AN ABSTRACT OF THE THESIS OF

Chun-shu Lee for the Master of Science
(Name of student) (Degree)
in Botany presented on May 1, 1968
(Major) (Date)

Title: COMPARATIVE WOOD ANATOMY OF THE FAGACEAE
OF TAIWAN

Abstract approved

Frank H. Smith

Many species of the Fagaceae have been variously interpreted on the basis, primarily of external morphological characteristics. The objectives of this study are to elucidate generic and specific characteristics of the wood of Fagaceae and to attempt to obtain evidence regarding taxonomic relationships among some of the species occurring in Taiwan that have been variously interpreted.

There are 45 species (Lin and Liu, 1965) of Fagaceae, subdivided to seven genera, in Taiwan and 35 of these were obtained for study. Detailed descriptions are provided for all species and differences among species and genera are emphasized.

On the basis of comparative wood anatomy of the species studied, several suggestions are made regarding relationships of certain species.

The wood anatomy of Pasania urajana (Hay.) Schottky is very
similar to that of Castanopsis and quite different from the anatomy of other species of Pasania or of Lithocarpus. The cupula is cup-like, however, so that it differs in this important generic character from Castanopsis. It probably should be treated under a distinct genus, Limlia, as Masamune and Tomiya (1947) suggested.

The comparison of wood anatomy between Pasania dodoniaefolia and Pasania formosana shows consistent differences. Pasania dodoniaefolia shows distinct growth rings, homogeneous rays and absence of crystals in the parenchyma cells. Pasania formosana shows indistinct growth rings, heterogeneous rays and presence of crystals in parenchyma cells. Since the morphological characters are also somewhat different (Lin and Liu, 1965), they probably should be treated as two distinct species.

Morphologically, Castanopsis carlesii var. sessilis is very similar to Castanopsis carlesii, but is quite different with regard to wood anatomy. Since Castanopsis carlesii var. sessilis has ring porous wood, conspicuous growth rings and pore size transition abrupt, while Castanopsis carlesii has diffuse porous wood, inconspicuous growth rings, pore size transition gradual, these should be considered as separate species and the original name, Castanopsis stipitata should be recognized as the valid name.

The genera Lithocarpus and Pasania could not be separated anatomically. These genera have been separated primarily on the
basis of the cupula but they are very similar with regard to other morphological characteristics. If both anatomy and external morphology are considered, these should be treated as one genus, Lithocarpus.
Comparative Wood Anatomy of the Fagaceae of Taiwan

by

Chun-shu Lee

A THESIS

submitted to

Oregon State University

in partial fulfillment of the requirements for the degree of Master of Science

June 1968
APPROVED:

[Signature]

Professor of Botany
In Charge of Major

[Signature]

Head of Department of Botany and Plant Pathology

[Signature]

Dean of Graduate School

Date thesis is presented: May 1, 1968

Typed by Ruth Baines
ACKNOWLEDGMENTS

I want to express my deepest gratitude to Dr. Frank H. Smith, Department of Botany, Oregon State University, who directed this thesis. I am especially indebted to him for his kind encouragement and careful guidance and for his help in the preparation of this thesis.

The personal interest and encouragement of my friend, Mr. Tsing Liu, Taxonomist, Taiwan Forestry Research Institute, Republic of China, who at present is studying in the Department of Forest Management, Oregon State University, are most gratefully acknowledged. He provided the basic elements of the problem and counseled in taxonomical questions which arose.

I am grateful to my colleague, Mr. David Hansen, Department of Botany and Plant Pathology, Oregon State University, for his help in the photographic aspects of this study.

My academic training and this study would not be achieved without a grant from the National Science Council, Republic of China. Here I express my heartfelt gratefulness.
TABLE OF CONTENTS

INTRODUCTION 1

MATERIALS AND METHODS 4

SPECIES DESCRIPTIONS OF WOODS 5

ANATOMICAL KEY TO SPECIES OF FAGACEAE IN TAIWAN 55

DISCUSSION AND CONCLUSIONS 59
  Fagus (Tourn.) Linn. 60
  Castanea Tourn. 60
  Castanopsis Spach. 61
  Lithocarpus Bl. and Pasania Oerst 61
  Quercus Linn. 62
  Cyclobalanopsis Oerst 62

BIBLIOGRAPHY 69

APPENDIX 71
<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Species of Fagaceae collected in Taiwan.</td>
<td>3</td>
</tr>
</tbody>
</table>
COMPARATIVE WOOD ANATOMY OF THE FAGACEAE OF TAIWAN

INTRODUCTION

Trees of the Fagaceae are the principal components of the broad-leaved forests to Taiwan. Because of the large size and commercial value of the wood, they are considered to be economically important for use as lumber.

Originally, only five genera of the Fagaceae were recognized in Taiwan. They are *Fagus* (Linn. Syst. ed. I, 1735), *Castanea* (Tourn. ex Linn. Syst. ed. I, 1735), *Gastanopsis* (Spach. Hist. Veg. Phan. XI, 185, 1842), *Lithocarpus* (Blume, Bijdr. 526, 1825) and *Quercus* (Linn. Syst. ed. I, 1735). In more recent years, four additional genera have been recognized by various authors. They are *Pasania* (Oerst. in Kjoeb. Vidensk. Med. 81, 1866), *Cyclobalanopsis* (Oerst. in Kjoeb. Vidensk. Med. 77, 1866), *Shiia* (Makino in Journ. Jap. Bot. V, 23, 1928) and *Limlia* (Masam. et Tomiya in Acta Bot. Taiwan, I, 1, 1947). Actually, *Pasania* was separated from *Lithocarpus*; *Cyclobalanopsis* was separated from *Quercus*; *Shiia* and *Limlia* were derived from some species of *Castanopsis* and were recognized by only a few Japanese taxonomists.

A review of the systematic studies of the Fagaceae of Taiwan shows that several species have been interpreted differently by various authors. The problematic species which have been
considered by the author in this study are *Castanopsis carlesii* (Hemsl.) Hay. var. *sessilis* Nakai, which was treated as a distinct species, *Castanopsis stipitata* by Kanehira (1939); *Pasania uraiana* (Hay.) Schottky, which has been treated under various genera by various taxonomists because of the confusing characters of the plant; *Pasania formosana* (Skan) Schottky and *Pasania dodoniaefolia* Hay. which are considered to be conspectific by Li (1953), but Lin and Liu (1965) deem that they are distinct species as originally described.

The objectives of this study are to elucidate generic and specific characteristics of the wood of Fagaceae and to obtain evidence regarding taxonomic relationships among the species occurring in Taiwan.

According to Lin and Liu (1965), there are 45 species, subspecies and varieties of Fagaceae in Taiwan, among which are six introduced species. Unfortunately our wood collection is incomplete to date, but 35 species have been collected, of which four are introduced (Table 1). However, several of the species which have been variously interpreted are included, and it is hoped that this study might be helpful for solving some of the confusing classification problems.
Table 1. Species of Fagaceae collected in Taiwan. Introduced species are indicated by an asterisk.

