

THE ANATOMY OF SOME IMPORTANT TAIWAN WOODS

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Abstract

A study was made of single wood samples from 35 species (27 genera and 16 families) of important Taiwan timbers. Results have been compared with information published by Kanehira in 1921 (30) and others (31, 44).

The anatomy of these woods is described in detail. A key based on microscopic features is included for identification. Descriptions follow standard terms of the International Association of Wood Anatomists.

Two of the coniferous species, Pinus armandi Franch. and Chamaecyparis formosensis Matsum., and nine hardwood species Carpinus kawakamii Hay., Quercus gilva Bl., Quercus longinux Hay., Cinnamomum camphora Nees., Cinnamomum randaiensis Hay., Lagerstroemia subcostata Koehne., Gordonia axillaris (Don.) Szysz., Trochodendron aralioides S. et Z., and Trema orientalis Bl. had features similar to those reported (30, 31, 44).

Seven hardwood species, Alnus formosana (Burkill.) Makino., Quercus stenophylloides Hay., Engelhardtia formosana Hay., Beilschmiedia erythrophloia Hay., Cinnamomum micranthum Hay., Zelkova formosana Hay., and Tectona grandis Linn. f. showed different anatomical features from those recorded by Kanehira (30) and Kribs (31).

No previous description of wood anatomy has been found for seventeen species including Tsuga chinensis (Franch.) Pritz., Cunninghamia konishii Hay., Libocedrus formosana Hay., Chamaecyparis taiwanensis Masam. et Suzuk., Scheffera octophylla (Lour.) Harms., Castanopsis longicaudata Hay., Castanopsis stipitata Hay., Lithocarpus amygdalifolia Hay., Actinodaphne nantoensis Hay., Machilus arisanensis Hay., Machilus pseudolongifolia Hay., Machilus zuihoensis Hay., Cassia siamiae Lam., Michelia formosana Mas., Illicium leucanthum Hay., Schima superba Gard. et Champ. and Ternstroemia gymnanthera Spr. All species treated in this study are described in more detail than occurs in past records.

Mass grouping of longitudinal parenchyma appears as a normal feature of Cunninghamia konishii Hay. This type of parenchyma distribution could be a taxonomic feature of Cunninghamia not previously described in the literature.

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The Anatomy of Some Important Taiwan Woods

Introduction

Taiwan is an island off the southeastern coast of the Chinese mainland, separated from the mainland China province of Fukien by the Taiwan Straits. Its exact location is $21^{\circ}45'25''$ to $25^{\circ}27'23''$ North Latitude and $119^{\circ}18'13''$ to $122^{\circ}6'12''$ East Longitude. The Tropic of Cancer crosses southern Taiwan.

Taiwan has an area of 13,808 square miles excluding 77 smaller outlying islands. According to a provincial aerial survey 55.1% of the land area of Taiwan is forested. Conifers comprise 18.9% of the forested land, mixed stands 2.8%, hardwoods 72.5%, while the remaining 5.8% is covered with bamboo.

Important coniferous tree species of Taiwan are Chinese hemlock, Taiwan cypresses, Chinese pine, Taiwan spruce and Taiwan fir; among hardwoods, camphor, oak, teak, Zelkova spp. and Michelia spp. are of great economic value, particularly the camphor yielding trees. The so-called true camphor, Cinnamomum camphora Nees., known as "king of the forest", is one of the major species used for producing camphor and camphor oil. The most extensive camphor tree forests in the world are in Taiwan (34) which supplies 70% of the world's yearly requirement of natural camphor products.

There are about 105 tree species providing useful woods in Taiwan. These were screened by the author while working at the National Taiwan University. This thesis describes 35 species among 27 genera and 16 families. The author believes that the work has value, since there has been no serious anatomical study of Taiwan woods since that of Kanehira in 1921 (30).

Review of Literature

Woods of both Cupressaceae and Taxodiaceae have been detailed by Peirce (36, 37), while many species and genera of Pinaceae have been described by Brown and Panshin (2) and Kanehira (30).

Metcalfe and Chalk (35) have reviewed the literature on microscopic features of world hardwoods. They have collected all taxonomic features and made their own system depending on morphology of trees and anatomical features of woods. Their taxonomic system is followed in this study. Kanehira (30) gave much information about Taiwan hardwoods. Lauraceae has been completely examined by Stern (44) while Record (38) and Record and Hess (40) described American woods in the families Theaceae and Lauraceae with general notes on genera. Many families were described by Record and Dadswell (39). Some species included in this study were examined by Kribs (31). Information from these sources is given under Families. A general summary follows on anatomical features of porous wood taxonomic groups included in this study.

According to pore arrangement, woods of Araliaceae, Betulaceae and Lauraceae are exclusively diffuse-porous and those of Verbenaceae are exclusively ring-porous. Juglandaceae and Lythraceae always include both types of woods, ring-and diffuse-porous. Some species of Leguminosae are ring-porous while others are semi-ring-porous. Some species of Theaceae and Ulmaceae are semi-ring-porous, while others in these families are either ring-or diffuse-porous.

As regards perforation plates, woods with exclusively scalariform plates occur in Betulaceae, Magnoliaceae, Schisandraceae (*Illicium* only) and Theaceae while those of Juglandaceae, Lauraceae, Leguminosae, Ulmaceae and Verbenaceae are exclusively simple. However, woods of Araliaceae and Fagaceae include both types of plates, simple and scalariform.

Vestured intervessel pitting of vessels characterizes some woods of Leguminosae. Scalariform pitting, however, is a typical feature of

Araliaceae. The vessels of Lauraceae always have coarse pits alternately arranged, while those of Leguminosae have small pits alternately arranged.

Vasicentric tracheids with scalariform pitting seem to be the special characteristic of *Trochodendron*. Fibres of Araliaceae, Lauraceae, Leguminosae, Lythraceae and Verbenaceae are always septate. Most woods of Juglandaceae, Magnoliaceae, Schisandraceae (*Illicium* only) and Theaceae contain fibres with bordered pits while those of Lauraceae, Leguminosae, Ulmaceae and Verbenaceae have fibres with simple pits. Fagaceae, however, contains fibres with both simple and bordered pits.

Longitudinal parenchyma in wood is more complex in arrangement than other features. Woods possessing only one parenchyma arrangement are those of Araliaceae, Leguminosae and Schisandraceae with paratracheal, Juglandaceae with apotracheal, Magnoliaceae with terminal and Trochodendraceae with metatracheal-diffuse. Betulaceae has two types of parenchyma arrangement, diffuse and terminal, while Fagaceae has both diffuse and apotracheal. Woods with even more complicated types of parenchyma are those of Lauraceae, Lythraceae and Ulmaceae.

Rays are another taxonomic feature in wood. Araliaceae has exclusively multiseriate rays while Lythraceae has simple rays only. Woods of Fagaceae, Juglandaceae, Trochodendraceae and Ulmaceae always possess two types of rays, simple and multiseriate. Only Betulaceae has three types of rays, simple, multiseriate and aggregate.

Botanists have always considered wood to be a refractory material to section usually requiring time-consuming schedules for preliminary softening. Usual paraffin embedding methods have seldom been found useful with normal woods. Some hardwoods cause difficulty in microtome sectioning due to high mineral content (19, 29, 41), particularly various silicates (7, 35). Crystals of calcium oxalate and ellagic acid were also found in some woods by Chattaway (7, 8). There are

about 1,000 genera among 160 families containing different kinds of crystals (8). These are useful in identification, but cause difficulty in preparing materials. Hence, many chemicals have been used to soften refractory woods prior to sectioning (17, 20). Most operate through removal of mineral and crystalline matter.

Penetration of water into wood blocks is another important factor affecting microtome sectioning (46). Numerous methods have been described to accomplish this (16, 17, 20, 41). Among these, the most effective method has been to reflux wood blocks in solvents that remove extractives peculiar to the species being treated. Common solvents include water, alcohols, benzene and ether. Following these pretreatments the time required for complete saturation of wood blocks is much shortened (46).

Techniques for sectioning, staining and mounting, as well as photomicrography methods are detailed in several texts and publications (1, 10, 14, 18, 19, 29, 41, 42). Methods for fibre maceration with mixtures of hydrogen peroxide and acetic acid are available in the literature (15, 48). Film stop bath and wash water test solutions are particularly valuable photomicrographic techniques which have been discussed by Shillaber (42).

Classifications of various anatomical features for describing dicotyledonous woods were made by many authors (5, 6, 11, 22, 23, 24, 25, 26, 27, 43) and were followed in this study. Terminology of wood anatomy and wood properties have been described by the International Association of Wood Anatomists, as well as wood technologists and botanists (2, 4, 8, 12, 13, 28, 31).

Methods

1. Source of materials

All wood samples were selected from authenticated mature, old growth tree stems grown in different parts in Taiwan. Part of these were collected by the author, the remainder was obtained from the Taiwan Forest Administration. One wood sample ($\frac{1}{2}$ " x 3" x 4") was examined for each species included.

2. Slide Preparation

Two to three small blocks were chosen for each surface of each species. All the blocks were cut to size for the three sections desired. Blocks for tangential and radial sections were prepared with a cutting surface of 0.5 x 1.0 cm., while blocks for cross-section had a 2.0 x 2.0 cm. face. The blocks were then sanded to improve directional orientation and limit microtome trimming.

Wood softening treatments followed two schedules. Coniferous woods were soaked in cold water until they sank (18, 19, 39). Deciduous woods were refluxed in water 10 to 30 minutes depending on specific gravity; boiled with alcohol-benzene for 15 minutes, then ethyl ether for 30 minutes; refluxed again in water 10 minutes with repeated trial microtome sectioning. Test-sections were examined microscopically following phloroglucin staining.¹ The solvent extractive treatments were especially useful with Cinnamomum spp. which are high in oil content and thereby resist water penetration.

A "Reichert" sliding microtome was used for preparation of sections at 15 and 20 microns. Green soap was applied as a lubricant. Curling, when it occurred, was controlled by the paper adhesion technique. Sections were stored in 30% ethyl alcohol following several washings in the watch glass.

1. Solution: phloroglucin 1 gm., HCl 25 ml. and H₂O 25 ml. applied for 5 minutes.

The staining schedule included Haidenhain's mordanted hematoxylin followed by Safranin O (10, 14, 19, 29, 41).² Repeated washings were done at appropriate stages. Dehydration was done through the ethyl alcohol series (50, 70, 85, 95%) and followed by 100% n-butyl alcohol with a maximum 10 minutes in each stage. Xylene was used as clearing agent followed by "Depex" mounting medium (16, 19). Slides were clipped and dried at 50° C. for one week.

3. Measurements of Anatomical Features on Sections (3,5,6,11,22, 23,24,25,26,43)

In this work, vessel density means the number of vessels occurring per square millimeter. Ten random measurements were made from a cross-section projected onto a target (9). Tangential vessel diameters were measured under a microscope using an eyepiece micrometer with 20 random measurements taken on a cross-section. The ten measurements occurring most frequently were selected and averaged to describe vessel diameter. Number of bars, bar thickness of scalariform plates and size of intervessel pits were measured on 3 to 5 vessels on both pulp slides and tangential sections; ten observations were obtained. Ray width and height were determined on the widest and highest simple ray occurring on a tangential section.

4. Photomicrography (1, 18, 29, 41, 42)

A "Leitz Wetzlar" microscope (10 x 10 magnification) and light source were used without filters in combination with a Leica (Wetzlar 1 G) 35 mm. camera. Exposure time was varied from 5-10 seconds through readings made on a "Wetzlar Microsix" photometer.

2. Mordant solution: iron alum 2 gm., glacial acetic acid 1 ml., conc. H_2SO_4 1 drop, H_2O 100 ml.; filtered immediately before use and applied for 30 minutes.

Hematoxylin solution: Hematoxylin 1 gm., thymol several grains, H_2O 100 ml., ripened, filtered and applied as 5% solution for 15 minutes until the proper color intensity was obtained; washed and treated with dilute NH_4OH .

Safranin solution: Safranin O 10 gm., aniline oil 20 ml., 95% ethyl alcohol 180 ml., filtered and applied as a 5% solution overnight followed by 30% ethyl alcohol leaching overnight.

Kodak plus-X panchromatic film was used. Exposed films were treated with Kodak D-11 developer for 5 minutes, washed briefly, drained, stopped 2 minutes,³, fixed 10 minutes in "Kodak Fixer"⁴ washed for 15 minutes⁵ and air dried. Enlargements (3½" x 4½") were made at a total 100x magnification with a "Durst 606" enlarger. Kodak F2-4 glossy, single weight enlargement papers were used with usual exposure time at 5-20 seconds. Exposed paper was treated with freshly prepared "Kodak Dektol Developer" for 2 minutes, stopped 2 minutes,⁶, fixed 15 minutes in "Kodak Fixer", washed 60 minutes⁵, soaked in glycerol water, drained, rolled on a chrome plate and dried 8 minutes in an "Arkay" dryer.

5. Maceration and Fibre Measurements (15, 45, 47, 48)

Match-stick sized pieces of wood were cooked in an active oxygen solution⁷ for up to one hour depending on species. The macerated materials were washed, shaken to defibrate and stained in Bismark brown Y overnight.⁸ A fibre suspension was made, aliquots were mounted with water soluble "Aquamount".

Fifty individual fibres were measured for length and diameter (center of fibre) from projections and using a systematic sampling method (9). The 25 fibres with most common length and diameter were used to describe fibre size. The average was the mean of the 25 numbers.

Cell wall thickness (center of fibre) was measured by micrometer under a microscope at 40 x 10 magnification. Twenty wall thickness readings were obtained on individual fibres. The ten most frequent readings from among these twenty numbers were averaged and used to

3. Film stop bath: chrome alum 14 gm., glacial acetic acid 8 ml., H₂O 1,000 ml.

4. Fixer tested with "Eduel Hypo-check" and discarded when two drops formed a white precipitate.

5. Wash water test solution: KMnO₄ 0.3 gm., NaOH 0.6 gm., H₂O 2,500 ml., with 1 ml. of stock solution diluted to 250 ml. with H₂O; if a few drops of wash water discolored the dilute solution orange the washing was continued.

6. Paper stop bath: glacial acetic acid 24 ml., water 500 ml.

7. Maceration solution: equal part of hydrogen peroxide and acetic acid.

8. Staining solution: Bismark brown Y 2 gm. in 100 ml. of 95% ethyl alcohol.

express wall thickness. The mean thickness of the fibre wall, however, was expressed in terms of the ratio of the mean fibre lumen width to the mean double fibre wall thickness (5). The mean fibre lumen width was obtained from the difference between the mean fibre diameter and the mean double fibre wall thickness.

6. Classification of Measurements

(1). Size of pores (27)

Class	Subclass	Tangential diameter in microns
Small	Extremely small	up to 25
	Very small	25-50
	Moderately small	50-100
Medium-sized		100-200
Large	Moderately large	200-300
	Very large	300-400
	Extremely large	over 400

(2). Density of pores (3)

Class	Number per sq. mm.
Very few	up to 2
Few	2-5
Moderately few	5-10
Moderately numerous	10-20
Numerous	20-40
Very numerous	over 40

(3). Diameter of intervessel pits (43)

Class	Subclass	Diameter in microns
Small	Extremely small	less than 3
	Very small	3-5
	Moderately small	6-8
Medium-sized		9-14
Large	Moderately large	15-17
	Very large	18-20
	Extremely large	over 20

(4). Diameter of fibres (43)

Class	Subclass	Diameter in microns
Fine	Extremely fine	less than 8
	Very fine	9-11
	Moderately fine	12-15
Medium-sized		16-21
Coarse	Moderately coarse	22-25
	Very coarse	26-29
	Extremely coarse	over 29

(5). Length of fibres (27)

Class	Subclass	Length in mm.
Short	Extremely short	less than 0.5
	Very short	0.5-0.7
	Moderately short	0.7-0.9
Medium-sized		0.9-1.6
Long	Moderately long	1.6-2.2
	Very long	2.2-3.0
	Extremely long	over 3.0

(6). Thickness of fibre walls (5)

Class	Ratio of lumen to double wall thickness
Very thin	over 6
Thin	6-4
Thick	4-2
Very thick	less than 2

(7). Width of rays (43)

Class	Subclass	Width in Microns
Fine	Extremely fine	up to 15
	Very fine	15-25
	Moderately fine	25-50
Medium-sized		50-100
Broad	Moderately broad	100-200
	Very broad	200-400
	Extremely broad	over 400

(8). Height of rays (3, 43)

Class	Height in mm.
Extremely low	up to 0.5
Very low	0.5-1.0
Low	1.0-2.0
Rather low	2.0-5.0
Moderately high	5.0-10.0
High	10.0-20.0
Very high	20.0-50.0
Extremely high	over 50

PINACEAE

The family comprises 9 genera and approximately 210 species, widely distributed through the Northern Hemisphere (21). There are 6 genera and 9 species of trees in Taiwan (32). The woods of two timber species are described.

Anatomical Features: Longitudinal tracheid diameter 25-50 microns; pitting one row or occasionally two rows; sometimes spiral thickening present; pits at ray crossing, small to wide window-like, 1-several per crossing. Both longitudinal and transverse resin canals present in Pinus, Picea, Pseudotsuga and Larix, only longitudinal resin canals present in Keteleeria. Traumatic longitudinal canals occasionally found in other genera. Longitudinal parenchyma absent in some genera. Rays fusiform in those genera containing ray canals; uniseriate to biseriate, rarely triseriate, height variable, up to 20 plus cells high. Ray tracheids present (2, 30).

Anatomical Features of Pinus and Tsuga: Longitudinal tracheids as the family description; spiral thickening absent; pits at ray crossing, medium to wide window-like, 1-several per crossing. Longitudinal parenchyma absent and terminal in some species of Tsuga. Both longitudinal and ray resin canals present in Pinus. Rays uniseriate and fusiform in Pinus, 1-12 cells high (2, 30).

Pinus armandi Franch.

Commercial Name: Chinese pine, Haw-san-soun (mandarin).

Other Names: Hon-saon-ba.

Tree: A large tree, ranging from 7,500 to 11,500 feet elevation from central to northern Taiwan; associated with Tsuga chinensis, Chamaecyparis formosensis, Chamaecyparis taiwanensis, Picea morrissonicola and Trochodendron aralioides.

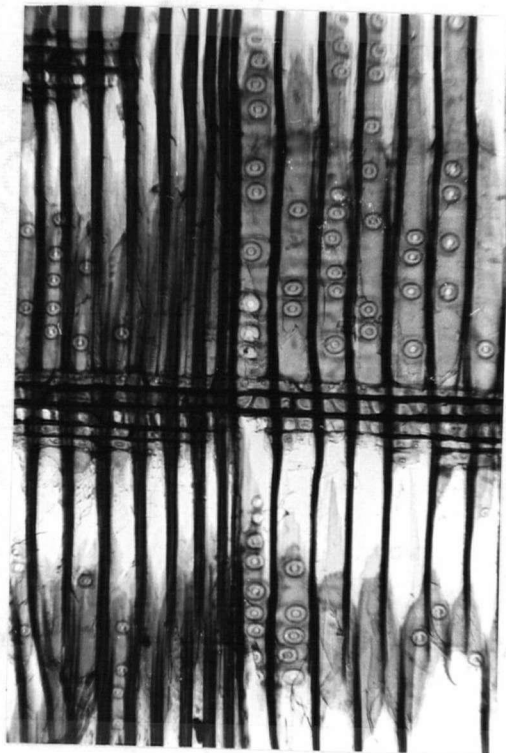
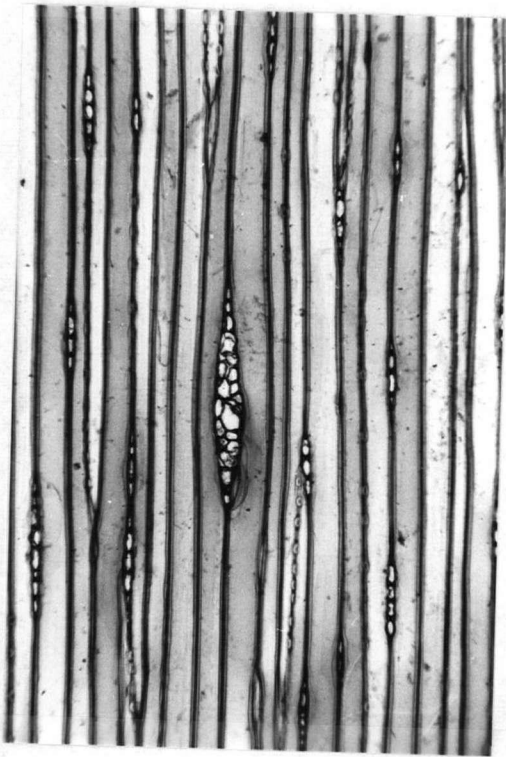
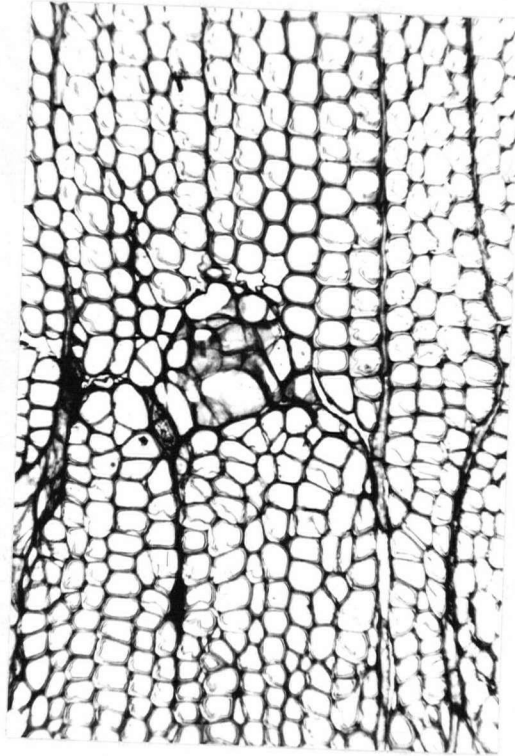


Fig. 1. Pinus armandi Franch.
(x-sec., t-sec. and r-sec.) at 100x

General Properties: Wood pink with medium lustre; grain straight; texture coarse; moderately light, specific gravity 0.43 (27 pounds per cubic foot); with pine odor and a bitter taste.

Macroscopic Features: Growth rings distinct and uniform with regular contour, delineated by narrow and conspicuous bands of dark summerwood, springwood to summerwood transition abrupt. Longitudinal and transverse resin canals present, sparse in all growth rings, but large and visible to the naked eye, mostly confined to the summerwood, arranged singly.

Microscopic Features: (See Fig. 1) Longitudinal tracheids mostly 45-50 (average 48) microns in diameter, 5.0-5.5 (average 5.3) millimeters in length; crassulae present; bordered pitting on radial walls first-formed springwood as one row or occasionally two rows; bordered pitting present on tangential walls last-formed summerwood; pits at ray crossings large, round, window-like, 1-2 (mostly 2) per crossing; spiral thickening absent. Longitudinal parenchyma absent. Longitudinal resin canals mostly 114-120 (up to 130) microns in tangential diameter; 1-2 per square millimeter; epithelium thin-walled; tylosoids present. Rays of two types: uniseriate, numerous (t), 1-9 plus cells in height (less than 30 microns high); fusiform scattered, with one transverse resin canal, two seriate at central portion tapering to uniseriate margins, up to 9 cells in height, epithelium thin-walled; ray tracheids present in both types of rays, marginal and interspersed, walls smooth; ray parenchyma thin-walled on all faces.

Uses: The wood is used for furniture manufacture, clothes cabinets, aqueducts and as match-stick blocks. Small wood is suitable for chemical pulp manufacture.

Remarks: Kanehira (30) has recorded similar features for P. armandi Franch.

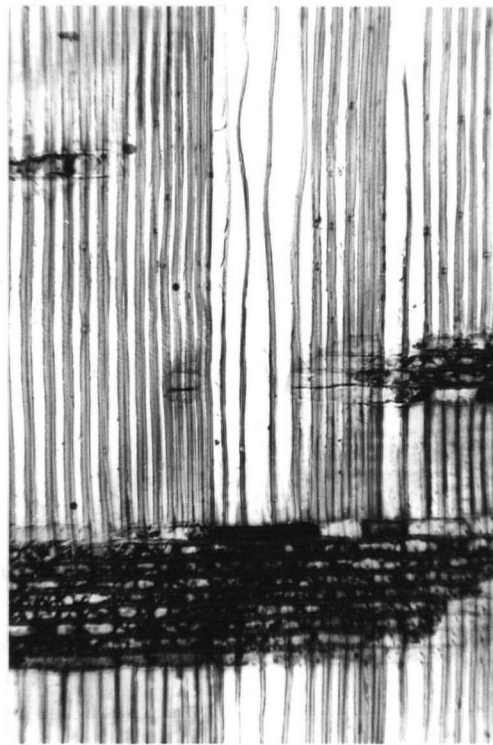
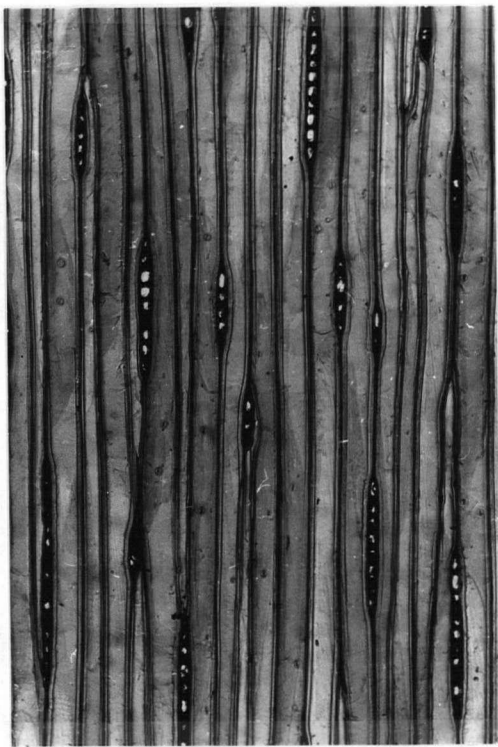
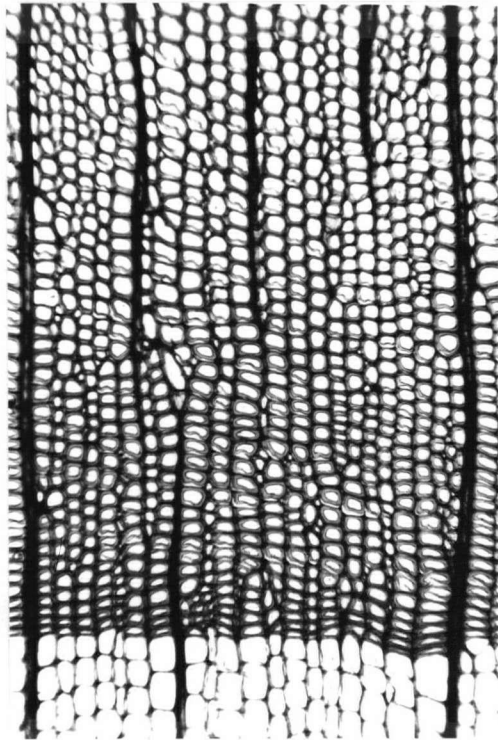


Fig. 2. Tsuga chinensis (Franch.) Pritz.
(x-sec., t-sec. and r-sec.) at 100x

Tsuga chinensis (Franch.) Pritz.

Commercial Names: Chinese hemlock, Ti-san (mandarin).

Other Names: U-saun.

Tree: A large tree, up to 150 feet tall, and 3-5 feet in diameter; ranging from 6,500 to 9,800 feet elevation about the whole island; associated with Chamaecyparis taiwanensis, Chamaecyparis formosensis, Pinus spp., Taxus chinensis, and Trochodendron aralioides.

General Properties: Wood yellow with medium lustre; grain straight; texture medium; moderately heavy, specific gravity 0.49 (30.5 pounds per cubic foot); without characteristic odor or taste.

Macroscopic Features: Growth rings distinct with regular contour due to narrow darker summerwood zones, springwood to summerwood transition gradual to abrupt. Normal longitudinal resin canals absent.

