

DATA FOR A COMPUTER-ASSISTED WOOD IDENTIFICATION SYSTEM
I. COMMERCIAL LEGUMES OF TROPICAL ASIA AND AUSTRALIA

by

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Summary

A wood anatomical key based on macroscopic and microscopic features has been developed for identification of the commercial Leguminosae of southeast Asia and Australia. All anatomical details are in accord with the standard list of characters suitable for computerised hardwood identification. Data on 39 species of 13 genera are included, which have been entered into the computer data base housed at the Forest Products Laboratory. On the basis of anatomical features, all genera are separable but some species are not.

Keywords: Leguminosae, wood anatomy, wood identification.

Introduction

The Leguminosae constitute a large and complex group of plants growing throughout the world. It is usually possible to identify legume woods to the genus but not to the species. This study was implemented with two objectives: first, to compile reliable data for input into a computer identification system (Miller, 1980), and second, to provide an anatomical key that can be used independently to identify the commercial species of tropical Asian and Australian Leguminosae. This is the first of three reports covering the commercial woods of Leguminosae. The 13 genera investigated are *Acacia*, *Acrocarpus*, *Albizia*, *Cynometra*, *Dalbergia*, *Dialium*, *Intsia*, *Koompassia*, *Pseudosindora*, *Pterocarpus*, *Sindora*, *Wallaceodendron*, and *Xylia*.

Materials and Methods

Wood samples were examined from the Madison (MADw) and S.J. Record (SJRw) collections housed at the Forest Products Laboratory. One hundred and nine specimens representing

40 species in 13 genera were examined. Wherever possible, 1-centimeter-square blocks were cut from wood samples to yield microscopic slide sections for the maximum survey area. After final sectioning of a block, a thick wafer was split from the radial face, macerated using Franklin's method (1946), stained with safranin, and mounted in glycerine.

Data collection followed the format described in the standard list of characters (Miller & Baas, 1981). Deviations from that standard are explained in the next section. For each sample, 50 each of fibre and vessel element lengths were measured from macerated material (Chalk & Chattaway, 1934). Maximum vessel (pore) diameters and height of tallest rays or multiseriate portion of tallest rays were made from prepared slides. These measurements were taken with the semi-automated sonic digitiser (Quirk, 1981). More measurements were taken than prescribed in the standard character list so as to obtain values for the coefficient of variation.

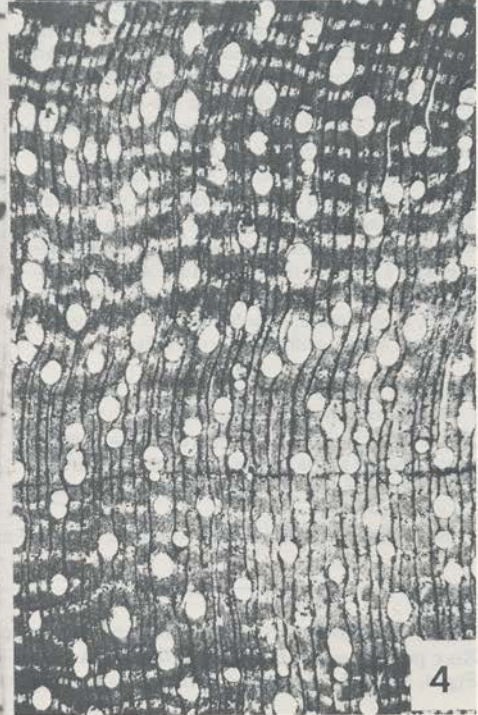
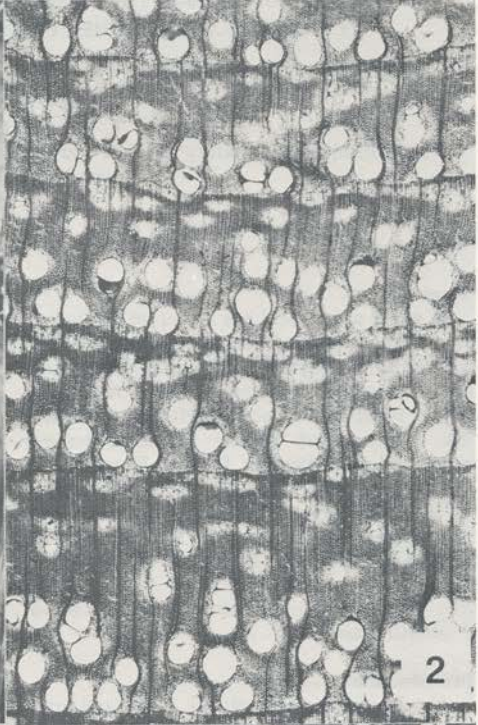
The proportion of multiseriate to uniseriate rays was examined on the tangential section. Ten random fields of 1-millimeter-square (mm²) size were sampled. For those rays in which one-half or more of the ray length was within the count boundary, alternating halves were counted as in or out. When the rays consist of procumbent cells only, even if the marginal cells were enlarged, they were called homocellular. Heterocellular rays are rays that have square or upright marginal cells (Baretta-Kuipers, 1981).

Number of pores per mm² were counted in 1-mm² grids over the entire area of the transverse section.

For the froth and fluorescent tests (Miller & Baas, 1981), more samples were often tested

* Maintained at Madison, Wisconsin, in cooperation with the University of Wisconsin.

Fig. 1. Crystals in procumbent cells and marginal cells in *Acrocarpus fraxinifolius*; x 130.—Fig. 2. Ring porous wood in *Albizia julibrissin*; x 14. - Fig. 3. Septate fibres in *Albizia lebbek*; x 132.—Fig. 4. Parenchyma banded within growth zones in *Cynometra ramiflora*; x 14.



than were listed; e.g. for *Sindora* spp., where 5 specimens were examined for anatomical features, 32 specimens were examined for froth and fluorescence.

When possible, the description was cross-referenced in the literature (Burgess, 1966; Desch, 1941; Kribs, 1950; Metcalfe & Chalk, 1950; Pearson & Brown, 1932). Abbreviations for wood collections follow the Index Xylarium compiled by Stem (1978).

Results

The woods of the 13 legume genera vary widely in colour, weight, and density as well as in other physical properties. Some features, however, are common to most genera. Pores were not very numerous, and were solitary with radial multiples of 2 to 4 pores. Tyloses and spiral thickening were absent in the vessels. Perforation plates were exclusively simple and the intervascular pitting was alternate. Vessel-ray pitting was the same as intervascular pitting, and all species had vested pits except *Koompassia*.

Fibres did not have conspicuous bordered pits, and spirals in the fibres were absent.

Rays were low, narrow and numerous. Tile cells and silica bodies were absent.

Axial parenchyma patterns as viewed on the transverse section are variable, but banding when present was mostly 1 or 2 cells wide. Parenchyma strands were mostly 2 to 4 cells per strand. Prismatic crystals were common in the axial parenchyma.

None of the species examined reacted to Chrome-Azural-S. Tracheids, oil, or mucilage cells were absent. Splinters burned to a white ash except for *Dialium* which burned to charcoal.

The mean values in the genus descriptions are computed on the basis of each species having equal weight rather than every specimen having equal weight. Entries in the descriptions for fibre and vessel element length, vessel diameter, and ray height are given as in the following example for vessel element length: $\bar{x} = 279 \mu\text{m} \pm 54$ (95 to 740) where \bar{x} is the mean, ± 54 is the standard deviation, and (95 to 740) is the range. The means and standard deviations are included here for additional information. For other quantitative characters, such as intervascular pit size, only the mean and individual minimum and maximum measurements are reported.