<table>
<thead>
<tr>
<th>No.</th>
<th>Scientific Name</th>
<th>Collecting Date</th>
<th>Place</th>
<th>Collector</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fagus hayatae Palib.</td>
<td>May 20, 1966</td>
<td>Mt. Nan-cha-tein</td>
<td>C.N. Wu</td>
</tr>
<tr>
<td>3*</td>
<td>Castanea mollissima Bl.</td>
<td>Oct. 25, 1966</td>
<td>Wu-she</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>4</td>
<td>Castanopsis carlesii (Hemsl.) Hay. var. sessilis Nak.</td>
<td>Feb. 19, 1966</td>
<td>Liu-kuei</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>5</td>
<td>Castanopsis carlesii (Hemsl.) Hay.</td>
<td>Nov. 1, 1965</td>
<td>Lien-hua-chih</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>6</td>
<td>Castanopsis subacuminata Hay.</td>
<td>Feb. 18, 1966</td>
<td>Liu-kuei</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>7</td>
<td>Castanopsis formosana Hay.</td>
<td>Feb. 22, 1966</td>
<td>Liu-kuei</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>8</td>
<td>Castanopsis hystrix A. DC.</td>
<td>Nov. 2, 1965</td>
<td>Lien-hua-chih</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>10</td>
<td>Castanopsis kusanoi Hay.</td>
<td>Feb. 23, 1966</td>
<td>Liu-kuei</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>12</td>
<td>Lithocarpus amygdaifolius (Skan) Hay.</td>
<td>Nov. 3, 1965</td>
<td>Lien-hua-chih</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>13</td>
<td>Lithocarpus castanopsisfolius Hay.</td>
<td>Feb. 25, 1966</td>
<td>Liu-kuei</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>14</td>
<td>Pasania kodihoensis (Hay.) H. L. Li</td>
<td>Feb. 23, 1966</td>
<td>Liu-kuei</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>15</td>
<td>Pasania konishii (Hay.) Schottky</td>
<td>Nov. 4, 1965</td>
<td>Lien-hua-chih</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>16</td>
<td>Pasania brevicaudata (Skan) Schottky</td>
<td>Nov. 1, 1965</td>
<td>Lien-hua-chih</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>17</td>
<td>Pasania uralana (Hay.) Schottky</td>
<td>Nov. 3, 1965</td>
<td>Lien-hua-chih</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>18</td>
<td>Pasania kawakamii (Hay.) Schottky</td>
<td>Feb. 26, 1966</td>
<td>Liu-kuei</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>19</td>
<td>Pasania dodoniaefolia Hay.</td>
<td>Apr. 20, 1966</td>
<td>Taitung</td>
<td>C.N. Chang</td>
</tr>
<tr>
<td>20</td>
<td>Pasania randaiensis (Hay.) Schottky</td>
<td>Nov. 5, 1965</td>
<td>Lien-hua-chih</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>21</td>
<td>Pasania formosana (Skan) Schottky</td>
<td>Feb. 15, 1966</td>
<td>Mt. Nan-jen</td>
<td>C.N. Chang</td>
</tr>
<tr>
<td>22</td>
<td>Pasania tenuicupula (Hay.) Schottky</td>
<td>Nov. 4, 1965</td>
<td>Lien-hua-chih</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>23</td>
<td>Pasania nantouensis (Hay.) Schottky</td>
<td>Nov. 5, 1965</td>
<td>Lien-hua-chih</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>24</td>
<td>Quercus variabilis Bl.</td>
<td>Sept. 10, 1965</td>
<td>Taipei</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>25*</td>
<td>Quercus acutissima Carnuth.</td>
<td>Sept. 10, 1965</td>
<td>Taipei</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>26*</td>
<td>Quercus phyllyraeoides A. Gray</td>
<td>Sept. 11, 1965</td>
<td>Taipei</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>27</td>
<td>Quercus semicarpifolia Smith Subsp. glabra (Franch.) Handel-Mazz.</td>
<td>Oct. 9, 1966</td>
<td>Li Shan</td>
<td>T. Liu</td>
</tr>
<tr>
<td>28</td>
<td>Cyclobalanopsis pachycoma (O. Seem.) Schottky</td>
<td>Nov. 13, 1965</td>
<td>Lien-hua-chih</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>29</td>
<td>Cyclobalanopsis morii (Hay.) Schottky</td>
<td>May 6, 1966</td>
<td>Mt. Ta-hsueh</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>31</td>
<td>Cyclobalanopsis gilva (Bl.) Oerst.</td>
<td>Sept. 9, 1965</td>
<td>Taipei</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>32</td>
<td>Cyclobalanopsis stenophyloides (Hay.)</td>
<td>Feb. 24, 1966</td>
<td>Liu-juei</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>33</td>
<td>Cyclobalanopsis glauca (Thunb.) Oerst.</td>
<td>Sept. 19, 1965</td>
<td>Taipei</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>34</td>
<td>Cyclobalanopsis longimu (Hay.) Schottky</td>
<td>Feb. 26, 1966</td>
<td>Liu-kuei</td>
<td>C.S. Lee</td>
</tr>
<tr>
<td>35</td>
<td>Cyclobalanopsis globosa Lin et Liu</td>
<td>Sept. 18, 1966</td>
<td>Kuan-tao-hsi</td>
<td>Y.C. Liu</td>
</tr>
</tbody>
</table>
MATERIALS AND METHODS

All wood samples were collected from stems or branches at least 3 cm in diameter. Three blocks, 1x1x2 cm were cut from each sample so as to obtain cross, radial and tangential sections of each species. Since wood of the Fagaceae is very hard and difficult to cut with a microtome, all blocks were softened in 25% hydrofluoric acid for 6-8 weeks before sectioning. Thickness of sections varied with species and/or plane of sectioning. Sections were stained with Delafield's haematoxylin and safranin O and prepared as permanent slide specimens. Slides were also prepared from wood macerated according to the method of Jeffery (Johansen, 1940).

The wood of each species was analyzed with regard to the following characteristics:

(a) Distinctness of annual rings, and difference between early wood and late wood.

(b) Distribution, morphology, perforation, structure, and patterns of vessels and tracheids.

(c) Distribution and morphology of fibers.

(d) Distribution and structure of xylem parenchyma strands.

(e) Distribution, structure and cell types of rays.

Cross, radial and tangential sections were photographed separately, and reproduced at the same magnification so that direct comparisons can be made among the different species.
SPECIES DESCRIPTIONS OF WOODS


    Wood diffuse porous; growth ring distinct, delineated by a band of denser late wood.

    Pores evenly distributed, those in the early wood usually somewhat larger but the transition in pore size from early to late wood gradual, 150-225 per mm²; solitary and aggregated in clusters, tangential or radial rows of 2-several, polygonal, thin-walled, 1-1.5 μ in wall thickness, 15-61 μ in diameter; end walls oblique, perforation plates simple, reticulate and scalariform, 12-25 bars; pits leading to contiguous tracheal cells bordered, pit cavity orbicular or elliptical, aperture lenticular; vessel members 138-451 μ in length.

    Tyloses present in heartwood.

    Fibers 3-5 μ in wall thickness, 9-19 μ in diameter, 467-1,018 μ in length.

    Parenchyma apotracheal diffuse and paratracheal; (a) apotracheal diffuse parenchyma conspicuous, few cells with tannin inclusions; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath).

    Rays nonstoried, homogeneous or with marginal upright cells, broad and narrow; (a) broad rays several-many-seriate, up to 269 μ in width, a few cells with tannin inclusions; (b) narrow rays
1-3-seriate, 1-23 cells in height.


Wood ring porous; growth ring conspicuous, delineated by a narrow band of flattened fibers.

Pores unevenly distributed; early wood pores very large forming a broad, conspicuous band several pores in width, 9-21 per mm², solitary or occasionally in short radial rows, in late wood aggregated, orbicular or elliptical, 2-3 µ in wall thickness, 60-216 µ in diameter; late wood pores small, arranged in flame-like patches, 55-119 per mm²; the transition in pore size from early to late wood abrupt; end walls oblique, perforation plates simple or those in late wood occasionally scalariform, 3-5 bars; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture lenticular; vessel members 181-433 µ in length. Tyloses present in heartwood. Vascicentric tracheids present, confined to the vicinity of the early wood vessels.

Fibers abundant in late wood, 3-6 µ in wall thickness, 7-12 µ.
in diameter, 632-1,120 in length.

Parenchyma diffuse-in-aggregate and paratracheal; (a) diffuse-in-aggregate parenchyma abundant, especially in late wood; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath); a few cells with tannin inclusions.

Rays nonstoried, homogeneous, narrow, uniseriate or rarely in part biseriate, 1-19 cells in height.


   **Castanea crenata** sensu Henry in Elwer and Henry Trees

   Great Brit. and Irel. IV (1909) 854. (pro parte) non S.

   et Z.

   **Castanea sativa** Mill. var. **mollissima** Pampanini in Nuov.


   **Castanea sativa** Mill. var. **formosana** Hay. Mater. Fl.

   Formos. (1911) 304.


   **Castanea hupehensis** Dode in Bull. Soc. Dendr. France

   (1908) 151.

Wood ring porous; growth ring conspicuous, delineated by a
a narrow band of flattened fibers contiguous to a band of large pores.

Pores unevenly distributed; early wood pores very large forming a broad, conspicuous band several pores in width, 18-30 per mm$^2$, solitary, orbicular or elliptical, 2-3 µ in wall thickness, 49-218 µ in diameter; late wood pores small, polygonal, arranged in flame-like patches, 172-351 per mm$^2$; the transition in pore size from early to late wood abrupt; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture elliptical; vessel members 95-382 µ in length. Tyloses present in heartwood. Vasicentric tracheids present, sparse, confined to the vicinity of the early wood vessels.

Fibers arranged in radial rows, thin-walled, 1.5-3 µ in wall thickness, 5-18 µ in diameter, 675-965 µ in length.

Parenchyma diffuse-in-aggregate and paratracheal (a) diffuse-in-aggregate parenchyma abundant, very conspicuous, especially in late wood; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath); most of the cells with tannin inclusions.

Rays nonstoried, homogeneous, narrow, uniseriate or rarely in part biseriate, 2-16 cells in height; most of the cells with tannin inclusions.