Microscopic Features: (See Fig. 2) Longitudinal tracheids mostly 45-50 (average 46) microns in diameter, 4.5-5.0 (average 4.5) millimeters in length; bordered pitting on radial walls first-formed springwood as one row or sometimes 2 and 3 rows, bordered pitting present on tangential walls last-formed summerwood; pits at ray crossings medium, round, with border, 2-3 (mostly 2) per crossing; spiral thickening absent. Longitudinal parenchyma terminal, single cells sparse. Rays uniseriate, numerous (t), 1-14 plus cells in height (less than 35 microns high); ray tracheids present, marginal, walls smooth; ray parenchyma thin-walled on all faces.

Uses: The wood is used for structural timbers, veneer and plywood for tea cases, rail ties after preservative treatment and for chemical pulp manufacture.

Remarks: Kanehira (30) reports similar features for wood of T. formosana Hay.

TAXODIACEAE

The family contains about 8 genera, 4 of which are monotypic and 14 species distributed in eastern and southern Asia and western North America (21, 36). There are 3 genera and 4 species in Taiwan (32). The wood of one species is described.

Anatomical Features: Longitudinal tracheid diameters 30-60 microns; pitting biseriate to multiseriate in early wood, rarely uniseriate; spiral secondary thickenings absent; crassulae present, usually abundant. Longitudinal parenchyma abundant scattered or occasionally somewhat banded tangentially; intercellular canals absent. Rays uniseriate, occasionally partly biseriate (36).

Anatomical Features of Cunninghamia: Longitudinal tracheid diameters 30-60 microns, pitting uniseriate to multiseriate; pits at ray crossing often simple, elliptic and diagonal, occasionally circular, 2-4 per crossing; crassulae distinct. Longitudinal parenchyma abundant and scattered. Rays uniseriate, occasionally biseriate, 1-24 occasionally 30 cells high; cells rarely resinous; normal ray tracheids absent (36).

Cunninghamia konishii Hay.

Commercial Name: Han-san (mandarin).

Other Names: Woo-san.

Tree: A large tree; ranging from 4,300 to 5,900 feet elevation from central to northern Taiwan.

General Properties: Wood light pink with medium lustre; grain straight; texture medium; moderately light, specific gravity 0.41 (25.5 pounds per cubic foot); with fragrant odor and bitter taste.

Macroscopic Features: Growth rings distinct with regular contour due to narrow darker summerwood zones, springwood to summerwood transition gradual. Normal resin canals absent. Longitudinal parenchyma irregularly collected in large patterns.

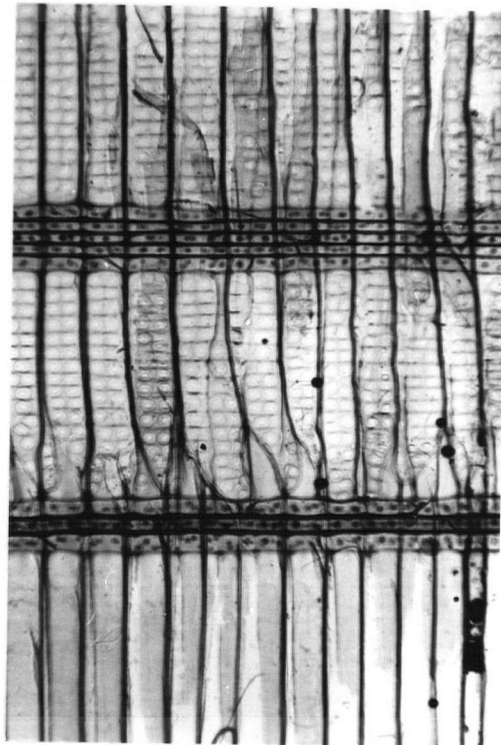
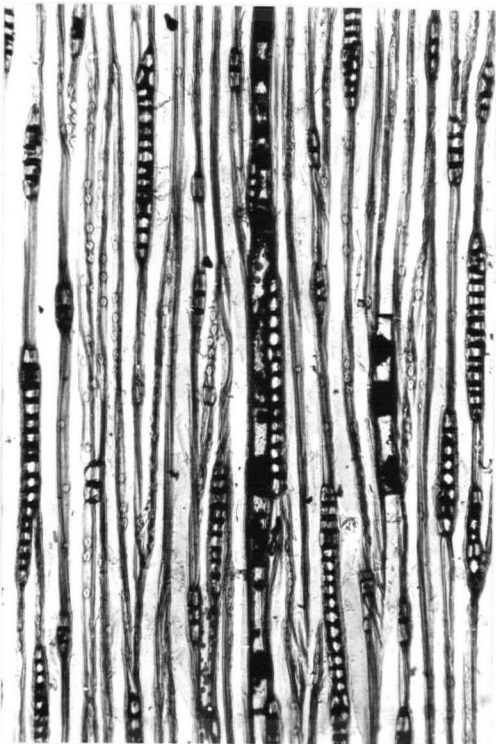
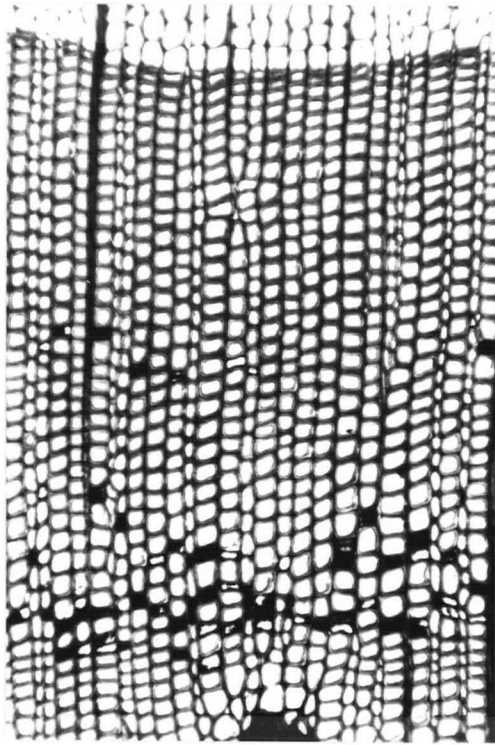
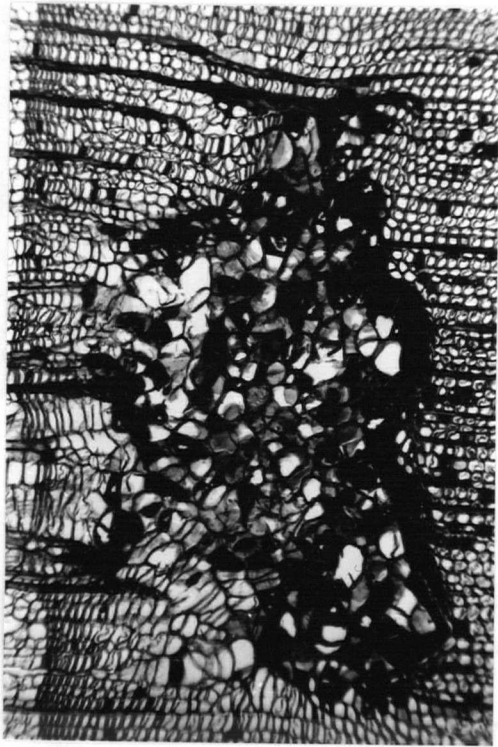


Fig. 3. Cunninghamia konishii Hay.

(x-sect., t-sect. and r-sect.) at 100 x and
x-sect. at 60 x showing mass grouping of
longitudinal parenchyma.

Microscopic Features: (See Fig. 3) Longitudinal tracheids mostly 30-55 (average 35) microns in diameter, 5.0-7.0 (average 5.5) millimeters in length; crassulae present; bordered pitting on radial walls first-formed springwood as two rows with microscopic checking present along the inner apertures, bordered pitting present on tangential walls last-formed summerwood; pits at ray crossings medium, oval to lenticular, 1-2 (mostly 2) per crossing; spiral thickening absent. Longitudinal parenchyma metatracheal; cells solitary or as tangential multiples of 2-cells with dark resinous contents, occasionally grouped in a large area. Rays uniseriate, 1-31 plus cells in height (less than 740 microns high), not infrequently biseriate, broadest rays 28.5 microns wide; ray parenchyma thin-walled on all faces; ray tracheids absent.

Uses: The wood is used for general construction, pencil stock and rail ties.

Remarks: Kanehira (30) reports C. konishii Hay. as a light yellow-brown wood with one-two rows of bordered pits on radial walls of springwood tracheids.

CUPRESSACEAE

The family comprises 15 genera, 6 of which are monotypic, and about 130 species widely scattered throughout the world, most genera occur in both the Northern and Southern Hemispheres (21, 37). There are 2 genera and 3 species in Taiwan (32). The woods of all three species are described.

Anatomical Features: Longitudinal tracheid diameters 35 microns; pitting uniseriate, occasionally biseriate and rarely multiseriate; pits at ray crossing elliptic to circular borders and slit-like to narrow elliptic, vertical to diagonal apertures, 2-4 per crossing. Normal resin canals absent. Rays uniseriate, occasionally partly biseriate and rarely multiseriate, height variable, 10-40 cells high, resinous deposits usually abundant in heartwood; ray tracheids present, but none in Actinostrobus and Libocedrus in part (37).

Anatomical Features of Libocedrus: Longitudinal tracheid pitting sometimes biseriate in early wood, pits at ray crossing as in family description, the pits small. Longitudinal parenchyma abundant, distribution variable. Rays uniseriate, occasionally biseriate, 22-27 microns or up to 24 cells high (37).

Anatomical Features of Chamaecyparis: Longitudinal tracheid pitting uniseriate to biseriate in early wood, rarely multiseriate; pits at ray crossing as family description. Longitudinal parenchyma abundant, often banded tangentially, occasionally scattered. Rays uniseriate, rarely partly biseriate, 15-19 microns or up to 24 cells high; ray tracheids present, sometimes numerous (37).

Libocedrus formosana Hay.

Commercial Name: Shao-nan (mandarin).

Other Name: Hwang-roa-soo.

Tree: A large tree, ranging from 1,000 to 6,200 feet elevation from central to northern Taiwan associated with the hardwood forest.

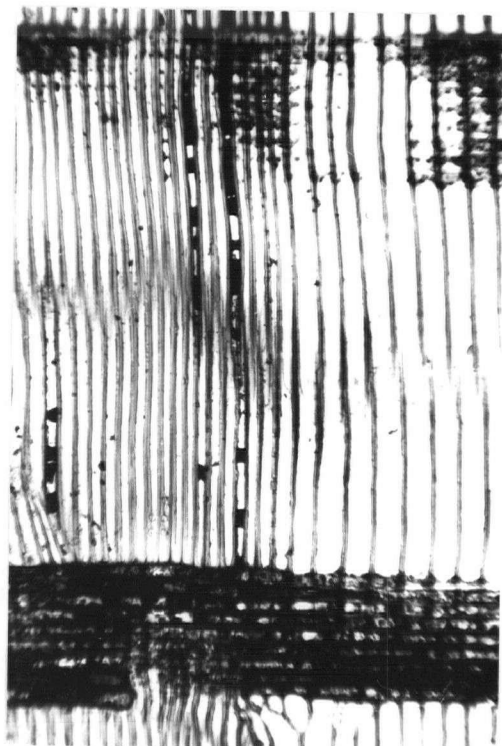
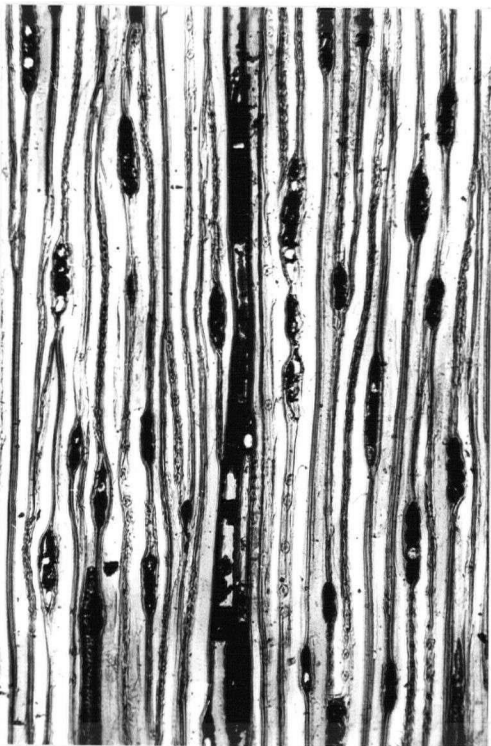
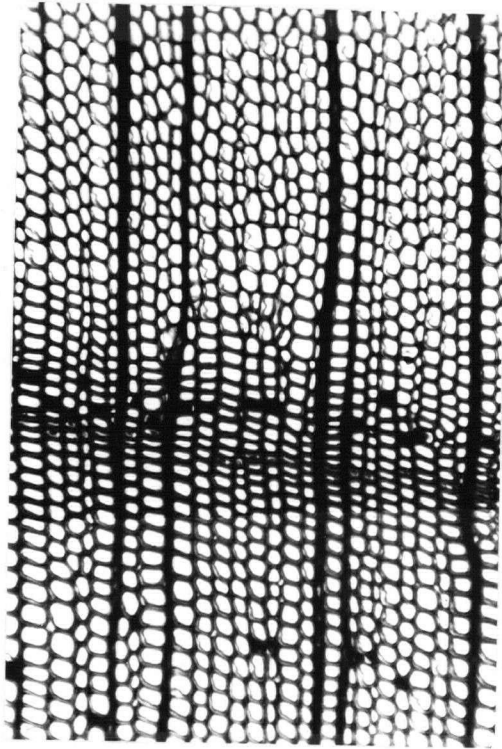


Fig. 4. Libocedrus formosana Hay.
(x-sec.; t-sec. and r-sec.) at 100 x

General Properties: Wood red-brown with medium lustre; grain straight; texture medium; heavy, specific gravity 0.59 (37 pounds per cubic foot); with fragrant odor, but no characteristic taste.

Macroscopic Features: Growth rings not very distinct, but with regular contour due to narrow bands of darker summerwood, springwood to summerwood transition gradual. Resin canals absent.

Microscopic Features: (See Fig. 4) Longitudinal tracheids mostly 30-35 (average 32) microns in diameter, 2.5-3.0 (average 2.8) millimeters in length; bordered pitting on radial walls first-formed springwood as one row, bordered pitting absent on tangential walls last-formed summerwood; pits at ray crossings medium, round to lenticular, 1-2 (mostly 2) per crossing; spiral thickening absent. Longitudinal parenchyma terminal and metatracheal. Rays uniseriate 1-13 plus cells in height (less than 50 microns high); ray parenchyma thin-walled on all faces; ray tracheids absent.

Uses: The wood is mostly used for structural purposes, furniture, carving and decoration.

Remarks: Kanehira (30) reports similar features for L. macrolepis Benth., except for tracheid length at 3.3-3.8 millimeters.

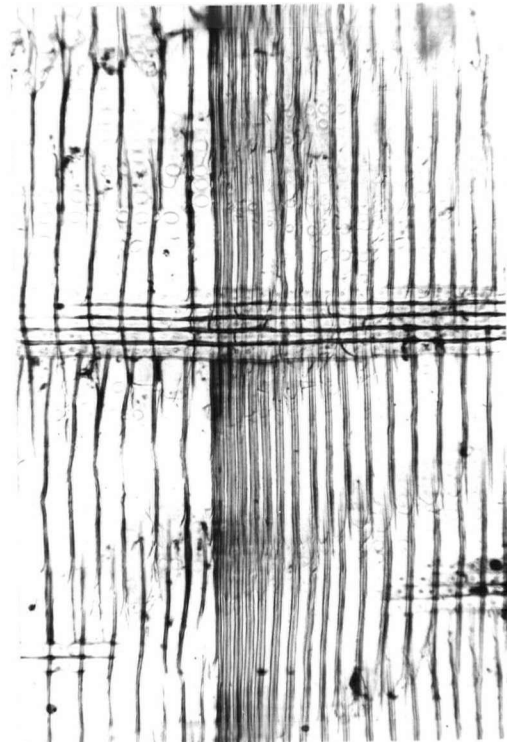
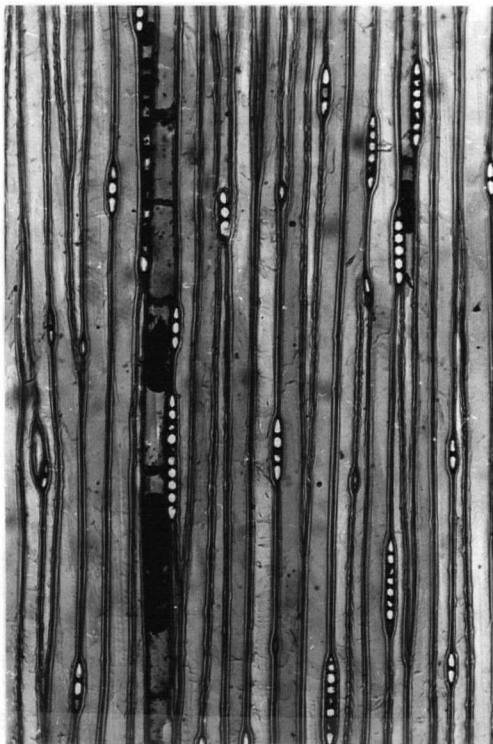
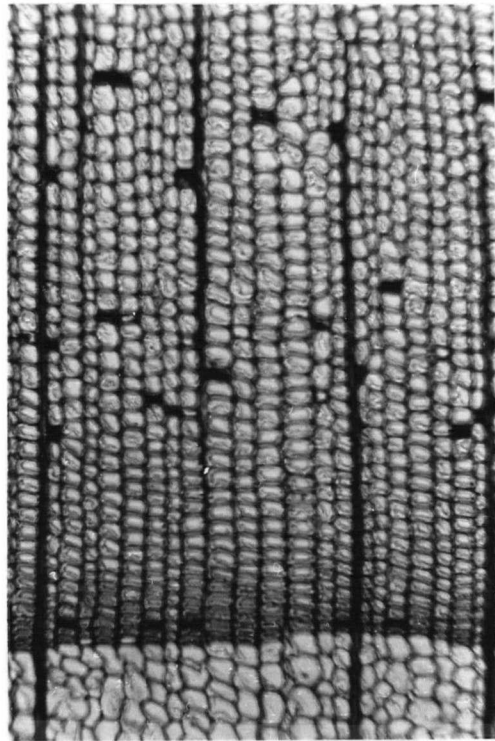


Fig. 5. Chamaecyparis formosensis Matsum.
(x-sec., t-sec. and r-sec.) at 100 x

Chamaecyparis formosensis Matsum.

Commercial Name: Red cypress, Hon-gha (mandarin).

Other Names: Bao-pi (thin bark), Ben-ni-hi (Japanese).

Tree: The largest of all Taiwan conifers, up to 36 feet in diameter and 148 feet in height; ranging from 3,400 to 6,600 feet elevation from central to northern Taiwan; associated with Chamaecyparis taiwanensis, Tsuga chinensis, Pinus armandi, Taxus chinensis and Taiwania cryptomerioides in the forest, or associated with hardwoods such as Neolitsea acuminatissima, Machilus pseudolongifolia, Quercus morii, Trochodendron aralioides, Schefflera taiwaniana, Acer rubescens and Castanopsis spp.

General Properties: Wood red to pink with medium lustre; grain straight; texture medium; moderately heavy, specific gravity 0.45 (28 pounds per cubic foot); with pronounced fragrant odor and spicy acrid taste.

Macroscopic Features: Growth rings distinct with regular contour due to slight darkening of terminal tissues, springwood to summerwood transition gradual to abrupt. Resin canals absent.

Microscopic Features: (See Fig. 5) Longitudinal tracheids mostly 30-40 (average 34) microns in diameter, 4.0-4.5 (average 4.1) millimeters in length; bordered pitting on radial walls first-formed springwood as one row, bordered pitting present on tangential walls last-formed summerwood; pits at ray crossings medium, round, lenticular, 1-2 per crossing; spiral thickening absent. Longitudinal parenchyma terminal, metatracheal and metatracheal-diffuse or occasionally more or less tending toward zonation. Rays uniseriate, 1-15 plus cells in height (less than 24 microns high); marginal ray tracheids present; ray parenchyma thin-walled on all faces.

Uses: The wood is used for structural purposes, furniture manufacture, rail ties, boat building and plywood manufacture.

Remarks: Kanehira (30) has reported similar features for C. formosensis Matsum.

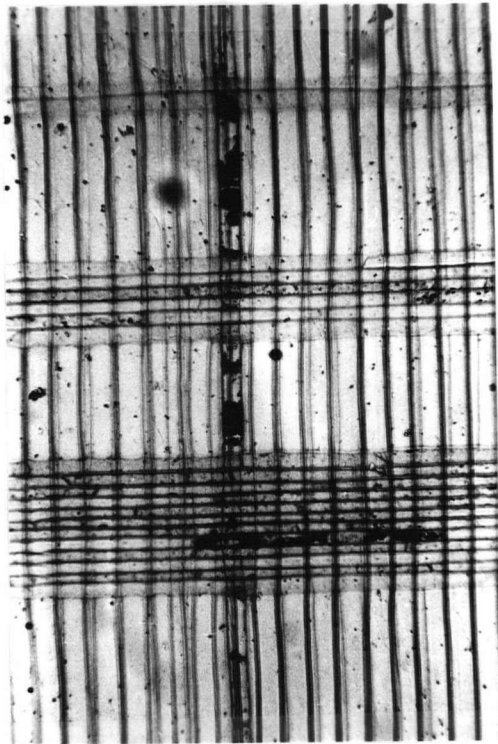
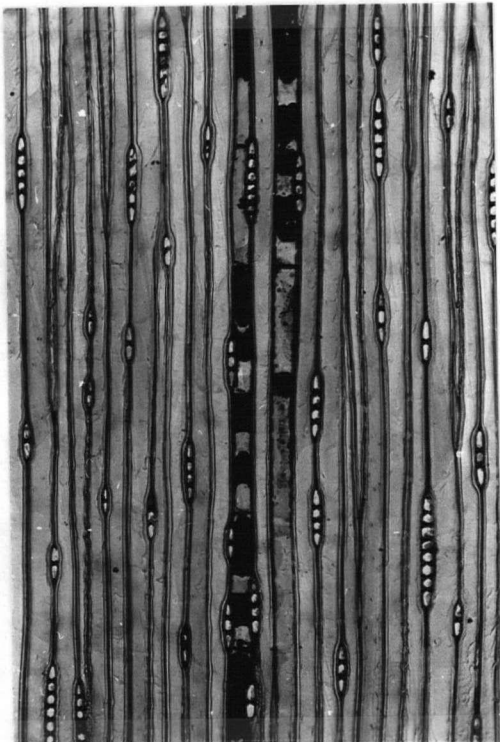
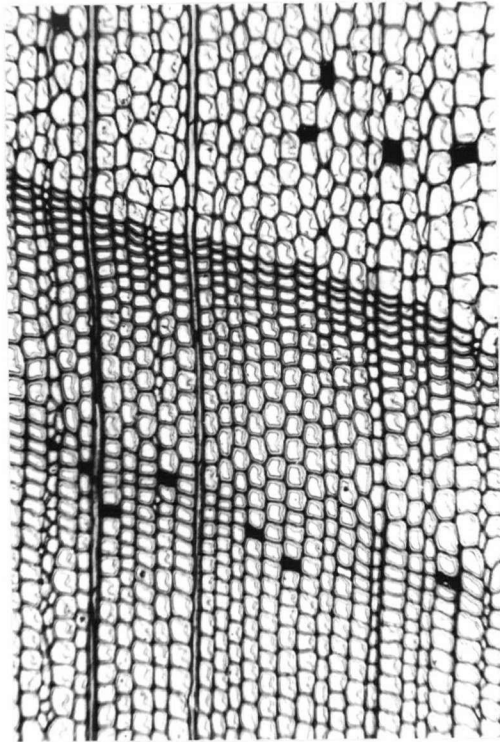


Fig. 6. Chamaecyparis taiwanensis Masam. et Suzuk.
(x-sec., t-sec. and r-sec.) at 100 x

Chamaecyparis taiwanensis Masam. et Suzuk.

Commercial Name: Yellow cypress, Pin-ber (mandarin).

Other Names: Hoo-pi (thick bark), Hi-nor-ki (Japanese).

Tree: A large tree, ranging from 4,300 to 9,200 feet elevation from the central mountains to eastern Taiwan; associated with Chamaecyparis formosensis, Tsuga chinensis, Pinus armandi, Taxus chinensis and Taiwania cryptomerioides.

General Properties: Wood yellow with red strips and low lustre; grain straight; texture medium; moderately heavy, specific gravity 0.48 (30 pounds per cubic foot); with fragrant odor and acrid taste.

Macroscopic Features: Growth rings distinct with regular contour due to slight darkening of terminal tissues, springwood to summerwood transition gradual. Resin canals absent.

Microscopic Features: (See Fig. 6) Longitudinal tracheids mostly 30-35 (average 34) microns in diameter, 3.5-4.0 (average 3.7) millimeters in length; bordered pitting on radial walls first-formed springwood as one row, bordered pitting present on tangential walls last-formed summerwood; pits at ray crossings small, orbicular to lenticular, 2-4 (mostly 2) per crossing; spiral thickening absent. Longitudinal parenchyma metatracheal-diffuse. Rays uniseriate, 1-11 plus cells in height (less than 20 microns high); marginal ray tracheids present and entirely forming some low rays, walls dentate; ray parenchyma thin-walled on all faces.

Uses: The wood is used for structural timbers, general construction, furniture, wagons, agricultural implements, carving and plywood. In addition, wood shavings are used for making hats.

Remarks: Kanehira (30) does not record C. taiwanensis Masum. et Suzuk., but does report on C. obtusa S. et Z. with light yellow-brown heartwood and slightly finer texture in comparison to C. formosensis Matsum.

ARALIACEAE

The family comprises 56 genera and many species of trees and shrubs, mostly tropical (35). There are 11 genera and 14 species in Taiwan (30, 32). The wood of one timber species is described.

Taxonomic Notes: The genera in this family are not very clearly defined (35).

Anatomical Features: Several genera are ring-porous, while others are diffuse-porous (39). Pore arrangements are solitary, as short radial multiples and as clusters. Intervascular pitting is coarse with a tendency toward scalariform. Perforation plates are simple or scalariform. Medium length to moderately short fibres are commonly septate in the simple pitting. Longitudinal parenchyma is paratracheal and extremely sparse. Rays are heterogeneous, up to 4-6 cells wide (35).

Anatomical Features of Scheffera: All features are as the above description. In addition, intervascular pitting is alternate and perforation plates are scalariform. Intercellular canals are reported in rays of some species (35).

Scheffera octophylla (Lour.) Harms.

Commercial Name: Chian-moo (mandarin).

Other Names: Ya-moo-pan.

Tree: A semi-deciduous tree, up to 65 feet in height and 28 inches in diameter; occurring at sea level about the whole island.

General Properties: Heartwood yellowish-white with medium lustre; grain wavy; texture fine; moderately heavy, specific gravity 0.46 (29 pounds per cubic foot); without characteristic odor or taste.

Macroscopic Features: Growth rings indistinct. Vessels visible at 10 x magnification; wood diffuse porous with pores evenly distributed. Pore arrangement solitary, as radial chain multiples up to 4 and as cluster groupings up to 5. Broad rays distinct.