On the basis of anatomical features all genera were separable, but some species were not. The features described above and the following generic descriptions permit one to encode all necessary data on the data sheets (Miller & Baas, 1981) for entry into the Computer-Assisted Wood Identification System. Any feature on the data sheet not mentioned in the text can be entered as negative.

Acacia Mill.

Twenty-two specimens of seven species were examined. Sapwood greyish, heartwood mostly some shade of brown. Basic specific gravity* (sp. gr.) 0.69 (0.52 to 0.91). Diffuse porous, growth rings absent, but zones distinct as marked by irregular zonate bands of parenchyma.

Vessels - Solitary to radial multiples of 2 to 4. Frequency 9/mm² (2 to 26). Diameters $\bar{x} = 171 \mu\text{m} \pm 16$ (95 to 350). Member length $\bar{x} = 279 \mu\text{m} \pm 54$ (95 to 740). Interspiral pitting $\bar{x} = 8 \mu\text{m}$ (5 to 11), vested.

Fibres - Walls moderately thick. Length $\bar{x} = 1,076 \mu\text{m} \pm 124$ (600 to 1,800). Some septate fibres found in *A. koa*.

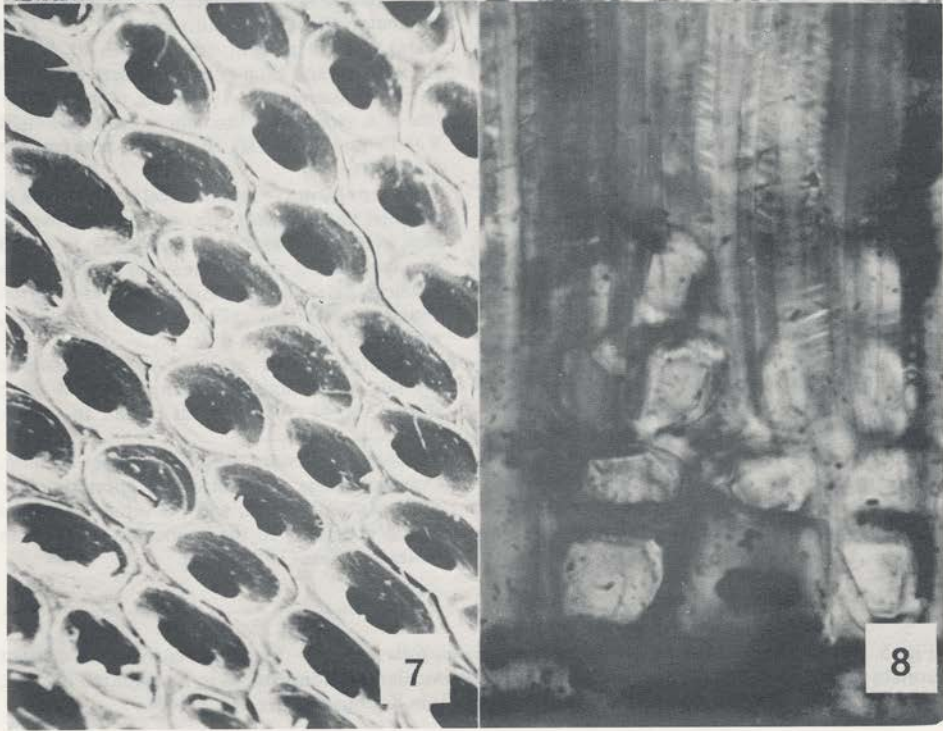
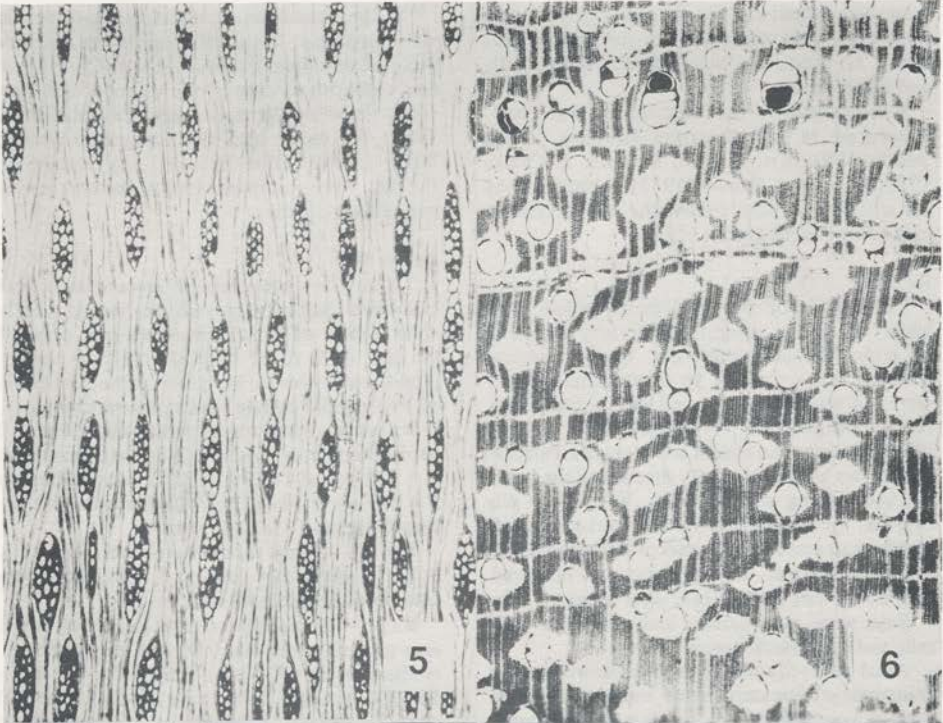
Rays - Homocellular rays. Height of tallest rays generally less than 600 μm except for *A. mollissima* ($\bar{x} = 734 \mu\text{m}$). Height $\bar{x} = 441 \mu\text{m} \pm 56$ (200 to 885). Tallest rays $\bar{x} = 28$ (13 to 60) cells. Essentially uniseriate in *A. acuminata* & *A. koaia*: 50 percent multiseriate (2 to 3 cells wide) and 50 percent uniseriate in *A. koa* & *A. confusa*; and 80 percent multiseriate and 20 percent uniseriate in *A. catechu*, *A. melanoxylon* & *A. mollissima*. Procumbent ray cell height $\bar{x} = 15 \mu\text{m}$ (11 to 20). Number of rays per mm $\bar{x} = 7$ (4 to 14).

Parenchyma - Apotracheal parenchyma in irregular zonate bands one or two cells wide except in *A. acuminata* & *A. mollissima*, in which the apotracheal parenchyma was scanty. Paratracheal parenchyma vasicentric. Parenchyma strands mostly four cells except in *A. catechu*, which had up to eight cells.

Crystals - All specimens had prismatic crystals in the axial parenchyma. Most were short (2 to 4) crystalliferous chains. In *A. acu-*

* Based on oven-dry weight and green volume. Determinations were made at approximately 6% moisture content, and the values were converted according to the applicable equation in Miller and Baas (1981: 143).

Fig. 5. Rays storied and multiseriate in *Dalbergia latifolia*; x 82. - Fig. 6. Parenchyma in distinct zonate bands in *Intisia bakeri*; x 14. - Fig. 7. Interspiral pits nonvested in *Koompassia excelsa*; x 2000. - Fig. 8. Crystals in chambered upright cells in *Koompassia excelsa*; x 645.



minata & *A. mollissima*, long chains (8 or more) occurred. Prismatic crystals were found in the procumbent ray cells in *A. acuminata*. *A. catechu* & *A. mollissima*. In addition, prismatic crystals in radial alignment in ray cells were found in *A. catechu* & *A. mollissima*.

