Officer in Charge, Wood Structure Section (Structure and properties of wood; classification of timbers).
Staff members: Dr. E. W. J. Phillips (Structure and properties of wood; classification of timbers, especially Coniferae; physiology of the growth ring and lignification); Mr. J. D. Brazier (Structure and properties of wood; classification of timbers, especially Dipterocarpaceae); Mr. G. L. Franklin (Identification of timbers; microtechnique).
Collection: Approximately 23,000 specimens; about 2,100 genera.
Specialization: The collection is particularly rich in timbers of tropical Africa and southeast Asia.
Voucher material: No herbarium is connected with the wood collection. Herbarium material collected with timber specimens is generally deposited in the Forest Herbarium, Oxford (Imperial Forestry Institute). Records are kept of herabarium material correlated with wood specimens and deposited elsewhere; about 30 per cent.
Important collections: Fujioka (Japan, 1929); Vigne (Gold Coast, ca. 1930–45); Krukoff (West Africa, Brazil, Sumatra, 1932–1934); Desch (Malaya, 1933–1939); Walker (Solomon Islands, 1946); most of the timber collections of the Imperial Institute, South Kensington, London, and the Cambridge School of Forestry including the collections of Elwes and Henry, and Herbert Stone; authentic collections made by the Forest Departments of: Burma (ca. 1920–1930), Uganda (1933–date), Kenya (1936–date), British Guiana (1942–date), Ceylon (1944), North Borneo (1950–date), Sarawak (1935–date), etc.
Samples for sectioning: Yes.
Microscope slides: Yes; yes.
Exchange: Yes; wanted, authentic specimens of actual or potential economic importance, especially tropical timbers.

Remarks: Standard size of specimens is 6 × 4¾ × 1 inch (smaller specimens acceptable). Separate exhibit collection of about 250, 6 ft. specimen boards of commercial timbers.

QUITO: Museo Botánico-Forestal, Departamento Forestal del Ministerio de Economía, Calle Guayaquil No. 1914, Quito, **Ecuador.**

Foundation: 1951.
Curator: Prof. Jorge A. Gallegos Teran, Director del Departamento Forestal del Ecuador; Prof. Vicente Alvarado Montesdeoca, Colector-Herborizador, Jefe del Museo.
Collection: 450 specimens; 150 genera.
Specialization: Ecuador.
Voucher material: Yes; 100 per cent.
Periodical or serial works: Boletín de Divulgación Técnica.
Samples for sectioning: Yes.
Microscope slides: Yes; yes.
Exchange: Yes, by exchange or for the price of $.10 each.

REINBECK BEI HAMBURG: Bundesforschungsanstalt für Forst- und Holzwirtschaft, Reinbeck bei Hamburg, Schloss, **Germany.**

Foundation: 1940.
Curator: Professor Dr. Hans Mayer-Wegelin, präsidierender Direktor der Bundesforschungsanstalt; Direktor des Instituts für Holzbiologie.
Staff members: Helmut Gottwald (Wood anatomy).
Collection: 9,333 specimens; 1,340 genera.
Specialization: Unspecialized.
Voucher material: Yes; about 1 per cent.
Samples for sectioning: Yes.
Microscope slides: Yes; yes.
Exchange: Yes, some samples; wanted, woods from South America.

RIO DE JANEIRO: Jardim Botânico do Rio de Janeiro, Rua Jardim Botanico 1008, Rio de Janeiro, **Brazil.**

Foundation: 1942.
Curator: Armando de Mattos Filho, Naturalista (Wood anatomy).
Staff members: Paulo Agostinho Matos Araujo, Agrônomo Silvicultor (Wood technology).
Collection: 2,796 specimens; 810 genera.
Specialization: Brazil, especially Amazonian region.
Voucher material: Yes; 33 per cent.
Periodical or serial works: Arquivos do Jardim Botânico; Arquivos do Serviço Florestal; Arquivos do Instituto de Biologia Vegetal; Rodriguesia.
Samples for sectioning: Yes from some specimens.
Microscope slides: Yes.
Exchange: Yes; wanted, Brazilian and South American woods.

RIO DE JANEIRO, D. F.: Xiloteca da Divisão do Florestamento e Reflorestamento, Instituto Nacional do Pinho, Rua México, Rio de Janeiro, D. F., **Brazil.**

Foundation: 1949.
Collection: 439 specimens.
Specialization: Mostly Brazilian.
Periodical or serial works: Anuário Brasileiro de Economia Florestal.
Exchange: Yes; wanted, commercial timbers from any country.

RIO PIEDRAS: Tropical Forest Research Center, Agricultural Experiment Station, Río Piedras, Puerto Rico.

Foundation: 1921.
Curator: Franklin R. Longwood (Wood utilization).
Collection: 300 specimens; 50 families.
Specialization: Puerto Rico.
Voucher material: Yes; about 50 per cent.
Periodical or serial works: The Caribbean Forester.
Samples for sectioning: Yes, in the near future.
Exchange: Yes, in near future; wanted, woods of tropics.

SANTA TECLA: Xiloteca Nacional de El Salvador, Servicio Cooperativo Agrícola Salvadoreño Americano, Centro Nacional de Agronomía, Santa Tecla, El Salvador.

Foundation: 1951.
Curator: Oscar Enrique Chavez, Encargado de la Sección Forestal (El Salvador).
Collection: 122 genera; 136 species.
Specialization: El Salvador.
Samples for sectioning: Yes.
Remarks: Each species is represented by six specimens of different sizes: two 7 × 2 × ¾ inches; two 6½ × 4¼ × ¼ inches (one polished, one polished and varnished); one is a cube; one is a stem section 2½ inches wide including bark.

SAO PAULO: Brazilian Commercial Timbers, Instituto de Pesquisas Tecnológicas, Praça Coronel Fernando Prestes 110, Caixa Postal 7141, São Paulo, **Brazil.**

Foundation: 1928.
Curator: Calvino Mainieri, Agronomy Engineer (Brazil).
Collection: 8,122 specimens; about 1,200 genera.
Specialization: Commercial timbers of Brazil.
Voucher material: No; records are kept of vouchers deposited elsewhere; 20 per cent.
Periodical or serial works: Boletim do Instituto de Pesquisas Tecnológicas.
Samples for sectioning: Yes.
Microscope slides: Yes; no.

Exchange: Yes; wanted, commercial timbers of Central America and northern South America.

SOUTH MELBOURNE: Division of Forest Products, Commonwealth Scientific and Industrial Research Organization, 69 Yarra Bank Road, South Melbourne, Victoria, **Australia.** (Postal address: Box 18, Post Office, South Melbourne).

Foundation: 1929.
Curator: Dr. H. E. Dadswell, Chief Research Officer-in-Charge, Section of Wood and Fibre Structure (General wood anatomy, cell wall structure, structure in relation to properties and growth).
Staff members: Mr. H. D. Ingle, Senior Research Officer (Wood anatomy); Dr. M. Margaret Chattaway, Senior Research Officer (Wood and bark anatomy); Mr. C. F. James, Senior Technical Officer (Wood anatomy and timber identification).
Collection: Over 17,000 specimens; about 1,400 genera.
Specialization: Southwest Pacific area, particularly Australia and New Guinea.
Voucher material: No; records kept of voucher specimens deposited elsewhere; about 80 per cent.
Important collections: New Guinea Forests Collections; Collections by C. S. I. R. O. Natural Resources Survey team (New Guinea); New Caledonia; Lane-Poole (New Guinea); Desch (Malaya).
Periodical or serial works: Australian Journal of Botany.
Samples for sectioning: Yes.
Microscope slides: Yes; yes to qualified persons depending upon the request.
Exchange: Yes; wanted, miscellaneous woods.

STELLENBOSCH: Institute for Forestry and Wood Technology, University of Stellenbosch, Stellenbosch, **Union of South Africa.**

Foundation: 1933.
Curator: Prof. G. Hartwig, Professor of Wood Technology.
Collection: About 1,050 specimens.
Specialization: South Africa.
Samples for sectioning: Yes.
Microscope slides: Yes.
Exchange: Yes; desired, woods from South America.

STOCKHOLM: Wood Technology Department, Section of Wood Structure and Properties, Swedish Forest Products Research Laboratory, Drottning Kristinas väg 67, Stockholm O, **Sweden.**

Foundation: 1944.
Curator: Fil. Kand. J. B. Boutelje (Collections and properties of wood).

Collection: 731 specimens; about 250 genera.
Specialization: General.
Samples for sectioning: Yes, but mostly from New Zealand.
Microscope slides: Yes.
Exchange: Available, samples from Sweden; wanted, tropical woods.

SYDNEY: Forestry Commission of New South Wales, Division of Wood Technology, 96 Harrington Street, Sydney, New South Wales. **Australia.**
Foundation: 1935.
Curator: R. K. Bamber, Research Officer (Identification of timbers and wood structure, New South Wales and trade timbers).
Staff members: Miss J. W. Lanyon, Research Officer (Identification of timbers and wood structure, New South Wales and trade timbers).
Collection: 7,000 specimens; 2,600 species.
Specialization: Mostly New South Wales commercial species; also other trade timbers.
Voucher material: Yes; about 95 per cent.
Important collections: Lane-Poole (New Guinea).
Periodical or serial works: Technical Notes.
Samples for sectioning: Yes.
Microscope slides: Yes, under certain circumstances.
Exchange: Yes; wanted, timbers not represented in our collection.

SYRACUSE: Harry Philip Brown Wood Collection, Department of Wood Technology, College of Forestry, State University of New York, Syracuse 10, New York, **U.S.A.**
Foundation: Prior to 1925.
Curator: Dr. Carl de Zeeuw, Assistant Professor of Wood Technology (General wood anatomy and relation of anatomy to physical properties of wood).
Staff members: Mr. Harold Core, Instructor (Wood fiber identification; timbers in world trade).
Collection: Over 25,000 specimens; 1900 genera.
Specialization: North American timber trees, Indian timbers and Brazilian Amazonia.
Voucher material: Yes, for the North American collections. Record maintained of herbarium material deposited elsewhere; between 66 and 80 per cent.
Important collections: Wood Technology Project I (North America); Gamble (India); Krukoff (Brazilian Amazonia, West African Meliaceae, Sumatra); Kanehira; Desch (Malaya); Imperial Institute; Lecomte (Madagascar and Indochina).
Samples for sectioning: Yes.
Microscope slides: Yes; yes.
Exchange: Yes, only on exchange basis; wanted, any authenticated specimens.

SZEGED: Institutum Botanicum Universitatis, Szeged, **Hungary.**
Foundation: 1946.
Curator: Prof. Dr. Paul Greguss (Wood anatomy, paleo-anatomy).
Collection: About 360 species; 50 genera.
Specialization: Coniferae of the world.
Periodical or serial works: Acta Biologica Szeged.
Samples for sectioning: Yes.
Exchange: Yes.

TANANARIVE: Inspection Générale des Eaux et Forêts (Section de Recherches Forestiéres), Tananarive, **Madagascar.**
Foundation: 1951.
Curator: R. Mouranche, Inspecteur des Eaux et Forêts, Chef de la Section de Recherches.
Staff members: R. Capuron, Inspecteur des Eaux et Forêts, Chef de la Division de Botanique.
Collection: 1,996 specimens; 206 genera.
Specialization: Madagascar and Comores; more especially Lauraceae, Meliaceae and Sapotaceae.
Voucher material: An herbarium of 15,000 specimens is connected with the wood collection; 90 per cent.
Samples for sectioning: Yes.
Microscope slides: Only slides of some Lauraceae.
Exchange: Yes; none desired in return.

TOKYO: Wood Technology Division, Government Forest Experiment Station, Ministry of Agriculture and Forestry, Meguro, Tokyo, **Japan.**
Foundation: The present collection is of recent origin, the old one having been destroyed during World War II.
Curator: Syoji Sudo, Research Officer (Wood anatomy).
Staff members: Yaichi Kobayashi, Research Officer (Wood anatomy).
Collection: About 3,000 specimens.
Specializaiton: Mostly Japan, others from U. S. A., Formosa, China, Philippines, India, Indonesia, Thailand, Burma, Australia and South America.
Voucher material: No; record is kept of the herbarium vouchers taken at the same time as the wood; almost all specimens are represented by vouchers.
Samples for sectioning: Yes.
Microscope slides: Yes; yes.
Exchange: Yes; wanted, woods from southern Asiatic countries, Africa and Europe.

UNIVERSITY PARK: Buckhout Laboratory, Pennsylvania State University, University Park, Pennsylvania, **U.S.A.**

Foundation: 1925.
Curator: Dr. DAVID A. KRIBS, Professor of Plant Anatomy (Commercial foreign woods on the American market).
Collection: 10,000 specimens, about 2,000 genera.
Specialization: Latin America, Philippines, West coast of Africa, U. S. A.
Voucher material: No, records kept of vouchers deposited elsewhere; about 95 per cent.
Important collections: Sargent (U.S.A.); H. P. Brown (U.S.A.).
Microscope slides: Yes; yes.
Exchange: Yes.

UTRECHT: Botanical Museum and Herbarium of the State University of Utrecht, Lange Nieuwstraat 106, Utrecht, **Netherlands.**

Foundation: 1946.
Curator: Dr. ALBERTA M. W. MENNEGA, Scientific Officer (Wood anatomy and taxonomy, chiefly of genera from Suriname and tropical South America).
Staff members: Miss N. C. REM, Botanical Analyst.
Collection: Over 5000 specimens; 453 genera.
Specialization: Tropical South America, chiefly Suriname.
Voucher material: Yes, incorporated in the general herbarium; 95 per cent.
Important collections: Stahel, Lands Bosbeheer, Suriname-Expeditie 1948 continued by Lindeman and Schulz, Mennega (Suriname).
Samples for sectioning: Yes.
Microscope slides: Yes.
Exchange: Yes; wanted, woods from tropical South and Central America or other tropical regions.

WAGENINGEN: Instituut voor Bosbouwkundig Onderzoek, afdeling Bosexploitatie, Generaal Foulkesweg 64, Wageningen, **Netherlands.**

Foundation: The original collection founded many years ago was destroyed during World War II; the present collection has been amassed since that time.
Curator: Dr. IR. J. F. KOOLS, Professor of Forest Utilization and Forest Politics.
Staff members: C. H. JAPING, Scientific Officer.
Collection: About 4000 specimens.
Specialization: General.
Voucher material: Deposited at the Botanical Museum and Herbarium of the State University of Utrecht, Netherlands; Forest Research Institute Bogor, Indonesia; probably elsewhere; 50 per cent.

Important collections: Forest Research Institute, Indonesia; Forest Service, Suriname; Royal Forest Department, Siam; Forest Products Laboratories, Canada; Forest Products Institute, South Africa; Conservator of Forests, North Borneo; Laboratoire Forestier de l'Etat, Belgium and Musée de Congo Belge, Belgium (Belgian Congo); Service des Eaux et Forêts, New Caledonia; Laboratorio Estudos Florestais, Portugal (Portuguese colonies); Forestry Department, Gold Coast; Division of Forest Products, Australia; New Zealand Forest Service and Timber Development Association (New Zealand); Instituto de Pesquisas Tecnológicas, Brazil; Chicago Natural History Museum, U. S. A. (tropical America).
Samples for sectioning: Yes.
Micoscope slides: Yes, but not available on loan.
Exchange: Available; wanted, Indonesian and Surinam samples.

WAGENINGEN: Laboratorium voor Plantkunde, Arboretumlaan 4, Wageningen, **Netherlands.**

Foundation: 1948.
Curator: Dr. CORNELIA A. REINDERS-GOUWENTAK, Professor of Botany (Wood anatomy and plant physiology).
Staff members: Dr. JETSKE DE ZEEUW, Senior Scientific Officer (Wood anatomy); Ir. E. W. SCHIERBEEK, Scientific Officer (Wood anatomy); Ir. F. SCHNEIDER, Junior Scientific Officer (Wood anatomy); Dr. E. REINDERS, Professor of Botany, retired (Wood anatomy).
Collection: 1000 specimens; about 650 genera.
Voucher material: Deposited at Arboretum Generaal Foulkesweg, Wageningen; Botanical Laboratory, Lange Nieuwstraat, Utrecht; probably at Bosbouwproefstation, Bogor, Indonesia; 65 per cent.
Important collections: Stahel, De Hulster, WS (Surinam).
Samples for sectioning: Yes.
Microscope slides: Yes, but not available on loan.
Exchange: Available; wanted, Surinam woods.
Remarks: On our wood specimens and microscope slides, the following abbreviations *may* have been used: de H or De H for de Hulster wood blocks collected by the Forest Service, Paramaribo and indicated with Arabic numbers; dHS for wood sectors sampled by de Hulster and indicated with Roman dates (cf. *Acta bot. Neerl.* 4: 461–462. 1955; WS for Welvaartsfonds Suriname.

+ **WASHINGTON:** Section of Wood Technology, Division of Crafts and Industries, Department of Engineering and Industries, United States National Museum, Smithsonian Institution, Washington 25, D. C., **U.S.A.**

Foundation: 1915.
Curator: Mr. WILLIAM N. WATKINS, Curator, Division of Crafts and Industries (Specific determination within genera of woods used in domestic and foreign furniture).
Collection: 14,027 specimens (Study samples and exhibit specimens catalogued in same series).
Specialization: General.
Voucher material: Some in the United States National Herbarium; records kept of vouchers deposited elsewhere; about 50 per cent.
Important collections: Pittier (Panama); Krukoff (Brazil); New York State College of Forestry (U.S.A.); A. C. Smith (Fiji); Stahel (Surinam).
Samples for sectioning: Yes, some.
Microscope slides: Yes, but not for loan.
Exchange: Yes; desired, authentic Malayan, South Pacific Island and East African woods.

+ **WHAKAREWAREWA:** Forest Research Institute, P. B. Whakarewarewa, Rotorua, **New Zealand.**

Foundation: 1926.
Curator: Mr. H. R. ORMAN, Senior Forest Products Officer.
Staff members: Mr. J. M. HARRIS, Timber Physics Officer.
Collection: 2500 specimens.
Specialization: New Zealand timbers and minor species.
Voucher material: No, records kept of vouchers deposited elsewhere; not more than 5 per cent.
Important collections: Ll. Williams (Peru, Mexico); Krukoff (Brazil); Acosta-Solis (Ecuador); Smith (U. S. A.).
Periodical or serial works: New Zealand Forestry Research Note.
Samples for sectioning: Yes, New Zealand woods only.
Microscope slides: Yes, not normally available for loan outside the Institute.
Exchange: Available, New Zealand samples.

+ **ZAGREB:** Wood Structure Section, Forestry-Agriculture Faculty, University of Zagreb, Post Box 95, Zagreb-Maksimir, **Yugoslavia.**

Foundation: 1947.
Curator: Dr. ZVONIMIR SPOLJARIC, University Lecturer.
Collection: 920 specimens; 260 genera; 82 families.
Specialization: Commercial woods of the world; especially Yugoslavian woods.

Periodical or serial works: Glasnik za sumske pokuse.
Samples for sectioning: Yes.
Microscope slides: Yes; yes.
Exchange: Available, samples 8 × 12 × 1.5 cm.; wanted, indigenous woods, especially those of commercial value.

+ **ZURICH:** Institut für Allgemeine Botanik, Eidgenössische Technischen Hochschule, Laboratorium für Holzuntersuchung, Universitätsstrasse 2, Zürich, **Switzerland.**

Curator: Dr. H. H. BOSSHARD (Wood biology).
Collection: 3200 specimens; 1700 species.
Specialization: Switzerland.
Samples for sectioning: Yes.
Microscope slides: Yes.
Exchange: Yes, by agreement.

WOOD ANATOMY OF MUTISIEAE (COMPOSITAE)

SHERWIN CARLQUIST

The Claremont Graduate School, Rancho Santa Ana Botanic Garden, Claremont, California

INTRODUCTION

Of the numerous arboreal and shrubby Compositae which occur in tropical regions, relatively few have been studied with respect to wood anatomy. Although this neglect may derive partly from the limited commercial importance of composite timbers and partly from the unfamiliarity of the botanist with the tropical representatives of the family, the phylogenetic and taxonomic aspects of wood anatomy of Compositae merit attention. The tribe Mutisieae, occurring largely in tropical and subtropical North and South America, is distinguished by its high proportion of woody genera. Because certain Mutisieae contain characters which are seemingly archaic for the family, the wood anatomy of this tribe becomes of particular interest. Moreover, understanding of wood anatomy of composites should aid in demonstrating phylogenetic trends within the family at large, perhaps in regard to the question as to whether Compositae are ancestrally woody or herbaceous. In woods of Compositae, even the least specialized conditions are relatively advanced, compared to woods of other dicotyledons; only simple perforation plates have been found in vessels of Compositae, for example. However, sufficient variation in a number of characters is present, so that phylogenetic interpretations seem warranted.

In the present study, an attempt was made to secure wood of as many truly woody Mutisieae as possible. Most of these belong to the subtribe considered most primitive, Gochnatinae (Hoffmann, 1890). The study was particularly enhanced by the availability of an excellent series of materials of Mutisieae recently discovered in the Guayana Highland of Venezuela by Maguire and others (Maguire, et al., 1953, 1957). These mutisioids are believed by Maguire (1956) to form a phylogenetic unit, with *Stenopadus* and allied genera (*Stomatochaeta, Chimantaea, Quelchia*) forming, together with *Stifftia*, an Amazonian genus, the most primitive elements in Gochnatinae. *Gongylolepis* and allies (*Achnopogon, Duidaea, Neblinaea*) are considered closely-related primitive elements of the subtribe Gerberinae (Mutisinae of Hoffmann). The monotypic genus *Glossarion*, from the same area, is of uncertain position with regard to these two groups. The writer wished to determine if data from wood anatomy support Maguire's hypothesis, and, if so, how the xylem in genera with shrubby habit (*Stomatochaeta, Quelchia, Achnopogon, Duidaea, Neblinaea*, and *Glossarion*), or megaphytic habit,[1] (*Chimantaea*) compares with the xylem of the trees *Stenopadus, Gongylolepis*, and *Stifftia*.

In addition to species from Guayana, a varied assemblage of Mutisieae forms the basis for this study. *Cnicothamnus* (Argentina), *Flotovia* (Chile), *Hesperomannia* (Hawaii), *Nouelia* (Yunnan), and *Stifftia* (Brazil) are freely-branched trees. *Anastraphia* (West Indies), *Barnadesia* (South America), *Chuquiragua* (South America), *Hecastocleis* (southwestern United States), *Lycoseris* (Peru), *Proustia* (South America), and *Trixis* (United States–South America) are shrubby, while *Wunderlichia* (Brazil) is a megaphyte.

[1] "Megaphyte" is used in the sense of Cotton (1944) for a rosette plant which forms a single thick stem by prolonged growth.

According to the treatment of Hoffmann (1890), all of these belong to the subtribe Gochnatinae, with the exception of *Barnadesia, Nouelia*, and *Proustia* (Mutisinae) and *Trixis* (Nassauvinae).

Materials and Methods

Most of the woods studied were available as samples of large stems or logs, although in some instances two to five-year-old twigs provided the only material. In either case, these were boiled, soaked for about three months in commercial-strength hydrofluoric acid, and sectioned on a sliding microtome. Sections were stained with safranin, and mounted in Canada balsam. Wood macerations were prepared to confirm measurements and anatomical details. Sets of wood sections employed in this study have been distributed to the wood slide collections of the Yale School of Forestry and of Harvard University.

The writer wishes to express his gratitude to Dr. William L. Stern for wood samples from the Yale collections, to Dr. Bassett Maguire for materials from the New York Botanical Garden, and to Dr. Lincoln Constance, who collected woods of South American Mutisieae for the writer. In addition, appreciation is extended to the curators of the University of California Herbarium, Berkeley, and the Rancho Santa Ana Botanic Garden Herbarium for the use of their materials. Particular acknowledgment is due Dr. I. W. Bailey, who interested the writer in problems of wood anatomy in Compositae, sent him materials from the Harvard wood collections, and offered numerous helpful suggestions in the preparation of the manuscript.

Anatomical Descriptions

Table 1 summarizes the features of wood anatomy in which significant variation was observed among the taxa investigated. In the second column, the source of each specimen is indicated, giving either the Harvard (H) or Yale (Y) wood collection accession number, or the herbarium specimen which documents a wood sample or from which a wood sample was taken. Herbarium abbreviations are according to Lanjouw and Stafleu, *Index herbariorum*, ed. 3, 1956. The names given for woods studied are in accordance with the voucher specimens studied with two exceptions. *Gongylolepis Martiana* is considered the correct name for Y-41538 *(G. Maroana* Badillo). *Wunderlichia mirabilis* is given here as the name for Glaziou 2168G, since the

herbarium name, *W. tomentosa* Glaziou, is a *nomen nudum*, and the specimen seems referable to the type species of the genus, *W. mirabilis*. Although current taxonomic opinion seems to favor union of *Anastraphia* with *Gochnatia*, nomenclatural changes have not yet been made, and the former genus is retained here.

Table 1. CHARACTERS OF WOOD ANATOMY IN MUTISIEAE

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SPECIES	WOOD COLLECTION OR HERBARIUM SPECIMEN NO.	WIDTH OF LARGEST VESSELS (μ)	VESSEL ELEMENT LENGTH, AVERAGE (μ)	VESSEL END WALL ANGLE MORE THAN, LESS THAN, OR ABOUT 45°	VESSELS SOLITARY OR IN LIMITED GROUPS	VESSELS IN RADIAL ROWS	RING-POROUS TENDENCY	VESSELS WITH HELICAL BANDS	VESSEL PITTING SCALARIFORM-TRANSITIONAL	APOTRACHEAL PARENCHYMA	RAY CELLS ISODIAMETRIC TO ERECT	RAY CELLS ISODIAMETRIC TO PROCUMBENT	RAY CELLS ALL ISODIAMETRIC	RAYS PREDOMINANTLY OR ALL UNISERIATE	HEIGHT, UNISERIATE RAYS (MM.)	RAYS EXCLUSIVELY MULTISERIATE	HEIGHT, MULTISERIATE RAYS (MM.)
Achnopogon virgatus Maguire, et al.	Steyermark & Wurdack 742 (NY)	22	230	>		+		+			+			+	.13		.54
Anastraphia Cowellii Britton	Howard 5098 (A)	38	235	=		+						+		+	.50		
A. enneantha Blake	Y-7468	55	152	<	+								+		.08		.12
A. Northropiana Greeman	Y-4267	60	220	<		+		+		+		+			.11		.13
Barnadesia Dombeyana Less.	Constance 2227 (UC)	54	218	<		+					+				.16		.60
Chimantaea mirabilis Maguire, et al.	Steyermark & Wurdack 821 (NY)	43	290	>		+			+				+	+	.80		
Chuquiragua insignis H. & B.	Y-44410-A	80	370	=	+						+					+	2.5
Cnicothamnus Lorentzii Griseb.	H-20692	55	290	<	+					+		+			.22		.29
Duidaea pinifolia Blake	Steyermark 58143 (GH)	22	220	>		+					+			+	.20		.45
Flotovia leiocephala Wedd.	Constance 10732 (UC)	43	320	<		+	+	+					+		.15		.75
Glossarion rhodanthum Maguire, et al.	Maguire, et al. 37190 (NY)	37	230	=		+				+	+				.17		.50
Gongylolepis Martiana (Baker) Steyermark & Cuatrecasas	Y-41538	110	290	<	+							+			.17		.68
Hecastocleis Shockleyi Gray	Hutch 7682 (RSA)	54	130	<			+	+			+			+	.22		
Hesperomannia arborescens Gray	Carlquist H29 (UC)	65	330	<	+					+	+				.22		2.0
Lycoseris triplinervia Less.	Constance 2288 (UC)	130	310	<	+						+				.17		1.7
Neblinaea promontorium Maguire, et al.	Maguire 37009 (NY)	43	370	>		+		+			+				.20		1.0
Nouelia insignis Franch.	Rock 11714 (A)	92	290	<		+	+	+			+				.28		.70
Proustia pungens Poepp.	Rossi 490 (RSA)	80	220	<			+	+			+					+	.90
Quelchia × *grandiflora* Maguire, et al.	Steyermark & Wurdack 755 (NY)	50	500	>		+			+			+			.22		.60
Stenopadus cucullatus Maguire	Maguire 35053 (NY)	127	300	<	+							+			.08		.17
Stifftia chrysantha Mikan	Y-40071	120	310	<	+			+		+	+				.55		.70
Stomatochaeta cymbifolia (Blake) Maguire, et al.	Steyermark & Wurdack 509 (NY)	50	320	=		+						+		+	.20		
Trixis californica Kell.	Balls 18829 (RSA)	50	170	<		+						+		+	.07		.22
Wunderlichia mirabilis Ried.	Glaziou 2168G (UC)	80	210	<		+			+			+		+	.17		?

Vessels

Vessel shape and size.—Because vessel diameters and vessel element length were found to vary greatly within a single stem, statistical treatment was considered inadvisable. One measurement which seems to provide a significant figure, however, is the diameter of the largest vessels observed in a species. The figures for average length of vessel elements aid in a rough comparison among the taxa, since some (e. g., *Quelchia*) have markedly longer vessel elements than others (*Hecastocleis*). The angle the end wall forms with the horizontal is an interesting figure, since it appears to be correlated with the narrowness of vessels. Of those species having vessels 50 microns or less in diameter, nearly all have end wall angles of 45° or higher. The writer does not believe that narrower vessels with higher end wall angles are, in Mutisieae, necessarily indicative of a more primitive condition; many of the species with high inclination of perforation plates (end walls) have relatively short vessel elements, which would be considered advanced according to the data of Frost (1930). Rather, fluctuation of end wall angle may be correlated with vessel diameter.

Such a correlation occurs in the Guayana group, and is apparently related to habit: genera with truly woody habit (*Stenopadus*, fig. 7; *Gongylolepis*, fig. 13) have relatively wide vessels, the end walls forming an angle of less than 45° with the horizontal, whereas shrubby or megaphytic genera (*Chimantaea*, fig. 9, 10; *Stomatochaeta*, fig. 11; *Quelchia*; *Achnopogon*, fig. 12; *Duidaea*, *Neblinaea*, and *Glossarion*) have higher end wall angles, narrower vessels, and, correspondingly, less cross-sectional area of vessels per square millimeter. Within the genus *Gongylolepis* such a fluctuation is seen, since *G. fruticosa*, a shrubby species, has vessels with a maximum diameter of 35 microns, as compared to 110 for the tree *G. Martiana*. *Quelchia* has narrow vessels with high end wall angles, although vessel elements are appreciably longer than those of other genera studied.

Other Mutisieae, which appear to be rather advanced for the tribe, do show short vessel elements with low end wall angles. Examples are seen in *Anastraphia enneantha*, *Barna-*

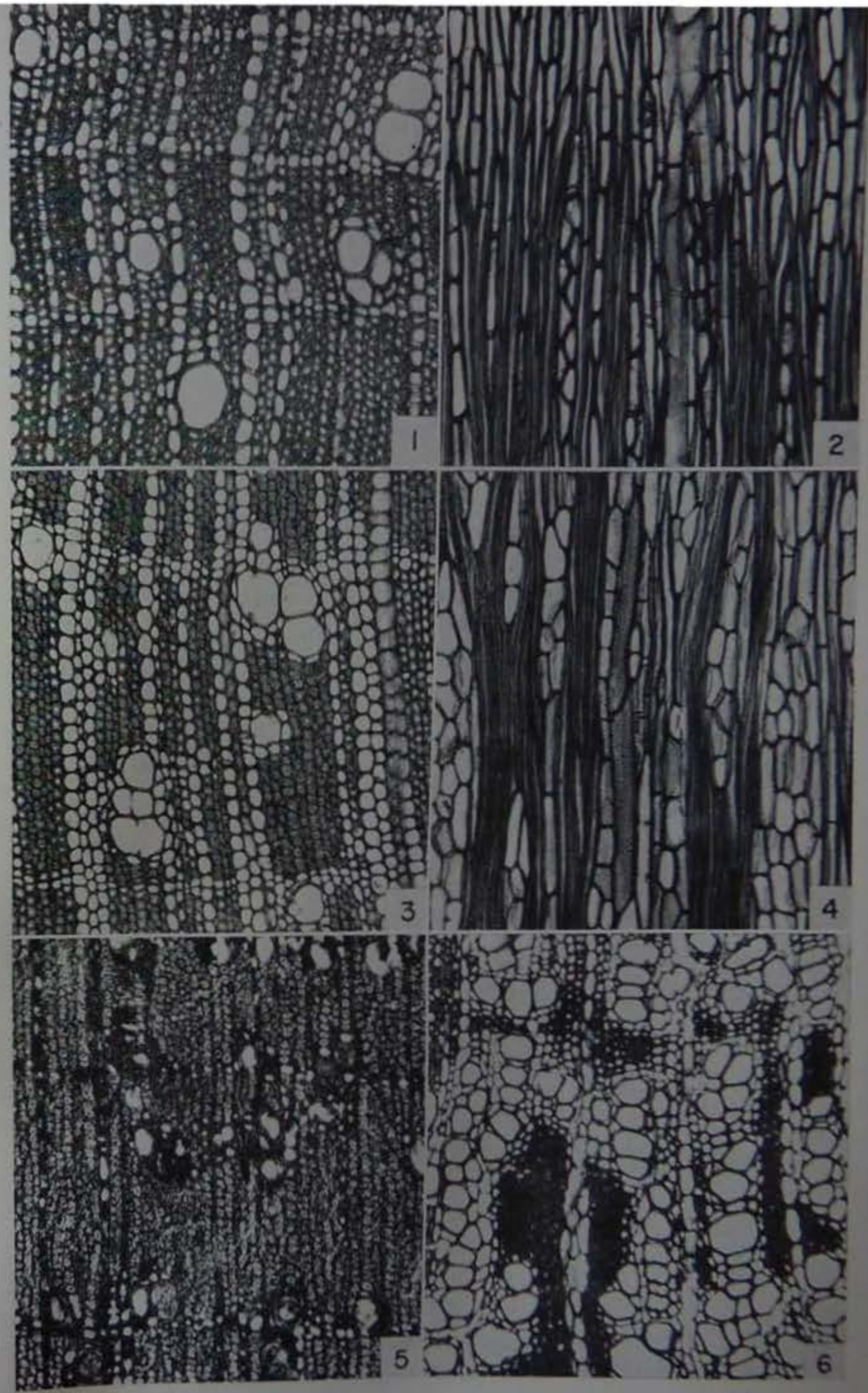

Fig. 1–6.—Fig. 1–2. *Stifftia chrysantha*, transverse, tangential sections.—Fig. 3–4. *Hesperomannia arborescens*, transverse, tangential sections.—Fig. 5. *Cnicothamnus Lorentzii*, transection.—Fig. 6. *Wun-*

desia Dombeyana, *Hecastocleis Shockleyi* (fig. 20), *Proustia pungens* (fig. 22), *Trixis californica*, and *Wunderlichia mirabilis*. The pattern of variation in respect to vessel diameter, vessel element length, and end wall angle does not permit unequivocal conclusions concerning phylogenetic changes in these characters. Differences in habit and differential evolution rates may, in Mutisieae, result in patterns different from the correlations of Frost (1930) which were based on a survey of dicotyledons at large.

Vessel arrangement.—In most genera of Mutisieae investigated, the vessels are in radial rows (*Wunderlichia*, fig. 6; *Stomatochaeta*, fig. 11; *Achnopogon*, fig. 12; *Nouelia*, fig. 23; *Flotovia*, fig. 24). In some genera, however, vessels are most often solitary, although radial pairs or limited clusters may occur. This condition obtains in genera with relatively wide vessel diameter (*Stenopadus*, fig. 7; *Gongylolepis*, fig. 13) and those in which vessels are of moderate diameter (*Hesperomannia*, fig. 3; *Cnicothamnus*, fig. 5). Radial rows of vessels seem to be the more derived condition, in agreement with Tippo (1946). An example of such specialization is seen within the genus *Gongylolepis*, where the reduced species *G. fruticosa* has vessels in radial chains, whereas they are solitary or in limited groups in *G. Martiana*. Likwise, the shrubby genera closely related to *Gongylolepis* (*Achnopogon*, *Duidaea*, and *Neblinaea*) show radial rows of vessels. Radial rows of vessels have been reported for the mutisioid genera *Flotovia* and *Gochnatia* by Metcalfe and Chalk (1950).

A significant condition which occurs in some genera studied is a tendency toward ring porosity. This has been reported for *Proustia* (Record, 1936) and *Gochnatia* (Metcalfe and Chalk, 1950). In the genera considered here, a tendency toward ring porosity is seen prominently in *Hecastocleis Shockleyi* (fig. 19), *Proustia pungens* (fig. 21), and, to a lesser degree, in *Flotovia leiocephala* (fig. 24) and weakly in *Nouelia insignis* (fig. 23). In each of these, the ring-porous condition takes the form of more numerous and larger vessels in early wood, fewer and smaller in late wood. This is associated with more abundant parenchyma in early wood, more abundant fibers in late wood. The ring-porous habit in these species may be associated with the markedly seasonal character of their habitats, north temperate in the case of *Hecastocleis* and *Nouelia*, south temperate for *Proustia* and *Flotovia*. Ring porosity in these latter two genera forms an exception to the thesis of Gilbert (1940) that ring porosity is exclusively a north temperate development. Evidence from mutisioid woods supports his idea, however, that ring porosity is an advanced character.

Lateral vessel walls.—The pattern of intervascular pitting for wood having attained a mature pattern was observed to be of three types in the Mutisieae studied: (1) alternate bordered pits; (2) alternate bordered pits, with superimposed helical thickenings; (3) scalariform-transitional. The basic type seems to be alternate bordered pits (fig. 4, 8, 14, top of 16). Most genera possess only this type of pitting in vessels of older stems.

In some taxa, numerous fine striations or helical thickenings appear on the vessels (*Neblinaea*, fig. 15; *Nouelia*, fig. 16; *Stifftia*). In their least conspicuous form, these striations are grooves which connect the apertures of pits. As development of this condition becomes more marked, these grooves are widened and the intervening areas, which form a helical pattern in the vessel as a whole, become thickened. Thus, no clear line can be drawn in these instances between striations and helical thickenings. In genera with more moderate development of helices, they are seen most conspicuously on certain walls of the vessel, such as those facing parenchyma (fig. 16, below). In such instances, they may form irregular patterns. In genera with marked development of helices, they are equally prominent on all walls, and form one or more continuous bands (*Flotovia*, fig. 18). Concomitant with a greater development of thickenings is their presence on elements other than vessels. Although apparently not present on wood or ray parenchyma, they occur, in *Flotovia*, *Hecastocleis*, and *Proustia*, on vascular tracheids and occasionally on fibers. Helical thickenings have been recorded in Compositae by Record (1936) for *Proustia*, *Flotovia*, and *Vernonia*. They have been suggested to be an advanced

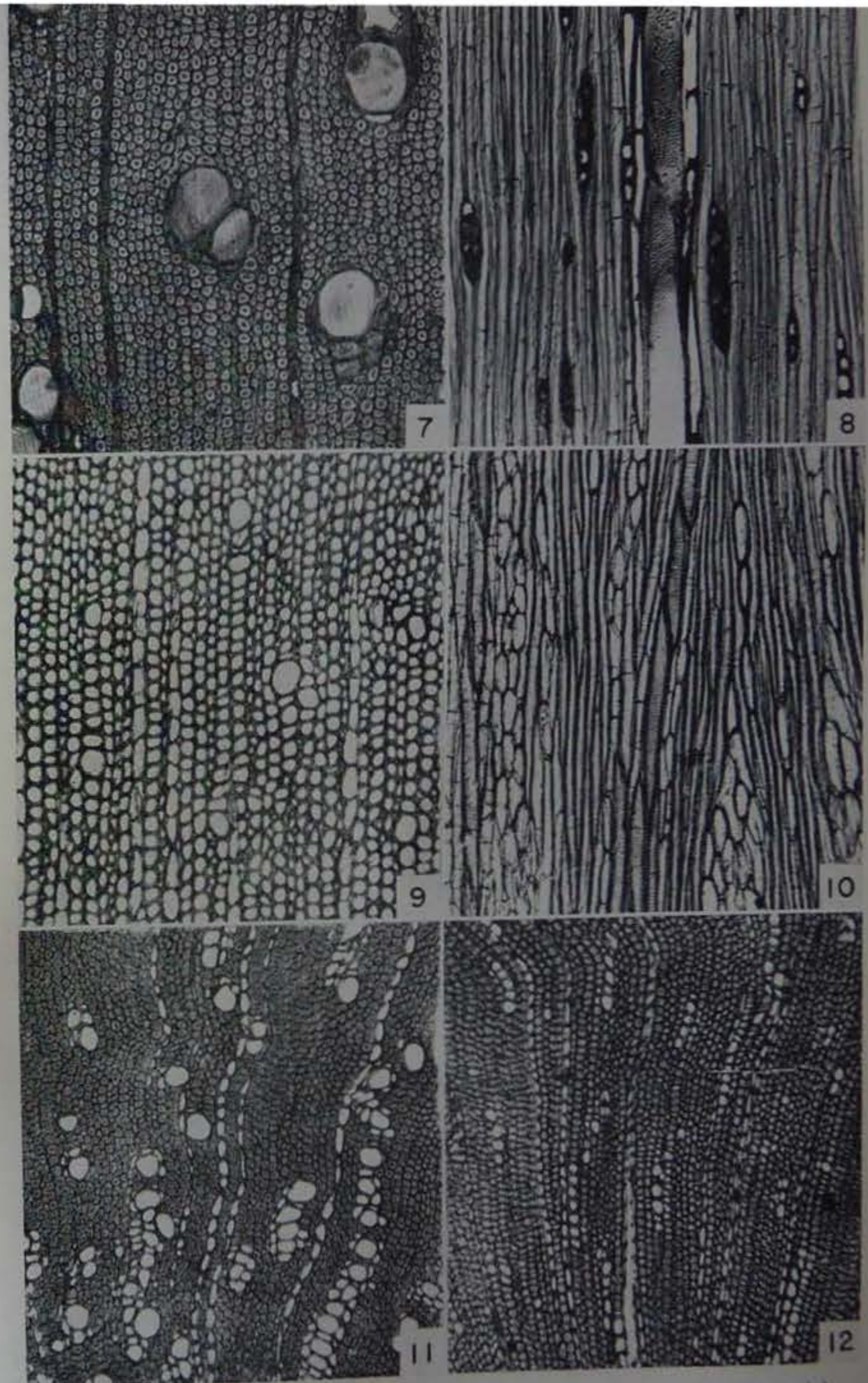

Fig. 7–12.—Fig. 7–8. *Stenopadus cucullatus*, transverse, tangential sections.—Fig. 9–10. *Chimantaea mirabilis*, transverse, tangential sections.—Fig. 11. *Stomatochaeta cymbifolia*, transection.—Fig. 12. *Achnopogon virgatus*, transection. Collections given in table 1. All

character by Frost (1931) and Moseley (1948). Although Metcalfe and Chalk (1950) are skeptical of this interpretation, since they note helical thickenings in vessels of less specialized woods, it seems possible to interpret such instances as parallel advances in a number of groups with relatively primitive wood.

Scalariform-transitional pitting characterizes the lateral vessel walls in older stems of the genera *Chimantaea* (fig. 17), *Quelchia*, and *Wunderlichia*. It is noteworthy in this connection that all of these genera are relatively herbaceous, and *Chimantaea* and *Wunderlichia* could be classified as megaphytes. It is possible that scalariform-transitional pitting, considered a primitive character by Frost (1931), has persisted in smaller vessels, and in surfaces that are in contact with parenchyma. A more likely explanation for the three above genera, however, seems to be that tracheary wall thickenings characteristic of primary xylem have been carried over for considerable distances into the secondary xylem, a phenomenon which occurs also in "megaphytic" cycads.

Vascular Tracheids

Fiber-tracheids and tracheids are notably absent in Compositae, almost all elements being capable of classification into vessel elements or libriform wood fibers. However, in four genera of temperate regions *(Hecastocleis, Trixis, Flotovia,* and *Proustia)* imperforate elements with prominent bordered pits are present. In *Hecastocleis, Flotovia,* and *Proustia,* these vascular tracheids occur in early wood, and are associated with a ring-porous condition (fig. 20, 22). Although *Trixis californica* is clearly diffuse porous, vascular tracheids are a marked seasonal production, appearing in concentric bands. In Mutisieae, the occurrence of vascular tracheids seems best interpreted as an advanced character.

Fibers

Extremely thick-walled libriform fibers are characteristic of most Mutisieae *(Hesperomannia,* fig. 3; *Cnicothamnus,* fig. 5; *Wunderlichia,* fig. 6; *Stenopadus,* fig. 7; *Stomatochaeta,* fig. 11; *Achnopogon*, fig. 12). In view of this very prevalent tendency, it is of interest to examine the genera with only moderately thick fibers. These include genera with ring porosity (fig. 19, 21, 23, 24), *Chuquiragua* (fig. 20), *Gongylolepis* (fig. 13), *Chimantaea* (fig. 9), and *Trixis*. While the genera of this study are insufficient for any clear conclusions, it appears that the genera with markedly thinner-walled fibers are more advanced.

Vertical Parenchyma

Although all taxa considered have scanty vasicentric parenchyma, as is characteristic of Compositae at large, only a few possess apotracheal parenchyma (table 1). Even in genera where it does occur, apotracheal parenchyma is rather limited. It is best developed in *Hesperomannia* (fig. 3), where the concentric bands may be 1–4 cells in width; it is nearly as conspicuous in the bands of *Stifftia* (fig. 1, upper portion of fig. 2), although the rings are only 1–2 cells in thickness. Similar to *Stifftia* in this respect is *Cnicothamnus* (fig. 5), in which bands are mostly a single cell in thickness (Burgerstein, 1912). Discontinuous bands of apotracheal parenchyma are seen in *Anastraphia Northropiana*, *Gongylolepis Benthamiana*, and *Glossarion rhodanthum*. This situation parallels that found in Heliantheae (Carlquist, 1957b), in which only the genera *Fitchia* and *Oparanthus* have been found to have concentric or fragmentary bands of apotracheal parenchyma. The totality of anatomical characters in both Heliantheae and Mutisieae would seem to suggest that the presence of apotracheal parenchyma may be primitive, although further study is needed before this interpretation can be certain. Apotracheal parenchyma has been reported elsewhere in Compositae (Metcalfe and Chalk, 1950), but many of these cases may be referable to specialized conditions involving paratracheal parenchyma. At present, the supposition of primitiveness of apotracheal parenchyma can rest only on its correlation with less specialized conditions in a limited number of species, and a wider survey is necessary before any definite conclusions can be reached.

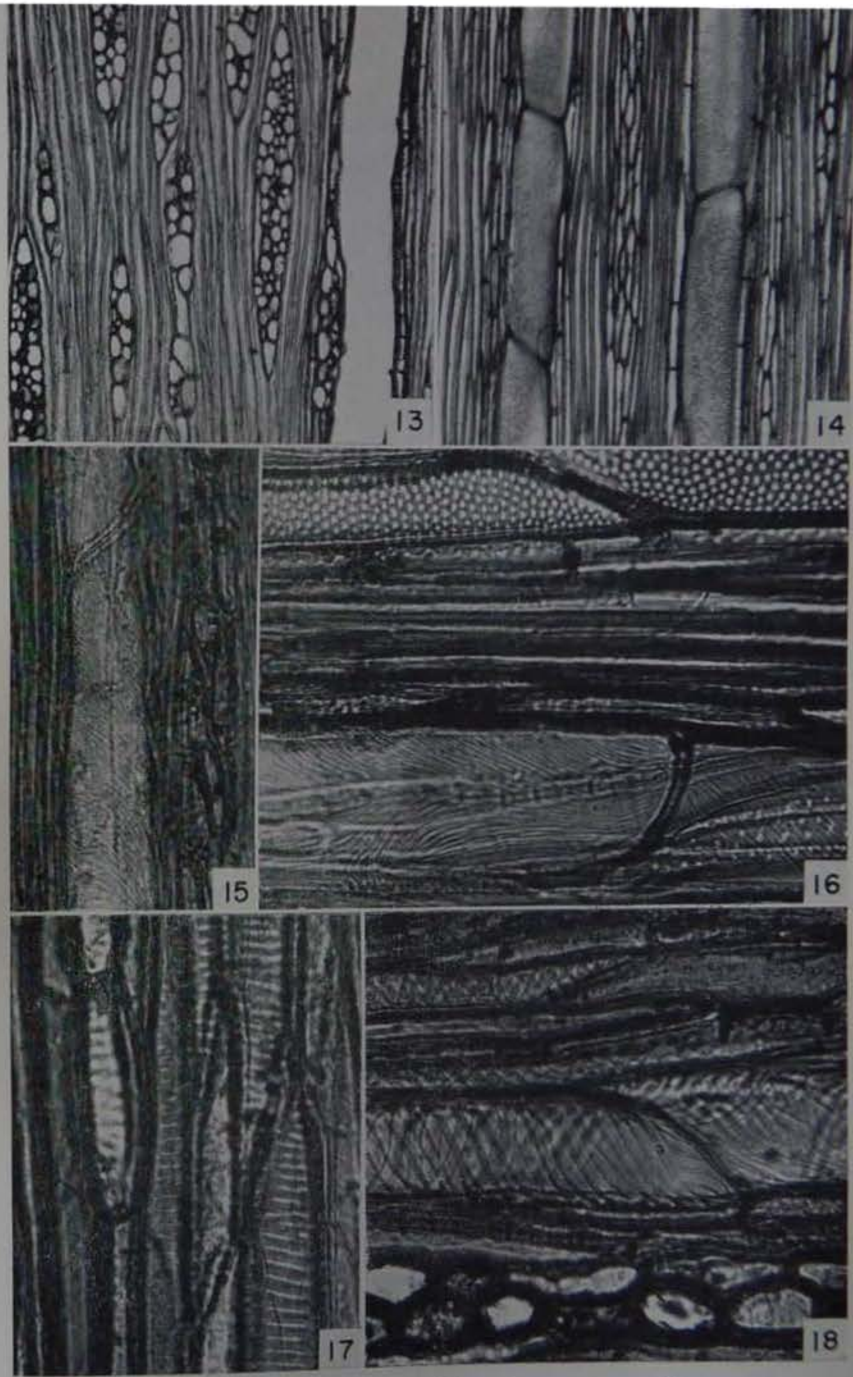

Fig. 13–18.—Fig. 13–14. Tangential sections. × 72.—Fig. 13. *Gongylolepis Martiana*.—Fig. 14. *Chuquiragua insignis*.—Fig. 15–18, portions of vessels from tangential sections to show lateral walls. × 360.—Fig. 15. *Neblinaea promontorium*.—Fig. 16. *Nouelia insignis*.—Fig. ... Fig. 18. *Flotovia leiocephala*. Collections

Paratracheal parenchyma is seen most prominently in the genera possessing apotracheal parenchyma (*Stifftia*, fig. 1; *Hesperomannia*, fig. 3). In these taxa, it forms a complete sheath, 1–2 cells thick, around each vessel or vessel group. Other genera, which lack apotracheal parenchyma (e.g., *Stenopadus*, fig. 7; *Stomatochaeta*, fig. 11; *Achnopogon*, fig. 12) show incomplete sheathing of vessels by vasicentric parenchyma. Disappearance of vasicentric parenchyma is perhaps best interpreted as advanced. As reported by Metcalfe and Chalk (1950), strands of 1–2 vasicentric parenchyma cells are characteristic of Compositae. The writer could not, however, confirm their finding of 2–4 or 6 cells in *Stenopadus* (see fig. 8), the typical condition of 1–2 being observed in the writer's material.

When genera with groupings of large numbers of vessels are considered, the interpretation of wood parenchyma forms a problem, one which is most apparent in those genera with a ring-porous tendency. Is all the parenchyma which is associated with groupings of vessels basically paratracheal, referable to the category "vasicentric-confluent" (Hess, 1950)? or is apotracheal parenchyma also involved in this grouping? The writer tends toward the former interpretation, since the presence of degenerate vessels (vascular tracheids) in such genera as *Proustia* renders likely the possibility that all parenchyma is associated with vessels in the broad sense. An interesting diffuse-porous instance is shown by *Wunderlichia* (fig. 6). In this genus, development of the megaphytic habit has probably been associated with emphasizing of vessels, expansion of associated parenchyma, and diminution of the area of fibers, which remain, however, thick-walled. It seems likely in *Wunderlichia*, that the abundance of parenchyma is directly correlated with abundance of vessels, and that only paratracheal parenchyma is involved ("vasicentric-conglomerate" of Hess, 1950). The small amount of secondary xylem produced in stems of this genus does not provide a clear interpretation, however. It is of interest, nevertheless, to contrast *Wunderlichia* with a genus quite similar in habit, *Chimantaea* (fig. 9, 10). In *Chimantaea*, the vasicentric parenchyma (probably basically quite scanty, as in its closest allies, *Stenopadus* and *Stomatochaeta)* is not expanded, although the cells are larger, nor are the vessels in larger groups. Instead the relatively soft wood is characterized by thin-walled fibers. In both *Wunderlichia* and *Chimantaea*, the megaphytic habit would seem to place less emphasis on mechanical strength in the secondary xylem, and the decrease in areas of thick-walled fibers in *Wunderlichia*, or the formation only of thin-walled, though abundant, fibers in *Chimantaea*, seem alternative adaptations to this habit.