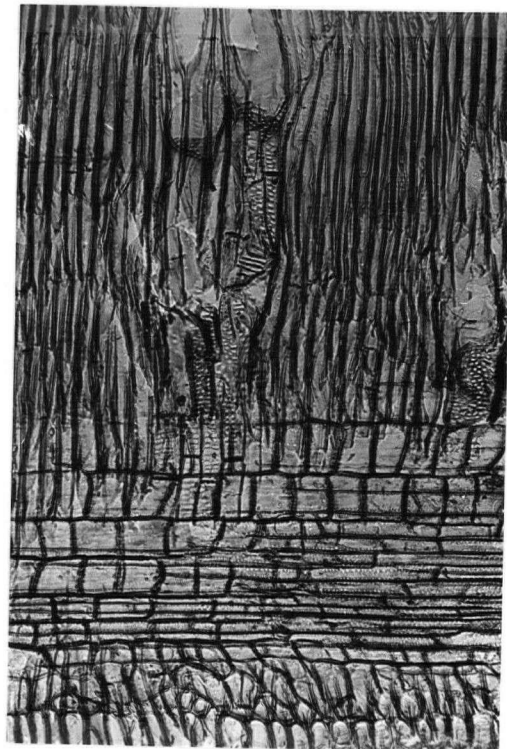
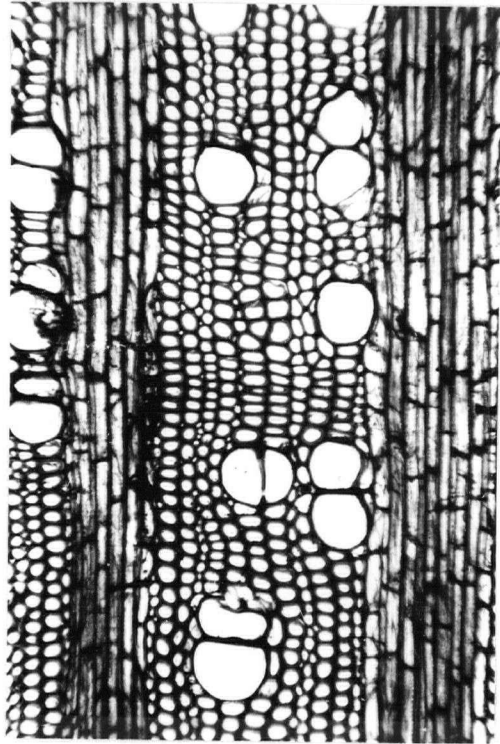


Fig. 7. Scheffera octophylla (Lour.) Harms.
(x-sec., t-sec. and r-sec.) at 100 x

Microscopic Features: (See Fig. 7) Vessels numerous 20-35 per square millimeter, the larger medium-sized mostly 100-110 (up to 135) microns in diameter; perforation plates scalariform with 3-13 bars 10 microns in thickness; intervessel pits orbicular, very small (4-5 microns in largest diameter), close, orifices lenticular, oppositely arranged in transverse rows. Fibres thick-walled; extremely coarse, mostly 30-35 (average 33) microns in diameter; medium length 1.0-1.5 (average 1.4) millimeters; longitudinal parenchyma metatracheal diffuse with cells widely spaced. Rays of two types: simple, very low 0.53 mm. or up to 8 cells high; multiseriate moderately broad 140 micron or up to 10 cells wide; simple rays comprised entirely of procumbent cells.

Use: The wood is used for furniture, back boards, tea cases, wooden slippers, match-stick blocks and mechanical pulp.

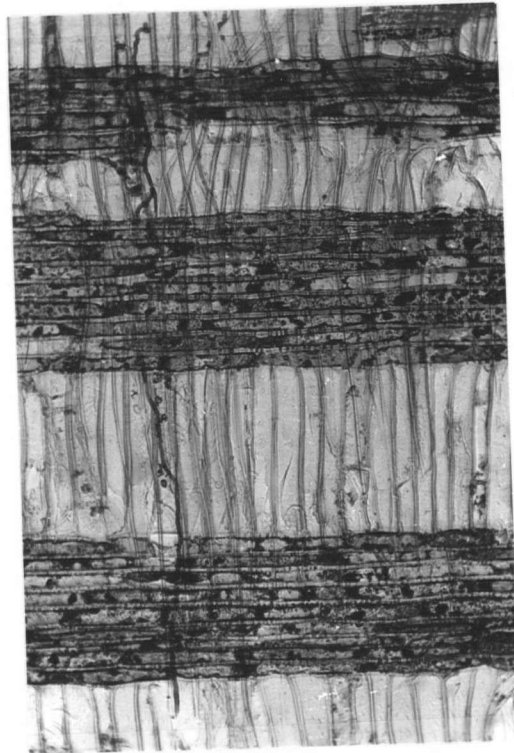
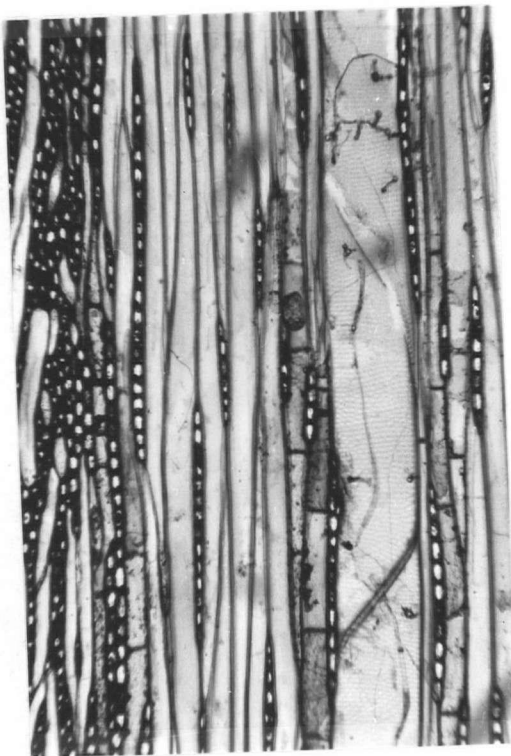
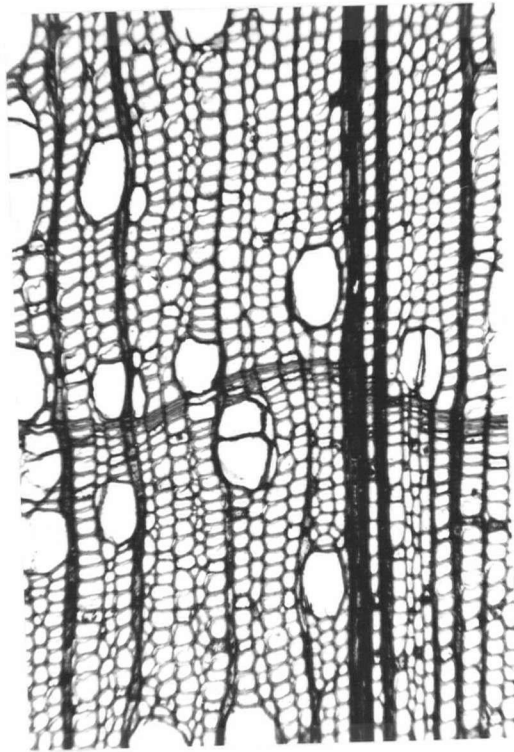


Fig. 8. Alnus formosana (Burkill.) Makino.
(x-sec., t-sec. and r-sec.) at 100 x

BETULACEAE

The family includes 6 genera and about 100 species of deciduous trees and shrubs which are restricted mostly to cooler regions of the Northern Hemisphere (21). There are 2 genera and 2 species in Taiwan (30,32). The woods of both species are described.

Taxonomic Notes: Alnus is considered the most primitive, while Carpinus is the least primitive (35).

Anatomical Features: Diffuse-porous (39). Vessels small; perforation plates scalariform with many bars. Fibres of medium length to moderately long. Longitudinal parenchyma diffuse and terminal. Rays of two types, homogeneous, 3-4 cells wide or exclusively uniseriate; aggregate (35).

Alnus formosana (Burkill.) Makino.

Commercial Name: Formosan alder, Chi-yung (mandarin).

Other Names: Sau-low-tsu.

Tree: A deciduous tree, up to 31 inches in diameter; ranging from sea level to 8,200 feet elevation.

General Properties: Seasoned heartwood light brown with high lustre; grain straight; texture fine to medium; moderately heavy, specific gravity 0.44 (27.5 pounds per cubic foot); without characteristic odor or taste.

Macroscopic Features: Growth rings distinct due to bands of darker terminal fibres. Vessels visible at 10 x magnification; wood diffuse porous with pores evenly distributed. Pore arrangement solitary and in radial chain multiples up to 4. Broad rays distinct.

Microscopic Features: (See Fig. 8) Solitary vessels elliptical or oval, numerous 20-35 (mostly 20) per square millimeter, the larger mostly moderately small 85-95 (up to 115) microns in diameter;

perforation plates scalariform with 10-25 bars 7 microns in thickness; intervessel pits orbicular to oval, very small (4.5-5.5 microns in largest diameter), close, orifices lenticular, oppositely arranged as transverse rows. Fibres septate, thin-walled; pits distinct; extremely coarse mostly 30-35 (average 32) microns in diameter, medium length 1.5-2.0 (average 1.4) millimeters. Longitudinal parenchyma metatracheal diffuse, fusiform cells absent. Rays of two types: simple uniseriate very low up to 0.54 millimeters or 19 plus cells high; aggregate rays very broad 210 microns, containing units similar to simple rays, but with longitudinal fibers and vessels included; simple rays homogeneous, all cells procumbent; cells with contents.

Uses: The wood is used for tea cases, mine props, charcoal production and for making mechanical and chemical pulp.

Remarks: Wood from this species was previously described by Kanehira (30) as semi-diffuse porous. Other differences include his measurements of 35-50 vessels per square millimeter, inter-vessel pits at 9 microns, and simple rays up to 30 cells high.

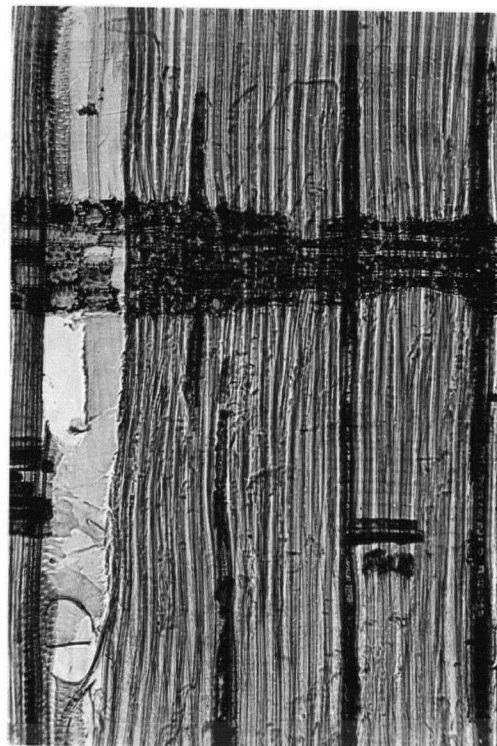
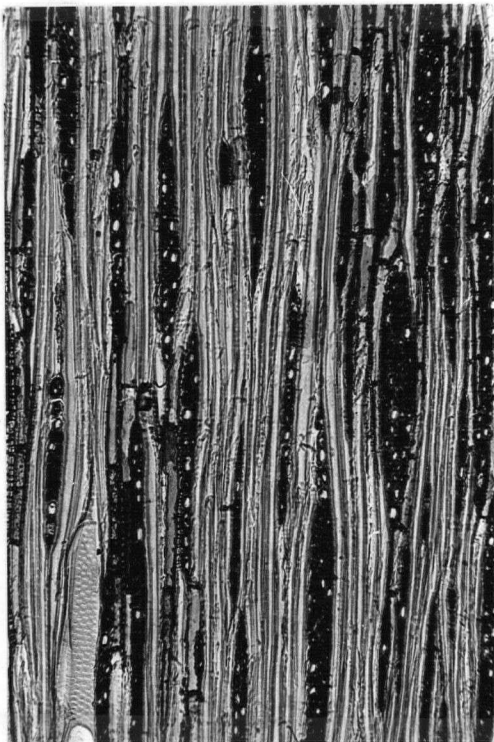
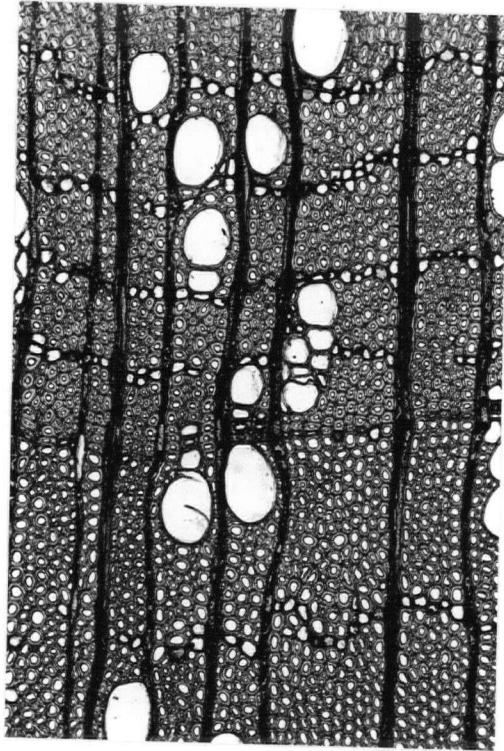


Fig. 9. Carpinus kawakamii Hay.
(x-sec., t-sec. and r-sec.) at 100 x

Carpinus kawakamii Hay..

Commercial Name: Shang-son-soo-li (mandarin).

Other Names: Chi-go.

Tree: A medium-sized deciduous tree, up to 20 inches in diameter; ranging from central to southern Taiwan.

General Properties: Heartwood light gray with low lustre; grain straight; texture medium; heavy, specific gravity 0.68 (42.5 pounds per cubic foot); without characteristic odor and taste.

Macroscopic Features: Growth rings undulating and distinct to the naked eye due to a line of terminal parenchyma. Vessels visible at 10 x magnification; wood diffuse porous with pores evenly distributed. Pore arrangement solitary, as radial chain multiples up to 6 plus and in cluster groupings of several.

Microscopic Features: (See Fig. 9) Solitary vessels elliptical, numerous 20-40 per square millimeter, the larger moderately small mostly 70-80 (up to 90) microns in diameter; perforation plates simple, occasionally scalariform with 1-2 bars 5 microns in thickness; walls with spiral thickenings; intervessel pits orbicular, medium-sized (10-13 microns in largest diameter), widely spaced, orifices linear, oppositely arranged as transverse rows. Fibres very thick-walled; pits indistinct; moderately fine, mostly 15-18 (average 17) microns in diameter, medium length 1.0-1.8 (average 1.1) millimeters. Longitudinal parenchyma of two types; terminal 1-cell wide; and metatracheal-zonate 1-2 cells wide. Rays simple 1-2 seriate and very low 0.57 millimeters or up to 30 plus cells high; rarely 3 plus cells wide; mostly homogeneous, occasionally heterogeneous; cells containing dark deposits.

Uses: The wood is used as structural timbers (bridge work) and construction lumber, as well as for manufacture of wagons and agricultural implements.

Remarks: All features agree well with those reported by Kanehira (30): except that he records the wood as rosy-brown in color. He also examined a second species C. randaiensis Hay. which appears to have

different sized elements.

FAGACEAE

The family includes 6-9 genera (35, 37) and about 600 species of trees and shrubs scattered throughout both hemispheres, but occurring mostly in the northern temperate zone (21). There are about 4 genera and 13 species of trees in Taiwan (32, 35). The woods of six timber species are described.

Taxonomic Notes: The family seems to be more highly specialized anatomically than Betulaceae (35).

Anatomical Features: Pores solitary, very small to very large; perforation plates simple or scalariform in the smallest vessels (39). Fibre pits are simple to bordered. Longitudinal parenchyma is apotracheal, diffuse or in fine lines. Rays are heterogeneous, uniseriate or 20-60 cells wide (35).

Anatomical features of Castanopsis, Lithocarpus and Quercus: All features are as the above descriptions. Vessels are medium-sized to large among diffuse-porous species, while some temperate species are ring-porous; perforation plates are scalariform in some of the evergreen species of Quercus, tyloses sometimes occur in species of Quercus (39). Rays are exclusively uniseriate in Castanopsis and both uniseriate and multiseriate in Lithocarpus and Quercus, and aggregate commonly in all the genera. Vasicentric tracheids are characteristic of all three genera (35).

Castanopsis longicaudata Hay.

Commercial Name: Kow-tsu (mandarin).

Other Names: Va-yue-kaw.

Tree: A medium-sized deciduous tree, up to 16 inches in diameter; ranging from eastern to southern Taiwan.

General Properties: Heartwood medium brown in color without lustre; grain straight; texture coarse; heavy, specific gravity 0.62 (38.5 pounds per cubic foot); with characteristic odor and acrid taste.

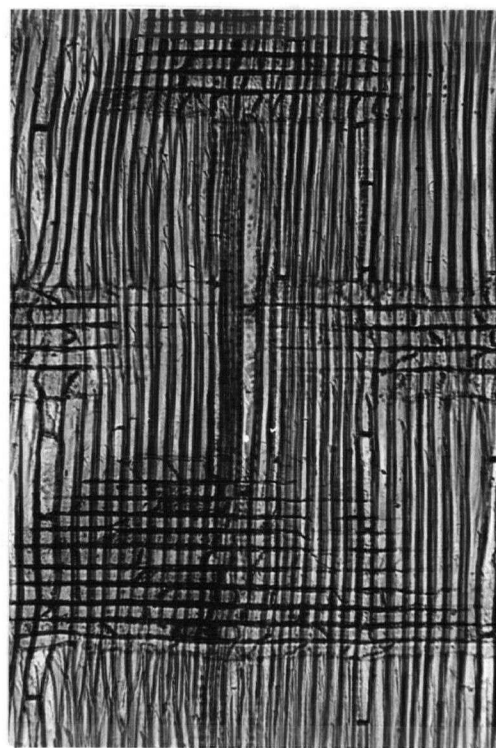
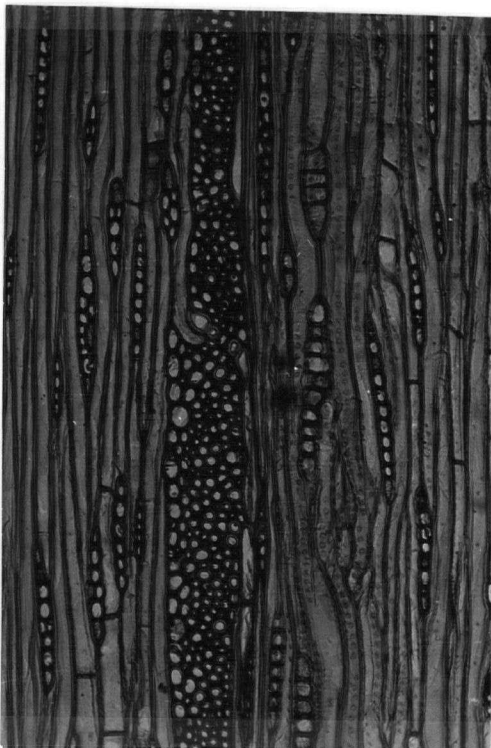
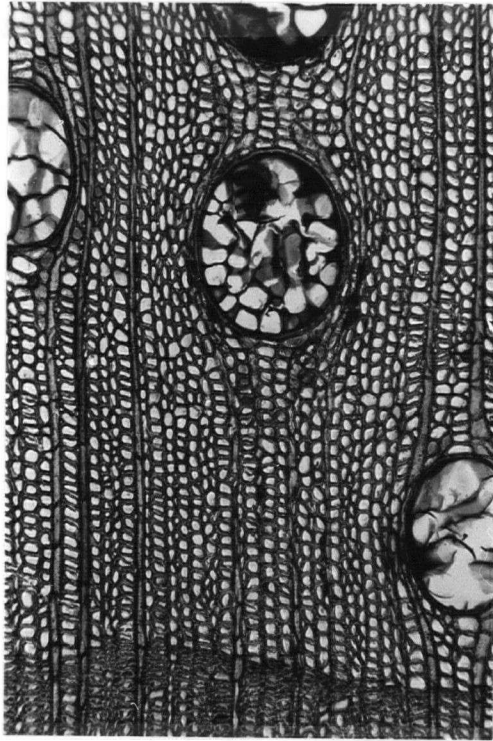


Fig. 10. Castanopsis longicaudata Hay.
(x-sec., t-sec. and r-sec.) at 100 x

Macroscopic Features: Growth rings distinct due to darker terminal bands of fibrous tissue. Largest vessels visible to the naked eye; wood ring porous. Summerwood pores arranged in cluster groupings; springwood pores with occasional tyloses evenly distributed and arranged solitary or as radial chain multiples. Aggregate rays distinct.

Microscopic Features: (See Fig. 10) Solitary vessels rounded, moderately few 5-15 per square millimeter, the larger medium-sized mostly 100-200 (up to 215) microns in diameter; perforation plates simple, occasionally scalariform in the smaller summerwood vessels with 1-2 bars 2.5 microns in thickness; summerwood intervessel pits orbicular, very small (5-6 microns in largest diameter), widely spaced, orifices lenticular, oppositely arranged as transverse rows. Fibres very thick-walled; round bordered pits distinct; medium diameter mostly 18-23 (average 20) microns, medium length 1.2-1.3 (average 1.2) millimeters. Longitudinal parenchyma metatracheal diffuse in fibrous tissues, sparse. Rays of two types: simple uniseriate very low 0.54 millimeter. or up to 17 plus cells high; aggregate moderately broad 132 microns or up to 7 seriate and including longitudinal fibres and small vessels; simple rays heterogeneous, upright cells marginal.

Uses: The wood is used for agricultural implements.

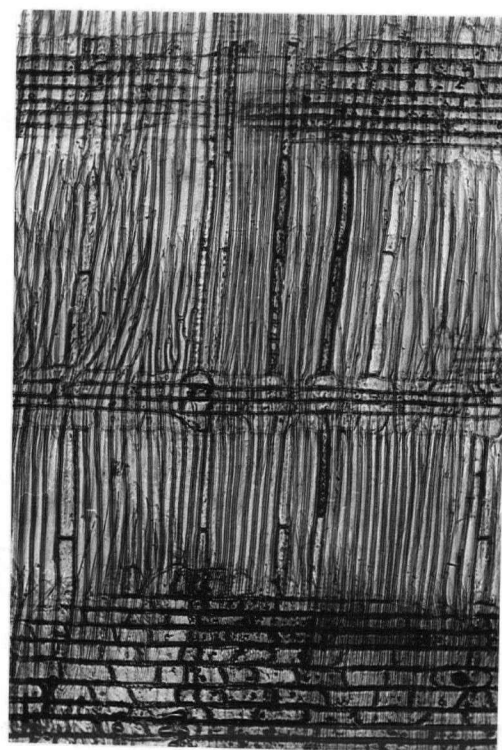
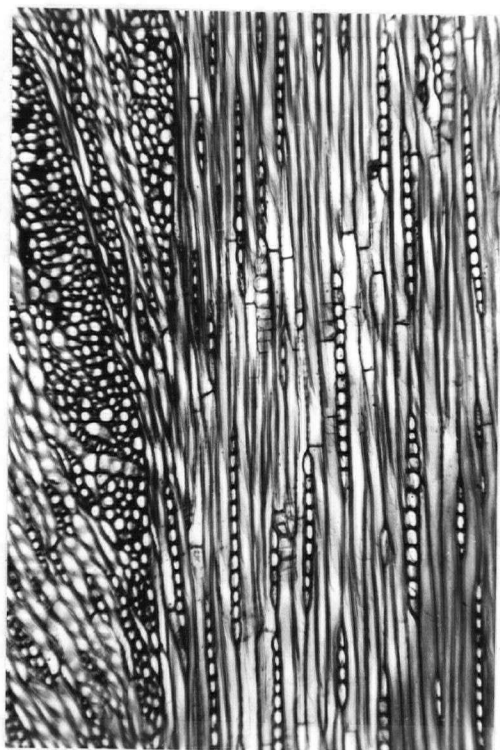
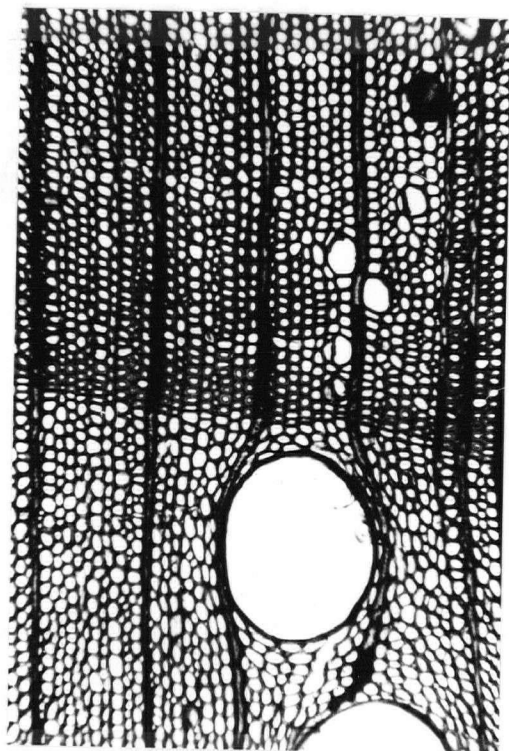


Fig. 11. Castanopsis stipitata Hay.
(x-sec., t-sec. and r-sec.) at 100 x

Castanopsis stipitata Hay.

Commercial Name: Dan-tau-shu-li (mandarin).

Other Names: Kaw-tsu.

Tree: An evergreen tree, up to 39 inches in diameter; ranging the whole island.

General Properties: Heartwood light brown without lustre; grain straight; texture coarse; heavy, specific gravity 0.64 (40 pounds per cubic foot); without characteristic odor and taste.

Macroscopic Features: Growth rings dimpled and distinct due to bands of thick-walled fibres. Largest vessels visible to the naked eye; wood ring porous. Summerwood pores small, unevenly distributed and occasionally containing tyloses. Pore arrangement solitary and in radial chain multiples up to 3. Aggregate rays distinct.

Microscopic Features: (See Fig. 11) Vessels moderately few 5-10 (mostly 10) per square millimeter, the larger moderately large 255-285 (up to 290) microns in diameter; perforation plates simple in both springwood and summerwood vessels; intervessel pits elongated, oval or orbicular, moderately small (6-7 microns in largest diameter), widely spaced, orifices lenticular, oppositely arranged as transverse rows. Vasicentric tracheids associated with springwood vessels with rounded bordered pits. Fibres very thick-walled; pits indistinct; medium diameter mostly 18-23 (average 19) microns, medium length 1.2-1.4 (average 1.3) millimeters. Longitudinal parenchyma of several types: terminal 1-cell wide; metatracheal-diffuse; metatracheal-zonate 2-3 cells wide; metatracheal-aggregates forming short tangential zones in the summerwood; and paratracheal-confluent forming irregular tangential or diagonal bands. Rays of two types: simple uniseriate extremely low 0.47 millimeters up to 18 cells high; aggregate extremely broad 440 microns up to many-seriate and including longitudinal fibres and small vessels; simple rays heterogeneous with small marginal upright cells; procumbent cells containing dark deposits.

Uses: The wood is used for construction of wagons and agricultural implements.

Remarks: Kanehira (30) described the wood from Taiwan species of Castanopsis including C. kawakamii Hay. C. taiwaniana Hay. C. formosana Hay. and C. subaciminata. All show some differences from C. longicaudata Hay. and C. stipitata Hay. reported here, although common elemental features of the genus persist.

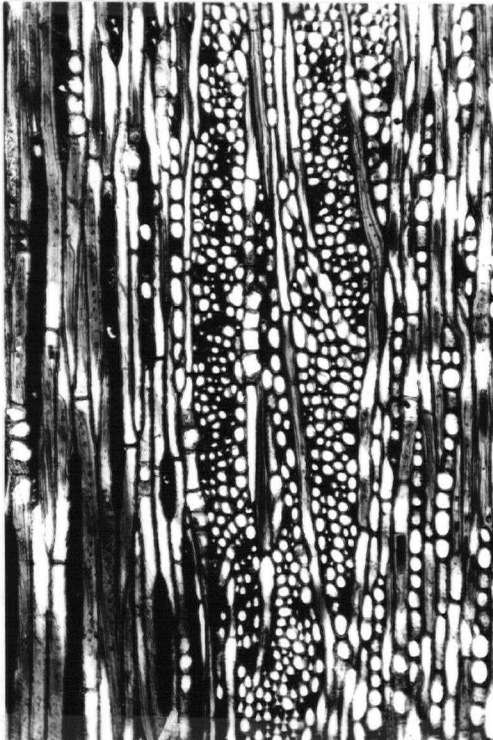
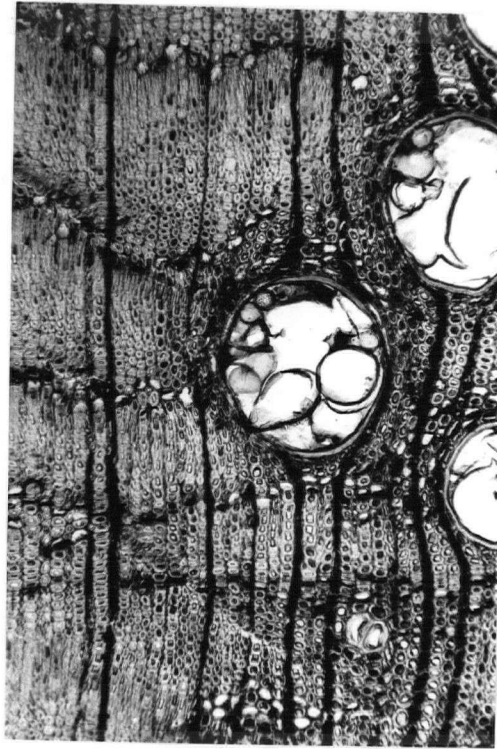


Fig. 12. Lithocarpus amygdalifolia Hay.
(x-sec., t-sec. and r-sec.) at 100 x

Lithocarpus amygdalifolia Hay.