Other features - Fresh-cut surfaces fluoresced a yellow colour except two specimens of *A. catechu*. Water extract colourless to yellow-brown, not fluorescent except in *A. catechu* which fluoresced a light blue. Ethanol extract colourless to yellow-brown and with a blue-green fluorescence in all species. Froth test variable.

Specimens examined - *Acacia acuminata* Benth.: Australia (SJRw 9913); Australia, CSIRO 3565 (MADw 14522); Australia, CSIRO 3328 (SJRw 48095). - *A. catechu* Willd.: India, Hosley P 1196 (MADw 1501); India (MADw 6934); Phil., FPRI 419 (MADw 21647); India, FI 550, Kew C-203 (MADw 21650). - *A. confusa* Merr.: China, TAIw 31 (MADw 3254); Phil., CLPW 28232 BF (SJRw 5833); Formosa, TAIw 37 (SJRw 9405); Taiwan, TAIw 002 (MADw 24847). - *A. koa* A. Gray: Hawaii (SJRw 566); Hawaii, J.F. Rock 40? (SJRw 1860); Hawaii, Nogle 252 (MADw 32345). - *A. koaia* Hillebr.: Hawaii (MADw 3388); Hawaii, J.F. Rock 30 (MADw 32330); Hawaii (MADw 32331). - *A. melanoxylon* R. Br.: Australia, Arnold Arb. 128-12 (D 2024) (SJRw 19341); Tasmania, Arnold Arb. 128-12 (SJRw 19383); Australia (MADw 24996); Australia, CSIRO 6070 (SJRw 48096); Tasmania (MADw 32344). - *A. mollissima* Willd.: Australia, E.H. Long 680 (SJRw 50563).

Acrocarpus fraxinifolius Wight ex Arn.

Three specimens were examined. Sapwood greyish, heartwood mostly a yellowish brown. Basic sp. gr. 0.47 (0.45 to 0.50). Diffuse porous; growth rings absent but zones distinct as marked by irregular zonate bands of parenchyma.

Vessels - Solitary to radial multiples of 2 to 4. Frequency 2/mm² (1 to 3). Diameters = 263 $\mu\text{m} \pm 26$ (190 to 330). Member length $\bar{x} = 443 \mu\text{m} \pm 115$ (220 to 735). Intervascular pitting K = 10 μm (8 to 11), vested.

Fibres - Walls moderately thick. Length $\bar{x} = 1,530 \mu\text{m} \pm 173$ (1,000 to 2,000). Some fibres septate.

Rays - Heterocellular with one row of upright cells. Height $\bar{x} = 430 \mu\text{m} \pm 51$ (250 to 640). Tallest rays $\bar{x} = 23$ (15 to 35) cells. Ray width mostly three to four cells, rarely five. Procumbent ray cell height $\bar{x} = 17 \mu\text{m}$ (15 to 19). Number of rays per mm $\bar{x} = 4$ (2 to 6). Occasional sheath cells present.

Parenchyma - Apotracheal parenchyma in irregular zonate bands one or two cells wide. Paratracheal parenchyma vascentric, aliform, to confluent. Parenchyma strands mostly four, some eight, cells per strands.

Crystals - Prismatic crystals in the axial parenchyma; mostly in short chains, but often as singles. Occasionally more than one crystal of the same size per cell or chamber. Prismatic crystals also in the procumbent and upright ray cells; occasionally in two-chambered upright cells (Fig. 1).

Other features - Fresh-cut surfaces fluoresced yellow. Water extract colourless to light yellow-brown, nonfluorescent. Ethanol extract colourless and fluoresced a pale green-blue. Froth test variable.

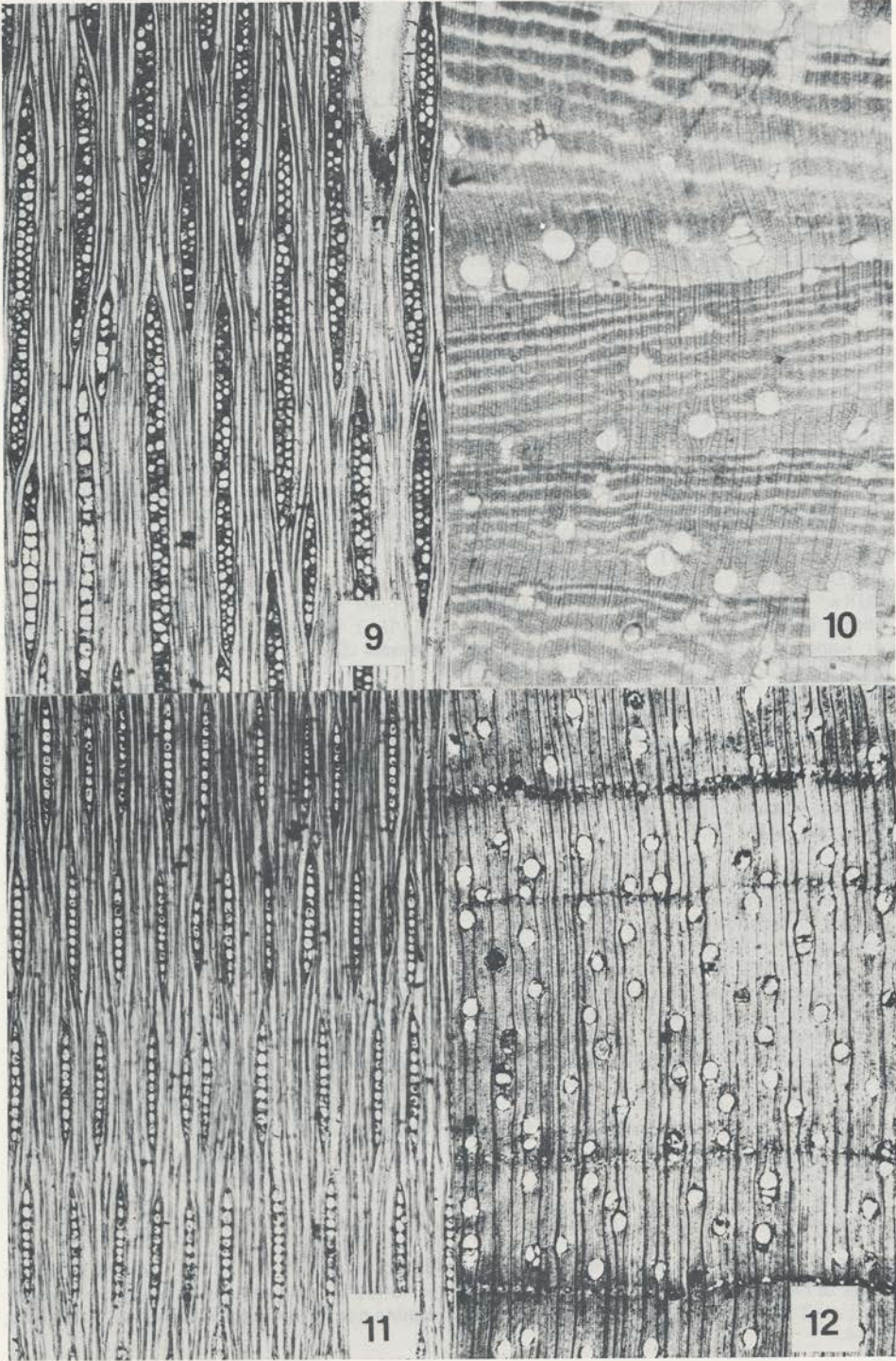
Specimens examined - *Acrocarpus fraxinifolius* Wight: India, Manson E 667 (MADw 11489); Burma, PRFw 4485 (MADw 16796); Burma (SJRw 21394).