Storied parenchyma occurs in some species of *Proustia* (Metcalfe and Chalk, 1950), and was observed by the writer in *Hecastocleis* (fig. 20). Other elements of the wood are non-storied. Storied rays, however, have been reported for the mutisioid genus *Gochnatia* (Metcalfe and Chalk, 1950). In view of the very advanced nature of the wood of *Proustia* and *Hecastocleis*, there seems little doubt that storied parenchyma in these is an advanced character, in agreement with the proposals of Bailey (1923).

VASCULAR RAYS

As indicated in table 1, Mutisieae may have both multiseriate and uniseriate rays, or either multiseriate or uniseriate exclusively. Most genera studied have both types of rays, and could be classified according to Kribs' (1935) Heterogeneous Type II. As will be noted from table 1, the shape of ray cells, as seen in radial section, is either mostly isodiametric, isodiametric to procumbent, or isodiametric to upright. Since ray cells of both uniseriate and multiseriate rays in a particular species were found to follow one of these patterns, a species could be classified as Heterogeneous IIA or Heterogeneous IIB according to whether erect or procumbent cells are present, respectively. Of those species having both multiseriate and uniseriate rays, most species possess multiseriate rays limited in width to 2–3 cells *(Stifftia*, fig. 2; *Stenopadus*, fig. 8). Even in those species with wide multiseriate rays, the central cells do not always show a tendency toward procumbency *(Hesperomannia*, fig. 4). Such instances as *Hesperomannia* show exception to the

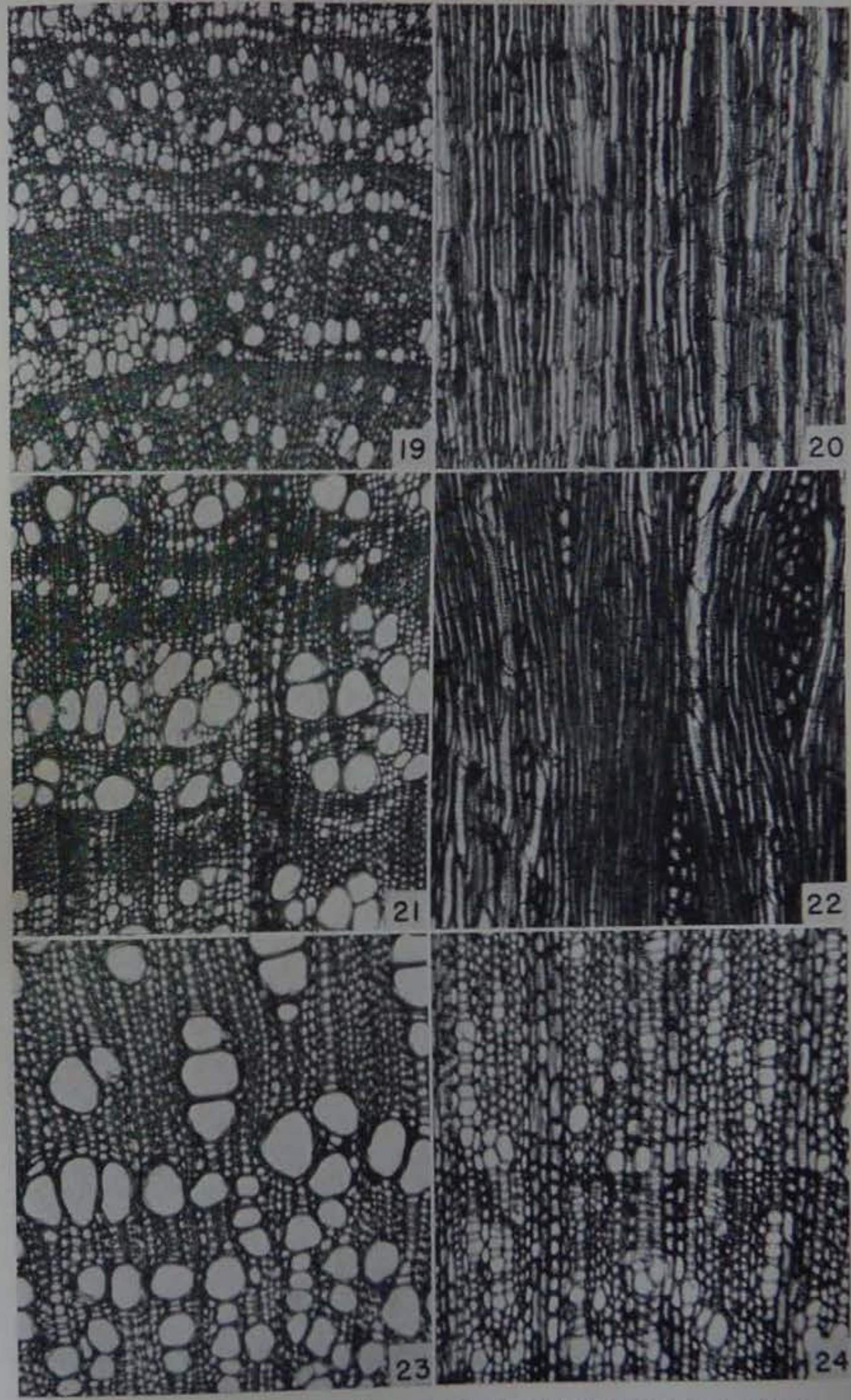

Fig. 19–24.—Fig. 19–20. *Hecastocleis Shockleyi*, transverse, tangential sections.—Fig. 21–22. *Proustia pungens*, transverse, tangential

description of Heterogeneous II by Kribs (1935). Examples of genera which do agree with his description in having procumbent cells in the central portion of the ray include *Gongylolepis* (fig. 13) and *Proustia* (Metcalfe and Chalk, 1950). The wide multiseriate rays of *Chimantaea* (fig. 10) are not to be regarded as multiseriate rays in the same sense as those of *Gongylolepis* since in *Chimantaea* the wide foliar rays are broken up into multiseriate rays rather tardily, and are present in the outer wood of rather old stems, a condition seen also in *Wunderlichia*. Barghoorn (1941) has noted the tendency for vertical elongation of ray initials, a tendency which ultimately results in their conversion to fusiform initials, thus forming a xylem lacking rays. While no ray-less woods were observed in Mutisieae, a number show markedly elongate ray cells (e. g., *Chuquiragua*, fig. 14). This tendency towards a predominance of erect rays cells seems best interpreted as an advanced character. In most taxa studied, the deviation from the isodiametric form toward either procumbency or erectness is small, however. The report of square to upright cells in *Stenopadus* (Metcalfe and Chalk, 1950) was not confirmed on the basis of the writer's material, which showed isodiametric to procumbent cells in rays.

A tendency toward the elimination of multiseriate rays was seen in a number of genera (table 1). In some (e.g., *Hecastocleis*, fig. 14), no multiseriate rays were found. In accordance with the interpretation of Kribs (1935) and Barghoorn (1941), this tendency seems to be an advanced condition in Mutisieae. Absence or scarcity of multiseriate rays has been reported in Mutisieae by Metcalfe and Chalk (1950) for *Gochnatia*, *Moquinia*, and *Stenopadus*. In a similar manner, the nearly complete absence of uniseriate rays in *Proustia*, and their absence in *Chuquiragua*, seem to be advanced. The writer agrees with Barghoorn (1941) and Metcalfe and Chalk (1950) that restriction to multiseriate rays does not necessarily involve homogeneity in the ray, as stated by Kribs (1935). The instances of both exclusively multiseriate and exclusively uniseriate rays show heterogeneity in ray structure for the Mutisieae in which these occur.

Relative vertical height of rays was found to vary considerably among the taxa studied. While those species having few or no multiseriate rays have relatively short rays, as one might expect, the species with abundant, wide multiseriate rays show either limited vertical height (*Gongylolepis*, fig. 13) or almost indefinite height (*Chuquiragua*, fig. 20). Because of the limited number of genera involved in this study which show significant differences in ray height, it seems difficult to draw any conclusions as to the phylogenetic significance of such variation within the group. Attention is called to these differences, however, as conspicuous taxonomic characters.

Resin Deposits and Crystals

In Compositae at large, deposition of resins either in canals, cavities, or ordinary intercellular spaces is common in vegetative parts of the plant. Compositae are seemingly lacking, however, in structures specialized for resin deposition within the secondary xylem. Resin deposits in secondary xylem, therefore, are usually formed within vessels, parenchyma cells, and less often in fibers adjacent to parenchyma. Among the photographs shown, conspicuous resin deposits are seen in *Stenopadus cucullatus* (fig. 7) and *Cnicothamnus Lorentzii* (fig. 5), in which many vessels are entirely filled with such contents. None of the other species showed such abundant deposits, although resins can be found to a small degree in many of the taxa considered.

The report of calcium oxalate crystals in ray cells of *Proustia pungens* (Metcalfe and Chalk, 1950) is confirmed here, although no other Mutisieae were observed to have crystals within the secondary xylem.

Discussion and Conclusions

The above descriptions show that wood of Mutisieae varies in a number of characters; the taxonomic pattern of correlations of these characters has indicated possible phylogenetic interpretation. These features have been compared with the interpretations of workers who have used a wide range of dicot woods. The relative discreteness of the group studied and the opportunity to compare the results of wood anatomy with studies of floral anatomy (Koch, 1930; Carlquist, 1957a) and pollen (Wodehouse 1928, 1929a, 1929b; Carlquist, 1957a) as well as gross morphology in Mutisieae have aided the writer in suggesting lines of specialization.

The following characters seem to be relatively primitive: relatively wide (55 microns or more) vessels; solitary or limited grouping of vessels, with no tendency toward ring porosity; vessels lacking prominent spiral thickenings; absence of vascular tracheids; non-storied wood; rays Heterogeneous II. Opposing or alternative characters are considered to be advanced. Genera studied which have all the primitive characters listed include *Cnicothamnus*, *Gongylolepis*, *Hesperomannia*, *Lycoseris*, *Stenopadus*, and *Stifftia*. It is worthy of note that all of these genera, with the exception of *Lycoseris* and *Stenopadus*, possess apotracheal parenchyma. Both isodiametric to erect and isodiametric to procumbent types of ray cells are found in these genera, however.

Specialized in one or two features are *Anastraphia*, *Barnadesia*, *Chuquiragua*, *Nouelia*, and *Trixis*. The most specialized genera are those with a ring-porous condition: *Flotovia*, *Hecastocleis*, and *Proustia*. In each of these genera, a series of advanced characters occurs, such as presence of vascular tracheids, and prominent helical thickenings on vessels and other elements. Characters other than these suggest that the three genera may not be closely related, however. Rays are both multiseriate and uniseriate in *Flotovia*, uniseriate only in *Hecastocleis*, and almost all multiseriate in *Proustia*. *Flotovia* and *Hecastocleis* differ from *Proustia* in having relatively narrow vessels, although vessel elements are relatively long in *Flotovia*, very short in *Hecastocleis*. The geographical separation of these genera also suggests their independent acquisition of a ring-porous condition.

Within the Guayana Mutisieae, the two genera, *Stenopadus* and *Gongylolepis*, suggested by Maguire to be primitive in Gochnatinae and Gerberinae respectively, appear to be relatively unspecialized in wood anatomy. This interpretation is supported by data from pollen and floral venation (Carlquist, 1957a). *Stenopadus* differs from *Gongylolepis* in its thicker-walled fibers and narrower multiseriate rays. In the genera most closely associated with *Stenopadus*, specializations are seen in *Stomatochaeta* (narrow vessels in radial rows, few multiseriate rays), *Chimantaea* and *Quelchia* (narrow vessels in radial rows, probable retention of metaxylem pitting, few multiseriate rays). Genera related to *Gongylolepis* are specialized in the following ways: *Achnopogon* and *Duidaea* have extremely narrow vessels in radial rows and lack multiseriate rays; *Neblinaea* has narrow vessels in radial rows, with helical thickenings on vessel walls. *Glossarion* seems most similar to *Gongylolepis* in its wood anatomy, and differs in few respects. The pattern of variation within the woods of Guayana Mutisieae does not contradict the idea that they represent a single phylogenetic unit, although specializations within the group are clearly evident.

The woods of Mutisieae studied here cannot resolve the question as to whether Compositae are ancestrally herbaceous, as postulated by Cronquist (1955), or ancestrally woody. Further study of a larger number of forms within the family is necessary for the correlated data required for such a conclusion. The writer believes, however, that the genera utilized in this study will prove to be significant in providing a clearer phylogenetic picture of the family.

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THE AMERICAN SPECIES OF *DACRYODES*

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The genus *Dacryodes* Vahl (Burseraceae) based on Puerto Rican specimens, was described by Vahl in 1810 in a Danish journal (Skrift. Dansk. Naturhist. Selsk. 6: 115). But the original description is better known through the copy published by Endlicher in his *Genera Plantarum* (p. 1425) in 1840. *Dacryodes* is derived from the Greek word *Dakryon*, meaning lachrymose or tearful, referring to the resinous exudate of the bark. The type species was called *D. excelsa* by Vahl. Bentham and Hooker in *Genera Plantarum* (1: 327. 1862) listed the genus as one of doubtful identification. In the *Flora of the British West Indian Islands* Grisebach (174. 1864), gave a somewhat more extensive description and added new localities in two more islands. He referred the species to *Amyris hexandra* Hamilton, 1825, and adopted this epithet to form *D. hexandra*, which is postdated. Marchand in his work on Burseraceae (Adansonia 8: 37. 1867), still could not see the definite position of *Dacryodes* among the other Burseraceae. Urban, in 1905 (Sym. Ant. 4: 323), gave a few new characters for the West Indian species and made known many new localities.

In the first comprehensive treatment of the Burseraceae, made by Engler in the de Candolles' *Monographiae Phanerogamarum* 4. 1883, *Dacryodes* appears with a more complete description, yet with a single species. But in the first edition of *Die Natürlichen Pflanzenfamilien* (3–4: 243. 1896), Engler joined *Dacryodes* to the African genus *Pachylobus* and used the binomial *Pachylobus hexandrus* for the West Indian species. The same criterion was followed in the second edition of *Pflanzenfamilien*, including here a second American species *P. peruvianus* Loes.

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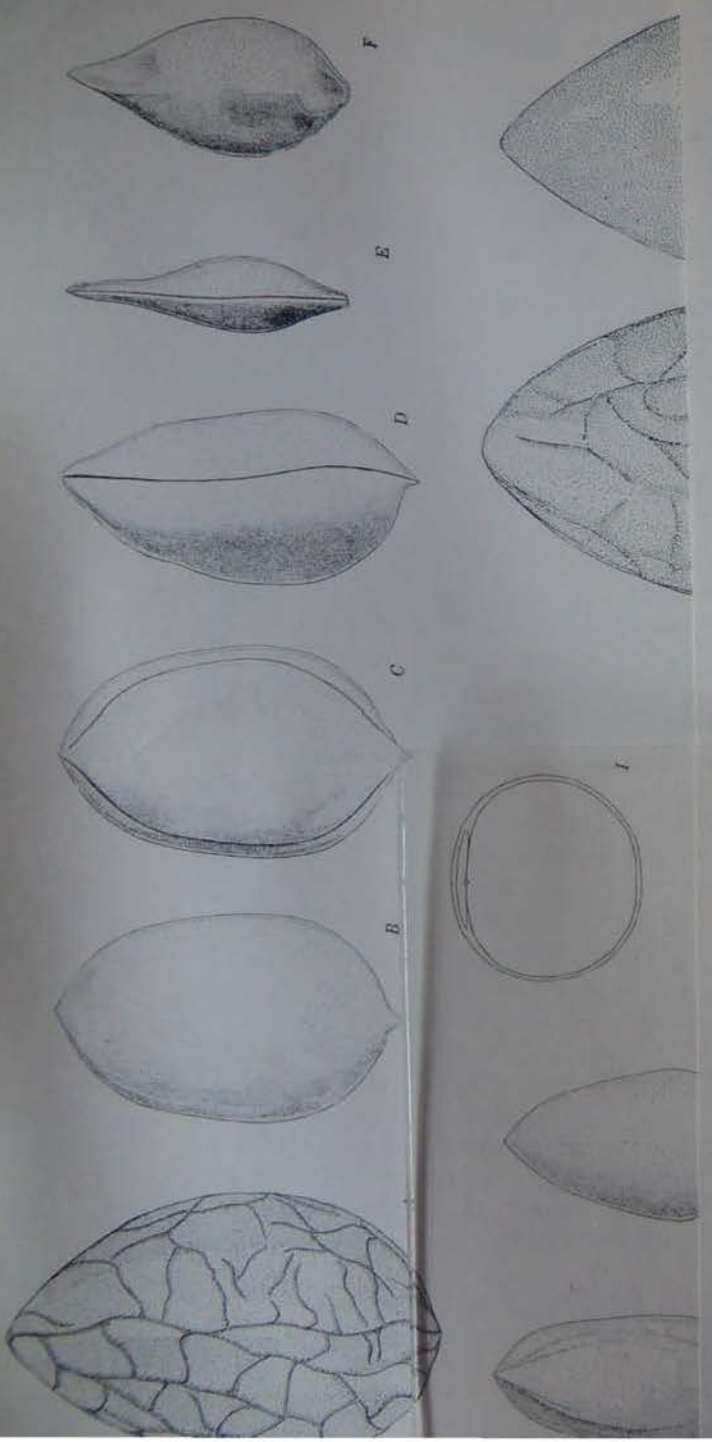

The genus *Pachylobus* was first published by G. Don with the African *P. edulis* as a type in 1832; as it is actually congeneric with *Dacryodes*, it has to be regarded as a synonym. Harms, the editor of volume 19a of *Pflanzenfamilien*, stated this fact in a footnote, reserving his responsibility for Engler's use of *Pachylobus*. The earlier name *Dacryodes* has been since used, as did Lam in his excellent monographic treatment of the Burseraceae of the Malay Archipelago and Peninsula (Bull. Jard. Bot. Buitenz. 12: 334. 1932) and in the recent *Flora Malesiana* (Ser. 1. 5: 219. 1956) and Macbride in his *Flora of Peru* (Field Mus. Nat. Hist. Bot. Ser. 13: 3:2: 716. 1949).

In the arrangement of the Burseraceae in tribes elaborated by Engler, the main feature in his separations is the degree of concrescence of the carpels in the fruit. In *Dacryodes* this concrescence is complete, so that the endocarp is practically a single plurilocular pyrene. For this reason it belongs to the tribe *Canarieae* Engler, being the only genus of this tribe (otherwise of considerable diffusion in the Old World tropics) present in America. The fruit is the most characteristic feature of *Dacryodes;* it is oblong-ovoid or ellipsoid, with a glabrous, carnose, corrugate pericarp when dry, with a rather thin corneous or cartilaginous endocarp, apical stigma and digitate and folded cotyledons (fig. 2). Through these characters it can be easily distinguished from the closely related Old World genera *Canarium*, *Santiria*, *Santiriopsis*, and *Haplolobus*.

The genus *Dacryodes* has a large representation in tropical Asia and Africa. According to the last account by Lam in 1956 (*Flora Malesiana* Ser. 1.5: 220), there are 22 species in Africa ascribed to the section *Pachylobus* Lam and 15 species between Cochin-China and Malaysia belonging to the section *Tenuipyrena* Engl. Many of these species were originally described in other genera, mostly under *Canarium* or *Santiria*. Most of the species are large rain forest trees of more or less economic value as low-quality timber and as a source of resins.

The American species form the section *Dacryodes*, slightly different from the Old World sections in their connate

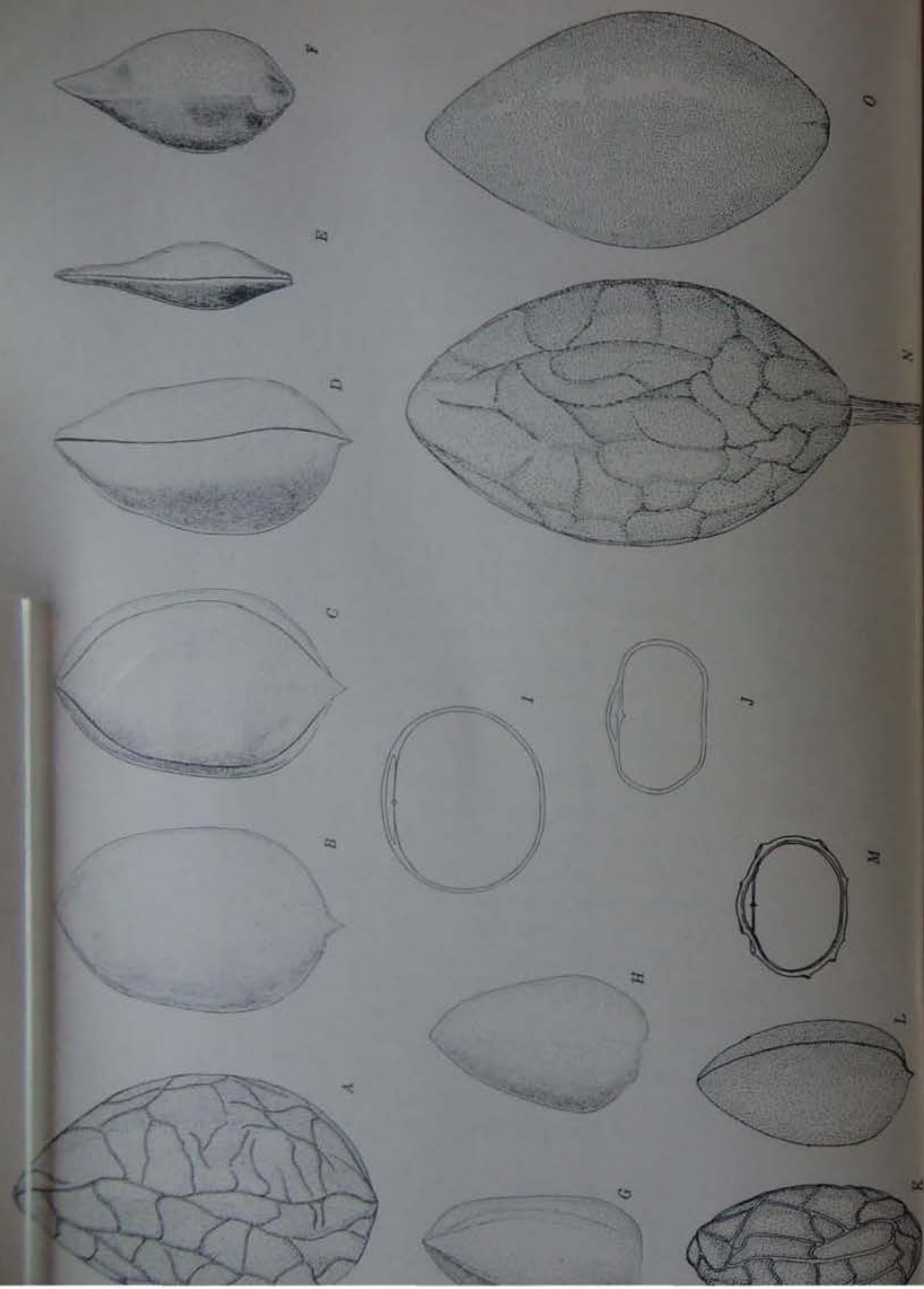

Fig. 2. Dacryodes granatensis: a. leaf and male inflorescence, × ¼; *b,* stamen inside view, *c.* stamen outside view, *d.* stamen lateral view, × 10; *e.* bud of a male flower, × 5; *f.* male flower open with a petal removed, *g.* male flower with petals and 3 stamens removed, × 5.

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n the Old World sections in their connate

sepals which form a truncate or subtruncate calyx, connivent anthers and a 3–2-celled ovary. Their affinity is strongest with the section *Tenuipyrena* (also with connate sepals), and this speaks for a common origin of the American and Asian species.

Until recently only two species were known from the American continent: the West Indian *D. excelsa* and the Peruvian *D. peruviana* (collected only once). During the author's explorations in Colombia it was realized that *Dacryodes* was also an important element in the composition of the Colombian primary forests. Considering only the west section of the country, four species could be described. Later collections by F. B. Lamb provided another species from the Magdalena Valley. A subsequent search in United States herbaria, brought to light more specimens of *Dacryodes* which in the past had been mostly confused with *Protium*, *Trattinickia*, or some other genus. Complementary material from Brazil, kindly sent to me by Dr. Murça Pires from Belém do Pará, has contributed to a better understanding of the Amazonian species.

On the whole, I would arrange the present available collections into 15 species distributed through Colombia, Ecuador, Peru, Venezuela, Brazil, and part of the West Indian islands. Although the collections are scarce (most species being represented only by one specimen), their geographical distribution shows a broad expansion of the genus covering a large tropical area of South America. The author is confident that future explorations of the American tropics will result in the discovery of new species and many new localities thus expanding the geographic range in the tropical area of distribution (fig. 1).

For the moment, it is thought advisable to publish a synopsis of the existing data of the genus for America, giving a key for the 15 species considered. In *Dacryodes*, as in other Burseraceae, the useful characters for identification are not always present in the specimens, for which reason the keys are based mostly on the shape and texture of the leaves. These characters, although taxonomically reliable, are often difficult to translate into descriptions. The following con-

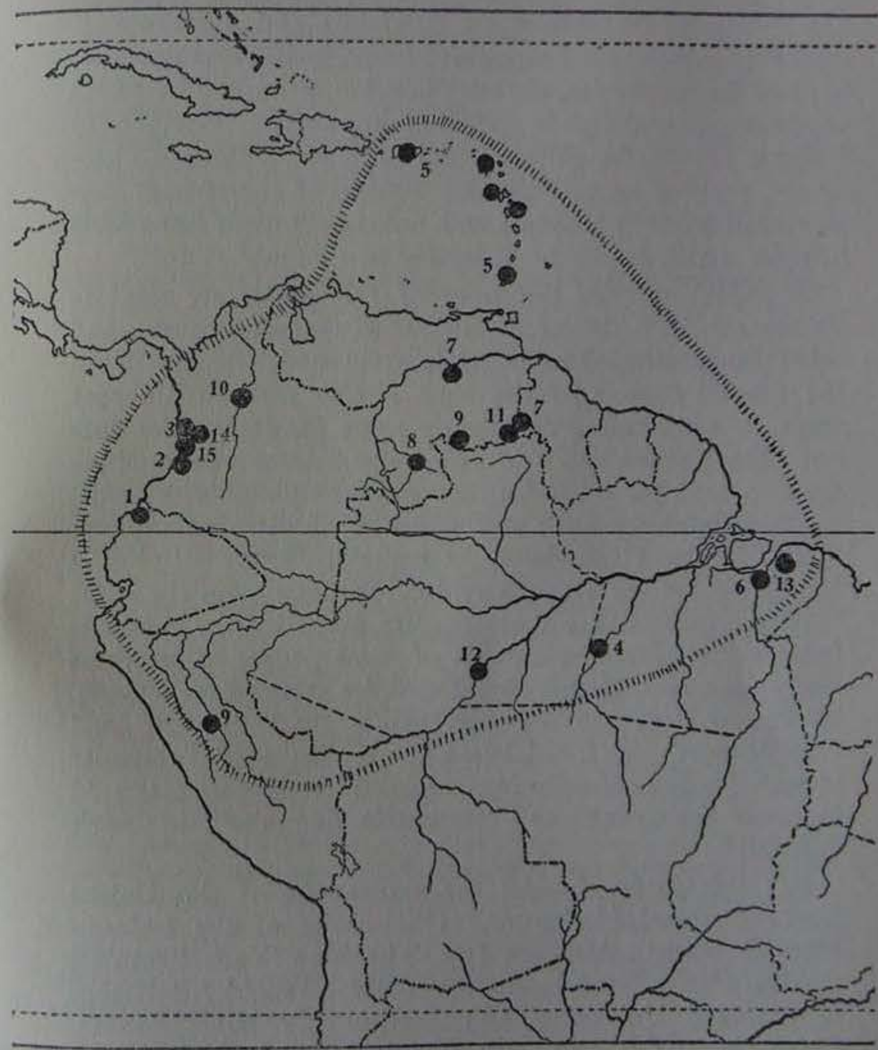

Fig. 1. Distribution of the genus *Dacryodes* sect. *Dacroydes*. Numerals refer to the numbered species listed in this synopsis.

cepts of Lam serve to emphasize these difficulties; referring to the Burseraceae Malesianae (*Flora Malesiana* 1. 5: 212): "As nearly all the species are dioecious, and moreover ♀ trees very rarely bear flowers and fruits at the same time, the keys to the species are, as far as possible, primarily based on vegetative characters. It appeared impossible, however, to frame a key to the genera based only on vegetative characters; without an intimate knowledge of the species it is indeed often very difficult and not rarely even impossible to refer sterile specimens definitely to a genus."

In South America the trees of *Dacryodes* are used as timber, which is similar in quality to that of *Protium* and other Burseraceae. The balsamic resin which exudes from the natural fissures of the bark is also used in different ways. A special common generic name for *Dacryodes* does not exist. Natives apply to its members some names which are also used for other Burseraceae. In Colombia the most common local name for *Dacryodes* is "anime." Pires quotes "breu sucuruba" as the only name in Brazil (Pará); in Venezuela for the Guyane region, Cardona gives the name "urá" and states that the seeds are eaten by the Arekuna Indians. Certainly the custom of some people to eat these seeds must be widespread but definite records are lacking. In Puerto Rico the common names are "tabanuco" and "candle tree"; in Guadaloupe "bois d'encens," "gommier blanc," "bois cochon"; in Dominica "bois gommier"; in Grenada "gommier" and "mountain gommier"; in Nevis "gumlin."

For this study, besides the collections of the United States National Herbarium (US), those of the Chicago Natural History Museum (F), The New York Botanical Garden (NY), Gray Herbarium (GH), Arnold Arboretum of Harvard University (A), Instituto Botánico, Bogotá, Colombia (COL), and the Facultad de Agronomía del Valle, Palmira, Colombia (VALLE), have been used.

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Pachylobus G. Don

DON, G. Gen. Hist. 6: 89. 1832.
ENGLER. Natürliche Pflanzenfamilien 3–4: 243. *fig. 138.* 1896.
ENGLER. Natürliche Pflanzenfamilien ed. 2. 19a: 450. *fig. 215.* 1931.

Flowers unisexual, trimerous. Sepals connate or free. Petals free, ovate, valvate, usually with an incurved thickened apex. Stamens obdiplostemonous, 6, glabrous; filaments flattened, free or connate to the back of the disc; anthers oblong-elliptic to ovate, dorsifixed to basifixed. Disc thick, discoid or cupular, intrastaminal, glabrous. Ovary ovoid, glabrous, 2–3-locular, in the male flowers usually reduced to a rudiment included in the conical center of the thickened disc; cavities 2-ovulate. Stigma sessile, subcapitate, entire or 2–3-lobate. Fruit drupaceous, ellipsoid or oblong-ovoid; pericarp carnose, balsamiferous, moderately thick or thin, wrinkled when dry; endocarp corneous, 2–3-locular, usually with only one large seminiferous (monospermous) cavity and one tiny, adpressed sterile cell. Seed elliptical, the episperm filmy, the cotyledons digitate and folded or contortuplicate. Dioecious evergreen trees, with resiniferous ducts in the bark and usually in the medulla of the petioles and twigs. Leaves alternate, imparipinnate; leaflets entire, petiolulate, mostly coriaceous or subcoriaceous. Stipules absent. Inflorescences paniculate, axillary or terminal.

SECTION *DACRYODES*

Section *Dacryodes* (Vahl) Engler *in* Natürliche Pflanzenfamilien. l. c. 451.
Section *Archidacryodes* Lam. Bull. Jard. Bot. Buitenz. l. c. 335.
Section *Dacryodes* Lam in Flora Malesiana. l. c. 220.

Sepals connate, the calyx cupular, truncate or subtruncate; anthers connivent; ovary 2–3 celled.

Key to the Species

1. Leaflet blades linear-oblong or elliptic-oblong, elongate, 3–4 times as long as wide, the reticulation very conspicuous. ....2.
1. Leaflet blades ovate or elliptic, usually less than twice as long as wide. ....4.
2. Leaflet blades membranaceo-chartaceous, thin, flexible, with prominent lax reticulation, linear-oblong, attenuate towards the apex, abruptly cuspidate, obtuse-cuneate or obtuse at the base, glabrous above, with very scattered and minute hairs beneath, 17–24 cm. long, 5–6 cm. wide, the acumen 2.5–5 cm. long, the secondary nerves 15–20 pairs. Petiole 16 cm. long, appressed-pubescent or puberulous. Calyx cupuliform, truncate. Petals 2 mm. long. Terminal branchlets appressed-pubescent. ....1.*D. cupularis.*
2. Leaflet blades coriaceous, firm, finely reticulate. ....3.
3. Leaf rachis glabrous or subglabrous. Blades elliptic-oblong or obovate-oblong, obtuse-cuneate or obtuse at the base, subrounded or moderately attentuate and abruptly acuminate at the apex, glabrous, with a fine, prominent reticulum on both sides, 8–20 cm. long, 4.5–7 cm. wide, the acumen 5–8 mm. long, the secondary nerves 10–14 pairs. Petioles puberulous, 12–16 cm. long. Internodes 4–5 cm. long, glabrous. Inflorescences about 9 cm. long, shortly puberulous. Calyx truncate, obsoletely 3-dentate, glabrous. Young branchlets puberulous, later glabrate. Leaves 3-jugate. ....2.*D. granatensis.*
3. Leaf rachis minutely tomentose. Blades oblong, rounded at base, obtusely and abruptly acuminate at the apex, glabrous or very scarcely and minutely papillose-pilose, with a fine reticulum (weak above, strongly prominent beneath), 20–26 cm. long, 5.5–6.5 cm. wide, the acumen 15 mm. long, the secondary nerves about 16 pairs. Petioles 20 cm. long, short and appressed tomentulose. Internodes 4–7 cm. long. Inflorescence 10 cm. long, minutely tomentose. Fruit lanceolate-obovoid, flattened, 22–24 mm. long, 12 mm. wide. Branchlets minutely tomentose. Leaves 4–5-jugate. ....3.*D. acutipyrena.*
4. Blades membranaceo-chartaceous, thin, ovate-oblong or oblong-elliptic, rounded or very obtuse at the base, narrowed towards and acuminate at the apex, glabrous, with 11–12 pairs of spreading secondary nerves slightly prominent underneath, the fine reticulation slightly prominent but very conspicuous, the size 8–14 cm. long, 3.5–5.2 cm. wide, the acumen 6–12 mm. long. Petioles 5–7 cm. long, glabrous or subglabrous. Internodes 2.5–4 cm. long, slender, glabrous. Inflorescence 9 cm. long, glabrous. Fructiferous pedicels glabrous, 6–10 mm. long. Fruits ovoid, about 9 mm. long, 5 mm. wide, 4 mm. thick. Leaves 2–3-jugate. Young branchlets subglabrous. ....4.*D. paraensis.*
4. Blades coriaceous or subcoriaceous. ....5.

5. Leaves small, the leaflets usually 2–12 cm. long, 1.5–6 cm. wide. ..6.
5. Leaves larger with leaflets usually 8–28 cm. long and 4–10 cm. wide. ....10.
6. Leaflet blades thick, firmly coriaceous. Fruits fairly large (18–28 mm. long.). ....7.
6. Leaflet blades subcoriaceous, flexible, firm, glabrous. Leaves 1–2-jugate. Fruit small (8–15 mm. long). ....8.
7. Blades slightly reticulate above, strongly reticulate beneath, ovate or elliptic-ovate, subrounded or obtusely cuneate at base, rounded or obtuse at apex, sometimes abruptly and obtusely acuminate, (minutely and scarcely scaly-pilose beneath), usually 8–12 cm. long, 4.5–6 cm. wide (rarely 6–17 × 7.5–9 cm.), the reticulation coarse and almost obsolete above and fine and prominent beneath, the secondary nerves 8–9 pairs. Petioles 2–6 cm. long, minutely puberulous or glabrate. Internodes 2–4 cm. long. Inflorescence 7–10 cm. long, minutely and sparsely puberulous. Calyx truncate, 2 mm. across. Petals 2.1–2.4 mm. long. Fruit 24–28 mm. long, 13–15.5 mm. broad. Young branchlets shortly appressed-puberulent. Leaves 1–3-jugate. ....5.*D. excelsa.*
7. Blades strongly reticulate above, slightly so beneath, oblong-elliptic or ovate-oblong, obtusely cuneate at the base, abruptly and shortly acuminate at the apex, glabrous above, shortly puberulous beneath, 6.12 cm. long, 2.5 cm. wide, the acumen 3.5 mm. long, the secondary nerves 10–12 pairs. Petioles 2.5–4 cm. long, minutely puberulous or glabrous. Internodes 2–3 cm. long, minutely pubescent. Inflorescences to 10 cm. long, shortly pubescent. Fructiferous pedicels 10–12 mm. long. Fruit 18–20 mm. long, 11–12 mm. broad. Young branchlets minutely appressed-pubescent. Leaves 2–3-jugate. ....6.*D. belemensis.*
8. Inflorescences 1–3 cm. long, branched from near the base, the axis and branchlets rather thick, angular, minutely and sparsely puberulous. Flowers glomerate, sessile or subsessile. Leaflet blades small, firm, ovate or elliptic-ovate, rounded at the base, abruptly narrowed at the apex, obtuse-acuminate, with a fine and very prominent reticulum on both sides, 2.5–6.5 cm. long, 1.5–3.5 cm. wide, the secondary nerves 6–8 pairs. Fruit ellipsoid, 9–10 mm. long, 6–7 mm. broad. ....7.*D. glabra.*
8. Inflorescences longer, lax, glabrous throughout, 3–7 cm. long, with a slender, flexible axis and branchlets. Pedicels 2–5 mm. long, leaflet blades flexible, ovate-elliptic, rounded or obtuse-cuneate at the base, attenuate and cuspidate at the apex, with 11 pairs of slender and prominulous secondary nerves beneath, the fine reticulation slightly prominent but conspicuous above and strong underneath. Sepals and petals glabrous. ....9.
9. Leaves 1–2-jugate with leaflets ovate or elliptic-ovate, 5–11 cm. long, 3–6 cm. wide. Fruit about 10 mm. long, 6 mm. broad.............. ....8.*D. microcarpa.*

9. Leaves 1-3-jugate with leaflets ovate-lanceolate, 7–14 cm. long, 2.7–5 cm. wide. Fruit about 14–15 mm. long, and 8 mm. wide. ....*D. microcarpa* var. *lanceolata.*

10. Blades coriaceous. ....12.

10. Blades subcoriaceous, flexible, large, broadly elliptic-oblong or ovate-oblong, 15–28 cm. long, 7–10 cm. wide (or the lower ones ovate and smaller), subrounded or obtuse at the base, somewhat attenuate and obtusely acuminate at the apex (acumen 1–2 cm. long), glabrous, the reticulation sublax and prominent on both sides. Petioles 11 cm. long, pulverulent or glabrate. Inflorescences 22 cm. long, with minutely papillose-pulverulent branchlets. Calyx subtruncate, obsoletely 3-dentate. Petals 2 mm. long. Young branchlets appressed-pulverulent-puberulous. ....11.

11. Blades with 13–15 pairs of secondary nerves; the rachis internodes 3–4 cm. long. ....9.*D. peruviana.*

11. Blades with 8–12 pairs of secondary nerves; the rachis internodes 6–9 cm. long. Fruits 22–23 mm. long, 14–16 mm. wide. Endocarp about 20 mm. long and 15–16 mm. broad. ....*D. peruviana* var. *caroniensis.*

12. Blades minutely ferrugineo-tomentose beneath (chiefly along the nerves), elliptic-oblong, rounded or obtuse at the base, narrowed and acuminate at the apex, 7–10 cm. long, 3–4 cm. wide, with 10–14 pairs of secondary nerves, the fine reticulation prominent beneath and flat above. Petioles about 12 cm. long, tomentose-puberulent. Internodes about 2 cm. long. Inflorescences about 15 cm. long, ferrugineo-tomentose. Fruit ellipsoid, about 30 mm. long, 18 mm. wide, 12 mm. thick, the endocarp 28 mm. long, 11–15 mm. wide. ....10.*D. colombiana.*

12. Blades glabrous or minutely and sparsely appressed-pilose. ......13.

13. Leaflets thick, rigid-coriaceous, the venation immersed or slightly conspicuous above and obsolete or slightly prominent beneath. ..14.

13. Leaflets coriaceous, less rigid with more conspicuous venation. ..15.

14. Fruit small (15–17 mm. long, 10–11 mm. broad.), the endocarp 15–16 mm. long, 9–10 mm. broad. Blades oblong, obtuse cuneate at the base, attenuate at the apex, obtusely acuminate, 8–18 cm. long, 3.5–7 cm. wide (acumen 5–10 mm. long), the spreading secondary nerves 11–14 pairs, the reticulation obtusely prominent. Petioles minutely pulverulent. Internodes 2.5–5 cm. long. Inflorescences 8–12 cm. long, minutely pulverulent-puberulous. ....11.*D. roraimensis.*

14. Fruit large (29–32 mm. long, 17–19 mm. broad), the endocarp 28–30 mm. long, 17–14 mm. broad. Blades larger, oblong-ovate or oblong-elliptic, obtusely cuneate at the base, narrowed towards the apex, scarcely acuminate, 11–14 cm. long, 5.5–9 cm. wide (acumen 0.5 mm. long), the ascendent secondary nerves 8–10 pairs. Petioles 8–15 cm. long, minutely puberulous or glabrate. Internodes 4–7 cm. long. Young branchlets minutely appressed-puberulous. ....12.*D. sclerophylla.*

15. Leaflets rather thick and firm with slightly prominulous but with a very conspicuous reticulum above. Blades elliptic-oblong (or the lower and terminal ones obovate-elliptic), obtusely cuneate at the base, rounded at the apex, abruptly acuminate, subglabrous (minute scarce hairs beneath), with 12 pairs of slender, prominent, spreading secondary nerves, with prominulous reticulum beneath; 10–18 cm. long, 7–7.5 cm. wide, the acumen 4–8 mm. long. Petioles 10 cm. minutely pubescent. Internodes 4.5 cm. long. Inflorescences 12–18 cm. long, shortly pubescent. Fructiferous pedicels incrassate at apex, 10–12 mm. long. Fruit 30 mm. long, 20 mm. broad, 16–17 mm. thick, shiny; the endocarp 27 mm. long, 15–17 mm. broad. ....13.*D. nitens.*

15. Leaflets more or less flexible, not at all minutely and prominently reticulate above. ....16.

16. Blades with 14–20 pairs of spreading secondary nerves, very prominent beneath and with a conspicuous, more or less prominent, reticulum beneath; the shape ovate, elliptic-ovate, sometimes oblong, rounded or obtusely cuneate and asymmetrical at the base, slightly attenuate and obtusely acuminate at the apex; 8–20 cm. long, 3–8 cm. wide (acumen to 10 mm. long). Petioles 10 cm., subglabrous, with scarce, shortly squamulose hairs. Internodes 1.5–3.5 cm. long. Inflorescences 6–7 cm. long, minutely tomentose. Fruit 26–30 mm. long, 18–20 mm. broad, the endocarp 25–28 mm. long, 15–18 mm. broad. Young branchlets pubescent, later glabrous. ....14.*D. olivifera.*

16. Blades with 8–11 pairs of ascendent secondary nerves, prominent beneath and with lax, slightly prominent reticulum; the shape ovate, ovate-elliptic or elliptic, rounded or subrotundate at the base, obtuse or rounded at the apex, abruptly acuminate, 11–20 cm. long, 7–10 cm. wide, (acumen 10–12 mm. long). Petiole 6–9 cm. long, puberulous. Internodes glabrous, 4.5–5 cm. long. Inflorescence 6 cm. long, minutely puberulous. Fruit 22–25 mm. long, 13–16 mm. broad, the endocarp 20–11 mm. long. Young branchlets minutely pubescent. ....15.*D. occidentalis.*

1. **Dacryodes cupularis** Cuatr. sp. nov.—Arbor grandis ramis terminalibus viridi-ochraceis subteretibus sparse lenticellatis minute adpresseque pubescentibus.

Folia alterna imparipinnata 5-juga circa 60 cm. longa. Petiolus 16 cm. longus leviter striatus supra canaliculatus basi incrassatus, minute adpresseque pubescens subochraceus. Internodia rhachis 2.5–5 cm. longa angulosa striolata supra superne carinata minute pubescentia. Petioluli 7–10 mm. longi striati minute puberulenti terminalis 3.5 cm. longus. Foliola membranaceo-papiracea lineari-oblonga basi sensim angustata inaequilatera obtusa vel obtuse cuneata, ad apicem attenuata et cuspidata, margine integra, 17–24 cm. longa 5–6 cm. lata acumine 10–15 mm. longo; supra glabra viridia costa anguste prominenti basim versus saepe minutissime puberula, nervis secundariis reticuloque visibilibus paulo prominulis; subtus palliodiora costa eminenti striolata nervis secundariis 15–20 utroque latere teneribus prominentibusque patulis ad marginem arcuato anastomosatis venulis in reticulum sublaxum bene prominulum anastomosatis, superficie visu glabra sed minutissimis pilis squamulosis sparsis praedita interdum pilis minutis adpressis ad costam instructa.

Inflorescentiae masculae anguste thyrsoideo-paniculatae axillares elongatae 10–24 cm. longae, axi subrecto vel flexuoso tenui anguloso etiam cum ramis ramulisque minute pubescentibus vel puberulis, bracteolis brevibus ad 1 mm. longis puberulis ovato-lanceolatis. Pedicelli 1–2 mm. longi crassiusculi adpresse pubescentes. Flores masculi trimeri. Calyx late cupularis, margine truncato laevis, circa 0.7 mm. altus basi paulo puberulis reliquus glaber. Petala 3 libera late ovata obtusa crassa glabra sed margine papillosa 2 mm. longa 2 mm. lata, in anthesi recurvis. Stamina 6 filamentis planis glabris 0.4 mm. longis et latis antheris crassis obovato-ellipsoideis paulo bilobatis glabris circa 1 mm. longis et crassis in anthesi paulo incurvis et conniventibus. Discus valde crassus cum ovarii rudimento tuberculo centrale crasso subacuto instructus.

ECUADOR: ESMERALDAS, at Playa de Oro, 1 km. east up Rio Santiago. Large tree. Bark of wood sample gray, smooth and many whitish round lenticels 1 mm. Large pinnately compound leaves. Minute green flowers in panicles. "anime." Collected 1 April 1943, *E. L. Little 6416* (HOLOTYPE, US).

Dacryodes cupularis is characterized by its slender, papery, narrow and elongate leaflets, by the very short pubescence of its branchlets, petioles and leaf rachis, by its elongate and pubescent inflorescences, and by the cupular calyx of the male flowers which is obvious even in the bud stage.

2. **Dacryodes granatensis** Cuatr. Notas Fl. Colombia XII. Rev. Acad. Col. de C. E. F. y N. 8: 473. 1952. fig. nostra 2.

COLOMBIA: VALLE, Cordillera Occidental, vertiente occidental; Hoya del rio Anchicayá, lado derecho, bosques entre Pavas y Miramar, 350–450 m. alt. *Cuatrecasas 14413* (HOLOTYPE, F; ISOTYPE, VALLE).

3. **Dacryodes acutipyrena** Cuatr. Notas Fl. Colombia XII. Rev. Acad. Col. de C. E. F. y N. 8: 474. *fig. 1, 2 y 3.* 1952.

COLOMBIA: VALLE, bajo rio Calima, entre Pailón y El Coco, 50 m. alt., *Cuatrecasas 21260* (HOLOTYPE, F; ISOTYPE, VALLE).

4. **Dacryodes paraensis** Cuatr. sp. nov.—Arbor ramulis terminalibus badiis paulo angulatis aspectu glabris sed minutissimus pilis sparsis praeditis.

Folia alterna imparipinnata 2–3-juga 20–28 cm. longa. Petiolus 5–7 cm. longus tenuis subteres basi valde incrassatus glaber vel minutissimis pilis adpressis sparsissimis munitus. Internodia rhachis 2.5–4 cm. longa glabra tenuia sed rigida subteretia. Petioluli 3–8 mm. longi glabri angulosi supra sulcati flexuosi terminalis 14–25 mm. longus. Lamina membranaceo-chartacea flexibilis ovato-oblonga vel elliptico-oblonga basi rotundata vel obtusissima apice angustato-acuminata margine integerrima plana 8–14 cm. longa 3.5–5.2 cm. lata, acumine obtusiusculo 6–12 mm. longo 3–4 mm. lato, utrinque glaberrima; supra costa conspicua subimmersa leviter carinata nervis secundariis rubropallidis conspicuis nervulis in reticulo filiformi prominulo; subtus costa prominula carinata vel sulcata nervis secundariis filiforme prominulis 11–12 utroque latere patulis pallide rubescentibus marginem versus arcuato anastomosantibus venulis teneribus prominulis reticulatis.

Inflorescentia axillaris fructifera 9 cm. longa glabra. Pedicelli fructiferi teneres rigidi glabri apice incrassati 6–10 mm. longi.

Drupa (specimine singulo) ovata in sicco 9 mm. longa 5 mm. lata 4 mm. crassa pericarpio carnoso tenui in sicco rugoso endocarpio chartilagineo rigidiusculo biloculare uno loculo lato fertile altero minusculo sterile.

BRAZIL: ESTADO DO PARÁ: Vila Nova rio Tapajós logo abaixo da Cachoeira Chacorão 12 km. abaixo da Cachoeira Capoeira, mata de terra firme, 23 December 1951, *J. M. Pires 3613* (HOLOTYPE, US).

Dacryodes paraensis is closely related to *D. microcarpa* from which it differs by its larger leaves with 2–3 pairs of leaflets, by the more slender rachises and petioles, which are longer, and by the submembranaceous, usually oblong leaflets with a prominent, slender reticulation.

5. **Dacryodes excelsa** Vahl. Skrift. Dansk. Naturhist. Selsk. 6: 116. Urban. Symbolae Antillanae 4: 323. 1905. Rose, North American Flora 25: 258. 1911. Britton and Wilson, Botany of Porto Rico, N. Y. Acad. Sci. 5: 462. 1924. *Amyris hexandra* Hamilton. Prodr. Fl. Ind. Occid. 34. 1825. *Bursera acuminata* in DC. Prodr. 2: 78. 1825, not *B. acuminata* Willd. *Dacryodes hexandra* (Hamilton) Griesbach. Flora British West Indian Islands. 174. 1864. *Pistacia occidentalis* Baillon, Adansonia 9: 181. 1874. *Pachylobus hexandrus* (Hamilton) Engler. Natürliche Pflanzenfamilien 3–4: 243. 1896; ed. 2, 19a: 452. 1931.

Illustrations: DC. Monogr. Phanerog. 4: *pl. 3 fig. 39–44.* Contr. U. S. Natl. Herb. 8: *pl. 34.* Natürliche Pflanzenfamilen 3–4: *fig. 138;* ed. 2, 19a: *fig. 215.*

PUERTO RICO: SIERRA DE LUQUILLO, *Eggers 1314;* "tabonuco," *Holdridge 206;* in monte Jimenes, *Sintenis 1416;* Catalina-Yunque Trail, 425 m., *Britton & Bruner 7673;* MONTE MORALES, near Utuado, *Britton & Cowell 449;* CIELITOS, *Britton & Britton 7964;* FAJARDO, Rio Arriba, *Britton & Shafer 1672;* prope MARICAO in sylvis circa Hacienda, *Sintenis 231;* TABUCOA, in sylvis montis Guayava, *Sintenis 5299.*

GUADALOUPE: Bois DES BANS-JAMES, Houelmont, Morne Gabelin 300–800 m., "bois d'encens," "gommier blanc," *Père Duss 3492;* Morne Gabelin, Gombegu, *Père Duss 3307;* MORNE ROUGE DU LORRAIN, Savanne Chizeau, 400–800 m., ça et la dans les grands bois du champflore, "bois cochon," "gommier blanc," *Père Duss 1946.*

DOMINICA: Rainforest bordering IMPERIAL ROAD, 549 m., (rainfall 508 cm.), rich volcanic soil underlain with hardpan; trunk used by Caribs for canoes, trunk gray smooth pillar-like 30–50 m. tall, to 2 m. diam., "bois gommier" *Hodge 653.*

ST. KITTS: In the forest BELMONT ESTATE, *Britton & Cowell 381.*

GRENADA: GRAND ETANG RESERVE, rain forest large tree 30 m., flowers yellow, yields aromatic gum and useful timber, "gommier," *Pamela Beard 1300;* MT. FELIX, in sylva, arbor 100' alt., fruct. oliviformibus, *Eggers 6082;* GRAND ETANG, *Broadway. November 1896;* MIRABEAU MOUNTAINS, St. Davids "mountain gommier," *Broadway. November 1896.*

Britton and Wilson (Botany of Porto Rico 5: 462) give the following information about this tree: "Forests, mostly at higher elevations, the most majestic tree of Porto Rico; Montserrat to Grenada. The brown wood is hard, heavy and strong, used for furniture, in carpentry and construction. The trunks and roots exude a white fragrant resin, used for candles and torches; tabanuco, candle tree."