Commercial Name: Gau-li (mandarin).

Other Names: Shi-li.

Tree: A large evergreen tree, up to 28 inches in diameter; mostly ranging from 4,900 to 6,600 feet elevation in central Taiwan.

General Properties: Heartwood light brown without lustre; grain straight; texture medium; heavy, specific gravity 0.70 (43.5 pounds per cubic foot); without characteristic odor or taste.

Macroscopic Features: Growth rings indistinct. Largest vessels visible to the naked eye; wood diffuse porous with pores unevenly distributed, thick-walled and containing tyloses. Pore arrangement solitary. Broad rays distinct.

Microscopic Features: (See Fig. 12) Vessels rounded, few 2-5 per square millimeter, the larger moderately large mostly 200-210 (up to 240) microns in diameter; perforation plates simple; intervessel pits orbicular, extremely small (2.4-3.6 microns in largest diameter), widely spaced, orifices lenticular, oppositely arranged as transverse rows. Vasicentric tracheids are present intermingled with parenchyma as 1-2 plus cells surrounding vessels and otherwise aggregated with longitudinal parenchyma; round bordered pits distinct. Fibres very thin-walled; pits indistinct; extremely coarse mostly 43-47 (average 45) microns in diameter, very long 2.2-3.7 (average 2.9) millimeters. Longitudinal parenchyma of several types: metatracheal-diffuse; metatracheal short tangential zones and aggregated; metatracheal-zonate usually 1-cell wide always combined with paratracheal-vasicentric. Rays of two types: simple uniseriate, numerous and variable in height (very low 0.55 millimeter or 2 plus cells high); aggregate rays very broad 230 microns, composed of simple rays separated by strands of fibrous tissue; simple rays homogenous to heterogenous, when heterogenous upright cells marginal; ray cells containing dark deposits.

Uses: The wood is used for general construction, agricultural implements and wooden slippers.

Remarks: Kanehira (30) does not record any Lithocarpus, but does report briefly on anatomy of Quercus amygdalifolia Skau. which closely matches the description of L. amygdalifolia Hay. given here, except that his sample had smaller fibres (14-16 microns in diameter and 0.8-1.5 millimeters in length).

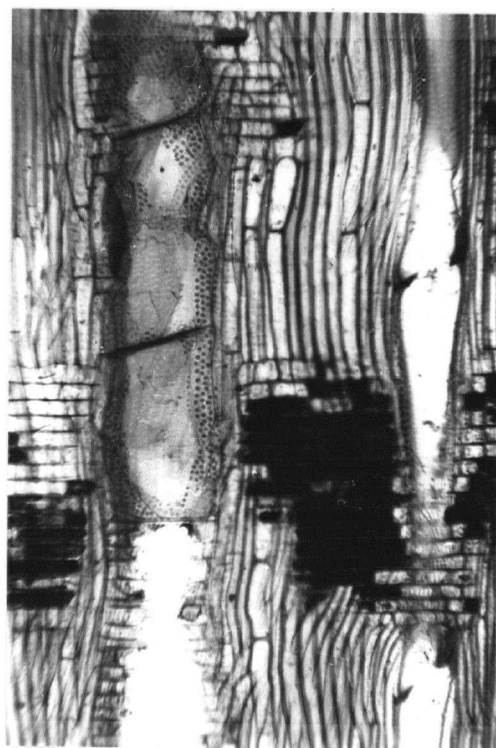
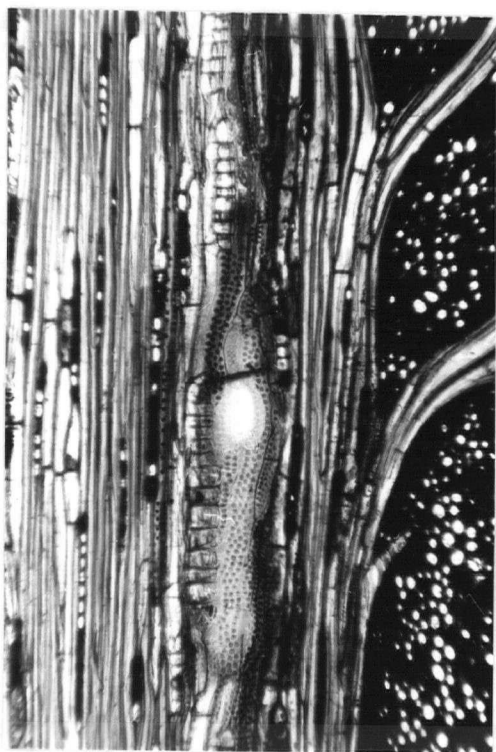
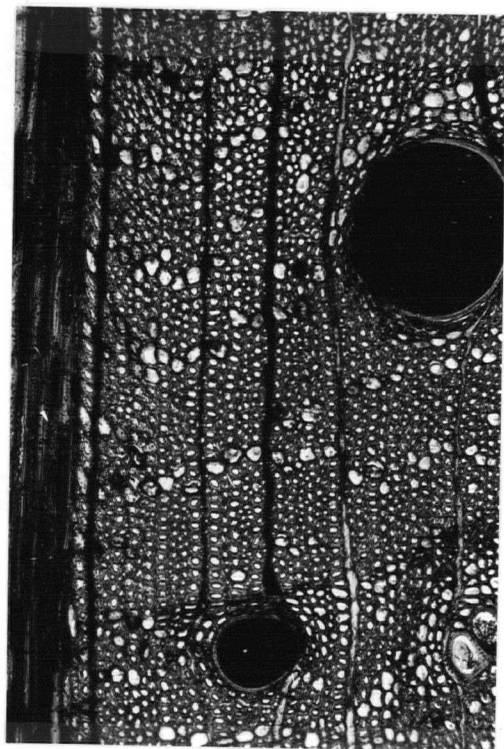


Fig. 13. Quercus gilva Bl.

(x-sec., t-sec. and r-sec.) at 100 x

Quercus gilva Bl.

Commercial Name: Si-choo (mandarin).

Other Names: Chi-pi.

Tree: A large evergreen tree, up to 10 feet in diameter; ranging from sea level to 800 feet elevation in northern Taiwan.

General Properties: Heartwood light pink with medium to high lustre; grain straight; texture medium to coarse; heavy, specific gravity 0.76 (47.5 pounds per cubic foot); without characteristic odor or taste.

Macroscopic Features: Growth rings indistinct. Largest vessels visible to the naked eye; wood diffuse porous with pores unevenly distributed and containing dark gum. Pore arrangement radial, solitary or as occasional pairs. Broad rays distinct.

Microscopic Features: (See Fig. 13) Vessels moderately few 5-8 (mostly 5) per square millimeter, the larger moderately large mostly 220-235 (up to 280) microns in diameter; perforation plates simple; intervessel pits orbicular, very small (4.8-6.1 microns in largest diameter), close, orifices round, alternately arranged spirally, or small, widely spaced pits oppositely arranged. Vasicentric tracheids present, with round, bordered pits; medium-sized mostly 0.9-1.3 millimeters in length. Vascular tracheids present as imperforate cells resembling small vessels in form. Fibres very thick-walled; pits indistinct; moderately fine 15-20 (average 17) microns in diameter, medium length 1.0-1.5 (average 1.4) millimeters. Longitudinal parenchyma of several types: metatracheal-diffuse; metatracheal-zonate; paratracheal-vasicentric 1-several cells wide, intermingled with vasicentric and vascular tracheids and extending to paratracheal-confluent. Rays of three types: simple uniseriate, numerous and varying in height extremely low 0.45 millimeter or up to 25 cells high; multiseriate very broad 340 microns or 18-25 cells wide; aggregate rays composed of simple rays and longitudinal fibres; simple rays homogeneous; cells usually containing dark deposits.

Uses: The wood is used for rail ties, agricultural implements and musical instruments.

Remarks: This description reconfirms that made by Kanehira (30) for wood from Q. gilva Bl., except for color which he records as dark red-brown.

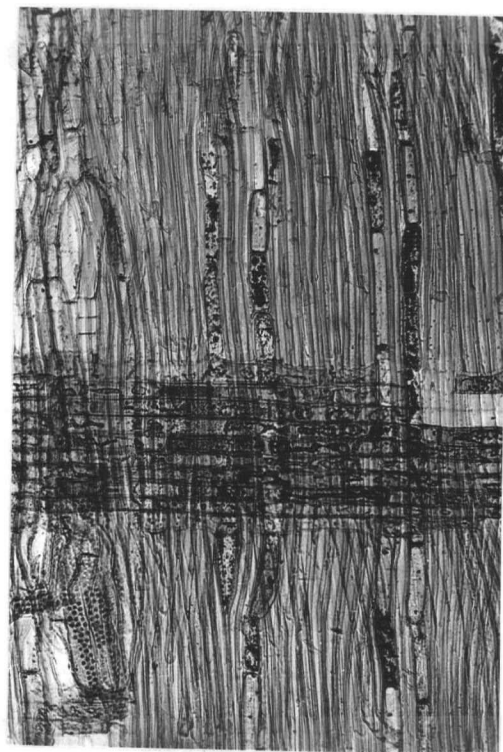
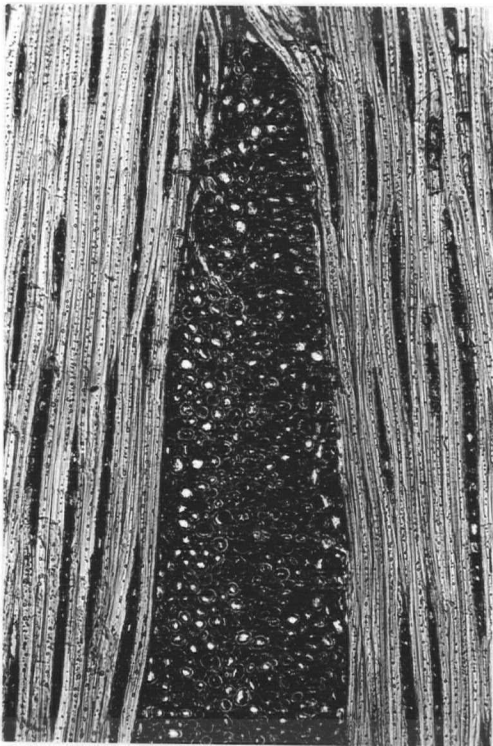
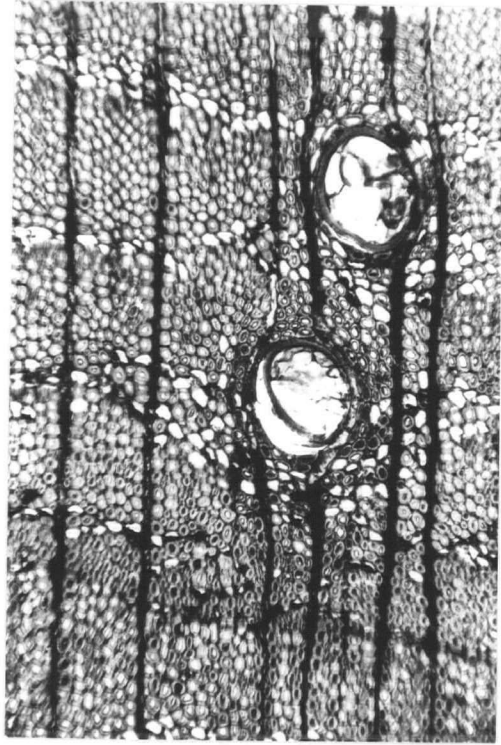


Fig. 14. Quercus longinux Hay.
(x-sec., t-sec. and r-sec.) at_100 x

Quercus longinux Hay.

Commercial Name: Zou-go-li (mandarin).

Other Names: Dau-tsu.

Tree: A medium-sized evergreen tree, up to 23 inches in diameter; ranging from 2,600 to 4,600 feet elevation about the whole island.

General Properties: Heartwood pinkish brown with medium lustre; grain straight; texture coarse; very heavy, specific gravity 0.82 (51 pounds per cubic foot); without characteristic odor or taste.

Macroscopic Features: Growth rings indistinct. Largest vessels visible to the naked eye; wood diffuse porous with pores unevenly distributed and usually containing tyloses. Solitary pores arranged radially with elliptical, oval or rounded shape and mostly uniform in size. Broad rays distinct.

Microscopic Features: (See Fig. 14) Vessels few 2-5 (mostly 4) per square millimeter, the larger medium-sized mostly 160-180 (up to 190) microns in diameter; perforation plates simple; intervessel pits orbicular, very small (3.6-4.8 microns in largest diameter), widely spaced, orifices confluent, oppositely arranged as transverse rows. Vasicentric tracheids are present with rounded bordered pits. Fibres very thick-walled; pits indistinct; medium diameter mostly 16-18 (average 17) microns, medium length 1.1-1.6 (average 1.3) millimeters. Longitudinal parenchyma of several types: metatracheal-zonate up to 3-cells wide; paratracheal-vasicentric 1-several cells wide intermingled with vasicentric tracheids and extending to paratracheal-aliform. Rays of two types: simple uniseriate, numerous and variable in height extremely low 0.35 millimeter or up to 25 cells high; aggregate rays very broad 390 microns or 20-24 plus cells wide through the central portion in association with fibres, vessels and tracheids; simple rays heterogeneous, upright cells marginal.

Uses: The wood is used for rail ties and agricultural implements.

Remarks: This confirms and expands on the brief anatomical account given by Kanehira (30) for Q. longinux Hay.

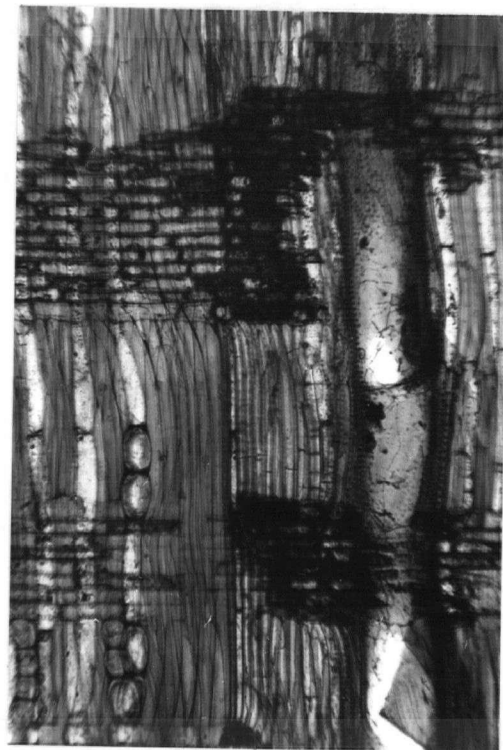
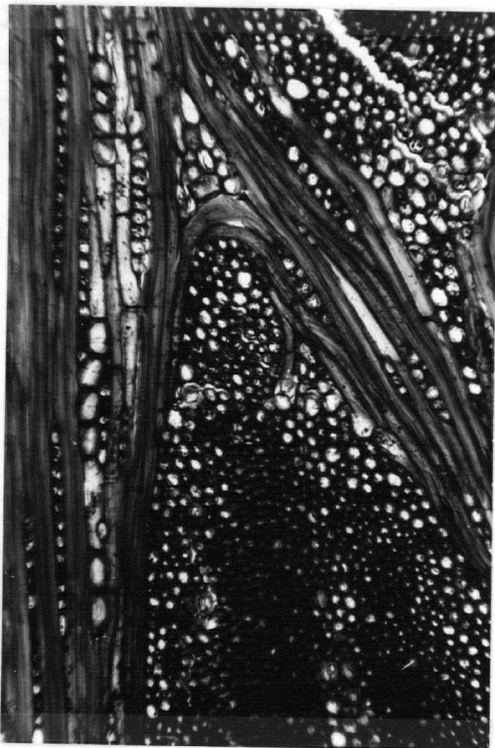
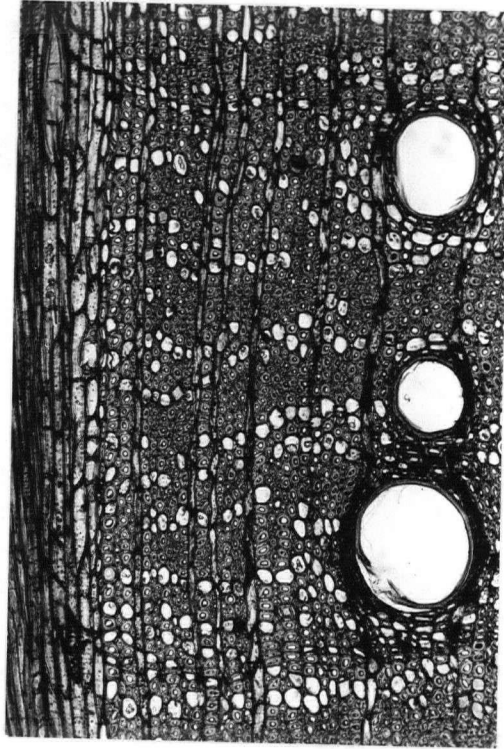


Fig. 15. Quercus stenophylloides Hay.
(x-sec., t-sec. and r-sec.) at 100 x

Quercus stenophylloides Hay.

Commercial Name: Arisan-li (mandarin).

Other Names: Gau-san-li.

Tree: A medium-sized evergreen tree, up to 16 inches in diameter; occurring in the Arisan mountains of central Taiwan.

General Properties: Heartwood medium brown in color without lustre; grain straight; texture coarse; very heavy, specific gravity 0.79 (49 pounds per cubic foot); without characteristic odor or taste.

Macroscopic Features: Growth rings barely distinct, partially delineated by dark bands of thick-walled fibres. Largest vessels visible to the naked eye; wood ring porous with summerwood pores unevenly distributed, thick-walled, round or oval. Solitary pores arranged radially with wide spacing and with very wide spacing between radial rows. Broad rays conspicuous.

Microscopic Features: (See Fig. 15) Vessels few 3-8 (mostly 4) per square millimeter, the larger medium-sized mostly 180-210 (up to 230) microns in diameter; perforation plates simple in both springwood and summerwood; intervessel pits orbicular, very small (4.8-6.5 microns in largest diameter), widely spaced, orifices round, oppositely arranged as transverse rows. Fibres very thick-walled; pits indistinct; moderately fine mostly 13-17 (average 15) microns in diameter, medium length 1.2-1.5 (average 1.4) millimeters. Longitudinal parenchyma of several types: sparse, metatracheal-diffuse; numerous and conspicuous metatracheal-zonate mostly 2-3 cells wide; paratracheal-vasicentric 2-several cells wide. Rays of two types: simple very numerous, uniseriate and variable in height, very low 0.7 millimeter or up to 13 plus cells high; multiseriate extremely broad 550 microns or up to 35 cells wide; simple rays homogeneous; cells without dark deposits.

Uses: The wood is used for railties and agricultural implements.

Remarks: Wood of Q. stenophylloides Hay. was briefly described by Kanehira (30), with features matching those given here in more detail.

JUGLANDACEAE

The family includes 6 genera and about 40 species of trees and large shrubs which are widely distributed through the northern temperate zone, and to a lesser extent in tropical regions of both the northern and southern hemispheres (21). There are 4 genera and 4 tree species in Taiwan (30, 32, 35). The wood of one timber species is described.

Taxonomic Notes: The family is commonly regarded as primitive due to the occurrence of sieve tubes with lateral sieve areas (35).

Anatomical Features: Ring to diffuse-porous with pores widely variable in size, especially in ring-porous types; perforation plates usually simple, only scalariform in Alfaroa and Engelhardtia (43). Fibre pits are bordered. Longitudinal parenchyma is apotracheal, and intermediate between apotracheal and paratracheal. Rays are usually 1-7 cells wide, homogeneous to heterogeneous (35, 43).

Anatomical Features of Engelhardtia: Pore multiples up to 4 and loosely oblique in arrangement among some species; perforation plates simple or both simple and scalariform with few bars; intervascular pitting is alternate. Fibre pits are typically bordered. Parenchyma is typically apotracheal or as terminal bands; crystals present. Rays up to 2-4 cells wide (35).

Engelhardtia formosana Hay.

Commercial Name: Hwang-gii (mandarin).

Other Names: Lan-gii.

Tree: A semi-deciduous tree, up to 31 inches in diameter; ranging the whole island.

General Properties: Heartwood gray with medium lustre; grain straight; texture medium; heavy, specific gravity 0.65 (40.5 pounds per cubic foot); with disagreeable odor and taste.

Macroscopic Features: Growth rings barely distinct, delineated in part by wide dark bands of fibrous tissue. Largest vessels visible to the naked eye; wood diffuse porous with pores evenly distributed.

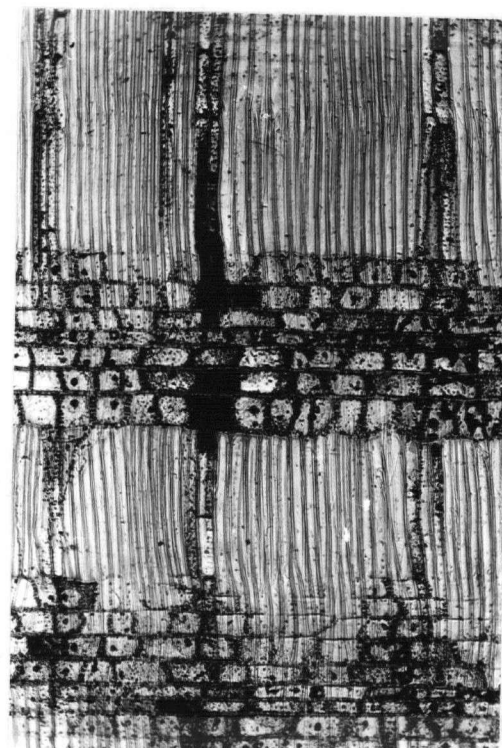
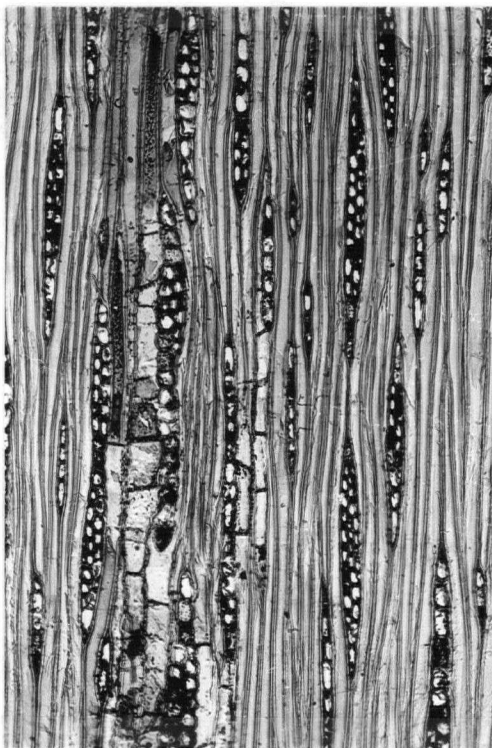
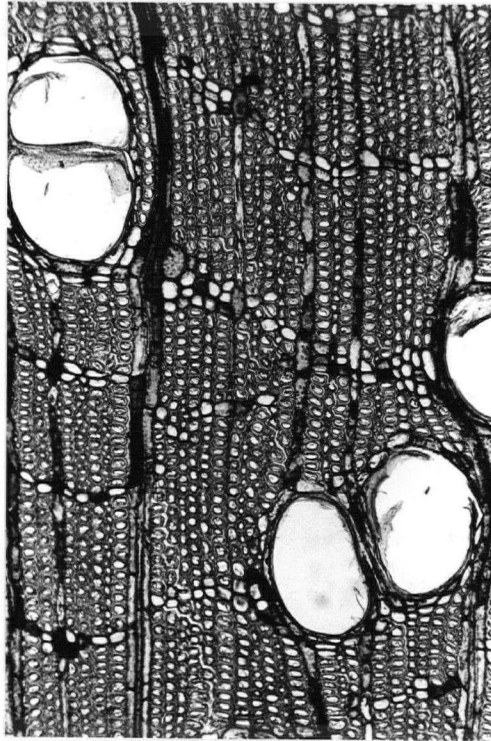


Fig. 16. Engelhardtia formosana Hay.

(x-sec., t-sec. and r-sec.) at 100 x

Pore arrangement solitary, as radial chain multiples up to 4 and in cluster groupings up to 4.

Microscopic Features: (See Fig. 16) Vessels moderately few, 5-12 per square millimeter, the larger elliptical moderately large, mostly 210-215 (up to 220) microns in diameter; perforation plates simple with a long tail; intervessel pits oval, very small (4.8-6.5 microns in largest diameter), widely spaced, orifices lenticular, oppositely arranged as transverse rows. Fibres very thick-walled; pits indistinct; moderately fine, mostly 15-20 (average 18) microns in diameter, medium length 1.0-1.5 (average 1.3) millimeters. Longitudinal parenchyma of two types: metatracheal-zonate 1-2 cells wide; paratracheal-vasicentric combining with metatracheal; paratracheal-vasicentric 1-3 cells wide; cells containing dark deposits and always with crystals. Rays simple; uniseriate very low 0.7 millimeter or up to 20 plus cells high, homogeneous; biseriate and triseriate rays numerous, heterogeneous, with upright cells marginal; cells containing dark deposits.

Uses: The wood is used for furniture manufacture, packing boxes, general construction and agricultural implements.

Remarks: Wood from E. formosana Hay. was described in detail by Kanehira (30). Data given here mostly reconfirms and elaborates on the original description.

LAURACEAE

The family comprises about 45 genera and 1,000 species of trees and shrubs which are mostly evergreen (21, 30, 32, 35, 40, 44). Many of these are tropical, although a few extend into the temperate zones. Many species are rich in fragrant substances and are the commercial source of aromatic products (33, 34, 39). There are 13 genera and more than 60 tree species in Taiwan. The genus, Cinnamomum includes numerous species used in Taiwan by the camphor industry. Unfortunately, many of these species are not morphologically distinguishable, but are classified by the quantity and constitution of camphor oil and camphor produced. The woods of eight timber species from this family are described.

Taxonomic Notes: The family is remarkably uniform in wood anatomy. The genera are by no means sharply defined (35).

Anatomical Features: Diffuse-porous, except Sassafras. Vessels are mostly medium-sized and solitary, occasionally with some multiples of 4 or more; perforation plates exclusively simple or scalariform with few bars; pitting coarse and alternate. Medium length to moderately short fibres have simple pits and are commonly septate. Parenchyma is paratracheal and typically scanty to vasicentric, occasionally aliform, terminal bands present in a few genera, often containing oil cells (35, 39, 40, 44). Rays are weakly heterogeneous to homogeneous, very fine, usually 2-3 cells wide, but up to 8 cells wide in some species, usually accompanied by few uniseriate rays. Oil or mucilage cells are a characteristic of the family, occurring in the longitudinal parenchyma or rays or, less commonly, in both, but seldom entirely absent (35, 44).