Albizia Durazz.

Twenty-seven specimens of seven species were examined. Sapwood white to light brown with a slight tinge of pink in *A. falcataria* and not sharply delineated from the yellow-brown to brown heartwood. *A. julibrissin*, *A. procera* & *A. toona* frequently contained streaks. Basic sp. gr. 0.47 (0.24 to 0.80). Diffuse porous, except *A. julibrissin* which is ring porous (Fig. 2). Growth zones distinct in *A. lebbek*, *A. odoratissima*. *A. procera* & *A. toona* as marked by irregular zonate bands of parenchyma, one or two cells wide.

Vessels - Solitary to radial groups of 2 to 4; in clusters in *A. julibrissin* and in echelon arrangement in *A. zanthoxylon*. Frequency 2/mm² (1 to 7), *A. julibrissin* not included. Diameters $\bar{x} = 257 \mu\text{m} \pm 28$ (140 to 410). Member length $\bar{x} = 346 \mu\text{m} \pm 76$ (160 to 710). Intervascular pitting $\bar{x} = 9 \mu\text{m}$ (7 to 11), vested. White deposits common in vessels of *A. zanthoxylon*.

Fig. 9. Heterocellular rays more than 1 mm tall in *Pseudosindora palustris*; x 82. - Fig. 10. Growth rings in *Pterocarpus indicus*; x 14. — Fig. 11. Rays stoned and uniseriate in *Pterocarpus macrocarpus*; x 82. - Fig. 12. Vertical canals embedded in zonate parenchyma bands in *Sindora intermedia*; x 14.



Fibres - Walls moderately thick. Length \bar{x} = 1,237 μm \pm 129 (620 to 1,860). Fibres septate in *A. lebbek* (Fig. 3) & *A. odoratissima*.

Rays - Homocellular rays. Height \bar{x} = 382 μm \pm 48 (125 to 850). Tallest rays \bar{x} = 28 (12 to 54) cells. Essentially uniseriate, some biseriate in *A. falcataria*. Fifty percent multiseriate (2 to 3 cells wide) and 50 percent uniseriate in *A. zanthoxylon*. Two to three cells wide with 20 percent uniseriate in the others. Procumbent ray cell height \bar{x} = 16 μm (12 to 23). Number of rays per mm \bar{x} = 5 (4 to 12).

Parenchyma - Apotracheal parenchyma in irregular zonate bands one or two cells wide in *A. lebbek*, *A. odoratissima*, *A. procera* & *A. toona*. Diffuse in *A. falcataria*, *A. julibrissin* & *A. zanthoxylon*. Paratracheal parenchyma vasicentric to aliform except in *A. falcataria* & *A. julibrissin* which were vasicentric to scanty paratracheal. Some aliform in last-formed latewood vessels in *A. julibrissin*. Parenchyma two to, four cells per parenchyma strand.

Crystals - No crystals in the ray cells. Long strands of prismatic crystals in axial parenchyma.

Other features - Fresh-cut surfaces of all specimens fluoresced yellow. Water extract colourless to yellowish brown, without fluorescence. Ethanol extract colourless to yellow-brown in *A. falcataria*, *A. julibrissin* & *A. procera* and colourless to reddish brown in *A. lebbek*, *A. odoratissima*, *A. toona* & *A. zanthoxylon*. In all species the ethanol extract fluoresced a green-blue. Froth test positive.

Specimens examined - *Albizia falcataria* (L.) Fosberg: Phil., CLPwN-5 (MADw 1): Hawaii (MADw 3360); Hawaii, SJRW 55227 (MADw 2141); Hawaii, SJRW 55228 (MADw 2142); Hawaii, SJRW 55229 (MADw 2143). - *A. julibrissin* Durazz.: Japan, Fujioka 2630 (MADw 7409); Japan, Fujioka 52 (MADw 8310); U.S.A. cultivated (SJRW 43325); U.S.A. cultivated USw 5828 (SJRW 53519). - *A. lebbek* (L.) Benth.: India, Cherry w748 (MADw 1503); India (MADw 6928); Andaman Islands (MADw 32189); India (MADw 32190). - *A. odoratissima* Benth.: Burma, Brandis B 1427 (MADw 1504); India (MADw 6919); Ceylon, C.P. Jayawardana 34 (MADw 17922); India, FI 541, Kew D-1084 (MADw 26164). - *A. procera* (Roxb.) Benth.: Cultivated in Cuba, A.J. Fors 251 (MADw 13892); Philippines, CLPw 348 (MADw 22580); Philippines, CLPw 565 (MADw 22620); India, FI 521, Kew B-329 (MADw 26165); Burma, W.A. Robertson 365, SJRW 13104 (MADw 32199). - *A. toona* Bail.: Australia, CTQw 2597 (MADw, 6778); Australia (MADw 8124). - *A. zanthoxylon* C.T. White &

Francis. Australia (SJRW 19417); Australia, W. Cain 127, SJRW 46368 (MADw 2344).

Cynometra L.

Three specimens of two species were examined. Sapwood lighter than heartwood, but not clearly differentiated. Heartwood streaked and mostly brown with pink or red overtones. Basic sp. gr. 0.76 (0.73 to 0.79). Diffuse porous. Growth rings absent.

Vessels - Solitary to radial multiples of 2 to 4. Frequency 4/mm² (1 to 10). Diameters \bar{x} = 190 μm \pm 15 (110 to 260). Member length \bar{x} = 402 μm \pm 72 (280 to 650). Intervascular pitting \bar{x} = 5 μm (4 to 6), vested.

Fibres - Walls moderate to very thick. Length \bar{x} = 1,928 μm \pm 203 (1,260 to 2,740). Nonseptate.

Rays - Heterocellular with one row of up right cells. Height \bar{x} = 1,076 μm \pm 142 (500 to 1,450). Tallest rays \bar{x} = 43 (25 to 85) cells. Width two to three cells. Procumbent ray cell height \bar{x} = 24 μm (20 to 27). Number of rays per mm \bar{x} = 10 (8 to 14).

Parenchyma - Apotracheal banded parenchyma mostly three or more cells wide often visible to the naked eye (Fig. 4); also reticulate. Paratracheal parenchyma vasicentric-aliform to confluent. Parenchyma mostly four, some eight, cells per strand.

Crystals - Prismatic crystals in both the procumbent and upright ray cells. Some upright cells with two-chambered crystals. Prismatic crystals in long crystalliferous chains (8 or more) in axial parenchyma.

Other features - Fresh-cut surfaces not fluorescent. Water extract yellowish brown, no fluorescence. Ethanol extract colourless to yellowish brown, faint light blue fluorescence. Froth test variable.

Specimens examined - *Cynometra inaequifolia* A. Gray: Philippines, CLPw 3773 (MADw 6768); Malaya, KEPw 4573, SJRW 38976 (MADw 32043). - *C. ramiflora* L.: Mus. PL. 226 (MADw 7837).

Dalbergia L.

Thirteen specimens of four species were examined. Sapwood greyish to yellowish white. Heartwood mostly some shade of red-brown, streaked with darker lines and very variable in colour within a species. Basic sp. gr. 0.73 (0.53 to 0.91). Diffuse porous. Growth rings absent.

Vessels - Solitary to radial multiples of 2 to 4. Frequency 3/mm² (1 to 8). Diameters \bar{x} = 266 μm \pm 21 (145 to 310). Member length \bar{x} = 224 μm \pm 35 (135 to 460). Intervascular pitting \bar{x} = 11 μm (8 to 12), vested. White

deposits were found in the vessels of *D. sissoo*.