**Quercus carlesii** Hemsl. in Hook. Icon. pl. XXVI pt. 2591 (1899).


**Quercus longicaudata** Hay. Icon. pl. Formos. IV (1913) 182.

**Pasania longicaudata** Hay. l. c.


**Synaedrys carlesii** Koidz. in Bot. Mag. Tokyo XXX (1916) 186.

Wood diffuse porous; growth ring inconspicuous. Pores unevenly distributed, arranged in stream-like clusters which extend for some distance radially across several to many rings; those in the early wood somewhat larger but the transition in pore size from early to late wood gradual; 11-25 per mm²; solitary or in radial
groups of two, polygonal, 2-3 \( \mu \) in wall thickness, 28-108 \( \mu \) in diameter; end walls oblique, perforation plates simple, very few scalariform with 1-2 bars; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture elliptical; vessel members 175-525 \( \mu \) in length. Very few tyloses in heartwood. Vasicentric tracheids present, confined to the vicinity of larger vessels.

Fibers abundant, 2-3.5 \( \mu \) in wall thickness, 7-21 \( \mu \) in diameter, 610-1,120 in length.

Parenchyma apotracheal banded and paratracheal; (a) banded parenchyma conspicuous, in numerous, concentric, continuous 1-4-seriate (mostly 1-2) ragged lines; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath).

Rays nonstoried, heterogeneous; (a) compound and aggregate rays several-many-seriate, up to 124 \( \mu \) in width, many cells (into the hundreds) up to 3,421 \( \mu \) in height; aggregate rays composed of smaller rays separated by strands of fibrous tissue, otherwise comparable to the compounds rays; (b) narrow rays very numerous, uniseriate, 1-23 cells in height; a few cells with tannin inclusions.


*Quercus junghuhnii* sensu Hay. Fl. Mont. Formos. (1908) 203, non Miq.


*Lithocarpus stipitata* Koidz. in L. c. XXXIX (1925) 2.

*Shiia stipitata* Kudo et Masam. in L. c. XLIV (1930) 406.

*Quercus carlesii* sensu Hay. Mater. Fl. Formos. (1911) 289 non Hemsl.

Wood ring porous; growth ring conspicuous, delineated by a narrow band of flattened fibers contiguous to a broad band of large pores.

Pores unevenly distributed; early wood pores very large, forming a broad, conspicuous band several pores in width, 6-11 per mm², solitary or occasionally in pairs, polygonal, orbicular or elliptical, 3-5 µ in wall thickness, 55-177 µ in diameter; late wood pores small, polygonal, arranged in flame-like patches, 101-153 per mm²; the transition in pore size from early to late wood abrupt;
end walls oblique, perforation plates simple or those in the smaller late wood vessels occasionally scalariform, 1-3 bars; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture orbicular or elliptical; vessel members 211-635 µ in length.

Tyloses present in heartwood. Vasicentric tracheids present, confined to the vicinity of the early wood large vessels.

Fibers 2-5 µ in wall thickness, 7-22 µ in diameter, 568-1,008 µ in length.

Parenchyma apotracheal banded and paratracheal; (a) apotracheal banded parenchyma in numerous, concentric, continuous, 1-3-seriate ragged tangential bands; (b) paratracheal parenchyma sparse, restricted to occasional cells.

Rays nonstoried, heterogeneous; (a) aggregate rays composed of smaller rays separated by strands of fibrous tissue; (b) narrow rays very numerous, uniseriate or biseriate, 1-25 cells in height; very few cells with tannin inclusions.


Syn. **Castanopsis indica** sensu Hay. Fl. Mont. Formos. (1908) 204 non A. DC.
Wood diffuse porous; growth ring distinct in heartwood, indistinct in sap wood.

Pores unevenly distributed, arranged in stream-like clusters which extend for some distance radially, those in the early wood usually somewhat larger but the transition in pore size from the early to late wood gradual, 1-11 per mm²; solitary, polygonal or oval, 2-3 µ in wall thickness, 45-227 µ in diameter; end wall oblique, perforation plates orbicular or elliptical, aperture lenticular; vessel members 211-375 µ in length. Tyloses present in heartwood. Vasicentric tracheids present, forming a 1-3 seriate sheath, interrupted by parenchyma, about the vessels.

Fibers abundant, 3-4 µ in wall thickness, 10-75 µ in diameter, 623-961 µ in length.

Parenchyma diffuse-in-aggregate and paratracheal; (a) diffuse-in-aggregate parenchyma abundant, a few cells with book-shaped crystals; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath).

Rays nonstoried, heterogeneous, narrow, uniseriate or rarely in part biseriate, 1-21 cells in height.


Wood diffuse porous; growth ring distinct, delineated by a band of thick-walled fibers.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 6-18 per mm²; solitary, polygonal, orbicular or oval, 2-3 μ in wall thickness, 46-139 μ in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular or elliptical, aperture lenticular; vessel members 139-486 μ in length. Tyloses present in heartwood. Vasicentric tracheids present, forming a sheath, interrupted by parenchyma, about the vessels.

Fibers thick-walled, 3-6 μ in wall thickness, 7-15 μ in diameter, 628-945 μ in length.

Parenchyma apotracheal banded and paratracheal; (a) banded parenchyma abundant, in numerous, concentric, continuous, 1-3-seriate ragged tangential bands; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath); a few cells with
book-shaped crystals.

Rays nonstoried, heterogeneous or nearly so; uniseriate, 1-20 cells in height; many cells with tannin inclusions.


Wood ring porous; growth ring conspicuous, delineated by a narrow band of flattened fibers bordered with a broad band of large pores.

Pores unevenly distributed, early wood pores very large forming a conspicuous band several pores in width, 5-12 per mm², solitary, polygonal, orbicular or oval, 204 µ in wall thickness, 61-188 µ in diameter; late wood pores small, polygonal, arranged in flame-shaped clusters, 119-197 per mm², the transition in pore size from early to late wood abrupt; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular or elliptical, aperture lenticular; vessel members 172-562 µ in length. Few tyloses present in heartwood. Vasicentric tracheids present, forming 1-3-seriate sheath, interrupted by parenchyma, confined to the vicinity of the early wood large
vessels.

Fibers arranged in numerous, concentric bands, 3-6 µ in wall thickness, 8-19 µ in diameter, 553-1,126 µ in length.

Parenchyma apotracheal banded and paratracheal; (a) banded parenchyma abundant, conspicuous, in numerous, concentric, continuous, 1-3-seriate ragged tangential bands; (b) paratracheal parenchyma sparse, restricted to occasional cells.

Rays nonstoried, heterogeneous; (a) compound and aggregate rays several-many-seriate, up to 133 µ in width, many cells, up to 1,672 µ in height; aggregate rays composed of smaller rays separated by strands of fibrous tissue; (b) narrow rays numerous, uniseriate, 2-21 cells in height.


Wood ring porous; growth ring conspicuous, delineated by a very narrow band of flattened fibers bordered with a 1-3-seriate band of large vessels.

Pores unevenly distributed, early wood pores very large forming a conspicuous, tangential band 1-3 pores in width, 6-13 per mm², solitary, orbicular or oval, 2-4 µ in wall thickness, 49-151 µ in diameter; late wood pores small, polygonal, arranged in broad, flame-shaped patches, 101-188 per mm², the transition in pores size from early to late wood abrupt; end walls oblique, perforation
plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular or elliptical, aperture elliptical or lenticular; vessel members 120-485 μ in length. Tyloses occasionally present in vessels. Vasicentric tracheids forming a sheath interrupted by parenchyma, confined to the vicinity of the early wood large vessels.

Fibers thick-walled, arranged in obliquely radial patches, 3-6 μ in wall thickness, 7-22 μ in diameter, 475-968 μ in length.

Parenchyma apotracheal banded and paratracheal; (a) banded parenchyma distinct, uniseriate; (b) paratracheal parenchyma sparse; few cells with tannin inclusions.

Rays nonstoried, heterogeneous, 1-2-seriate, 2-21 cells in height; almost all the cells with tannin inclusions.


Wood semi-diffuse porous; growth ring distinct, delineated by a band of thick-walled, flattened fibers.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 2-14 per mm²; solitary, polygonal or orbicular, 3-5 μ in wall thickness, 28-193 μ in diameter; end walls oblique, perforation plates simple; pits
leading to contiguous tracheal cells bordered, pit cavity orbicular or elliptical, aperture lenticular (fusiform); vessel members 239-648 μ in length. Tyloses present in heartwood. Vasicentric tracheids present, confined to the vicinity of larger vessels.

Fibers thin-walled, 2-5 μ in wall thickness, 7-24 μ in diameter, 598-982 μ in length.

Parenchyma poorly differentiated against the background of fibrous tissue; (a) diffuse parenycyma sparse; (b) apotracheal banded parenchyma abundant, in numerous, concentric, 1-3-seriate, ragged tangential bands; (c) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath).

Rays nonstoried, heterogeneous, uniseriate, 1-19 cells in height.


Wood diffuse porous; growth ring distinct, delineated by a band of thick-walled fibrous tissue.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 6-18 per mm²;
solitary, polygonal, orbicular or elliptical, 2-4 µ in wall thickness, 59-181 µ in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular or elliptical, aperture lenticular; vessel members 139-512 µ in length. Tyloses present in heartwood. Vasicentric tracheids present, confined to the vicinity of large vessels.