Anatomical features of Actinodaphne, Beilschmiedia, Cinnamomum and Machilus: Vessels 5 per sq. mm. in some species of Beilschmiedia and Cinnamomum; perforations typically simple (35, 40); intervascular pitting alternate and typically large. Fibre pits are typically simple, but with occasional small, rather indistinct borders in some of the species lacking septate fibres of Actinodaphne and

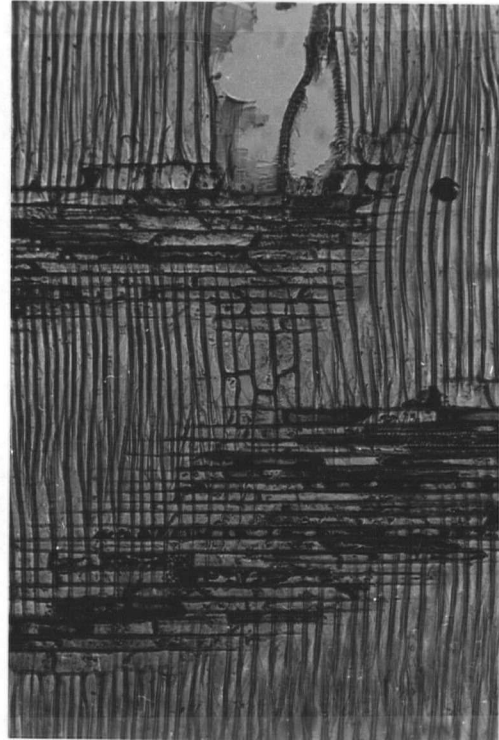
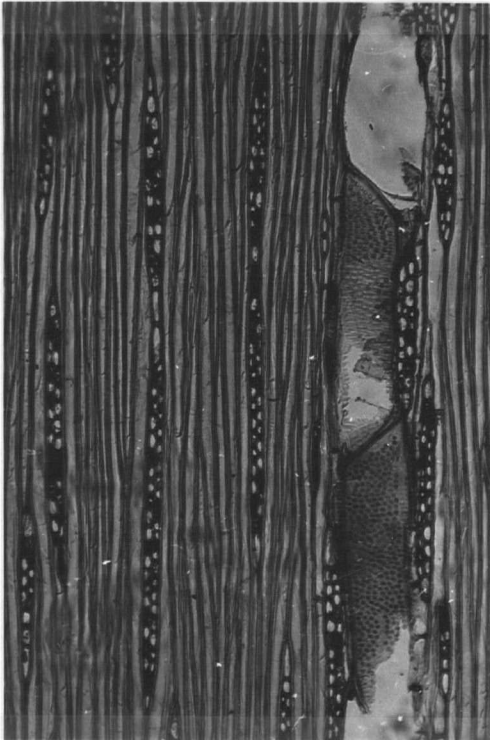
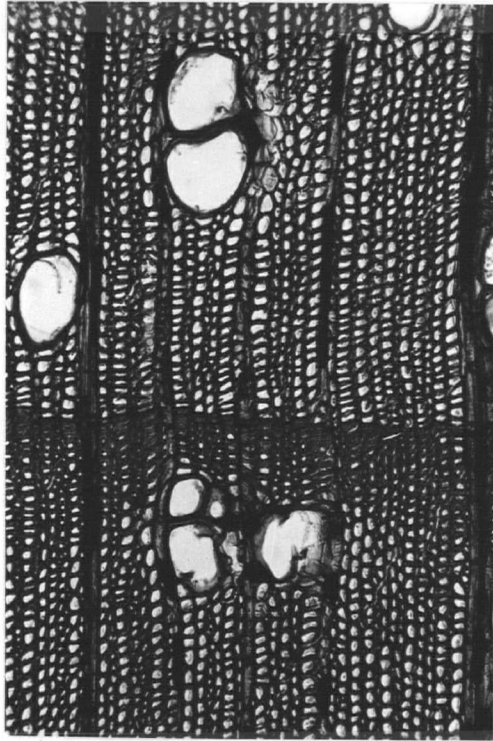


Fig. 17. Actinodaphne nantoensis Hay.
(x-sec., t-sec. and r-sec.) at 100 x

Beilschmiedia; septate in Cinnamomum and Machilus (35). Longitudinal parenchyma paratracheal as irregular and often incomplete sheaths around each vessel, sometimes tending to be aliform in Beilschmiedia or as irregularly spaced bands that appear terminal in some species of the genus. Rays typically 2-3 cells wide and up to 4-8 cells wide in some species of Beilschmiedia and Cinnamomum, composed entirely of upright cells in some species of Beilschmiedia. Oil or mucilage cells are a characteristic of the woods of these genera (40), occurring usually in either the wood parenchyma or ray parenchyma in Cinnamomum, but not observed or very rare in some species of Actinodaphne and Beilschmiedia (35, 40).

Actinodaphne nantoensis Hay.

Commercial Name: Hwang-loo-nan (mandarin).

Other Names: None known.

Tree: A small tree, ranging to about 4,900 feet elevation.

General Properties: Heartwood yellow-gray without lustre; grain wavy; texture medium to fine; heavy, specific gravity 0.60 (37.5 pounds per cubic foot); without characteristic odor or taste.

Macroscopic Features: Growth rings distinct due to bands of thick-walled fibres. Vessels visible at 10 x magnification; wood diffuse porous with pores evenly distributed. Pore arrangement solitary, as radial chain multiples up to 5 and in occasional cluster groupings up to 6.

Microscopic Features: (See Fig. 17) Vessels moderately numerous 10-20 per square millimeter, the larger moderately small, mostly 90-100 (up to 120) microns in diameter; perforation plates simple; intervessel pits orbicular, moderately small (7.5-9.5 microns in largest diameter), widely spaced orifices lenticular, oppositely arranged as transverse rows. Fibres very thick-walled; pits indistinct; moderately fine, mostly 15-20 (average 19) microns in diameter, medium length 1.0-1.5 (average 1.1) millimeters. Longitudinal parenchyma metatracheal-diffuse in fibrous tissues. Rays simple 1-2-seriate rarely triseriate, very low 0.55 millimeter or up to 9 plus cells high; heterogeneous.

Uses: The wood is used for agricultural implements and as fuel.

Remarks: Kanehira (30) has described the woods of A. citrata Hay. and A. pedicellata Hay. which appear to differ in minor ways from A. nantoensis Hay. as given here.

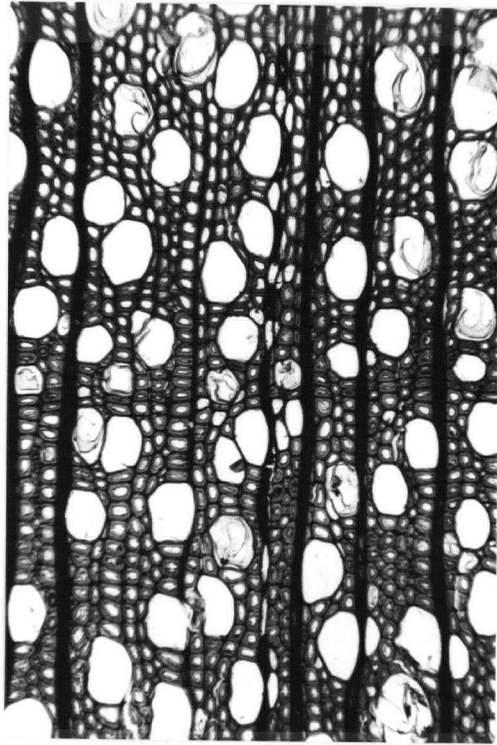


Fig. 18. Beilschmiedia erythrophloia Hay.
(x-sec., t-sec. and r-sec.) at 100 x

Beilschmiedia erythrophloia Hay.

Commercial Name: Kgin-nan (mandarin).

Other Names: Kue-gon-gu.

Tree: A large tree; ranging to about 7,200 feet elevation in central Taiwan, particularly in the Arisan mountain.

General Properties: Heartwood light brown with red strips and without lustre; grain straight; texture coarse; heavy, specific gravity 0.65 (40.5 pounds per cubic foot); without characteristic odor or taste.

Macroscopic Features: Growth rings distinct due to terminal parenchyma. Vessels invisible to the naked eye; wood diffuse porous with pores evenly distributed. Pore arrangement solitary and in radial chain multiples of 2-3.

Microscopic Features: (See Fig. 18) Vessels very numerous 55-85 per square millimeter, the larger very small 40-45 (up to 60) microns in diameter; perforation plates simple and scalariform with 10-14 bars 5 microns in thickness; intervessel pits orbicular, medium-sized (10-12 microns in largest diameter), widely spaced, orifices round, oppositely arranged as transverse rows. Fibres thick-walled; pits distinct and bordered; moderately coarse mostly 25-30 (average 27) microns in diameter, medium length 1.0-1.5 (average 1.3) millimeters. Longitudinal parenchyma of three types: terminal 3-8 cells wide; metatracheal-diffuse in fibrous tissues; paratracheal-vasicentric 1-5 cells wide, more or less confluent. Rays simple uniseriate and occasional biseriate very low 0.70 millimeter or up to 30 cells high; homogeneous, entirely upright cells; cells containing dark deposits.

Uses: The wood is used for general construction, furniture and agricultural implements.

Remarks: The wood of B. erythrophloia Hay. as detailed by Kanehira (30) varies from this description including color (yellow-gray), vessel size (60-160 microns in diameter) and fibre diameter (16-25 microns).

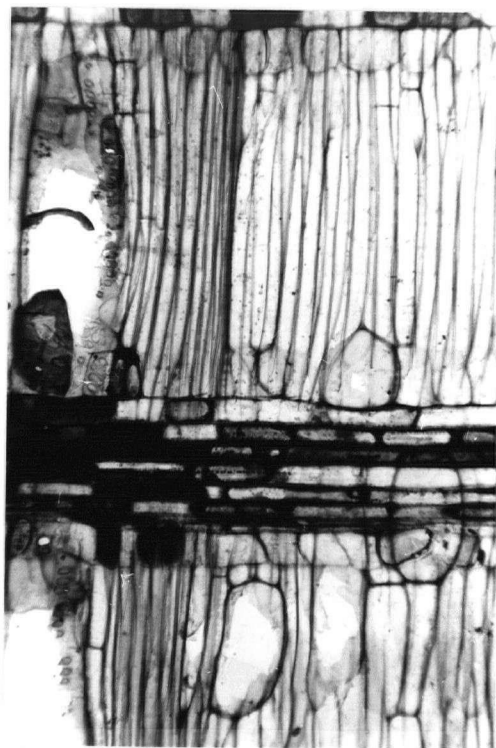
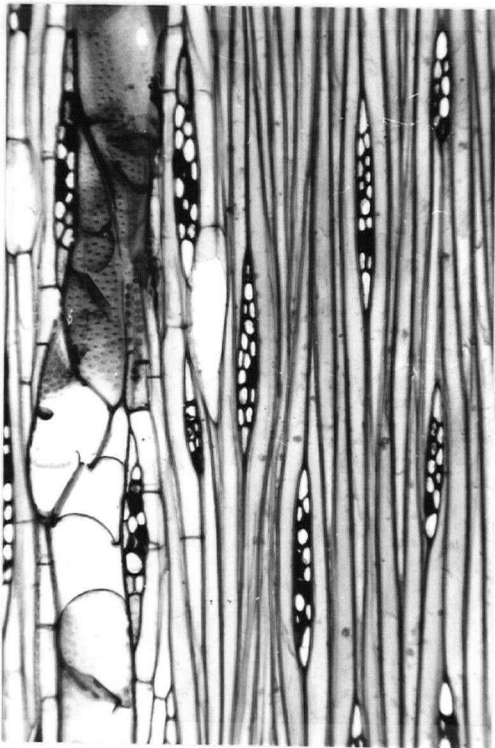
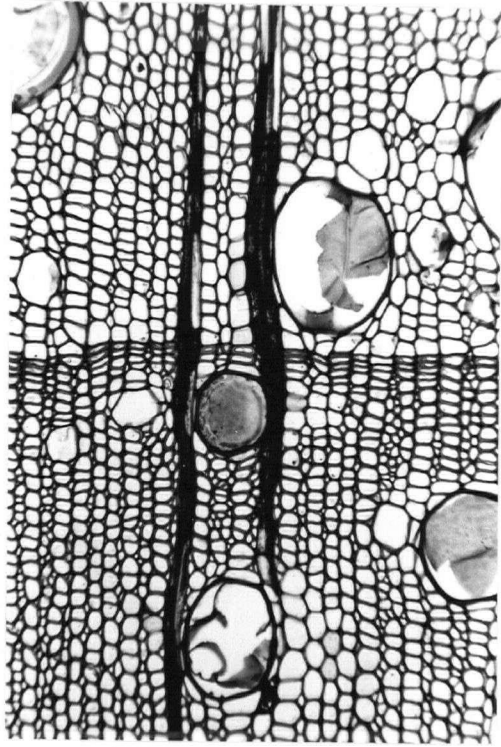


Fig. 19. Cinnamomum camphora Nees.
(x-sec., t-sec. and r-sec.) at 100 x

Cinnamomum camphora Nees.

Commercial Name: Chaun-sue (mandarin).

Other Names: None known.

Tree: A large tree; ranging from 3,900 to 5,900 feet elevation; occurring mostly in central Taiwan as pure forest stands or associated with Machilus spp.

General Properties: Heartwood light pink with dark stripes and high lustre; grain straight; texture medium to fine; heavy, specific gravity 0.64 (40 pounds per cubic foot); with characteristic camphor odor and taste.

Macroscopic Features: Growth rings distinct due to dark bands of fibrous tissue. Larger vessels visible to the naked eye; wood diffuse porous with pores evenly distributed and usually containing tyloses. Pore arrangement solitary and in radial chain multiples up to 3.

Microscopic Features: (See Fig. 19) Vessels moderately few 7-15 per square millimeter, the larger elliptical or oval medium-sized mostly 130-165 (up to 220) microns in diameter; perforation plates simple; intervessel pits orbicular, mostly medium-sized (9-13 microns in largest diameter), close, orifices linear, alternately arranged spirally. Fibres thick-walled; pits indistinct; medium diameter mostly 20-25 (average 22) microns, medium length 1.5-2.0 (average 1.8) millimeters. Longitudinal parenchyma of several types: metatracheal-diffuse; paratracheal-vasicentric 1-4 cells wide extending to paratracheal-aliform with short wings and paratracheal-confluent connecting 2-3 pores diagonally; large vertical oil cells usually surrounding vessels measure up to 63 microns wide and 256 microns high in tangential view. Rays simple, few uniseriate 2-3 cells high; numerous biseriate extremely low 0.45 millimeter, 8-12 cells high; heterogeneous; containing dark brown deposits; marginal oil cells interspersed with several upright cells.

Uses: The wood is mainly used for camphor and camphor oil production. Other uses include furniture, musical instruments, and small articles.

Remarks: Wood from C. camphora Nees. et Ebe. as reported by Kanehira (30) varies from this description by having more numerous pores in springwood, angular intervessel pits and septate fibres. Stern (44) also reports more pores (17-35 per square millimeter), as well as multiseriate rays. Vessel diameters of 70-150 microns were recorded by Kribs (31) who also reports fibre tracheids with small bordered pits and rays 2-3 cells wide for this species.

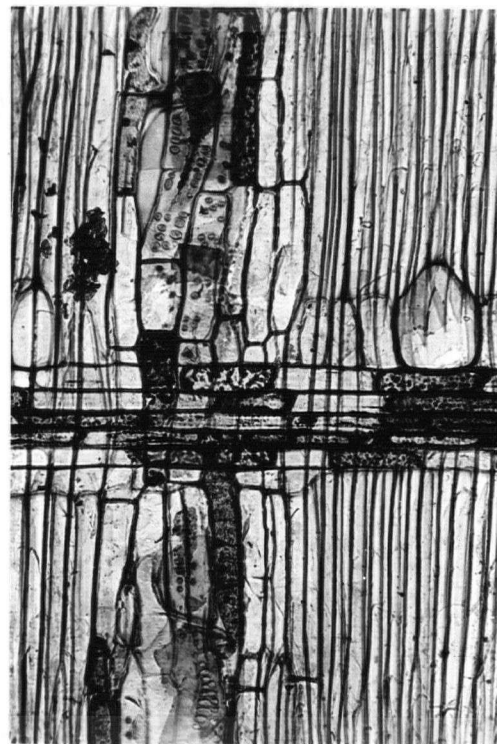
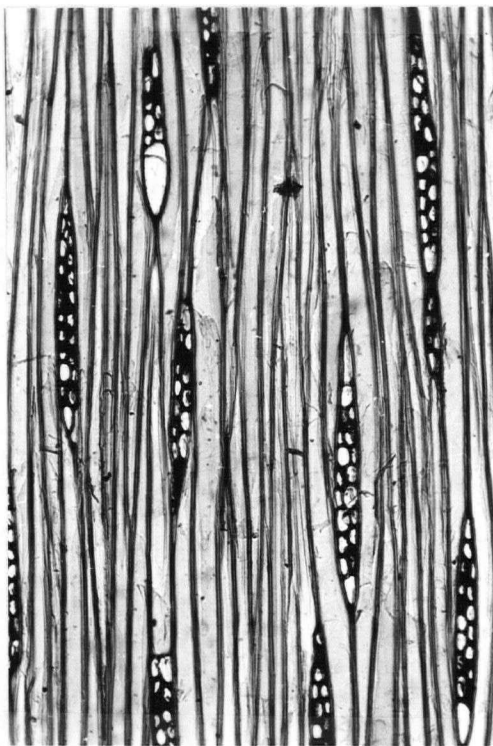
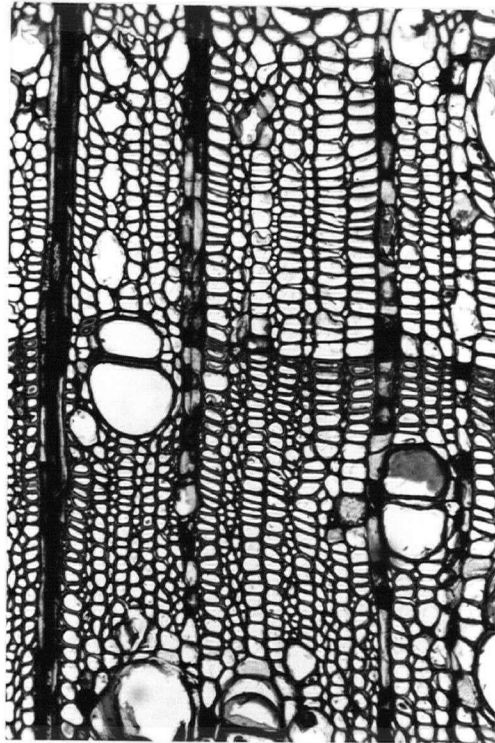


Fig. 20. Cinnamomum micranthum Hay.
(x-sec., t-sec. and r-sec.) at 100 x

Cinnamomum micranthum Hay.

Commercial Name: Pan-chaun (mandarin).

Other Names: New-chaun.

Tree: A medium-sized tree; occurring in northern Taiwan.

General Properties: Heartwood light brown with red stripes and high lustre; grain straight to roey; texture coarse; moderately light, specific gravity 0.40 (25 pounds per cubic foot); with characteristic camphor odor and taste.

Macroscopic Features: Growth rings distinct due to dark bands of fibrous tissue. Larger vessels visible to the naked eye; wood diffuse porous with pores evenly distributed and usually containing tyloses. Pore arrangement solitary, as radial chain multiples up to 3 and in occasional cluster groupings.

Microscopic Features: (See Fig. 20) Vessels moderately numerous 10-20 per square millimeter, the larger round or oval medium-sized mostly 150-180 (up to 250) microns in diameter; perforation plates simple or rarely scalariform in small vessels with 4-5 bars 2.5-3.0 microns in thickness; intervessel pits square, medium-sized (8.5-10.0 microns in largest diameter), close, orifices round, alternately arranged spirally. Fibres very thin-walled; pits indistinct; extremely coarse mostly 30-35 (average 32) microns in diameter, medium length 1.0-1.5 (average 1.3) millimeters. Longitudinal parenchyma of three types: terminal as partial lines 1-2 cells wide; metatracheal-diffuse as solitary cells or in radial multiples of several cells along rays; paratracheal-aliform extending to paratracheal-confluent; large vertical oil cells measured up to 68 microns wide and 220 microns high in tangential view. Rays simple mostly biseriate, occasional triseriate and extremely low 0.45 millimeter or up to 16 cells high; heterogeneous; marginal oil cells at intervals; cells containing dark deposits.

Uses: The wood is used for camphor oil production.

Remarks: C. micranthum Hay. as described by Kanehira (30) varies from this description in size of elements (vessel diameters 70-160 microns, fibres 15-32 microns in diameter), and by having inconspicuous paratracheal parenchyma and sparse secretory cells.

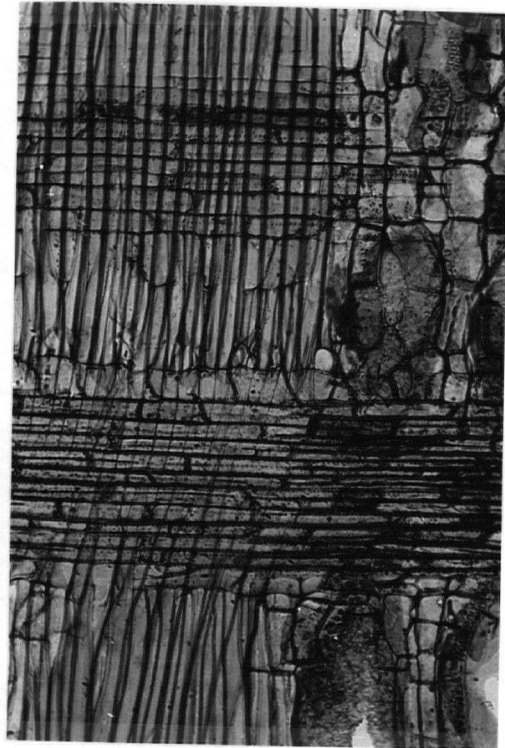
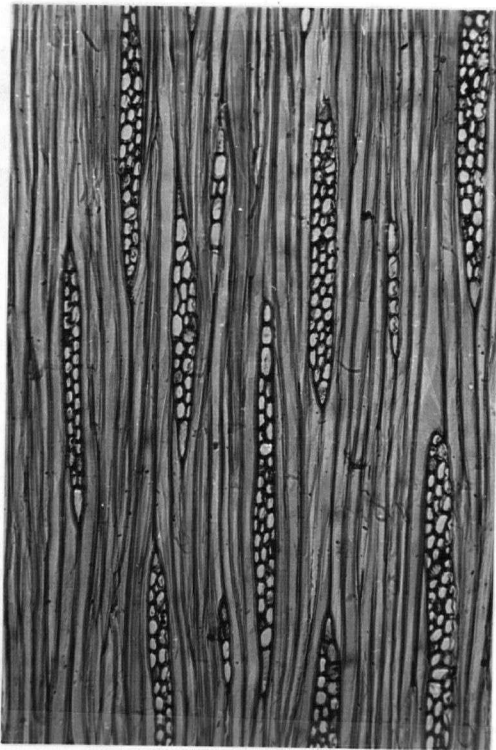
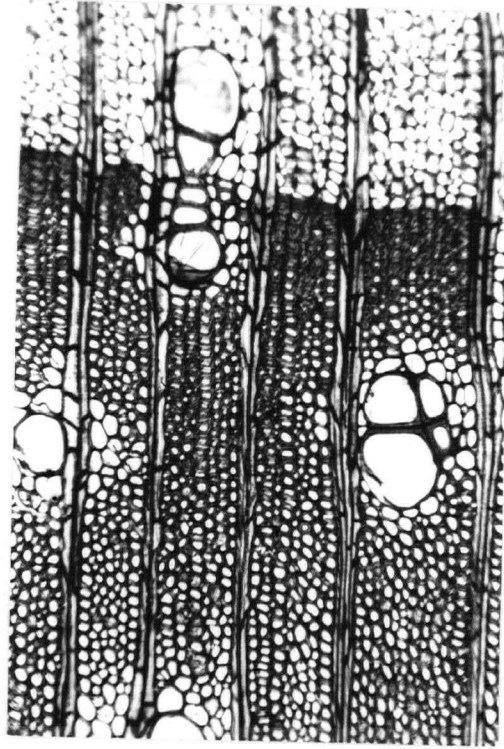


Fig. 21. Cinnamomum randaiensis Hay.
(x-sec., t-sec. and r-sec.) at 100 x

Cinnamomum randaiensis Hay.

Commercial Name: Shan-chaun (mandarin).

Other Names: Lan-da-chaun.

Tree: A medium-sized evergreen tree, up to 20 inches in diameter; ranging to about 1,600 to 4,900 feet elevation.

General Properties: Heartwood light pink with medium to high lustre; grain straight; texture medium; heavy, specific gravity 0.58 (36 pounds per cubic foot); lacking camphor odor or taste.

Macroscopic Features: Growth rings distinct due to wide, dense bands of fibres. Vessels indistinct to the naked eye, but visible at 10 x magnification; wood diffuse porous with pores unevenly distributed and containing tyloses. Pore arrangement solitary, as radial chain multiples up to 5 plus and in occasional cluster groupings up to 5.

Microscopic Features: (See Fig. 21) Vessels few 3-12 per square millimeter, the larger medium-sized mostly 120-125 (up to 150) microns in diameter; perforation plates simple or occasionally scalariform in small vessels with 4-6 bars 5-10 microns in thickness; inter-vessel pits orbicular or linear, very small (4.5-6.5 microns in largest diameter), widely spaced, orifices linear, alternately arranged spirally. Fibres very thick-walled; pits indistinct; moderately fine mostly 15-20 (average 18) microns in diameter, medium length 1.2-1.5 (average 1.2) millimeters. Longitudinal parenchyma of several types: metatracheal-diffuse; paratracheal-vasicentric several cells wide extending to paratracheal-aliform with short wings and paratracheal-confluent connecting 2-3 pores diagonally; occasionally many parenchyma cells fused over a large area; vertical oil cells sparse, small for the genus (60 microns wide, 120 microns high). Rays simple uniseriate very low 0.70 millimeter or up to 8 plus cells high, and often biseriate or triseriate; occasionally showing a uniseriate portion at one end; heterogeneous; no horizontal oil cells present.

Uses: The wood is used for producing volatile oils.

Remarks: Wood anatomy of C. randaiensis Hay. was briefly recorded by Kanehira (30); with a major difference in frequency of pores (13-19 per square millimeter).

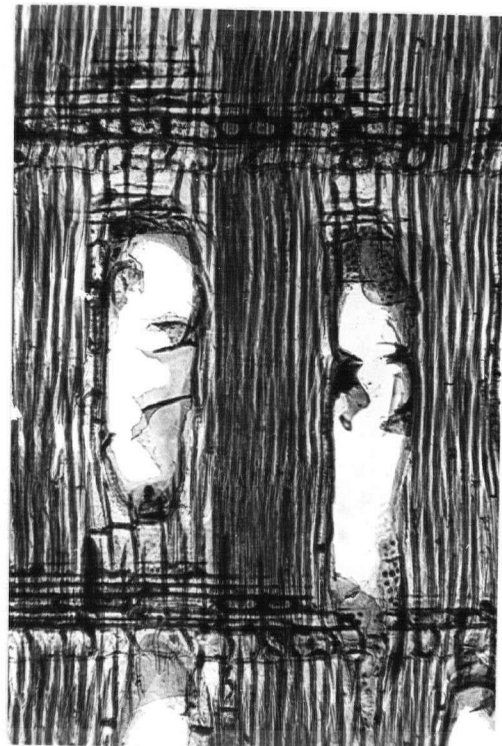
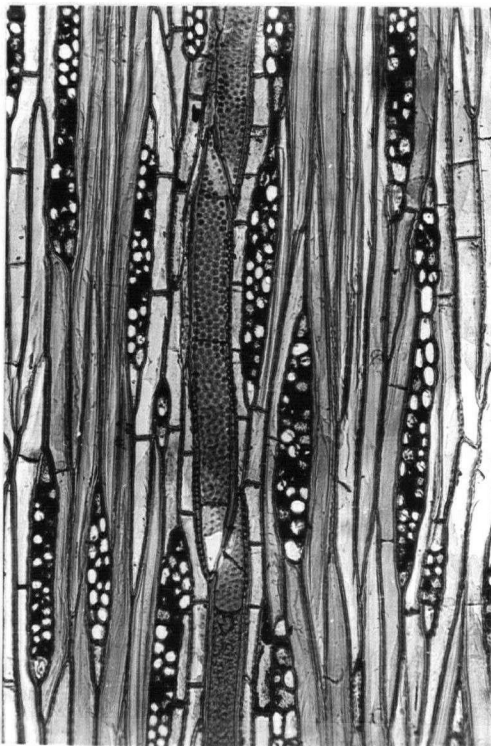
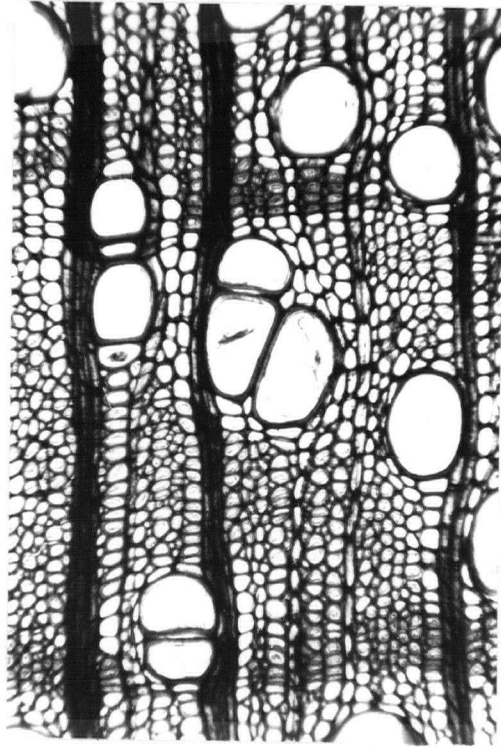


Fig. 22. Machilus arisanensis Hay.
(x-sec., t-sec. and r-sec.) at 100 x

Machilus arisanensis Hay.