Fibres - Walls thick to very thick. Length $\bar{x} = 1,164 \mu\text{m} \pm 96$ (900 to 1,570). Nonseptate.

Rays - Storied, $\bar{x} = 55$ (40 to 70) tiers per cm; homocellular (Fig. 5). Height $\bar{x} = 190 \mu\text{m} \pm 25$ (100 to 400). Tallest rays $\bar{x} = 10$ (6 to 16) cells. Ray width two to three cells. Procumbent ray cell height $\bar{x} = 19 \mu\text{m}$ (13 to 25). Number of rays per mm $\bar{x} = 11$ (8 to 21).

Parenchyma - Apotracheal banded parenchyma mostly three or more cells wide not visible to the naked eye and reticulate. Paratracheal parenchyma aliform in *D. cochinchinensis* and aliform to confluent in the others. Parenchyma two cells per strand.

Crystals - Prismatic crystals in procumbent ray cells. Both short and long chains in the axial parenchyma of *D. latifolia*, and only in axial parenchyma in *D. cochinchinensis*, *D. oliveri* & *D. sissoo*.

Other features - Diffuse vertical canals were sometimes found in *D. latifolia*. Fresh-cut surfaces not fluorescent (except specimen MADw 6901 of *D. oliveri* from India). Water extract colourless to yellow-brown; not fluorescent. Ethanol extract red-brown in *D. cochinchinensis*, *D. oliveri* & *D. sissoo*. Ethanol extract red or purple in *D. latifolia*. Ethanol extract fluorescent blue. Froth test negative.

Specimens examined - *Dalbergia cochinchinensis* Pierre: Vietnam (MADw 6055); Vietnam (MADw 14491); Thailand (MADw 14544). - *D. latifolia* Roxb.: India, Cherry 2729 (MADw 4863); India (MADw 6902); Java, BKFw (MADw 7247); Indonesia, WIBw (MADw 31950). - *D. oliveri* Gamble: India (MADw 6901); Burma (MADw 31959). - *D. sissoo* Roxb.: India (MADw 4862); India (MADw 6900); India, SJRW 9755 (MADw 11206); India, DDW (MADw 31964).

Dialium platysepalum L.

Two specimens of one species were examined. Sapwood white to yellowish white, heartwood brown. Basic sp. gr. 0.80 (0.79 to 0.82). Diffuse porous. Growth rings absent.

Vessels - Solitary to radial multiples of 2 to 4. Frequency 4/mm² (1 to 7). Diameters $\bar{x} = 240 \mu\text{m} \pm 22$ (190 to 320). Member length $\bar{x} = 389 \mu\text{m} \pm 43$ (260 to 470). Intervascular pitting $\bar{x} = 9 \mu\text{m}$ (8 to 10), vested. White deposits common in the vessels.

Fibres - Walls moderate to very thick. Length $\bar{x} = 1,533 \mu\text{m} \pm 168$ (1,260 to 1,930). Nonseptate.

Rays - Stoned, $\bar{x} = 28$ (25 to 31) tiers per cm; homocellular. Height $\bar{x} = 340 \mu\text{m} \pm 31$ (260 to 515). Tallest rays $\bar{x} = 23$ (20 to 30)

cells. Ray width two to three cells. Procumbent ray cell height $\bar{x} = 17 \mu\text{m}$ (16 to 18). Number of rays per mm $\bar{x} = 9$ (6 to 10).

Parenchyma - Apotracheal banded parenchyma mostly three or more cells wide not visible to the naked eye. Paratracheal parenchyma sparse. Parenchyma three or four cells per strand.

Crystals - Prismatic crystals in short chains in the axial parenchyma. No crystals in the rays.

Other features - Fresh-cut surfaces not fluorescent. Water extract yellow-brown, not fluorescent. Ethanol extract colourless to yellowish, fluoresces bright blue. Splinter burns to black charcoal. Froth test negative.

Specimens examined - *Dialium platysepalum* Bak.: Java (MADw 7250); Malaya, BZFw (MADw 9126).

Intsia Thou.

Ten specimens of five species were examined. Sapwood off-white to pale yellow. Heartwood mostly yellow or shades thereof. Basic sp. gr. 0.64 (0.50 to 0.77). Diffuse porous. Growth rings absent, but zones distinct as marked by irregular zonate bands of parenchyma (Fig. 6).

Vessels - Solitary to radial multiples of 2 to 4. Frequency 4/mm² (1 to 6). Diameters $\bar{x} = 252 \mu\text{m} \pm 23$ (185 to 425). Member length $\bar{x} = 364 \mu\text{m} \pm 63$ (160 to 720). Intervascular pitting $\bar{x} = 7 \mu\text{m}$ (6 to 10), vested. Yellowish deposits in vessels common.

Fibres - Walls thin to moderately thick. Length $\bar{x} = 1,495 \mu\text{m} \pm 150$ (830 to 2,340). Nonseptate.

Rays - Homocellular rays. Height $\bar{x} = 418 \mu\text{m} \pm 62$ (250 to 1,330). Tallest rays $\bar{x} = 22$ (16 to 31) cells. Width two to four cells. Procumbent ray cell height $\bar{x} = 23 \mu\text{m}$ (15 to 35). Number of rays per mm $\bar{x} = 7$ (4 to 10).

Parenchyma - Apotracheal parenchyma in irregular zonate bands one to two cells wide. Paratracheal parenchyma aliform, seldom confluent. Parenchyma two to four cells per strand.

Crystals - Prismatic crystals in long crystalliferous chains in the axial parenchyma. Absent in rays.

Other features - Fresh-cut surfaces fluorescent. Water extract colourless to yellowish brown; fluorescence variable, very light blue-green or none. Ethanol extract yellowish brown; fluorescence variable, bright light green or none. Froth test positive, but marginal in all specimens of *I. bijuga* and in *I. palembanica*. Characteristic astringent odour and taste.

Specimens examined - *Intsia acuminata* Merr.: Philippines, CLPw SH-219 (MADw

18462). - *I. amboinensis* Thou.: Java, BZFW (MADw 7251). - *I. bakeri* Prain: Java, BZFW (MADw 7252); Malaya, KEPw (MADw 9124). - *I. bijuga* (Colebr.) Kuntze: Malaya, SAN A 3710 (MADw 31787); Burma, Conservtr. of For. 2057 (SJRw 12537); New Guinea, CSIRO 4094 (SJRw 36038); Marshall Island, MADw 15722 (SJRw 48074). - *I. palembanica* Miq.: Malaya, KEP 64205 (SJRw 5 1722).

***Koompassia* Maingay.**

Eight specimens of two species were examined. Sapwood off-white to yellowish or with a pinkish tinge. Heartwood mostly brown or with reddish tinge. Diffuse porous. Growth rings absent. Basic sp. gr. 0.72 (0.64 to 0.81).

Vessels - Solitary to radial multiples of 2 to 4. Pores in echelon arrangement in *K. malaccensis*. Frequency 2/mm² (1 to 5). Diameters \bar{x} = 280 $\mu\text{m} \pm 27$ (210 to 390). Member length \bar{x} = 489 $\mu\text{m} \pm 90$ (270 to 750). Intervascular pitting \bar{x} = 10 μm (9 to 12), nonvestured (Fig. 7). Yellowish deposits in vessels.

Fibres - Walls moderately thick to very thick. Length \bar{x} = 1,777 $\mu\text{m} \pm 151$ (1,200 to 2,250). Nonseptate.