6. **Dacryodes belemensis** Cuatr. sp. nov.—Arbor ramulis terminalibus adpresse pubescentibus pilis minutissimis tectis, paulo striatis et lenticellati-verrucosis.

Folia alterna imparipinnata 2–3-juga, 15–22 cm. longa. Petiolus 2.5–4 cm. longus striolatus supra planus basi incrassatus minutissimis pilis subsquamosis adpressis praeditus vel denique glabratus. Internodia rhachis 2–3 cm. longa leviter striata minutissime pubescentia. Petioluli 4–6 mm. longi pubescentes crassiusculi supra sulcati recti vel flexuosi, terminalis 18–23 mm. longus tenuis utrinque extremis incrassatis. Lamina firme coriacea oblongo-elliptica vel ovato- vel obovato-oblonga basi paulo attenuata obtuse cuneata paulo asymmetrica apice subite breviterque acuminata margine integra leviter revoluta, 6–12.5 cm. longa 2–5 cm. lata, acumine obtusiusculo 3–5 mm. longo 3–4 mm. lato; supra glaberrima costa angustissima prominenti nervis secundariis discoloribus venulis reticulatis prominulis; subtus costa eminenti carinata plus minusve striata nervis secundariis 10–12 utroque latere prominentibus patulis prope marginem curvato-anastomosatis reliquis

nervulis reticulum conspicuum prominulum formantibus, pilis minutissimis ochraceis vel rubellis ad costam copiosis in cetera sparsis praedita.

Inflorescentia ad 10 cm. longa, in specimina statu fructifero, ramis ramulisque angulosis minute pubescentibus. Pedicelli fructiferi 10–12 mm. longi apice ampliati. Drupa ovoidea vel ellipsoideo-ovoidea 18–20 mm. longa 11–12 mm. lata, pericarpio tenui in sicco rugoso olivaceo glabro, endocarpio corneo ovoideo 16–18 mm. longo circa 10 mm. lato.

BRAZIL: BELÉM EM TERRAS DO INST. AGRON. DO NORTE (Reserva de floresta nativa), Horto Mucambo, arvore no. *10–18, J. M. Pires* (HOLOTYPE, US).

Dacryodes belemensis differs from *D. roraimensis* essentially in its smaller leaves with fewer leaflets and more slender rachis, and by its thinner, smaller and shorter leaflets which are reticulate and glabrous above and more puberulous beneath; it also differs in its larger fruits.

7. **Dacryodes glabra** (Steyerm.) Cuatr. comb. nov.—*Trattinickia glabra* Steyermark, Fieldiana. Botany 28: 277, 1952.

Folia 6–12 cm. longa 1–2-juga. Petiolus 2–3.5 cm. longus. Petioluli 4–5 mm. terminalis 6–10 mm. Foliola firmula tenuiter coriacea ovata vel elliptico-ovata basi rotundata apice subite angustata obtuse acuminata margine integra 2.5–6.5 cm. longa 1.5–3.5 cm. lata; supra costa discolor subplana conspicua nervis secundariis paulo conspicuis nervulis minute reticularis bene prominulis; subtus costa elevata nervis secundariis prominulis 6–8 utroque latere patulis prope marginem arcuato-anastomosatis venulis in reticulum bene prominulum notatis.

Inflorescentiae axillares 1–3 cm. longae paniculatae ad basim ramosae ramulis crassis rigidis brevibus angulosis minutissime sparseque puberulis. Flores masculi glomerati sessiles vel subsessiles. Calyx breviter cupularis 3-lobato-sinuatus subglaber (sparsissimis minutissimis pilis). Petala 3 libera rigida crassa rotundato-ovata obtusa vel obtusiuscula rubescentia dorso minutissimis sparsis pilis munita margine papillosa, 2–2.4 mm. longa et lata. Antherae triangulari-ovoatae subsessiles glabrae 0.6 mm. longae. Discus crassus subplanus 6-lobatus 1.5 mm. diam. glaber. Ovarium rudimentarium in disco inmersum. Stylus minimus bilobatus. Drupa ellipsoidea 9–10 mm. longa 6–7 mm. lata in sicco epicarpio rugoso glabro, endocarpio corneo tenui ovato-elliptico basi rotundato apice obtuso biloculari uno loculo lato fertili altero minimo vacuo.

VENEZUELA: BOLÍVAR, savanna bordering forest of Rio Karuai, between Santa Teresita de Kavanayén and base of Ptari-tepui, 1220 m. alt., shrub 8–12 ft. tall, leaves subcoriaceous dark green above, dull green below, perianth deep brick, calyx dull green, 18 November 1944, *Steyermark 60312* (HOLOTYPE, F; ISOTYPE, NY); Cerro

Bolívar, bushy tree 1–4 m., flowers reddish brown, occasional above tunnel E-5, 750 m., 25 February 1953, *Wurdack 34389;* shrub or small tree 2 m. tall, occasional on ore body near hard ore bench, 2 December 1951, *B. Maguire 32688*.

8. **Dacryodes microcarpa** Cuatr. sp. nov. fig. nostra 3.—Arbor ramulis terminalibus valde juvenilibus sparsis pilis adpressis mox glaberrimis, squamato-resinosis.

Folia alterna imparipinnata 1–2-juga, saepe trifoliolata interdum bifoliolata 12–20 cm. longa. Petiolus 2.5–5 cm. longus paulo striatus fuscus nitidus glaberrimus. Internodia rhachis 1.5–4 cm. longa glabra leviter striata. Petioluli laterales 6–11 mm. longa, terminales 1.2–3 cm. longi, glabri squamoso-resinosi. Foliola tenuiter coriacea glabra, ovata vel elliptico-ovata basi obtuse cuneata vel subrotundata apicem versus angustata et subite in acumen producta margine integerrima, 5–11 cm. longa 3–6 cm. lata, acumine 7–15 mm. longo 2–3 mm. lato acutiusculo; supra costa bene conspicua sed immersa, nervis secundariis reticuloque obtuse elevatis discolore conspicuis areolis inter reticulum plus minusve impressis; subtus costa lata prominula nervis secundariis praecipue 10 utroque latere filiforme prominulis paulo ascendentibus prope marginem tenuioribus arcuatis evanescenti-anastomosatis, nervulis gracilem reticulum elevatum formantibus.

Inflorescentiae axillares et subterminales 3–8 cm. longae pauciflorae axi ramulisque tenuibus flexuosis nitidis glabris tantum sursum ramulosae floribus pedicellatis. Pedicelli 2–5 mm. longi glaberrimi apice incrassati. Calyx cupularis brevis crasse truncato-marginatus glaber. Petala 3 ovato-elliptica obtusiuscula crassa glabra margine minutissime papillosula 1.6–2 mm. longa 1.1–1.5 mm. lata. Stamina 6 sterilia filamento brevissimo 0.2 mm. longo, antheris rotundato-ovatis, 0.4–0.5 mm. longis. Discus breviter cupularis crassus leviter 6-lobatus glaber. Ovarium ovatum glabrum 0.8 mm. altum biloculare loculis biovulatis. Stigma sessilium crasso-capitatum. Fructus ellipsoideus 10 mm. longus 6 mm. latus, pericarpio in sicco paulo rugoso viridi-griseo glabro subnitido vel squamuloso-resinoso, tenui. Nucula cornea elliptica bilocularis loculo uno magno fertili alterocompresso vacuo.

VENEZUELA: ESMERALDA, rocky top of Esmeralda Ridge, about 325 ft., flower and berry green, 6 October 1928, *G. H. H. Tate 195* (HOLOTYPE, US; ISOTYPE, NY); another collection, same locality *Tate 211* (NY).

Dacryodes microcarpa is characterized by its small fruits which in the typical form do not surpass 1 cm. in length, and by having smaller leaflets than most of the species. It differs from the closely related *D. glabra* in its larger, more flexible leaves and leaflets with less conspicuous venation above, and by the longer, flexuose inflorescences with more racemose, isolated and long pedicellate flowers. Furthermore, in this species the flowers and panicles are completely glabrous, while in *D. glabra* there is a slight scattered puberulence on

Fig. 3. *Dacryodes microcarpa.* Photograph of fruiting specimen.

the branchlets, pedicels, sepals and petals. The fruits seem to be longer in a variety of *D. microcarpa*. *Dacryodes microcarpa* differs from other *Dacryodes* species in its small and oblong fruits with thin pericarp and thin, flexible, endocarp. The leaves are small with ovate, acuminate, flexible, chartaceous leaflets, which are reticulated on both sides. The axis and branchlets of the inflorescences are slender.

D. microcarpa var. **lanceolata** Cuatr. var. nov.—Folia 12–16 cm. longa 1–3-juga. Petiolus 2.5 cm. longus. Internodia 2.5–4 cm. longa. Foliola tenuiter coriacea firmula-ovato-lanceolata longe cuspidata basi obtuse cuneata vel obtusa 7–14 cm. longa (cauda inclusa) 2.7–5 cm. lata, caudicula 12–22 mm. longa 2 mm. lata (basi latiori), utrinque prominule reticulata. Drupa oblongo-ellipsoidea 14–15 mm. longa 8 mm. lata in sicco epicarpio corrugato.

VENEZUELA: ESMERALDA 325 ft. Tree savannas, "Tyler-Duida Expedition" 2 October 1928, *Tate 319* (HOLOTYPE, NY).

At first sight this plant looks different from Tate's other specimens of *D. microcarpa*. However, in *Tate 195* there can be found some elongate leaflets which tend to become lanceolate. On the contrary, *Tate 211* has more ovate and shorter leaflets than the type.

9. **Dacryodes peruviana** (Loesner) Lam. Bull. Jard. Bot. Buitenz. ser. 3. 12: 336. 1932. Macbride, Flora of Peru *in* Field Mus. Nat. Hist. Bot. Ser. 13: 3: 2: 716. 1949. *Pachylobus peruvianus* Loesner *in* Engl. Bot. Jahrb. 37: 569. 1906.

PERU: HUANUCO, prov. Huamalies, in silva aperta inter Monson et fluvium Huallaga, sita in 700 m. alt., *Weberbauer 3697* (HOLOTYPE, B).

Dacryodes peruviana var. **caroniensis** Cuatr. var. nov.—Arbor 30 m. alta.

Folia imparipinnata 60 cm. longa 3–4-juga. Petiolus rhachisque minutissime puberulenti vel glabrati, internodiis 6–9 cm. longis striatis. Petioluli robusti 1–2 cm. longi, terminalis ad 6.5 cm. longus. Foliola tenuiter coriacea subrigida, elliptico-oblonga vel ovato-oblonga vel inferiora ovata basi asymmetrica subrotundata vel obtusa ad apicem paulo attenuata subiteque acuminata, 12–28 cm. longa 6–10 cm. lata, acumine obtuso 1–2 cm. longo 3–5 mm. lato; supra glabra nervo medio angusto prominulo nervis secundariis filiformibus vix prominulis reticulo nervulorum sublaxo plus minusve prominulo; subtus glabra sed minutissime pulverulento-papillosa, costa valde prominenti striolata, nervis secundariis angustis et prominentibus 8–12 utroque latere subascendentibus marginem versus arcuatis anastomosantibus, nervulis minoribus in reticulum prominulum anastomosatis.

Fructus olivaceus, ellipsoideus in sicco 22–23 m. longus 14–16 mm. latus pericarpio in sicco corrugato glabro subnitido nigro-viridi. Nucula cornea suboblongo-elliptica, paulo ovoidea 20 mm. longa 15–16 mm. lata, bilocularis uno loculo tantum fertile, altero vacuo minimo complanato.

VENEZUELA: Bolívar, Bosques del Ikabarú, 420 m. Caroní, Guayana, arbol 30 m. cuyo fruto llamado "urá" es comido por los Arekunas, October 1947, *F. Cardona 2364* (HOLOTYPE, US).

The variety *caroniensis* differs from the typical form in its larger leaves, larger and more oblong leaflets with fewer, more ascendent, secondary nerves; the leaflets are also narrowed near the apex and longer acuminate. A complete comparison is not possible because the Peruvian type was described from flowering material and the Cardona plant has only fruits. It has not been possible at this time to see Weberbauer's type specimen once deposited at Berlin-Dahlem (presumably destroyed), a photograph of which exists (photo Field Mus. 12562). The *Weberbauer* specimen 6960, cited in *Flora of Peru*, belongs to *Protium*.

10. **Dacryodes colombiana** Cuatr. Prima flora Colombiana I. Burseraceae. Webbia 12(2): 1957 (in press).

COLOMBIA: Boyacá, valle del Magdalena, Cimitarra, 3 km. of Ermitaño road, forest tree 50 ft. tall, scented gum in bark, "anime blanco," *F. B. Lamb 130* (HOLOTYPE, US; ISOTYPE, COL).

11. **Dacryodes roraimensis** Cuatr. sp. nov.—Arbor circa 20 m. alta caule 35 cm. diamitenti.

Folia imparipinnata 30–40 cm. longa 4-juga. Petiolus paulo angulosus subteres striatus quam rhachis minutissime denseque ochraceo-pulverulentus. Internodia quam petiolus breviora 2.5–5 cm. longa. Petioluli 6–10 mm. longi incrassati rimossi (in sicco) minute pulverulenti. Foliola crasse firmissime coriacea in sicco pallida, elliptico-oblonga basi obtuse cuneata paulo asymmetrica ad apicem attenuata et plus minusve obtuseque acuminata margine integerrima leviter revoluta 8–18 cm. longa 3.5–7 cm. lata acumine 5–10 mm. longa 2.5–6 mm. lato; supra costa filiformi tantum prominula reticulo nervulorum paulo conspicuis juvenilia pilis rubellis minutissimis microscopicis sparsis praedita denique glabrata; subtus costa eminentissima carinata vel striolata nervis secundariis 11–14 utroque latere prominentibus patulis marginem versus arcuato ascendentibus anastomosantibusque, venulis reticulum obtuse prominulum formantibus, superficie aspectu glabra sed praecipue juvenilis minutissimis pilis squamulosis rubellis sub lente tantum visibilibus munita.

Inflorescentiae paniculatae 8–12 cm. longa pedunculo (1–4 cm. longo) ramulisque angulosis minute pulverulento-puberulis. Pedicelli fructiferi graciles 4–7 mm. longi puberuli. Calyx fructifer discoidalis circa 3 mm. diamitens glaber. Discus glaber. Fructus ellipsoideus vel ovoideo-ellipsoideus in sicco 15–17 mm. longus circa 10–11 mm. latus epicarpio corrugato, ochraceo-olivaceo subnitido. Nucula cornea subtenuis ellipsoidea basi rotundata brevissime apiculata ad apicem

paulo attenuata, 15–16 mm. longa 9–10 mm. lata, bilocularis loculo uno magno fertili altero sterile parvo compresso.

VENEZUELA: Bolívar, Mt. Roraima District, Vicinity of Arabupu, in mixed forest on clay soil s.w. slopes of Mt. Roraima, alt. 4600 ft., tree 65 ft. high, trunk 14 in. diam., fruit yellowish green, 23 December 1939, *Albert S. Pinkus 86* (HOLOTYPE, US; ISOTYPE, NY).

Dacryodes roraimensis can be distinguished from *D. sclerophylla* by its smaller leaves and fruits, in its closer and more spreading secondary nerves and by a more conspicuous venation. The new species differs from *D. excelsa* in its oblong and thicker leaflets and smaller fruits.

12. **Dacryodes sclerophylla** Cuatr. sp. nov.—Arbuscula 10 m. alta. Ramuli terminales lenticellati adpresse minuteque pubescentes denique glabrati.

Folia 40–50 cm. longa imparipinnata 2–3-juga. Petiolus 8–15 cm. longus, pariter rhachis robustus leviter striatus lenticellatus minutissime pubescens demum glabratus basi incrassatus. Internodia rhachis 4–7 cm. longa subteretia. Petioluli 5–10 mm. longi crassi puberuli vel glabrati. Foliola opposita lamina rigide crasseque coriacea oblongo-ovata vel oblongo-elliptica vel inferiori ovata basi obtuse cuneata paulo asymmetrica apice angustata breviter obtuseque acuminata margine integerrima, 11–24 cm. longa 5.5–9 cm. lata, acumine 3–5 mm. longo 4–5 mm. lato vel subnulo utrinque viridipallida (in sicco); supra glabra laevis costa nervisque secundariis pallidis vix conspicuis reticulo venulorum obscure notato; subtus aspectu glabra sed minutissimis pilis squamoso-glandulosis pallido-rubellis sparsis munita, costa valde elevata robusta striata, nervis secundariis 8–11 utroque latere prominentibus arcuato-ascendentibus marginem versus evanescentibus anastomosantibusque, venulis in reticulo vix prominulo vel immerso instructis.

Drupa olivaeformis oblongo-ovato-elliptica 29–32 mm. longa 17–19 mm. lata epicarpio papiraceo olivaceo in sicco ochraceo glabro nitido, mesocarpio pulposo endocarpio corneo. Nucula 28–30 mm. longa circa 17 mm. lata et 14 mm. crassa ovoideo-oblonga basi paulo attenuata obtusa apice magis angustata subacuta, bilocularis uno loculo fertili monospermo altero loculo adpresso minimo vacuo.

BRAZIL: Amazonas, basin of rio Madeira, Municip. Humayta on plateau between Rio Livramento and Rio Ipixuna, shrub 30 ft. high, on campinarana, resinous liquid from inner bark, 7–18 November 1934, *Krukoff 7053* (HOLOTYPE, NY; ISOTYPE, US).

Dacryodes sclerophylla is related to *D. olivifera* but it is different in its thicker, rigid, cuneate and almost symmetrical leaflets, which are subobtuse and have fewer and less prominent secondary nerves and a less conspicuous venation. *D. olivifera* has a larger number of prominent and spreading secondary nerves (17–20 pairs) and more ovoid and acute pyrenes. The West Indian *D. excelsa* has smaller leaves than the Brazilian plant, shorter, oval or ovate leaflets with an obtuse or subrotundate base and prominent reticulum beneath; it has also smaller fruits with an elliptic endocarp.

13. **Dacryodes nitens** Cuatr. sp. nov.—Arbor magna ramis terminalibus subteretibus verrucoso-lenticellatis minute adpresse pubescentibus.

Folia 45–50 cm. longa imparipinnata 5-juga. Petiolus circa 10 cm. longus robustus paulo striatus supra planus, minute lenticellato-verrucosus minutissime pubescens. Internodia robusta 4–5 cm. longa subteretia minutissime puberula vel glabrata. Petioluli crassi 7–10 mm. longi glabri vel paulo puberuli terminalis 2.5 cm. longus. Foliola opposita in sicco tabacina firme crassiuscule coriacea elliptico-oblonga vel basilaria et terminalia obovato-elliptica basi obtuse cuneata apice rotundata subite acuminata, 10–18 cm. longa 5–7.5 cm. lata acumine 4–8 mm. longo margine integerrima; supra glabra opaca costa anguste prominenti nervis secundariis pallidis bene conspicuis venulis paulo prominulis sed minute conspicueque reticulatis; subtus pilis minutissimis raris munita costa eminenti carinata striolata nervis secundariis tenuibus prominentibus 12 utroque latere subpatulis marginem versus arcuato-anastomosatis nervulis venulisque prominulis reticulatis.

Inflorescentiae fructiferae axillares paniculatae e basi ramosae 12–18 cm. longae axi robusto rigido angulato parce lenticellato-verrucoso minutissime pubescenti ramulis patulis robustis basilaribus ad 8–10 cm. longis. Pedicelli fructiferi robusti 10–20 mm. longi apicem versus satis incrassati. Drupa maturitate ovoidea vel elliptico-ovoidea nigro-olivacea nitidissima siccitate circa 30 mm. longa 20 mm. lata 16–17 mm. crassa pericarpio crasso siccitate plus minusve corrugato; endocarpio osseo duro ovoideo circa 27 mm. longo 15–17 mm. lato biloculare uno loculo fertile seminifero altero minusculo adpresso vacuoque. Cotyledones crassae digitatae conduplicatae.

BRAZIL: PARA, Belém, terra firme, arbore grande "Breu Sucuruba," 13 January 1953, *J. M. Pires & N. T. Silva 4431* (HOLOTYPE, US).

Dacryodes nitens differs from *D. sclerophylla* in its less thick and rigid leaflets marked with conspicuous, minute venation on both sides, by the more elliptical and oblong leaflets, rounded and abruptly acuminate at the apex, in its more numerous, more slender and spreading secondary nerves and the smaller number of leaflets. The stiffness, the elliptic-oblong form and the minute, conspicuous reticulation of the leaflets as well as the larger fruits, distinguish this species from *D. peruviana*.

14. **Dacryodes olivifera** Cuatr. Notas Fl. Colombia XII. Rev. Acad. Col. de C. E. F. y N. 8: 473, *fig. 7, 8, 9* y *10*. 1952. fig. nostra 4.

COLOMBIA: VALLE, Cordillera Occidental, vertiente occidental, Hoya del rio Dígua, lado izquierda, Piedra de Moler, bosques 900–1180

Fig. 4. *Dacryodes olivifera: A.* fruit; *B. C. D.* endocarp; *I.* transversal section of endocarp. *Dacryodes acutipyrena: E. F.* endocarp. *Dacryodes occidentalis: G. H.* endocarp; *J.* cross section of endocarp. *Dacroydes roraimensis: K.* fruit, *L.* endocarp, *M.* cross section of fruit. *Dacryodes sclerophylla: N.* fruit, *O.* endocarp. All × 2.

m., árbol 40 m., "anime," *Cuatrecasas 14944* (HOLOTYPE, F; ISOTYPE, VALLE); Hoya del río Sanquininí, (abajo de Naranjal), La Laguna, bosques 1250–1400 m. alt., árbol 41 m. alto, 110 cm. diam., "anime," *Cuatrecasas 15536*, (F, VALLE); Hoya del rio Dígua, La Elsa, quebrada La Cristalina, bosques 1000–1150 m., árbol 40 m. alt., 80 cm. diam., *Cuatrecasas 15227*, (F, VALLE).

15. Dacryodes occidentalis Cuatr. Notas Fl. Colombia XII. Rev. Acad. Col. de C. E. F. y N. 8: 474, *fig. 4, 5 y 6*, 1952.

COLOMBIA: VALLE, Costa del Pacífico, Bahía de Buenaventura, Quebrada de San Joaquín 0–10 m. alt., arbolito 10 m., 8 cm. diam., *Cuatrecasas 19917* (HOLOTYPE, F; ISOTYPE, VALLE).

SURVEY OF AFRICAN WOODS. II.[1]

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Aucoumea klaineana Pierre Gaboon Burseraceae

Trade names for this species are gaboon in the United States and Great Britain, and okoumé in France (Forest Products Laboratory, 1951; Organisation for European Economic Co-operation, 1951, 1953). Local names in the Cameroons, Gabon, and Belgian Congo include acoume, angouma, bengouma, moukoumi (Brush, 1944).

Mature trees attain heights of 110–130 feet and diameters of 3–5 feet. The trunk is straight, cylindrical and clear of branches for a distance of 75 feet. Several thin, wing-like buttresses extend up the trunk from the ground to a height of 8–9 feet. Gaboon has a restricted range, occurring in Spanish Guinea and the French Equatorial African states of Gabon and Moyen Congo (Brush, 1944). It is found along the borders of dense forests where it extends out into the adjoining grassy plains generally occurring on hillsides bordered by small stream beds.

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[1]The reader is directed to *Tropical Woods* 105: 13–38 for tables and the introduction to this series.

The heartwood is pinkish to pinkish brown in color, sometimes with a distinct reddish tinge (Brush, 1944; Kribs, 1950). Sapwood is lighter in color, often somewhat grayish, and usually 1–3 inches wide. Distinctive taste and odor are lacking. The grain is variable from wavy or curly to interlocked, producing a very attractive figure on quartered surfaces. Texture is medium and the surface luster is high and satiny. Growth rings are usually distinct. The pores are distinct without a lens, numerous, evenly distributed and solitary or in radial groups of 2–3. The parenchyma is invisible to the naked eye, scanty and paratracheal. Rays are invisible to the unaided eye on the end surface and conspicuous on the radial surface being darker than the background.

The wood is moderately light with an average weight per cubic foot at 12 per cent moisture content of 29 pounds (27–31 pounds; Brush, 1944). Specific gravity (oven-dry weight, air-dry volume) averages 0.42 (0.39–0.45).

The wood air-seasons and kiln-seasons satisfactorily with little tendency towards degrade (Brush, 1944; Jay, 1947). In some instances end-splitting may be encountered but is unlikely to be of a serious nature.

The results of mechanical tests on air-dry material are reported in table 1. Gaboon compares favorably with domestic hardwoods of similar specific gravity in most strength categories. The seasoned wood of gaboon may be compared with that of quaking aspen. In static bending strength, it is equal to quaking aspen in fiber stress at the proportional limit (5760 p.s.i.; Banks, 1954) and stiffness, but somewhat inferior in modulus of rupture. It is inferior in maximum crushing strength but harder on the end and side surfaces and stronger in shear. Tests of impact strength conducted in France (Association Colonies, 1927), using French methods, indicate that gaboon is somewhat less resistant to impact loads than African mahogany *(Khaya ivorensis)*.

The green to oven-dry shrinkage values for gaboon—volumetric 12.6, tangential 6.1 and radial 5.6 per cent

(Harrar, 1942), may be compared with values of 11.3, 7.1 and 5.2 per cent respectively, for American black walnut. The magnitude of the shrinkage of gaboon is similar to most domestic woods of the same specific gravity except that gaboon in general exhibits slightly less tangential shrinkage.

The wood has low resistance to decay by fungi and is not suitable for use in damp conditions (Brush, 1944).

Gaboon works well with hand and machine tools in most operations but may be difficult to saw. Pick-up in planing is encountered due to the irregular grain (Brush, 1944; Jay, 1947). Extensive tests on the veneering and plywood fabricating qualities of the wood have been conducted at the British Forest Products Research Laboratory (1953). In rotary peeling, smooth and flexible veneer is readily obtainable which is generally free from defects. Some brash veneer is produced in the zone less than 10 inches from the pith where brittleheart may be encountered. The gluing properties of the veneer are excellent.

Gaboon has many uses in Africa, Europe, and to a limited extent in the United States. Its principal uses are for interior woodwork including paneling and flush-door construction. furniture lining and backings, and plywood manufacture (Brush, 1944). In the form of plywood, it is used for boxes, light packing cases, light trunks and suitcases. It is also used for shipbuilding in place of Spanish cedar *(Cedrela* spp.) and mahogany *(Swietenia* spp.). Two-ply planking of gaboon in the form of thin lumber or plywood was used for small wartime craft such as landing and rescue boats.

Baikiaea plurijuga Harms Rhodesian teak Leguminosae

Though the English trade name for this species is Rhodesian teak, *Baikiaea plurijuga* differs appreciably from the true teak *(Tectona grandis)* in both anatomy and properties (Chalk et al., 1932). Common names for the species include redwood and Rhodesian redwood. Local native names are igusi (Southern Rhodesia); mukusi (Northern Rhodesia); unpapa (Angola).

The tree is of medium size, seldom over 50 feet in height (Forest Products Research Laboratory, 1945). The bole is almost cylindrical, up to two and one half feet in diameter, and clear of branches for a length of 20–35 feet (Martin, 1940). The species occurs in the deciduous savanna forests of Northern Rhodesia, Southern Rhodesia, northern Bechuanaland Protectorate and southeastern Angola. It is found in a region of low relief on sandy soils from 3000–4000 feet in altitude. In many areas, pure stands of 50 trees to the acre occur. Of these, 20–25 may be of exploitable size (12 inches or more in diameter).

The sapwood is 1–2 inches wide, bright yellow near the bark, grading to pale pink toward the heartwood. Heartwood is reddish brown when freshly cut and fades to a dull red upon exposure (Kribs, 1950). Irregular light and dark streaks in the heartwood give the wood a striking appearance. The grain is straight to somewhat interlocked and the texture is fine. Odor and taste are not distinct and the luster is low. Growth rings are distinct. The pores are invisible without a lens, numerous, evenly distributed and solitary or in radial groups of 2–8. Parenchyma is not visible to the naked eye and is paratracheal, exhibiting short wings which are sometimes confluent. Rays are invisible to the unaided eye on the end surface and inconspicuous on the radial surface. The rays are storied and ripple marks are distinct and regular.

The wood is exceedingly heavy; the average weight per cubic foot air dry is 59 pounds (50–63 pounds; Scott, 1949). The specific gravity (oven-dry weight, air-dry volume) averages 0.86 (0.73–0.92).

Rhodesian teak dries slowly, particularly in thicker sizes. It is inclined to develop surface checks if dried rapidly. Material should be closely stacked and air seasoned very slowly for six months prior to shipment. The British Forest Products Research Laboratory (1945) suggests a kiln schedule similar to that recommended for lignum vitae.

The results of mechanical tests on air-dry material are reported in table 1. Compared with domestic hardwoods of

equal specific gravity, Rhodesian teak is somewhat inferior in strength. The seasoned wood of Rhodesian teak may be compared to that of black cherry although the latter wood has a specific gravity only 60 per cent that of Rhodesian teak. In the static bending properties of fiber stress at the proportional limit (9480 p.s.i.; Banks, 1954) and modulus of rupture, Rhodesian teak compares favorably with black cherry; but in stiffness, it is somewhat inferior to the domestic wood. It has an appreciable margin over black cherry in maximum crushing strength and shear. It is twice as hard on the end surface and three times as hard on the side surfaces as black cherry.

The dimensional change between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 18 per cent and 11.5 per cent respectively) is 1.6 per cent tangentially and 1.0 per cent radially of the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). These values are only slightly higher than comparable values of 1.3 per cent and 0.8 per cent for teak.

The results of decay tests on samples of Rhodesian teak wood are presented in table 3. After 8 months exposure to the action of white-rot and brown-rot fungi, the samples exhibited an average weight loss due to decay of 4.9 per cent. The wood is therefore classified as very resistant to decay by wood-destroying fungi (Findlay, 1938). However, logs are susceptible to longhorn beetle attack and the sapwood is liable to attack by powder-post beetles (Forest Products Research Laboratory, 1945).

The wood is somewhat difficult to work with hand and machine tools and has an appreciable dulling effect on cutting edges (Forest Products Research Laboratory, 1945). In machining operations, material must be held firmly in order to prevent vibration. A cutting angle of 20° is recommended when planing in order to reduce grain pickup. The wood turns well and gives excellent results with the usual finishes.

In Rhodesia, the species is most used for railway ties for which its density, durability and dimensional stability render it a very desirable material (Tongue, 1928). In England, Rhodesian teak finds greatest use in high-quality flooring (Forest Products Research Laboratory, 1945). The handsome appearance of the wood has stimulated its use in furniture and railway coach paneling. The dimensional stability, durability and great hardness of the wood indicate that it may be suitable for exterior woodwork and decking, planking, keels and underwater structural members in boatbuilding.

Berlinia grandiflora (Vahl) Hutch. & Dalz.[2]
B. ariculata Benth. Berlinia Leguminosae
B. heudelotiana Baill.

The three above-listed species of *Berlinia* are the predominant timbers comprising commercial consignments of berlinia wood (Forest Products Research Laboratory, 1952b). Local names in western Africa are common to all three species and also to other species of the genus *Berlinia* (Dalziel, 1937). These names include sau (Senegal); kpendeguli (Sierra Leone); gbor-du-orh (Liberia); agyemera, wupa (Gold Coast); mélegba (Ivory Coast); apado, obwa, ububa (southern Nigeria); esule (Cameroons). The wood of the three species is sufficiently similar in appearance and properties to make separation unnecessary. Therefore, the following description applies to all three species of *Berlinia.*

The tree attains a height of 80–140 feet at maturity and a diameter up to 4 feet (Forest Products Research Laboratory, 1952b). The bole is clear, reasonably straight, cylindrical and free from buttresses. The species occur in western Africa from Sierra Leone westward through Liberia, Ivory Coast, Gold Coast, Nigeria, to the Cameroons. They are found in the main high forest belt in frequencies of 25–175 trees, 2 feet or more in diameter, per square mile.

[2]Synonym: *Berlinia acuminata* Soland. ex Hook. f. & Benth.

The sapwood is pink when freshly cut but turns to a white or gray with a pink tint upon exposure (Forest Products Research Laboratory, 1952b). The heartwood varies in color from pale red to dark red brown, with irregular, darker, purple or brown streaks which give the wood a handsome appearance. The width of the sapwood varies greatly, from 1–12 inches, but is more commonly 4–6 inches. The grain is usually interlocked but sometimes very irregular and the texture is coarse. The wood, when dry, is without a distinct taste or odor and the surfaces are lusterless (Cooper and Record, 1931). Growth rings are distinct. Pores are discernible on the end surface, not numerous, and evenly distributed. The parenchyma is arranged about the pores, sometimes confluent joining adjacent pores, diffuse-in-aggregates and terminal. The rays are invisible to the naked eye on the end surface and inconspicuous on the radial surface.

The wood is heavy, with an average weight per cubic foot air dry of 45 pounds (35–52 pounds; Forest Products Research Laboratory, 1952b). The specific gravity (oven-dry weight, air-dry volume) averages 0.63 (0.49–0.73).

Berlinia seasons rather slowly, but satisfactorily, with isolated cases of moderate distortion (Forest Products Research Laboratory, 1952b). Existing splits may extend somewhat and there is a pronounced tendency for mold growth to develop and discoloration to occur. The British Forest Products Research Laboratory (1952b) suggests a kiln schedule similar to that recommended for sugar maple and American black walnut.

The results of mechanical tests on air-dry material are reported in table 1. The tests were conducted on material of much lower specific gravity than the average for the species. Nevertheless, berlinia compares favorably with domestic hardwoods of equal specific gravity. The seasoned wood of berlinia may be compared to that of American sycamore of slightly lower specific gravity. In the static bending properties of fiber stress at the proportional limit (8210 p.s.i.; Banks, 1954), modulus of rupture, and stiffness, berlinia is very similar to American sycamore. In the property of fiber stress at the proportional limit in bending, it exceeds American sycamore by almost 30 per cent. It is comparable with American sycamore in maximum crushing strength and side hardness but appreciably inferior in end hardness.

Steam-bending tests conducted at the British Forest Products Research Laboratory (1952b) indicate that berlinia is a moderately good steam-bending species. Steamed material can be bent to radii of curvature of 17.5 inches per inch of thickness when supported by a steel tension strap and 19.5 inches per inch of thickness when unsupported.

The green to oven-dry shrinkage values for berlinia are reported in table 2. These values–volumetric 15.5, tangential 10.0 and radial 6.0 per cent–are comparable to white oak except that the radial and tangential values are somewhat greater than for this species. The dimensional change between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 19 per cent and 12 per cent respectively) is 2.0 per cent tangentially and 1.2 per cent radially of the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). The tangential dimensional change is considerably less than the 2.8 per cent value for white oak, the radial dimensional change being similar for both woods.

Berlinia is moderately resistant to decay by wood-destroying fungi (Forest Products Research Laboratory, 1952b). However, it is susceptible to attack by powder-post beetles. The heartwood is very resistant to impregnation with creosote but the sapwood is more permeable and can be satisfactorily treated under pressure or by the open tank process.

The working qualities of the wood vary considerably with the density of the material (Forest Products Research Laboratory, 1952b). Sapwood and lighter-weight heartwood work readily with hand and machine tools but with a moderate blunting effect on cutting edges. The denser heartwood is more resistant to cutting and has a more severe dulling effect on cutting edges. Grain pick-up is encountered in planing and may be arrested by employing a cutting angle of 20°. The wood takes nails fairly well but care is necessary to avoid splitting when nailing near edges. Staining and finishing qualities are variable; irregular grain in the sapwood requires special care in order to produce satisfactory results. Other material produces good results with the usual stains and finishes.

Berlinia is suggested as an alternative to oak in construction and woodwork (Forest Products Research Laboratory, 1952b). However, material must be carefully selected to avoid brittleheart. Selected material has been used to a limited extent for decorative veneers. The Organisation for European Economic Co-operation (1951) reports that berlinia is a good construction timber and is suitable for decorative furniture and paneling in the form of veneer. It may also prove suitable for use in agricultural implements and vehicles.

Celtis spp. Celtis Ulmaceae

Dalziel (1937) reports on five species of the genus *Celtis* in Africa of which three are mentioned as of potential commercial importance (Forest Products Research Laboratory, 1951c): *C. adolfi-friderici* Engl., *C. soyauxii* Engl. and *C. zenkeri* Engl.

The species are known locally as esa (Gold Coast); ita, ohia (Nigeria), these names being general for all three species. *C. soyauxii* and *C. zenkeri* are known in the Ivory Coast as mgua and tongo (Dalziel, 1937).

The trees are tall, from 100–150 feet in height, and attain diameters of 3 feet or more. The boles are generally straight and clear for lengths up to 80 feet, although heavily buttressed to heights of 10–20 feet (Forest Products Research Laboratory, 1945, 1951c). *C. zenkeri* shows a more marked tendency to have a somewhat crooked bole than the others. The trees are found in western, central, and parts of eastern Africa generally in the drier high forests where they may be quite gregarious.

The wood is white to creamy in color throughout tending to become a grayish white over a period of time. The grain is straight to irregular, the texture fine and the luster high (Forest Products Research Laboratory, 1951c; Jay, 1947). Growth rings are distinct to indistinct on the end surface. The pores are barely distinct to the naked eye and not numerous in *C. adolfi-friderici* and *C. zenkeri*, moderately numerous in *C. soyauxii*, evenly distributed, and mostly solitary but sometimes in radial groups of 2–4. The parenchyma is visible to the naked eye on the end surface, vasicentric, aliform, aliform confluent and banded, forming wavy tangential lines. The rays are fine, barely visible to the naked eye in *C. adolfi-friderici* and *C. soyauxii*, visible with a lens in *C. zenkeri*, conspicuous on the radial surface and inconspicuous on the tangential surface (Yale 23576, *C. adolfi-friderici;* 47208, *C. soyauxii;* 47350, *C. zenkeri*[3]).

The wood is very heavy, averaging approximately 50 pounds per cubic foot air dry (Forest Products Research Laboratory, 1951c). The average specific gravity (oven-dry weight, air-dry volume) is approximately 0.70, which is slightly greater than that of domestic white oak.

The wood seasons well but is susceptible to staining and has a slight tendency to split and cup. Other forms of distortion are negligible and knots remain sound. The British Forest Products Research Laboratory (1945) suggests a kiln schedule similar to that recommended for American basswood and Sitka spruce (for non-aircraft purposes).

The results of mechanical tests conducted in England on green and air-dry material of *C. soyauxii* are reported in table 1. The unseasoned wood of celtis is superior to domestic hardwoods of equal specific gravity in most strength categories. Celtis is superior to white oak and hickory in modulus of rupture and stiffness in bending. It is slightly inferior to white oak in work to maximum load, total work and impact strength (150 in.-lbs. per specimen; Armstrong,

[3]Numbers refer to specimens in the *S. J. Record Memorial Collection* of woods housed at the Yale School of Forestry.

1953). It is 80 per cent stronger than white oak in maximum crushing strength and 35 per cent harder on the end and side grain. It has moderate resistance to splitting in the radial plane and superior splitting resistance in the tangential plane.

Upon drying from the green to the air-dry condition, celtis undergoes increases in strength in all mechanical properties. The most notable change is in impact strength which increases 50 per cent over the value for the unseasoned wood.

In the air-dry condition, celtis is superior to white oak in all static bending properties. It is 25–30 per cent higher than white oak in modulus of rupture, modulus of elasticity and work to maximum load, and slightly superior in total work in bending. It is considerably stronger in maximum crushing strength, appreciably harder and somewhat superior in shearing strength parallel to the grain and resistance to splitting. The impact strength of celtis (210 in.-lbs. per specimen; Armstrong, 1953) is superior to that of white oak by 40 per cent.

The green to oven-dry shrinkage values for celtis—volumetric 15.4, tangential 10.4 and radial 5.6 per cent—are reported in table 2. The shrinkage of celtis is very similar to domestic white oak, both species being of approximately the same specific gravity. The dimensional change between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 20 per cent and 12 per cent respectively) is 2.5 per cent tangentially and 2.0 per cent radially (Forest Products Research Laboratory, 1954). Celtis is generally comparable to white oak in dimensional stability but exhibits considerably more dimensional change in the radial direction than white oak.

Durability tests conducted in England indicate that the wood is highly susceptible to decay by fungi (Findlay, 1938). After 8 months exposure to decay fungi, specimens of *C. soyauxii* lost 41.2 per cent of their original weight due to decay. The wood exhibits a somewhat greater susceptibility to white-rot fungi than to brown-rot fungi and is classed as perishable. It is also susceptible to damage by pinhole borers, powder-post beetles and termites. It is moderately resistant to impregnation but can be satisfactorily treated by a pressure or open tank process, penetration occurring mainly through the vessels (Forest Products Research Laboratory, 1945).

The wood works with moderate ease in machining operations, but is slightly hard to work with hand tools. Its working qualities are similar to English oak *(Quercus robur;* Forest Products Research Laboratory, 1945). Straight-grained material machines cleanly but quarter-sawn material may exhibit grain pick-up when interlocked grain is present. It has a moderate dulling effect on cutting edges but does not require special treatment in any operation. The wood is resistant to the driving of nails and tends to split in nailing, requiring preboring. It stains and finishes well with little grain filler required (Forest Products Research Laboratory, 1951c).

The wood has been suggested as a substitute for hickory and ash but has been found unsuitable for the more exacting purposes for which these woods are used (Forest Products Research Laboratory, 1945). It should prove suitable for constructional work where a medium density wood is desired. The main obstacle to its use is its susceptibility to stain and pinhole borer attack in the log form and its low resistance to decay by fungi (Forest Products Research Laboratory, 1951c). Rotary-cut veneer of suitable quality for commercial grades of plywood can be peeled from selected logs.

Chlorophora excelsa (Welw.) Benth. & Hook. f. Iroko Moraceae

The species is most commonly known as iroko in the export trade although other names are applied such as "African teak," "Nigerian teak," roko and muvule. Locally it is known as tumbiro (Portuguese Guinea); sili, simé, timmé bonzo (Senegal and French Guinea); koe-tema, semei, sili (Sierra Leone); agui, bakana, elon, edum, gui (Ivory Coast); eding, elui, odum (Gold Coast); loko (north-

ern Nigeria); iroko, uloko, efriyo, osan (southern Nigeria); momangi, bobang, emang (Cameroons); iroko, odum (British East Africa; Brush, 1943; Dalziel, 1937).

Old-growth trees attain a maximum height of 160–200 feet with a diameter from 7–9 feet. The trunk is clear and cylindrical for a length up to 50 feet, occasionally with slight buttresses extending a few feet up the trunk (Forest Products Research Laboratory, 1945; Kinloch and Miller, 1949). The natural range of the species is within a belt extending across the African continent between 10° north latitude and 15° south latitude mainly in Portuguese Guinea, Ivory Coast, Gold Coast, Nigeria, Cameroons, Angola, Belgian Congo and eastward to Uganda and Tanganyika. It occurs as a scattered tree in the forest attaining maximum size and number in the mixed deciduous forests toward the coast. Further inland, it is found in the drier forests and in the forests bordering the savanna (Brush, 1943; Eggeling and Harris, 1939). It is often found scattered on abandoned farm lands in the open where it has come in as a pioneer species.

The freshly cut wood is yellow to yellowish brown in color; the heartwood is darker than the sapwood. Upon drying, the heartwood darkens to a golden brown which on exposure to sunlight will deepen further to a rich brown color (Wood, 1950). The sapwood is narrow, about 1–4 inches wide, remains pale upon exposure, and is sharply delineated from the heartwood (Brush, 1943; Eggeling and Harris, 1939). The wood possesses no distinct taste or odor. Iroko bears a remote resemblance to teak but can be distinguished from teak by the soft tissue which forms zigzag markings on the plain-sawn surface after planing. The grain is typically interlocked producing a roey, ribbon-like figure on the quarter (Kribs, 1950). The texture is medium to coarse. Growth rings are indistinct when present (due to a difference in fiber density). The pores are distinct without a lens, sparse, evenly distributed and mostly solitary or in radial pairs. Parenchyma is distinct without a lens and aliform to aliform confluent, forming wavy tangential bands.

The rays are barely visible on the transverse section without a lens and inconspicuous on the radial surface. Occasionally latex-bearing structures are present in the rays. The wood has a slightly oily or waxy sensation (Brush, 1943).

Iroko is hard and heavy, exhibiting wide variations in density. The weight per cubic foot varies from 40–45 pounds air dry (Eggeling and Harris, 1939), the average being approximately 41 pounds per cubic foot. Boulton and Price (1931) report the specific gravity of iroko to vary between 0.70 and 0.80 at 12 per cent moisture content (approximately 0.65 to 0.75 based on oven-dry weight and volume). By way of contrast, tests at the University of Michigan (Brush, 1943) established the average specific gravity of iroko at 0.61 based on oven-dry weight and volume.

Iroko is reported to season well at a moderate rate with some tendency toward degrade in the form of splitting and warping (Brush, 1943; Eggeling and Harris, 1939). Approved drying schedules are required to produce satisfactory results. Other sources (Clifford, 1953; Forest Products Research Laboratory, 1945; Jay, 1947) report the ease with which the wood dries. The particular drying behavior of the wood may depend upon the straightness-of-grain in the individual pieces. Tests at the Philadelphia Naval Shipyard in 1944 (Tippo and Spackman, 1946) indicate that the presence of interlocked grain in iroko results in considerable warp in the form of bow and twist, checks, raised grain, and side and end splits. Straight-grained material seasons well with few if any defects.

The results of mechanical tests on green and air-dry material are reported in table 1 for iroko. Iroko is quite similar to teak and may be compared to it in many properties. In the unseasoned condition, iroko is somewhat inferior to teak in bending. It is 90 per cent as strong in maximum bending strength (modulus of rupture), 80 per cent as stiff, and 80 per cent as great as teak in values of total work in bending. The comparison is consistent with impact strength also, iroko being 80 per cent as strong in this category. Iroko is 85 per cent as strong in maximum crushing strength, but slightly superior in shearing strength, resistance to cleavage and hardness.

Upon drying to the air-dry condition, iroko exhibits slight to moderate increases in most strength categories. Values for total work, impact resistance and cleavage decrease upon drying.

In the air-dry condition, the strength values of iroko are again proportionately similar to teak. Iroko is 80 per cent as strong as teak in bending (modulus of rupture) and stiffness, 65 per cent as great in total work in bending, 90 per cent as strong in resistance to impact loads, and 85 per cent as strong in maximum crushing strength. It is approximately 30 per cent harder and 30 per cent stronger than teak in shear.

The values of shrinkage from green to oven dry—volumetric 8.8, tangential 3.8 and radial 2.8 per cent—for iroko are low compared to domestic hardwoods such as white oak and yellow poplar. The species compares very favorably with teak in this respect. The dimensional change between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 15 per cent and 12 per cent respectively) is 1.0 per cent tangentially and 0.5 per cent radially based on the 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. On the basis of these laboratory tests, iroko appears equal to or superior to teak in dimensional stability. However, in a search for suitable ship decking to supplement the limited supplies of teak, the Philadelphia Naval Shipyard installed 37,500 board feet of a 45,000-board-foot shipment of iroko on the main weather deck of the battleship U.S.S. Wisconsin in February 1944 (Tippo and Spackman, 1946). The individual decking pieces were fastened down by nuts and washers on steel studs welded to the deck plates. At the time of installation, the material was at 12 per cent moisture content. Three-fourths of the material was flat-grained, the remainder being edge-grained. By May 1944, the iroko decking had shrunk considerably, opening up the caulking both at the sides and ends of the pieces. Warping had caused the ends of some of the planking to pull away from the studs requiring replacement of these planks. By August of the same year, 2 per cent of the butts had to be replaced. Apparently, the presence of interlocked grain was the cause of the poor dimensional stability. In the selection of this species for an exacting use such as decking, pieces with interlocked grain should be avoided to eliminate distortion in service.

Durability tests were conducted at the British Forest Products Research Laboratory, in 1935 and 1936 on material from Uganda exposed to five wood-destroying fungi (table 3). After 8 months of exposure to optimum conditions for decay, only three samples out of 180 showed decay (Eggeling and Harris, 1939). The timber was classified as very resistant to decay but is susceptible to infestation by pinhole borers. The seasoned sapwood is also liable to powder-post beetle infestation (Lyctidae and Bostrychidae). Iroko is resistant but not immune to termite and marine borer attack. The wood cannot be penetrated laterally by creosote even under high pressure. Longitudinal penetration at the ends is only an inch or two (Forest Products Research Laboratory, 1945). Therefore, the wood is classed as extremely resistant to preservative treatment and considered untreatable.

The working properties of iroko are good but somewhat variable. Interlocked grain may result in picking up fibers during sawing and planing. Occasional "stones" of calcium carbonate, apparently more frequently encountered in pieces from certain areas, cause damage to cutting edges. The occurrence of mineral deposits is often the result of wounding and insect damage. The wood finishes well and stains satisfactorily, but requires a grain filler. It has good nailing, screwing and gluing properties, and can be cut into veneer (Clifford, 1953; Eggeling and Harris, 1939; Forest Products Research Laboratory, 1945; Jay, 1947).

The species has many uses both local and international. Locally, it is used for construction, furniture, cabinets,

high-quality millwork, framing, paneling, flooring, shingles, canoes and railway ties (Dalziel, 1937). The latex of this species is used frequently as an adulterant in rubber. In Great Britain, iroko is often used as a substitute for teak (Forest Products Research Laboratory, 1945; Wood, 1950), and is commonly used for laboratory benches and other heavy woodwork.

Cistanthera papaverifera A. Chev. Danta Tiliaceae

Other names for this species include redwood (United Kingdom); kotibé (France); balaké, koti, bello, bakabakué, ahia, sinani (Ivory Coast); apuropurow, akumba, epru (Gold Coast); alele, oro, otutu (southern Nigeria; Dalziel, 1937; Jay, 1947). The tree attains heights of 90–100 feet and diameters of two to two and one half feet (Forest Products Research Laboratory, 1945). The bole is clear and cylindrical to a height of 45–50 feet. The species occurs in the Ivory Coast, Gold Coast and southern Nigeria on dry sites in the deciduous forests. It attains frequencies of 200–1000 stems per square mile based on trees with diameters of one and one half feet or larger (Chalk et al., 1933; Forest Products Research Laboratory, 1952a).

The sapwood is light brown with a slightly pink tinge, about 1 inch in width, and sharply defined (Chalk et al., 1933). The heartwood is of a uniform brick-red to red brown color occasionally with darker streaks (Kribs, 1950). Distinct odor and taste are lacking. Grain is interlocked, the texture is fine, and the luster is medium. Growth rings are not distinct. The pores are barely visible without a lens, few to rather numerous, evenly distributed, solitary and in radial groups of 2–8 and in clusters. Vessel lumina contain a red "gum." Parenchyma is indistinct with a lens, diffuse-in-aggregates forming closely spaced uniseriate tangential lines between the rays. The rays are invisible without a lens on the transverse section and inconspicuous on the radial surface. Ripple marks are distinct and regular, and all elements are storied.

The wood is very heavy, averaging 47 pounds per cubic foot air dry with a specific gravity of 0.70 based on oven-dry weight and volume (Imperial Institute, 1931).

Danta seasons slowly but with little tendency to develop drying defects (Forest Products Research Laboratory, 1952a). An intermediate temperature schedule similar to that recommended for sugar maple and black walnut is suggested for danta (Forest Products Research Laboratory, 1945).