Commercial Name: Arisan-nan (mandarin).

Other Names: Shao-yue-nan.

Tree: A medium-sized tree; ranging from sea level to 6,600 feet elevation, occurring particularly in the Arisan mountain.

General Properties: Heartwood light red-brown without lustre; grain straight; texture medium; heavy, specific gravity 0.64 (40 pounds per cubic foot); without characteristic odor or taste.

Macroscopic Features: Growth rings distinct due to dark bands of fibrous tissue. Vessels indistinct to the naked eye, but visible at 10 x magnification; wood diffuse porous with pores evenly distributed. Pore arrangement solitary, as radial chain multiples up to 4 and in cluster groupings up to 7.

Microscopic Features: (See Fig. 22) Vessels moderately numerous 15-25 per square millimeter, the larger elliptical and oval medium-sized mostly 140-145 (up to 150) microns in diameter; perforation plates simple; intervessel pits orbicular to oval and partly grouped, moderately small (7.5-8.5 microns in largest diameter), close, orifices round, mostly alternately arranged spirally. Fibres very thick-walled; pits indistinct; moderately coarse mostly 25-30 (average 28) microns in diameter, medium length 1.1-1.5 (average 1.2) millimeters. Longitudinal parenchyma of several types: paratracheal-vasicentric 1-2 cells wide extending to paratracheal-aliform with short wings and paratracheal-confluent connecting up to 3 pores diagonally. Rays simple very low 0.70 millimeter. uniseriate 3-4 cells high, numerous biseriate and occasional triseriate; heterogeneous with marginal upright cells; cells containing dark deposits.

Uses: The wood is used for furniture manufacture.

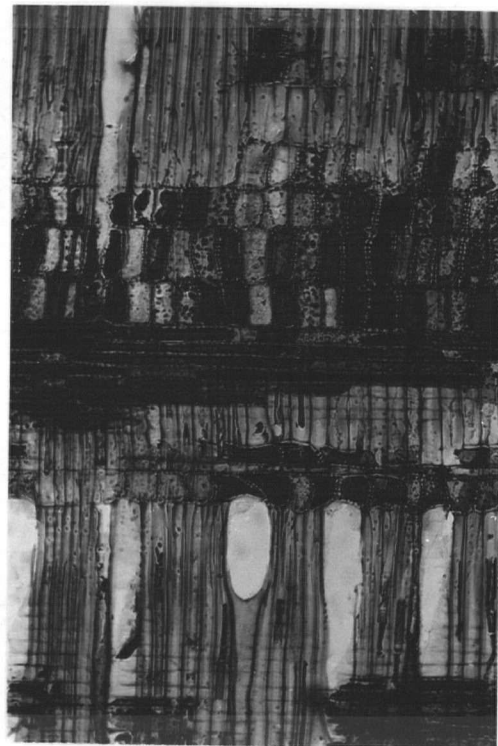
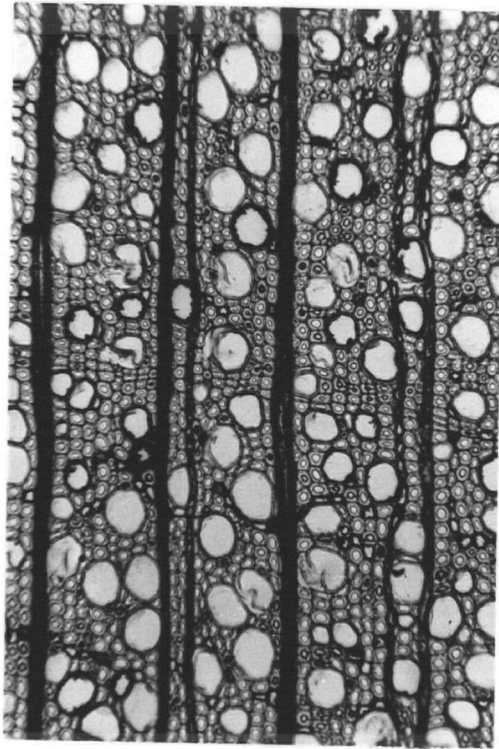


Fig. 23. Machilus pseudolongifolia Hay.
(x-sec., t-sec. and r-sec.) at 100 x

Machilus pseudolongifolia Hay.

Commercial Name: Gau-yue-nan (mandarin).

Other Names: None known.

Tree: A medium-sized tree; ranging the whole island.

General Properties: Heartwood light red-brown with medium lustre; grain straight; texture medium to fine; moderately heavy, specific gravity 0.46 (28.5 pounds per cubic foot); without characteristic odor or taste.

Macroscopic Features: Growth rings distinct due to wide dense bands of fibrous tissue. Vessels indistinct at 10 x magnification.

Microscopic Features: (See Fig. 23) Wood diffuse porous with pores evenly distributed and containing dark deposits. Pore arrangement solitary. Vessels very numerous 80-170 per square millimeter, the larger very small mostly 40-45 (up to 60) microns in diameter; perforation plates simple; intervessel pits orbicular, very small (4.5-5.5 microns in largest diameter), widely spaced, orifices round, oppositely arranged as transverse rows. Fibres very thick-walled; round bordered pits distinct; mostly medium diameter 17-26 (average 21) microns, medium length 1.4-1.9 (average 1.5) millimeters.

Longitudinal parenchyma of two types: metatracheal-diffuse; metatracheal-zonate 1-cell wide, 2-4 cells long. Rays simple uniseriate very low 0.60 millimeter or up to 9 plus cells high, biseriate always showing a long uniseriate portion on one end; triseriate rays infrequent; heterogeneous; cells containing dark deposits.

Uses: The wood is used for furniture manufacture.

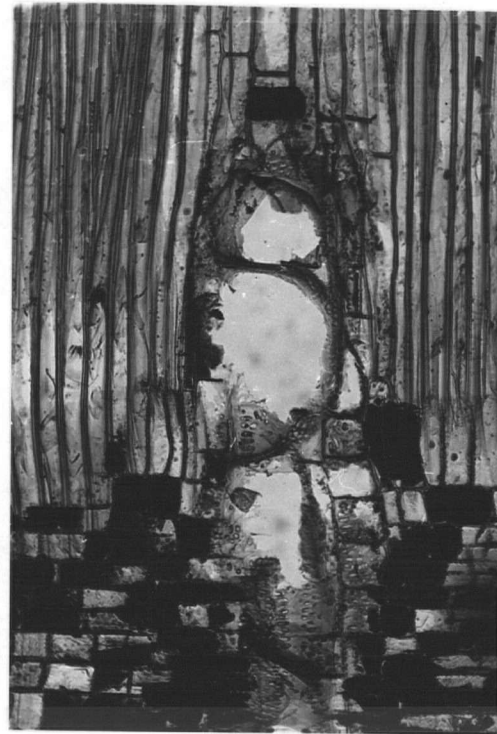
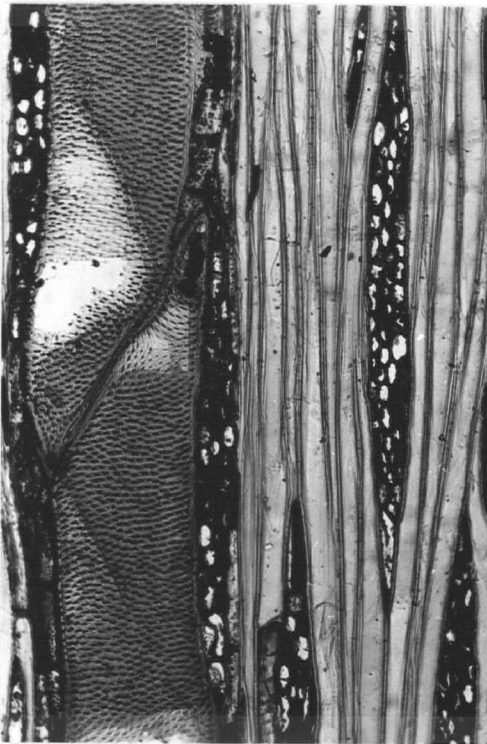
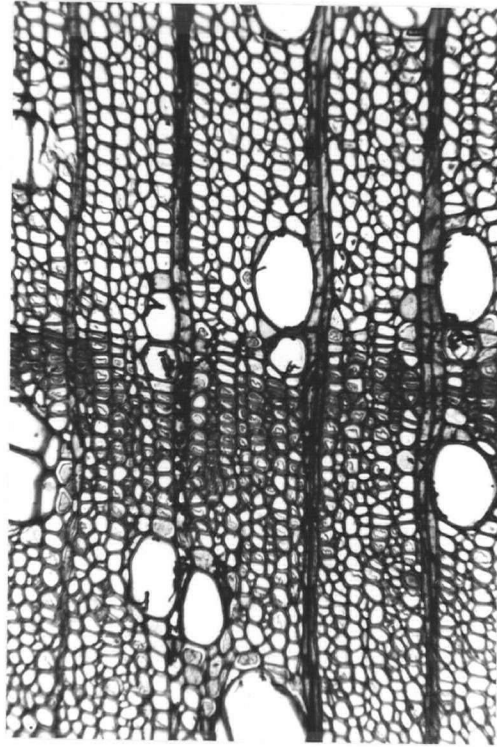


Fig. 24. Machilus zuihoensis Hay.
(x-sec., t-sec. and r-sec.) at 100 x

Machilus zuihoensis Hay.

Commercial Name: Shan-nan (mandarin).

Other Names: Raw-fan-nan.

Tree: A medium-sized tree; ranging the whole island at sea level.

General Properties: Heartwood light pink without lustre; grain straight; texture coarse; heavy, specific gravity 0.54 (33.5 pounds per cubic foot); with odor and acrid taste similar to camphor.

Macroscopic Features: Growth rings distinct due to narrow, dense bands of fibrous tissue. Vessels indistinct to the naked eye, but visible at 10 x magnification; wood diffuse porous with pores evenly distributed and containing tyloses. Pore arrangement solitary, as radial chain multiples of 2-3 and in tangential pairs.

Microscopic Features: (See Fig. 24) Vessels moderately numerous 10-25 per square millimeter, the larger moderately small mostly 95-115 (up to 200) microns in diameter; perforation plates simple; intervessel pits rectangular to orbicular, moderately small (7.5-8.5 microns in largest diameter), widely spaced, orifices round, oppositely arranged as transverse rows, fibres thick-walled; pits indistinct; moderately coarse mostly 25-30 (average 26) microns in diameter, medium length 1.0-1.5 (average 1.4) millimeters. Longitudinal parenchyma of two types; paratracheal scanty and occasional paratracheal-vasicentric 2-3 cells wide. Rays simple very low 0.85 millimeter uniseriate up to 10 plus cells high, biseriate variable in height, triseriate flanked with a uniseriate portion up to 8 cells high; heterogeneous with tall upright cells; cells containing dark deposits.

Uses: The wood is used for tea cases, boat building, furniture, and general construction.

Remarks: Kanehira (30) described the wood from 3 Taiwan species of Machilus including M. kusanoi Hay., M. longipaniculata Hay. and M. suffrutescens Hay. The major differences between these and the three species reported here appear to be in frequency and size of vessels.

LEGUMINOSAE

The family includes about 500 genera and over 15,000 species of trees, shrubs, lianas and herbs widely distributed over the world (21). There are 59 genera and 6 tree species native to Taiwan (32, 35). The wood of one introduced species is described.

Taxonomic Notes: Leguminosae includes three sub-families, namely Papilionaceae, Caesalpiniaceae and Mimosaceae varying in degree of specialization. Cassia belongs to Caesalpiniaceae on this basis (35).

Anatomical Features: Ring-porous or semi-ring-porous in a few species. Vessels rather large to very small, typically mostly solitary, sometimes with a few small multiples and irregular clusters; perforation plates simple; pits small, alternate and vested. Fibre pits small and simple, fibres septate in some genera. Longitudinal parenchyma typically paratracheal in round or diamond-shaped sheaths and containing crystals. Rays 1-9 (mostly 2-5) cells wide or exclusively uniseriate, with some tendency to echelon or storied arrangement in all species, but seldom distinct (35, 39).

Anatomical Features of Cassia: Vessels large in some species. Fibres are septate. Parenchyma usually moderately abundant and predominantly aliform and mostly diamond shaped or intermediate between the above and paratracheal or in more regular bands that are difficult to classify. Rays mostly 2-3 cells wide, exclusively uniseriate or with only a few biseriate rays in some species, often multiseriate accompanied by few uniseriate rays (31, 35).

Cassia siamiae Lam.

Commercial Name: Bombay black wood, rosewood, Ti-dau-moo (mandarin).

Other Names: None known.

Tree: A medium-sized tree, introduced from mainland China; ranging from central to southern Taiwan.

General Properties: Heartwood dark gray without lustre; grain interlocked; texture coarse; very heavy, specific gravity 0.75 (47 pounds per cubic foot); without characteristic odor or taste.

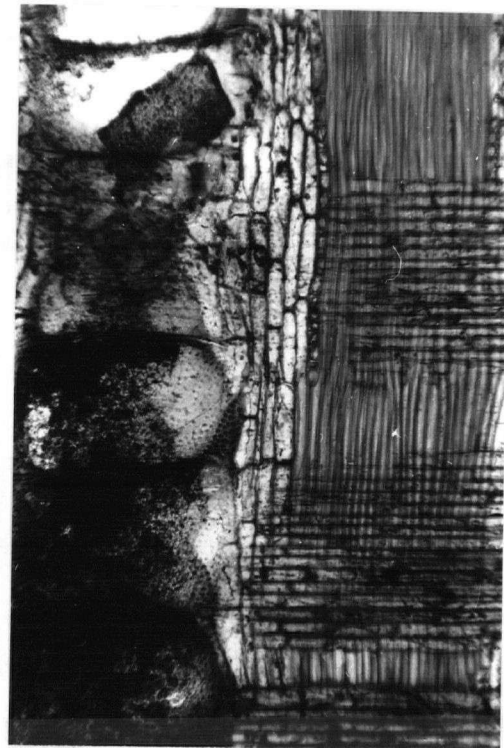
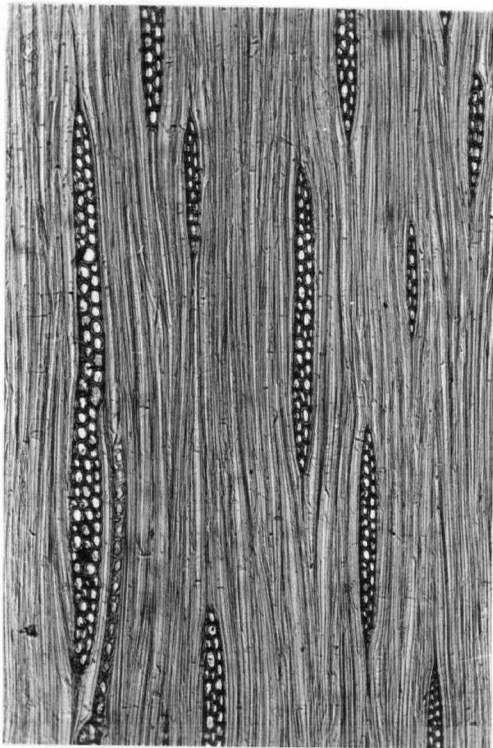
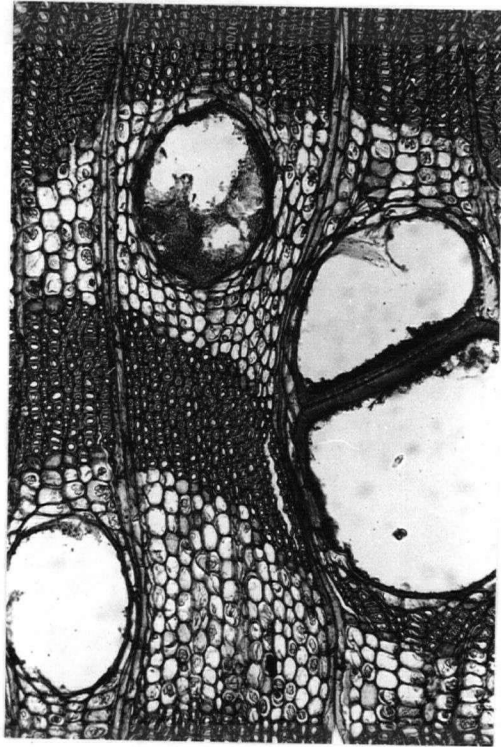


Fig. 25. Cassia siamiae Lam.
(x-sec., t-sec. and r-sec.) at 100 x

Macroscopic Features: Growth rings indistinct. Vessels visible to the naked eye; wood diffuse porous with pores evenly distributed and containing gum. Pore arrangement solitary and in radial chain multiples of 2-3 (mostly 2).

Microscopic Features: (See Fig. 25) Vessels very few 1-8 (mostly 1) per square millimeter, the larger oval moderately large mostly 240-275 (up to 290) microns in diameter; perforation plates simple; intervessel pits round to oval, moderately small (6.5-7.5 microns in largest diameter), widely spaced, orifices lenticular, oppositely arranged as transverse rows. Fibres very thick-walled; pits indistinct; moderately fine mostly 15-20 (average 18) microns in diameter, medium length 1.0-1.5 (average 1.3) millimeters; lumina frequently with crystals. Longitudinal parenchyma of two types: terminal; paratracheal-confluent forming concentric bands up to 10 cells wide. Rays simple very low 0.55 millimeter few uniseriate up to 8 cells high, numerous biseriate variable in height, and rare triseriate; heterogeneous; cell contents lacking.

Uses: The wood is used for furniture and trim lumber.

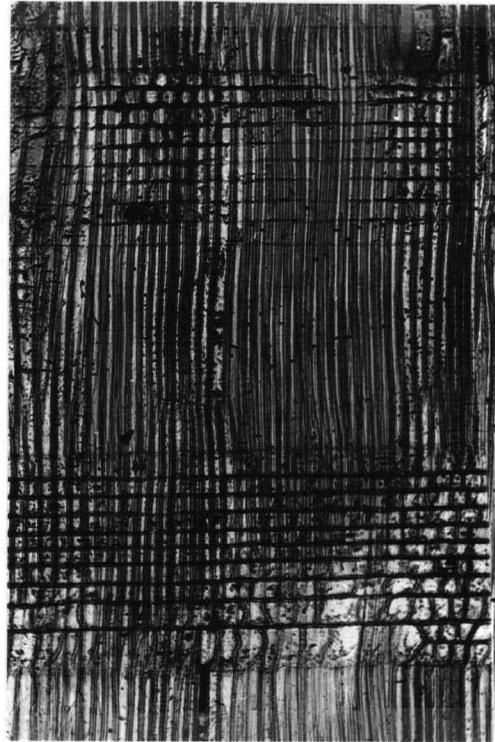
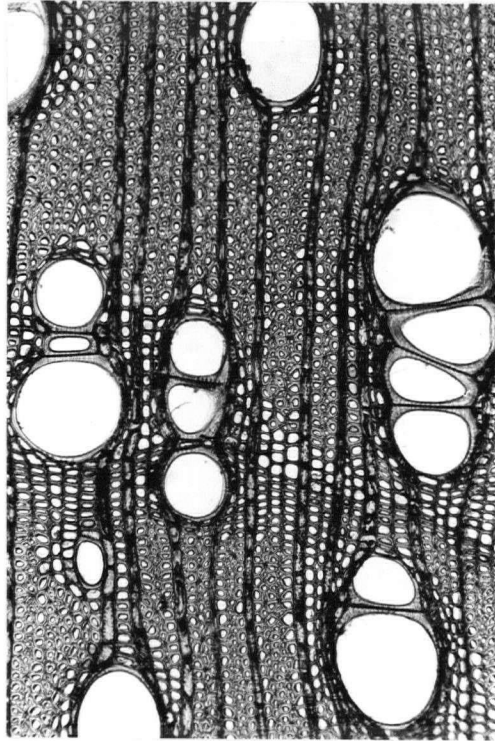


Fig. 26. Lagerstroemia subcostata Koehne.
(x-sec., t-sec. and r-sec.) at 100 x

LYTHRACEAE

The family comprises about 20 genera and many species of trees, shrubs and herbs widely distributed in the world (35). There are 3 genera and 7 tree species in Taiwan (30, 32). The wood of one timber species is described.

Taxonomic Notes: The genera in this family are well defined (35).

Anatomical Features: Ring-porous in some species. Vessel perforation plates simple. Fibres commonly septate. Longitudinal parenchyma predominantly paratracheal, scanty or vasicentric to aliform and confluent, sometimes with crystals. Rays exclusively uniseriate or up to 2-3 cells wide (35).

Anatomical Features of Lagerstroemia: Ring-porous. Vessels 5 per sq. mm., sometimes with deposits of gum and with tyloses. Fibre pits simple and fibres often septate. Longitudinal parenchyma paratracheal, abundant and aliform to confluent with crystals. Rays exclusively simple in most species, homogeneous (35).

Lagerstroemia subcostata Koehne.

Commercial Name: Ku-gone (mandarin).

Other Names: None known.

Tree: A large deciduous tree, up to 23 inches in diameter; occurring in northern Taiwan.

General Properties: Heartwood light brown without lustre; grain straight to wavy; texture coarse; very heavy, specific gravity 0.85 (53 pounds per cubic foot); without characteristic odor or taste.

Macroscopic Features: Growth rings distinct due to narrow bands of thick-walled fibres. Larger vessels visible to the naked eye; wood diffuse porous with pores evenly distributed and occasionally containing tyloses. Pore arrangement solitary and in radial chain multiples up to 6.

Microscopic Features: (See Fig. 26) Vessels moderately numerous 15-25 per square millimeter, the larger elliptical medium-sized mostly 125-140 (up to 175) microns in diameter; perforation plates simple; intervessel pits slit-like, very small (4.5-5.5 microns in largest diameter), widely spaced, orifices linear, oppositely arranged as transverse rows.

Vasicentric tracheids present, round bordered pits distinct. Fibres very thick-walled; pits indistinct; mostly moderately fine 15-20 (average 18) microns in diameter; very short 0.5-1.0 (average 0.9) millimeters in length. Longitudinal parenchyma of several types: terminal up to 2 cells wide; metatracheal zonate 3-12 cells wide; paratracheal-aliform and paratracheal-confluent intermingled with vasicentric tracheids. Rays simple uniseriate, slender and low 1.3 millimeter or up to 65 plus cells high, heterogeneous with upright cells included and marginal; cells rectangular in tangential view; cell contents lacking.

Uses: The wood is used for charcoal production.

Remarks: Kanehira (30) reported on wood of L. subcostata Koehne. as yellow in color, fine textured and having uni-and biseriate rays up to 20 cells high.

MAGNOLIACEAE

The family includes about 10 genera and 80 species of trees and shrubs occurring in the temperate and subtropical portions of America and eastern Asia (21). There are 5 genera and 10 tree species in Taiwan (30, 32, 35). The woods of two species are described.

Taxonomic Notes: The family is considered primitive due to scalariform perforation plates and scalariform intervacular pitting (35).

Anatomical Features: Vessels solitary and in small groups; perforation plates typically scalariform with few, widely spaced bars. Fibre pits are bordered. Longitudinal parenchyma is only terminal. Rays usually up to 3 or 4 cells wide with few uniseriate (35).

Anatomical Features of Michelia: Vessels usually medium-sized but small in some species; spiral thickening present; perforation plates typically scalariform with few widely spaced bars. Fibre pits are small- to moderately large-bordered and typically very few. Longitudinal parenchyma occurring in terminal bands; silica sometimes present. Rays usually 3-4 cells wide, uniseriate rays very few (35).

Michelia formosana Mas.

Commercial Name: Woo-sin-shee (mandarin).

Other Names: None known.

Tree: A medium sized tree; ranging from 700 to 5,900 feet elevation about the whole island.

General Properties: Heartwood dull yellow with dark green stripes and medium lustre; grain straight; texture medium; heavy, specific gravity 0.55 (34.5 pounds per cubic foot); with disagreeable odor, but lacking taste.

Macroscopic Features: Growth rings distinct due to concentric lines of terminal parenchyma. Vessels indistinct to the naked eye, but visible at 10 x magnification; wood diffuse porous with pores evenly distributed and occasionally containing tyloses. Pore arrangement mostly as radial chain multiples up to 8 plus and in tangential clusters of 2-5, occasionally solitary.

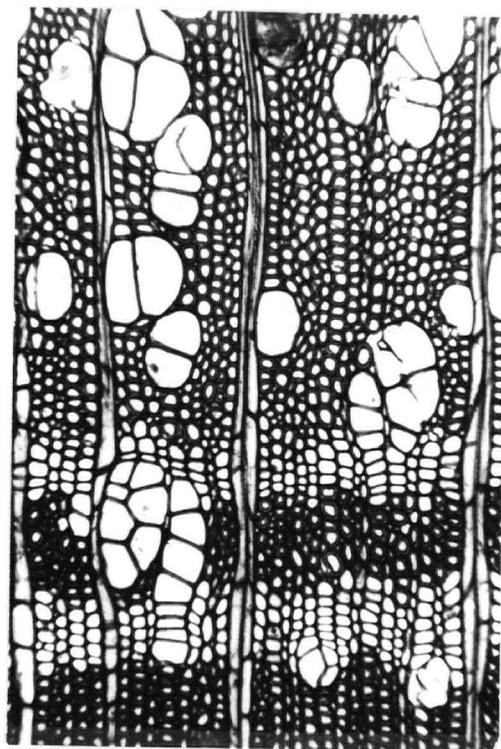


Fig. 27. Michelia formosana Mas.

(x-sec., t-sec. and r-sec.) at 100 x

Microscopic Features: (See Fig. 27) Vessels numerous 35-75 per square millimeter, the larger moderately small mostly 75-85 (up to 95) microns in diameter; perforation plates scalariform with 2-5 bars 4.5 microns in thickness; spiral thickening on vessel walls; intervessel pits scalariform, extremely large (55-60 microns in largest diameter) and close. Fibres very thick-walled; pits indistinct; moderately fine mostly 15-20 (average 18) microns in diameter, medium length 1.0-1.5 (average 1.4) millimeters. Longitudinal parenchyma of several types: terminal in lines 2-5 (mostly 3) wide; metatracheal-diffuse; scanty paratracheal. Rays simple very low 0.85 millimeters rarely uniseriate up to 9 cells high, frequent biseriate variable in height; heterogeneous with one or more marginal rows of upright cells.

Uses: The wood is used for furniture manufacture, musical instruments and as decoration.

Remarks: The wood of M. compressa Max. as described by Kanehira (30) closely resembles M. formosana Mas. reported here, varying only in having conspicuous metatracheal-zonate parenchyma and fewer bars (2-5) in scalariform perforation plates.