Fibers 3-6 µ in wall thickness, 8-18 µ in diameter, 672-995 µ in length.

Parenchyma apotracheal banded and paratracheal; (a) banded parenchyma abundant, conspicuous, in numerous, concentric, more or less continuous, 1-3-seriate, tangential bands; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath), some cells with tannin inclusions.

Rays nonstoried, heterogeneous, uniseriate, 1-25 cells in height, few cells with tannin inclusions.


Syn. **Quercus amygdalifolius** Skan in Forbes et Hemsl. Ind. Fl. Sin. II (1899) 506.


Wood diffuse porous; growth ring indistinct.
Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 4-19 per mm²; solitary, orbicular or oval; 3-8 µ in wall thickness, 32-168 µ in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture lenticular; vessel members 141-524 µ in length. Vas-icentric tracheids present, forming a 1-2-seriate sheath, interrupted by parenchyma, about the larger vessels.

Fibers thick-walled, 3-7 µ in wall thickness, 7-22 µ in diameter, 432-842 µ in length.

Parenchyma apotracheal banded or paratracheal; (a) banded parenchyma abundant, conspicuous, in numerous, concentric, continuous, 1-3-seriate (mostly 1-seriate) tangential bands; (b) paratracheal parenchyma sparse, restricted to occasional cells, a few cells with tannin inclusions.

Rays nonstrored, heterogeneous; (a) aggregate rays composed of smaller rays separated by strands of fibrous tissue; (b) narrow rays numerous, uniseriate, 1-19 cells in height; most of the cells with tannin inclusions.


(1916) 72.


Pasania castanopsisifolia Hay. l. c.


Wood diffuse porous; growth ring scarcely distinct, delineated by a band of flattened fibers.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 4-16 per mm²; solitary, orbicular or elliptical, 2-4 μ in wall thickness, 31-176 μ in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture orbicular or elliptical; vessel members 134-586 μ in length. Tyloses present in heartwood. Vasicentric tracheids present, confined to the vicinity of larger vessels.

Fibers 2-6 μ in wall thickness, 7-23 μ in diameter,
581-987 μ in length.

Parenchyma diffuse-in-aggregate and paratracheal; (a) diffuse-in-aggregate parenchyma conspicuous; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath); a few cells with book-shaped crystals or tannin inclusions.

Rays nonstoried, heterogeneous; (a) compound and aggregate rays several-many-seriate, up to 750 μ in width, many cells (into the hundreds) and up to 5,121 μ in height; aggregate rays composed of smaller rays separated by strands of fibrous tissue, otherwise comparable to the compound rays, few cells with crystals; (b) narrow rays very numerous, unseriate, occasionally biseriate, 1-23 cells in height.


**Quercus kodaihoensis** Hay. Icon. Pl. Formos. IV (1914) 21.


Wood diffuse porous; growth ring indistinct.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 3-5 per mm²; solitary and occasionally in groups of 2, orbicular or elliptical,
3-6 µ in wall thickness, 31-196 µ in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture lenticular; vessel members 149-485 µ in length. Tyloses present, numerous in heartwood. Vasicentric tracheids present, confined to the vicinity of larger vessels.

Fibers thick-walled, 3-7 µ in wall thickness, 11-34 µ in diameter, 451-896 µ in length.

Parenchyma diffuse-in-aggregate and paratracheal; (a) diffuse-in-aggregate parenchyma abundant, conspicuous; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath); few cells with book-shaped crystals.

Rays nonstoried, heterogeneous; (a) compound and aggregate rays several-many-seriate, up to 165 µ in width, many cells (into hundreds) and up to 7,510 µ in height; aggregate rays composed of smaller rays separated by strands of fibrous tissue, otherwise comparable to the compound rays, few cells with book-shaped crystals; very few sclereids present; (b) narrow rays very numerous, uniseriate, occasionally biseriate, 1-24 cells in height.


Quercus cornea Lour. var. konishii Hay. Icon. Fl. Formos. III (1913) 179.

Wood diffuse porous; growth ring distinct, delineated by thick-walled fibers bordering on light colored early wood.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially. 15-28 per mm²; solitary, orbicular or elliptical, 3-7 µ in wall thickness, 28-149 µ in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture orbicular or lenticular; vessel members 144-491 µ in length. Vasicentric tracheids present, forming a 1-2-seriate sheath, interrupted by parenchyma, about the vessel.

Fibers 3-6 µ in wall thickness, 7-21 µ in diameter, 459-1,060 µ in length.

Parenchyma conspicuous; (a) diffuse-in-aggregate parenchyma numerous; (b) apotracheal banded parenchyma in concentric, continuous, 1-4-seriate, tangential bands; (c) paratracheal parenchyma sparse, restricted to occasional cells; a few cells with book-shaped crystals.
Rays nonstoried, heterogeneous; (a) aggregate rays composed of smaller rays separated by strands of fibrous tissue; (b) narrow rays numerous, 1-2-seriate, 1-41 cells in height.


*Quercus brevicaudata* Skan in Journ. Linn. Soc. XXVI (1899) 308.


*Pasania impressivena* (Hay.) Schottky in l. c. 675.


*Syneaedrys brevicaudata var. pinnativena* Suzuki ex Masam. Short Fl. Formos. (1936) 43.

Wood diffuse porous; growth ring scarcely distinct, delineated by a faint narrow line of denser fibrous tissue at the outer margin.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 6-25 per mm²; solitary, orbicular or elliptical, 3-5 µ in wall thickness, 25-189 µ in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture lenticular; vessel members 132-558 µ in length. Tyloses present in heartwood. Vasicentric tracheids present, forming a 1-2-seriate sheath, interrupted by parenchyma, about the vessels.

Fibers thin-walled, 2-5 µ in wall thickness, 6-26 µ in diameter, 498-972 µ in length.

Parenchyma apotracheal diffuse, banded and paratracheal; (a) diffuse parenchyma sparse, scattered among fibers as single cells; (b) banded parenchyma abundant, conspicuous, in numerous, concentric, continuous, 1-3-seriate, tangential bands; (c) paratracheal parenchyma sparse, restricted to occasional cells.

Rays nonstoried, heterogeneous (marginal cells upright); (a) compound and aggregate rays several-many-seriate, up to 152 µ in width; aggregate rays composed of smaller rays separated by strands of fibrous tissue, otherwise comparable to the compound rays; (b) narrow rays numerous, uniseriate, 1-16 cells in height; many cells with tannin inclusions.

**Syn.** *Quercus uraiana* Hay. Mater. Fl. Formos. (1911) 299.


Wood ring porous; growth ring conspicuous, delineated by thick-walled fibrous tissue bordering on early wood.

Pores unevenly distributed, early wood pores very large forming a narrow, conspicuous band 1-3 pores in width, 2-9 per mm$^2$; solitary, polygonal, orbicular or elliptical, 3-5 $\mu$ in wall thickness, 52-183 $\mu$ in diameter; late wood pores small, polygonal, arranged in flame-like patches. 69-149 per mm$^2$, the transition in pore size from early to late wood abrupt; end walls oblique, perforation plates simple or those in the smaller late wood vessels occasionally scalariform, 1-4 bars; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture orbicular or lenticular;
vessel members 230-634 µ in length. Tyloses present, abundant in heartwood. Vasicentric tracheids present, confined to the vicinity of the early wood vessels.

Fibers 3-7 µ in wall thickness, 7-21 µ in diameter, 383-996 µ in length.

Parenchyma apotracheal banded and paratracheal; (a) banded parenchyma abundant, in numerous, concentric, continuous, 1-3-seriate, tangential bands; (b) paratracheal parenchyma sparse, restricted to occasional cells.

Rays nonstoried, heterogenous; (a) aggregate rays composed of smaller rays separated by strands of fibrous tissue; (b) narrow rays very numerous, uniseriate, 1-21 cells in height.


Wood diffuse porous; growth ring distinct.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 2-12
per mm$^2$; solitary, orbicular or elliptical, 3-5 $\mu$ in wall thickness, 49-189 $\mu$ in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture orbicular or lenticular; vessel members 195-510 $\mu$ in length. Tyloses present in heartwood. Vasicentric tracheids present, confined to the vicinity of larger vessels.

Fibers 2-5 $\mu$ in wall thickness, 8-25 $\mu$ in diameter, 501-976 $\mu$ in length.

Parenchyma apotracheal banded and paratracheal; (a) banded parenchyma very abundant, conspicuous, in numerous, concentric, continuous, 1-4-seriate (mostly 2-3-seriate), tangential bands;
(b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath); some cells with tannin inclusions.

Rays nonstoried, heterogeneous; (a) compound and aggregate rays several-many-seriate, up to 159 $\mu$ in width, many cells (into the hundreds) up to 13,920 $\mu$ in height; aggregate rays composed of smaller rays separated by strands of fibrous tissue, otherwise comparable to the compound rays; (b) narrow rays very numerous, uniseriate, occasionally biserial, 1-27 cells in height; most of the cells with tannin inclusions.