Strength data for danta are reported in table 1 for both green and air-dry material. The tests were conducted in England for the purpose of evaluating the suitability of danta as a substitute for ash and hickory for tool handles (Imperial Institute, 1931). Although the test results indicate high strength and toughness for the wood, it is nevertheless inferior to hickory and ash in toughness and stiffness. The unseasoned wood of danta is superior to the domestic ashes in all strength properties except total work in bending and cleavage. It exceeds white ash in the bending properties of fiber stress at the proportional limit (6370 p.s.i.; Imperial Institute, 1931) by 25 per cent. Danta compares very favorably with domestic hickories in all properties except work to maximum load, total work in bending and impact resistance. In the category of total work, the hickories are far superior; between 40 to 200 per cent superior depending upon the species of hickory considered. Danta is 75 per cent as resistant to impact loads as is mockernut hickory and in compression loads parallel to the grain has a 15 per cent margin of superiority in fiber stress at the proportional limit (3650 p.s.i.; Imperial Institute, 1931) and a 30 per cent margin in maximum crushing strength.

Upon drying from the green to the air-dry condition, danta undergoes moderate to appreciable increases in all strength properties with the exception of total work in bending, impact strength and cleavage. Work to maximum load increases slightly but total work in bending decreases 35 per cent and impact strength decreases to slightly over

one half the green value. Cleavage in the tangential plane remains nearly constant.

In the air-dry condition, danta may be compared to white ash in most strength categories. The similarity to hickory in strength properties in the green condition is not found in the seasoned wood, hickory being far superior in most properties due to greater strength increases upon drying. Danta is as strong as white ash in the bending properties of fiber stress at the proportional limit (8720 p.s.i.; Imperial Institute, 1931), modulus of rupture, and stiffness, but approximately 80 per cent as great in work to maximum load, total work and impact strength. It is about 25 per cent superior in maximum crushing strength but appreciably inferior in the property of fiber stress at the proportional limit (5240 p.s.i.; Imperial Institute, 1931) in compression parallel to the grain and 10 per cent more resistant to splitting. Danta is harder than white ash on the side grain but not as hard on the end grain and somewhat less resistant to shear parallel to the grain.

The species is classed as a good steam-bending wood accepting bends to radii of curvature of 8 inches per inch of thickness when supported by a steel tension strap and 24 inches per inch of thickness when unsupported (Forest Products Research Laboratory, 1945).

The green to oven-dry shrinkage values for danta—volumetric 14.3, tangential 7.0 and radial 6.3 per cent—are presented in table 2. The species is intermediate between white ash and white oak in shrinkage. The dimensional change between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 21.5 per cent and 13.5 per cent respectively) is 2.0 per cent in the tangential direction and 1.5 per cent in the radial direction based on the per cent of the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). These values are in the class of medium dimensional change along with white oak.

The results of decay resistance tests are presented in table 3. Material from Nigeria showed only slight weight loss due to decay after 4 months exposure to white-rot and brown-rot fungi. Material from the Gold Coast exhibited appreciable weight loss due to decay by white-rot fungi after 8 months of exposure. The results indicate a greater susceptibility to decay by white-rot fungi. The presence of pinhole borer damage in logs is reported. In the open tank process, the wood is resistant to lateral penetration of preservatives but less resistant to penetration along the grain (Forest Products Research Laboratory, 1945).

Tests conducted at the Imperial Institute (1931) in London, indicate that the wood works easily and that good surfaces are produced. Little difficulty is met in either rip-sawing or cross-cut-sawing with very little chip-out at the saw exit. Grain pick-up in planing is commonly encountered owing to the presence of interlocked grain. Boring at high speeds produces smooth surfaces but with some charring. Reduction in drill speed eliminates charring but results in rougher surfaces. The wood tends to split in nailing but takes screws and glues satisfactorily. Good results are obtained with the usual finishes but a grain filler is required (Forest Products Research Laboratory, 1945; Imperial Institute, 1931).

In England, the wood has been approved for use as cross-arms and is considered suitable for railway construction, shipbuilding and flooring (Forest Products Research Laboratory, 1945; Organisation for European Economic Co-operation, 1951). In 1931, the Imperial Institute conducted an intensive investigation of the suitability of danta as a substitute for ash and hickory for tool handles. Selected material of danta was found suitable for hammer handles but not for high-class pick and shovel handles. The wood may prove suitable as a substitute for white oak in ship framing, since it is in the same density group and is equal or superior to white oak in strength and comparable in steam-bending characteristics.

Cylicodiscus gabunensis (Taub.) Harms — Okan — Leguminosae

Local names for okan include imbeli-deli (Sierra Leone); bouémon (Ivory Coast); adada, denya (Gold Coast); olosan, owese, okan, anyan (southern Nigeria); adum (Cameroons). The tree grows to very large sizes, often with a clear bole 120 feet in length and 10 feet in diameter. The species occurs in Sierra Leone, Liberia, Ivory Coast, Gold Coast, southern Nigeria and the Cameroons (Dalziel, 1937; Jay, 1947).

The sapwood is pinkish in color and the heartwood yellow brown with dark brown or reddish brown streaks (Jay, 1947; Kribs, 1950). The odor is tallow-like; taste is not distinct. The grain is interlocked; the texture is medium; and surfaces are lustrous. Growth rings are distinct. Pores are visible to the naked eye, evenly distributed, solitary and in radial groups of 2–3. Vessel lines are visible on the longitudinal surfaces due to yellowish deposits in the lumina. The parenchyma is indistinct without a lens and forms concentric rings 3–6 cells wide, often with short to long wings about the pores. The rays are indistinct on the end surface and inconspicuous on the radial surface. Ray cells contain a yellow, gummy deposit.

The wood is exceedingly heavy, averaging 60–65 pounds per cubic foot air dry (Organisation for European Economic Co-operation, 1951) which is a specific gravity of 0.83–0.91 based on oven-dry weight and air-dry volume. Okan is prone to check and distort in seasoning (Jay, 1947).

The results of mechanical tests on green and air-dry material are reported in table 1. Okan compares favorably in strength properties with domestic woods of comparable specific gravity. The unseasoned wood of okan may be compared with that of pignut hickory although okan is approximately 20 per cent heavier. It is appreciably superior to pignut hickory in the static bending properties of modulus of rupture and stiffness but notably inferior in work to maximum load and total work. The impact strength values for okan are not reported but are expected to show the same comparison with pignut hickory as the property of total work. Okan is superior to pignut hickory, and most other important domestic hardwoods, in maximum crushing strength, hardness, shear and cleavage.

Upon drying from the green condition to 12 per cent moisture content, the wood undergoes moderate to pronounced increases in strength. Of all the properties reported for the wood in the unseasoned and seasoned condition, only the property of cleavage exhibits a decrease upon seasoning. Work to maximum load and total work in static bending undergo moderate increases upon drying.

In the air-dry condition, okan may be compared with pignut hickory in bending properties. It is notably inferior to pignut hickory in work to maximum load and total work in static bending, being only 40 per cent as great in these properties. In maximum crushing strength, it is slightly superior to lignum vitae *(Guaiacum officinale)*. In the properties of hardness, shear and cleavage, okan compares favorably with greenheart *(Ocotea rodiei)*.

Green to oven-dry shrinkage values for okan are reported in table 2. These values–volumetric 12.6, tangential 7.3 and radial 4.3 per cent–are not notably different from the shrinkage values of 12.3, 7.1 and 4.0 per cent (volumetric, tangential and radial respectively) for yellow poplar.

Durability tests conducted in England produced the results shown in table 3. After 4 months exposure to the action of four wood-destroying fungi, the specimens of okan exhibited negligible weight loss due to decay. The species is therefore classified as very resistant to decay.

The Imperial Institute of London (1930), reports that the wood is very difficult to work with hand and machine tools. There is some dulling effect on cutting edges (Jay, 1947) and the wood tends to pick up badly on the radial surfaces in planing. Nail driving is virtually impossible with okan and the driving of screws requires large prebored holes. It is difficult to glue probably because of the waxy nature of the wood. Stains are absorbed in only small quantities for the same reason. Well finished surfaces are apparently obtainable only after special treatment.

Okan is recommended for heavy flooring and construction work (Jay, 1947) for which its strength and durability should prove suitable. It may be found useful in marine construction as a substitute for greenheart. However, its difficulty in working, fabrication and great weight, may limit its use elsewhere.

Cynometra alexandri C. H. Wright Muhimbi
Leguminosae
C. ananta Hutch. & Dalz. Ananta

The English trade names for *Cynometra alexandri* are muhimbi and Uganda ironwood (Eggeling and Harris, 1939). The common name for *C. ananta* is ananta (Imperial Institute, 1928). Muhimbi is a local name employed in Uganda; whereas local names for ananta include dah (Liberia); apomé (Ivory Coast); ananta, awonia, takorowa (Gold Coast; Dalziel, 1937).

Muhimbi attains a maximum height of over 120 feet and a maximum diameter above the buttresses in the neighborhood of five feet. The trunk is relatively short but straight and sound; the old stems being somewhat twisted and gnarled. The base of the trunk is fluted, exhibiting thin, wide-spreading buttresses which extend 5–6 feet outward and 12 feet or more along the bole. Ananta is somewhat smaller, attaining a maximum height of 100 feet and a diameter of 3 feet. The bole is straight and clear with narrow buttresses 6–10 feet high at the base. Muhimbi is confined in range to Uganda and the Belgian Congo, where it is found on dry forest sites and also in swamps. Ananta occurs in Liberia, Ivory Coast and Gold Coast. Here it is abundant throughout the evergreen and semi-evergreen forests (Cooper and Record, 1931; Eggeling and Harris, 1939).

The wood of both species is very similar in appearance. Sapwood is light brown and 2–3 inches wide; the heartwood is reddish brown, darkening somewhat with exposure (Cooper and Record, 1931; Eggeling and Harris, 1939). The grain is generally interlocked and the texture is fine. Odor and taste are not evident. Growth rings are distinct.

The pores are barely visible to invisible without magnification, sparse, evenly distributed though somewhat less numerous near the margin of the ring, and solitary or in radial groups up to seven. Parenchyma is visible to the naked eye, occurring as wavy, continuous tangential lines connecting the pores. Rays are storied but indistinct to the unaided eye on all surfaces. Ripple marks are present and visible without magnification, regular in muhimbi and irregular in ananta.

The wood of both species is exceedingly heavy. The average weight per cubic foot of muhimbi is 55 pounds at 10 per cent moisture content (Banks, 1954). This corresponds to a specific gravity (oven-dry weight, volume at 10 per cent moisture content) of 0.80. Ananta averages 60 pounds (55–62) per cubic foot at 17.8 per cent moisture content (Imperial Institute, 1928). The specific gravity (oven-dry weight, volume at 17.8 per cent moisture content) averages 0.81 (0.75–0.84). Ananta, in general, is a slightly heavier wood than muhimbi.

No seasoning investigations have been carried out to date but the wood is known by experience to be subject to severe degrade in the form of warp, end-splitting, and checking unless stacked properly and dried slowly (Eggeling and Harris, 1939).

The results of mechanical tests on air-dry material of muhimbi and ananta are reported in table 1. Although of somewhat greater specific gravity than muhimbi, ananta is inferior in most strength properties. Compared with domestic hardwoods of similar specific gravity, both species are superior in most strength categories. The seasoned wood of muhimbi may be compared to that of flowering dogwood *(Cornus florida)*. In comparison with flowering dogwood of similar specific gravity, muhimbi is somewhat superior in fiber stress at the proportional limit in static bending and 50 per cent superior in modulus of elasticity and stiffness. The maximum crushing strength of muhimbi exceeds that of dogwood by 45 per cent. Muhimbi is approximately 50 per cent harder on the end and side grain and somewhat stronger in shear. The seasoned wood of ananta may be compared

to that of mockernut hickory of 10 per cent lower specific gravity. In static bending properties, ananta is appreciably inferior in fiber stress at the proportional limit (1830 p.s.i.; Imperial Institute, 1928), but comparable in modulus of rupture and superior in stiffness. Ananta is somewhat inferior in work to maximum load in static bending and fiber stress at the proportional limit in compression perpendicular to the grain. It is superior to mockernut hickory in maximum crushing strength and shear and comparable to dogwood in hardness. Ananta is somewhat stronger than white oak in cleavage and tension perpendicular to the grain (1145 p.s.i.; Imperial Institute, 1928).

The dimensional change for muhimbi between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 20 per cent and 13 per cent respectively) is 2.8 per cent tangentially and 1.4 per cent radially of the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). These values are very similar to those for white oak.

Muhimbi is reported to be very durable even when exposed to conditions especially favorable to decay. It is also very resistant to termite attack (Cooper and Record, 1931; Eggeling and Harris, 1939). Ananta probably exhibits high resistance to decay also, being very similar to muhimbi.

Working tests have been conducted at the Imperial Institute in London (1928) on ananta. Reports of the working qualities of muhimbi by Eggeling and Harris (1939) indicate that both species are essentially similar in working operations. Cutting is difficult with hand saws but moderately easy with machine saws. The wood picks up badly on quartered surfaces in planing and heats up considerably in boring with machine tools although no undue difficulty is encountered. Turning is accomplished with moderate ease and a smooth finish is produced by sanding. The wood is very resistant to the driving of nails and the driving of screws is difficult. The gluing properties of the wood are relatively poor but staining and finishing produce good results.

Owing to its weight and difficulty in working with hand tools, neither species is used by the natives. Muhimbi is employed for heavy construction in bridges and mine shafts and for railway ties (Eggeling and Harris, 1939). Muhimbi is also suggested for possible use in shipbuilding, flooring and rolling stock (Organisation for European Economic Co-operation, 1951). Ananta, probably owing to its greater weight, apparently has received little attention as a utilizable wood.

Daniellia spp. Ogea Leguminosae

There are several species of *Daniellia* in western Africa of which *D. ogea* Rolfe and *D. thurifera* Bennett are most important as commercial timbers (Jay, 1947). *D. ogea* is recorded only in southern Nigeria where it is known as juya, okineten, omugo and oziya. *D. thurifera* is known locally as santang (Senegal); pau incense, sandan (Portuguese Guinea); gbese (Sierra Leone); sru-ah (Liberia); faro (Ivory Coast); eyele (Gold Coast); ojia (southern Nigeria; Dalziel, 1937).

The mature trees of both species attain heights of over 100 feet and diameters of 4–5 feet (Forest Products Research Laboratory, 1951b). The boles are straight and cylindrical, free from buttresses, and clear for a length of 50–100 feet. Both species occur in the high forest zone; *D. thurifera* is limited to the wetter region and *D. ogea* is restricted to drier areas.

The sapwood is almost white to straw-colored and unusually wide, commonly 4–7 inches. The heartwood is reddish brown or golden brown in color with darker brown streaks (Forest Products Research Laboratory, 1951b; Kribs, 1950). The grain is interlocked, the texture is coarse, and the surfaces have a high luster. The wood lacks a definite taste or odor. Growth rings are evident as concentric lines of terminal parenchyma. The pores are distinct without a lens, not numerous, and evenly distributed or in radial groups of 2–6. Parenchyma is visible with a lens and terminal in concentric bands 3–6 cells wide and aliform with

short wings. Rays are indistinct without a lens on the end surface and inconspicuous on the radial surface. Ripple marks are obvious and regular, and all elements are storied. "Gum" ducts are vertical and diffuse, large, and filled with brownish contents.

The wood is light, having an average weight per cubic foot air dry of 29 pounds (26–36 pounds; Forest Products Research Laboratory, 1951b). The specific gravity (oven-dry weight, air-dry volume) is 0.40 (0.36–0.50).

The British Forest Products Research Laboratory (1951b) reports that ogea kiln-seasons from the green condition fairly rapidly with little tendency to degrade. Slight distortion and collapse may occur in thick material but these defects seldom are of a severe nature. A kiln schedule similar to that recommended for Sitka spruce (for non-aircraft purposes) is suggested for ogea.

The results of mechanical tests on air-dry material are reported in table 1. Ogea compares favorably in mechanical properties with domestic woods of the same specific gravity. The seasoned wood of ogea may be compared to that of American sycamore in mechanical properties. The specific gravity of American sycamore is 10 per cent greater than that of ogea; nevertheless, ogea is superior to the domestic wood in the static bending properties of modulus of rupture and work to maximum load. Both woods are similar in the static bending properties of stiffness and total work. Ogea is somewhat less resistant to impact loads than American sycamore, but it is superior in maximum crushing strength (by approximately 10 per cent) and equally as strong in shear, hardness and cleavage.

Limited laboratory tests conducted at the British Forest Products Research Laboratory (1951b) indicate that ogea is a very poor steam-bending species.

The green to oven-dry shrinkage values for ogea are reported in table 2. These values—volumetric 11.7, tangential 9.0 and radial 3.0 per cent—are not widely different from those for black cherry and black walnut. The dimensional change occurring between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 20 per cent and 12 per cent respectively) is 2.0 per cent tangentially and 1.0 per cent radially of the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). The dimensional change values for ogea are considerably less than comparable values for white oak, although both woods are classified as exhibiting medium dimensional change.

Laboratory tests and observations indicate that the wood is not resistant to decay by fungi and damage by insects (Forest Products Research Laboratory, 1951b). Although material of the species contains considerable amounts of sapwood, the wood is generally resistant to preservative treatment.

Tests conducted at the Imperial Institute in London (1926) indicate that the wood works easily and readily with hand and machine tools. Both fine textured and coarse textured material exhibit grain pick-up on quartered surfaces in planing. Fine textured material splits readily in nailing and screwing operations, whereas coarse textured material exhibits little tendency to split. Strong glue joints are readily obtainable and the wood stains satisfactorily. Finishing qualities are good but grain filler is required with the coarse textured material.

The wood may prove suitable as a softwood substitute and for use in general millwork, furniture linings and core-stock for plywood (Organisation for European Economic Co-operation 1951). The cylindrical log form and large diameters suggest the possible conversion of logs to veneer for plywood but little is known about the veneering qualities of the wood.

Distemonanthus benthamianus Baill. Ayan Leguminosae

This species is also known in the export trade as Nigerian satinwood, Nigerian yellow satinwood (United Kingdom) and movingué (French West Africa). Local names include barré (Ivory Coast); dua anyán, duabai (Gold Coast); ayán, anyaran, edo (southern Nigeria); basong (Cameroons); oquéminia (Gabon; Dalziel, 1937; Jay, 1947).

Ayan is a tall, slender tree over 100 feet high and two and one half feet in diameter (Forest Products Research Laboratory, 1945). The bole is straight and cylindrical or somewhat undulating with some tendency toward weakly developed buttresses. The species occurs as a scattered tree in the rain forests of the Ivory Coast, Gold Coast, Nigeria, Cameroons, Gabon and the Belgian Congo. It is found in frequencies of 10–30 trees per square mile and occurs in greatest abundance in the Cameroons and Belgian Congo (Forest Products Research Laboratory, 1951a).

The narrow sapwood has a creamy color and is moderately distinct from the yellow to yellowish brown heartwood. The wood is highly lustrous. It commonly exhibits interlocked and irregular grain which produces a handsome figure. The texture is fine to medium. Growth rings are indistinct. Pores are visible without a lens, numerous, evenly distributed, and solitary and in radial groups of 2–4. The parenchyma is visible without a lens, vasicentric, aliform with short to long wings, and confluent, forming long, wavy, tangential bands. Rays are barely visible on the transverse section and inconspicuous on the radial surface; lumina of cells contain a yellow "gum." The pores often contain a yellow extractive which when moist acts as a direct dye on textiles (Forest Products Research Laboratory, 1951a; Kribs, 1950).

The wood is generally heavy, but consignments of this species are often rather variable (Forest Products Research Laboratory, 1951a). The heavier material is a dark yellow brown and contains a high proportion of silica which is almost entirely lacking in the light, yellow colored wood. The weight per cubic foot in the air-dry condition ranges from 38–49 pounds (specific gravity, air-dry volume, 0.53–0.68), with an average weight of 45 pounds (specific gravity, air-dry volume, 0.63).

The timber seasons satisfactorily, but not rapidly, with little tendency to split or warp. However, degrade may occur in the form of discoloration of the sapwood. A kiln schedule similar to the one recommended for black walnut and sugar maple is suggested for ayan (Forest Products Research Laboratory, 1945).

The results of mechanical tests on air-dry material are reported in table 1. The strength properties of ayan are very similar to those of American beech with the exception of impact load resistance. In the air-dry condition, ayan is equally as strong as beech in bending. The values for moduli of rupture and elasticity are almost identical for both. The value of work to maximum load for ayan is only 85 per cent and total work only 70 per cent of that for American beech. This is reflected in the 25 per cent lower impact resistance of ayan. Ayan is 10 per cent stronger in crushing, 90 per cent as strong in shear, 60 per cent as resistant to splitting, and equally hard as beech.

The green to oven-dry shrinkage values for ayan are reported in table 2. These values—volumetric 10.7, tangential 5.2 and radial 3.1 per cent—are very similar to those for butternut. The dimensional change between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 15 per cent and 11 per cent respectively) is 1.3 per cent tangentially and 0.8 per cent radially based on the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). These values are identical with those for teak.

Field tests in Nigeria indicate that ayan is moderately resistant to decay by fungi and damage by termites. The wood is very resistant to impregnation, penetration occurring as longitudinal streaks in scattered pores (Forest Products Research Laboratory, 1945, 1951a).

Considerable difficulty is encountered in sawing the darker, heavier wood which has a high silica content and a corresponding blunting effect on cutting edges. Overheating is caused by gum deposits collecting on the saw. This can be partly alleviated by slightly increasing the set. In sawing the darker material, tungsten carbide-tipped teeth are strongly recommended. In most other operations, the wood works fairly well although some charring in boring may be encountered. A cutting angle of 20° in planing usually

prevents grain pick-up on the quarter and results in smooth surfaces. There is a tendency for splitting to occur in nailing, but screwing, gluing and finishing properties are good (Forest Products Research Laboratory, 1945, 1951a).

In England, the wood has been used for cabinet work, fixtures, joinery, flooring, stair cases and wheelwright's work. It is suggested as an alternate for oak providing resistance to splitting is not critical. In France, it is suggested as a substitute for oak, ash and walnut in fine joinery, banisters and luxury parquet (Forest Products Research Laboratory, 1945, 1951a; Organisation for European Economic Co-operation, 1953).

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CURRENT LITERATURE

The Rain Forests of Golfo Dulce. *Paul H. Allen*, with drawings by *Dorothy O. Allen*, University of Florida Press, Gainesville. xi-417 pages, 34 plates, 22 figures. 1956. $8.50.

The identification of the trees of the tropical lowland forests has been and will long continue to be a challenge to scientists. Although it is possible to identify tropical trees through arduous botanical collections of fertile material, there are some definite and sometimes insurmountable difficulties. These include such items as the large size of the trees, the short flowering and fruiting seasons of some species, travel hardships, and so on. On the other hand, it seems astounding to trained scientists to observe native people display their knowledge of vegetation. The tree may lack flowers or fruit, it may be in its juvenile stage, or with its lowest branches beyond possible reach, but to the native, one glance, or sometimes a small machete incision into the bark, will suffice for identification. True, it is only the local name, and the same people, if their knowledge were required in some different, unknown region, would be quite helpless. Nevertheless, in their home land they are adept at identification, and the trained scientist may depend upon them a great deal.

What combination of talents enables the native to recognize trees which puzzle the scientist? It is doubtless the result of long training in observation of vegetative characteristics, such as the shape of the trees, the structure and color of the bark, the different exudations, odors, etc. The recognition of vegetative characters is precisely what author Allen, for many years a botanist and collector in tropical Central America, has attempted to describe in this book.

The forest region of Golfo Dulce embraces an area of roughly 1000 square miles in southern Costa Rica, where a combination of different climatic and edaphic conditions, together with fire and other anthropogenic influences, has resulted in a great variety of vegetation. The book, dealing only with trees, includes 433 species belonging to 267 genera and 72 families. The scarcity of information on the flora of this region is revealed by the fact that 40 species and one genus have been newly described.

Numerous dichotomous keys permit the identification of the trees, including palms. In fact, the originality and greatest value of the book lie essentially in its keys. Besides the extensive keys which list all trees for each of the author's 13 ecological formations and their divisions, there are keys covering other striking features. Thus, trees with conspicuous flowers or fruits, or with prominent buttresses, unusual roots, distinctive bark, sap or latex, or which harbor stinging ants or are gregarious in their growth habits, are listed in the keys. There is even a small key for trees known as *limoncillo* in Central America! There are lists of species for the different ecological formations, of poisonous trees, and of economically important species. The bulk of the book consists of an alphabetical index of families, genera, species and common names of the trees found in the Golfo Dulce area. For each family, the genera are separated by keys. Genera are keyed to species and each of the latter is briefly described and useful notes on ecology, utilization, etc., are appended.

Twenty-two excellent figures of botanical specimens, drawn by the author's wife, are worthy of special mention

for their artistic interpretation and botanical accuracy. A short glossary of botanical nomenclature, 34 excellent plates, Latin descriptions of 10 new species—a rather unusual feature for such a publication—a list of 65 references and a short index of miscellaneous items complete the book. Besides the arduous task of accumulating field notes and intelligently employing the published literature, especially Standley's floras on Central American regions and Record and Hess' monumental *Timbers of the New World*, there is no doubt that the useful keys represent a skillful and original piece of work which is badly needed in other regions of the tropics.

In the ecological descriptions, always a controversial subject, the author uses broadly Beard's classification for delineating the formations, but with some rather unusual additions, as for instance, "transitional" formations. One of the climatic formations, the "littoral woodland" has been divided into "sandy beaches" and "rocky seashores." The four "transitional" formations are "savanna," "pastures," "fence rows and trailside thickets" and "second growth." These are clearly stages of succession, as the author himself hints. Such ecological concepts may be difficult to reconcile with current terminology. Since the word "formation" is generally used for more or less stable climax communities, it seems hardly fitting to employ it for clear-cut stages of succession. It might be said, however, that there are some practical advantages in differentiating such communities, as for listing and identifying their trees. But since the author divided some of the formations into associations, consociations, and faciations, there seems to be a lack of consistency in the terminology.

One of the most interesting formations is certainly the "lower montane rain forest," which covers the hillsides below 2000 feet, but is above the "evergreen lowland forest." It contains many more species than any other formation but no apparent reason for this is given. Compared with the "evergreen lowland forest," the "lower montane rain forest" shows a somewhat higher percentage of the emergent species that are deciduous, and for somewhat longer periods, making the term "rain" for describing this formation appear rather inappropriate. As the lists of species indicate, it seems that the evergreen lowland forest and much of the lower montane rain forest are differentiated mainly by drainage factors. Moreover, according to the data on rainfall published for Costa Rica, there are variations from 120 to over 240 inches in that area, so that two or even three different climatic formations may be found, the first two having high temperature but different rainfall patterns, while the third one refers to the colder belt, found on the slopes at higher elevations but still below 2000 feet.

Rather than being a criticism, the former notes indicate the unfortunate confusion that exists in the nomenclature of tropical vegetation. It seems that we have reached a point where it actually becomes difficult if not impossible for an Indian, African or Australasian scientist to follow the ecological nomenclature of some of their tropical American colleagues. Since we know that the physiognomy of tropical vegetation in all continents bears striking similarities, the difficulty seems hardly natural, rather man-made. We cannot but join the plea of tropical ecologists for a unification of terminology and procedures in classifying vegetation.

One feature which makes the ecology of the Golfo Dulce area more difficult to solve is the scarcity of a good map. The rather scant sketch on page five could have been considerably improved. An attempt to show some of the topography or even to map some of the described ecological formations would have been most useful. Many of the locality names cited in the text are not reproduced on the map.

The difficult task of using entirely vegetative characters in the keys is often infringed upon, as for example, the keys for Meliaceae and Annonaceae are definitely based on floral or fruiting characteristics. Since author Allen remarks (page nine): "Many times I have accompanied Doctors of Philosophy in Botanical Sciences in the field and seen them

speculate endlessly and futilely on the identity of some common, conspicuous tree, because it did not happen to be in bloom," it appears that in some cases there is no good alternative. Most keys, however, are remarkable for the inclusion of easily distinguishable vegetative characters and this trend is to be highly recommended for future studies of a similar nature. There might have been some minor improvements in a few of the keys. For example, it seems rather odd to separate consistently the *Cecropia* species on the basis of their rather inconspicuous black sap, since this is probably one of the easiest genera to recognize, through other striking characters, in the whole tropical American flora.

Among other minor details, it is noticeable that *Cordia alliodora* is not included in the group of species which harbor stinging ants; an omission, since ants are mentioned in the species description. Furthermore, in *Clarisia*, a valuable species easily recognized by the reddish tint on the superficial roots and buttresses, and by the milky sap, neither of these obvious characters is mentioned or used in the keys.

The extensive indexing of common names, families, genera and species within the text deserves special mention. The common names refer only to Central American countries, that is from Panama to British Honduras, and some of them appear rather dubious. Many pages are almost completely filled with names, so much so that author Allen should perhaps have included a separate index for them. It might also have been advantageous if common names from nearby Colombia or other South American countries with related floras, could have been mentioned. However, it should be said that not only are common names with their scientific equivalents presented, but also the region of use, and whenever the same name applies to several species—quite a common occurrence in Central America—a few notes help to elucidate the situation. In general, for the purpose of identification, common names can provide important clues; however, they may at times be misleading. Common names are usually orthographically correct, except on several occasions where accents are omitted. Scientific names appear to have been carefully revised.

The over-all impression certainly is excellent; the book is well layed out and accurately printed. Its usefulness definitely goes beyond the Golfo Dulce area. It is a "must" for everyone interested in the tropical American forest flora.—*Gerardo Budowski*, Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica.

Genetics in Silviculture. *C. Syrach Larsen*. Translated by Mark L. Anderson. Oliver and Boyd, Edinburgh and London. xi-224 pages, 70 figures. 1956. 30 s.

Dr. Larsen is Director of the National Arboretum at Horsholm, Denmark, a member of the Danish Academy of Technical Science, and recipient of the Danish "Augustinus" prize in 1952.

I welcome the opportunity of calling attention to this book, especially since it deals with a field of forestry with which I have long been acquainted, and which, unfortunately, has long been neglected, especially in the United States. I refer to the improvement of our forest trees. I do not mean the improvement as they now stand, by thinning, correct spacing, protection from fire, insect pests, diseases, etc., but an actual improvement of the quality of their living substance or protoplasm. Here we are working with the fundamentals, the bases on which depend the form,[1] rate of growth, quality of timber, disease resistance, hardiness—in short, all of the characters which go to make up a tree.

In our timber-cutting operations we in this country have too long been selecting the best trees for lumber, leaving the poorer individuals for seed. This process has been going on, at least here in the East, for generations. The result is easy to understand. The forests have, *in general*, been undergoing a sort of negative selection, until the best

[1] Under this head are understood not only the general external form of the tree, but all of its morphological characters—those of leaf, stem and root, including of course internal characters such as wood and bark cells.

trees now represent the stock that has been repeatedly passed along as inferior by former generations.

Recently, certain foresters in the East have shown an interest in tree improvement. But, for the most part, such improvement is done by seeking out the best or "elite" trees (that is, the best that can be found) and using them for seed and for grafting stock. This is, of course, the well-known method of breeding by selection. Many foresters seem to be blind to the fact that great strides can be accomplished by *generative* breeding of trees, i.e., the hybridization of species, varieties or even of races. Thus, it should be possible to develop new planting stock with greater vigor, taking advantage of the well-known phenomenon of heterosis. We have only to look at the remarkable results attained by the agriculturist to be convinced of the truth.

I have talked with foresters about this. Selection of elite trees as they occur in Nature is "o.k.," they say. These can be used for seed gardens[2] or for grafting stock. But as to generative breeding, depending on controlled pollination, this is too detailed (they say) to justify the attention of a busy forester. Very well, if this is the case, let the work be put in charge of a special man or department. The result will certainly be worth while.

Dr. Larsen's book should be in the hands of every American forester, chiefly because he calls especial attention to this much neglected area of forestry work, namely, hybridization. He shows how, in comparison to the rather easy method and results of hybridization in herbaceous plants, foresters, although apparently at a disadvantage, really have an advantage in tree breeding: they can preserve the original parents. Thus, they are enabled to repeat the original crossing process from time to time, or even use the parents for grafting or budding in order to carry on more extensive repetitive experiments; that is, assuming that the original crossing resulted in valuable progeny.

There are chapters on "Controlled Pollination," showing various methods; on "Vegetative Propagation," such as

[2] Also known as "seed orchards."

grafting, budding, and rooting cuttings, setting forth the advantages of these methods to the tree breeder, with illustrations and clear directions for the principal methods of grafting. And I note with satisfaction that the author emphasizes the importance of a healthy *stock* for success in grafting, a point that so far has not been sufficiently emphasized in our texts.

Dr. Larsen says of "Seed-gardens," "This is our 'trump card' in forest-tree breeding." He describes several methods of making them, the primary object of which is to produce large quantities of the best tree seed. For this purpose the seed garden, composed of the best trees, either selected hybrids or derived from grafts of best trees, must be located in an isolated area, at least far enough from other trees of the same kind so as not to be contaminated by their pollen. By natural intercrossing the resulting seed will be of the highest quality, and in good quantity.

In the chapter on "Tree-shows" the method of "Estimation of the Genotype in Forest Trees" is set forth in some detail, reference being made to the author's paper on this subject in the Year Book for 1947 of the Royal Veterinary and Agricultural College in Copenhagen. Very briefly, this is a method of determining whether the form of a given tree is caused by the environmental influences (chiefly soil and site), or whether it is due to characters inherent in the protoplasm. If the first is true, the tree in question is a phenotype and its form is not hereditary; if the second, the tree is a genotype. The test is made by grafting scions of the tree in question on stocks of the same variety and origin. If the scions develop a form like that of the tree to be tested, this proves that the tree is a genotype (with hereditary form) and not a phenotype (with form influenced by environment). The method can be extended to test the quality of the timber.

It is unfortunate that the term "Tree-shows" is used. I think the words, "Tree Tests" would better express the meaning. Possibly the the term has suffered in translation from the Danish.

The chapters which follow, "Breeding and Diseases," "Hybrids," "Genetics," and the "Breeding of Larch," with which genus the author has had signal success—all these chapters are replete with ideas and suggestions and serve to point up the importance of generative breeding.

May I suggest that if a revised edition is published, a bibliography be added? A wealth of references is scattered throughout the book, in the text, but these are sometimes hard to find. If collected into an alphabetized list at the end, the value and usefulness of the book would be much increased. The figures are excellent, and admirably illustrate the author's points.—*Arthur H. Graves*, Genetics Department, Connecticut Agricultural Experiment Station, New Haven, Connecticut.

INTERNATIONAL ASSOCIATION OF WOOD ANATOMISTS

Dr. H. E. Dadswell, former Secretary-Treasurer of the I. A. W. A., has asked that it be announced that this position has been transferred to Professor A. Frey-Wyssling by unanimous approval of the Council of the Association. Professor Frey-Wyssling has appointed Dr. H. H. Bosshard as his deputy. The office of Secretary-Treasurer has been in Melbourne, Australia since 1946.

The new subscription rate for Association membership will be seven Swiss francs per annum. Members are asked to pay by postal money order on Compte de cheque postal VIII 50938, Zürich, Switzerland. The address of the Secretary-Treasurer will be:

Laboratorium für Holzforschung
Eidgenössische Technische Hochschule
Universitätsstrasse 2
Zürich 6, Switzerland

ERRATUM

On page 48, line 8, of *Tropical Woods* 105, please change "aware" to *unaware*. The Editor regrets this unfortunate error.

YALE UNIVERSITY SCHOOL OF FORESTRY

TROPICAL WOODS

NUMBER 107 OCTOBER 1957

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TROPICAL WOODS

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

Subscription price $3.00 for two semi-annual numbers. Remittances should be made payable to TROPICAL WOODS. All communications should be addressed to the Editor, 205 Prospect Street, New Haven 11, Connecticut, U. S. A.

Manuscripts on all phases of tropical forestry and tropical woods and trees will be considered for publication. Manuscripts should be typed double-spaced throughout on one side of paper. Drawings, done in black ink, or photographs, should be mounted on stiff card-board and the desired reduction plainly indicated. Figures should be planned so that after reduction they occupy the entire width of a page (4 inches) and any portion of the height (6 inches). Economy of space is important; therefore, the editor cannot accept loose figures or those so mounted as to leave large unused spaces on the printed page. Figures should be numbered consecutively. Legends for figures should be typewritten and included with the manuscript. All legends for one group of figures should form a single paragraph. In cases where magnifications are stated, they should apply to the reduced figures.

In general, *style should follow the most recent number of* TROPICAL WOODS especially as regards punctuation, literature citation, capitalization, use of italics, and references to literature and illustrations. Main divisions are indicated by centered headings; subdivisions by italicized marginal captions. Footnotes should be minimized. The editors alone retain the right to accept or reject manuscripts.

TROPICAL WOODS

NUMBER 107 OCTOBER 1957

INTERNATIONAL GLOSSARY OF TERMS USED IN WOOD ANATOMY

COMMITTEE ON NOMENCLATURE
INTERNATIONAL ASSOCIATION OF WOOD ANATOMISTS[1]

INTRODUCTION

The need for a revision of the *Glossary of terms used in describing woods* (Trop. Woods 36: 1–13.1933) was raised at the Stockholm meeting of the International Association of Wood Anatomists in 1950, but no concrete proposals for achieving this were made till the Paris meeting in 1954. By that time revised definitions of wood anatomy terms were in demand for Part II of the British Commonwealth Forest Terminology. It was therefore suggested at the Paris meeting that immediate steps should be taken to prepare a revised version of the *Glossary* in English, that would be available both for the British Commonwealth Forest Terminology publication and as the basis of a multilingual, illustrated glossary to be issued by the International Association of Wood Anatomists.

Dr. L. Chalk was therefore asked to prepare a preliminary list of terms and definitions (see I.A.W.A. News Bulletin, Sept. 1954) and this was in due course submitted to all members of the Association for comment. As agreed at the Paris meeting, a small working committee, selected from members who could meet in person, was appointed by the Council to collate the suggestions made by various members. This committee consisted of Dr. L. Chalk (Chairman), Prof. Dr. Br. Huber, M. D. Normand, and Dr. E. W. J. Phillips. After doing all that was possible by correspondence this

[1]Members of the Association may obtain uncovered reprints from the Editor at $.15 a copy, and covered reprints from the Secretary-Treasurer, Institut für allgemeine Botanik, Eidgenössische Technische Hochschule, Zürich, Switzerland at $.20 a copy. Prices for non-members are $.30 and $.40 for uncovered and covered copies respectively.

committee met in person during the I.U.F.R.O. Congress at Oxford in July 1956, with Mr. B. J. Rendle as an additional and co-opted member, and reached agreement on such difficulties as had remained outstanding.

There are, of course, still some problems that must wait further research before they can be solved satisfactorily. For example, knowledge of the fine structure of the cell wall is advancing so rapidly that the Committee has decided to exclude all the terminology for this subject from the present revision. In other cases, such as "heterogeneous" and "homogeneous" rays, the Committee has put forward a preferred solution, but has at the same time indicated the alternatives. The definitions have been kept as brief as possible, commensurate with reasonable accuracy, and the Committee has tried to resist the temptation to indulge in lengthy explanatory notes, since further information is readily available in several textbooks.

It has been thought best to publish separately the English version that has been the result of these deliberations. It is intended ultimately to prepare a multilingual, illustrated glossary with the definitions in English, French, and German, and the terms themselves in several other languages. The preparation of this, however, may take a considerable time.

The Committee wishes to express its thanks to the many members of the Association who have contributed to this work.

Glossary[2]

Apical meristem.—See Meristem, apical.

Awn.— See Callitrisoid thickening.

Bark.—A non-technical term used to cover all the tissues outside the xylem cylinder. In older trees usually divisible into *inner* (living), cf. Phloem, and *outer* (dead), cf. Rhytidome.

[2]See page 34 for illustrations, notes and abbreviations.

Bark, early.—The bark formed during the earlier stages of the season, cf. early wood*. Note: In typical cases *(Alnus, Betula)* consisting mainly of sieve tubes with companion cells, or sieve cells.

Bark, hard.—The part of the bark that consists of fibres or other strengthening cells: sometimes in concentric layers that alternate within a growth ring with layers of soft bark, or more irregularly distributed in a ground tissue of soft bark. A layer of hard bark formed at the end of the season (as in *Quercus* and *Castanea*) is called the *Terminal layer.*

Bark, inner.—See Bark.

Bark, late.—The bark formed during the later stages of the season, cf. late wood*. In typical cases consisting mainly of bark parenchyma and only fewer and smaller sieve tubes or sieve cells. At the end of the season there is sometimes a terminal layer (see under Bark, hard) of fibres.

Bark, outer.—See Bark.

Bark, soft.—The part of the bark that consists of sieve tubes and parenchymatous and suberized cells, but not including fibres or other strengthening cells; present either as concentric layers that alternate within a growth ring with layers of hard bark*, or forming a ground tissue in which the cells of the hard bark are irregularly distributed.

Bar(s) of Sanio.—See Crassula(e) and Trabecula(e).

Brachysclereid.—See Stone cell.

Callitrisoid, callitroid thickening.—Pairs of bars of thickening across the pit, as in *Callitris*. Also described as awns* when seen in section. Note: "Callitroid" is in common use, but "callitrisoid" is preferable on etymological grounds.

Cambial initial.—An individual cell of the cambium*, cf. Fusiform initial and Ray initial.

Cambial zone.—A term of convenience for the layer of varying width composed of cambial initials and their undifferentiated derivatives (IAWA modif.).

Cambium (vascular cambium).—The actively dividing layer of cells that lies between, and gives rise to, secondary xylem* and phloem* (BCF modif.).

Cambium, cork.—See Phellogen.

Cambium, storied.—Cambium characterized by a horizontal seriation of the initials (IAWA).

Cell.—A chamber or compartment at some time containing a protoplast*; cells form the structural units of plant tissues.

Cell wall.—The limiting membrane of a cell. In mature cells it consists ontogenetically of several superimposed walls, as follows:

Primary. The wall of the meristematic cell modified during differentiation (not to be confused with the thin, markedly anisotropic, first-formed part of the secondary wall; IAWA). See Lamella, compound middle.

Secondary. The wall formed inside the primary wall (IAWA modif.).

Tertiary. A term that has been applied to the spiral thickening of tracheids*, wood fibres* and vessels*; also to the inner layer of the secondary cell wall. See also Note 2.

Cell wall check.—A fissure in the secondary cell* wall, as in the tracheids of compression wood*.

Chambered crystalliferous cell.—See Crystalliferous cell, chambered.

Companion cell.—A sister cell of a sieve-tube member, intimately connected with it and retaining the nucleus and dense cytoplasm. Note: Companion cells may undergo some transverse or other divisions preceding their differentiation.

Conjunctive tissue.—A special type of parenchyma associated with included phloem*. Note: Sometimes forming anastomosing concentric bands, as in *Avicennia*, or enclosing the phloem strand, as in *Strychnos*.

Cork.—A non-technical term for phellem*.

Cortex.—The primary ground tissue of a stem or root between the epidermis* or phellem* and the vascular system.

Crassula(e).—The thicker portion of the intercellular* layer and primary cell walls* between primary pit-fields* (IAWA). Syn. *Bar(s) of Sanio* (deprec.), *Rim(s) of Sanio* (deprec.).

Cross-field.—A term of convenience for the rectangle formed by the walls of a ray cell and an axial tracheid, as seen in a radial section. Used mainly for conifers. Syn. *Ray crossing* (Am.; deprec.).

Crystal.—The following are among the types commonly distinguished:

Acicular. A slender, needle-shaped crystal. Note: Not to be confused with a styloid, which is a columnar crystal.

Crystal sand. A granular mass of very fine crystals.

Druse. A globular cluster of crystals, sometimes with an organic core, either attached to the cell wall by a peg or lying free in the cell.

Raphid(e), *raphis*, pl. *raphides*. A needle-shaped (acicular) crystal occurring typically as one of a closely packed, sheaf-like bundle.

Styloid. An elongated crystal, typically about four times as long as broad, with pointed or square ends.

Crystalliferous cell.—A cell containing one or more crystals. Note: Radial and axial parenchyma cells are often crystalliferous; fibres and tyloses less commonly.

Crystalliferous cell, chambered.—A crystalliferous cell that is divided into compartments by septa.

Druse.—See Crystal.

Element.—A general term used for an individual cell. Note: Used in wood anatomy, particularly to distinguish between vessels and the individual cells of which they are composed–the vessel* elements or vessel* members.

Elements, axial.—A term of convenience in wood anatomy for all the cells other than those of the rays*. Syn. *Vertical elements* (deprec.).

Elements, congeneric.—Cells of the same anatomical type.

Elements, storied.—Cells arranged in tiers as seen on the tangential surface.

Elements, vertical.—See Elements, axial.

End wall.—A term of convenience in wood anatomy for (a) A wall at right angles to the longitudinal axis of a parenchyma cell, i.e., for the tangential walls of ray cells or the transverse walls of axial parenchyma cells, and (b) The oblique or transverse wall between two vessel* members. See Note 1.

End wall, nodular.—The end wall of a parenchyma cell having a beaded appearance in sectional view.

Epidermis.—The outermost layer of cells on the primary plant body; often with strongly thickened and cuticularized outer walls; sometimes consisting of more than one layer of cells.

Epithelial cell.—A cell of the epithelium*.

Epithelium.—The layer of secretory parenchymatous cells that surrounds an intercellular* canal or cavity (IAWA modif.). Syn. *Epithelial layer*.

Fibre, Fiber (Am.).—A general term of convenience in wood anatomy for any long, narrow cell of wood or bast other than vessels* and parenchyma*. Note: Often further qualified as wood fibres* or bast fibres*; the former including both the tracheids of gymnosperms and the libriform wood fibres and fibre-tracheids of woody angiosperms. Also used loosely for wood elements* in general.

Fibre, bast.—A fibre of the phloem*.

Fibre, gelatinous.—A fibre having a more or less unlignified inner wall with a gelatinous appearance. See also Wood, tension.

Fibre, intermediate.—See Parenchyma cell, fusiform.

Fibre, libriform wood.—An elongated, commonly thick-walled cell with simple pits*; usually distinctly longer than the cambial* initial as inferred from the length of vessel* members and parencyhma* strands (IAWA). See note under Fibre-tracheid.

Fibre, mucilaginous (obs.).—Replaced by fibre, gelatinous.

Fibre, septate wood.—A fibre with thin transverse walls across the lumen* (IAWA). Note: In these elements the protoplast* divides after the formation of the secondary cell* wall.

Fibre, substitute.—See Parenchyma cell, fusiform.

Fibre, wood.—A fibre of the xylem*.

Fibre-tracheid.—A fibre-like tracheid*; commonly thick-walled with a small lumen*, pointed ends, and bordered pit-pairs* having lenticular to slit-like apertures (IAWA modif.). This term is applicable to the late wood tracheids of gymnosperms as well as to the fibre-like tracheids of woody angiosperms.

Note: The definitions of fibre-tracheid and libriform wood fibre present considerable difficulty, not as regards the extreme types such as the fibre-like tracheids that occur, for example, in *Dillenia* and the libriform fibres that are associated with storied structure, but in placing and defining the intermediate types. The 1933 *Glossary*, which has been followed here, adopted the presence or absence of bordered pits as the simplest and most practical distinction between the two types and so relegated all the intermediates with vestigial bordered pits to the category of fibre-tracheids (see I. W. Bailey, Trop. Woods 45: 18–23. 1936).

The alternative conception, based on the classification of Sachs, as used by Janssonius (see E. Reinders, Trop. Woods 44: 30–36. 1936), is of a fibre-tracheid strictly limited by the exclusion of intermediates. The definition of such a fibre-tracheid suggested by Reinders in 1951 (I. A. W. A. News Bull. Feb. 1951: 6–9) is as follows: "Moderately elongated; commonly with thick and apparently somewhat swollen walls, rarely with mucilaginous layers; hardly ever septate; never containing starch; having rather large bordered pits with lenticular to slit-like apertures. The pits are comparatively numerous in the tangential walls, in many instances outnumbering those in the radial. When such fibres constitute the ground tissue, the pits toward the vessels ordinarily have borders of much the same size as those of pits in the walls of contact between two vessels." This conception would necessitate complimentary changes in the definition of the libriform wood fibre. As defined in the *Glossary*, the fibre-tracheid, with its pits to congeneric elements bordered, is technically a form of tracheid.

Fibril.—A thread-like component of cell walls, visible under an optical or light microscope. Note: This term, used without qualification, is equivalent to "macrofibril" as opposed to "microfibril." See Note 2.

Fibril angle.—The angle between the longitudinal axis of the cell and the direction of the fibrils* in the cell wall.

Fusiform (cambial) initial.—A cambial initial giving rise to an axial element of xylem or phloem; it is spindle-shaped (fusiform) as seen in tangential section (IAWA modif.).

Fusiform parenchyma cell.—See Parenchyma cell, fusiform.

Fusiform ray.—See Ray, fusiform.

Gelatinous fibre.—See Fibre, gelatinous.

Growth layer.—A layer of wood or bark produced apparently during one growing period; frequently, especially in woods of the temperate zones, divisible into early and late wood* or bark* (IAWA).

Growth ring.—See Ring, growth.

Growth ring boundary.—See Ring boundary, growth.

Gum duct.—An intercellular* canal containing gum.

Heartwood.—The inner layers of wood which, in the growing tree, have ceased to contain living cells and in which the reserve materials (e.g., starch) have been removed or converted into heartwood substances. It is generally darker in colour than sapwood*, though not always clearly differentiated. See Wood, intermediate. Syn. *Duramen* (obs.).

Note: A distinction is sometimes made between dark-coloured heartwood and that which shows no appreciable difference in colour from sapwood; the term *Ripewood* is used for this latter category. In commercial practice it is usual to restrict the term heartwood to the darker-coloured wood that is visually distinct from the sapwood.

Heterogeneous ray tissue.—See Ray, heterogeneous.

Homogeneous ray tissue.—See Ray, homogeneous.

Idioblast.—A cell differing markedly in form and contents from other constituents of the same tissue. Note: Examples in wood are certain crystalliferous* cells, oil* cells and mucilage* cells.

Indenture.—A narrow groove in the transverse (horizontal) wall of a ray cell along the junction with the tangential (end) wall. In radial section an indenture appears as a depression in the transverse wall where the tangential wall is inserted. Note: Used only for conifers.

Initial, cambial.—See Cambial initial.

Initial, ray.—See Ray initial.

Intercellular canal.—A tubular intercellular space of indeterminate length, generally serving as a repository for resin, gum, etc., secreted by the epithelium*. Note: May be (1) axial, or (2) radial (within a ray) (IAWA modif.). Syn. *Resin canal*, *Gum duct*, cf. Intercellular cavity.

Intercellular canal, radial.—A canal extending across the grain in a radial direction, contained in a fusiform ray*.

Intercellular canal, traumatic.—A canal formed in response to injury to the living tree. Note: Often abnormal in size and may be axial or radial.

Intercellular cavity.—An intercellular* space of limited length, generally serving as a repository for resin, gum, etc., and generally formed in response to injury to the living tree, cf. Intercellular canal.

Intercellular layer.—The layer between adjacent cells; it is isotropic and lacks cellulose (IAWA modif.). Syn. *Middle lamella* (deprec.). Note: The intercellular layer often appears to merge imperceptibly into the primary cell walls (see Lamella, compound middle), and special techniques may be needed distinguish it.

Intercellular space.—A space between cells. Two types can be distinguished:

Secretory, including intercellular* canals and intercellular* cavities, which may be schizogenous*, lysigenous* or schizo-lysigenous*.

Non-secretory, i.e., an interstitial* space.

Intermediate wood.—See Wood, intermediate.

Interstitial space.—A non-secretory space between cells.

Lamella, compound middle.—In wood anatomy a term of convenience for the compound layer between the secondary walls of adjacent cells, consisting of two primary cell* walls and an intercellular* layer of varying thickness. Note: The term *Middle lamella* has often been used loosely for this compound structure.

Lamella, middle.—See Intercellular layer.

Latex canal.—See Latex tube.

Latex trace.—A term used to describe the slit-like passages (as they appear in seasoned timber) running radially through the wood of certain latex-bearing trees (notably *Alstonia* spp. and *Dyera* spp. of the Apocynaceae). They are characterized by the presence of latex tubes* and have their origin in the traces from the leaves and axial buds. Incorrectly called latex canals and latex ducts, cf. Latex tube.

Latex tube.—A laticifer* enclosed in a ray. Note: The tubes are modified cells or series of cells and not intercellular canals. Syn. *Latex canal* (deprec.).