Rays - Not obviously stoned to occasionally storied; \bar{x} = 20 (18 to 25) tiers per cm. Homocellular rays except for occasional single row of upright cells in *K. excelsa*. Height \bar{x} = 500 $\mu\text{m} \pm \bar{x}$ (365 to 720). Tallest rays \bar{x} = 27 (20 to 33) cells. Width two to four cells. Procumbent ray cell height \bar{x} = 20 μm (16 to 23). Number of rays per mm \bar{x} = 6 (3 to 10).

Parenchyma - Apotracheal banded parenchyma mostly three or more cells wide, not visible to the naked eye in *K. excelsa*. Apotracheal parenchyma sparse or not observed in *K. malaccensis*. Paratracheal parenchyma confluent in *K. excelsa*. Paratracheal parenchyma aliform to confluent in *K. malaccensis*. Parenchyma five to eight cells per strand.

Crystals - No crystals found in *K. malaccensis*. In *K. excelsa* prismatic crystals occurred in chambered (Fig. 8) or unchambered upright cells and in long crystalliferous chains in the axial parenchyma.

Other features - Fresh-cut surfaces not fluorescent. Water extract colourless to yellowish brown, not fluorescent. Ethanol extract colourless to yellowish brown, not fluorescent. Froth test negative.

Specimens examined - *Koompassia excelsa* (Becc.) Taub.: Malaya, SAN A 3508 (MADw 31690). - *K. malaccensis* Maing.: Java, BZFW (MADw 7248); Malaya, KEPw (MADw 9125); Malaya, PRFW 9597 (MADw 16817).

Pseudosindora palustris Symington.

Four specimens of one species of this genus were examined. Sapwood greyish light brown, sometimes with a tinge of pink. Heartwood dark brown with a pinkish tinge and black streaking. Heartwood oily to the touch. Basic sp. gr. 0.64 (0.60 to 0.70). Diffuse porous. Growth rings absent, but zones distinct as marked by irregular zonate bands of parenchyma.

Vessels - Solitary to radial multiples of 2 to 4. Frequency 2/mm² (1 to 8). Diameters \bar{x} = 227 $\mu\text{m} \pm 19$ (185 to 310). Member length \bar{x} = 502 $\mu\text{m} \pm 118$ (220 to 800). Intervascular pitting \bar{x} = 10 μm (8 to 12), vestured. Whitish deposits common in vessels.

Fibres - Walls moderately thin. Length \bar{x} = 1,380 $\mu\text{m} \pm 127$ (1,070 to 1,830). Nonseptate.

Rays - Heterocellular rays with one row of upright cells (Fig. 9). Height \bar{x} = 1,160 $\mu\text{m} \pm 150$ (825 to 1,940). Tallest rays \bar{x} = 42 (15 to 60) cells. Two cells wide. Procumbent ray cell height \bar{x} = 28 μm (25 to 30). Number of rays per mm \bar{x} = 7 (4 to 9).

Parenchyma - Apotracheal parenchyma in irregular zonate bands one or two cells wide. Traumatic canals observed in one specimen in short tangential line. Paratracheal parenchyma vasicentric. Parenchyma three or four cells per strand.

Crystals - Prismatic crystals in long crystalliferous chains in the axial parenchyma.

Other features - Fresh-cut surfaces fluorescent. Water extract red-brown, fluoresces green-blue. Ethanol extract red-brown, fluoresces green. Characteristic spicy odour. Froth test negative.

Specimens examined - *Pseudosindora palustris* Sym.: Sarawak, PRFW 21 188 (MADw 18366); Sarawak, PRFW 21291 (MADw 18367); Sarawak, PRFW 284a (SJRw 47964); Sarawak, PRFW 284 (SJRw 50025).

Pterocarpus L.

Ten specimens of three species were examined. Sapwood straw colour. Heartwood mostly yellow-brown in *P. indicus*, mostly red-brown and streaked in *P. macrocarpus* & *P. santalinus*. Basic sp. gr. 0.70 (0.42 to 0.90). *P. indicus* at the lower end of the density range with an average basic density of 0.52; *P. macrocarpus* averaged 0.70, and *P. santalinus* averaged 0.86. Ring porous although marginally so in some specimens (Fig. 10), especially *P. santalinus*. Growth zones absent to distinct as marked by marginal bands of parenchyma.

Vessels - Predominantly solitary, some in radial multiples of 2 to 4. Frequency 3/mm² (1

to 8). Diameters $\bar{x} = 280 \mu\text{m} \pm 27$ (160 to 460). Member length $\bar{x} = 253 \mu\text{m} \pm 37$ (160 to 490). Intervascular pitting $\bar{x} = 9 \mu\text{m}$ (6 to 10), vested. Yellowish or whitish deposits common in the vessels.

Fibres - Walls moderately thick. Length $\bar{x} = 1,214 \mu\text{m} \pm 106$ (770 to 1,880). Nonseptate.

Rays - Storied, $\bar{x} = 46$ (39 to 62) tiers per cm; homocellular (Fig. 11). Height $\bar{x} = 188 \mu\text{m} \pm 15$ (100 to 275). Tallest rays $\bar{x} = 8$ (6 to 13) cells. Width mostly one-celled, some two-celled. Procumbent ray cell height $\bar{x} = 22 \mu\text{m}$ (20 to 25). Number of rays per mm $\bar{x} = 12$ (6 to 20).

Parenchyma - Apotracheal marginal bands of one to four cells wide. Also banded in confluent layers throughout the growth zone; some bands mostly three or more cells wide visible to the naked eye, some not. Paratracheal parenchyma aliform to confluent. Parenchyma two cells per strand.

Crystals - Prismatic crystals in short to long chains in the axial parenchyma.

Other features - Fresh-cut surfaces variable in fluorescence in *P. indicus* & *P. macrocarpus*; negative in *P. santalinus*. Water extract yellowish brown (amber); fluoresces blue in *P. indicus* but negatively in *P. santalinus* & *P. macrocarpus*. Ethanol extract predominantly reddish brown; fluoresces a blue-green in *P. indicus*, blue with purple overtones in *P. santalinus* & *P. macrocarpus*. A fragrant odour is present in *P. indicus* but not in the others. Froth test negative.

Specimens examined - *Pterocarpus indicus* Willd.: New Guinea (MADw 25382); Philippines, CLPw 666 (MADw 22663); Philippines (MADw 31413); India (MADw 31416). - *P. macrocarpus* Kurz: India, Seaton B 548 (MADw 1487); India (MADw 6842); Burma, PRFw 232A (MADw 14129). - *P. santalinus* L. f.: India, DDw 113 (SJRw 3855); India, DDw (SJRw 46692); India (SJRw 40421).

Sindora Miq.

Five specimens of five species were examined. Sapwood grey brown to beige with a pink tinge. Heartwood mostly a red-brown and streaked. Basic sp. gr. 0.62 (0.55 to 0.83). Diffuse porous. Growth rings absent, but zones distinct as marked by irregular zonate bands of parenchyma.

Vessels - Solitary to radial multiples of 2 to 4. Frequency 4/mm² (1 to 12). Diameters $\bar{x} = 189 \mu\text{m} \pm 17$ (130 to 290). Member length $\bar{x} = 410 \mu\text{m} \pm 83$ (220 to 650). Intervascular pitting $\bar{x} = 10 \mu\text{m}$ (8 to 12), vested. Whitish deposits common in the vessels.

Fibres - Walls moderately thin. Length $\bar{x} = 1,370 \mu\text{m} \pm 157$ (1,000 to 2,000). Nonseptate.