Quercus dodoniaefolia Hay. Icon. Pl. Formos. III (1913) 181, t. 27.

Synaedrys formosana (Skan) Koidz. var. dodoniaefolia

Wood diffuse porous; growth ring distinct.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 5-19 per mm²; solitary, orbicular or elliptical, 3-5 µ in wall thickness, 42-168 µ in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture lenticular; vessel members 179-691 µ in length. Tyloses present in heartwood. Vasicentric tracheids present, confined to the vicinity of larger vessels.

Fibers 2-6 µ in wall thickness, 7-18 µ in diameter, 546-895 µ in length.

Parenchyma apotracheal banded and paratracheal; (a) banded parenchyma very abundant, conspicuous, in numerous, concentric, continuous, 1-3 (mostly 2-3) seriate bands; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath); some cells with tannin inclusions.

Rays nonstoried, heterogeneous; (a) compound and aggregate
rays several-many-seriate, up to 225 µ in width, many cells in height; aggregate rays composed of smaller rays separated by strands of fibrous tissue, otherwise comparable to the compound rays; (b) narrow rays numerous, uniseriate, 1-31 cells in height; most of the cells with tannin inclusions.


*Quercus rhombocarpa* Hay. Icon. Pl. Formos. III (1913) 186.

*Pasania rhombocarpa* Hay. l. c.


*Lithocarpus nakaii* Hay. Icon. Fl. Formos. IX (1920) 106, f. 34.


Synaedrys nakaii (Hay.) Kudo in l. c.

Synaedrys rhombocarpa (Hay.) kudo form. suishaensis
Kudo in l. c. 389.


Wood diffuse porous; growth ring scarcely distinct.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 11-31 per mm²; solitary, orbicular or elliptical, 3-5 µ in wall thickness, 30-189 µ in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture orbicular or lenticular; vessel members 86-432 µ in length. Tyloses present in heartwood. Vasicentric tracheids present, forming a 1-3-seriate sheath, interrupted by parenchyma, about the vessels.

Fibers 3-6 µ in wall thickness, 7-23 µ in diameter, 452-963 µ in length.
Parenchyma abundant, conspicuous, distributed in (a) diffuse-in-aggregate or (b) irregularly apotracheal banded; (c) para-tracheal parenchyma sparse, restricted to occasional cells (not forming a sheath); a few cells with tannin inclusions.

Rays nonstoried, heterogeneous; (a) Broad rays aggregate, composed of smaller rays separated by strands of fibrous tissue, many cells (into the hundreds) and up to 13,490 µ in height; (b) narrow rays numerous, uniseriate, 1-32 cells in height; a few cells with tannin inclusions.


Wood diffuse porous; growth ring indistinct.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 3-13 per mm²; solitary and occasionally in groups of 2, orbicular or elliptical,
3-4 µ in wall thickness, 49-133 µ in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture lenticular; vessel members 179-573 µ in length. Tyloses present in heartwood. Vasicentric tracheids present, confined to the vicinity of larger vessels.

Fibers thick-walled, 3-7 µ in wall thickness, 7-18 µ in diameter, 381-863 µ in length.

Paranchyma diffuse-in-aggregate and paratracheal; (a) diffuse-in-aggregate parenchyma abundant; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath); some cells with tannin inclusions, a few cells with book-shaped crystals.

Rays nonstoried, heterogeneous, (a) compound and aggregate rays several-many-seriate, up to 238 µ in width, many cells (into the hundreds) and up to 1,028 µ in height; aggregate rays composed of smaller rays separated by strands of fibrous tissue, otherwise comparable to the broad rays; (b) narrow rays very numerous, uniseriate, 1-31 cells in height; most of the cells with tannin inclusions; few cells with book-shaped or polyhedral crystals.


Synaedrys matsudai (Hay.) Kudo in l. c. 388.


Wood diffuse porous; growth ring distinct, delineated by denser fibers bordering on early wood.

Pores unevenly distributed, arranged in flame-like or stream-like clusters (sometimes in broader patches) which extend for some distance radially, 10-51 per mm²; solitary, orbicular or elliptical, 4-7 µ in wall thickness, 30-173 µ in diameter; end walls oblique,
perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture lenticular; vessel members 81-508 µ in length. Tyloses occasionally present in heartwood. Vas-icentric tracheids present, forming a 1-3-seriate sheath, interrupted by parenchyma, about the vessels.

Fibers 3-7 µ in wall thickness, 7-20 µ in diameter, 392-804 µ in length.

Parenchyma abundant, conspicuous, apotracheal banded and paratracheal; (a) banded (sometimes diffuse-in-aggregate) paren-chyma in concentric, more or less continuous, 1-3-seriate ragged bands; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath); many cells with tannin inclusions.

Rays nonstoried, heterogeneous, (a) compound and aggregate rays several-many-seriate, up to 163 µ in width, many cells (into the hundreds) and up to 6,213 µ in height; many sclereids and book-shaped crystals in heartwood rays; aggregate rays composed of smaller rays separated by strands of fibrous tissue; (b) narrow rays numerous, uniseriate, 1-18 cells in height; many cells with tannin inclusions.


Wood diffuse porous; growth ring indistinct.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 10-25 per mm²; solitary, orbicular or elliptical, 3-7 μ in wall thickness, 29-159 μ in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture orbicular or lenticular; vessel members 142-528 μ in length. Tyloses present in heartwood. Vasicentric tracheids present, forming a 1-3-seriate sheath, interrupted by parenchyma, about the vessels.

Fibers 3-7 μ in wall thickness, 7-20 μ in diameter, 368-896 μ in length.

Parenchyma abundant, conspicuous, apotracheal banded and paratracheal; (a) banded parenchyma in numerous, concentric, more or less continuous, 1-2-seriate, tangential bands; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath); a few cells with tannin inclusions.

Rays nonstoried, heterogeneous; (a) compound and aggregate rays several-many-seriate, up to 309 μ in width, many cells (into
the hundreds) and up to 7,123 μ in height; aggregate rays composed of smaller rays separated by strands of fibrous tissue, otherwise comparable to the compound rays; (b) narrow rays numerous, uniseriate, 1-22 cells in height; a few cells with tannin inclusions.


Syn. Quercus serrata sensu Carruth. in Journ. Linn. Soc.

VI (1862) 32. non Thunb.

Quercus chinensis sensu Bunge in Mem. Sav. Etr. Acad.


61; non. Abel.


Wood semi-diffuse porous; growth ring distinct, delineated through an abrupt difference in size between the pores of the late wood and those in the early wood of the succeeding ring.

Pores scattered, those in the early wood large, decreasing gradually in size toward the outer margin of the ring, 29-53 per mm²; solitary, orbicular or elliptical, 3-7 μ in wall thickness, 29-219 μ in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular or elliptical, aperture lenticular; vessel members 115-384 μ in length. Tyloses present in heartwood. Vasicentric tracheids present, forming a 1-3-seriate sheath, interrupted by parenchyma, about the vessels.
Fibers thick-walled, abundant in late wood, sometimes gelatinous; 3-7 µ in wall thickness, 7-18 µ in diameter, 528-893 µ in length.

Parenchyma conspicuous; (a) diffuse-in-aggregate parenchyma abundant, distributed at random; (b) apotracheal banded parenchyma in concentric, continuous, 1-3-seriate ragged tangential bands; (c) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath); a few cells with book-shaped crystals or tannin inclusions.

Rays nonstoried, homogeneous; (a) compound and aggregate rays several-many-seriate, up to 719 µ in width, many cells (into the hundreds) and up to 4,192 µ in height; aggregate rays composed of smaller rays separated by strands of fibrous tissue; (b) narrow rays numerous, uniseriate, 1-27 cells in height; many cells with book-shaped crystals or tannin inclusions.

25. Quercus acutissima Carruth. in Journ. Linn. Soc. VI (162) 33.  

Wood semi-diffuse porous; growth ring distinct, delineated through an abrupt difference in size between the pores of the late wood and those in the early wood of the succeeding ring.

Pores scattered, those in the early wood large, decreasing
gradually in size toward the outer margin of the ring, 10-41 per
2
mm; solitary and occasionally in radial groups of 2; orbicular or
elliptical, 3-5 µ in wall thickness, 29-159 µ in diameter; end walls
oblique, perforation plates simple; pits leading to contiguous tra-
cheal cells bordered, pit cavity orbicular or elliptical, aperture
orbicular or lenticular; vessel members 141-431 µ in length. Few
tyloses present in heartwood. Vasicentric tracheids present, form-
ing a 1-4-seriate sheath, interrupted by parenchyma, about the
vessels.

Fibers thick-walled, sometimes gelatinous, 3-7 µ in wall
thickness, 8-19 µ in diameter, 489-963 µ in length.