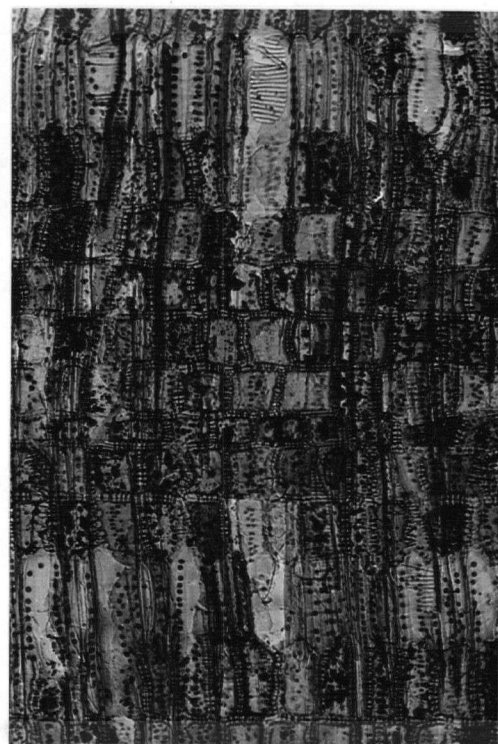
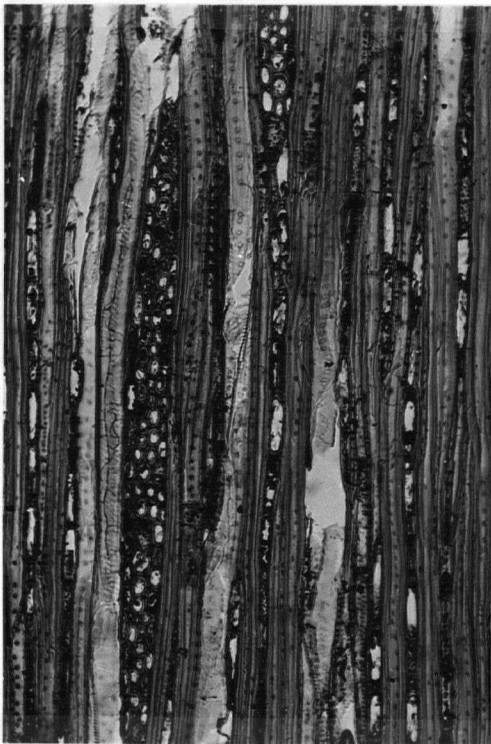
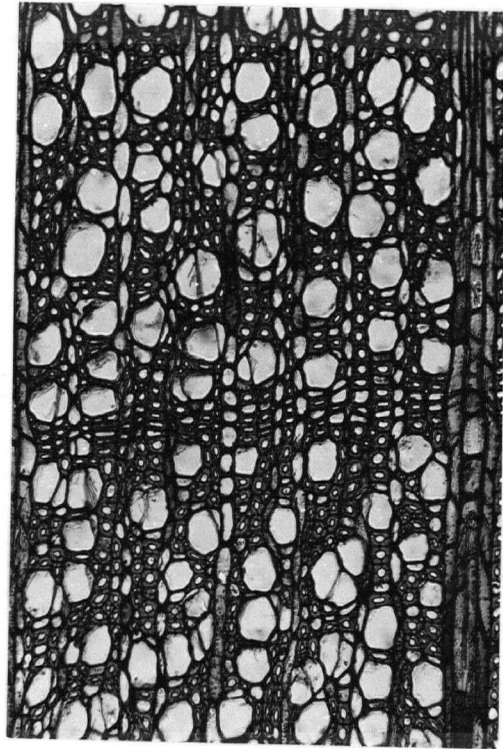


Fig. 28. Illicium leucanthum Hay.
(x-sec., t-sec. and r-sec.) at 100 x

SCHISANDRACEAE

The family is mostly represented by shrubs, some of which have a trailing habit. Its members occur in China, Malaya, Australia and in southeastern United States of America (35). One genus and three species occur in Taiwan. The wood of one timber species is described.

Taxonomic Notes: The family is separated into two parts due to taxonomic differences. The first group includes three genera, Austrobaileya, Kadsura and Schisandra. The second group consists of Illicium (35).

Anatomical Features of Illicium: Vessels solitary; perforation plates scalariform. Fibre pits are bordered. Longitudinal parenchyma sparse, paratracheal and sometimes scattered along the ring-boundary. Rays up to 3 cells wide, with numerous uniseriate rays markedly heterogeneous (35).

Illicium leucanthum Hay.

Commercial Name: Bar-ghau (mandarin).

Other Names: Hon-bar-ghao.

Tree: A medium-sized tree, up to 16 inches in diameter; ranging from 2,600 to 4,900 feet elevation from central to northern Taiwan.

General Properties: Heartwood red to pink without lustre; grain straight; texture medium to coarse; heavy, specific gravity 0.55 (34.5 pounds per cubic foot); without characteristic odor or taste.

Macroscopic Features: Growth rings distinct due to narrow dark bands of thick-walled fibres. Vessels not visible at 10 x magnification.

Microscopic Features: (See Fig. 28) Wood diffuse porous with pores evenly distributed. Pore arrangement solitary as radial pairs and in tangential groupings up to 4. Vessels very numerous 115-180 mostly per square millimeter, the larger very small mostly 45-50 (up to 60) microns in diameter; perforation plates scalariform with 20 plus bars 1.5 microns in thickness; intervessel pits round to elliptical, mostly moderately small (4.5-12.5 microns in largest diameter), widely spaced, orifices lenticular to linear, oppositely arranged in vertical rows. Fibres very thick-walled; bordered pits distinct; extremely

coarse mostly 29-34 (average 30) microns in diameter, moderate length 1.5-2.0 (average 1.8) millimeters. Longitudinal parenchyma metatracheal-diffuse in fibre areas. Rays simple uniseriate low 1.1 millimeters or up to 17 plus cells high, homogeneous comprised entirely of upright cells; frequent triseriate always flanked with portion as uniseriate ray, heterogeneous.

Uses: The wood is used for general construction and furniture manufacture.

Remarks: Kanehira (30) records features for I. anisatum L. (Magnoliaceae) very similar to this description for I. leucanthum Hay., with major difference in intervessel pits which are reported as scalariform.

THEACEAE

The family comprises about 23 genera and 350 species of trees and shrubs with wide tropical distribution particularly in the Malayan Archipelago and Latin America (32, 33). The family is also represented to a limited extent in China, Japan and the United States. The best known member of the family is the tea plant (Camellia sinensis L. or Thea sinensis (L) O. Ktze.) (38). There are 12 genera and 26 tree species in Taiwan (30). The woods of three timber species are described.

Taxonomic Notes: Ternstroemiaceae does not constitute a group and hence Ternstroemia must belong to Theaceae (35, 38).

Anatomical Features: Semi-ring-porous in some species. Vessels typically small; perforation plates scalariform with 15-100 bars, simple only in Archylaea and Bonnetia. Fibre pits are bordered, fibres are medium length to very long (35, 38).

Anatomical Features of Schima, Gordonia and Ternstroemia: Vessels are typically small in some species of Schima and Ternstroemia, mostly 30-140 per square millimeter, but fewest in some species of Gordonia; spiral thickening is absent except for some species of Gordonia (38); tyloses sometimes present; perforation plates scalariform. Fibre pits are bordered. Longitudinal parenchyma is apotracheal and diffuse. Rays commonly 2-3 cells wide, but 4-8 in Ternstroemia and exclusively uniseriate in Schima (35).

Gordonia axillaris (Don.) Szysz.

Commercial Name: Pa-tau-cha (mandarin).

Other Names: None known.

Tree: A small tree; ranging the whole island at sea level.

General Properties: Heartwood red-brown with medium lustre; grain roey; texture medium, heavy, specific gravity 0.51 (31.5 pounds per cubic foot); without characteristic odor or taste.

Macroscopic Features: Growth rings distinct due to terminal bands of thick-walled fibres. Vessels barely visible at 10 x magnification; wood diffuse porous with pores evenly distributed and containing dark deposits. Pore arrangement solitary, as radial pairs and multiples and as tangential pairs. Multiseriate rays visible.

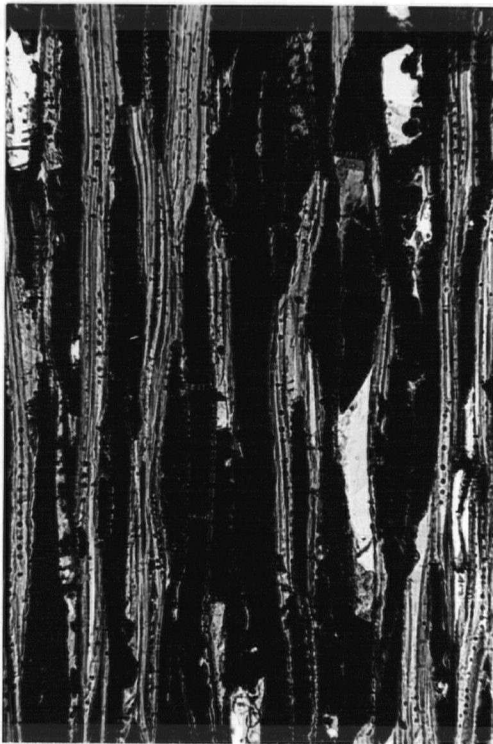
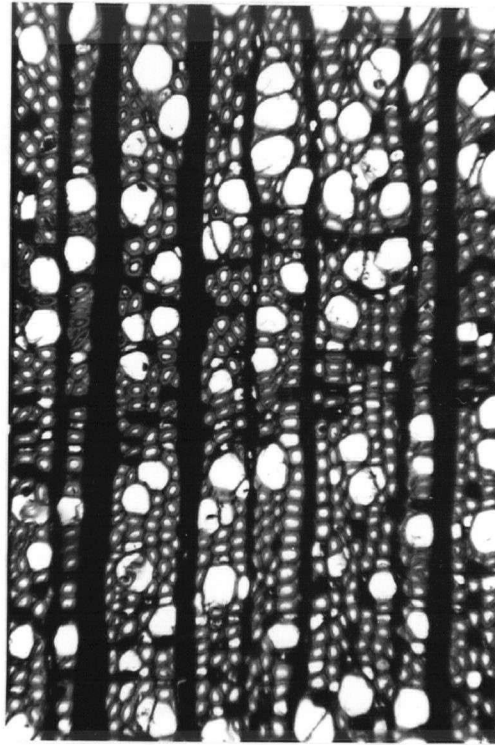


Fig. 29. Gordonia axillaris (Don.) Szysz.
(x-sec., t-sec. and r-sec.) at 100 x

Microscopic Features: (See Fig. 29) Vessels very numerous 115-160 per square millimeter the larger very small mostly 45-50 (up to 75) microns in diameter; perforation plates scalariform with 15 plus bars 3.5 microns in thickness; intervessel pits scalariform, large (18-20 microns in largest diameter) widely spaced. Fibres very thick-walled; bordered pits distinct; mostly moderately coarse 25-30 (average 26) microns in diameter, medium length 1.5-2.0 (average 1.6) millimeters. Longitudinal parenchyma of two types: metatracheal-diffuse and diffuse-aggregated; cells containing dark deposits. Rays of two types: simple uniseriate very low 0.65 millimeters high, mostly upright cells, variable in height frequent biseriate and triseriate; multiseriate extremely broad 500 microns or many cells in width; heterogeneous; cells containing dark deposits.

Uses: The wood is used for charcoal production.

Remarks: Kanehira (30) reports similar wood anatomy for G. axillaris (Don.) Szysz., but noted a diminishing number of pores as seasonal growth progressed to latewood. G. anomala Spreng. is thought to be the same species.

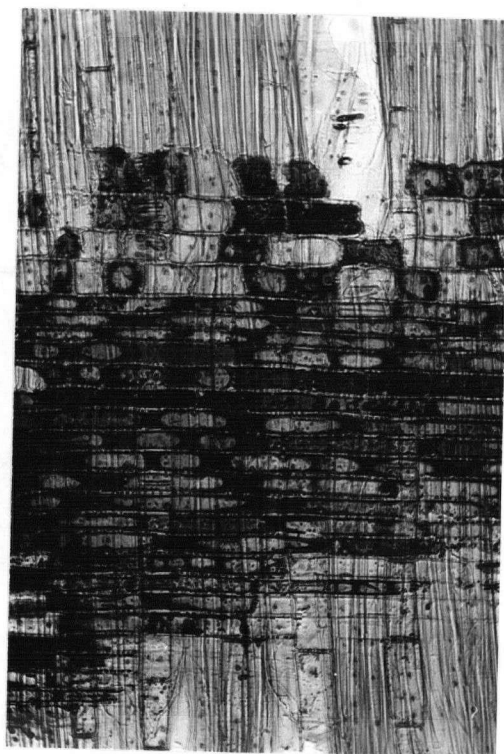
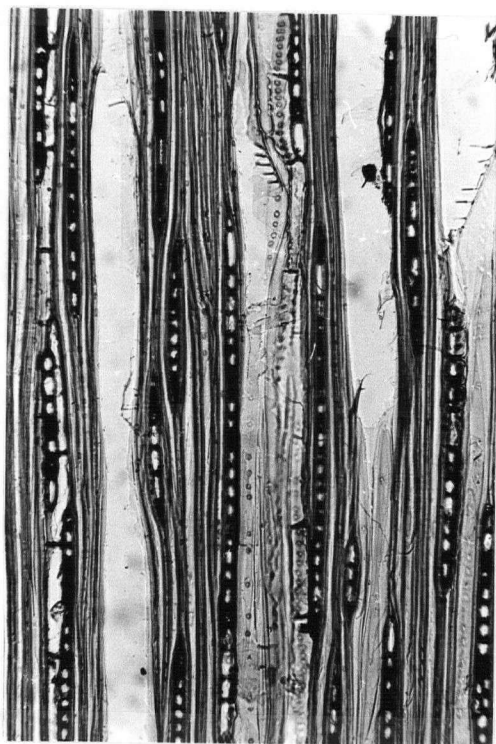
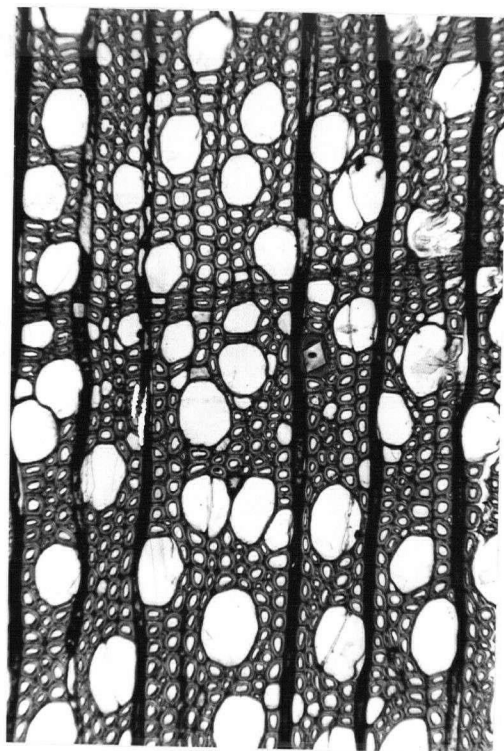


Fig. 30. Schima superba Gard. et Champ.
(x-sec., t-sec. and r-sec.) at 100 x

Schima superba Gard. et Champ.Commercial Name: Moo-ho (mandarin).Other Names: None known.Tree: A medium-sized tree; occurring in southern Taiwan.General Properties: Heartwood yellow-gray with medium lustre; grain straight; texture fine; heavy, specific gravity 0.61 (38 pounds per cubic foot); without characteristic odor or taste.Macroscopic Features: Growth rings indistinct. Vessels barely visible at 10 x magnification; wood diffuse porous with pores evenly distributed. Pore arrangement solitary and rarely as radial pairs.Microscopic Features: (See Fig. 30) Vessels very numerous 45-50 per square millimeter, the larger oval moderately small mostly 55-70 (up to 85) microns in diameter; perforation plates scalariform with 6-14 bars 1.5 microns in thickness; intervessel pits orbicular, very small (5.0-6.0 microns in largest diameter), widely spaced, orifices round, oppositely arranged as transverse rows. Fibres very thick-walled; simple, slit-like pits distinct; extremely coarse mostly 30-35 (average 30) microns in diameter, moderately long 2.0-2.5 (average 2.2) millimeters. Longitudinal parenchyma metatracheal-diffuse in fibre areas. Rays simple uniseriate low 1.2 millimeters or up to 20 plus cells high, occasionally biseriate in part; heterogeneous; cells containing dark deposits.Uses: The wood is used for furniture manufacture.Remarks: Kanehira (30) recorded wood anatomy for S. noronhae Reinw., which differs from that of S. superba Gard. et Champ. reported here by having more vessels (50-90 per square millimeter) less evenly distributed in growth increments.

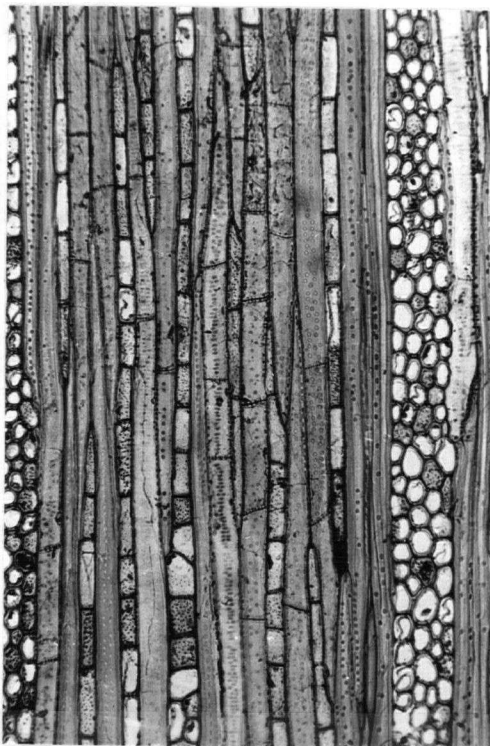
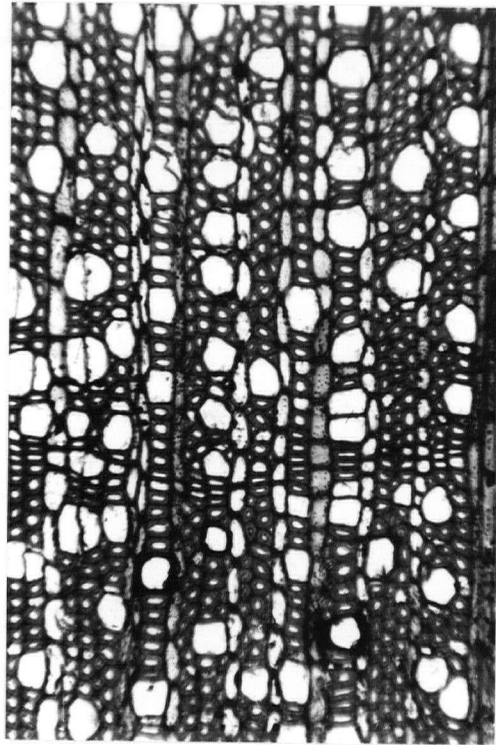


Fig. 31. Ternstroemia gymnanthera Spr.
(x-sec., t-sec. and r-sec.) at 100 x

Ternstroemia gymnanthera Spr.

Commercial Name: Hoo-pi-shan (mandarin).

Other Names: None known.

Tree: A large tree; occurring in central Taiwan.

General Properties: Heartwood light orange with medium lustre; grain straight to roey; texture medium, heavy, specific gravity 0.58 (36 pounds per cubic foot); without characteristic odor or taste.

Macroscopic Features: Growth rings indistinct. Vessels barely visible at 10 x magnification; wood diffuse porous with pores evenly distributed. Pore arrangement solitary or as radial pairs. Multi-seriate rays visible.

Microscopic Features: (See Fig. 31) Vessels extremely numerous 90-120 per square millimeter, the larger very small mostly 50-60 (up to 70) microns in diameter; perforation plates scalariform with 30 plus bars 2.5 microns in thickness; intervessel pits orbicular, very small (4.5-5.5 microns in largest diameter), widely spaced, orifices round, oppositely arranged as vertical rows. Fibres very thin-walled; bordered pits distinct; medium diameter mostly 20-30 (average 24) microns, moderately long 2.0-2.4 (average 2.2) millimeters. Longitudinal parenchyma metatracheal-diffuse in fibre areas. Rays of two types; simple rather low 2.5 millimeters high uniseriate homogeneous, entirely upright cells, up to 50 cells high, rarely biseriate, multiseriate medium-sized 69 microns or 4 cells wide heterogeneous, always flanked with a uniseriate portion at one end.

Uses: The wood is used for furniture manufacture.

Remarks: Kanehira (30) reports on T. japonica Thunb. which appears very similar to T. gymnanthera Spr. described here.

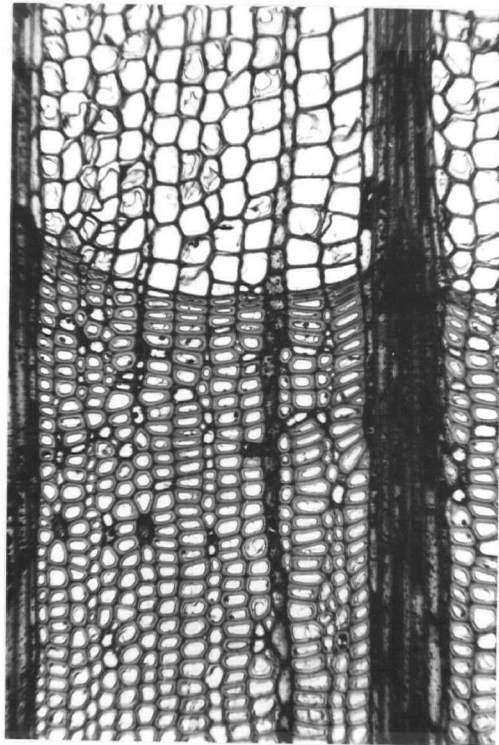


Fig. 32. Trochodendron aralioides S. et Z.
(x-sec., t-sec. and r-sec.) at 100 x

TROCHODENDRACEAE

The family, in its strictest sense, consists of one genus and species, a rather small tree of eastern Asia (39).

Taxonomic Notes: Trochodendron, formerly classified as a genus of Magnoliaceae, is not now considered part of this family due to distinct taxonomic differences (35).

Trochodendron aralioides S. et Z.

Commercial Name: Vin-yue (mandarin).

Other Names: Soo-kau-zue.

Tree: A large evergreen tree, up to 55 inches in diameter; ranging from central to northern Taiwan; associated with Chamaecyparis formosensis and C. taiwanensis.

General Properties: Heartwood gray-brown with medium lustre; grain straight; texture medium; heavy, specific gravity 0.62 (38.5 pounds per cubic foot); without characteristic odor or taste; conspicuous rays give a figure to quarter-sawn material.

Macroscopic Features: Growth rings conspicuous due to narrow bands of thick-walled tracheids. No vessels are present, vasicentric tracheids being the principal wood element and these indistinct at 10 x magnification. Broad rays distinct.

Microscopic Features: (See Fig. 32) Vasicentric tracheids extremely coarse mostly 30-35 (average 37) microns in diameter, extremely long 4.0-4.5 (average 4.3) millimeters in length; wall thickness varying across growth increment; pits between contiguous tracheal cells scalariform, arranged in vertical rows, apertures extended with occasional microscopic checking, semi-bordered pits at ray crossings small, rounded and up to 10 plus per crossing. Longitudinal parenchyma sparse metatracheal-diffuse. Rays of two types: simple, uniseriate moderately long 2.0 millimeters or 1-20 (mostly 3-10) cells high; multiseriate moderately broad 140 millimeters or 4-9 (mostly 4-6) cells wide and variable in height (mostly 40-100 cells or 1.0-2.5 millimeters high); simple rays homogeneous, entirely comprised of upright cells.

Uses: The wood is used for chemical pulp.

Remarks: Kanehira (30) reports similar anatomical characteristics for T. aralioides S. et Z., as do Record and Dadswell (39).

UIMACEAE

The family comprises about 15 genera and more than 150 species of trees, shrubs and herbs widely distributed over the temperate regions of both hemispheres (21). A few species occur in tropical regions. There are 4 genera and 5 tree species in Taiwan (30, 32, 35). The woods of two timber species are described.

Taxonomic Notes: There are relatively more ring-porous species in Ulmaceae than in Moraceae and consequently a greater number of species with advanced characters than are usually associated with the development of ring-porousness (35).

Anatomical Features: Semi-ring-porous in some species; vessels solitary or as radial multiples; perforation plates simple. Fibre pits are simple. Longitudinal parenchyma paratracheal, scanty vasicentric, confluent, or as broad bands, storied in several genera. Rays up to 2-11 cells wide, heterogeneous to homogeneous (35).

Anatomical Features of *Trema* and *Zelkova*: Semi-ring-porous in *Zelkova*. Vessels variable in arrangement, solitary in some species of *Trema* and in wavy, uniform tangential bands in *Zelkova*. Fibre pits are small and bordered. Longitudinal parenchyma is paratracheal. Rays usually up to 3 cells wide, but 6-12 cells wide in *Zelkova* (35).

Trema orientalis Bl.

Commercial Name: San-ma-hwang (mandarin).

Other Names: None known.

Tree: A large deciduous tree; ranging the whole island at sea level.

General Properties: Heartwood red-brown with medium lustre; grain straight; texture coarse; moderately light, specific gravity 0.38 (23.5 pounds per cubic foot); without characteristic odor or taste.

Macroscopic Features: Growth rings barely distinct. Large vessels visible to the naked eye; wood diffuse porous with pores evenly distributed and occasionally continuing tyloses. Pore arrangement solitary with elliptical, oval or rounded shape and as radial chain multiples up to 5.

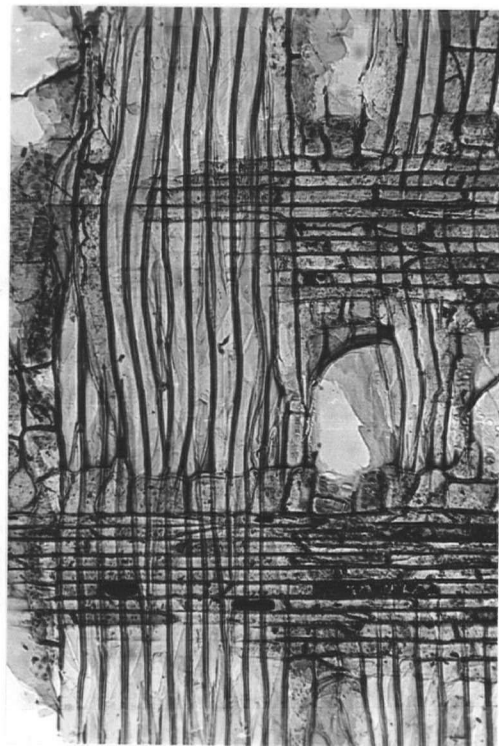
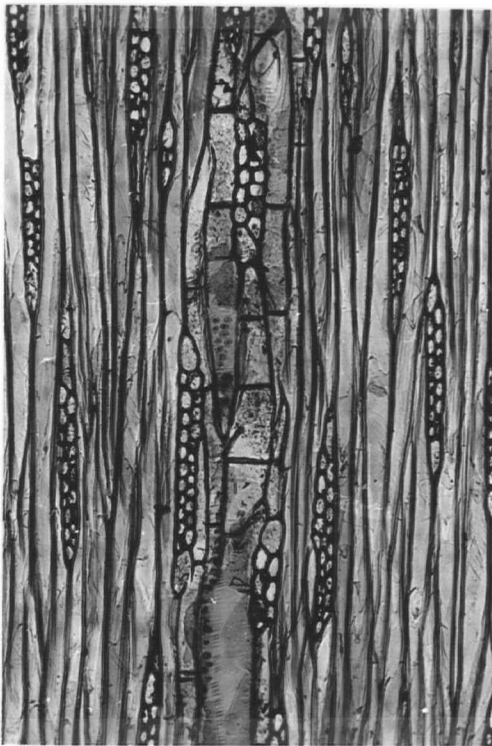
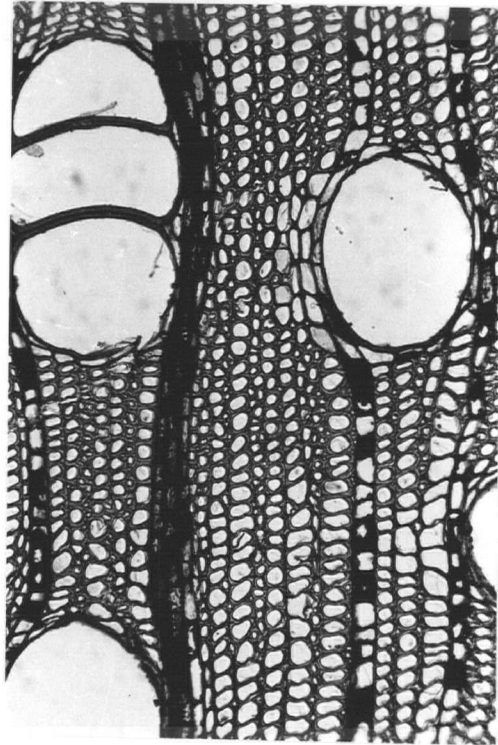


Fig. 33. Trema orientalis Bl.