Rays - Heterocellular rays with a single row of upright cells. Height $\bar{x} = 525 \mu\text{m} \pm 71$ (460 to 980). Tallest rays $\bar{x} = 26$ (12 to 39) cells. Width mostly two to three cells. Procumbent ray cell height $\bar{x} = 24 \mu\text{m}$ (20 to 30). Number of rays per mm $\bar{x} = 7$ (5 to 9).

Parenchyma - Apotracheal parenchyma in irregular zonate bands three or more cells wide. Vertical canals in concentric arrangement (Fig. 12) embedded in bands. Paratracheal parenchyma vascentric. Parenchyma in strands of two to eight cells.

Crystals - Prismatic crystals in long crystalliferous chains in the axial parenchyma.

Other features - Fresh-cut surfaces not fluorescent. Water extract essentially yellow-brown, *S. coriacea* & *S. velutina* yielding a red-brown colour; not fluorescent. Ethanol extract essentially yellow-brown. *S. intermedia* & *S. velutina* essentially colourless; fluorescence light green-blue except for *S. siamensis*, which fluoresces blue or purple. Spicy odour present. Froth test positive in *S. siamensis* and negative in all other species.

Specimens examined - *Sindora coriacea* Prain: Malaya, KEPw 1756 (MADw 31363). - *S. intermedia* Bak.: Malaya, KEPw 2963 (MADw 31369). - *S. leiocarpa* Bak.: Java, BZFW #e 707 (MADw 7245). - *S. siamensis* Teysm.: Siam, BKFW (MADw 14465). - *S. velutina* Bak.: Malaya, KEPw 1757, KEPw 4378 (SJRw 29099).

Wallaceodendron celebicum Koord.

Four specimens of the species were examined. Sapwood whitish. Heartwood mostly shades of yellow-brown. Basic sp. gr. 0.52 (0.48 to 0.54). Diffuse porous. Growth rings absent.

Vessels - Solitary to radial multiples of 2 to 4. Many pores in oblique or slight echelon arrangement. Frequency 4/mm² (1 to 6). Diameters $\bar{x} = 239 \mu\text{m} \pm 19$ (180 to 320). Member length $\bar{x} = 357 \mu\text{m} \pm 82$ (160 to 580). Intervascular pitting $\bar{x} = 5 \mu\text{m}$ (4 to 6), vested.

Fibres - Walls thin. Length $\bar{x} = 1,245 \mu\text{m} \pm 131$ (990 to 1,640). Nonseptate.

Rays - Homocellular rays. Height $\bar{x} = 286 \mu\text{m} \pm 32$ (200 to 430). Tallest rays $\bar{x} = 18$ (14 to 28) cells. Width mostly one-celled, some two-celled. Procumbent ray cell height $\bar{x} = 18 \mu\text{m}$ (15 to 22). Number of rays per mm $\bar{x} = 8$ (4 to 11).

Parenchyma - Apotracheal parenchyma sparse. Paratracheal parenchyma vascentric, aliform, and occasionally confluent. Parenchyma two or four cells per strand.

Crystals - Prismatic crystals in long crystalliferous chains in the axial parenchyma.

Other features - Fresh-cut surfaces not fluorescent. Water extract colourless or yellowish, not fluorescent. Ethanol extract colourless, not fluorescent. Froth test negative.

Specimens examined - *Wallaceodendron celebicum* Koord.: Philippines, Mus. Plank 86 (MADw 5469); Philippines, Mus. Pillar 9 (MADw 5471); Philippines (MADw 4130); Philippines (MADw 4217).

Xylia dolabriformis Benth.

Four specimens of the species were examined. Sapwood pale reddish white. Heartwood reddish brown with streaks. Basic sp. gr. 0.75 (0.67 to 0.80). Diffuse porous. Growth rings absent, but zones distinct as marked by irregular zonate bands of parenchyma.

Vessels - Solitary to radial multiples of 2 to 4. Many pores in echelon arrangement. Frequency 7/mm² (1 to 12). Diameters \bar{x} = 196 μ m \pm 16 (140 to 245). Member length 390 μ m \pm 80 (160 to 640). Intervascular pitting \bar{x} = 7 μ m (5 to 10), vested. Tyloses rare. Whitish deposits in vessels.

Fibres - Walls thick. Length \bar{x} = 1,284 μ m \pm 140 (980 to 1,720). Septate.

Rays - Homocellular rays. Height \bar{x} = 500 μ m \pm 82 (205 to 960). Tallest rays \bar{x} = 32 (20 to 47) cells. Width two to three cells. Procumbent ray cell size \bar{x} = 19 μ m (15 to 22). Number of rays per mm \bar{x} = 12 (10 to 14).

Parenchyma - Apotracheal parenchyma in irregular zonate bands one or two cells wide. Paratracheal parenchyma vasicentric and aliform. Parenchyma three or four cells per strand.

Crystals - Prismatic crystals in long crystalliferous chains in axial parenchyma.

Other features - Fluorescence of fresh-cut surfaces variable: three positive and three negative. Water extract brown, not fluorescent. Ethanol extract red-brown, not fluorescent. Froth test positive.

Specimens examined - *Xylia dolabriformis* Benth.: India, FI 517, Kew w-857 (MADw 26413); Burma, For. Botanist 2511BS (MADw 31269); India, Barrett W1222 (MADw 1496); India (MADw 6869).

Discussion

At the macroscopic (hand lens) level, the key characters used to break the 13 genera into

small groups are as follows: ring versus diffuse porosity, storied structure, aliform to confluent to banded parenchyma, and marginal or irregular zonate parenchyma absent or present. All species examined were diffuse porous except *Albizia julibrissin*, and some specimens of *Pterocarpus* spp. which were ring porous. One-fourth of the species exhibited storied ray structure and nonfluorescent heartwood, and the other three-fourths were nonstoried woods, mostly having fluorescent heartwood.

Appendix I lists helpful features for identifying species, and Appendix II is a macroscopic and microscopic wood anatomy key to the commercial legumes of tropical Asia and Australia.

References

- Baretta-Kuipers, T. 1981. Wood anatomy of Leguminosae: its relevance to taxonomy. In: Advances in legume systematics (eds. R.M. Polhill & P. Raven): 677-705. Royal Bot. Gardens, Kew.
- Burgess, P.R. 1966. Timbers of Sabah. Sabah Forest Records 6: 343-385.
- Chalk, L. & M.M. Chattaway. 1934. Measuring the length of vessel members. Trop. Woods 40: 19-26.
- Desch, H.E. 1941. Manual of Malayan timbers. Malayan Forest Records no 15 (1): 253-301.
- Franklin, G.L. 1946. A rapid method of softening wood for microtome sectioning. Trop. Woods 88: 35-36.
- Kribs, D.A. 1950. Commercial foreign woods on the American market. Edwards Brothers, Ann Arbor, Michigan.
- Metcalfe, C.R. & L. Chalk. 1950. Anatomy of the dicotyledons. Vol. 1: 476-535. Clarendon Press, Oxford.
- Miller, R.B. 1980. Wood identification via computer. IAWA Bull. n.s. 1: 154-160.
- & P. Baas. 1981. Standard list of characters suitable for computerized hardwood identification. IAWA Bull. n.s. 2: 99-145.
- Pearson, R.S. & H.P. Brown. 1932. Commercial timbers of India. Vol. 1: 348-471.
- Quirk, J.T. 1981. Semi-automated recording of wood cell dimensions. For. Sci. 27 (2): 336-338.
- Stem, W.L. 1978. Index Xylariorum. International Wood Collections of the World. 2. Taxon 27: 233-269.

Appendix I

Helpful features in identifying legumes of tropical Asia and Australia.