Parenchyma conspicuous; (a) diffuse-in-aggregate paren-
chyma sparse, restricted to occasional cells (not forming a sheath);
a few cells with book-shaped crystals or tannin inclusions.

Rays nonstoried, homogeneous (very few heterogeneous) or
nearly so; (a) compound and aggregate rays several-many-seriate,
up to 628 µ in width, many cells (into the hundreds) and up to 5,123 µ
in height; aggregate rays sparse; (b) narrow rays very numerous,
uniseriate, 1-28 cells in height; a few cells with book-shaped crys-
tal or tannin inclusions.

26. **Quercus phillyraeoides** A. Gray, Mem. Am. Acad. N. S. VI
(1858-59) 406.
Syn. Quercus illex L. var. phillyraeoides Franch. in Journ. de Bot. (1899) 152.

Quercus illex L. var. acordonda Skan in Journ. Linn. Soc. XXVI (1899) 516.

Quercus acrodonta Seem. in Engl. Bot. Jahrb. XXIII No. 57 (1897) 48; XXIX (1900) 290.


Wood diffuse porous; growth ring scarcely distinct.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 3-48 per mm²; solitary, orbicular or elliptical, 3-7 µ in wall thickness, 193-522 µ in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture orbicular or lenticular; vessel members 127-409 µ in length. Tyloses present in heartwood. Vasicentric tracheids present, sparse, sometimes forming a uniseriate sheath, interrupted by parenchyma, about the larger vessels.

Fibers thick-walled, sometimes gelatinous, 3-7 µ in wall thickness, 7-19 µ in diameter, 497-942 µ in length.

Parenchyma apotracheal banded and paratracheal; (a) banded parenchyma abundant, conspicuous, in numerous, concentric,
continuous, 1-3-seriate (mostly 1-2) ragged tangential bands;

(b) paratracheal parenchyma very sparse; few cells with book-shaped or polyhedral crystals.

Rays nonstoried, homogeneous; (a) compound and aggregate rays several-many-seriate, up to 526 µ in width, many cells (into the hundreds) and up to 12,750 µ in height; aggregate rays very sparse; (b) narrow rays very numerous, uniseriate, occasionally biseriate, 1-19 cells in height; few cells with book-shaped crystals or tannin inclusions; sclereids occasionally present in groups.


**Syn.** **Quercus** **Ilex** L. var. **spinosa** sensu Hay. Mater. Fl. Formos. (1911) 290. non Franch.

**Quercus spinosa** A. David var. **miyabei** Hay. Icon. Pl. Formos. VII (1918) 37.


Wood diffuse porous; growth ring scarcely distinct.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 4-47 per mm²; solitary, orbicular or elliptical, 3-6 µ in wall thickness, 31-116 µ in diameter; end walls oblique, perforation plates simple; pits
leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture lenticular; vessel members 74–302 µ in length. Tyloses present in heartwood. Vasicentric tracheids present, forming a uniseriate sheath, interrupted by parenchyma, about the vessels.

Fibers 3-6 µ in wall thickness, 7-22 µ in diameter, 397-908 µ in length; many gelatinous fibers in early wood.

Parenchyma diffuse-in-aggregate and paratracheal; (a) diffuse-in-aggregate parenchyma abundant, conspicuous; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath); few cells with tannin inclusions.

Rays nonstoried, homogeneous or with very few upright marginal cells; (a) broad rays mostly aggregate which are composed of smaller rays separated by strands of fibrous tissue; (b) narrow rays very numerous, uniseriate, 1-23 cells in height; most of the cells with tannin inclusions; few cells with book-shaped or polyhedral crystals.


**Quercus tomentosicupula** Hay. Icon. Pl. Formos. III (1913) 185, f. 33.
Cyclobalanopsis tomentosicupula Hay. l. c.


Quercus pachyloma O. Seem. var. tomentosicupula (Hay.) Metcalf. Fl. Fukien I (1942) 76.

Wood diffuse porous; growth ring indistinct.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 7-22 per mm²; solitary, orbicular or elliptical, 3-6 μ in wall thickness, 30-188 μ in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture orbicular or lenticular; vessel members 159-542 μ in length. Vasicentric tracheids present, 1-several-seriate, sometimes forming large, confluent groups about the pore clusters.

Fibers thick-walled, sometimes gelatinous, 3-7 μ in wall thickness, 7-22 μ in diameter, 542-1,039 μ in length.

Parenchyma apotracheal banded and paratracheal; (a) banded parenchyma conspicuous, in numerous, concentric, continuous, 1-2-seriate, ragged tangential bands; (b) paratracheal parenchyma sparse, restricted to occasional cells; very few cells with crystals; a few cells with tannin inclusions.

Rays nonstoried, heterogeneous; (a) compound and aggregate
rays several-many-seriate, up to 312 µ in width, many cells (into
the hundreds) and up to 5,863 µ in height; (b) narrow rays numerous,
uniseriate, 1-21 cells in height, a few cells with tannin inclusions.

XLVII (1912) 658.


Wood diffuse porous, growth ring distinct, delineated by
denser fibers bordering on early wood.

Pores unevenly distributed, arranged in flame-like or stream-
like clusters which extend for some distance radially, 3-15 per mm²;
solitary (very few in groups of 2-3), polygonal, elliptical or oval,
3-5 µ in wall thickness, 35-196 µ in diameter; end walls oblique,
perforation plates simple; pits leading to contiguous tracheal cells
bordered, pit cavity orbicular, aperture lenticular; vessel members
135-501 µ in length. Vasicentric tracheids present, forming a uni-
seriate sheath, interrupted by parenchyma, about the vessels.

Fibers thin-walled, sometimes gelatinous, 2-4 µ in wall
thickness, 10-32 µ in diameter, 432-961 µ in length.

Parenchyma diffuse-in-aggregate and paratracheal; (a) dif-
fuse-in-aggregate parenchyma abundant, sometimes in large clus-
ters; (b) paratracheal parenchyma sparse, restricted to occasional
cells (not forming a sheath); very few cells with crystals.
Rays nonstoried, heterogeneous; (a) aggregate rays composed of smaller rays separated by strands of fibrous tissue; (b) narrow rays numerous, uniseriate, occasionally biseriate, 1-55 cells in height; few cells with tannin inclusions.


Wood diffuse porous; growth ring indistinct.

Pores unevently distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 2-20 per mm²; solitary, orbicular or elliptical, 3-5 µ in wall thickness, 33-152 µ in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture lenticular; vessel members 119-486 µ in length.

Vasicentric tracheids present, forming a 1-3-seriate sheath, interrupted by parenchyma, about the vessels.

Fibers thick-walled, sometimes gelatinous, 3-6 µ in wall thickness, 7-27 µ in diameter, 532-967 µ in length.

Parenchyma apotracheal banded and paratracheal; (a) banded parenchyma abundant, conspicuous, in numerous, concentric, continuous, 1-3-seriate ragged tangential bands; (b) paratracheal
parenchyma sparse, restricted to occasional cells (not forming a sheath); many cells with book-shaped crystals or tannin inclusions.

Rays nonstoried, heterogeneous; (a) compound rays several-many-seriate, up to 273 µ in width, many cells (into the hundreds) and up to 10,500 µ in height; aggregate rays sparse; (b) narrow rays very numerous, uniseriate, occasionally biseriate, 1-24 cells in height; a few cells with book-shaped crystals or tannin inclusions.


Wood diffuse porous; growth ring distinct, delineated by a narrow line of fibrous tissue at the outer margin.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 3-18 per mm²; solitary, orbicular, 3-5 µ in wall thickness, 28-47 µ in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture lenticular; vessel members 134-452 µ in length. Vasicentric tracheids present, forming a 1-3-seriate sheath, interrupted by parenchyma, about the vessels.

Fibers thin-walled, occasionally gelatinous, 2-5 µ in wall thickness, 7-18 µ in diameter, 568-761 µ in length.
Parenchyma apotracheal banded and paratracheal; (a) banded parenchyma abundant, conspicuous, in numerous, concentric, continuous, 1-3-seriate, ragged tangential bands; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath); very few cells with book-shaped crystals.

Rays nonstoried, heterogeneous; (a) compound and aggregate rays several-many-seriate, up to 345 \( \mu \) in width, many cells (into the hundreds) and up to 2,510 \( \mu \) in height, aggregate rays composed of smaller rays separated by strands of fibrous tissue, otherwise comparable to the compound rays; (b) narrow rays very numerous, uniseriate, 1-20 cells in height; few cells with tannin inclusions; very few cells with book-shaped crystals.


Wood diffuse porous, growth ring scarcely distinct.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 2-17 per mm\(^2\); solitary, polygonal or orbicular, 2-5 \( \mu \) in wall thickness, 38-154 \( \mu \) in diameter; end walls oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular,
aperture lenticular; vessel members 119-517 µ in length. Tyloses present in heartwood. Vasicentric tracheids present, forming a 1-3-seriate sheath, interrupted by parenchyma, about the vessels.