Laticifer.—A general term for cells containing latex. Note: May be a single cell or a series of tubular cells.

Lenticel.—A specialized portion of the periderm*, variously shaped, but often lenticular, consisting of loosely arranged cells that are never more than slightly suberized; serving for the exchange of gases through the otherwise impermeable periderm.

Longitudinal wall.—See Note 1.

Lumen, pl. lumina.—The cell cavity (IAWA).

Lysigenous.—Formed by a disorganization or dissolving of cells.

Medullary ray.—See Ray, primary.

Meristem.—A tissue capable of active cell division, thereby adding new cells to the plant body. See Meristem, apical and Cambium.

Meristem, apical.—The meristem at the growing point of shoots and roots.

Metaxylem.—Later-formed primary xylem*, with pitted tracheary* elements (IAWA), cf. Protoxylem.

Middle lamella.—See Lamella, middle.

Mucilage cell.—A specialized cell of the ray or axial parenchyma containing mucilage; typically rounded in outline. Note: Limited to woody dicotyledons and similar to an oil* cell, except for contents.

Nodular end wall.—See End wall, nodular.

Oil cell.—A specialized cell of the ray or axial parenchyma containing oil, typically rounded in outline. Note: Limited to woody dicotyledons and similar to a mucilage* cell, except for contents.

Parenchyma.—Tissue composed of cells that are typically brick-shaped or isodiametric and have simple pits*; formed in wood from (a) fusiform* cambial initials by later transverse divisions of the daughter cells (axial parenchyma), or (b) ray* initials (ray or radial parenchyma). Syn. *Soft tissue, Storage tissue*. See also Parenchyma cell, fusiform. Note: Primarily concerned with the storage and distribution of food materials. Termed wood parenchyma or xylem parenchyma* if occurring in the xylem, and phloem parenchyma* if in the phloem.

Parenchyma, abaxial.—See Parenchyma, unilaterally paratracheal.

Parenchyma, adaxial.—See Parenchyma, unilaterally paratracheal.

Parenchyma, aliform.—Paratracheal parenchyma with wing-like lateral extensions, as seen in cross section.

Parenchyma, apotracheal.—Axial parenchyma typically independent of the pores or vessels. Note: This includes *Terminal, Diffuse*, and *Banded apotracheal parenchyma*.

Parenchyma, axial.—Parenchyma cells derived from fusiform* cambial initials. Syn. *Longitudinal paren-*

chyma (deprec.), *Vertical parenchyma* (deprec.), cf. Parenchyma, ray.

Parenchyma, banded.—Axial parenchyma forming concentric lines or bands, as seen in cross section. Note: Termed *Apotracheal banded*, if typically independent of the vessels, syn. *Metatracheal* (deprec.); *Paratracheal banded*, if associated with the vessels, syn. *Confluent*.

Parenchyma, confluent.—Coalesced aliform parenchyma forming irregular tangential or diagonal bands, as seen in cross section (IAWA modif.).

Parenchyma, diffuse.—Single apotracheal parenchyma strands or cells distributed irregularly among fibres*, as seen in cross section (IAWA modif.).

Parenchyma, diffuse-in-aggregates.—Apotracheal parenchyma cells that tend to be grouped in short tangential lines from ray to ray, as seen in cross section. Syn. *Diffuse-zonate*. Note: This type is often also reticulate (see under Parenchyma, reticulate).

Parenchyma, disjunctive.—Axial or radial parenchyma cells partially disjoined during the process of differentiation; contact is maintained by means of tubular processes (IAWA). Syn. *Conjugate* (obs.).

Parenchyma, initial.—Apotracheal parenchyma cells occurring either singly or forming a more or less continuous layer of variable width at the beginning of a season's growth, cf. Parenchyma, terminal.

Parenchyma, longitudinal.—See Parenchyma, axial.

Parenchyma, metatracheal.—See Parenchyma, banded.

Parenchyma, paratracheal.—Axial parenchyma associated with the vessels or vascular tracheids (IAWA modif.). Note: This includes *Scanty paratracheal*, *Vasicentric*, *Aliform* and *Confluent parenchyma*.

Parenchyma, phloem.—Parenchyma occurring in the phloem*.

Parenchyma, ray.—Parenchyma composing the rays wholly or in part (IAWA modif.). Syn. *Radial parenchyma*.

Parenchyma, reticulate.—A descriptive term for the net-like pattern formed on the cross section by rays and regularly spaced bands or lines of axial parenchyma when the bands or lines and the rays are of about the same width and distance apart, cf. Parenchyma scalariform.

Parenchyma, scalariform.—A descriptive term for the ladder-like pattern formed on the cross section by rays and regularly spaced bands or lines of axial parenchyma when the latter are distinctly narrower than the rays, cf. Parenchyma, reticulate.

Parenchyma, scanty paratracheal.—Incomplete sheaths or occasional parenchyma cells around the vessels.

Parenchyma, terminal.—Apotracheal parenchyma cells occurring either singly or forming a more or less continuous layer of variable width at the close of a season's growth. Note: Before a distinction was made between "terminal" and "initial" parenchyma, this term was used to include both forms and is still used in this sense as a term of convenience.

Parenchyma, traumatic.—Parenchyma cells of irregular size, shape and distribution resulting from injury to the cambium (SAF modif.). Syn. *Wound parenchyma*.

Parenchyma, unilaterally paratracheal.—Paratracheal parenchyma limited to the outer (abaxial) or inner (adaxial) sides of the vessels. Note: Such parenchyma may be further distinguished as *Unilaterally scanty*, *Unilaterally aliform* or *Unilaterally confluent*. Syn. *Abaxial*, *Adaxial parenchyma*.

Parenchyma, vasicentric.—Paratracheal parenchyma forming a complete sheath around a vessel, of variable width and circular or slightly oval in cross section (IAWA modif.).

Parenchyma, vertical.—See Parenchyma, axial.

Parenchyma, wood.—See Parenchyma, xylem.

Parenchyma, wound.—See Parenchyma, traumatic.

Parenchyma, xylem.—Parenchyma occurring in the xylem. Usually in two systems: (1) axial, and (2) radial (ray parenchyma). Syn. *Wood parenchyma.*

Parenchyma cell, fusiform.—An axial parenchyma* cell, derived from a fusiform* cambial initial without subdivision (IAWA modif.). Syn. *Substitute fibre* (deprec.), *Intermediate fibre* (deprec.), cf. Parenchyma strand.

Parenchyma cell, septate.—An axial or radial parenchyma cell with one or more thin transverse walls across its lumen* (IAWA modif.). Note: In these elements the protoplast* divides after the formation of the secondary cell* wall.

Parenchyma strand.—An axial series of two or more parenchyma cells derived from a single fusiform* cambial initial (IAWA), cf. Parenchyma cell, fusiform.

Perforation, multiple.—A perforated end wall in a vessel element consisting of two or more openings in a perforation* plate (IAWA modif.), cf. Perforation, simple.

Perforation, simple.—A single and usually large and more or less rounded opening in the perforation* plate, cf. Perforation, multiple (IAWA).

Perforation, vessel.—An opening from one vessel* member to another (IAWA).

Perforation plate.—A term of convenience for the area of the wall (originally imperforate) involved in the coalescence of two members of a vessel (IAWA).

Perforation plate, ephedroid.—A plate having a small group of circular openings (as in *Ephedra*). (IAWA).

Perforation plate, reticulate.—A plate with multiple perforations having a net-like appearance (as in certain Bignoniaceae). (IAWA).

Perforation plate, scalariform.—A plate with multiple perforations elongated and parallel. The remnants of the plate between the openings are called *Bars* (IAWA).

Perforation rim.—The remnant of a perforation plate forming a border about a simple perforation (IAWA).

Periderm.—The layers that replace the epidermis* as the impermeable covering of older stems; produced externally by the phellogen*.

Phellem.—A tissue produced externally by the phellogen* in a stem or root. The cell walls are generally suberized, and, in thick-walled kinds, there may be additional lignified layers towards the cell lumen. Unsuberized cells of the phellem are known as *Phelloid cells.*

Phelloderm.—A tissue that generally resembles cortical parenchyma in appearance, but which consists of the inner derivatives of the phellogen*. In woody plants the cells may become enlarged and thickened to form stone* cells, and are sometimes radially elongated.

Phellogen.—The meristematic layer that produces the periderm*. Syn. *Cork cambium.*

Phelloid cell.—See Phellem.

Phloem.—The principal food-conducting tissue of the vascular plants. It occurs both as primary and secondary tissue, and is usually, but not invariably, associated with xylem. In the stems of most gymnosperms and dicotyledons the secondary phloem is separated from the secondary xylem by the cambium* from which it is derived. The basic types of cells of which it is composed are sieve* elements, parenchyma* cells, fibres* and sclereids*.

Phloem, included.—Phloem strands or layers included in the secondary xylem of certain dicotyledonous woods. Syn. *Interxylary phloem* (deprec.). Two types are distinguished:

Concentric (Corpus lignosum circumvallatum). The cambium is short-lived and is replaced by new meristematic tissue, which develops in either the pericycle or the cortex and repeats the structure of the young stem. The stem thus consists of alternating zones of xylem and phloem. Syn. *Avicennia type.*

Foraminate (Corpus lignosum foraminatum). A single permanent cambium continues to function throughout the life of the stem and the xylem is normal except for the occurrence of strands of phloem imbedded in it. Syn. *Strychnos type.*

Phloem, internal.—Primary phloem internal to the primary xylem (IAWA). Syn. *Intraxylary phloem* (deprec.), *Perimedullary phloem.*

Phloem, primary.—First formed phloem; in stems and roots it is differentiated below the apical meristem* before a definite cambium* can be recognized.

Phloem, secondary.—Normally, the part of the bark formed by the cambium* (IAWA). See Phloem.

Phloem mother cells.—Cells that are cut off on the outer side by the fusiform* cambial initials, but which undergo further periclinal divisions before differentiating into phloem cells.

Phloem ray.—See Ray, phloem.

Pit.—A recess in the secondary wall of a cell, togther with its external closing membrane; open internally to the lumen. Note: Essential components are the pit* cavity and the pit* membrane (IAWA modif.). The following are terms used in describing pits:

Blind. A pit without a complementary pit in an adjacent cell. Note: A common form occurs opposite to an intercellular* space (IAWA modif.). Syn. *Air-pit* (deprec.).

Bordered. Typically, a pit in which the membrane is overarched by the secondary cell* wall.

Cupressoid. A cross-field* pit in early wood* with an ovoid, included (see under Pit aperture) aperture that is rather narrower than the lateral space on either side between the aperture and the border, as in *Cupressus.* Note: Used only for conifers.

Fenestriform. See Pinoid.

Half-bordered. See Pit-pair, half-bordered.

Linear. A pit with an aperture that is long, narrow and of more or less uniform breadth, as seen in surface view.

Piceoid. A cross-field* pit in early wood* with a narrow, and often slightly extended (see under Pit aperture) aperture as in *Picea.* Syn. *Piciform* (deprec.). Note: Used only for conifers.

Pinoid. A term of convenience for the smaller types of early wood* cross-field* pits found in several species of *Pinus* (but excluding the large, *window-like, fenestriform* pits found in *P.*

sylvestris, P. strobus, etc.). Characteristically simple or with narrow borders, and often variable in size and shape.

Ramiform. Simple pits with coalescent canal-like pit* cavities, as in stone* cells (IAWA).

Simple. A pit in which the cavity, becomes wider, or remains of constant width, or only gradually narrows during the growth in thickness of the secondary cell* wall, i.e., towards the lumen* of the cell (IAWA modif.).

Taxodioid. A cross-field* pit in early wood*, with a large, ovoid to circular, included aperture that is wider than the lateral space on either side between the aperture and the border, as in *Sequoia*. Note: Used only for conifers.

Vestured. A bordered pit with the pit* cavity wholly or partially lined with projections from the secondary cell* wall (IAWA). Syn. *Cribriform membrane* (deprec.).

Window-like. See under Pit pinoid.

Pit aperture.—The opening or mouth of a pit (IAWA). The following terms are used to describe pit apertures:

Coalescent. Slit-like apertures united to form grooves on the inner surface of the secondary cell* wall (IAWA modif.).

Extended. An inner aperture whose outline, in surface view, extends beyond the outline of the pit* border (IAWA).

Included. An inner aperture whose outline, in surface view, is included within the outline of the pit* border (IAWA).

Inner. The opening of the pit* canal into the cell lumen* (IAWA).

Lenticular. A slit-like aperture with the appearance in surface view of a double convex lens seen in section.

Outer. The opening of the pit* canal into the pit* chamber (IAWA).

Pit border.—The overarching part of the secondary cell* wall (IAWA).

Pit canal.—The passage from the cell lumen* to the chamber of any bordered pit. Note: Simple pits in thick walls usually have canal-like cavities (IAWA).

Pit cavity.—The entire space within a pit from the membrane to the lumen* (IAWA).

Pit chamber.—The space between the pit* membrane and the overarching pit* border (IAWA).

Pit membrane.—The part of the intercellular* layer and primary cell wall* that limits a pit* cavity externally (IAWA modif.). A central, thicker part of a pit* membrane is termed the *Torus*. Note: A torus with an indented or scalloped margin, as in *Cedrus*, is known as a *Scalloped torus*.

Pit-field, primary.—A thinner area of the intercellular* layer and primary cell* walls within the limits of which one or more pit-pairs* usually develop. Syn. *Primordial pit* (IAWA).

Pit-pair.—Two complementary pits of adjacent cells (IAWA).

Pit-pair, aspirated.—A bordered pit-pair in which the torus (see under Pit membrane) is laterally displaced so as to block one of the apertures.

Pit-pair, bordered.—An intercellular pairing of two bordered pits.

Pit-pair, half-bordered.—An intercellular pairing of a simple and a bordered pit (IAWA).

Pit-pair, simple.—An intercellular pairing of two simple pits.

Pith.—The central core of a stem, consisting chiefly of parenchyma* or soft tissue (BSI).

Pith ray.—See under Ray.

Pith fleck.—An irregular strand of abnormal (often traumatic) parenchymatous tissue embedded in the wood and appearing on a longitudinal surface as a streak. Commonly caused by the larvae of cambium miners.

Pitting.—A collective term for pits or pit-pairs.

Pitting, alternate.—Multiseriate pitting in which the pits are in diagonal rows. Note: When the pits are crowded, the outlines of the borders tend to become hexagonal in surface view.

Pitting, cross-field.—The pitting occurring in the rectangle formed in a radial section by the walls of a ray cell and those of an axial tracheid. Note: A term used mainly for conifers.

Pitting, intervascular.—A term used (a) in a wide sense for pitting between tracheary elements, and (b) in a narrower sense in wood anatomy for pitting between vessel members.

Pitting, opposite.—Multiseriate pitting in which the pits are in horizontal pairs or in short horizontal rows (IAWA). Note: When the pits are crowded the outlines of the borders tend to become rectangular in surface view.

Pitting, ray–vessel.—Pitting between a ray cell and a vessel member. Note: Certain anatomists distinguish the following types: *Gash-like, horizontal; Gash-like, vertical; Kidney-shaped; Large rounded; Similar to the intervascular pitting.*

Pitting, scalariform.—Pitting in which elongated or linear pits* are arranged in a ladder-like series (IAWA).

Pitting, sieve.—An arrangement of small pits in sieve-like clusters (IAWA modif.).

Pitting, unilaterally compound.—Pitting in which one pit subtends two or more smaller pits in the cell adjacent (IAWA).

Pore.—A term of convenience for the cross section of a vessel or of a vascular tracheid (IAWA).

Pore, solitary.—A pore completely surrounded by other elements (IAWA).

Pore chain.—A series or line of adjacent solitary pores (IAWA modif.).

Pore cluster.—See Pore multiple.

Pore multiple.—A group of two or more pores crowded together and flattened along the lines of contact so as to appear as subdivisions of a single pore (IAWA). Note: The most common type is a *Radial pore multiple*, in which the pores are in radial files with flattened tangential walls between them. Another type is a *Pore cluster*, in which the grouping is irregular.

Prosenchyma.—A general term for elongated cells with tapering ends. Note: Used in the past as a collective term for the fibres and tracheids, and sometimes the vessel members, as opposed to the parenchyma.

Protoplast.—The mass of protoplasm enclosed by a cell wall.

Protoxylem.—First-formed primary xylem*, with tracheary* elements characterized by annular or spiral thickenings (IAWA), cf. Metaxylem.

Radial multiple.—See Pore multiple.

Radial parenchyma.—See Parenchyma, ray.

Raphid(es).—See Crystal.

Ray.—A ribbon-like aggregate of cells formed by the cambium and extending radially in the xylem and phloem (IAWA modif.). Note: The terms *Medullary ray* and *Pith ray* are now restricted to the parenchyma connecting the primary cortex with the pith.

In the 1933 edition of the *Glossary*, *Heterogeneous* and *Homogeneous* rays were defined as follows:

Ray, heterogeneous.—A xylem ray composed of cells of different morphological types (typically, with the cells of the multiseriate part radially elongated and those of the uniseriate parts vertically elongated or square).

Ray, homogeneous.—A xylem ray composed of radially elongated cells.

An unsatisfactory feature of these definitions is that they do not cover the individual ray composed entirely of square or upright cells. Rays of this type are homogeneous in the literal sense of the term; research has shown, however, that they commonly occur as uniseriates accompanying markedly heterogeneous multiseriate rays and may be regarded as an essential component of the more primitive types of heterogeneous ray tissue. For this reason some wood anatomists have extended the term heterogeneous to include rays composed entirely of square or upright cells, a practice which is apt to cause confusion and is not generally acceptable.

The terms have been used in a quite different sense by C. Reinders-Gouwentak as translations of H. H. Janssonius' "*einfach*" and "*zusammengesetzt.*"

Accordingly the Committee has decided to recommend that the use of the terms "homogeneous" and "heterogeneous" for *individual rays* should be discontinued. They consider it more satisfactory to describe the structure of individual rays in full, for example: "The multiseriate portion composed of procumbent cells, the uniseriate margins composed of square or upright cells," or "rays uniseriate, composed entirely of procumbent cells."

Alternately, the terms "homocellular" and "heterocellular" proposed by Kribs (Bot. Gaz. 96 (3): 547–557. 1935) could be used in their literal sense, as follows:

Ray, homocellular.—A xylem ray composed of cells of the same morphological type, e.g., in the case of woody dicotyledons, all procumbent; or all square or upright; or, in the case of conifers, composed entirely of parenchyma cells. Note: Square and upright cells are considered to be of the same morphological type.

Ray, heterocellular.—A xylem ray composed of cells of different morphological types, e.g., in the case of woody dicotyledons, procumbent cells and square or upright cells; or, in the case of conifers, composed of parenchyma cells and tracheids.

The Committee recommends that the terms "homogeneous" and "heterogeneous" should be applied to the *ray tissue* of hardwoods; this follows the proposals by Kribs loc. cit. They recommend the following terms and definitions:

Heterogeneous ray tissue.—Ray tissue in which the individual rays are composed wholly or in part of square or upright cells. Note: Not to be applied to conifers.

Homogeneous ray tissue.—Ray tissue in which the individual rays are composed wholly of procumbent cells. Note: Not to be applied to conifers.

Ray, aggregate.—A group of small, narrow, xylem rays appearing to the unaided eye or at low magnification as a single large ray (IAWA).

Ray, fusiform.—Literally a ray that is spindle-shaped in tangential section. Used especially for the rays that contain resin canals in conifers. Syn. *Lenticular ray*.

Ray, multiseriate.—A ray two or more cells wide as seen in tangential section.

Ray, phloem.—The part of a ray external to the cambium (IAWA).

Ray, primary.—In wood anatomy, a ray originating in the primary tissues and extended by cambial growth. Syn. *Medullary ray* (deprec.), cf. Ray, secondary. Note: Commonly used for any ray that can be traced inwards to the pith. See also note under Ray.

Ray, secondary.—In wood anatomy a ray derived from the cambium (i.e., originating after the development of secondary xylem), and not extending inwards as far as the pith, cf. Ray, primary.

Ray, uniseriate.—A ray one cell wide as seen in tangential section.

Ray, wood or xylem.—The part of a ray internal to the cambium (IAWA), cf. Ray, phloem.

Ray cell, procumbent.—A ray cell with its longest axis radial (IAWA).

Ray cell, square.—A ray cell approximately square as seen in radial section. Note: Such cells compose certain uniseriate rays* and parts, typically the margins, of some multiseriate rays*, cf. Ray cell, upright.

Ray cell, upright.—A ray cell with its longest dimension axial (IAWA modif.). Note: Such cells compose certain uniseriate rays* and parts, typically the margins, of some multiseriate rays*.

Ray crossing.—See Cross-field.

Ray initial.—A cambial* inital giving rise to a ray cell; usually one of a group and often more or less isodiametric as seen in tangential section (IAWA modif.), cf. Fusiform initial.

Ray parenchyma.—See Parenchyma, ray.

Ray tracheid.—A tracheid* forming part of a ray.

Resin canal.—An intercellular* canal containing resin. Syn. *Resin duct.*

Rhytidome.—The phellem* and tissues isolated by it; often enclosing pockets of cortical or phloem tissues. A technical term for the outer bark*. Note: The rhytidome may be shed to leave a smooth trunk, or retained as a thick, fibrous or corky layer.

Ring, annual.—In wood and bark, a growth* layer of one year as seen in cross section (IAWA modif.), cf. Ring, growth.

Ring, discontinuous growth.—A growth ring* that is not present all around the stem.

Ring, double (or multiple).—An annual ring* consisting of two (or more) growth rings* (IAWA). Syn. *Multiple annual ring.*

Ring, drought.—See Ring, traumatic.

Ring, false annual.—One of the growth rings of a double (or multiple) ring* (IAWA modif.).

Ring, frost.—See Ring, traumatic.

Ring, growth.—In wood and bark a growth* layer as seen in cross section (IAWA modif.).

Ring, traumatic.—A zone of traumatic tissue produced by a cambium that has been injured. Note: Common causes are frost (usually late frost), drought and fire. The tissues tend to include irregularly-shaped wound parenchyma and to be coloured dark by the presence of gums and resins; intercellular* canals and drought cracks are sometimes present. Such rings may be distinguished as *Frost rings* or *Drought rings*, if the cause is known.

Ring boundary, growth.—The outer limit of a growth ring* (IAWA).

Ripewood.—See Heartwood.

Ripple marks.—Fine horizontal striations visible on the tangential longitudinal surfaces of certain woods, due to the storied* arrangement of the rays* or of the axial elements* or of both.

Sand, crystal.—See Crystal.

Sapwood.—The portion of the wood that in the living tree contains living cells and reserve materials (e.g., starch), cf. Heartwood. Syn. *Alburnum* (obs.).

Sapwood, included.—Wood included in the heartwood*, having the appearance and properties of sapwood. Living cells are no longer present as in normal sapwood but reserve materials may remain. Syn. *Double sapwood* (deprec.), *Internal sapwood*.

Scalloped torus.—See under Pit membrane.

Schizogenous.—Formed by the separation of tissue elements owing to the splitting of the common wall between adjacent cells.

Schizo-lysigenous.—Originating by the splitting of the cell wall, and developing by the breakdown of surrounding tissues.

Sclereid.—A strengthening element that is not markedly prosenchymatous*, but which has thick, often lignified secondary walls and which commonly lacks a

protoplast* when mature. Syn. *Sclerotic cell.* Note: Sclereids vary in shape from polyhedral to somewhat elongated and are often branched. The type commonly found in wood and bark is the *brachysclereid** or stone* cell. Such cells are often described as sclerotic, e.g., "sclerotic ray cells."

Sclerotic cell.—See Sclereid.

Sheath cell.—One of a series of upright cells (see Ray cell) on the margins of, and tending to form a sheath around, the procumbent cells* of a multiseriate ray* as seen in tangential section.

Sieve area.—A depressed area in the wall of a sieve element, perforated by a sieve-like cluster of minute pores through which the protoplast is connected with that of a contiguous sieve element. Syn. *Sieve field.*

Sieve cell.—A long, slender, conducting cell of the phloem, that does not form a constituent element of a sieve tube, but which is provided with relatively unspecialized sieve areas, especially in the tapering ends of the cells that overlap those of other sieve cells.

Sieve plate.—A specialized part of the wall of a sieve tube member that has a solitary sieve area (simple sieve plate), or several closely placed sieve areas, often arranged in a scalariform or reticulate manner (compound sieve plate).

Sieve tube.—A food-conducting tube of the phloem made up of an axial series of sieve tube members.

Sieve tube member.—A long, conducting cell of the phloem that forms one of an axial series of such cells arranged end to end to form a sieve tube, the common walls, which may be inclined or transverse, being sieve plates; sometimes with additional, less specialized sieve areas elsewhere in the walls.

Soft tissue.—See Parenchyma.

Spiral thickening.—Helical ridges on the inner face of, and part of, the secondary wall (IAWA). See Cell wall. Note: Often erroneously called tertiary spirals to distinguish them from the spirals of primary xylem*.

Stone cell.—An approximately isodiametric cell with a massive lignified secondary wall, which is often conspicuously laminated, and which may contain ramiform pits*, e.g., sclerotic tyloses*. Syn. *Brachysclereid.* See Sclereid.

Storied (storeyed).—A term applied to the axial cells and rays in wood when these are arranged in horizontal series on tangential surfaces. Note: The term is applied to particular tissues, e.g., "storied parenchyma" or used in a general sense, as in "woods with storied structure." The presence of storied structure is the cause of the ripple* marks visible with the unaided eye.

Strand, wood parenchyma.—See Parenchyma strand.

Styloid.—See Crystal.

Tile cell.—A special type of apparently empty upright ray* cell of approximately the same height as the procumbent ray* cells and occurring in indeterminate horizontal series usually interspersed among the procumbent cells (IAWA modif.). Note: Common in certain of the Tiliales and Malvales.

Torus.—See under Pit membrane.

Trabecula, pl. trabeculae.—A rod-like or spool-shaped part of a cell* wall which projects radially across the lumen* (IAWA). Syn. *Beam(s) of Sanio* (deprec.), *Bar(s) of Sanio* (deprec.).

Tracheary elements.—The principal water conducting elements of the xylem, mostly vessel* members and tracheids (IAWA). Note: In primary xylem the tracheary elements may have only annular, spiral, or reticulate thickenings and no pits.

Tracheid.—An imperforate wood cell with bordered pits to congeneric elements (IAWA modif.). See note under Fibre-tracheid.

Tracheid, disjunctive.—A tracheid partly disjoined laterally from another during differentiation; contact is maintained by means of tubular processes (IAWA). Syn. *Conjugate tracheid* (deprec.).

Tracheid, fibre-.—See Fibre-tracheid.

Tracheid, ray.—See Ray tracheid.

Tracheid, septate.—See under Tracheid, strand.

Tracheid septate fibre-.—A fibre-tracheid with thin transverse walls across the lumen (IAWA modif.). Note: In these elements the protoplast divides after the formation of the secondary walls.

Tracheid, strand.—A tracheid of an axial series (strand) of tracheids (or of mixed tracheids and parenchyma cells), each series originating from a single cambial* initial (IAWA). Syn. *Septate tracheid* (deprec.).

Tracheid, vascular.—An imperforate cell resembling in form and position a small vessel member (IAWA modif.). Syn. *Imperfect vessel member.*

Tracheid, vasicentric.—A short, irregularly-formed tracheid in the immediate proximity of a vessel* and not forming part of a definite axial row (IAWA modif.).

Transverse wall.—See Note 2.

Traumatic ring.—See Ring, traumatic.

Tylosis, pl. tyloses.—An outgrowth from an adjacent ray or axial parenchyma cell through a pit cavity in a vessel wall, partially or completely blocking the vessel lumen*. Note: Tyloses may be few or many crowded together; thin- or thick-walled; pitted or unpitted; with or without starch, crystals, resins, gums, etc.

Tylosis, sclerotic.—A tylosis, with an exceptionally thick, laminated, lignified wall and ramiform pits*. A form of stone* cell.

Tylosoid.—A proliferation of a thin-walled epithelial* cell into an intercellular* canal. Note: A tylosoid differs from a tylosis in that it does not pass through a pit* cavity.

Vessel.—An axial series of cells that have coalesced to form an articulated tube-like structure of indeterminate length; the pits to congeneric elements* are bordered (IAWA modif.). Syn. *Trachea.*

Vessel member or element.—One of the cellular components of a vessel (IAWA). Syn. Vessel segment (deprec.).

Vessel member or element, fibriform.—A vessel member of relatively small diameter bearing a resemblance to a fibre-tracheid*.

Vessel perforation.—See Perforation, vessel.

Wood.—The principal strengthening and water-conducting tissue of stems and roots. Characterized by the presence of tracheary* elements. Syn. *Xylem.*

Wood, compression.—Reaction wood* formed typically on the lower sides of branches and leaning or crooked stems of coniferous trees and characterized anatomically by heavily lignified tracheids* that are rounded

in tranvserse section and bear spiral cell* wall checks; zones of compression wood are typically denser and darker than the surrounding tissue. Syn. *Glassy wood, Hard streak, Redwood, Rotholz,* cf. Wood tension.

Wood, diffuse-porous.—Wood in which the pores* are of fairly uniform or only gradually changing size and distribution throughout a growth ring*, (IAWA).

Wood, early.—The less dense, larger-celled, first-formed part of a growth ring* (IAWA). Syn. *Spring wood.*

Wood, intermediate.—Inner layers of the sapwood that are transitional between sapwood and heartwood in colour and general character, cf. Ripewood under Heartwood.

Wood, late.—The denser, smaller-celled, later-formed part of a growth ring* (IAWA). Syn. *Autumn wood* (deprec.), *Summer wood.*

Wood, non-pored.—Wood devoid of pores* or vessels*; characteristic of conifers. Syn. *Non-porous wood* (deprec.), cf. Wood, pored.

Wood, pored.—Wood with vessels*; typical of woody dicotyledons as opposed to conifers. Syn. *Porous wood* (deprec.).

Wood, primary.—See Xylem, primary.

Wood, reaction.—Wood with more or less distinctive anatomical characters, formed typically in parts of leaning or crooked stems and in branches and tending to restore the original position, if this has been disturbed. Note: In dicotyledons this consists of tension wood* and in conifers of compression wood*.

Wood, ring-porous.—Wood in which the pores* of the early wood* are distinctly larger than those of the late wood* and form a well-defined zone or ring, cf. Wood, diffuse-porous (BSI modif.).

Wood, semi-ring-porous.—Wood in which the early wood* is marked by a zone of (a) occasional large vessels, or (b) numerous small vessels.

Wood, spring.—See Wood, early.

Wood, summer.—See Wood, late.

Wood, tension.—Reaction wood* formed typically on the upper sides of branches and leaning or crooked stems of dicotyledonous trees and characterized anatomically by lack of cell wall lignification and often by the presence of an internal gelatinous layer in the fibres*. Syn. *Zugholz*, cf. Wood, compression.

Xylem.—See Wood.

Xylem, primary.—First formed xylem*, differentiated from an apical meristem*. Note: Ordinarily at the edge of the pith* (IAWA).

Xylem, secondary.—Wood produced by a cambium* (IAWA modif.).

Xylem, mother cell.—A cell that is cut off on the inner side by a fusiform cambial* initial, but which undergoes further periclinal division before differentiating into a xylem cell.

NOTES

Note 1. Terms denoting orientation.—The terms "transverse," "axial," "radial" and "tangential" are used with reference to the axis of the stem (or branch). The term "axial" thus replaces "vertical" where this appeared in the original *Glossary*.

The position in relation to the axis may not be known or may be immaterial for individual cells, as for example in macerated material. Here the terms "end wall" and "longitudinal wall" are used in relation to the long axis of the cell. Examples are illustrated in fig. 1 below.

Note 2. Terminology of the fine structure of the cell wall.—Knowledge of this subject is increasing so rapidly with the use of

the electron microscope that the terminology is likely to prove very unstable for some years to come. It has therefore been decided to omit all such terms from the present glossary and to include only the terms for features that can be seen with an optical or light microscope.

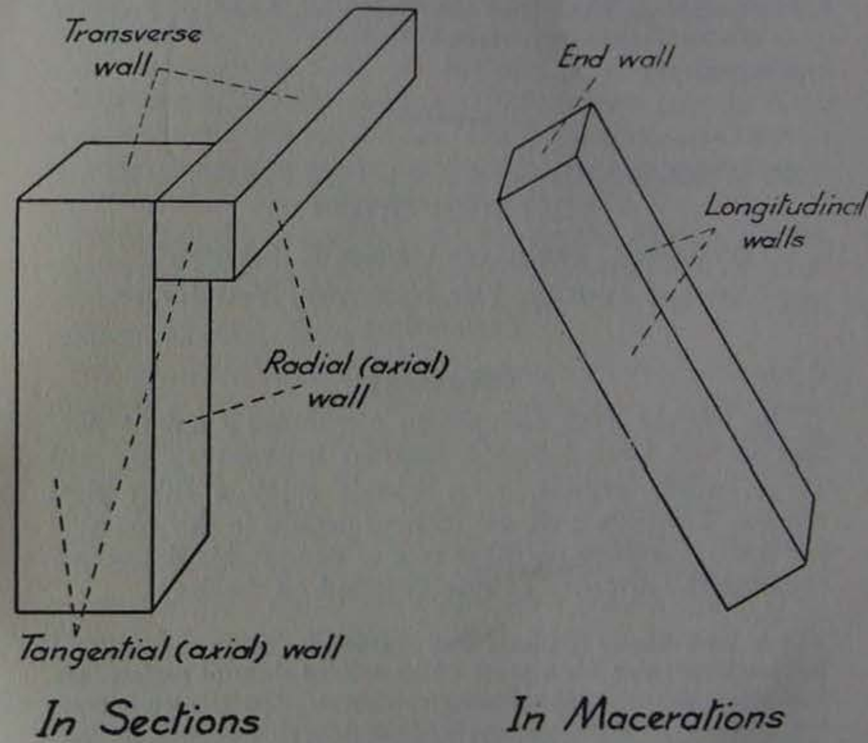

Fig. 1. Terminology for the orientation of cell walls.

ABBREVIATIONS

* = Indicates the key word determining the alphabetical position of a term defined elsewhere; e.g., "tension wood*" will be found under "Wood, tension."

Am. = North American.

BCF = Definitions taken from Part I of the British Commonwealth Forest Terminology, 1953.

BSI = Definitions taken from the British Standards Institution publication B.S. No. 565, 1949, "Glossary of terms applicable to timber, plywood and joinery."

deprec. = deprecated.

IAWA = Definitions taken from the "Glossary of terms used in describing woods," Trop. Woods 36: 1–13. 1933.

modif. = modified.

obs. = obsolete.

pl. = plural.

SAF = Definitions taken from the Society of American Foresters' "Forest Terminology," 1950.

Syn. = synonym.

THE WOODS AND FLORA OF THE FLORIDA KEYS. INTRODUCTION

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Geography

The Florida Keys archipelago constitutes a unique portion of the United States. Situated between 24°30′ and 25°30′ north latitude, these islands enjoy a subtropical climate. The flora is almost without parallel in this country, for there is perhaps no other area of comparable size which supports the diversity of species found on the Keys.

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This arc of islands begins on the north with Soldier Key and slopes toward the southwest terminating in the Marquesas Keys, and atoll-like cluster of islets 18 or 19 miles west of Key West (fig. 1). The archipelago is bounded on the north and west by a series of sounds, the most extensive being the Bay of Florida which merges at its western-most extremity with the Gulf of Mexico. On the south and east, the Straits of Florida direct the Gulf Stream past the Keys and across the Atlantic Ocean. The Bahama Islands (Bimini) lie a scant 50 or 60 miles to the east, and extending northeastward and southeastward, they separate the Straits of Florida and the Santaren Channel from the Atlanitc Ocean. South of the Keys, across the Straits of Florida and the Gulf of Mexico, is Cuba. To the north and west lies the mainland of Florida (fig. 2).

On maps the Keys appear as a numberless group of islands ranging in size from the smallest consisting of a few mangrove plants, to Key Largo, which is 28 miles long and up to 3.5 miles wide, and Big Pine Key, which is eight miles long and over two miles broad at the widest part. In outline the individual keys are highly irregular, but taken as a whole they show certain consistencies in geographical orientation. The axes of the Upper Keys (Small, 1913), from Soldier Key south to Bahia Honda, parallel the axis of the island arc; the axes of the Lower Keys are roughly perpendicular to the axis of the archipelago (fig. 1). Many of the smaller keys are awash part of the time and it is doubtful whether even the largest are much more than 18 feet above the mean tide level (Windley's and Plantation Keys; Vaughan, 1914b). Differences in elevation on the Keys profoundly influence the flora and vegetation.

Geology

The rock of which the surface of the Florida Keys is composed is calcareous and was formed under water during the Sangamon interglacial stage of the Pleistoncene epoch. At this time the seas invaded southern Florida and reached depths of about 100 feet above the present level. The Upper Keys, from Soldier Key to Bahia Honda, were formed by

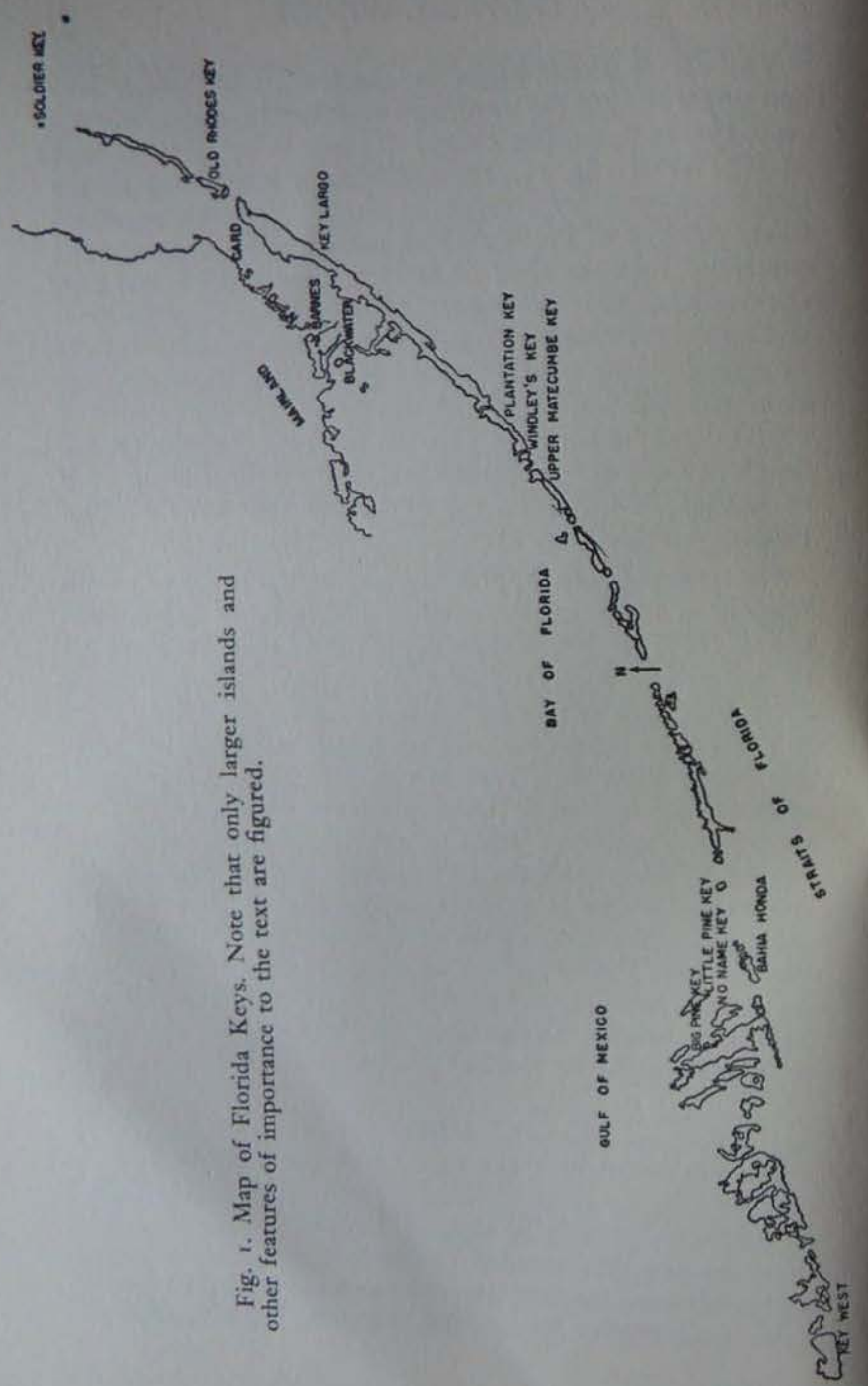

Fig. 1. Map of Florida Keys. Note that only larger islands and other features of importance to the text are figured.

living corals which built a reef upon the Pliocene Tamiami formation. The remains of this coral reef are now known as the Key Largo limestone. Contemporaneously, the Lower Keys, from Little Pine Key and No Name Key southward, as well as certain parts of the mainland, were in the process of being deposited. These rocks now comprise the Miami oolite. It is of interest to note here, that Sanford (1909) restricted this designation to the sandier oolite of the mainland and named the almost pure oolitic outcroppings on the Lower Keys, the Key West oolite. However, Parker and Cooke (1944) have chosen to use Miami oolite to cover both the mainland rock and that on the Keys, for they say that "The Miami oolite underlies the Atlantic coastal ridge from a transition zone near Boca Raton to Florida City; it floors the Bay of Florida and reappears above water-level once again in the lower keys. . . ." This rock is also underlain by the Pliocene Tamiami formation.

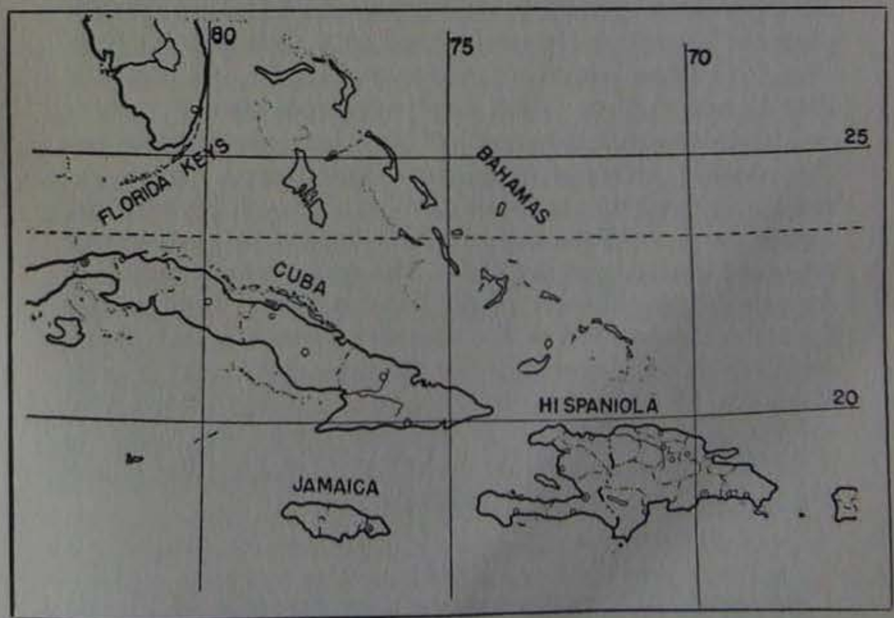

Fig. 2. Map of the Florida Keys area including some of the West Indies.

Following these events, the sea receded in the early Wisconsin and erosion took place characterized by channel cutting and solution in the Miami oolite. During mid-Wisconsin (Pamlico time) the sea rose to about 25 feet above the present level and again flooded much of southern Florida. In late Wisconsin time, the sea receded slowly to 25 feet or more below the present level. During Recent time the sea reached its existing level and a new coral reef began to fringe the Keys on the seaward side. Thus the recent geologic history of the Keys has been characterized by oscillations in the sea level coincident with fluctuations in glacial movement.

It is perhaps germane to examine briefly the geologic relations between the Florida Keys and the closest insular masses, viz., Cuba and the Bahama Islands (fig. 2). We read in Vaughan (1914b) that ". . . the Floridian, Andros (Bahamas) and Cuban reefs all have a similar relation to the oscillation of sea-level, as in each instance there has been an elevation antecedent to depression which has brought the platform on which the reefs stand into their present positions." Vaughan points out, however, that the oscillations in Florida and Andros Island have occurred without notable crustal movements; whereas in Cuba there was conspicuous deformation accompanying these fluctuations. In an extremely interesting account, Vaughan (1914a) describes the formation of the Bahaman and Floridian oolites through the action of denitrifying bacteria. The oolite which occurs in the sea bottom off some of the Bahama Islands is of exactly the same composition as the southern Florida oolite. Moreover, the oolitic deposits of the Bahamas and Lower Florida Keys are of precisely the same age. Further information on the geologic history of the Keys may be found in Vaughan (1910) and Parker and Cooke (1944), from whom the writers have drawn extensively.

Soils

Recourse to Henderson (1939) on the soils of Florida failed to reveal much information regarding the soils of the Keys. Furthermore, most of the soils of Florida have not

been mapped; many types as yet remain unclassified. The soil association map of Dade County, Florida (Leighty, et al., 1954), which includes the Upper Keys south to Old Rhodes Key, groups the soils on these islands in "Miscellaneous land units." As regards the existing soils on the Keys, it can be said that in large areas, the rock is not covered by any mantle which could properly be termed soil. Davis (1943) remarks that in certain places on the mainland underlain by the Miami oolite, there are areas with so little soil that the growth of vegetation is greatly inhibited. Also, the prevalent fires often reduce to ashes the shallow organic soils. No doubt this is the case on Big Pine Key where large areas are frequently ravaged by fires to the detriment of soil resource. Such exposed regions are commonly called "rocklands."

In these rocklands, numerous "solution holes" or "lime sinks" occur. Here the limestone has been irregularly dissolved leaving jagged-margined holes of varying area; organic debris collects and rots in the moisture at the bottom. Solution holes are somewhat protected from fire and gradually a layer of soil is formed, probably akin to the A_1 horizon of the true soil. This is often covered by partly decomposed organic remains. Such depressions are oases in the pinelands and frequently support an entirely different flora from the surrrounding country. From one such place on Big Pine Key, west of the "quarry hole," the writers collected *Annona glabra*, *Chrysobalanus icaco* and *Persea borbonia*, none of which was found growing in the adjacent pinelands.

In Watson's Hammock on Big Pine Key, there occur deposits (at least 20 inches deep) of a dark soil apparently rich in organic matter (fig. 8). These deposits support a luxuriant growth of hammock vegetation. The area is quite secluded and lies on the northwest end of the key between the pinelands and the mangroves bordering Pine Channel. No evidence of recent fires was observed. Goggin and Sommer (1949) also report a layer of "very black soil" which they uncovered during archaelogical operations on Upper Matecumbe Key. In the hammocks of North Key Largo, a thin layer of soil is present under a blanket of leaf litter. On the landward side of the mangrove vegetation on many of the keys, flats covered by a dark gray, sticky mud are conspicious. These areas, called "salinas" by the inhabitants, support *Randia aculeata*, *Bumelia celastrina*, *Lycium carolinianum*, *Conocarpus erectus* and somtimes *Avicennia nitida*. There apparently have been parallel modifications in the vegetative structure of plants growing in these salina areas, for *Randia*, *Bumelia* and *Lycium* are hardly distinguishable from each other until the reproductive portions are closely examined. All are stunted, short-branched, small-leaved, gray-barked shrubs.

Origin and Distribution of the Flora

The striking similarity between the flora of the Florida Keys and the West Indian Islands suggest that plants on the Keys migrated there from the south. The tropical and subtropical species that comprise the flora of the Keys gradually become less numerous as one goes northward onto the mainland. At about 27° north latitude this tropical influence gives way to the more northerly elements of the flora (Small, 1913; Harshberger, 1911, 1914; Brendel, 1874; Guppy, 1917; Britton and Millspaugh, 1920; Millspaugh, 1907; Davis, 1942, and others). The resemblance of the West Indian and Keys flora is especially noticeable when one compares the flora fo the Keys with such West Indian islands as the Bahamas, which show similar topography and geological history. Davis (1942) states unequivocally that "These Sand Keys and the whole south Florida region derive their flora from all the Caribbean region." Small (1913), who botanized extensively on the Keys, states, "Thus we find here (on the Keys) a tropical flora made up almost wholly of West Indian elements, and closely related to the floras of Bermuda, the Bahamas, and Cuba."

That the flora of the Keys and the flora of the West Indies are alike should not seem strange if one considers the nature of the ocean currents in the Caribbean-Gulf of Mexico-Florida area, the proximity of the insular masses (fig. 2), the geologic history and similar climate of the area, the

efficient means for water dispersal of some of the plants, the presence of frugivorous and wading birds, and even perhaps prehistoric man (Goggin and Sommer, 1949; Rouse, 1949). Guppy (1917) has shown how sea currents can act as vectors of fruits and seedlings, and has emphasized the remarkable durability of some of these propagules when in contact with salt water. The Gulf Streams sweeps past the Keys carrying all sorts of vegetable debris some of which undoubtedly drifts or is swept ashore during storms, takes root and grows. Davis (1942) mentions experiments in which mangrove seedlings (*Rhizophora mangle*) were cast overboard in the Sand Key region only to be recovered on the shores of the Tortugas islands. It is a noteworthy fact that in this region where the main ocean currents move from west to east, these seedlings migrated from east to west! Davis reports that "Other evidence showed that it is entirely probable that the other mangrove species (viz., *Laguncularia racemosa* and *Avicennia nitida*) can also float efficiently, and that no doubt all mangroves are able to survive long voyages.[2]" Also this same author stresses aquavection as the "most efficient mode of dispersal." Guppy would doubtlessly agree.

Frugivorous birds in this region most likely feed on the fleshy fruits of *Coccoloba uvifera*, *Coccothrinax argentata*, *Thrinax* spp., *Opuntia* spp., *Jacquinia keyensis*, *Krugiodendron ferreum*, *Ximenia americana* and other plants. The feet of wading birds probably carry seeds of certain beach and shore plants. With the narrow distances that separate many of these islands and island groups, it is reasonable to assume that birds are responsible for some of the dispersion of the flora. Man cannot be overlooked as a vector, for some of the plants brought here by him, even in historical times, have become naturalized—others appear now to be in the process of becoming established. Among the former we can cite *Casuarina equisetifolia*, *Thespesia populnea*, *Tamarindus indica* and *Psidium guajava*.

[2]See Egler, F. E. 1948. The dispersal and establishment of red mangrove, *Rhizophora* in Florida. Carib. Forester 9: 299–320, for further information on this topic.

In summary it might be well to note Davis' (1942) conclusions for the dispersal of the Sand Keys flora: ". . . that most of the mangrove, salt-marsh, and strand-beach plants are aquavectant; the strand-dune plants are both aquavectant and avevectant; and most of the fruiting shrubs and trees of the strand scrub and strand hammock are avevectant." The flora of the Florida Keys has thus originated from regions to the south–the Caribbean–and has been transported mostly by the sea and by birds, and to a small extent by man.

VEGETATION

Because Davis' (1943) classification of south Florida vegetation seems best to fit the situation on the Keys, an abridged form will be employed in descriptions here. Other classifications of south Florida vegetation have been proposed, among which are those of Harshberger (1914) and Harper (1927). Of the five groups chosen from Davis to describe the vegetation of the Keys, three can properly be said to represent forests. The others consist mainly of shrubs and herbs. The forest areas probably cover the greatest land masses on the Keys.

Pine forests or pinelands.–In these forests the most conspicuous plant is the south Florida slash pine, *Pinus elliottii* var. *densa.* On the Keys, pinelands grow on the Miami oolitic limestone and may occur where little if any soil is present. Some of the woody plants characteristically associated with the pines are: *Guettarda scabra, Myrtus verrucosa* (syn. *Eugenia longipes*), *Ardisia escallonioides, Croton linearis, Pithecellobium guadalupense, Pisonia rotundata, Urechites lutea, Torrubia* spp., *Caesalpinia pauciflora, Byrsonima lucida* and *Crossopetalum ilicifolium.* Several species of palms always appear with the pines and form with them the greater part of the arborescent vegetation, viz., *Coccothrinax argentata, Thrinax microcarpa,* and to a lesser extent, *Sabal palmetto. Serenoa repens* occasionally occurs on Big Pine Key. As stated previously within the rocky substratum of pinelands, areas called "lime sinks" may be present. These holes are commonly filled with a dark organic soil which supports vegetation not found in the fringing pinelands.

Hammock forests.–Davis (1943) defines hammock forests as "Hardwood and palm forests usually dominated by broad-leaved evergreen trees and limited to relatively small areas, growing on high upland to seasonally flooded soils and containing a great variety of . . . tropical species. Often a climax forest developed after a series or succession of other stages of vegetation." On the Keys, hammocks comprise the most nearly tropical type of vegetation in Florida.