Ring porous	<i>Albizzia julibrissin</i> <i>Pterocarpus</i> *	Water extract fluorescent	<i>Acacia catechu</i> <i>Dalbergia latifolia</i> and <i>D. oliveri</i>
Pores in echelon	<i>Albizzia zanthoxylon</i> <i>Koompassia malaccensis</i> <i>Wallaceodendron celebicum</i> <i>Xylia dolabriformis</i>		<i>Pseudosindora palustris</i> <i>Pterocarpus indicus</i> and <i>P. macrocarpus</i>
Parenchyma in bands	<i>Dalbergia sp.</i> <i>Dialium platysepalum</i> <i>Koompassia excelsa</i> <i>Pterocarpus sp.</i>	Uniseriate rays	<i>Acacia acuminata</i> <i>Albizzia falcataria</i> <i>Pterocarpus</i>
Fibres septate	<i>Acacia koa</i> * <i>Acrocarpus fraxinifolius</i> * <i>Albizzia lebbek</i> and <i>A. odoratissima</i> <i>Xylia dolabriformis</i> *	Stonedstructure	<i>Dalbergia</i> <i>Dialium</i> <i>Koompassia</i> * <i>Pterocarpus</i>

* Not present in all specimens.

Appendix II

Macroscopic and microscopic key to commercial Southeast Asian Leguminosae

1	Rays not storied	2
1	Rays storied	26
2	Ring porous	<i>Albizzia julibrissin</i>
2	Diffuse porous	3
3	Rays heterocellular.	4
3	Rays homocellular	8
4	Vertical canals present	<i>Sindora</i>
4	Vertical canals absent	5
5	Apotracheal parenchyma banded within growth zones; not in irregular zonate bands	6
5	Apotracheal parenchyma not banded within growth zones; parenchyma in irregular zonate bands	7
6	Intervascular pits vested, crystals absent in rays	<i>Cynometra</i>
6	Intervascular pits not vested, crystals present in rays	<i>Koompassia excelsa</i>
7	Parenchyma aliform, rays less than 0.5 mm tall; crystals present in rays	<i>Acrocarpus fraxinifolius</i>
7	Parenchyma vasicentric, rays more than 1 mm tall, crystals absent in rays	<i>Pseudosindora palustris</i>
8	Parenchyma in irregular zonate bands	9
8	Parenchyma not in irregular zonate bands	21
9	Parenchyma in regular distinct zonate bands	<i>Intsia</i>
9	Parenchyma in irregular, often indistinct, or marginal discontinuous bands	10
10	Pores in echelon	11
10	Pores not in echelon	12
11	Rays 1 and 2 cells wide, intervascular pits 6–8 μ m vested, white deposits in vessels	<i>Xylia dolabriformis</i>
11	Rays 3–4 cells wide, intervascular pits 10–12 μ m nonvested, yellow deposits in vessels	<i>Koompassia malaccensis</i>
12	Fibres septate	13
12	Fibres nonseptate	15
13	Parenchyma aliform	14
13	Parenchyma vasicentric to scanty	<i>Acacia koa</i>

14	Rays 3-5 cells wide, sp. gr. 0.70	<i>Albizia odoratissima</i>
14	Rays mostly 2-3 cells wide, sp. gr. 0.50	<i>Albizia lebbek</i>
15	Froth test positive, parenchyma mostly aliform	(<i>Albizia</i>) 16
15	Froth test negative, parenchyma vascentric or scanty	(<i>Acacia</i>) 17
16	Rays 3-5 cells wide, intervacular pits 8-10 μ m	<i>Albizia procera</i>
16	Rays mostly 2-3 cells wide, intervacular pits 6-8 μ m	<i>Albizia toona</i>
17	Rays 3-5 cells wide, crystals in rays	<i>Acacia catechu</i>
17	Rays 3 cells or less wide, crystals absent in rays	18
18	Vessels mostly more than 200 μ m in diameter	19
18	Vessels mostly less than 200 μ m in diameter	20
19	Heartwood streaked, vessels mostly more than 300 μ m in diameter, sp. gr. 0.50	<i>Acacia koa</i>
19	Heartwood not streaked, vessels mostly less than 200 μ m in diameter, sp. gr. 0.56	<i>Acacia melanoxylon</i>
20	Heartwood streaked, sp. gr. 0.86	<i>Acacia koaia</i>
20	Heartwood not streaked, sp. gr. 0.71	<i>Acacia confusa</i>
21	Pores in echelon	22
21	Pores not in echelon	22
22	Intervacular pits 10-12 μ m, not vested, yellow deposits in vessels	<i>Koompassia malaccensis</i>
22	Intervacular pits 4-6 μ m, vested, white deposits in vessels	23
23	Heartwood fluorescent, ethanol extract fluorescent	<i>Albizia zanthoxylon</i>
23	Heartwood not fluorescent, ethanol extract not fluorescent	<i>Wallaceodendron celebicum</i>
24	Rays uniseriate to partially biseriate	25
24	Rays 2-3 cells wide	<i>Acacia mollissima</i>
25	Pores less than 200 μ m in diameter, crystals in rays, froth test negative	<i>Acacia acuminata</i>
25	Pores more than 300 μ m in diameter, crystals absent in rays, froth test positive	<i>Albizia falcataria</i>
26	Rays uniseriate to partially biseriate	(<i>Pterocarpus</i>) 27
26	Rays 2-3 cells wide	29
27	Growth rings generally distinct, delimited by widely spaced larger vessels at the beginning of the ring. Largest vessels more than 325 μ m in diameter, spicy odour, yellow deposits in vessels, sp. gr. 0.52	<i>Pterocarpus indicus</i>
27	Growth rings present but inconspicuous, no odour, yellow deposits in vessels	28
28	Marginal parenchyma mostly 3 or more cells wide, heartwood fluorescent (\pm), sp. gr. 0.70	<i>Pterocarpus macrocarpus</i>
28	Marginal parenchyma mostly 1 or 2 cells wide, heartwood not fluorescent, sp. gr. 0.86	<i>Pterocarpus santalinus</i>
29	Ripple marks less than 100/inch (20-30/cm)	30
29	Ripple marks more than 100/inch (40-70/m)	(<i>Dalbergia</i>) 32
30	Rays heterocellular	<i>Koompassia excelsa</i>
30	Rays homocellular	31
31	Parenchyma aliform, pores in echelon, yellowish deposits in vessels, pits 10-12 μ m not vested	<i>Koompassia malaccensis</i>
31	Parenchyma banded, pores solitary and in short radial multiples, white deposits in vessels, pits 8-10 μ m vested	<i>Dialium platysepalum</i>
32	Bands of parenchyma mostly 3 or more cells wide, heartwood streaked	33
32	Bands of parenchyma mostly 1 or 2 cells wide, heartwood streaked or not, ripple marks 50-60/cm, sp. gr. 0.83	<i>Dalbergia cochinchinensis</i>
33	White deposits in the vessels, ripple marks 65/cm, water extract not fluorescent, widest rays (3 cells) more than 55 μ m wide, sp. gr. 0.60	<i>Dalbergia sissoo</i>
33	No deposits in the vessels, ripple marks 40-60/cm, water extract fluoresces a faint blue, widest rays (3 cells) less than 55 μ m wide	34
34	Ripple marks 40-50/cm, wood reddish-brown without purplish cast, ethanol extract red-brown, fluoresces a purple-blue	<i>Dalbergia oliveri</i>
34	Ripple marks 50-60/cm, wood variable, shades of light rose-purple to deep purple or black with pronounced purplish cast, ethanol extract has distinct purplish cast, fluoresces a bright blue	<i>Dalbergia latifolia</i>

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