Fibers sometimes gelatinous, 3-6 µ in wall thickness, 7-21 µ in diameter, 539-967 µ in length.

Parenchyma diffuse, diffuse-in-aggregate and paratracheal; (a) diffuse parenchyma ubiquitous; (b) diffuse-in-aggregate parenchyma conspicuous, sometimes in more or less continuous, 1-2-seriate ragged tangential bands; (c) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath); many cells with book-shaped crystals.

Rays nonstoried, heterogeneous; (a) compound and aggregate rays several-many-seriate, up to 375 µ in width, many cells (into the hundreds) and up to 5,983 µ in height, a few cells with book-shaped crystals; aggregate rays composed of smaller rays separated by strands of fibrous tissue, otherwise comparable to the compound rays; (b) narrow rays very numerous, uniseriate, 1-26 cells in height.


*Quercus annulata* Smith in Raes. Cyclop. XXIX No. 22 (1819).
Quercus phullata Hamilton apud D. Don Prodr. Fl. Nepal (1825) 57.

Perytis glauca Rafin Alsog. Am. (1838) 29.


Quercus sasakii Kaneh. ex Hay. Icon. Pl. Formos. VI (1916) 64.

Quercus laxiflora Lindley in Wallich Cat. No. 2774 (nomen nudum) (1929).

Quercus dentosa Lindley in l. c. 2775.


Wood diffuse porous; growth ring scarcely distinct.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 3-14 per mm²; solitary, orbicular or elliptical, 4-7 µ in wall thickness, 40-168 µ in diameter; end walls slightly oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture lenticular; vessel members 109-441 µ in length. Tyloses present, sparse, in heartwood. Vasicentric tracheids present, forming a 1-3-seriate sheath, interrupted by parenchyma, about the vessels.

Fibers sometime gelatinous, thick-walled, 3-7 µ in wall
thickness, 8-22 µ in diameter, 462-907 µ in length.

Parenchyma diffuse-in-aggregate and paratracheal; (a) diffuse-in-aggregate parenchyma numerous, conspicuous, many larger cells with book-shaped crystals; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath).

Rays nonstoried, heterogeneous; (a) compound and aggregate rays several-many-seriate, up to 405 µ in width, many cells (into the hundreds) and up to 3,374 µ in height, most of the cells with book-shaped crystals; many highly sclerified cells present in heartwood; aggregate rays sparse; (b) narrow rays numerous, uniseriate, occasionally biseriate, 1-22 cells in height; most of the cells with tannin inclusions.


**Quercus pseudomyrsinaefolia** Hay. Mater. Fl. Formos. (1911) 292.

**Quercus taichuensis** Hay. l. c. 296.

**Cyclobalanopsis pseudomyrsinaefolia** Hay. Mater. Fl. Formos. (1911) 292.

**Cyclobalanopsis taichuensis** (Hay.) Schottky in l. c. 683.

Wood diffuse porous; growth ring indistinct.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 1-10 per mm²; solitary, orbicular or elliptical, 3-5 µ in wall thickness, 59-250 µ in diameter; end walls slightly oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture lenticular; vessel members 121-512 µ in length. Tyloses present in heartwood. Vasicentric tracheids present, forming a 1-3-seriate sheath, interrupted by parenchyma, about the vessels, sometimes forming confluent, large patches about the pore clusters.

Fibers thick-walled, very few gelatinous, 3-7 µ in wall thickness, 8-25 µ in diameter, 501-993 µ in length.

Parenchyma apotracheal banded and paratracheal; (a) banded parenchyma conspicuous, in numerous, concentric, continuous, 1-3-seriate, ragged tangential bands; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath); few cells with tannin inclusions.

Rays nonstoried, heterogeneous; (a) compound and aggregate rays several-many-seriate, up to 453 µ in width, many cells (into the hundreds) and up to 5,251 µ in height, a few cells with book-shaped crystals; aggregate rays sparse; (b) narrow rays numerous, uniseriate, occasionally biseriate, 1-29 cells in height, most of the cells with tannin inclusions.

Wood diffus porous; growth ring indistinct.

Pores unevenly distributed, arranged in flame-like or stream-like clusters which extend for some distance radially, 4-11 per mm²; solitary, elliptical, 3-5 μ in wall thickness, 41-203 μ in diameter; end walls slightly oblique, perforation plates simple; pits leading to contiguous tracheal cells bordered, pit cavity orbicular, aperture lenticular; vessel members 119-451 μ in length. Very few tyloses present in heartwood. Vasicentric tracheids present, forming a 1-3-seriate sheath; interrupted by parenchyma, about the vessels.

Fibers thick-walled, 3-7 μ in wall thickness, 7-19 μ in diameter, 503-992 μ in length.

Parenchyma diffuse-in-aggregate and paratracheal; (a) diffuse-in-aggregate parenchyma ubiquitous, conspicuous, sometimes reticulate, a few cells with book-shaped crystals; (b) paratracheal parenchyma sparse, restricted to occasional cells (not forming a sheath).

Rays nonstoried, heterogeneous; (a) compound and aggregate rays several-many-seriate, up to 495 μ in width, many cells (into the hundreds) and up to 3,724 μ in height, a few cells with book-shaped crystals; aggregate rays sparse; (b) narrow rays very numerous, uniseriate, occasionally biseriate, 1-32 cells in height, a few cells
with tannin inclusions.
ANATOMICAL KEY TO SPECIES OF FAGACEAE IN TAIWAN