The hammocks of the Lower Keys are characterized by a great diversity of species among which are: *Coccoloba diversifolia, Krugiodendron ferrum, Savia bahamensis, Reynosia septentrionalis, Byrsonima lucida, Cupania glabra, Dipholis salicifolia, Ficus* spp., *Chiococca alba, Chrysophyllum oliviforme, Citharexylum fruticosum, Dodonaea ehrenbergii* (syn. *D. microcarya) Myrtus verrucosa, Hippomane mancinella, Mimusops emarginata, Exothea paniculata, Metopium toxiferum, Bursera simaruba* and *Jacquinia keyensis.* Plants normally existing in hammocks on the Lower Keys may also occur to a lesser extent in the adjacent pinelands. Hammocks on the Upper Keys support many trees and shrubs some of which are found in the hammocks of the Lower Keys as can be seen below: *Exostema caribaeum, Citharexylum fruticosum, Gymnanthes lucida, Hypelate trifoliata, Bursera simaruba, Colubrina reclinata, Guaiacum sanctum, Swietenia mahagoni, Simaruba glauca, Sideroxylon foetidissimum, Metopium toxiferum, Drypetes diversifolia, Reynosia septentrionalis, Canella winterana, Calyptrathes pallens* and *Psychotria undata.*

Mangrove swamp forest.–Swamp forests are always a feature of the north or bay side of the Florida Keys and frequently encircle some of the smaller keys. On small, low-lying keys, the entire vegetation may consist solely of mangroves. A definite zonation is exhibited by these mangrove forests. The outermost zone, closest to the sea, is made up exclusively of the red mangrove, *Rhizophora mangle,* whose prominent stilt roots make this region conspicuous even at a distance. To the landward side of the red mangroves, but still subject to high tides, we find the zone of black mangroves, *Avicennia nitida.* This is sometimes a mixed zone, the black mangroves sharing their niche with the white mangrove, *Laguncularia racemosa*. An evident feature of the black mangrove region is the presence of pneumatophores which project 8 or 10 inches above the substratum. Pneumatophores are irregular, spongy, penicilliform, aerial protuberances from the roots of *Avicennia*. The buttonwood *(Conocarpus erectus)* zone may accompany the former zones on areas above the influence of normal high tide levels.

On the Keys, the mangrove swamp forests may form a narrow rim around an island, or they may produce an extensive, highly impenetrable jungle. Young swamp forests at times contain only *Rhizophora mangle;* older swamp forests usually show the typical trizonate configuration. The red mangroves vary in size from shrub-like plants only a few feet in height to large trees 50–60 feet high. The stunted, shrub-like red mangroves constitute the most common form encountered on the Keys.

Strand vegetation.–A calcareous sandy substratum, winds carrying salt spray, and a high water table caused by nearness to the sea, make up in large part the environment the strand plants must endure. The vegetation is mostly herbaceous consisting of grasses and a few vines such as *Sesuvium portulacastrum*, *Canavalia lineata* and *Ipomea pes-caprae*. The woody vegetation is sparse, and most of this is shrub-like. Along the very exposed outer areas grow the hardy *Coccoloba uvifera*, *Tournefortia gnaphalodes*, *Scaevola plumieri* and *Suriana martima*. Inland from this zone of sentinels, and more protected from the effects of the open sea, grow *Genipa clusiaefolia*, *Cordia sebestena*, *Pithecellobium unguis-cati*, *Caesalpinia bonduc* and *Yucca aloifolia*. The coconut palm, *Cocos nucifera*, is common in this region especially in the vicinity of habitations. These and other plants may form the so-called coastal hammocks.

Among the factors which control the zonation along the beaches are the tolerance of the plants to saline conditions coupled with their drought resistance and ability to grow on a loose and somtimes shifting substratum. The strand plants, along with the mangroves, are probably among the first to colonize newly-formed land on the Keys.

Salt water marshes.–On the Keys the salt water marshes are common in or near the mangrove swamp forests. For the most part the plants in this category accompany the black mangrove zone and grow among the pneumatophores. Here we find low shrubs and semi-shrubs: the saltwort, *Batis maritima* and glasswort, *Salicornia perennis*.

Without going into great detail, it seems evident that on the Keys, where relief is relatively nonexistent, the ability to withstand saline conditions is of prime importance in determining the distribution of the vegetation and flora. The hammocks (excepting perhaps the coastal kind) and pinelands are most likely composed of plants with little or no tolerance to salt. These areas are usually inland and thereby protected from high water tables (this is relative on the Keys) and the effect of salt spray. Where strand vegetation merges with the more inland vegetation, a coastal hammock may arise. The plants composing this vegetation probably have some tolerance to salt, since they must come under the influence of the sea to some extent. The mangrove and marsh vegetation is composed of halophytes, for the sea bathes the roots of these plants at one time or another.

Observations made by the writers in the pinelands of Big Pine Key and No Name Key seem to point to the conclusion, that the pinelands would evolve into hammocks were fire excluded. Davis (1943) states that "These hammocks are the climax development of vegetation in southern Florida." Simpson (1920) concurs and emphasizes that the pinelands would disappear in southern Florida if fire were controlled.

Since 1948, when a hurricane wrenched a gaping hole in the wooden Big Pine–No Name bridge, interrupting intercourse with the mainland, fire has been absent from No Name Key and the effects are conspicuous. Before this time there were permanent residents on the latter island; today it is believed the only inhabitants are transient visitors. For many years fires have swept through and ravaged the pinelands of Big Pine Key. These conflagrations burn and kill most of the hardwood vegetation associated with the pines (fig. 7). However, the pines and palms appear to be only partially damaged by these fires. No doubt the degree of killing is largely dependent upon the severity and duration of the fire; in any event, the pines and palms seem to be somewhat fire resistant. Along with the destruction of the hardwood vegetation, fires frequently burn the accumulations of leaf litter on the forest floor. Thus they also affect the soil building processes. There is no doubt also an effect on the seed bed, which in turn influences the ability of seeds to germinate.

In general the pinelands in Big Pine Key present a very open aspect and consist mainly of pines and palms with a scattering of low and often stunted hardwood trees and shrubs (fig. 3). Ground cover in the form of soil or leaf litter is largely absent (fig. 5). In contrast, the pinelands of No Name Key have not been harassed by fires for at least six years. Observation shows that here an abundant leaf litter has already accumulated (fig. 6), and the hardwoods have formed a dense growth under the pines. It is impossible to see into the forest for more than a few feet in the No Name pinelands (fig. 4). Some hammock plants always accompany the pines as has been pointed out previously; therefore it is reasonable to hypothesize, even though the authors have not carried out any systematic researches, that if protected from fires for a long enough period, the pinelands of the Keys would become transformed (revert?) into hammock forests.

Botanical Exploration on the Florida Keys

Two phases in the botanical exploration of the Florida Keys can be recognized. The first can be called *historical* and continued from about 1775 to 1830; the second, or *scientific* phase, followed. The historical phase is characterized by reports of plants seen on the Keys by more or less competent persons. These records appear mostly in general works on the history and geography of Florida, and point out only the outstanding or useful plants. As far as the authors can determine, there are no plants now in herbaria collected during this historical period. The scientific phase of botanical exploration on the Keys begins with the actual collection and preservation of plants accompanied by more

Fig. 3–4.—Fig. 3. Pinelands on Big Pine Key to illustrate the open aspect of vegetation and lack of hardwood growth as conditoned by fire.—Fig. 4. Pinelands on No Name Key showing dense undergrowth of hardwoods which has sprung up since the exclusion of fire in 1948.

Fig. 5–6.—Fig. 5. Surface of ground in pinelands of Big Pine Key. Note lack of any organic mantle, the relative absence of shade and presence of young pine seedlings.—Fig. 6. Surface of ground in pinelands of No Name Key. Note leaf litter, the heavy shade, absence of pine seedlings and the presence of young hardwood vegetation.

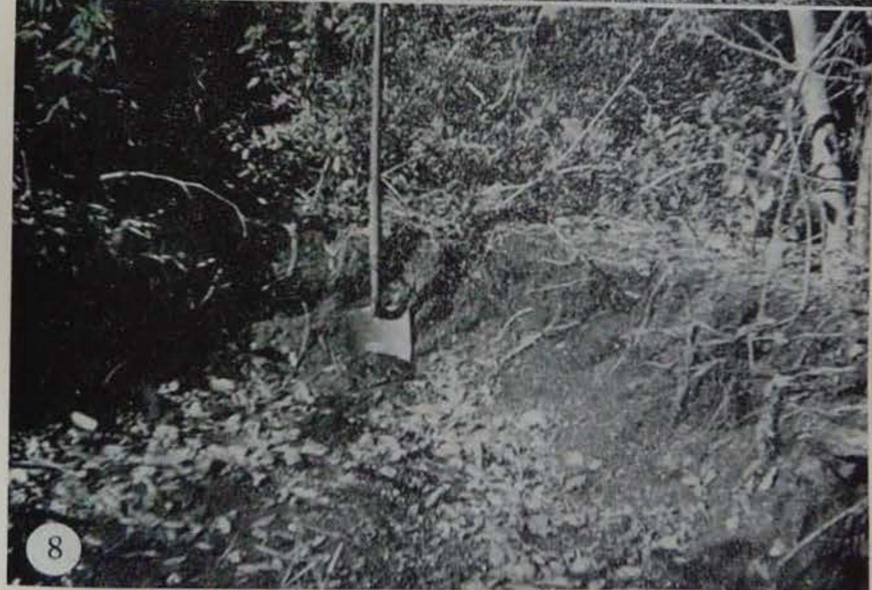

Fig. 7–8.—Fig. 7. Pinelands on Big Pine Key immediately after fire has swept through. Hardwood vegetation appears to be totally absent and little or no organic remains cover the ground. The pines and palms seem to be relatively fire resistant.—Fig. 8. Watson's Hammock on Big Pine Key showing the layer of dark-colored soil that is present in this area which has been relatively free from highly destructive fires.

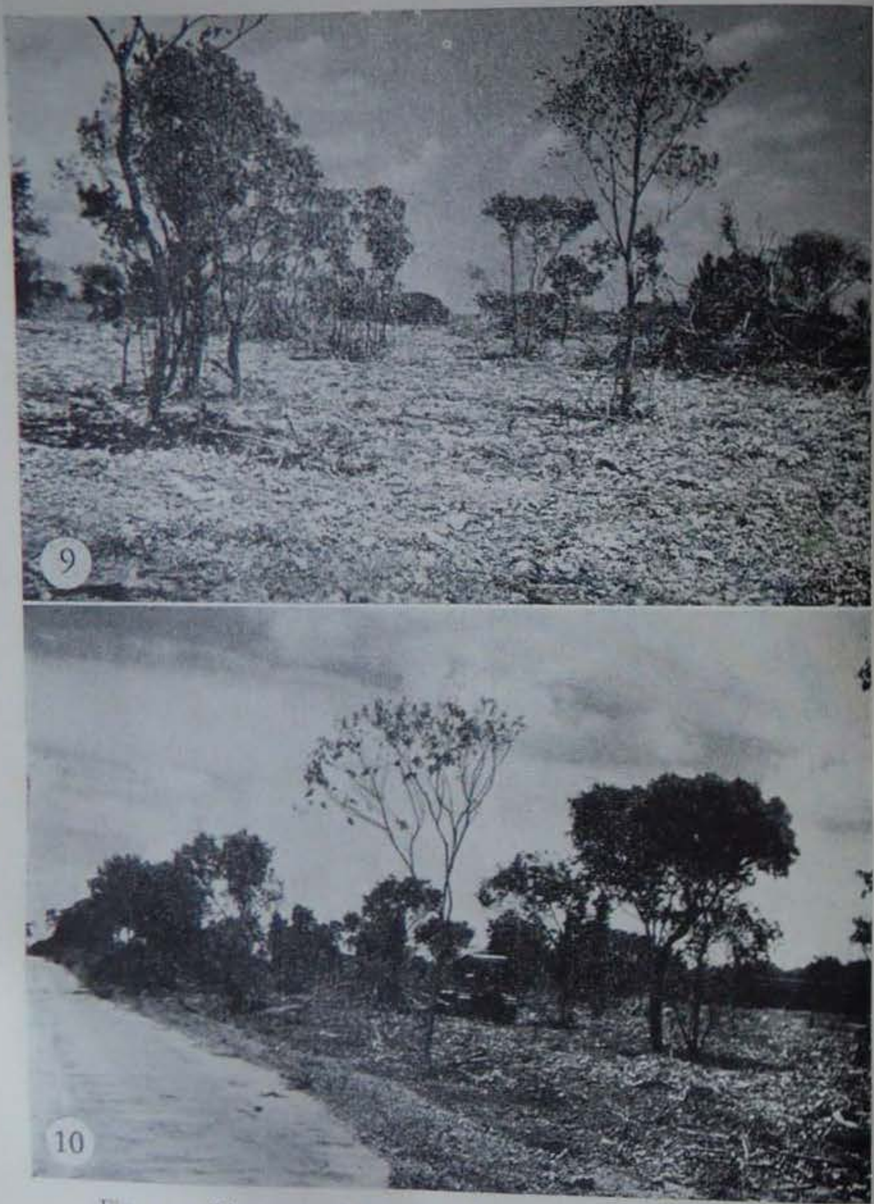

Fig. 9–10. The rape of Plantation Key. Both figures show the results of promiscuous bulldozing. Note the barren surface of the ground in figure 9, and the pile of debris heaped for burning.

or less detailed notes. These specimens, deposited in herbaria, have served as the bases for floristic and other botanical studies of the Florida Keys.

Historical phase.—The earliest report (ca. 1575) of plants on the Keys known to the authors, is that of Hernando d'Escalante Fontaneda (1532?–?). Fontaneda, born of Spanish parents in Carthagena, Chile, was shipwrecked and captured by Indians off the coast of Florida about 1545. Seventeen years later he was rescued and brought to Spain. Because of his experience, he accompanied the expedition of Don Pedro Menéndez to Florida in 1565 for whom he acted as interpreter. Later he returned to Spain. Regrettably, Fontaneda reports only a single plant from the Florida Keys: "On these islands is likewise a wood we call here *el palo para muchas cosas* (the wood of many uses), well known to physicians; also much fruits of many sorts, which I will not enumerate, as, were I to attempt to do so, I should never finish" (True, 26. 1945). Buckingham Smith, one of the translators of Fontaneda's *Memoir*, adds the following: "No doubt *Guaiacum officinale* (lignum vitae) is meant. It covers, says Williams, the higher points of the interior keys" (True, 41. note 11S. 1945). However, the only species of *Guaiacum* that occurs on the Keys, is *G. sanctum*, to which, no doubt, Smith's note refers. A hiatus of about 200 years follows the report in Fontaneda's *Memoir*. That no records of plants from the Keys occur during this time may be due to a real lack of such reports, or the authors' inability to locate these.

In 1775, Bernard Romans (ca. 1720–1783) published his work *A concise natural history of East and West-Florida*. In this book a number of Florida plants, without specific reference to the Florida Keys, are cited by their common and Latin names. However, in the general description of the Florida Keys, five local plant species are mentioned by common names: "Between Sound Point or Cape Florida[3]

[3]The designation Cape Florida was applied to the promontory in the middle of Key Largo, however, the name has been mostly restricted to the southern end of Key Biscayne, or employed as another name for this key (Vignoles, 84, 117, 118. 1823).

. . . and this last island (Key Rodriguez) is another sheltering place, or roadstead, for small vessels, within a ridge or reef on which we generally see some turtle crawls, but it is seldom occupied except by the timber-cutters, the peninsula affords in this place Lignum-Vitae *(Guaiacum sanctum)*,[4] Mastick *(Sideroxylon foetidissimum)* and Mahogany *(Swietenia mahagoni)*, the two last are indeed found on every part thereof (but on none of the Keys north of Saunders-Key or Las-Tetas nor on none to the south of the last key north of young Matacombe, all these timbers are however now nearly cut off" (Romans, xxxii. 1775). And further on, in the description of Mascaras, i.e., "7 rocks next to the Soldier Keys," we read: "There are some mangrove *(Rhizophora mangle)* and blackwood bushes *(Avicennia nitida)* on them" (Romans, xxvii. 1775). "The History of East and West Florida is a work of no little interest to botanists, as Romans was the first person with any knowledge of plants who visited the coasts and islands of southern Florida; it gives the earliest account of the Ogeechee Lime, and of the Florida Fig, *Ficus aurea*, and first makes known the fact that several West Indian trees are found on the Florida coast" (Sargent, 4: 5. 1892).

The work of George Gauld, *Observations on the Florida Keys* . . ., published in 1796, contains in general little of interest to botanists. We find here, however, apparently the earliest mention of *Sabal palmetto* as an inhabitant of the Keys. In his observations on the Bahia Honda Keys, Gauld mentions: ". . . tall palmetto cabbage-trees of the Long Island on the right (of Bahia Honda) coming in; they make it the more remarkable, as there are no cabbage-trees to the westward of it . . ."

James G. Forbes visited the Florida Keys in 1803. An account of this visit to the Keys is given in 1821 in *Sketches, historical and topographical, of the Floridas* . . . In the general descriptions of the Keys, Forbes says: "Beside the general character of these keys, or islands, for the purposes of privateering and turtleing, to which they have been long

[4]Parenthetical scientific names have been inserted.

subervient, they were formerly well timbered with fustic, mahogany, lignum vitae, and brazilletto. But they have been cut and carried off by the wreckers from the Bahamas; who, since the wars have ceased to yield them their usual harvests, have depended for their support, in a great measure, upon this encroachment on the Spanish territory" (Forbes, 107. 1821). Forbes' citation of fustic *(Chlorophora tinctoria)* and brazilletto *(Peltophorum brasiliense)* as having occurred on the Keys is probably erroneous. Of course it is also possible that these common names were incorrectly applied by Forbes to some truly native species of the Keys.

In 1823, Charles B. Vignoles (1793–1875) published his interesting *Observations upon the Floridas*. Regrettably, the only reference to the flora of the Keys is found in the brief description of Key Largo: "Key Largo formerly abounded with mastic *(Sideroxylon foetidissimum)*, lignum vitae *(Guaiacum sanctum)* and mahogany *(Swietenia mahagoni)* but the most valuable has been long cut down, and there is none now but very young timber. A portion of good rich land is on this key, among the principal growth of which is found the wild cinnamon *(Canella winterana)*, wild olive *(Sideroxylon foetidissimum)*, etc." This is the earliest report of *Canella winterana* from the Keys. *Sideroxylon foetidissimum* is cited twice, but under different common names. It is possible that in citing mastic, Vignoles quoted Romans, but wild olive may have been Vignoles' name for the *Sideroxylon* actually seen by him. Vignoles may not have known that both common names referred to the same species.

The last, and the most outstanding contributor to the historical phase of botanical exploration, is John Lee Williams (1775–1856), whose brief biography has been extracted from Federick W. Dau's *Florida old and new* (185. footnote 1. 1934): "John Lee Williams, to whom we are much indebted for early Florida history, was born in Salem, Massachusetts, 1775, and died in Florida at Picolata, 1856, aged eighty-one. After studying law he came to Florida in 1820, first settling at Pensacola, then lived in St. Augustine and finally made his home to the end of his life in Picolata, where he engaged in the study of botany and music. He wrote two enlightening books: A View of West Florida, and The Territory of Florida, 1837. All trace of his former home at Picolata has disappeared."

The observations on the flora of temperate and subtropical Florida by Williams on his numerous exploring trips around 1830 are summed up in the chapter "Production of the soil" in his *The Territory of Florida*. Although a great number of plants from temperate Florida are listed by Latin and common names in this chapter, it includes relatively few plants (mostly trees) from subtropical Florida ". . . found about the capes and keys" (Williams, 98. 1837). These mostly appear only with common names, however, it is a fairly good catalogue of the more familiar trees of the Florida Keys. Some errors are present, e.g., "Logwood.—Haematoxilon" is cited as a native of the Keys and *Cordia sebestena* is called *Sesbanea Coccina*. Perusal of *The Territory of Florida* shows clearly that Williams was a keen observer with a more or less extensive knowledge of plants. Therefore, it is unfortunate that Williams' original plans regarding the study of the natural history of Florida were not fulfilled, for Williams states in the preface to the above-mentioned work: "In the natural history of Florida, I have come very short of my original intentions. Want of leisure and books were both felt as obstacles to the investigation of a field so boundless, but they were not the only ones. It was suggested to me by some friends whose opinions I have been accustomed to respect, that the subjects of natural history are not generally interesting to the mass of readers, and that it might be more expedient to devote to these a separate work" (Williams, v. 1837). His hopes were never realized. In Rafinesque's *New flora and botany of North America* Williams was mentioned as a botanical collector (2: 9. 1837). Apparently Rafinesque had good reasons for this, however, we have not succeeded in locating Williams' herbarium, nor have we seen any citations of his herbarium specimens. We can assume then, that Williams' herbarium, if it ever existed, is not now extant.

Scientific phase.—On pages 89 and 90 of volume seven of the Journal of the Academy of Natural Sciences of Philadelphia, Nuttall published two new species from Key West, namely, *Malvaviscus floridanus* and *Rhamnus ferrugineus*, based on specimens collected by Titian R. Peale. Although these new species were later reduced to synonomy with other taxa, viz., *Hibiscus pilosus* and *Colubrina arborescens* respectively, they represent, as far as the authors are aware, the first specimens collected and preserved from the Florida Keys (ca. 1830). Titian R. Peale (1799–1885), painter and naturalist, was for some time an agent in Florida for Charles Lucien Bonaparte, charged with the collection of specimens and preparation of drawings to illustrate Bonaparte's *American ornithology* (1825–1833). Apparently at that time (the exact date is unknown to the authors) Peale collected a few (five?) herbarium specimens on the Keys and in East Florida, possibly in connection with his ornithological mission.

For practical purposes, the first botanical collector on the Florida Keys was the Reverend Alva Bennett (?–1841), a clergyman and teacher of the Protestant Episcopal Church. Unfortunately, only a bare outline of Bennett's official career (1826–1841) could be extracted from the literature. From 1826, when Reverend Bennett was a deacon and minister of Trinity Church in Windham, Greene County, New York, to his death in 1841, he carried out the duties of a missionary. He also held administrative positions in religious secondary schools mostly in New York State. In 1834, the Missionary Society in New York appointed Alva Bennett missionary to Key West. He arrived there in October 1834, and remained until April 1835. Bennett established the first school in Key West and was the first clergyman to have a charge on the island (Browne, 27, 28. 1912). "But Mr. Bennett was not pleased with the climate; and he returned north after a residence of about five months. 'Yet,' said the wardens and vestrymen, 'the good effects of his residence among us become apparent. . . . The moral tone of the whole population was elevated' " (Pennington, 29, 30. 1938). During his residence on Key West, Alva Bennett, a man of feeble health, employed his rare intervals of leisure in the collection of plants. We know that at least once he distributed a collection of plants, apparently desiring to attract the attention of botanists to the peculiar flora in the extreme southern part of the country. Having returned north, Bennett communicated his herbarium to Torrey and Gray, as they state in the preface to their *A Flora of North America:* "The Rev. Mr. Bennett of Geneseo, New York, presented us with many plants collected by himself during a residence at Key West . . ." (xii. 1840). Two species new to science, namely, *Galactia spiciformis* and *Coelestina maritima*, were described from herbarium specimens collected by Bennett. John K. Small (199. 1917) mentioned Bennett in *The tree cacti of the Florida Keys*, where he states: "The existence of this plant *(Cephalocereus keyensis)* was first made known to a few botanists through meager specimens collected and distributed by Mr. Bennett, who at one time was a resident of Key West . . ." The genus *Clusia* on the Florida Keys, was probably discovered by Bennett on Key West. This discovery is usually attributed to Blodgett. However, in Torrey and Gray (168. 1838) we read: "The figure of *Clusia rosea* by Catesby Car. t. 99, was most probably taken from a West Indian specimen; it has not been found in Carolina. We have received, however, the leaves of a species of *Clusia* (probably *C. rosea)* from the extreme southern part of Florida." This note was published in July 1838. According to Sargent (1: 33. 1894), Blodgett did not settle in Key West until December 1838. Moreover, in the preface to the *Flora* (1: xii. 1840) Torrey and Gray state: ". . . and we have received a complete and excellent set of plants of that island (Key West) from Mr. J. L. Blodgett, which however reached us at too late a period to receive notice in this volume." It is likely then, that the specimen of *Clusia* received by Torrey and Gray and mentioned by them in an item published in July 1838, before Blodgett's advent in Key West, was collected by Bennett. It is possible that this specimen was added by Torrey to the Key West collections of Blodgett and sent to Nuttall who identified it as *Clusia flava* and ascribed its discovery to Dr. Blodgett. This supposition gains credence in that the specimens of Bennett and Blodgett have been otherwise confused in the herbarium: written in pencil on the isotype of *Galactia spiciformis* which Torrey and Gray described from specimens collected by Alva Bennett is, "Key West, Blodgett." In any event, the modest, almost forgotten clergyman, who disliked the climate on Key West, stands as the first important collector of plants on the Florida Keys.

John L. Blodgett (1809–1853) is perhaps the most outstanding of the early botanists on the Florida Keys. In December 1838, he settled on Key West, where he established himself as a physician and druggist. He continued to reside there nearly to the time of his death. During his residence on Key West (1838–1853), Blodgett extensively explored the flora of the Florida Keys and discovered many new species several of which bear his name. According to Sargent (1: 33. 1894), Dr. Blodgett was the first botanist who explored the flora of the Florida Keys. His earliest collections on Key West were communicated in about 1840 to Torrey and a part of them (about 40 arborescent species) was later communicated by Torrey to Nuttall. Blodgett's collections are located in several herbaria in the United States, Great Britain (Kew) and in Ireland (Trinity College, Dublin).

Ferdinand Rugel (1806–1897), apothecary and physician, devoted several years to collecting plants in the southern states and in Cuba for the English botanist Robert James Shuttleworth. The herbarium of the latter is preserved in the British Museum (Sargent, 9: 110. 1896). In 1846 and 1848, Rugel collected on Key West. Several specimens of his collection from this island are cited by J. Cosmo Melvill in his *List of the phanerogams of Key West*. William H. Harvey (1811–1866), of Trinity College, Dublin, author of the classical *Nereis Boreali-Americana*, as well as *Thesaurus capensis* and coauthor of *Flora capensis*, spent a month in the winter of 1850 on Key West collecting algae and phanerogams. James Graham Cooper (1830–1902), surgeon and naturalist, explored the arborescent flora of East Florida, from Key West north, between March 6 and

June 10, 1859. At that time, he was studying the geographical distribution of North American trees. William T. Feay (1803?–1879), of Savannah, Georgia, lived for a year or more on Key West and collected a series of plants there. The exact date of his residence on the island is not known but the early 1870s seems to be a good guess. Several specimens collected by Feay on Key West are cited by J. C. Melvill (1884).

Alvan W. Chapman (1809–1899), physician, distinguished explorer of peninsular Florida and author of the *Flora of the southern United States,* has not been previously mentioned as a collector on the Florida Keys. However, Robert B. Clarke (1942) in his monograph of the genus *Bumelia,* cited among the specimens of *B. angustifolia* from Key West, "*Chapman s. n.* (NY, co-type of *B. parvifolia*)." If Clark's citation is correct, Chapman visited the Florida Keys at least once and collected on Key West. J. Cosmo Melvill (1845–1929), English botanist and conchologist, collected algae and phanerogams, as well as mollusks, on Key West in 1872. Accounts of his collections were published in 1875 (algae), 1881 (mollusks) and 1884 (phanerogams). In 1871–1872, Melvill also collected a large number of phanerogams (about 1000 sheets) in Canada, the United States (New York, Massachusetts, Pennsylvania, Virginia, North and South Carolina and peninsular Florida), and Cuba (only a few specimens). Edward Palmer (1833–1911), physician and renowned collector of plants in western North America, also collected about 65 numbers on Key West in 1874, on his way to the Bahamas (Nassau) (McVaugh, 58. 1956). Frank Tweedy (1854–1937) collected on Key West. At least some specimens of his collections from that island (collected in 1879 and 1880) are cited by several authors (sometimes as F. Tweedie).

Allen H. Curtiss (1845–1907), a native of Central Square, Oswego County, New York, was a prolific collector in southern Virginia, Florida and the West Indies. He explored widely on the Florida Keys during several cruises following the year 1880, and distributed many sets of his collections from these islands. Charles Sprague Sargent (1841–1927),

distinguished dendrologist and author of the monumental *Silva of North America,* traveled the Keys in late 1880s collecting and making observations. In 1886 he was accompanied by A. H. Curtiss, C. E. Faxon and Lieutenant Hubbard when he discovered *Pseudophoenix sargentii* on Elliott's Key. This palm is apparently restricted to a very small area of the Florida Keys. Hubbard seems also to have collected on his own on Key West in 1886, apparently during the same trip. Joseph H. Simpson (1841–1918) collected on the Keys as well as on peninsular Florida in the early 1890s. Several of his specimens have been distributed by the U. S. Department of Agriculture (Harper, 1949). Herbert J. Webber (1865–1946) of the U. S. Department of Agriculture collected on the Keys in the middle 1890s. Charles L. Pollard (1872–1945), Guy N. Collins (1872–1938) and Edward L. Morris (1870–1913) explored the Keys and collected extensively in 1898. Stewardson Brown (1867–1921) was a member of the staff of the Clarence B. Moore Archaeological Expedition to Florida in 1904, and collected plants on the Keys.

Odell E. Lansing, Jr. (1867–1918) was commissioned in 1903 by the Field Museum of Natural History in Chicago to explore the Sand Keys west of Key West. In 1904 he collected a series of plants (587 numbers) from these islands from which Millspaugh prepared his *Flora of the Sand Keys of Florida.* Lansing also collected on Key West. John Kunkel Small (1869–1938), the author of floras on the Southeast, collected extensively on the keys for almost 40 years beginning in 1901. Of his many associates on these exploratory trips Percy Wilson (1879–1944), of the New York Botanical Garden and Joel J. Carter (1843–1912) of Pleasant Grove, Pennsylvania should be mentioned.

Other collectors on the Keys in the late 1890s and early 1900s were: Walter T. Swingle (1871–1952), Nathaniel L. Britton (1859–1934), Charles T. Simpson (1846–1932), and Charles L. Hitchcock. Of the many recent collectors in this area the following can be noted: Roland M. Harper whose first records of Florida plants were noted in 1903; Ellsworth P. Killip; Walter M. Buswell, who in company with Walter

S. Phillips and Roy O. Woodbury rediscovered *Clusia rosea* on Big Pine Key in 1938 (Little, 1953); Taylor R. Alexander and John D. Dickson, III. There are certain to be other collectors who have not been noted by the authors. However, it is hoped that most of the important collectors are listed.

The scientific phase of botanical exploration was productive in that several floras appeared in which plants from the Florida Keys were presented. In most of these works, plants of the Keys form a relatively small portion. Below is a brief enumeration of the more important floristic studies containing descriptions of plants from the Florida Keys.

In 1838–1843 John Torrey, and Asa Gray published two volumes of their unfinished work *A flora of North America*. The flora of the Florida Keys is represented here through the collections of Alva Bennett, John Blodgett (only in the second volume), and Titian Peale (only two species). Peale's collection of *Malvaviscus floridanus* from Key West is erroneously ascribed in their *Flora* to Ware (Torrey 1: 229. 1938).

Thomas Nuttall's *The North American sylva* appeared in 1842–1849 in three volumes. This is generally regarded as a supplement to Michaux's work of the same title. The later edition of Nuttall's *Sylva* was published in two volumes in 1865. In the above-mentioned work, 40 arborescent species from the Keys, almost exclusively collected by Blodgett, are cited. In 1860 Alvan W. Chapman published his *Flora of the southern United States*. The second edition of his *Flora* followed in 1883 with a supplement (this edition was reissued in 1892 with a second small supplement), the third edition in 1897. In the first edition of Chapman's *Flora* many species from the Florida Keys are cited from Blodgett's collections; in later editions, numerous collections of Curtiss are also mentioned.

Charles Sprague Sargent's *The silva of North America* in 14 volumes, appeared in 1891–1902. Here is included most of the native arborescent species of the Florida Keys. In the second edition of Sargent's *Manual of the trees of North America*, published in 1922, the native arborescent flora of

the Keys is represented almost completely. In 1903 John Kunkel Small published his *Flora of the southeastern United States* (second edition appeared in 1911) and in 1933 his *Manual of the southeastern flora*. The latter is substantially a revised edition of the former. These thorough studies also include the plants of the Florida Keys. Small, in 1913, published the *Flora of the Florida Keys* which presents an essentially complete picture of the flora of this area. However, some additions (besides those made by Small in his *Manual)* of newly discovered species, as well as certain taxonomic revisions appear to be necessary.

Many species from the Florida Keys are treated in *North American flora*, which was begun by Nathaniel L. Britton and others, and has been published since 1905 by the New York Botanical Garden.

Thus, from 1575, when the first (?) report of plants from the Florida Keys was made by Fontaneda, to Small's *Manual* of 1933, botanical exploration of these islands has progressed from random observations to highly specialized floristic and vegetational studies. The latter works have been dependent in large part on the collections of those plantsmen who traveled the Keys from the early Nineteenth Century to the present. Although the flora has been extensively studied there is still a great deal to be discovered through future intensive investigations.

THE FUTURE

John K. Small was a sensitive man. During his travels throughout Florida in the quarter century before 1929 he was greatly impressed with the destruction of Florida's wilds by the heedlessness of man. In *From Eden to Sahara, Florida's tragedy* (1929), Small points with bitter alarm to the desecration of the vegetation and flora. He remarks: "The present is evident. The future may confidently be predicted, in part, by the aims and actions of the white man—he who began, and has consistently persevered in, a course of devastation almost unequaled elsewhere. Beginning in the earliest post-Columbian times, this reckless, even wanton, devastation has now gained such headway that the future of North America's most prolific paradise seems to spell DESERT . . . Not only are Fauna and Flora threatened with extermination, but in many places the very soil which is necessary to their production and maintenance is being drained and burned and reburned until nothing but inert mineral matter is left. . . . In some ways man has progressed. . . . In other ways he is still typically a 'savage'." Other lovers of Florida's out-of-doors, as Thomas Barbour (1944) and Charles Torrey Simpson (1920), have also signaled the future destruction of this natural legacy.

Today, almost 30 years after Small's writing, the destruction is being carried on apace. Species once common over large areas have become rare and indeed some have not been seen for many years. Huge bulldozers scrape across Plantation Key cutting down the vegetation—tearing off what little soil is present and heaping the mass of tangled debris into piles to which the torch is set (fig. 9, 10). A few clumps of trees are allowed to escape the blade of the bulldozer—in ignorance these are composed primarily of *Metopium toxiferum*, the noxious Florida poisonwood. Valuable archaeological sites are heedlessly destroyed to make boat slips (Goggin and Sommer, 1949); swamp areas are filled with coral rock on which dwellings will be constructed; fires are set to clear the land. In the Keys region where man does not (and probably cannot profitably) engage in agriculture, why must he sweep so clean a path? Certainly he could build, and by giving some consideration to his own future and that of others, leave the majority of the wild for all to enjoy.

A substantial amount of "lip service" is currently being spread regarding the supposed great concern of the state government for the preservation of one of Florida's great natural resources—its scenery (Anonymous, 1957). The land drained for agriculture (and subsequently abandoned after repeated fires destroyed the soil), the acres carelessly cleared for construction, the fires set to rid the ground of vegetation—these seem to go unnoticed by the authorities. A recent attempt to set aside part of Big Pine Key as a wildlife preserve was met by a wave of protests from landowners who are waiting to "cash in when the building boom hits Big

Pine." If the present carelessness continues, the only boast Florida will be able to use to entice tourists (tourism is Florida's number one industry) will be the climate, which fortunately cannot be drained, burned, or bulldozed.

In all justice, however, it must be stated that a large portion of southern Florida was set aside as a preserve in 1947—Everglades National Park, with 1,500,000 acres of land and water. The park includes the "Everglade Keys" which lie in the bay area north of the Florida Keys. There are other state and Federal preserves scattered throughout Florida. However, it is not the preservation of land that concerns the biologist so much as it is the conservation or *wise use* of the land. With wise use much of the flora and vegetation can retain its natural aspect and still be valuable for the enterprises of man. It was with these and other considerations in mind that the authors selected the Keys as a research area.

Aims and Objects

The wood anatomist engaged in comparative studies is frequently struck by the paucity of information, especially as regards the anatomy of some of the smaller and lesser-known taxa. Recourse to such comprehensive works as Metcalfe and Chalk (1950) and Solereder (1899), on the anatomy of dicotyledons, points up the sporadic nature of our anatomical knowledge in certain groups of plants. In order to add to this over-all knowledge of systematic wood anatomy, the authors have embarked on a study of the xylem anatomy of the woody plants of the Florida Keys.

Even though the Keys flora has been studied in the past, there are still areas where further study would not be amiss. One of these concerns the myrtaceous flora—are only *Eugenia* spp. present on the Keys? or are some of these actually species of *Myrtus?* Does *Eugenia bahamensis* occur on the Keys? or is it restricted to certain West Indian Islands as inferred by some botanists? Are there really four species of *Torrubia* on the Keys? or do they all represent variations within a single species? Is there a remnant of a more northern flora on the north end of Key Largo, as has been asserted by Alexander (1953)? Some previous descriptions of Keys plants are inaccurate, incomplete or both—plants recorded as herbs have been shown to be woody; others reported as exclusively low shrubs also occur as trees. The nomenclature of many species is in need of revision. Information on the distribution of plants within the Keys, and between the Keys and the West Indian Islands, should be more thoroughly investigated. In the taxonomic studies now in progress, new problems are constantly appearing; old ones are again becoming evident.

It has frequently been advantageous for the taxonomist and anatomist to collaborate in elucidating problems in systematics. A case in point is that concerning the anatomy and taxonomy of *Passiflora multiflora.* Recent observations have shown that this vine, formerly recorded as herbaceous, or at the most only somewhat woody, has an unquestionably woody stem an inch or more in diameter when mature. Furthermore, the structure of this stem is anomalous, and anomalous stem structure in Passifloraceae has not been noted by Metcalfe and Chalk, Solereder or Schenck (1893). Killip (1938), in his study of the American Passifloraceae, places *P. multiflora* into the subgenus *Apodogyne*, of which it is the only member. He remarks: "Indeed on the basis of sessile ovary it might perhaps be segregated as a genus." Following subsequent anatomical investigations it may prove desirable to follow Killip's suggestion and raise the taxon in question to the rank of a genus. In the series of accounts to follow this introductory presentation, the writers will report anatomic-taxonomic investigations of the plant families comprising the woody flora of the Keys. The xylem anatomy will be coupled with pertinent taxonomic notes. It is sincerely hoped that the ensuing work will help to complete our information on the trees, shrubs and woody vines of the Keys.

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THE UPPER STORY OF TROPICAL FORESTS[1]

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INTRODUCTION

In 1953 the Central Bureau for Aerial Survey in Surinam (Dutch Guiana) released Publication 13, wherein was given the results of tree and forest measurements. These data were taken for the purpose of determining the relationship between the image of the tropical forest on aerial photographs and its actual composition in the field. During the last three years similar work has been done in parts of the Amazon forests by the F.A.O. Forest Mission for the Amazon Valley, working in close cooperation with the Superintendencia do Plano de Valorisação Economica da Amazonia. Parts of the Amazon data have now been evaluated and the results show only small differences from the data obtained in Surinam. The forests from which data were taken in Surinam and in the Amazon Valley are located approximately 1000 km. apart (fig. 1A and B), so that the results very probably have a much more general value than was originally expected from the studies in Surinam.

Between the Rio Tapajoz and the Rio Xingu in the Amazon Valley (fig. 1B) an exploratory survey (Yates, 1953) was made covering an area of approximately 1,500,000 ha. The enumeration of samples was performed in the same way as in Surinam, i.e., the samples were taken along transects, all trees with a diameter of 25 cm. or more at breast height, or just above the buttresses, were tabulated and the crown width measured from those trees whose crowns completely emerged above the general level of the forest canopy. It is highly probable that the crowns of these trees will appear on aerial photographs, therefore it will be possible to count them and measure their diameters from aerial pictures with the help of a stereoscope. These trees were noted as *upper story trees*.

[1]To be continued in *Tropical Woods* 108.

Fig. 1. Map of South America. A. Forest area in Surinam. B. Forest area between the Rio Tapajos and the Rio Xingu. C. Forest area in the territory of Amapa. D. Forest area near Portel. E. Forest area west of the Rio Tapajoz.

Tolerance Classes

It is a well-known fact that the tree species of tropical forests behave very differently in their demands for light (Richards, 1952). There are trees that can grow fully in the shade of other trees, the so-called tolerant or shade-resistant trees; others need an abundance of light during most of their life, the so-called light-demanding trees. In trying to obtain a clear picture as to the degree of tolerance of the different tree species in their middle and mature states (i.e., from 25 cm. d.b.h. and upwards), their percentages in the upper story of the total enumerated were calculated and the results grouped in classes. For example, from tree species A, 1000 trees were counted and 8 noted as upper story trees. Therefore this species, with 0.8 per cent upper story trees, was classified in the class 0–10 per cent. In the tables below (1–7) some of the better-known species in the various classes are listed.

Table 1. Tree species comprising from 0–10 per cent of the upper story

COMMON NAME	SCIENTIFIC NAME	PER CENT IN UPPER STORY
Abiorana	*Pouteria* sp.	6.48
Acapu	*Vouacapoua americana*	1.60
Aquariquara	*Minquartia guianensis*	1.34
Andiroba	*Carapa guianensis*	7.80
Angelim rajado	*Pithecolobium racemosum*	3.65
Breu	*Protium* sp.	0.60
Caraipé	*Licania* sp.	9.64
Imbauba	*Cecropia juranyana*	5.69
Inga	*Inga* sp.	6.00
Jutai pororoco	*Dialium divaricatum*	5.24
Jutai rana	*Cynometra* sp.	2.55
Louro canela	*Ocotea* sp.	10.00
Louro amarelo	*Aniba* sp.	7.47
Mata mata branca	*Eschweilera longipes*	2.06 (4.60[1])
Rosadinha	*Chrysophyllum* sp.	9.09

[1]Data in parentheses are from Surinam, in Publication 12, Central Bureau for Aerial Survey.

Table 2. Tree species comprising from 10–20 per cent of the upper story

COMMON NAME	SCIENTIFIC NAME	PER CENT IN UPPER STORY
Axua	*Saccoglottis* sp.	13.39
Lakri	*Vismia angustis*	13.33
Louro branco	*Ocotea guianensis*	11.55
Lopuro preta	*Nectandra mollis*	18.60
Jarana	*Eschweilera jarana*	17.10
Maparajuba	*Manilkara paraensis*	12.45

Table 3. Tree species comprising from 20–30 per cent of the upper story

COMMON NAME	SCIENTIFIC NAME	PER CENT IN UPPER STORY
Axixa	*Sterculia* sp.	27.54
Cedro	*Cedrela odorata*	28.57
Faveira barbatimão	*Stryphnodendron* sp.	27.45
Freijo branco	*Cordia exaltata*	28.45
Itauba	*Mezilaurus itauba*	23.57
Tamanqueira	*Fagara* sp.	25.52
Ucuuba	*Virola sebifera*	29.53

Table 4. Tree species comprising from 30–40 per cent of the upper story

COMMON NAME	SCIENTIFIC NAME	PER CENT IN UPPER STORY
Anani	*Symphonia globulifera*	31.58
Amapa	*Parahancornia amapa*	38.14
Cupiuba	*Goupia glabra*	39.31 (40.70)
Cumaru	*Coumarouna odorata*	32.31
Freijo	*Cordia goeldiana*	35.17
Massaranduba	*Manilkara huberi*	38.02
Mututi	*Pterocarpus rhorii*	30.16

Table 5. Tree species comprising from 40–50 per cent of the upper story

COMMON NAME	SCIENTIFIC NAME	PER CENT IN UPPER STORY
Cuiarana	*Buchenavia* sp.	46.56
Jutai mirim	*Hymenaea parvifolia*	48.00
Marupa	*Simaruba amara*	41.66
Quaruba	*Qualea* sp.	47.30 (50.60 and 52.80)
Taxi	*Sclerolobium* sp.	43.10 (56.50)
Sapucaja	*Lecythis* sp.	44.89

Table 6. TREE SPECIES COMPRISING FROM 50–60 PER CENT OF THE UPPER STORY

COMMON NAME	SCIENTIFIC NAME	PER CENT IN UPPER STORY
Carapanauba	*Aspidosperma nitidum*	52.92
Copaiba	*Copaifera* sp.	54.46
Faveira folha fina	*Piptadenia suaveolens*	59.94
Faveira bolacha	*Vatairea cythrocarpa*	54.50
Para para	*Jacaranda copaia*	50.23
Pau d'Arco	*Tecoma* sp.	50.80
Piquia	*Caryocar villosum*	56.40
Sucupira	*Bowdichia nitida*	51.22
Tauari	*Couratari* sp.	52.37 (59.90)

Table 7. TREE SPECIES COMPRISING 60 PER CENT OR MORE OF THE UPPER STORY

COMMON NAME	SCIENTIFIC NAME	PER CENT IN UPPER STORY
Angelim pedra	*Hymenolobium petraeum*	79.00
Arueira	*Astronium lecointei*	64.63
Castanheira	*Bertholetia excelsa*	86.30
Faveira bolota	*Parkia pendula*	83.33
Faveira uing	*Enterolobium schomburgkii*	70.70
Jutai assu	*Hymenaea courbaril*	70.75
Miratawa	*Apuleia molaris*	74.55
Morototo	*Didymopanax morototoni*	60.80
Tatajuba	*Bagassa guianensis*	77.77

Altogether 172 species were found in the upper story of which 36 could not be classified because of insufficient data. For example, 6 sumauma *(Ceiba pentandra)* trees were noted in the upper story. This would indicate that *Ceiba pentandra* is 100 per cent light-demanding. However, it is a known fact that this tree, with its conspicuously umbrella shaped crown, occurs mostly in marsh forests on periodically water-logged soil. In the marsh forest small ceibas are often seen growing up under other larger trees. The occurrence of this species is rare in the dry land forest, as shown by the fact that only 6 were tabulated above. To a certain extent these classes can be regarded as tolerance classes. The class with the highest percentage contains the least tolerant tree species. Accurate interpretation of the data, however, demands great care. A few examples may serve to illustrate this point: imbauba *(Cecropia* sp.) is one of the most light-

demanding trees known–one of the pioneer species of the tropical forest. As soon as a sufficiently large opening occurs in the forest canopy to receive most of a full day of sunlight on the soil, imbauba appears. In this instance it must be recorded as one of the most tolerant trees belonging to class 0–10 per cent, because only trees from 25 cm. d.b.h. and upwards were enumerated. At that stage (i.e., from 25 cm. d.b.h. and upwards) imbauba is already a mature tree, very often near the end of its life cycle. Usually, it is then overgrown by other taller trees which laterally close the gap in the forest. Therefore it is practically impossible for imbauba to appear with a full crown in the upper part of the forest canopy of the dry land forest. The same is true for lakri *(Vismia* sp.; class 10–20 per cent).

Other trees as andiroba *(Carapa guianensis)*, angelim rajado *(Pithecolobium* sp.) and rosadinha *(Chrysophyllum* sp.) occur more frequently in the upper story of the lower forests (on more sandy and wet soils) than in the high dry land forest. Actually, these species grow taller, are of greater diameter and are better shaped in the higher forests than in the lower forests. It seems however, that it is impossible for them to by-pass the other taller trees which dominate, with their large crowns, the uppermost parts of the forest canopy. The remarkable difference between the data from the Amazon and Surinam forests for taxi *(Sclerolobium* spp.) is caused by the fact that taxi in the Amazon region is often overgrown and suppressed by very large trees such as massaranduba *(Manilkara huberi)* and castanheira *(Bertholetia excelsa)*.

Practically all tree species commonly found in the dry land forests can develop in the shade of the bigger trees. Some prefer the openings and the borders of the holes in the forest to regenerate, taxi *(Sclerolobium* spp.) for example. Others, as castanheira *(Bertholetia excelsa)* and piquia *(Caryocar villosum)* most probably need large openings which close very slowly, so that they have a maximum of light over a long period in which they can develop. That this development is normal and inherent to these forests could be deduced from the data obtained during the survey.

From the tree diameter analyses and the tabulation of trees with a diameter smaller than 25 cm. at breast height, it appears that these forests have a balanced diameter distribution (Meyer, 1953). Most of the common tree species show the same characteristics in a histogram of their diameters; the highest number of trees is found in the smallest diameter class, while the numbers of trees found in the succeeding diameter classes gradually decrease.

It is practically certain that only very few of the upper story trees were omitted by adopting a 25 cm. d.b.h. limit. In the diameter class of 25–34 cm., 12.5 per cent of the total number were enumerated, whereas the trees which just reached the 25 cm. limit came to 0.6 per cent. Most of the upper story trees belong to the diameter classes between 35 and 75 cm. d.b.h.

Photo-interpretation

As was done previously in the Surinam studies, the upper story trees were divided into a "low" and "high" class. When the estimated total height of the tree was 25 m. or less, it was placed in the "low" class; trees higher than 25 m. were put in the "high" class. The lower forests, and also the lower trees which are mostly less than 25 m. high, can, with sufficient experience, be distinguished from the higher forests and higher trees on aerial photographs (up to a scale of 1: 40,000) with the help of a stereoscope. This rather rough division into tree height classes has been made in order to correlate the field data with the tree height estimates obtained from the aerial photographs. Unfortunately this method had to be adopted because it is impossible to measure the tree heights with a parallax meter, because the bare ground normally cannot be seen on aerial photographs of evergreen tropical forests (Zonneveld, et al., 1952).

Fig. 2 gives the ranges of the crown diameters subdivided in tolerance classes, and "low" and "high" trees. It shows that the more light-demanding and the bigger the upper story trees are, the larger is the range of their crown widths. It is, of course, impossible for the "low" trees to have the same range in crown width as the "high" trees, since a com-

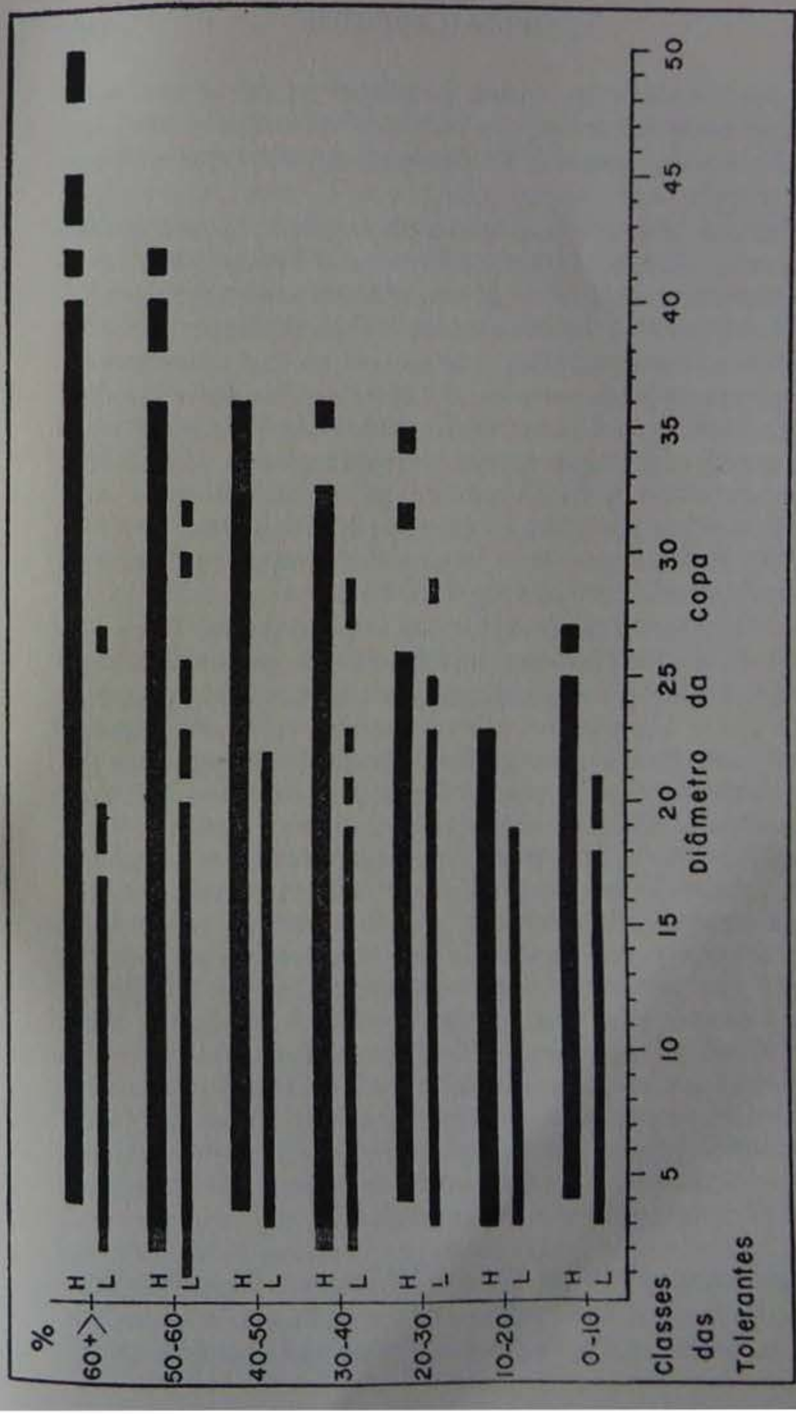

Fig. 2. Histogram illustrating the ranges of crown diameters per tolerance class (*Classes de tolerantes*) subdivided in "low" (L) and "high" (H) trees. Diameters of crowns (*Diametro da copa*) are given in meters.

paratively small tree, with a height of 25 m. or less, will, only in exceptional cases, have a large crown; for example, species which form disk or drooping crown types (Heinsdijk, 1955).