(x-sec., t-sec. and r-sec.) at 100 x

Microscopic Features: (See Fig. 33) Vessels few 4-7 (mostly 5) per square millimeter, the larger round, oval or elliptical moderately large mostly 250-270 (up to 388) microns in diameter; perforation plates simple; intervessel pits orbicular, medium-sized (9.5-10.5 microns in largest diameter), close, orifices lenticular, oppositely arranged spirally. Fibres very thin-walled; pits indistinct; extremely coarse mostly 30-35 (average 33) microns in diameter, medium length 1.0-1.5 (average 1.4) millimeters. Longitudinal parenchyma of two types: metatracheal-diffuse radially distributed along rays; paratracheal-vasicentric 1-2 cells wide. Rays simple very low 0.65 millimeters high few uniseriate 3-8 cells high, homogeneous comprised entirely of upright cells, biseriate, heterogeneous, 5-15 cells high always flanked by 1-5 marginal upright cells.

Uses: The wood is used for furniture manufacture, agricultural implements, match stick blocks and for pulp.

Remarks: Kanehira (30) records similar features for T. orientalis Bl. except for vessel diameters of 80-180 microns.

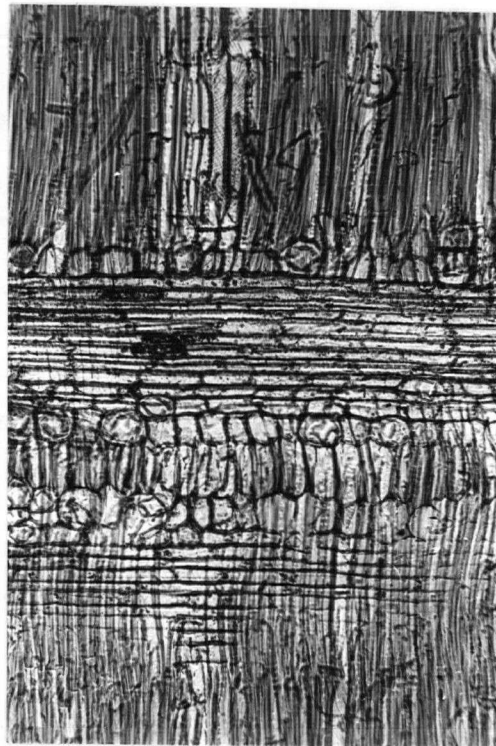
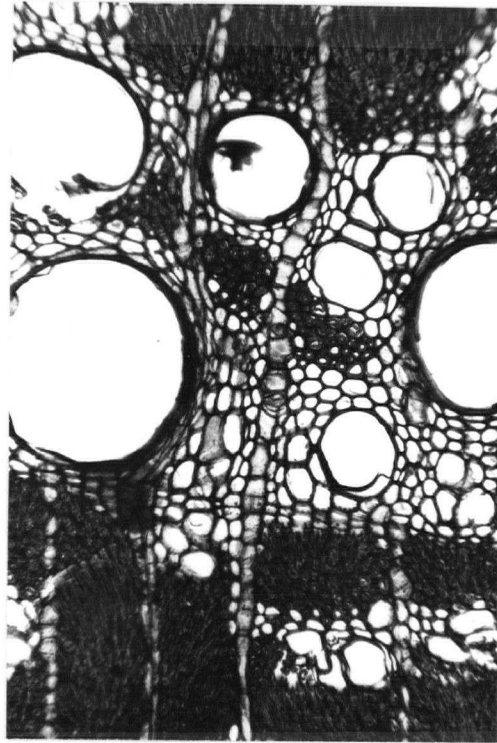


Fig. 34. Zelkova formosana Hay.

(x-sec., t-sec. and r-sec.) at 100 x

Zelkova formosana Hay.

Commercial Name: Taiwan-zsu (mandarin).

Other Names: Gi-u.

Tree: A large deciduous tree, up to 59 inches in diameter; ranging the whole island from sea level to 3,300 feet elevation; occurring as pure forests and in association with other hardwoods.

General Properties: Heartwood pink with golden-yellow stripe; medium lustre; grain straight; texture medium; very heavy, specific gravity 0.76 (47.5 pounds per cubic foot); without characteristic odor or taste.

Macroscopic Features: Growth rings conspicuous due to wide darker bands of fibrous tissue. Larger vessels visible to the naked eye; wood mostly ring porous, but occasionally semi-ring porous in some rings with pores evenly distributed, containing dark deposits and occasional tyloses. Pore arrangement solitary in springwood and as cluster groupings of 2-several in the summerwood. Rays distinct.

Microscopic Features: (See Fig. 34) Vessels moderately numerous 10-40 per square millimeter, the larger round to oval moderately large mostly 240-260 (up to 270) microns in diameter; perforation plates simple; spiral thickening present in summerwood vessels; summerwood intervessel pits orbicular, very small (4.5-5.5 microns in largest diameter) close, orifices lenticular, oppositely arranged as transverse rows. Fibres very thick-walled; pits indistinct; medium diameter mostly 20-25 (average 22) microns, medium length 1.5-2.0 (average 1.8) millimeters. Longitudinal parenchyma paratracheal-confluent extending to large areas. Rays multiseriate, moderately broad 110 microns or 5-8 cells wide and of uniform width in main body of the ray; heterogeneous with upright cells always containing crystals.

Uses: The wood is used for general construction, turnery and agricultural implements.

Remarks: Wood anatomy of Z. formosana Hay. as reported by Kanehira (30), differs from this description in vessel diameters (50-100 microns), intervessel pit size (10 microns) and the largely homogeneous character of rays.

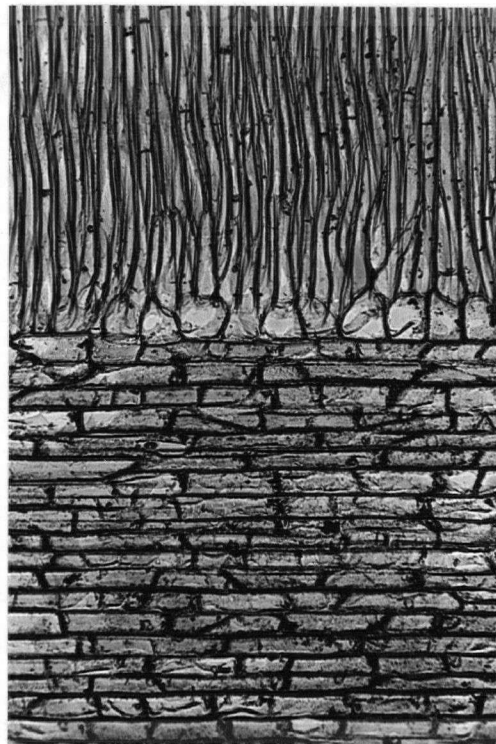
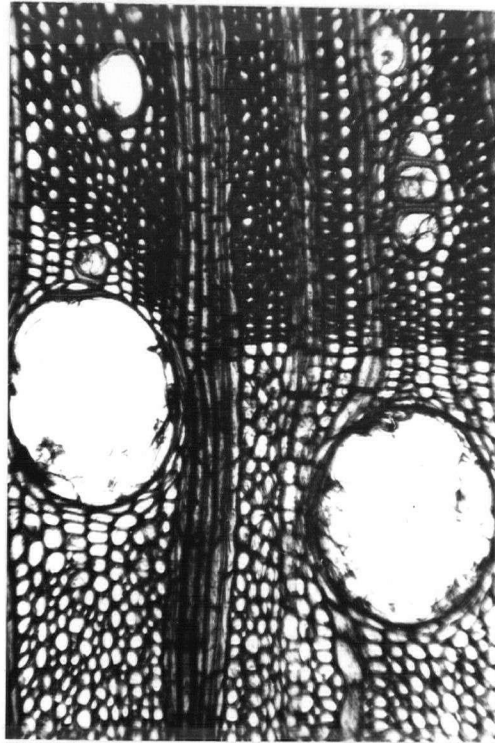


Fig. 35. Tectona grandis Linn. f.
(x-sec., t-sec. and r-sec.) at 100 x

VERBENACEAE

The family comprises about 20 genera and many species widely distributed and of diverse form including large forest trees, shrubs, lianas and herbs (35). There are 8 genera and 27 native species of small trees in Taiwan. The one species described was introduced to Taiwan in 1901 and has value as a commercial wood.

Anatomical Features: Wood structure is fairly uniform throughout the family (35). Ring-porous. Vessels mostly medium-sized; perforation plates typically simple. Fibre pits are simple, fibres are septate in most genera (35).

Anatomical Features of Tectona: Ring-porous or semi-ring-porous. Vessels medium-sized, 24-40 per square millimeter in some species; tyloses abundant. Fibres are septate. Longitudinal parenchyma in broad bands associated with pore-zones. Rays 5 or more cells wide (35).

Tectona grandis Linn. f.

Commercial Name: Teak, genuine; Iu-moo (mandarin).

Other Names: Ma-li.

Tree: A large deciduous tree; ranging from sea level to 2,300 feet elevation in southern Taiwan.

General Properties: Heartwood medium brown without lustre; grain straight; texture coarse; heavy, specific gravity 0.56 (35 pounds per cubic foot); without characteristic odor but acrid taste.

Macroscopic Features: Growth rings indistinct. Larger vessels visible to the naked eye; wood semi-ring porous or diffuse porous in some rings with pores evenly distributed and containing tyloses. Pore arrangement solitary and as radial pairs in summerwood. Broad rays distinct.

Microscopic Features: (See Fig. 35) Vessels moderately few 5-12 (mostly 7) per square millimeter, round to oval medium-sized mostly 160-210 (up to 325) microns in diameter; perforation plates simple; intervessel pits oval, very small (4.5-5.0 microns in largest diameter), close, orifices lenticular, oppositely arranged as transverse rows. Fibres very thick-walled; pits indistinct; moderately fine mostly 15-22 (average 20) microns in diameter, medium length 1.0-1.5 (average 1.2) millimeters. Longitudinal parenchyma of two types: terminal several

cells wide; paratracheal-vasicentric 1-several cells wide. Rays of two types: few simple extremely low 0.15 millimeters high variable in width from 1-3 seriate; multiseriate extremely broad 900 microns or 4-6 (mostly 4) cells wide; heterogeneous.

Uses: The wood is used for furniture, decoration and ship decking.

Remarks: Wood of Tectona grandis Linn. f. was described by Kribs (31) as ring-porous with pore diameter at 340-360 microns and containing yellowish gum and white deposits as well as tyloses. Other differences include alternately arranged intervessel pits of 6 microns diameter, septate fibres with simple pits, and mostly homogeneous rays.

Key For Separation of Thirty-five Taiwan
Woods Based On Microscopic Features

1. Wood non-porous (without vessels).....2
1. Wood porous (with vessels or other perforate conducting elements).....7
 2. Longitudinal and transverse resin canals present.....
 -Pinus armandi Franch. (p. 12, Fig. 1)
 2. Normal longitudinal and transverse resin canals absent...3
3. Ray tracheids present.....4
3. Ray tracheids absent.....6
 4. Longitudinal parenchyma terminal as single cells, sparse
 -Tsuga chinensis (Franch.) Pritz. (p. 14, Fig. 2)
 4. Longitudinal parenchyma metatracheal, or if terminal other types present.....5
5. Longitudinal parenchyma metatracheal-diffuse.....
 -Chamaecyparis taiwanensis Masam. et Suzuk. (p. 20, Fig. 6)
5. Longitudinal parenchyma terminal, metatracheal and metatracheal-diffuse.....
 -Chamaecyparis formosensis Matsum. (p. 19, Fig. 5)
6. Highest rays more than 20 cells, frequently biseriata; longitudinal parenchyma metatracheal with cells occasionally grouped as a large area.....
 -Cunninghamia konishii Hay. (p. 15, Fig. 3)
6. Highest rays less than 20 cells, biseriata infrequent or lacking; longitudinal parenchyma terminal and metatracheal.....
 -Libocedrus formosana Hay. (p. 17, Fig. 4)
7. Vasicentric tracheids radially aligned as main elements.....
 -Trochodendron aralioides S. et Z. (p. 61, Fig. 32)
7. Wood with vessels, lacking good radial alignment.....8

- 8. Perforation plates exclusively simple.....9
- 8. Perforation plates scalariform or in part scalariform...
.....24
- 9. Tyloses present.....10
- 9. Tyloses absent.....17
- 10. Tyloses abundant.....11
- 10. Tyloses not abundant.....13
- 11. Longitudinal and ray oil cells present.....
.....Cinnamomum camphora Nees. (p. 42, Fig. 19)
- 11. Longitudinal and ray oil cells absent.....12
- 12. The larger vessels more than 200 (mostly 200-210)
microns in diameter.....
.....Lithocarpus amygdalifolia Hay. (p. 31, Fig.12)
- 12. The larger vessels less than 200 (mostly 168-180)
microns in diameter.....
.....Quercus longinux Hay. (p. 34, Fig. 14)
- 13. Springwood vessels the same size or only slightly larger than
those in the summerwood (x); wood diffuse-porous.....14
- 13. Springwood vessels obviously larger (especially at low
magnification) than those in the summerwood (x); wood
ring-porous.....15
- 14. The larger vessels more than 200 (mostly 250-270)
microns in diameter.....
.....Trema orientalis Bl. (p. 62, Fig. 33)
- 14. The larger vessels less than 200 (mostly 125-140) microns
in diameter.....
.....Lagerstroemia subcostata Koehne, (p. 51, Fig. 26)
- 15. Pores solitary or in clusters; vessels containing dark dep-
osits; longitudinal parenchyma confluent, cells containing
crystals.....
.....Zelkova formosana Hay. (p. 64, Fig. 34)
- 15. Pores solitary and as radial multiples; vessels lacking deposits;
longitudinal parenchyma 2-several types, cells lacking
crystals.....16

- 16. Rays uniseriate and aggregate.....
 Castanopsis stipitata Hay. (p. 29, Fig.11)
- 16. Rays simple 1-3-seriate and multiseriate.....
 Tectona grandis Linn. f. (p. 65, Fig. 35)
- 17. Rays exclusively simple, 1-3-seriate.....18
- 17. Rays simple and other types.....23
- 18. The larger vessels more than 200 microns in diameter..
 19
- 18. The larger vessels less than 200 microns in diameter..
 20
- 19. Vessels containing dark deposits; longitudinal parenchyma
 terminal and paratracheal-confluent forming concentric
 bands, cells lacking dark deposits.....
 Cassia siamiae Lam. (p. 49, Fig. 25)
- 19. Vessels lacking dark deposits; longitudinal parenchyma
 metatracheal-zonate and paratracheal-vasicentric, cells
 containing dark deposits and crystals.....
 Engelhardtia formosana Hay. (p. 36, Fig. 16)
- 20. Bi- or tri-seriate rays showing a portion uniseriate
 at one end.....21
- 20. Bi- or tri-seriate rays not showing a portion uniseriate
 at one end.....22
- 21. The larger vessels more than 50 (mostly 95-115) microns in
 diameter.....Machilus zuihoensis Hay. (p. 48, Fig. 24)
- 21. The larger vessels less than 50 (mostly 40-45) microns in
 diameter...Machilus pseudolongifolia Hay. (p. 47, Fig. 23)
- 22. Longitudinal parenchyma metatracheal diffuse; ray
 cells large.....
 Machilus arisanensis Hay. (p. 46, Fig. 22)
- 22. Longitudinal parenchyma vasicentric, aliform and con-
 fluent; ray cells small.....
 Actinodaphne nantoensis Hay. (p. 39, Fig. 17)
- 23. Vessels containing dark deposits; rays of three types,
 uniseriate, multiseriate and aggregate.....
 Quercus gilva Bl. (p. 33, Fig. 13)

23. Vessels lacking dark deposits; rays of two types, uniseriate and multiseriate.....
.....Quercus stenophylloides Hay. (p. 35, Fig. 15)
24. Perforation plates exclusively scalariform.....25
24. Perforation plates scalariform and simple.....32
25. Pores as clusters and other types.....26
25. Pores not clustered, but as other types.....28
26. Tyloses present; intervessel pitting scalariform.....
.....Michelia formosana Mas. (p. 53, Fig. 27)
26. Tyloses absent; intervessel pitting opposite.....27
27. Rays of two types, simple and multiseriate, simple rays less than 1 mm. in height.....
.....Scheffera octophylla (Lour.) Harms. (p. 21, Fig. 7)
27. Rays exclusively simple, more than 1 mm. in height.....
.....Illicium leucanthum Hay. (p. 55, Fig. 28)
28. Longitudinal parenchyma vasicentric, terminal and metatracheal-diffuse; the larger vessels less than 50 (mostly 40-45) microns in diameter.....
.....Beilschmiedia erythrophloia Hay. (p. 41, Fig. 18)
28. Longitudinal parenchyma not vasicentric, but other types; the larger vessels more than 50 microns in diameter.....29
29. The taller simple rays more than 1 mm. in height, cells lacking deposits.....20
29. The taller simple rays less than 1 mm. in height, cells containing dark deposits.....31
30. Rays of two types, simple and multiseriate; scalariform perforation plates with 30 plus bars.....
.....Ternstroemia gymnanthera Spr. (p. 60, Fig. 31)
30. Rays simple; scalariform perforation plates with 6-14 bars..Schima superba Gard. et Champ. (p. 59, Fig. 30)
31. Rays uniseriate and aggregate; scalariform perforation plates with 10-25 bars; fibres septate.....
.....Alnus formosana (Burkill.) Makino. (p. 23, Fig. 8)

31. Rays simple, 1-3-seriate, multiseriate many cells wide;
 scalariform perforation plates with 15 plus bars; fibres
 not septate.....
Gordonia axillaris (Don.) Szysz. (p. 57, Fig. 29)
32. Oil cells present.....33
32. Oil cells absent.....34
33. Longitudinal and ray oil cells present; tyloses abundant...
Cinnamomum micranthum Hay. (p. 44, Fig. 20)
33. Longitudinal oil cells present, ray oil cells and tyloses
 absent.....Cinnamomum randaiensis Hay. (p. 45, Fig. 21)
34. Rays of two types, uniseriate and aggregate, cells
 lacking contents.....
Castanopsis longicaudata Hay. (p. 27, Fig. 10)
34. Rays simple 1-3-seriate, cells containing dark dep-
 osits.....Carpinus kawakamii Hay. (p. 25, Fig. 9)

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Glossary

(2, 4, 7, 8, 12, 13, 28, 31)

Bars: remnants of the perforation plates forming scalariform perforation.

Crassulae: thickened portions of the intercellular layer and primary cell wall between primary pit fields.

Cross-section: section cut at right angle to the grain; same as transverse section.

Crystal: inorganic mass of characteristic shape and color occurring in the cell lumen, frequently calcium oxalate, more frequently found in heartwood than in sapwood (7, 8).

Diffuse-porous: porous wood in which the pores exhibit little or no variation in size indicative of seasonal growth.

Epithelium: layer of secretory parenchymatous cells that surrounds an intercellular canal or cavity.

Fibre: general term of convenience in wood anatomy for any long narrow cell of wood other than vessels and parenchyma. It includes the libriform fibres, vasicentric tracheids and vascular tracheids of angiospermous woods.

Fibre, septate: fibre with thin transverse walls across the lumen.

Grain: arrangement and direction of alignment of wood elements when considered en masse.

Growth ring: increment of wood as it appears on transverse surface or transverse section; if one growth ring forms each year, it is called an annual ring.

Gum duct: intercellular canal containing gum.

Heartwood: inner layer of wood which, in the growing tree, has ceased to contain living cells and in which the reserve materials (e.g. starch) have been removed or converted into heartwood substance. It is generally darker in colour than sapwood, though not always clearly differentiated.

Lumen (pl. lumina): cell cavity.

Lustre: characteristic of wood enabling it to reflect light.

Marginal cell: cell on the upper or the lower margin of a wood ray as viewed in the tangential or radial section.

Macroscopic feature: characteristic visible to the naked eye and with hand lens (10x).

Microscopic checking: minute checks in wood between fibrils in the secondary walls that cannot be detected without a compound microscope.

Microscopic feature: characteristic visible only under a compound microscope.

Non-porous: wood devoid of pores or vessels, characteristic of conifers.

Oil cell: specialized cell of the ray or axial parenchyma containing oil.

Parenchyma: tissue composed of cells that are typically brickshaped 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).

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

Parenchyma, confluent: coalesced aliform parenchyma, forming irregular tangential or diagonal bands, as seen in cross-section.

Parenchyma, longitudinal: parenchyma cells derived from fusiform cambial initials and extending lengthwise in the stem.

Parenchyma, metatracheal: longitudinal parenchyma not associated with pores, often forming concentric lines or bands as seen in cross-section in coniferous wood and hardwood.

Parenchyma, metatracheal-diffuse: parenchyma, the cells of which are widely distributed between the tracheids in coniferous wood and in hardwood as seen in cross-section.

Parenchyma, metatracheal-zonate: longitudinal parenchyma forming concentric lines or bands as seen in cross-section.

Parenchyma, paratracheal: longitudinal parenchyma in association with vessels or vascular tracheids. It includes vasicentric parenchyma, aliform parenchyma and confluent parenchyma.

Parenchyma, ray: parenchyma composing the rays wholly or in part.

Parenchyma, terminal: parenchyma forming a more or less continuous layer of variable width at close of the growth increment as seen in cross-section in both coniferous and angiospermous woods.

Parenchyma, vasicentric: paratracheal parenchyma forming a complete sheath around a vessel, of variable width and circular or slightly oval in cross-section.

Parenchyma, strand: longitudinal series of two or more parenchyma cells derived from a single fusiform cambial initial.

Perforation, multiple: perforated end wall in a vessel element consisting of two or more openings in a perforation plate.

Perforation, simple: single and usually large and more or less rounded opening in a perforation plate.

Perforation: opening from one vessel member to another.

Perforation plate: term of convenience for the area of the wall (originally imperforate) involved in the endwise coalescence of two adjacent vessel segments.

Perforation plate, scalariform: plate with multiple perforations elongated and parallel.

Perforation plate, simple: single rounded opening in simple perforation.

Pit: recess in the secondary wall of a cell, together with its external closing membrane; opening internally to the lumen.

The following terms are used in describing pits:

Simple: 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.

Window-like: pit with a very wide pit aperture frequently arching into the lumen of a longitudinal tracheid and contacting a ray parenchyma cell; in certain Pinus spp.

Pit aperture: the opening or mouth of a pit. The following terms are used to describe pit apertures:

Extended: inner aperture with outline, in surface view, extending beyond the pit border.

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

Pit border: overarching part of the secondary cell wall associated with a pit.

Pitting: collective term for pits or pit-pairs.

Pitting, alternate: multiseriate intervessel pitting in which the pits are in diagonal rows, crowding may cause outlines of the borders to become hexagonal in surface view.

Pitting, opposite: multiseriate intervessel pitting in which the pits are in horizontal pairs or in short horizontal rows, crowding may cause outlines of the borders to become rectangular in surface view.

Pitting, scalariform: pitting in which elongated or linear pits are arranged in a ladder-like series.

Pore: term of convenience for the cross-section of a vessel or of a vascular tracheid.

Pore, solitary: pore completely surrounded by other elements.

Pore chain: series or line of adjacent pores.

Pore cluster: irregular grouping of pores.

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. The most common type is a radial pore multiple in which the pores are in radial files with flattened tangential walls between them.

Radial section: section cut along the grain parallel to the wood rays and usually at right angles to the growth rings.

Ray: ribbon-like aggregate of cells formed by the cambium and extending radially in the xylem, cambium and phloem.

Ray, aggregate: a group of small, narrow xylary rays interspersed with other tissues and appearing to the unaided eye or at low magnification as a single large ray.

- Ray, biseriate: ray two cells wide as seen in tangential section.
- Ray, broad: ray more than ten cells wide as seen in tangential section.
- Ray, fusiform: laterally, a ray that is spindle-shaped in tangential section. Used especially for coniferous rays that contain resin canals.
- Ray, heterogeneous: xylary 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: xylary ray composed entirely of the same cell form, either radially or longitudinally elongated, but not both.
- Ray, multiseriate: ray over three cells wide as seen in tangential section.
- Ray, narrow: ray one to three cells wide as seen in tangential section, especially in coniferous woods.
- Ray, simple: different rays including uniseriate, biseriate or triseriate; in contrast to fusiform rays of coniferous woods and multiseriate or aggregate rays of deciduous woods.
- Ray, triseriate: ray three cells wide as seen in tangential section.
- Ray, uniseriate: ray one cell wide as seen in tangential section.
- Ray cell, procumbent: ray cell with its longest axis radially aligned.
- Ray cell, upright: ray cell with its longest dimension axial, such cells compose certain uni- and biseriate rays and typically the margins of some multiseriate rays.
- Ray crossing: term of convenience for the rectangle formed by the walls of a ray cell and an axial element as seen in radial section. Used mainly with conifers.
- Ray tracheid: prosenchymous element with bordered pits forming part of a ray in certain coniferous woods.
- Resin canal: tubular, intercellular canal containing resin and sheathed by secreting cells (epithelium) in certain coniferous woods.

Ring, growth: growth layer in wood as seen in cross-section.

Ring-porous: porous wood in which the pores formed at the beginning of the growing season (springwood) are much larger than those formed later, particularly if the transition from one to the other type is more or less abrupt.

Sapwood: portion of the wood that in the living tree contains living cells and reserve materials.

Semi-diffuse porous: wood intermediate between diffuse- and ring-porous.

Semi-ring porous: wood in which the springwood is marked by a zone of (a) occasional large vessels, or (b) numerous small vessels.

Specific gravity: weight of a block of wood divided by the weight of an equal volume of distilled water at its greatest density (4°C); specific gravity of wood is taken under standard conditions and is expressed as a decimal. Data in this thesis are based on oven dry weight and green volume.

Spiral thickening: helical ridges on the inner face and part of the secondary wall.

Springwood: that portion of an annual increment or annual ring produced at the beginning of the growing season (in the spring); the inner portion of a growth ring.

Summerwood: that portion of an annual increment or annual ring produced during the latter part of the growing season (during the summer); the outer portion of a growth ring.

Tangential section: section cut along the grain at right angles to wood rays.

Texture: expression that refers to the size and the proportional amounts of woody elements; in coniferous woods, the average tangential diameter of the tracheids is the best indicator of texture; in hardwoods the tangential diameters and number of vessels and rays are used to describe this feature.

Tracheid: an imperforate wood cell of coniferous wood with bordered pits leading to contiguous similar elements.

Tracheid, vascular: imperforate cell occurring in certain hardwoods resembling in form and position a small 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.

Transverse section: section cut at right angles to the grain as seen in cross-section.

Tylosis (pl. tyloses); proliferation from an adjacent ray or axial parenchyma cell through a pit cavity in a vessel wall, partially or completely blocking the vessel lumen. They may be few or many crowded together; thin- or thick-walled; pitted or unpitted; with or without infiltration of starch, crystals, resins and gum.

Tylosoid: proliferation of a thin-walled epithelial cell into an intercellular canal.

Vessel: axial series of cells that have coalesced to form an articulated tube-like structure of indeterminate length; the pits to contiguous elements are bordered.