The identification from aerial photographs of tree species from tropical forests is very difficult and highly speculative, especially at a scale of 1: 40,000. Identification with certainty is only possible in a few cases: When the upper story of the forest is dominated by one species, so that it appears on the photograph as a pure stand (*Mora excelsa*, for example), or a mixed tropical forest with patches of upper story trees composed of a single species (*Goupia glabra*, *Hymenolobium petraeum*, etc.). Accuracy of identification is also possible when a certain forest type has only two or three species in the upper story having distinctly shaped crowns (usually possible for swamp forests).

For dry land forests such cases are exceptions. Here one must always look for combinations of tree species with large crowns which give an indication of the forest composition. The really big crowns, with a crown width of 30 m. or more, are found among the light-demanding species of tolerance class 30–40 per cent and over (fig. 2). This fact substantially reduces the number of tree species to be sought in the upper story. Since commonly not all of the tree species belonging to these tolerance classes produce large crowns, this number can be further reduced to approximately ten species. These ten species are for the photo interpreter the important ones; their crown shapes, the differences in tone of the images of their crowns on the photographs, their habit of growing in clusters or as isolated trees, must be studied very carefully. It is possible to deduce in this way, much information about the forest composition from aerial photographs. Nevertheless, the interpreter must have the necessary field experience and a great deal of samping data at his disposal.

Relationship Between Crown Width and Bole Diameter

In Surinam a close relationship was found between the crown width of the upper story trees and the diameter of their boles at breast height, or just above the buttresses. In fig. 3 the results for all upper story trees of the Amazon region are presented and compared with the corresponding results for Surinam. The Amazon data are from 7785 upper story trees; the Surinam data from 17,868 trees. As can be seen from the curves, the differences are small, not more than 7 cm. up to a crown width of 30 m.; betwen the crown widths of 15 to 25 m. differences are practically zero.

The Surinam curve shows an exactly linear relation from a crown width of 3 m. and up, whereas the Amazon curve shows this only from a crown width of 10 m. and above. The bend in the Amazon curve is mostly caused by the "low" trees, as can be seen in fig. 4, which presents the curves for the "low" and the "high" trees separately. In fig. 4 the curve for the "high" trees is practically straight and nearly identical with the curve for all trees together from the Surinam data. Corresponding data for the "low" and the "high" trees from Surinam are not available, but, as will be shown later on, the differences among the groups from Surinam are much smaller.

The forests in the Amazon region, in which the upper story trees were enumerated, were growing partly on heavy clay and partly on sandy soil; the composition everywhere was practically the same on each soil type. Compared with the forests on the clay soil, the tree growth on the sandy soil is very poor. Most of the "low" trees were found in the forests growing on sandy soils, which explains the differences in average diameter of the bole for the same crown width. To explain the differences between the Surinam data and the Amazon data is much more diffcult. At present, tree species found in Surinam and in the Amazon Valley are partly the same, and most belong to the same genera. In the Surinam data many swamp trees were included, as *Virola surinamensis*, *Triplaris surinamensis* and *Tabebuia* spp. (panta), which were not enumerated in the Amazon forests surveyed. Approximately 10 per cent of the upper story trees enumerated in Surinam were *Qualea* spp. or *Eperua falcata*, both species having, in comparison with the other trees, a heavy bole for the same crown width. In

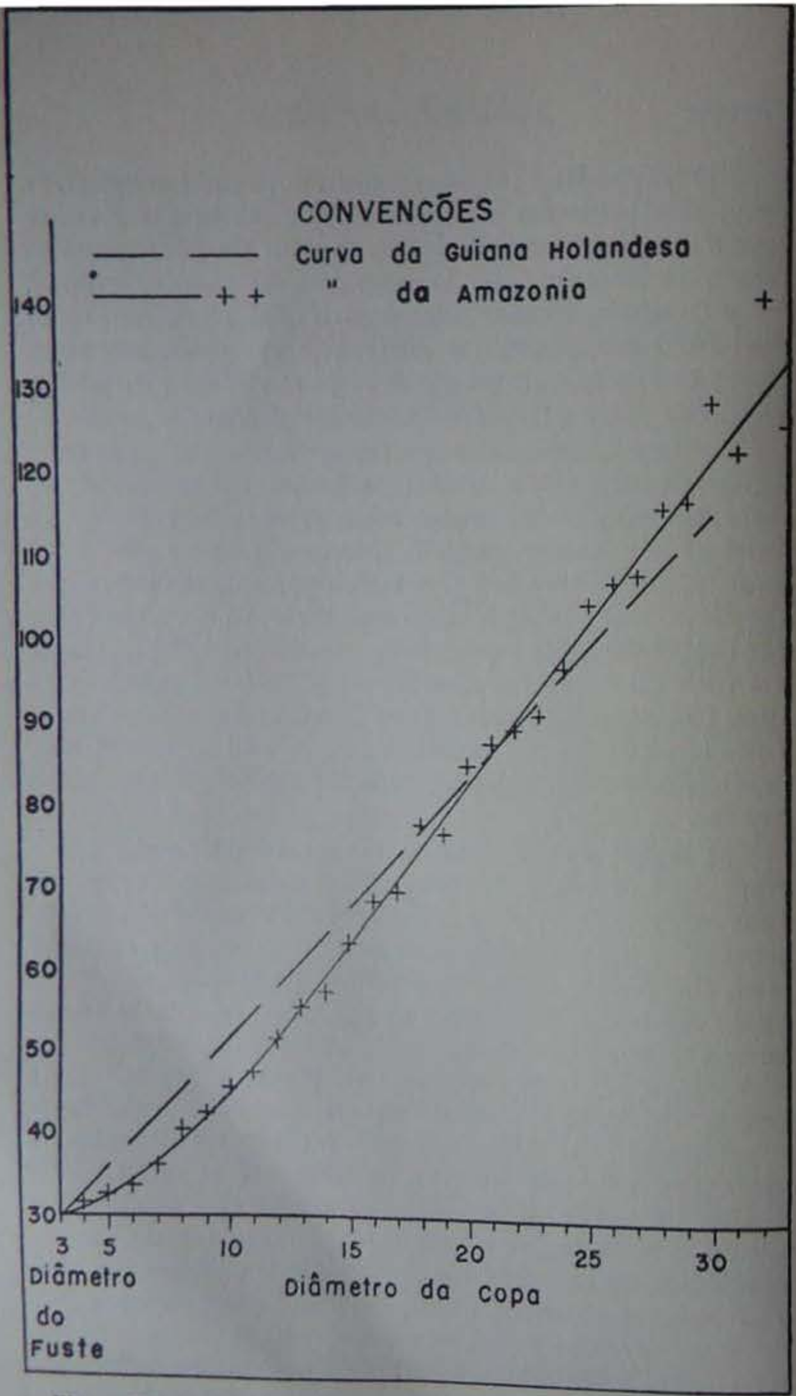

Fig. 3. The curve for the relationship of crown diameter to bole diameter for the Amazon data *(Curva da Amazonia)* as compared with the corresponding curve for Surinam *(Curva da Guiana Holandesa)*. The bole diameter *(Diametro do fuste)* is given in

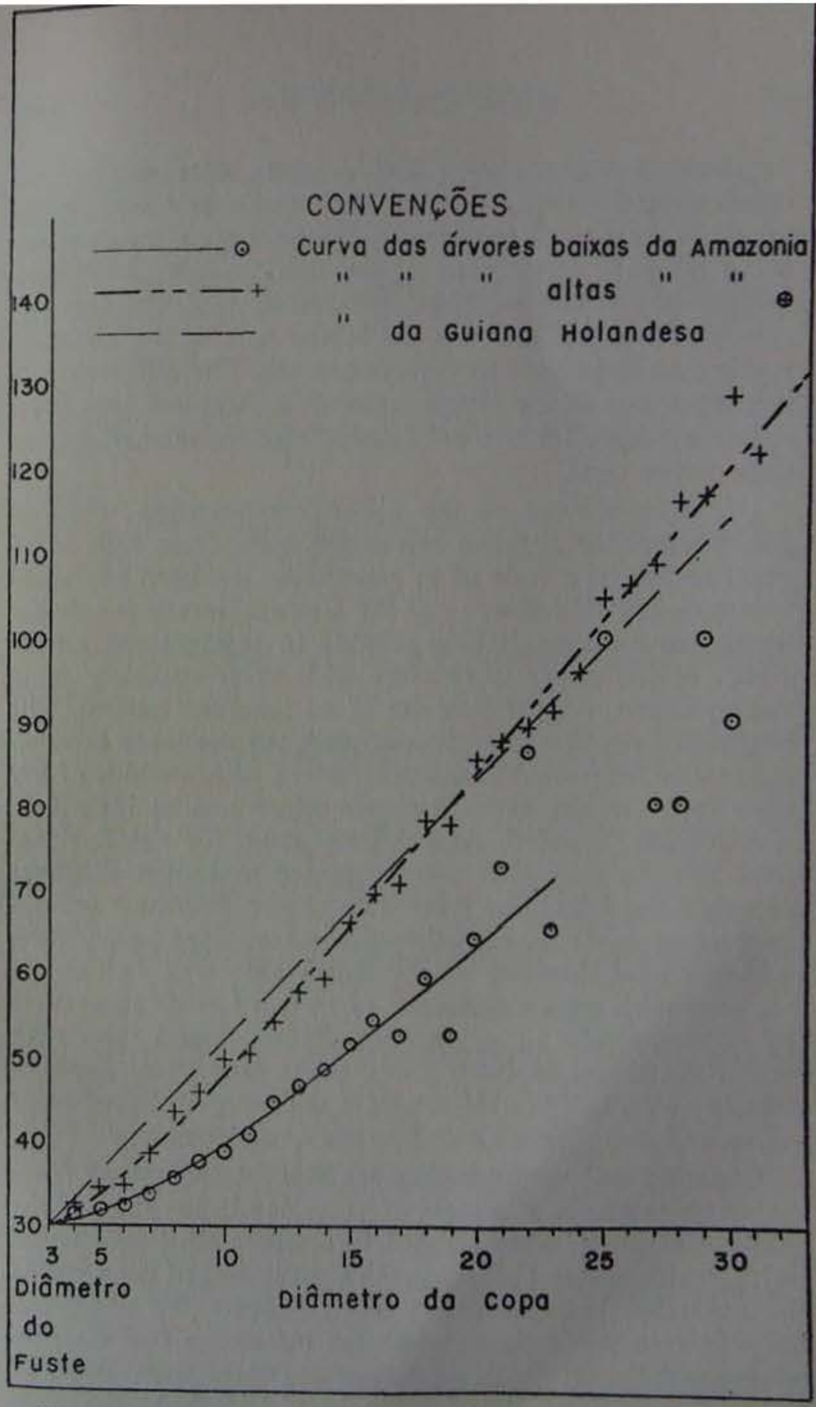

Fig. 4. This figure shows separately the curve for the relationship between crown diameter and bole diameter for the "low" *(Curva das arvores baixas da Amazonia)* and the "high" *(Curva das arvores*

the Amazon region fewer *Qualea* spp. were enumerated (approximately 2 per cent of the total), and no *Eperua falcata*. To what extent these differences were counterbalanced by such heavy trees as *Manilkara huberi*, *Bertholetia excelsa* and *Hymenolobium petraeum*, which were not enumerated in Surinam for the lower part of the curve, is at this time impossible to analyze exactly. The differences in the upper part of the curves, where the Amazon data show higher averages for the bole diameters, are mainly due to these heavy trees.

Up to now most of the photo-interpretation work in Surinam and the Amazon region has been done with aerial photographs on a scale of 1: 40,000. As has been explained at length in Publication 13 of the Central Bureau for Aerial Survey in Surinam, it is impossible to measure the crown width of the upper story trees with great accuracy from these pictures, even if they are of an excellent quality. The borders of the tree crowns, especially of the loose crowns, are mostly hazy and the smaller crowns with a width of less than 10 m. appear as small points which can be identified, but not be measured. As has been done for the Surinam data, the Amazon data were grouped in crown diameter classes: Class I includes trees with crown diameters from 2 to 3 m. up to 12 m. In reality this means upper story trees with a crown diameter of approximately 10 m. In Class II are trees with crown diameters of 13 to 17 m. or an average of approximately 15 m. In Class III are found trees with crown diameters of 18 to 22 m. or an average of approximately 20 m. In Class IV are trees with crown diameters of 23 m. and more, or with an average of approximately 25 m.

Counting and measuring upper story tree crowns from aerial photographs at a scale of 1: 40,000 is not easy. If the photo-interpreter were obliged to measure all these crowns with a micrometer (Spurr, 1948) a great deal of time would be expended in evaluating a single hectare. By using this classification it is only necessary to measure a few crowns, with the help of which, in a comparatively short time, all other crowns from the plot can be classified. At the same time the data do not pretend to achieve an accuracy which cannot be justified. Table 8 gives the averages for the differ-

Table 8. RELATIONSHIP BETWEEN AVERAGE CROWN DIAMETER, BOLE DIAMETER, LENGTH OF MERCHANTABLE BOLE AND HEIGHT OF BUTTRESSES

Tolerance class per cent	Crown diameter class	Number of observations "low"	Number of observations "high"	Crown diameter in m. "low"	Crown diameter in m. "high"	D.B.H. in cm. "low"	D.B.H. in cm. "high"	Length of merchantable bole in m. "low"	Length of merchantable bole in m. "high"	Height of buttresses in m. "low"	Height of buttresses in m. "high"
All	I	1321	2031	8.6	9.6	37	48	13.90	20.30	0.05	0.18
				(8.6)		(46)	(50)	(14.2)	(16.2)	(0.62)	
All	II	372	2186	14.5	14.9	50	65	12.20	18.80	0.11	0.45
				(14.6)		(64)	(67)	(14.2)	(16.6)	(1.00)	
All	III	54	1193	19.9	19.7	63	83	11.40	18.90	0.06	0.79
				(19.6)		(76)	(87)	(13.3)	(16.8)	(1.01)	
All	IV	11	617	26.7	26.9	82	109	11.70	18.30	0.27	1.16
				(25.5)		(93)	(103)	(12.7)	(16.4)	(1.13)	
0–10	I	268	324	8.7	9.9	38	51	13.46	18.85	0.09	0.19
10–20	I	195	245	9.3	9.5	38	50	13.57	20.61	0.06	0.15
20–30	I	190	345	8.1	9.1	38	46	14.48	21.36	0.00	0.06
30–40	I	94	168	8.8	9.7	39	50	13.48	20.85	0.01	0.13
40–50	I	232	316	9.2	10.2	36	44	13.36	18.58	0.04	0.20
50–60	I	204	405	8.2	9.6	36	49	14.43	21.18	0.07	0.27
60–	I	138	198	8.0	9.6	34	44	14.58	22.10	0.02	0.08
				30 observations not classified							
0–10	II	61	279	14.4	14.5	49	64	11.77	17.91	0.20	0.51
10–20	II	62	171	14.3	14.7	51	67	12.10	17.44	0.05	0.13
20–30	II	53	147	14.5	14.8	57	69	11.74	19.04	0.02	0.24
30–40	II	41	319	14.6	15.1	50	68	12.61	19.11	0.02	0.26
40–50	II	95	533	14.8	14.7	46	59	12.63	17.42	0.05	0.45
50–60	II	41	430	14.2	15.1	47	67	12.30	19.79	0.32	0.86
60–	II	19	281	14.5	15.0	53	64	12.32	21.29	0.21	0.22
				26 observations not classified							

Table 8—*Continued*

Tolerance class per cent	Crown diameter class	Number of observations "low"	"high"	Crown diameter in m. "low"	"high"	D.B.H. in cm. "low"	"high"	Length of merchantable bole in m. "low"	"high"	Height of buttresses in m. "low"	"high"
0–10	III	4	60	20.0	19.3	65	76	13.00	17.67	—	0.90
10–20	III	7	57	18.6	19.2	61	83	12.33	18.88	—	0.26
20–30	III	9	39	19.8	19.6	67	71	8.67	18.00	—	0.69
30–40	III	7	245	20.3	19.8	70	85	13.57	18.37	0.15	0.31
40–50	III	13	316	19.6	19.5	58	78	10.23	17.80	0.15	0.62
50–60	III	11	250	19.8	19.7	65	85	13.27	18.94	—	1.76
60–	III	3	213	19.3	19.8	57	88	8.70	22.00	—	0.48
13 observations not classified											
0–10	IV	—	11	—	24.1	—	82	—	17.82	—	1.55
10–20	IV	—	3	—	23.0	—	83	—	15.66	—	1.00
20–30	IV	4	12	25.5	26.3	70	93	13.00	16.08	0.75	1.42
30–40	IV	2	93	27.5	25.5	85	98	11.00	17.77	—	0.47
40–50	IV	—	110	—	25.6	—	100	—	17.32	—	0.83
50–60	IV	4	150	27.5	25.6	95	105	10.00	16.71	—	1.85
60–	IV	1	227	27.0	28.7	70	124	15.00	20.19	—	1.10
11 observations not classified											

ent crown diameter classes for the "low" and the "high" trees. Comparable data from Surinam are in brackets. Data are shown for all tolerance classes together and for these classes separately.

The average crown diameters in Class I for the "low" trees are mostly below 10 m. (theoretical average) compared with measurements for the "high" trees. These trees usually occurred in the lower forests, which were comparatively open with a great deal of palm growth underneath. Therefore the trees would appear more frequently with their crowns in the upper story. In the crown diameter Class IV (tolerance class 60 per cent and up) the average crown diameter is remarkably high and shows a comparatively large number of trees. It is here that the very big crowns occur.

The differences between the average diameters of the boles for the "low" and the "high" trees from the Amazon data are much larger than the corresponding differences as shown in the Surinam data (table 9). The same trend is present for the average length of the merchantable boles. The average heights of the buttresses are less in the Amazon than in Surinam. As could be expected, the biggest (oldest) trees have the highest buttresses.

Table. 9. DIFFERENCES BETWEEN AVERAGE DIAMETERS OF BOLES FOR "LOW" AND "HIGH" TREES IN CM.

REGION	CROWN DIAMETER CLASSES			
	I	II	III	IV
Surinam	4	3	11	10
Amazon	11	15	20	27

In table 10 the same data are presented as in table 8 for some tree species for which data from Surinam are also available. In comparing both, the following remarks can be made: In the Amazon forests under survey, the *Qualea* species are not as common as in Surinam. Here they occur only in the very high forests. The writer has the impression, that the *Qualea* species found in these high forests exist under better growing conditions than in Surinam, but that

Table 10. RELATIONSHIP BETWEEN AVERAGE CROWN DIAMETER, BOLE DIAMETER, LENGTH OF MERCHANTABLE BOLE AND HEIGHT OF BUTTRESSES, FOR SELECTED TREE SPECIES (Parentheses enclose comparable data from Surinam.)

Tolerance class per cent	Crown diameter class	Number of observations "low"	Number of observations "high"	Average crown diameter in m. "low"	Average crown diameter in m. "high"	Average crown diameter in m. (Surinam)	D.B.H. in cm. "low"	D.B.H. in cm. "high"	Length of merchantable bole in m. "low"	Length of merchantable bole in m. "high"	Height of buttresses in m. "low"	Height of buttresses in m. "high"	Height of buttresses in m. (Surinam)
					Qualea spp.								
40–50	I	12	34	9.7	10.0	(9.2)	38 (49)	51 (60)	13.5 (15.2)	20.4 (18.0)	—	0.10	(0.25)
40–50	II	4	58	13.8	15.2	(15.2)	45 (74)	69 (78)	12.8 (14.7)	19.2 (18.0)	—	0.16	(0.56)
40–50	III	—	38	—	19.9	(19.7)	— (81)	100 (95)	— (12.6)	20.3 (18.3)	—	0.34	(0.60)
40–50	IV	—	22	—	26.6	(25.5)	— (97)	133 (109)	— (15.0)	22.0 (16.8)	—	0.27	(0.80)
					Sclerolobium spp.								
40–50	I	144	191	9.0	10.5	(8.6)	34 (42)	41 (56)	13.7 (13.7)	17.5 (16.4)	0.03	0.15	(2.01)
40–50	II	48	346	14.6	14.7	(14.6)	44 (64)	56 (72)	12.5 (12.2)	16.6 (14.8)	0.10	0.45	(2.66)
40–50	III	6	188	19.0	19.1	(19.3)	49 (—)	72 (77)	8.8 (—)	16.1 (15.2)	0.30	0.58	(2.00)
40–50	IV	—	47	—	25.3	(—)	— (—)	86 (—)	— (—)	16.7 (—)	—	0.73	(—)
					Couratari spp.								
50–60	I	8	94	5.9	9.3	(9.0)	38 (46)	38 (53)	17.2 (15.0)	23.8 (17.9)	0.12	0.43	(1.51)
50–60	II	—	84	—	15.0	(14.9)	— (64)	68 (68)	— (13.4)	23.9 (17.0)	—	1.40	(2.72)
50–60	III	—	67	—	19.7	(19.8)	— (73)	88 (81)	— (13.0)	24.2 (15.6)	—	2.58	(3.36)
50–60	IV	—	34	—	26.2	(25.0)	— (—)	135 (87)	— (—)	19.2 (14.3)	—	4.15	(4.90)

they must overcome much more competition from other species. This seems to explain why so few trees were enumerated in the "low" height class. The differences in bole diameter per crown diameter class point in the same direction: less in the low classes and much more in the high classes. The average length of merchantable boles is also greater. This means, most likely, that the *Qualea* species must increase very rapidly in height in order to survive and develop into large trees.

Sclerolobium species are, in the Amazon forests under survey, much more common than in Surinam. In Surinam they belong among the high trees, whereas in the Amazon they belong to the middle class and are often suppressed by taller trees. The average diameter of the boles per crown diameter class are, for the Amazon trees, lower than for the Surinam trees. The average length of the merchantable bole is in reality higher, but the average height of the trees which corresponds with the average length of the merchantable bole plus the average height of the buttresses, is a little higher for the Surinam trees. Contrary to the general trend in the Amazon data, which have a lower average bole diameter in the low crown diameter classes and in the higher classes a greater average bole diameter, these species have in all crown diameter classes a lower average bole diameter. The impression is that the growing conditions for *Sclerolobium* in the Amazon area are better than in Surinam; tree growth seemed to be much more rapid, especially near the gaps in the forest canopy where the crowns have a greater opportunity to spread. There was less buttress formation than in Surinam, and the longevity of the trees seemed to be much shorter. Dying *Sclerolobium* trees, in the higher parts of the Amazon forests under survey, was a common sight.

The *Couratari* species belong to the tallest trees of the dry land forests and in the Amazon area are rarely found in lower forests. The data clearly show that the growing conditions for these species are much better in the Amazon forests than in Surinam. The typical differences between the two sets of data for these species can be seen in the average heights of the buttresses. When buttress formation is one of the characteristics of a certain tree species, as it is for *Couratari*, the height of the buttresses gives an indication of the growing conditions and the age of the tree. Under good growing conditions, the small (young) trees produce less buttress growth than under poor conditions. The big (old) trees form very large buttresses sometimes nearly over the whole length of their boles, in which case the total tree height is comparatively low. This generally indicates poor growing conditions.

To be continued

XYLEM ANATOMY OF *STROPHANTHUS* (APOCYNACEAE)

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In recent years, much interest has been directed toward the genus *Strophanthus*, primarily due to its medical value. Alkaloids, from which cortisone can be derived, have been isolated from *S. sarmentosus;* the seeds of a few other species, e.g., *S. kombe*, also yield alkaloids which are effective as heart stimulants, and vaso-constrictors. Because of the growing therapeutic significance of this group of plants, it is important that we become familiar with the morphology of the organs. It is to this purpose that the anatomy of the secondary xylem is investigated. The taxonomy of *Strophanthus* has been studied by Franchet (1893), Gilg (1903), Staner and Michotte (1934), and Krukoff and Letouzey (1950). However, so far as the writer is aware, xylem structure has not been examined.

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Wood for this study was collected by B. A. Krukoff and R. Letouzey during 1949 and 1950 in French Cameroons and Gabon, and is now on deposit in the Samuel James Record Memorial Collection of the Yale School of Forestry. Herbarium specimens were placed in the Muséum National d'Histoire Naturelle in Paris and in the herbarium of the New York Botanical Garden.

Because of the similarity in the wood structure of the various species, a detailed account is given for only one species, *S. sarmentosus*. The main xylem features, with dimensions of structural elements, are noted for other species. The information concerning the habit of the plants is based on the records of Krukoff and Letouzey. Terms used for vessel diameter are those recommended by the Committee on the Standardization of Terms of Cell Size of the International Association of Wood Anatomists (1939), and those for numerical distribution of vessels and wall thickness of fibers follow the proposals of Chattaway (1932).

XYLEM STRUCTURE OF THE GENUS

The wood is creamy white to pale straw colored or yellowish brown, somewhat lustrous to lustrous, without distinctive odor when dry, sometimes with a bitter taste (root wood), of medium density, fine textured, and usually straight grained.

Growth rings (fig. 1) are usually present but inconspicuous to scarcely distinct, wide or very narrow. They are defined by a scarcely visible band of parenchyma, and by the contrast between zones of fibers with slightly thicker walls and smaller lumina and fibers with slightly thinner walls and larger lumina. Often a difference in the size of pores in the latewood and earlywood also defines the growth rings.

Vessels range from moderately large (up to 240μ in tangential diameter) to small (less than 100μ in diameter), but are mostly medium-sized (100–200μ in diameter). Those in the earlywood are usually larger, for the most part in radial multiples of 2–7 or more (mostly 2–4), rarely in clusters, and infrequently solitary, very frequently with a contiguous ray on one and occasionally on both sides, oval in outline or, in multiples or clusters, compressed with common walls of contact flattened. Pores are moderately numerous to numerous and rather uniformly distributed. Vessel walls are medium thick and without spiral thickening. Perforations are simple with wide rims; intervascular pitting is alternate (fig. 3), the pits numerous, up to 6μ in diameter; pit borders rounded to oval, or polygonal through crowding, vestured. Pit apertures are lenticular, usually horizontal and included. Tyloses are sparsely developed in most cases, partially or sometimes entirely plugging the vessels; gum deposits are absent or occasional, occluding some vessels when present.

Wood parenchyma is paratracheal and apotracheal (fig. 2), in strands of 4–8, mostly 4–6, cells. Paratracheal parenchyma is limited to occasional cells about the vessels or vessel groups. Apotracheal parenchyma is of two types: (a) Reticulate or abundant diffuse-in-aggregates; (b) marginal parenchyma which is initial or terminal, in irregular, ragged, mostly 1–3-seriate bands. Gummy deposits in parenchyma cells are very sparse; crystals have not been observed.

In transverse section, wood fibers are polygonal to rounded or sometimes flattened radially on the outer margin of growth ring, in irregular radial rows, non-septate, non-gelatinous, up to 35, but mostly 15–27μ in diameter. Walls are 2–5μ in thickness; lumina for the most part are much wider than the thickness of the walls; inter-fiber pits are abundant, more numerous on the radial walls, minute, bordered, orbicular or oval, with slit-like, steeply oblique, extended apertures.

Vascular rays are 13–19 per mm., 1–3 cells wide, heterogeneous, and of two types: (a) Uniseriate, or very rarely with biseriate portions, usually consisting entirely of upright cells, up to 30 or more cells in height (fig. 3); (b) broader rays 2–3-seriate, 25–60μ in width, consisting of procumbent cells through the central portion, with uniseriate margins of 1–26 or more rows of upright cells (fig. 4). Vertically fused rays are frequent. Ray–vessel pit pairs are numerous,

oval to orbicular, with rounded to lenticular apertures, 3–5μ in diameter, frequently unilaterally compound; gummy infiltrations are sparse or lacking; crystals have not been observed.

Xylem Structure of the Species

Strophanthus sarmentosus DC.–This plant is a large liana up to 20 m. long and 10 cm. in diameter. The wood is cream colored to light yellow or light yellowish brown, somewhat lustrous to lustrous, without a characteristic odor, or taste, or somewhat bitter, of medium density, fine textured and straight grained. Growth rings are usually inconspicuous, but sometimes are fairly distinct to the naked eye because of a difference in the size of pores in the latewood and earlywood of adjoining rings.

Vessels are mostly 100–160μ in diameter, but may be up to 200μ; those in the earlywood are usually larger and visible to the naked eye. Pores are usually in radial multiples of 2–6 (mostly 2 or 3), rarely in clusters, and infrequently solitary, oval in outline or compressed when in multiples or clusters. There are 15–23 pores per square mm. Vessel members have medium thick walls. Perforations are simple, with prominent rims; intervascular pitting is alternate, the pits numerous, 3–5μ in diameter, oval to orbicular or angular through crowding, vestured, with lenticular, usually horizontal apertures. Tyloses are generally sparse, plugging some vessels; gummy deposits are occasional.

Wood parenchyma is paratracheal and apotracheal, in strands of 4–6 cells. Paratracheal parenchyma is scanty; apotracheal parenchyma is (a) abundant diffuse-in-aggregates or reticulate and (b) initial or terminal, forming irregular bands 1–3 cells wide. Parenchyma cells are up to 60μ but mostly 21–30μ in diameter.

Wood fibers are polygonal to rounded in transverse section or sometimes flattened radially on the outer margin of the ring, in irregular radial rows, up to 46, but mostly 16–26μ in diameter. Walls are 2–5μ thick; fiber lumina for the most part are much wider than the thickness of the walls; inter-fiber pits are abundant, more numerous on the radial walls, minute, bordered, oval, with slit-like, oblique, extended apertures. Gummy deposits are sparse; crystals have not been observed.

Rays are 16–21 per mm., 1–3 cells wide, heterogeneous, of two types: (a) Uniseriate or very rarely with biseriate portions, often consisting entirely of upright cells, up to 24 or more cells high and 900 or more microns in height; (b) broader rays 2–3-seriate, mostly biseriate, 26–45μ wide, consisting of procumbent cells through the central portion, tapering to uniseriate margins of 1–24 or more rows of upright cells, sometimes over 1,000μ in height, the central portion 90–220μ in height; vertically fused rays frequent. Ray–vessel pit pairs are numerous at each contact, oval to orbicular, with rounded to lenticular apertures, 3–4μ in diameter, frequently unilaterally compound. Gummy infiltrations are sparse or lacking; crystals have not been observed.

Material: Yale 47103 (Krukoff 1949-1); Yale 47104 (Krukoff 1949-10); Yale 47105 (Krukoff and Letouzey 133); Yale 47106 (Krukoff and Letouzey 139); Yale 47107 (Krukoff and Letouzey 135).

Strophanthus congoensis Franch.—This species is a liana attaining a length of 15 m., and a diameter of 7 cm. at the base. The wood is pale straw color. Growth rings are scarcely distinct, and rather narrow.

Vessels are up to 180, but mostly 100–150μ in diameter, for the most part in radial multiples of 2–6 (mostly 2–3), very rarely in clusters and infrequently solitary; 20–30 per square mm. Intervascular pits are up to 6μ in diameter. Tyloses are occasional, partly, or sometimes entirely, plugging the vessels. Parenchyma is in strands of 4–8 cells; cells are mostly 22–30μ in diameter but may be up to 50μ; gummy deposits are very sparse. Wood fibers are usually 15–25μ in diameter, sometimes reaching 37μ. Rays are 13–19 per mm., narrow rays are up to 23 or more cells high and 1,200μ or more in height; broader rays are mostly biseriate, occasionally triseriate, 25–60μ in width, with uniseriate margins consisting of 1–21 or more rows of upright cells, and 1,400μ or more in height, the central portion 60–350μ in height; ray-vessel pits are 3–4μ in diameter.

Material: Yale 47091 (Krukoff and Letouzey 176); Yale 47092 (Krukoff and Letouzey 212).

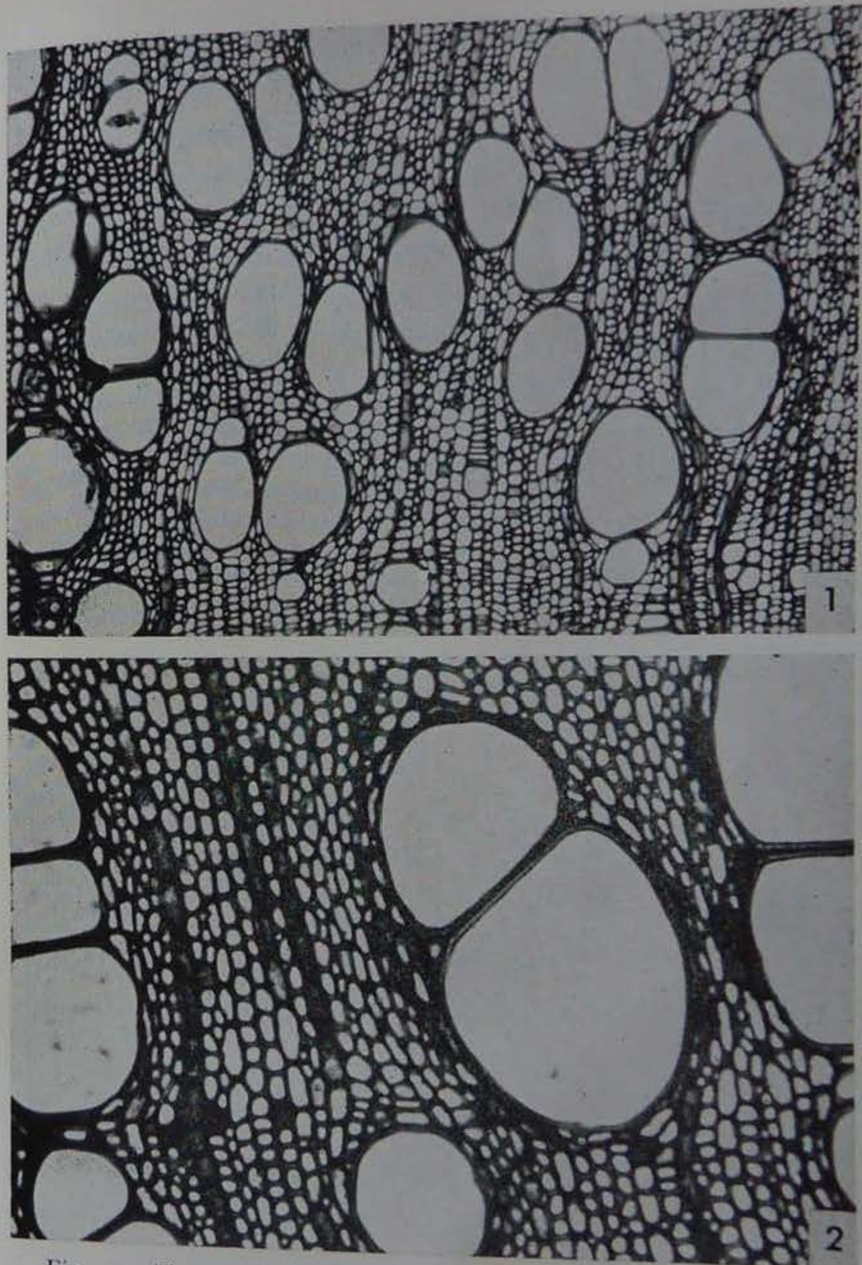

Fig. 1–2. Transverse sections of *Strophanthus* wood.—Fig. 1. *Strophanthus sarmentosus*, showing diffuse porosity and oval pores. × 75.—Fig. 2. *S. thollonii*, showing pores in radial multiples, paratracheal and apotracheal parenchyma. × 150.

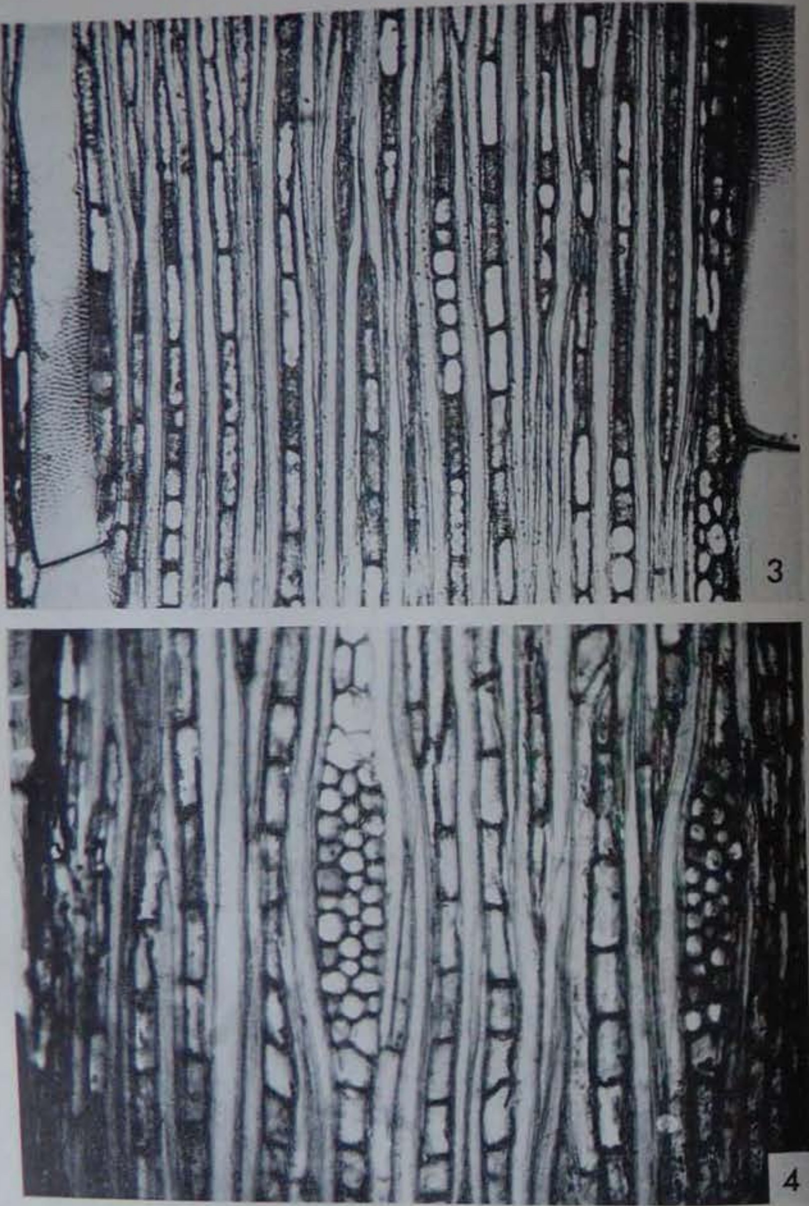

Fig. 3–4. Tangential sections of *Strophanthus* wood.—Fig. 3. *S. thollonii*, illustrating uniseriate rays. × 150.—Fig. 4. *S. gratus*, illustrating uniseriate and 3-seriate rays. × 150.

Strophanthus gratus (Wall. & Hook.) Franch.—These are large lianas reaching a length of 30 m. and a diameter of 12 cm. near the ground. Wood is creamy white to pale yellow or yellowish brown. Growth rings are scarcely distinct and rather narrow.

Vessels are mostly 120–180μ in diameter but may reach 240μ, for the most part in radial multiples of 2–6 or more (mostly 2–4), and 12–25 per square mm. Intervascular pits are 3–5μ in diameter. Wood fibers are usually 16–27μ in diameter with a maximum breadth of 35μ. Rays are 15–21 per mm.; narrow rays are up to 30 cells or more high and up to 1,700μ in height; broader rays are 2–3-seriate (3-seriate rays common) and 35–70μ wide, uniseriate margins with 1–25 or more upright cells and up to 1,500μ or more in height; ray-vessel pits are mostly 3–4μ in diameter.

Material: Yale 47093 (Krukoff 014); Yale 47094 (Krukoff and Letouzey 115); Yale 47095 (Krukoff and Letouzey 116); Yale 47096 (Krukoff and Letouzey 202).

Strophanthus hispidus DC.—These lianas attain a length of 25 m. and a diameter of 12 cm. The wood is cream or straw colored. The root is characterized by a bitter taste. Growth rings are inconspicuous to scarcely distinct, narrow to very narrow.

Vessels are mostly 100–180μ in diameter but may reach 200μ, for the most part in radial multiples of 2–6 or more (mostly 2–5), and 17–38 per square mm. Intervascular pits are up to 6μ in diameter. Tyloses are occasionally present; gum deposits are rare. Parenchyma occurs in strands of 4–6 (mostly 4) cells; cells are up to 55 but mostly 22–36μ in diameter. Wood fibers are mostly 15–25μ in diameter but may attain 37μ. Rays are 12–19 per mm.; narrow rays are 23 or more cells high and 1,300μ or more in height; broader rays are 2–3-seriate, mostly biseriate, 25–65μ wide, tapering at the ends to uniseriate margins of 1–26 or more rows of upright cells, up to 2,300μ or more in height with the broad central portion 140–350μ in height; ray-vessel pits are 4–5μ in diameter.

Material: Yale 47102 (Krukoff and Letouzey 235).

Strophanthus thollonii Franch.—These are lianas attaining lengths of 12 m. and diameters of 7 cm. at base. The wood is straw colored with scarcely distinct, narrow growth rings.

Vessels are mostly 120–160μ in diameter but up to 190μ at times, for the most part in radial multiples of 2–7 or more (mostly 2–4), and 26–32 per square mm. Intervascular pits are 3–5μ in diameter. Parenchyma occurs in strands of 4–6 cells; up to 45, mostly 20–27μ in diameter; gummy deposits are relatively abundant. Wood fibers are mostly 15–27μ in diameter but up to 35μ. Rays are 19–25 per mm.; narrow rays are up to 26 or more cells high and 1,200μ or more in height; broader rays are biseriate, 20–37μ wide, tapering at the end to uniseriate margins of 1–18 or more upright cells, and up to 1,050μ in height; ray-vessel pits are 3–4μ in diameter; gummy deposits are relatively abundant.

Material: Yale 47108 (Krukoff and Letouzey 101); Yale 47109 (Krukoff and Letouzey 103).

Discussion and Summary

Xylem study of *Strophanthus* reveals that this genus has a number of features commonly present in a majority of apocynaceous genera, namely: generally inconspicuous growth rings, small to medium-sized and numerous, or fairly numerous, pores arranged predominantly in radial rows of two to several (a few genera of Apocynaceae have exclusively solitary pores); absence of spiral thickenings on the walls of vessel members (spiral thickening has been reported in vessels of three genera of Apocynaceae; Solereder, 1908); simple vessel perforations with prominant rims (short scalariform plates have been reported in a few genera; Record and Hess, 1943); alternate intervascular pitting with very small to minute, vestured pits; thin to moderately thin-walled fibers and generally heterogeneous rays.

Anatomically, *Strophanthus* is similar to many other genera of the Apocynaceae. It can be separated from a number of genera by the presence of irregular, ragged, marginal parenchyma (marginal parenchyma is only present in a few genera of Apocynaceae; Record and Hess, 1943; Metcalfe and Chalk, 1950). The absence of septate fibers distinguishes *Strophanthus* from other apocynaceous taxa possessing marginal parenchyma (Record and Hess, 1943; Dadswell and Ingle, 1948; Metcalfe and Chalk, 1950). The rays of *Strophanthus*, based on the samples examined, are 1–3-seriate; genera characterized by wider rays can therefore be distinguished.

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SURVEY OF AFRICAN WOODS. III.[1]

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Entandrophragma angolense (Welw.) C. DC.
E. macrophyllum A. Chev. Tiama Meliaceae
E. septentrionale A. Chev.

Aubréville (1936) reports that the three above-listed botanical names are synonomous. Rendle (1938) states that ". . . the name *Entandrophragma angolense* is here used to include a number of closely related forms sometimes classed as distinct species." However, since the botanical differences among them are slight and their woods almost indistinguishable one from another, they will be considered as a group in this description.

In the export trade, the wood is known as mukusu, gedu-nohor, bodongo mahogany (United Kingdom; Forest Products Research Laboratory, 1945; Jay, 1947), and tiama (France; Organisation for European Economic Co-operation, 1953). Local names (Dalziel, 1937; Jay, 1947) are abenbegne (Gabon); timbi (Cameroons); edinam tiama-tiama (Ghana[2]); gedulohor (Nigeria); tiama (Ivory Coast and Belgian Congo).

The tree attains a maximum height of 160 feet with a diameter of 3 and one half to 4 and one half feet (Eggeling and Harris, 1939). The bole is often strongly buttressed to a height of 20 feet. Occurrence of the species is reported from the Ivory Coast, Ghana, Nigeria, Cameroons, Gabon. Angola and eastward across the continent through the Belgian Congo to Uganda (Rendle, 1938). The trees are generally found in the high, semi-evergreen forests, usually on moderately dry to somewhat moist sites.

[1]The reader is directed to *Tropical Woods* 105: 13–38, for Part I with tables and introduction, and to 106: 65–97, for Part II of the series.

[2]Ghana was formerly referred to as the Gold Coast in this series.

An unusual variation in wood coloration is noted in this group. The freshly cut wood is white to pale pink throughout. Upon drying, however, the heartwood of some logs darkens to a reddish to purplish brown, whereas in others only a slight color change in the heartwood may take place and the heartwood and sapwood are virtually indistinguishable. Color variations found in the group include a uniform pale pink wood, a light brown heartwood grading gradually into the pale pink sapwood, and a dark red brown heartwood sharply delineated from the pale pink sapwood (Forest Products Research Laboratory, 1938b). The intensity of the dark color of the heartwood is related to the amount of a dark reddish brown gum deposited in the cells. In the light colored wood, the gum is almost entirely lacking. The wood has a high golden luster and lacks a distinct taste or odor (Kribs, 1950). The grain is commonly interlocked; the texture medium (Clifford, 1953). Growth rings are distinct due to concentric lines of terminal parenchyma; pores are distinct without a lens, evenly distributed, and in solitary or radial groups of 2–3. The lumina of vessels are filled with red gum and a whitish substance. Parenchyma is terminal in concentric lines 2–5 cells wide, vasicentric 2–4 cells wide, aliform with short wings and rarely confluent connecting 2–3 pores. Rays are visible to the naked eye on the cross section; they are distinctly visible on the radial section being darker than background.

In the seasoned condition, the wood weighs 30–38 pounds per cubic foot (Kribs, 1950) with an average of approximately 32 pounds per cubic foot (Jay, 1947). The specific gravity (air-dry volume) ranges from 0.43–0.54, averaging approximately 0.46.

The timber air-seasons slowly with a pronounced tendency to warp and a slight tendency to split and check (Eggeling and Harris, 1939; Forest Products Research Laboratory, 1938b). Planks, 2 and one-half inches thick, piled in England in March and maintained under cover dried from 65 to 19 per cent moisture content in 18 months. In kiln-seasoning, low temperatures are advisable to prevent warp. If a mild schedule is used, little or no checking occurs and excessive warping is avoided in the thicker sizes. Two-inch planks seasoned in a forced-circulation kiln required 45 days to dry from 60 to 10 per cent moisture content with a schedule involving temperatures ranging from 95° to 140° F. and relative humidities ranging from 85 to 40 per cent.

The results of mechanical tests on unseasoned and seasoned material are presented in table 1. Tiama is similar in its strength properties to sycamore *(Platanus occidentalis)* of the same specific gravity.

The unseasoned wood is equally as strong as sycamore in bending properties including stiffness, work to maximum load and total work. It is 80 per cent as resistant to impact loads. Tiama is 20 per cent stronger than sycamore in maximum crushing strength, 15 per cent harder on the side-grain, and 20 per cent harder on the end-grain. Shearing strength and resistance to splitting are approximately the same as for sycamore.

Upon drying to the air-dry condition, both tiama and sycamore exhibit an approximate 50 per cent increase in modulus of rupture over the green values. Work to maximum load increases slightly for tiama and total work decreases about 5 per cent. Impact resistance properties also undergo but little change. Maximum crushing strength, shearing strength and end-hardness increase approximately 60 per cent. Increases in side hardness and cleavage upon seasoning are about 20 per cent.

In the air-dry condition, tiama is equal to sycamore in static bending strength, maximum crushing strength and cleavage. It is only slightly inferior to sycamore in impact resistance (maximum drop of 50-pound hammer to produce fracture). It is approximately 20 per cent harder on the end- and side-grain and 15 per cent stronger in shear parallel to the grain.

Shrinkage values for tiama are similar to comparable values for white oak (table 2). Volumetric shrinkage values of 15.7 per cent are equal for both species; tangential shrinkage of 10.6 per cent is greater for tiama, but radial

shrinkage is somewhat less. From 90 per cent relative humidity to 60 per cent reative humidity (equilibrium moisture contents of 22 per cent and 13.5 per cent respectively), the wood undergoes 1.6 per cent tangential and 1.2 per cent radial dimensional change (Forest Products Research Laboratory, 1954). The difference between radial and tangential shrinkage is not consistent in these values and in the shrinkage values reported in table 2.

Results of decay tests carried out in Great Britain are reported in table 3. After 8 months exposure to white- and brown-rot fungi, test specimens were appreciably reduced in weight by decay action. The one white-rot fungus employed *(Polystictus versicolor)* reduced wood specimen weight by one half. The wood is therefore classified as non-resistant to decay (Findlay, 1938) and shows particular susceptibility to deterioration by white-rot fungi. It is also susceptible to attack by boring insects (Clifford, 1953). The timber is not of the class normally given preservative treatment and is reported to be somewhat difficult to treat.

The working properties of the wood have been investigated in detail at the British Forest Products Research Laboratory (1938). It ripsaws cleanly with little dulling effect on cutting edges but some tooth vibration occurs when the angle of hook exceeds 20°. Bandsawing produced clean-sawn surfaces with slight chipping at the saw exit when cutting across the grain. Best results were obtained with bandsaws having 36 teeth to the foot. The wood planes well but some tearing of the interlocked grain on the quarter is noted. The wood turns well but may show picking-up of grain on the quarter. Boring is easily accomplished with smooth, clean holes and little tendency to chip. The wood stains very well, and has an attractive finish if the surface is smooth and clean (Clifford, 1953). Nailing, screwing and gluing properties are very good.

Tiama is intermediate between African mahogany *(Khaya ivorensis)* and sapele *(Entandrophragma cylindricum)* as a cabinet and decorative paneling wood. It lacks the prominent striped figure of sapele mahogany and generally shows a more attractive figure than is common for African mahogany. Tiama is primarily used as a decorative wood for paneling, cabinet work and high-class joinery (Eggeling and Harris, 1939; Clifford, 1953; Jay, 1947).

Entandrophragma cylindricum (Sprague) Sapele Meliaceae

This species is also known in trade as sapele mahogany, scented mahogany, sapele (United Kingdom); aboudikro, acajou sapelle (France; Jay, 1947). Local common names (Dalziel, 1937) are bibitu, bubussu, lotué (Ivory Coast); penkua (Ghana); atore owuru, ubilesan (southern Nigeria).

The tree attains a height of 180 feet with a clear, straight bole 80–90 feet long and up to 20 feet in diameter (Dalziel, 1937). Buttresses are common extending up the stem for about 12 feet. The tree is found in greatest frequency in West Africa from the Ghana southward through the Ivory Coast, Nigeria, to the French Cameroons, and eastward through the Belgian Congo to Uganda where it is found only in the forests of Buganda and Bunyoro. It commonly occurs in association with *Khaya* spp. in the evergreen and mixed deciduous forests (Eggeling and Harris, 1939; Jay, 1947).

The sapwood is pale in color with a pinkish tint; the heartwood is a more reddish in color when freshly cut, darkening to a rich red brown color when exposed (Wood, 1950). The wood has a distinct cedar-like aroma but lacks a distinctive taste (Jay, 1947). The odor remains even after long exposure (Dalziel, 1937). The wood is highly lustrous with a golden tone. The texture is medium and the grain interlocked, producing a striped figure on the quarter (Wood, 1950). Occasional logs have considerable grain variation which produces a blister figure. Growth rings are distinct due to concentric bands of terminal parenchyma. The pores are distinct to the naked eye, numerous, evenly distributed and solitary or in radial groups of 2–3. Parenchyma is terminal in concentric bands 2–10 cells wide, apotracheal, aliform and aliform confluent with red "gum" and crystals in the cell cavities. The rays are distinct as fine white lines on the cross-section and are visible on the radial

surface as dark marks due to "gum" and crystal deposits in the cavities of the cells (Kribs, 1950).

The wood is harder and heavier than African mahogany (*Khaya* spp.) with an average density of 40 pounds per cubic foot air dry (Kribs, 1950; Rendle, 1938), equivalent to a specific gravity of 0.62 based on oven-dry weight and air-dry volume. Harrar (1941) reports the specific gravity as 0.57 based on oven-dry weight and volume. Rendle (1938) shows a wide range in weight for the species.

Considerable variations in the seasoning behavior of the wood are reported. Most sources agree on the better drying results obtained with quarter-sawn rather than with plain-sawn material, the latter being very prone to warp. The wood dries slowly thus requiring mild drying conditions and good piling practices to minimize warp (Eggeling and Harris, 1939; Forest Products Research Laboratory, 1945; Jay, 1947). Severe drying conditions increase the incidence of warp in flat-sawn stock and may render the pieces useless. The British Forest Products Research Laboratory (1945) recommends a low temperature kiln schedule established for timbers which are particularly prone to warp.

The results of mechanical tests on green and air-dry material are reported in table 1. Sapele is notably inferior in static bending and impact strength to domestic hardwoods of comparable specific gravity.

In the green condition, sapele may be compared with white ash of the same density in most strength properties. It is equally strong in bending (modulus of rupture) and 80 per cent as stiff in bending as white ash. The maximum crushing strength of sapele exceeds that of white ash by 30 per cent. It is 20 per cent harder on the end and side grain, 30 per cent more resistant to cleavage and 85 per cent (150 in.-lb. per specimen) as resistant to impact loads as white ash.

Upon drying, the strength properties show erratic changes. The modulus of rupture in bending decreases slightly, impact strength exhibits a marked drop to 70 per cent of the green value and cleavage resistance along the radial plane shows no increase upon drying. Maximum crushing strength and hardness undergo moderate increases with drying. The strength behavior of the wood upon drying bears out the tendency of defects to develop in seasoning.

In the air-dry condition, sapele is approximately 60 per cent as strong in bending (modulus of rupture) and 70 per cent as stiff as white ash. It is equal to white ash in hardness and in resistance to cleavage and 15 per cent stronger in maximum crushing strength; however, it is only 50 per cent (102 in.-lb. per specimen) as resistant to impact loads. The lack of impact strength may be explained in part by the pronounced interlocked grain common to the species.

The shrinkage (see table 2) of sapele–volumetric 14.0, tangential 7.4, and radial 5.9 per cent–upon drying is similar to white ash except that the ratio of tangential to radial shrinkage is much less for sapele (1.23 to 1.54). The actual shrinkage of the wood may be somewhat erratic due to the irregularities of the grain and distortion in the form of warp frequently encountered.

The wood is moderately resistant to decay but converted stock has been noted to be susceptible to pinhole borer attack. The sapwood is susceptible to attack by powder-post beetles (Lyctidae and Bostrychidae) and termites (Clifford, 1953; Forest Products Research Laboratory, 1945).

The wood works readily with no undue dulling of cutting edges (Eggeling and Harris, 1939). It is 20 per cent more resistant to cutting than Honduras mahogany (Forest Products Research Laboratory, 1945). The presence of interlocked grain causes picking up on quarter-sawn surfaces and also some chipping out. However, a cutting angle of 15° produces uniformly good results. The wood works well in other operations and it nails, screws and glues satisfactorily. Sapele stains readily on smooth surfaces but requires care if the surface is not well machined. The wood finishes very well.

Sapele is used predominantly in the form of veneer for furniture, paneling, cabinets and high-class interior woodwork (Forest Products Research Laboratory, 1945). Little is used in the solid form because of seasoning and distortion problems. Eggeling and Harris (1939) state that solid sapele furniture offers good commercial possibilities if seasoning difficulties can be surmounted. The wood offers little possibility for construction work because of its poor dimensional behavior in lumber sizes.

Entandrophragma utile (Dawe & Sprague) Sprague
Sipo Meliaceae

Although of the same genus as sapele *(Entandrophragma cylindricum)* and tiama *(Entandrophragma* spp.), *E. utile* differs considerably in many properties from the other members of the genus.

As is the case with the other species of *Entandrophragma*, *E. utile* is often referred to in the trade as a type of mahogany, generally as mufumbi mahogany (Eggeling and Harris, 1939). Other trade names (Forest Products Research Laboratory, 1952b) are: utile (Great Britain); sipo (France and the Ivory Coast); and assie (Cameroons). The common name in Uganda is mufumbi. Local names (Dalziel, 1937; Organisation for European Economic Co-operation, 1951); include: sipo (Ivory Coast); efuo-konkonti (Ghana); akuk, gedulohor (southern Nigeria); m'vovo (Belgian Congo).

The tree is one of the most impressive of the forest, attaining a height of 150–170 feet at maturity (Forest Products Research Laboratory, 1952b). The bole is straight and cylindrical with very slight taper, 70–80 feet (occasionally up to 100 feet) long, and up to 8 feet in diameter (Eggeling and Harris, 1939). Buttresses are rounded and short but relatively wide-spreading from the base. The species occurs in the semi-evergreen forests of tropical western and central Africa from the Ivory Coast eastward through Ghana, southern Nigeria, Cameroons, Belgian Congo, to Uganda. It is most commonly found on the drier sites.

The heartwood is a fairly uniform reddish or purplish brown with a high, golden luster and is sharply delineated from the light brown sapwood which averages 2 inches in width (Wood, 1950; Forest Products Research Laboratory, 1938b). The wood lacks a distinct taste but possesses a faint, cedar-like scent. The grain is broadly interlocked producing a rather wide and often irregularly striped figure on quartered surfaces. Texture is medium generally being somewhat finer than the general run of African mahogany. Growth rings are distinct on a cleanly-cut end surface. Pores are distinct to the unaided eye, evenly distributed, and solitary or in radial groups of 2–3. Parenchyma is formed into wavy tangential bands which are discontinuous in the early portion of the growth ring. Rays are barely distinct without a lens on the end surface, visible on the tangential surface and conspicuous on the radial surface. Ripple marks are generally irregular or absent.

Sipo is a heavy wood with an average weight per cubic foot air dry of 42 pounds (35–48 pounds; Forest Products Research Laboratory, 1952b). The specific gravity (oven-dry weight, air-dry volume) averages 0.59 (0.48–0.67).

The British Forest Products Research Laboratory (1938b, 1952b) provides conflicting statements concerning the seasoning qualities of the wood. Apparently sipo air-seasons slowly with a slight to marked tendency toward degrade in the form of splitting and distortion. The severity of degrade development may vary considerably from piece to piece. Planks, 2 and one half inches in thickness, required 19 months under cover to dry from 50 per cent to 18 per cent moisture content. The wood kiln-dries well and quite rapidly with little tendency to check and split. Material with pronounced interlocked grain may exhibit appreciable warping, otherwise this defect is seldom severe.

The results of mechanical tests on green and air-dry material are reported in table 1. Compared with teak of slightly greater specific gravity, sipo is equal or superior in nearly all strength categories. In the category of static bending, the unseasoned wood of sipo is slightly inferior in modulus of rupture and somewhat less stiff but superior in

shock resistance as measured by work to maximum load. It is essentially equal to teak in maximum crushing strength and appreciably harder on the end and side grain. Sipo exceeds teak in shearing strength by 10 per cent and is equal to teak in resistance to cleavage.

Upon drying from the green to the air-dry condition, sipo undergoes appreciable increases in maximum crushing strength, end hardness and shear (approximately 50 per cent over the green value). Modulus of rupture and stiffness in static bending, side hardness and cleavage exhibit moderate increases upon seasoning. Work to maximum load remains practically unchanged but total work in static bending and impact resistance undergo serious decreases (35 per cent and 20 per cent of the green values respectively).

The seasoned wood of sipo is slightly superior to teak in the static bending properties of modulus of rupture and stiffness. It is also superior to teak in impact strength as measured by work to maximum load in static bending. Sipo is 10 per cent stronger in maximum crushing strength and 25 per cent harder on the side grain than teak. It is 50 per cent stronger in shear and 40 per cent more resistant to splitting.

Tests, conducted at the British Forest Products Research Laboratory (1952b), indicate that sipo is a very poor steam-bending species. The wood can not be compressed to any appreciable extent without buckling. Steamed material can be bent to radii of curvature of 36 inches per inch of thickness when supported by a steel tension strap and 40 inches per inch of thickness when unsupported.

Green to oven-dry shrinkage values are given in table 2. These values—volumetric 12.5, tangential 7.0 and radial 6.0 per cent—are somewhat below the average for domestic hardwoods of similar density. The shrinkage of sipo is approximately 50 per cent greater than that of African mahogany and twice as great as that of teak. The dimensional change between 90 per cent and 60 per cent of relative humidity (equilibrium moisture contents of 22 per cent and 14 per cent respectively) is 1.8 per cent tangentially and 1.6 per cent radially of the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). Sipo thus exhibits 40 per cent greater tangential and 100 per cent greater radial dimensional change than teak.

Results of decay tests carried out at the British Forest Products Research Laboratory (Findlay, 1938) are given in table 3. After 8 months exposure to the action of 4 wood-destroying fungi, sipo exhibited an average weight loss due to decay of 9.3 per cent. A greater susceptibility to brown-rot fungi is noted, nevertheless, the wood is classified as moderately resistant to decay. Sections of 2 × 2 inch dimensions have been found to have an average life of 14 years in contact with the ground in England (Forest Products Research Laboratory, 1952b). The sapwood is liable to attack by powder-post beetles. Sipo is extremely resistant to impregnation with creosote.

The working qualities of the wood have been investigated at the British Forest Products Research Laboratory (1938b) where it was found that sipo works fairly easily with hand and machine tools, requiring no special treatment in order to produce smooth surfaces. There is some tendency toward tooth vibration in sawing when a hook of 20° or more is used. Air-dry material is somewhat more resistant to cutting than green material but the dulling effect on cutting edges appears to be slight. Planing material with pronounced interlocked grain may result in grain pick-up and chip marks which can be eliminated by reducing the cutting angle to 20° (Forest Products Research Laboratory, 1952b). Chipping-out at tool exits is commonly encountered if the material is not properly supported. In drilling, some charring may also be encountered. Smooth surfaces are readily produced in all other operations but there is a slight tendency toward splitting in nailing. Good results are produced with the usual stains and finishes when a grain filler is employed.

Sipo does not have as handsome a figure as sapele but is used for the same purposes such as furniture, decorative paneling, woodwork and shop fittings (Forest Products Research Laboratory, 1952b). In addition, its moderate

weight, strength and shrinkage properties, combined with relative ease of working indicate that the wood may prove suitable for other exacting purposes. Although its shrinkage is considerably greater than that of teak or mahogany, sipo possesses certain other advantages (greater strength per unit weight and decay resistance) which may render it satisfactory in ship planking and decking and also in framing where good steam-bending qualities are not required. It appears to be a good general utility timber suitable for a wider range of uses than those for which it is now employed.

Gossweilerodendron balsamiferum (Vermoesen) Harms
Agba Leguminosae

Agba is also known as achi, agbara, emonga, loshierin, mobonron, okimeten (southern Nigeria) and in the trade as "pink mahogany" or "Nigerian cedar" (Jay, 1947).

The tree is one of the largest in west Africa, often attaining a height of 15 feet and a diameter at the base of 6 feet (Gerry, 1949; Jay, 1947). The bole is straight, clear and cylindrical up to a length of 100 feet (Forest Products Research Laboratory, 1945). No root swelling or buttresses occur at the base. A thick gummy substance exudes from trunk wounds which when hardened is collected and sold locally as an illuminant. The species is found in west Africa, predominantly in southern Nigeria and in Belgian and Portuguese Congo, occurring as a rain forest tree, scattered or in local "pockets."

The wood is yellowish to pinkish brown in color. The sapwood is distinctly lighter in color and approximately 4 inches wide (Forest Products Research Laboratory, 1952a). The luster is high, the texture fine and a distinctive taste and odor are lacking (Kribs, 1950). The grain is straight to slightly wavy or interlocked. A sticky substance is frequently found in cavities or splits near the heart. Some logs tend to contain large quantities of this material while other logs are almost free of the exudate. Growth rings are distinct due to fine concentric lines of terminal parenchyma; the pores are barely visible without a lens, numerous, evenly distributed and solitary or in radial groups of 2–3. The lumina of parenchyma cells contain a brownish deposit. The parenchyma is distinct and terminal in concentric lines, vasicentric, aliform with short wings, confluent connecting a few pores, and diffuse-in-aggregates forming broken tangential lines between the rays. The rays are barely visible without a lens on the cross section and inconspicuous on the radial surface. Secretory ducts are vertical, numerous, diffusely arranged and appear as white dots on the cross section.

The wood is moderately light in weight averaging from 30–32 pounds per cubic foot (Forest Products Research Laboratory, 1952a) with a specific gravity (oven-dry weight, air-dry volume) from 0.43–0.45.

Agba seasons fairly rapidly either in the air or in kilns with the little tendency toward degrade (Forest Products Research Laboratory, 1945, 1952a; Jay, 1947). High kiln temperatures should be avoided to prevent melting the gummy material and consequent exudation from the surface. The British Forest Products Research Laboratory recommends a kiln schedule similar to that suggested for sugar maple and black walnut.

The results of mechanical tests on air-dry material are presented in table 1. Agba exhibits strength properties very similar in all categories except impact strength to sweet gum.

The seasoned wood of agba is as strong as sweet gum in all bending properties except stiffness. It exceeds sweet gum in fiber stress at the proportional limit in bending and is equal to it in work to maximum load and total work in bending. However, agba is only 85–90 per cent as stiff in bending. Both woods are equal in maximum crushing strength and hardness. Agba is 70 per cent superior in compressive strength perpendicular to the grain, 85 per cent as strong in shear parallel to the grain and 80 per cent as strong in cleavage as sweet gum.

Values for shrinkage from the green to oven-dry condition for agba are not reported. The dimensional change

between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 17 per cent an 12 per cent respectively) is 1.8 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, and for white oak 2.8 per cent tangentially and 1.3 per cent radially. Agba is therefore classified as a wood with good dimensional stability.

Decay tests carried out in Great Britain on material from Nigeria indicate that agba is very resistant to decay by both white-rot and brown-rot fungi (Findlay, 1938). The results which are reported in table 3 show that after 4 months exposure to 4 wood-destroying fungi, specimens exhibited negligible weight loss due to decay. Logs are susceptible to pin-hole borer attack and the sapwood is liable to powder-post beetle infestation (Forest Products Research Laboratory, 1945). The wood is reported as resistant to termites in Nigeria. The species is very resistant to impregnation with preservatives by the open-tank process.

Tests of the working properties of agba[3] were carried out at the British Imperial Institute (1923). The tests indicate that the wood works easily with machine and hand tools giving excellent results in sawing but tending to show grain pick-up in planing. The wood is easily bored, nailed and screwed without splitting. The wood cuts well on a mortising machine and strong joints are obtainable. It generally glues and finishes well, although the gummy exudate may affect the finish.

[3]The results of these tests are reported in the *Bulletin of the Imperial Institute* 21: 457. 1923, on a species then identified as agba—*Pterolobium* sp. At the time of the test, botanical knowledge of the species was sketchy. A recent letter from B. J Rendle of the British Forest Products Laboratory resolved the uncertainty about the species. He reports that *Pterolobium* sp. was described in 1923 by Vermoesen as *Pterygopodium balsamiferum* (*Man. Essences Forest. Congo Belg.* 233. 1923) and was subsequently transferred to the genus *Gossweilerodendron* by Harms as *G. balsamiferum* (Notizbl. Berlin Bot. Gart. 9: 457. 1925).

The wood is recommended for use in joinery, construction work, flooring, interior fixtures and furniture (Forest Products Research Laboratory, 1945; Jay, 1947). In the Royal Suite at the Glasgow Empire Exhibition in 1938, agba was used in flooring.

Guarea cedrata (A.Chev.) Pelleg. Guarea Meliaceae
G. thompsonii Sprague & Hutch.

Both species are known by the misleading names Nigerian pearwood, Nigerian cedar, and cedar mahogany (Jay, 1947). *G. cedrata* is distinguished by the trade names scented guarea and white guarea, and *G. thompsonii* is known as guarea and black guarea. The trade name in France and in French West Africa is bosse. Local names (Dalziel, 1937) for white guarea include nguande, guissu, anokue, dzana, belii, pahiapo (Ivory Coast); kwadwuma, penkwa (Ghana); lofun, ogborogboro, obobo-nofwa (southern Nigeria); edoucie, timbi (Cameroons). Those local names for black guarea include boh-in-dah (Liberia); mutigbanaye, mietan'-dabo, koiguibe (Ivory Coast); kwabohoro, teninini, kwadwuma (Ghana); obobo-nekwi, ofe, ugbokpo, dirimo-ako (southern Nigeria).

Trees of white guarea attain heights of 65–100 feet or more and diameters of 3–4 feet (Forest Products Research Laboratory, 1945). The bole is cylindrical above the buttresses and clear to a height of 50 feet from the ground (Collardet, 1929). Black guarea is similar in growth habit to white guarea except that the bole is not as heavily buttressed. The ranges of both species overlap in the Ivory Coast, Ghana and southern Nigeria, white guarea extending further westward to the Cameroons and black guarea extending further eastward to Liberia (Forest Products Research Laboratories, 1945). Both species occur in the moist evergreen forests (Forest Products Research Laboratory, 1938a; Dalziel, 1937).

The freshly cut wood is a pinkish, creamy white color. The sapwood is approximately 4 inches wide and somewhat lighter than the heartwood (Collardet, 1929). Upon exposure, heartwood darkens to a light reddish brown, that of black guarea being somewhat lighter in color (Forest Products Research Laboratory, 1938a). The freshly cut wood has a distinct cedar-like odor which is more pronounced in white guarea, and slowly fades upon drying; no distinctive taste is present. The grain is straight, wavy or slightly interlocked; the texture medium fine and the luster high. Growth rings are indistinct; pores barely visible to the naked eye on a clean-cut end-surface, fairly numerous, evenly distributed, solitary or in radial groups of 2 to 3 or more, occasionally containing a dark-colored gum; parenchyma is in broken wavy, tangential lines barely visible on the end-surface in white guarea and in continuous tangential lines visible to the naked eye in black guarea; rays are fine, invisible without a lens except on the radial surface (Kribs, 1950). Both woods exude a gum which is more pronounced in white guarea (Forest Products Research Laboratory, 1938a).

The wood of white guarea is equal in density to black walnut, averaging 38 pounds per cubic foot air dry (Forest Products Research Laboratory, 1938a), with an average specific gravity (oven-dry weight, air-dry volume) of 0.53. Black guarea is somewhat heavier, averaging 40 pounds per cubic foot air dry (Forest Products Research Laboratory, 1945), with an average specific gravity (oven-dry weight, air-dry volume) of 0.56.

White guarea air-seasons well with normal care, but requires protection from the sun and rain while drying (Forest Products Research Laboratory, 1945). The wood kiln-seasons fairly readily with very little tendency to split or warp but may be degraded in appearance by the gummy exudation. A kiln schedule similar to that recommended for Sitka spruce (for non-aircraft use) and teak is suggested for white guarea by the British Forest Products Research Laboratory (1945). Black guarea tends to check slightly and to exude a clear gummy substance when air-seasoned. The wood kiln-seasons satisfactorily with little tendency to warp, but with a tendency to split. A kiln schedule similar to that recommended for sugar maple and black walnut is suggested for black guarea by the British Forest Products Research Laboratory (1945).

The results of mechanical tests on green and air-dry material are reported in table 1 for both species. Black guarea, being somewhat heavier than white guarea, is the stronger of the two species.

The unseasoned wood of white guarea may be compared in mechanical properties to the unseasoned wood of black cherry. White guarea is superior in modulus of rupture by 25 per cent but notably inferior in total work in bending and less resistant to impact loads. In all other strength categories ,white guarea is considerably superior to black cherry. Black guarea is in a class with American beech as far as strength properties are concerned. In bending, black guarea is superior to beech in modulus of rupture and stiffness, but somewhat inferior in total work, and only 65 per cent as strong in impact strength. It is 60 per cent stronger in maximum crushing strength but considerably less resistant to splitting.

Upon drying to the air-dry condition, both species exhibit moderate increases in most strength properties. White guarea undergoes a slight increase in work to maximum load, but black guarea exhibits a slight decrease in this property. Decreases in total work in bending occur for both species. Impact strength does not change for white guarea but decreases for black guarea by approximately 15 per cent. Decreases in cleavage occur for both species upon drying, black guarea undergoing the greatest decrease in this property.

In the air-dry condition, strength values for white guarea are almost identical to values for black cherry with the exception of end hardness, in which black cherry is superior, and shearing strength in which white guarea is superior. Black guarea is similar to American beech in maximum bending strength (modulus of rupture) and stiffness but somewhat inferior in work to maximum load and 60 per cent as strong in total work and impact strength. American beech is also somewhat harder and more resistant to shear and splitting than is black guarea.

Both species are classed as moderately good steam-bending woods (Forest Products Research Laboratory, 1945), white guarea being superior in this respect. The radii of curvature per inch of thickness to which the woods may be bent after steaming are 11 inches when supported with a steel tension strap and 20 inches when unsupported for white guarea, and 14 inches when supported and 36 inches when unsupported for black guarea.

Green to oven-dry shrinkage values are reported in table 2. Both species exhibit small shrinkage compared to domestic hardwoods of similar specific gravity, volumetric shrinkage amounting to 9.8 and 10.3 per cent, respectively, for white and black guarea. White guarea exhibits one fifth less tangential and volumetric shrinkage than black cherry, the radial shrinkage being similar for both. Black guarea undergoes one third less tangential and volumetric shrinkage than American beech and approximately one fifth less radial shrinkage. The dimensional changes between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 19 per cent and 13.5 per cent for white guarea, and 18 per cent and 12.5 per cent for black guarea respectively) are 1.6 per cent tangentially and 1.2 per cent radially for white guarea, and 1.6 per cent tangentially and 1.0 per cent radially for black guarea (Forest Products Research Laboratory, 1954). These values are not widely different from comparable values of 1.3 per cent and 1.0 per cent for mahogany *(Swietenia macrophylla)*.

The results of limited durability tests are reported in table 3. White guarea is not resistant to either white-rot or brown-rot fungi although black guarea exhibited resistance to decay by a white-rot fungus after 8 months exposure (Findlay, 1938). The sapwood of black guarea is reported as probably susceptiable to powder-post beetle attack; both species are moderately resistant to termites (Forest Products Research Laboratory, 1945). The heartwood of both species is impervious to the penetration of creosote even at pressures as high as 200 pounds per square inch and is classed as untreatable (Forest Products Research Laboratory, 1938a). The sapwood is easily impregnated under pressure and satisfactorily impregnated by the open tank process.

Tests of the working qualities of the wood conducted in England (Forest Products Research Laboratory, 1938a) indicate that the wood works with some difficulty but smooth surfaces are generally obtainable. Cutting with saws that usually prove suitable for material of this class was found to be slightly difficult with white guarea. This species has a tendency to exude gum which adheres to the saw and increases the resistance to cutting. For ripsawing, a saw running at 10,000 feet per minute peripheral speed and having a 20° hook is recommended. Black guarea has more pronounced interlocked grain but a lesser tendency to exude gum. If the same saw specifications are used as for white guarea, black guarea ripsaws with much less difficulty. In all other machining operations, good results are obtained with moderate ease except that black guarea may tend to show grain pick-up in planing. The nailing, screwing and gluing properties are good and satisfactory results are obtained with the usual finishing treatments. White guarea may tend to exude gum in finishing if exposed to warm air (Forest Products Research Laboratory, 1945).

The two species are very much alike and may be considered identical as far as their use is concerned (Forest Products Research Laboratory, 1945). They are very similar to African mahogany *(Khaya* spp.) in their essential properties and should prove suitable for similar uses such as furniture stock, interior woodwork, high-class millwork and boat building.

Khaya anthotheca D. DC. Munyama Meliaceae

This species combined with other species of *Khaya* is included in commercial consignments of African mahogany. However, in an attempt to differentiate this species from *Khaya ivorensis*, the trade names of munyama, Uganda mahogany and white mahogany have been applied to it in Great Britain (Eggeling and Harris, 1939). The name white mahogany is misleading and its use is discouraged. In France and French African territories, the trade names acajou krala and acajou blanc are applied (British Standards Institution, 1946). In the United States, the trade names African mahogany and khaya are used without regard to the particular species of *Khaya* involved. Local names (Dalziel, 1937) include diala, krala (Ivory Coast); kwabaho (Ghana); ogwango nofwa (southern Nigeria); mangona (Cameroons); munyama (Uganda).

Munyama is a deciduous forest tree attaining a height of 140–180 feet (Eggeling and Harris, 1939). The bole is heavily buttressed at the base for a length of 12 feet but is clear and cylindrical for 30–80 feet beyond the buttresses. The diameter of the bole ranges between 2 and one half and 4 feet in mature trees. The species occurs in a belt across the continent from the Ivory Coast through Ghana, Nigeria, Belgian Congo, to Uganda and southward along the western coast from Nigeria to the Cameroons, Gabon and Angola. It is found in the intermediate zone between the moist coastal forest where *K. ivorensis* occurs, and the drier, interior zone where *K. senegalensis* is found. Munyama is common on stream banks, requiring a good, deep soil and considerable moisture. In many parts of its range, it may be found in forested swamps where it develops considerable heartrot.

The freshly cut wood is pale pink with no differentiation between heartwood and sapwood (Eggeling and Harris, 1939; Hédin, 1930). Upon exposure, the heartwood darkens to a light reddish brown but the sapwood retains its light coloration and is distinct as a thin border about the heartwood. A distinct taste and odor are lacking. The grain is slightly interlocked producing a broad, inconspicuous striped figure on the quartered surfaces and the texture is medium. Growth rings are indistinct. Pores are visible to the naked eye, few, evenly distributed, and solitary or in radial groups of 2–6. The parenchyma is sparse, invisible to the naked eye, forming narrow borders about the pores and narrow, irregular tangential bands. Rays are fine, distinct to the naked eye on the end and tangential surfaces when moistened and sometimes locally storied. Ripple marks are irregular.

The wood is moderately heavy in weight and similar to *K. ivorensis* in density. The weight per cubic foot averages 35 pounds (32–45 pounds; Scott, 1949). The specific gravity (oven-dry weight, air-dry volume) averages 0.51 (0.46–0.66).

Munyama seasons easily with very little degrade (Forest Products Research Laboratory, 1935). Care is necessary to prevent warp however, in drying material in lumber sizes. 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. Munyama is markedly superior to domestic hardwoods of similar specific gravity in most strength categories.

The unseasoned wood of munyama may be compared to that of Central American mahogany of similar specific gravity. In static bending strength, it is inferior to Central American mahogany in the property of modulus of rupture, slightly less stiff, but superior in work to maximum load. The greater work expended in static bending to maximum load is also reflected in its somewhat greater impact strength. In maximum crushing strength and shear, munyama averages approximately 20 per cent below Central American mahogany, but has a moderate superiority in hardness and cleavage.

Upon drying from the green to the air-dry condition, munyama exhibits sizeable increases in modulus of rupture, maximum crushing strength, end hardness and shear. Stiffness and work to maximum load in bending and side hardness undergo small to moderate increases. However, total work expended in static bending, impact strength and cleavage exhibit rather serious decreases.

In the air-dry condition, munyama compares very well with Central American mahogany in all categories except maximum crushing strength and cleavage. In static bending, it is equal to Central American mahogany in modulus of rupture, superior in work to maximum load, but somewhat less stiff. It averages 10 per cent below Central American mahogany in maximum crushing strength and slightly below in cleavage but is decidedly harder, more resistant to shear and slightly stronger in impact. It is very similar to African mahogany *(K. ivorensis)* in all strength categories except cleavage in which it is somewhat inferior.

Collardet (1930) reports the volumetric shrinkage of munyama as 11.8 per cent. This is 50 per cent greater than the comparable value for Central American mahogany and 35 per cent greater than that of African mahogany of equal specific gravity.

Laboratory tests of the decay resistance of munyama have been carried out in England using 4 different wood-destroying fungi (Forest Products Research Laboratory, 1935). The results, which are reported in table 3, indicate that the wood is moderately resistant to decay. Logs are susceptible to attack by pinhole borers and longhorn beetles and the seasoned sapwood is liable to infestation by powder-post beetles (Forest Products Research Laboratory, 1945). The wood is impermeable to preservatives even under high pressure.

The working qualities of munyama are good except where pronounced interlocked grain is encountered (Forest Products Research Laboratory, 1935). The wood shows a distinct tendency to produce a rough surface when the end grain is machined. Picking-up of the grain on quartered surfaces is often encountered and necessitates a reduction of the cutting angle to 20° (Eggeling and Harris, 1939). Wooly surfaces are sometimes produced in turning. Munyama is a good veneering wood, may be sanded to a smooth surface, and produces an attractive finish with stains and varnish when a grain filler is employed.

The uses for the wood are identical with those for African mahogany since both species are indiscriminately mixed in commercial consignments (Brush, 1940). These uses include veneers for furniture, interior fixtures and paneling and lumber for ship planking, hulls and fixtures (Organisation for European Economic Co-operation, 1951). Munyama is much used for these purposes in Africa.

Khaya grandifolia C. DC. Big-leaf mahogany
K. senegalensis A. Juss. Dry-zone mahogany
Meliaceae

Khaya grandifolia and *K. senegalensis* are two of the four species of *Khaya* which comprise commercial consignments of African mahogany shipped from Africa. However, they represent a very small portion of export consignments mainly due to their remote location from shipping centers (Rendle, 1938). Big-leaf mahogany is locally known as diala-iri (Ivory Coast and Ghana); akuk, ogwango (Nigeria); eri, mario (Uganda); bandoro, bele, trio (Sudan; Eggeling and Harris, 1939; Dalziel, 1937). Dry-zone mahogany is known locally as diala (French Guinea, French Sudan and Sierra Leone); bisselon (Portuguese Guinea); loko, koka (Ghana); frimu, haemu (Togo); ma'dachi, agwanwo (Nigeria). The commercial name for dry-zone mahogany in France is acajou du Senegal.

The trees of big-leaf mahogany are medium-sized to large, often over 100 feet in height with a bole 80 feet long (Brush, 1940; Eggeling and Harris, 1939). Those of dry-zone mahogany are much smaller, seldom over 80 feet in height and 3 feet in diameter. Big-leaf mahogany occurs in a belt immediately inland from the range of munyama *(K. anthotheca)* in the Ivory Coast, Ghana, Nigeria and Angola eastward to Uganda. Dry-zone mahogany is widely distributed in the interior savanna regions from Senegal to Angola, across the Belgian Congo to Uganda and is locally frequent along waterways.

The wood is pink when freshly cut. The heartwood darkens to a typical mahogany brown with the sapwood not sharply delineated but somewhat lighter in color (Eggeling and Harris, 1939). The grain is interlocked and the texture is coarse. Growth rings are indistinct and indicated by a zone of smaller pores. Pores are barely visible to the unaided eye, few, less numerous in the late wood and solitary or in radial groups of 2–6. Parenchyma is sparse, occurring as narrow borders around the pores and as irregular tangential bands faintly visible to the naked eye. Rays are fine, distinct without a lens on moistened end and tangential surfaces, and locally storied. Ripple marks are occasional and irregular.

The wood is very heavy having an average air-dry (15 per cent moisture content) weight of 48 pounds per cubic foot (Eggeling and Harris, 1939; Jay, 1947) which is 35 per cent greater than the average air-dry weight of *K. ivorensis*. The specific gravity (oven-dry weight, air-dry volume) averages 0.67.

Seasoning qualities of the wood are good. Drying proceeds at a moderately rapid rate with some warping and splitting developing if drying progresses too fast or adequate piling measures are not taken. It appears that the wood dries in a manner similar to *K. ivorensis*.

Strength tests have been conducted on dry-zone mahogany using the French methods of testing. Compared with *K. ivorensis* of 40 per cent lower specific gravity, dry-zone mahogany is superior but not always in proportion to its greater specific gravity. In bending and crushing, dry-zone mahogany is superior to *K. ivorensis*, almost in proportion to its greater specific gravity but in impact strength, it appears only slightly superior at best. However, it is appreciably harder than *K. ivorensis*.

Decay resistance of the wood is believed to be comparable to the other species of *Khaya* (Eggeling and Harris, 1939). Dry-zone mahogany is considered resistant to termites in Sudan.

The wood works similarly to that of *K. ivorensis* except that it is considerably harder and offers proportionately greater resistance to cutting (Eggeling and Harris, 1939). It is claimed that the working qualities of the wood are compatible with the exacting requirements of the cabinet-making trade. Finishing qualities are very good but grain filling is required.

The uses for big-leaf and dry-zone mahogany are essentially the same as for African mahogany *(K. ivorensis;* Brush, 1940). Since the species are indiscriminately mixed in shipments, all species have probably been used for common purposes. The principal uses are in furniture, fixtures and decorative paneling in the form of solid lumber or veneer. The woods are also suitable for plywood manufacture and are commonly used as the face veneer. Further uses for which African mahogany is well suited and for which big-leaf and dry-zone mahogany may be well adapted are in ship planking and frames, and for ribs, planking and decking in small boats. These two species are harder and may serve very well in boat construction where this property is desired.

Khaya ivorensis A. Chev. African mahogany Meliaceae

The commercial name African mahogany has been loosely applied to all of the species of *Khaya* which are exported from Africa (Brush, 1940). Recently, attempts have been made to reserve the name exclusively for *K. ivorensis* (Collardet, 1930), which is presently the most important species of *Khaya* in the export trade. The nomenclature of *Khaya* is further confused by the practice of denoting export consignments by the name of the ports of shipment, such as Lagos mahogany and Benin mahogany (Nigeria); Sekondi mahogany (Ghana); and Grand Bassam mahogany (Ivory Coast). This practice probably originated because consignments of *Khaya* were made up of several species in varying proportions.

In Great Britain, the name African mahogany is applied to all three of the major species: *K. anthotheca*, *K. grandifolia* and *K. ivorensis* (British Standards Institution, 1946). In France and French African territories, *K. ivorensis* is known as acajou d'Afrique and acajou de Bassam. The names African mahogany and khaya are indiscriminately applied to all of the major species of *Khaya* in the United States (British Standards Institution, 1946; Forest Products Laboratory, 1951). Local names (Dalziel, 1937) for this species include diburi, dukuma (Ivory Coast); dubini, dupuin (Ghana); biribu (Dahomey); ogwango (Nigeria).

The tree of *K. ivorensis* is the largest of the genus, attaining a height of 100–150 feet and a diameter of 3–6 feet above the buttresses (Jay, 1947). The bole is straight, cylindrical and clear of branches for a length up to 90 feet.

The species occurs in the coastal rain forests of the Ivory Coast, Ghana, Nigeria, Cameroons and Gabon (Brush, 1940).

When freshly cut, the wood is a uniform pale red (Kribs, 1950). Upon exposure to the air, the heartwood darkens to a deep red brown with a high golden luster. The grain is straight to interlocked, the latter being most common. The texture is medium to coarse and a distinct odor and taste are lacking. Growth rings are usually indistinct. Pores are visible to the naked eye on the end surface, evenly distributed, and solitary or in radial groups of 2–8. Parenchyma is indistinct to the unaided eye and occurs about the pores and in irregular tangential bands. The rays are distinct without magnification on the end surface and conspicuous on the radial surface being darker than the background.

The wood is moderately heavy with an average weight per cubic foot at 10 per cent moisture content of 35 pounds (32–45 pounds; Scott, 1949). The specific gravity (oven-dry weight, air-dry volume) averages 0.51 (0.46–0.65). African mahogany averages slightly less in specific gravity than Central American mahogany *(Swietenia macrophylla)*.

Air-seasoning and kiln-seasoning may readily be accomplished with little tendency toward degrade (Jay, 1947). Warping may be encountered in material having accentuated interlocked grain but this defect seldom becomes serious. The British Forest Products Research Laboratory (1945) suggests a kiln schedule similar to that recommended for sugar maple and American black walnut.

The results of mechanical tests on green and air-dry material are reported in table 1. African mahogany is somewhat inferior to Central American mahogany of slightly greater specific gravity in most strength categories but the differences in strength are generally small.

The unseasoned wood of African mahogany (average specific gravity, green volume, 0.43) averages somewhat less in strength than that of Central American mahogany of slightly greater specific gravity (0.45 based on green volume). In static bending strength, it is inferior to Central

American mahogany by 10 per cent in fiber stress at the proportional limit, 20 per cent in modulus of rupture and 15 per cent in stiffness. Both species are essentially equal in impact strength. African mahogany is slightly inferior in maximum crushing strength and comparison perpendicular to the grain and 70 per cent as hard. However, it is superior in shearing strength and considerably more resistant to splitting.

Strength increases upon seasoning to 12 per cent moisture content are moderate to appreciable in all categories except work expended in static bending, impact strength and cleavage. Maximum crushing strength and end hardness undergo the greatest increases upon drying (55 per cent and 90 per cent respectively). Fiber stress at the proportional limit and modulus of rupture in static bending increase by 45–50 per cent of the green value. However, work expended in static bending as measured by work to maximum load and impact strength decrease by 10 per cent and 15 per cent respectively. Cleavage values remain essentially unchanged.

In the air-dry condition, African mahogany, by virtue of greater strength increases upon seasoning, compares more favorably to Central American mahogany than in the green condition. The average strength values for African mahogany are less than 10 per cent below those of Central American mahogany in all categories reported except maximum crushing strength, shear and cleavage. In maximum crushing strength, African mahogany is inferior by 20 per cent, but in shearing strength and cleavage, it is superior to Central American mahogany. On the basis of specific strength (strength per unit weight) the seasoned wood of African mahogany compares favorably to that of Central American mahogany.

Green to oven-dry shrinkage values for the species are reported in table 2. The values reported by the U. S. Forest Products Laboratory (Heck, 1937)—volumetric 8.8, tangential 5.8 and radial 5.0 per cent—and the British Forest Products Research Laboratory (1945)—volumetric 8.5, tangential 4.0 radial 3.6 per cent—are in reasonable agreement with one another. However, those reported by Harrar (1942)—volumetric 16.9, tangential 8.4 and radial 4.1 per cent—are excessively high compared to American and British data and are inconsistent with the low-shrinkage properties commonly attributed to African mahogany. The dimensional change between 90 per cent and 60 per cent relative humidity (equilibrium moisture contents of 20 per cent and 13.5 per cent respectively) is 1.4 per cent tangentially and 0.8 per cent radially of the dimension at 60 per cent relative humidity (Forest Products Research Laboratory, 1954). Comparable values of 1.3 per cent and 1.0 per cent for Central American mahogany indicate the similarity between the two species in dimensional properties and serve to subject to further doubt the high shrinkage values reported for African mahogany by Harrar.

The wood is moderately durable when exposed to the action of wood-destroying fungi (Collardet, 1930). However, it is susceptible to infestation by powder-post beetles, longhorn beetles, pinhole borers and termites (Forest Products Research Laboratory, 1945). It is extremely difficult to impregnate with creosote even under high pressure.

The wood is somewhat variable in its working properties and the quality of surface produced depends upon the degree of interlocked grain (Forest Products Research Laboratory, 1945). Milder (softer) grades of straight-grained material work about 10 per cent harder than Central American mahogany and harder grades may be up to 50 per cent more difficult to work. The presence of interlocked grain results in grain pick-up on quartered surfaces unless the cutting angle is reduced to 15°. Nailing, screwing and gluing properties are very good and an excellent finish is readily obtainable.

The principal uses for African mahogany are in furniture, interior paneling and high-class woodwork (Brush, 1940). A large proportion of the timber is used for face veneer in plywood and lumber-core construction predominantly for the furniture industry. It is also widely employed for fixtures in stores, restaurants, banks and public buildings, particularly for counter tops, cabinets, tables and doors. Further uses are in passenger-ship cabins as a paneling wood and in small pleasure craft for ribs, planking and fixtures. It is generally suitable for many of the exacting purposes for which American mahoganies *(Swietenia* spp.) are used.

Lophira alata Banks var. *procera* Burtt Davy
Ekki Ochnaceae

Lophira alata and its variety *procera* are very similar botanically but differ greatly in growth habit (Chalk et al., 1933). *L. alata* is a savanna tree of short stature with a twisted bole having little if any present commercial importance. *L. alata* var. *procera* is a large rain forest tree of present commercial importance.

L. alata var. *procera* is commonly called ekki in the timber trade of the British African territories and azobe in the timber trade of French African territories. Other common names include ironpost, red ironwood, red oak, and African oak (Chalk et al., 1933; Jay, 1947; Kribs, 1950). Local names include endwi, rings (Sierra Leone); esore, nokue (Ivory Coast); kaku (Ghana); aba, kuru, okot, eki or ekki (Nigeria); boko, bongossi (Cameroons).

The trees attain large size up to 160 feet in height (Chalk et al., 1933) and 6 feet in diameter (Gerry, 1951). The bole is free from buttresses, but may be slightly swollen at the base, with an occasional graceful bend, and clear of branches for more than one half the height of the tree. The species occurs in western tropical Africa from Sierra Leone eastward trough Liberia, the Ivory Coast, Ghana, Nigeria, and the Cameroons. It is found in the fresh-water swamp forest, in the moist parts of the evergreen forests, and close to river banks. Apparently it is not found on sandy soil unless it is a swampy site.

The heartwood is a dark reddish brown or chocolate brown color (Chalk et al., 1933). The sapwood is much lighter in color and approximately 2 inches wide. The wood is tasteless and odorless when dry. Grain is interlocked, texture is coarse, and luster is low (Cooper and Record, 1931). Growth rings are not distinct (Kribs, 1950). Pores are open and visible to the naked eye, not numerous,

and evenly distributed or in echelon. The pore openings contain conspicuous yellow deposits. Parenchyma is visible to the naked eye and scattered between the pores in closely spaced tangential bands 3–7 cells wide. The rays are invisible without a lens on the end surface and indistinct on the radial surface. The cell cavities of ray cells contain a reddish "gum."

The wood is extremely heavy and hard. At 12 per cent moisture content the weight per cubic foot ranges from 56–71 pounds (Chalk et al., 1933), the average being approximately 63 pounds (Cooper and Record, 1931). The specific gravity (oven-dry weight, air-dry volume) varies between 0.80 and 1.02 with an average of 0.90. Cooper and Record (1931) report the average specific gravity (oven-dry weight and volume) as 0.98.

Tests on a limited amount of material at British and U. S. laboratories (Gerry, 1951; Jay, 1947), indicate that ekki is extremely refractory and cannot be satisfactorily kiln-dried directly from the green condition. Surface checking and end-splitting are severe and distortion is likely to occur. A combination of air-seasoning and kiln-seasoning may produce better results.

The results of mechanical tests on air-dry material conducted at the Imperial Institute (1926) are reported in table 1. Ekki is superior in strength to domestic hardwoods of equal specific gravity.

The seasoned wood of ekki is superior to mockernut hickory in the static bending properties of fiber stress at elastic limit (13,850 psi), modulus of rupture and modulus of elasticity; however, ekki is approximately 15–25 per cent more dense than mockernut hickory. It is superior to mockernut hickory in maximum crushing strength parallel to the grain and approximately equal to slightly superior in shearing strength parallel to the grain. In compression perpendicular to the grain and cleavage, ekki is comparable to persimmon. It is superior to persimmon in tension perpendicular to the grain (1555 psi) and equal to lignum vitae *(Guaiacum officinale)* in hardness. Gerry (1951) reports that ekki is comparable in shock resistance to greenheart *(Ocotea* *rodiei)*. Ekki is considered one of the strongest woods of Africa.

The green to oven-dry shrinkage values for ekki are comparable to dogwood which is only 80 per cent as dense as ekki. The dimensional change of ekki between 90 per cent relative humidity (equilibrium moisture content of 13.5 per cent) is 2.5 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 of dimensional change are similar to those for white oak; ekki is classed as a species with medium dimensional change.

Jay (1947) reports the species as very resistant to decay and is considered the most durable wood in western Africa. It is also very resistant to insects (termites, borers and ants) and marine borers (Gerry, 1951). Ekki is moderately resistant to impregnation with preservatives; crossties absorb 4–7 pounds of creosote mixture per cubic foot, all but a narrow strip in the center being penetrated (Marshall, 1941).

The working properties of ekki have been studied at the Imperial Forestry Institute, London (1926). The wood is moderately difficult to cut with hand and machine tools. In planing, good surfaces are produced on the tangential faces but grain pick-up on the radial faces makes smooth surfaces difficult to obtain. Resistance to boring is high, but clean tool cuts are readily obtainable in machine operations. The wood is very resistant to the driving of nails and large bored holes are required for the driving of screws. Strong glue joints are readily produced. The staining and finishing qualities of ekki are satisfactory but a grain filler is required.

Its suitability for various uses is limited by its weight and the difficulty encountered in conversion. The wood should prove suitable in heavy construction, heavy flooring and marine construction. Tests of ekki, greenheart and blue gum *(Eucalyptus* sp.) in Freetown, Liberia for suitability in marine piling, indicate that ekki is superior to blue gum and almost as resistant as greenheart to marine borer damage (Jay, 1947).

Lovoa spp. African walnut Meliaceae

There are seven known species of the genus *Lovoa* in tropical Africa of which *L. klaineana* Pierre & Sprague and *L. brownii* Sprague are most important commercially (Eggeling and Harris, 1939; Record, 1929). *L. klaineana* is one of the more important species in the export trade from western Africa and is exported to Europe and the United States under the trade names of African walnut, tigerwood, Congowood (U. S.); African walnut, Benin walnut (Great Britain); noyer d'Afrique, noyer du Gabon, acajou noir (France); Nussholz (Germany; Record, 1929). Local names (Dalziel, 1937) for the species include apetou, dibetou (Ivory Coast); kwatanuro, pepedom (Ghana); apopo, pereko, sida (southern Nigeria). *L. brownii* is restricted in range to Uganda and Tanganyika Territory in eastern Africa where it is known locally as Uganda walnut and nkoba (Eggeling and Harris, 1939). It is not important in the export trade from eastern Africa but is of considerable local commercial importance.

Neither African nor Uganda walnut is related to the true walnuts of the family Juglandaceae. The term walnut is applied to these species because of the similarity in the coloration of the *Lovoa* wood to that of the true walnuts, *Juglans* spp.

The mature trees of both species attain heights of over 100 feet; the African walnut attaining greater heights (120–130 feet) than the Uganda walnut (80–110 feet; Chalk et al., 1933; Eggeling and Harris, 1939). In both species, the bole is straight and cylindrical, 60–65 feet in length and 3–4 feet in diameter with short, blunt or rounded buttresses. African walnut is restricted in range to western Africa where it is found in Sierra Leone, the Ivory Coast, Ghana, Nigeria and Gabon. It occurs most frequently in the wetter zones of the rain forest and occasionally on moist sites near stream banks in the deciduous forest. Uganda walnut occurs on deep moist soils in the proximity of streams and lakes in Uganda and Bukoba Province of Tanganyika Territory.

The sapwood of African walnut is buff colored and narrow, commonly 1–2 inches wide (Chalk et al., 1933).

The color of the heartwood is variable, grading from grayish brown to dark chocolate brown with a distinct golden luster (Kribs, 1950). The wood of Uganda walnut is pale brown when freshly cut darkening to a yellow brown or mahogany brown upon exposure (Eggeling and Harris, 1939). The sapwood remains pale brown and is clearly distinguishable from the heartwood. The grain of both species is interlocked producing a ribbon figure on quartered surfaces. The texture is medium and the luster is high. Odor and taste are not distinct. Growth rings are indistinct on the end surface of African walnut and distinct on that of Uganda walnut. The pores are distinct to the naked eye, numerous, evenly distributed and solitary or in radial groups of 2–5. Parenchyma is indistinct to the naked eye, arranged in narrow bands about the pores and in concentric lines within the growth ring and at the terminus of the growth ring. Rays are fine and barely visible on the end surface of both species and conspicuous on the radial surface in African walnut.

The wood is moderately heavy, the average weight per cubic foot of African walnut is 37 pounds and that of Uganda walnut is 35 pounds (Eggeling and Harris, 1939; Forest Products Research Laboratory, 1945). Specific gravity (oven-dry weight, air-dry volume) averages 0.53 and 0.49 for African walnut and Uganda walnut respectively.

The wood air-seasons readily and fairly rapidly with a tendency toward degrade in the form of splitting and distortion. Fast early drying tends to promote the development of splits and the extension of existing splits. The wood kiln-dries readily with some tendency toward splitting and distortion. The British Forest Products Research Laboratory (1945) suggests a kiln schedule similar to that recommended for sugar maple and American black walnut.

The results of mechanical tests on green and air-dry material of African walnut are reported in table 1. African walnut compares favorably in strength properties with domestic hardwoods of equal specific gravity such as American elm. On a specific strength basis, it also compares

favorably with American black walnut which has a 15 per cent greater specific gravity.

The unseasoned wood of African walnut is comparable with American elm in most strength categories. It exceeds American elm in the static bending properties of modulus of rupture and is equal to elm in stiffness. It is only 80 per cent as resistant to impact loads but notably superior in maximum crushing strength and end hardness.

Upon drying from the green condition to 12 per cent moisture content, African walnut undergoes moderate increases in most strength properties. The modulus of rupture increases by 45 per cent of the value for the unseasoned wood but stiffness increases by only 25 per cent. Maximum crushing strength and hardness exhibit increases in the neighborhood of 50 per cent of the values for the unseasoned wood. The property of cleavage undergoes little change upon drying but impact strength exhibits rather serious decreases. The resistance to impact loads is reduced by 20 per cent and toughness decreases 45 per cent upon drying from the green condition to 12 per cent moisture content.

The seasoned wood of African walnut is comparable to that of American elm in most strength categories. The only wide differences between the strength of the two species are in the properties of impact strength, maximum crushing strength and shearing strength. African walnut is considerably inferior in impact strength (30 per cent), moderately superior in maximum crushing strength (20–25 per cent) and somewhat inferior in shearing strength (15 per cent).

Tests conducted at the British Forest Products Research Laboratory (1945) indicate that African walnut is only a moderately good steam-bending species. Steamed wood was bent to a radius of curvature of 24 inches per inch of thickness when supported by a steel tension strap.

The green to oven-dry shrinkage values for African walnut are reported in table 2. These values–volumetric 13.6, tangential 8.8 and radial 5.3 per cent–are intermediate between those for American elm and American black walnut.

The wood is classed as resistant to decay by fungi (Forest Products Research Laboratory, 1945). Logs are susceptible to pinhole borer and longhorn beetle attack and the sapwood is liable to infestation by powder-post beetles. Reports from Nigeria assert that the wood is resistant to impregnation with creosote by the open-tank process.

Investigations of the working qualities of African walnut have been conducted at the British Forest Products Research Laboratory (1945). African walnut works easily with hand and machine tools. It is easier to cut than the denser American black walnut. Material with interlocked grain has a tendency to pick-up on quartered surfaces in planing which can be partly arrested by employing a cutting angle of 15°. The wood finishes smoothly in other operations providing sharp cutting edges are maintained. It takes nails and screws readily and holds them firmly. The wood glues easily and good joints are readily obtainable. Staining and finishing qualities are satisfactory.

African walnut is used for furniture, millwork and woodwork in Africa and Europe (Forest Products Research Laboratory, 1945; Organisation for European Economic Co-operation, 1953). Uganda walnut is used for the same purposes in eastern Africa (Eggeling and Harris, 1939). Jay (1947) reports that selected material of African walnut has been stained and used as a substitute for mahogany in simulated antique furniture. It has also been used to a limited extent for gunstocks and flooring and may prove suitable as a substitute for American black walnut for these purposes.

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