1. Vasicentric tracheids absent
   - Fagus hayatae

1. Vasicentric tracheids present
   - 2

2. Gelatinous fibers absent
   - 3

2. Gelatinous fibers present
   - 24

3. Rays homogeneous
   - 4

3. Rays heterogeneous
   - 5

4. Scalariform perforations in late wood
   - Castanea crenata

4. Porous perforations in late wood
   - Castanea mollissima

5. Pores polygonal
   - 6

5. Pores not polygonal
   - 14

6. Wood clearly ring porous
   - 7

6. Wood semidiffuse or diffuse porous
   - 10

7. Scalariform perforations in late wood
   - 8

7. Porous perforations in late wood
   - 9

8. Fibers 3-7 µ in wall thickness
   - Pasania uraiana

8. Fibers 2-5 µ in wall thickness
   - Castanopsis carlesii var. sessilis

9. Some rays compound or aggregate
   - Castanopsis hystrix

9. All rays narrow
   - Castanopsis kawa-kamii

10. Wood semidiffuse porous
    - Castanopsis kusanoi

10. Wood diffuse porous
    - 11
<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>11.</td>
<td>Only porous perforations in late wood</td>
<td>12</td>
</tr>
<tr>
<td>11.</td>
<td>Some scalariform perforations in late wood</td>
<td>Castanopsis carlesii</td>
</tr>
<tr>
<td>12.</td>
<td>Parenchyma diffuse-in-aggregate and paratracheal</td>
<td>Castanopsis sub-acuminata</td>
</tr>
<tr>
<td>12.</td>
<td>Parenchyma apotracheal banded and paratracheal</td>
<td>13</td>
</tr>
<tr>
<td>13.</td>
<td>Parenchyma crystals present, tannins absent</td>
<td>Castanopsis for-mosàna</td>
</tr>
<tr>
<td>13.</td>
<td>Parenchyma crystals absent, tannins present</td>
<td>Castanopsis stella-tospina</td>
</tr>
<tr>
<td>14.</td>
<td>Growth ring indistinct or scarcely distinct</td>
<td>15</td>
</tr>
<tr>
<td>14.</td>
<td>Growth ring distinct</td>
<td>19</td>
</tr>
<tr>
<td>15.</td>
<td>Growth ring scarcely distinct</td>
<td>Lithocarpus castan-opsisfolius</td>
</tr>
<tr>
<td>15.</td>
<td>Growth ring indistinct</td>
<td>16</td>
</tr>
<tr>
<td>16.</td>
<td>Parenchyma apotracheal banded and paratracheal</td>
<td>17</td>
</tr>
<tr>
<td>16.</td>
<td>Parenchyma diffuse-in-aggregate and paratracheal</td>
<td>18</td>
</tr>
<tr>
<td>17.</td>
<td>Tyloses absent in heartwood</td>
<td>Lithocarpus amygdalifolius</td>
</tr>
<tr>
<td>17.</td>
<td>Tyloses present</td>
<td>Pasania nantoensis</td>
</tr>
<tr>
<td>18.</td>
<td>Tannin inclusions absent</td>
<td>Pasania kodainoensis</td>
</tr>
<tr>
<td>18.</td>
<td>Tanin inclusions present in parenchyma</td>
<td>Pasania formosana</td>
</tr>
<tr>
<td>19.</td>
<td>Tyloses absent</td>
<td>Pasania konishii</td>
</tr>
<tr>
<td>19.</td>
<td>Tyloses present in heartwood</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Description</td>
<td>Leaf</td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>20.</td>
<td>Parenchyma apotracheal banded and paratracheal</td>
<td>21</td>
</tr>
<tr>
<td>20.</td>
<td>Parenchyma diffuse, banded and paratracheal or diffuse-in-aggregate, banded and paratracheal</td>
<td>23</td>
</tr>
<tr>
<td>21.</td>
<td>Crystals present in ray cells</td>
<td>Pasania ternaticupulata</td>
</tr>
<tr>
<td>21.</td>
<td>Crystals absent</td>
<td>22</td>
</tr>
<tr>
<td>22.</td>
<td>Pit aperture orbicular and lenticular</td>
<td>Pasania kawakamii</td>
</tr>
<tr>
<td>22.</td>
<td>Pit aperture lenticular only</td>
<td>Pasania dodoniaefolia</td>
</tr>
<tr>
<td>23.</td>
<td>Parenchyma diffuse banded and paratracheal</td>
<td>Pasania brevicaudata</td>
</tr>
<tr>
<td>23.</td>
<td>Parenchyma diffuse-in-aggregate and paratracheal</td>
<td>Pasania formosana</td>
</tr>
<tr>
<td>24.</td>
<td>Rays homogeneous</td>
<td>25</td>
</tr>
<tr>
<td>24.</td>
<td>Rays heterogeneous</td>
<td>28</td>
</tr>
<tr>
<td>25.</td>
<td>Wood semidiffuse porous</td>
<td>26</td>
</tr>
<tr>
<td>25.</td>
<td>Wood diffuse porous</td>
<td>27</td>
</tr>
<tr>
<td>26.</td>
<td>Parenchyma diffuse-in-aggregate, banded and paratracheal</td>
<td>Quercus variabilis</td>
</tr>
<tr>
<td>26.</td>
<td>Parenchyma diffuse-in-aggregate and paratracheal</td>
<td>Quercus acutissima</td>
</tr>
<tr>
<td>27.</td>
<td>Parenchyma apotracheal banded and paratracheal</td>
<td>Quercus phillyraeoides</td>
</tr>
<tr>
<td>27.</td>
<td>Parenchyma diffuse-in-aggregate and paratracheal</td>
<td>Quercus semicarpifolia</td>
</tr>
<tr>
<td>28.</td>
<td>Tyloses absent</td>
<td>29</td>
</tr>
<tr>
<td>28.</td>
<td>Tyloses present in heartwood</td>
<td>32</td>
</tr>
<tr>
<td>29.</td>
<td>Growth ring indistinct</td>
<td>30</td>
</tr>
</tbody>
</table>
29. Growth ring distinct
30. Vasicentric tracheids forming large confluent groups
30. Vasicentric tracheids forming 1-3-seriate sheath about the vessels
31. Parenchyma diffuse-in-aggregate and paratracheal
31. Parenchyma apotracheal banded and paratracheal
32. Growth ring scarcely distinct
32. Growth ring indistinct
33. Parenchyma diffuse, diffuse-in-aggregate and paratracheal
33. Parenchyma diffuse-in-aggregate and paratracheal
34. Parenchyma apotracheal banded and paratracheal
34. Parenchyma diffuse-in-aggregate and paratracheal

Cyclobalanopsis pachyloma
Cyclobalanopsis championii
Cyclobalanopsis morii
Cyclobalanopsis gilva
Cyclobalanopsis stenophylloides
Cyclobalanopsis glauca
Cyclobalanopsis longinunx
Cyclobalanopsis globosa
DISCUSSION AND CONCLUSIONS

The foregoing description of the wood anatomy of seven genera and thirty-five species of the Fagaceae of Taiwan indicates the complexity of the secondary xylem in this family. There is considerable variation in the different types of xylem elements among the species studied. No single character was found to occur throughout the whole family but vasicentric tracheids are present in all genera except Fagus. All the genera can be separated easily on the basis of anatomical structures except Lithocarpus and Pasania. However, these two genera can be separated on the basis of morphology of reproductive structures. Species within each genus, especially in Pasania and Cyclobalanopsis, are in general rather difficult to separate anatomically. It is hoped that later studies of external morphology can be correlated with these anatomical studies to better clarify some of the taxonomic problems in this family. As Bailey (1957) stated, "If a truly natural classification of dicotyledons is to be attained, it must be based upon harmonizing evidence from all organs and parts of the plants. It is in this synthesizing task that wood anatomy has a significant role in taxonomy."

The following descriptions attempt to characterize the wood anatomy of each genus of the Fagaceae. As indicated above, difficulty was encountered with Pasania and Lithocarpus. Based on the
species studied, and as recognized in Taiwan, these two genera could not be separated anatomically.

**Fagus** (Tourn.) Linn.

Growth ring distinct. Wood diffuse porous with pores evenly distributed, polygonal; pore size transition gradual; perforations simple, reticulate and scalariform; pit cavity orbicular, oval to elliptical, aperture lenticular, tyloses present. Fibers not gelatinous. Parenchyma apotracheal diffuse and paratracheal. Rays homogeneous or with marginal upright cells, both compound and narrow. The above general description is based on the author's description of *Fagus hayatae* and Brown and Panshin's (1940) description of *Fagus grandiflora*.

**Castanea** Tourn.

Growth ring conspicuous. Wood ring porous with pores unevenly distributed in flame-like patches in late wood; pore size transition abrupt, pores orbicular or elliptical in early wood, polygonal in late wood, perforation simple or scalariform; pit cavity orbicular, aperture lenticular to elliptical; tyloses present. Vasicentric tracheids confined to the vicinity of the larger vessels. Fibers not gelatinous. Parenchyma diffuse-in-aggregate and paratracheal. Rays homogeneous, uniseriate, or rarely biseriate.
Castanopsis Spach.

Growth ring usually distinct, rarely inconspicuous. Wood diffuse or ring porous, pores unevenly distributed in radial flame-like or stream-like clusters; pore size transition gradual or abrupt, pores orbicular in early wood, polygonal in late wood; perforation simple or scalariform; pit cavity orbicular to elliptical, aperture orbicular; tyloses present. Vascentric tracheids forming 1-3-seriate sheath about the vessels. Fibers not gelatinous. Parenchyma diffuse, diffuse-in-aggregate, banded and paratracheal. Rays heterogeneous, compound and narrow.

Lithocarpus Bl. and Pasania Oerst.

Growth ring indistinct, scarcely distinct or distinct. Wood diffuse porous, with pores unevenly distributed in radial flame-like or stream-like clusters; pore size transition gradual, pores orbicular to elliptical; perforation simple; pit cavity orbicular, aperture orbicular to lenticular; tyloses present or absent. Vascentric tracheids forming 1-3-seriate sheath about the vessels or confined to the vicinity of larger vessels. Fibers thin-walled, not gelatinous. Parenchyma diffuse-in-aggregate, banded and paratracheal, with tannin or crystals. Rays heterogeneous, compound, aggregate and narrow. The above description does not include Pasania uraiana.
This species will be discussed in more detail later.

**Quercus** Linn.

Growth ring distinct or scarcely distinct. Wood semidiffuse or diffuse porous, pores scattered or unevenly distributed in radial flame-like or stream-like clusters; pore size transition gradual, pores orbicular to elliptical; perforation simple; pit cavity orbicular to elliptical, aperture orbicular to lenticular; tyloses present. Vasicentric tracheids forming 1-4-seriate sheath about the vessels. Fibers thick-walled, gelatinous. Parenchyma diffuse-in-aggregate, banded and paratracheal, with tannin or crystals. Rays homogeneous, compound, aggregate and narrow.

**Cyclobalanopsis** Oerst

Growth ring indistinct, scarcely distinct or distinct. Wood diffuse porous, with pores unevenly distributed in radial flame-like or stream-like clusters; pore size transition gradual, pores orbicular to elliptical; perforation simple; pit cavity orbicular, aperture lenticular or rarely orbicular; tyloses present or absent. Vasicentric tracheids forming 1-several-seriate sheath or large confluent groups about the vessels. Fibers thin-or thick-walled, gelatinous. Parenchyma diffuse-in-aggregate, banded and paratracheal, with tannin or crystals. Rays heterogeneous, compound, aggregate
and narrow.

### Key to Genera of Fagaceae in Taiwan

<table>
<thead>
<tr>
<th>1. No vasicentric tracheids</th>
<th>Fagus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Vasicentric tracheids present</td>
<td>2</td>
</tr>
<tr>
<td>2. Gelatinous fibers absent</td>
<td>3</td>
</tr>
<tr>
<td>2. Gelatinous fibers present</td>
<td>5</td>
</tr>
<tr>
<td>3. Rays homogeneous</td>
<td>Castanea</td>
</tr>
<tr>
<td>3. Rays heterogeneous</td>
<td>4</td>
</tr>
<tr>
<td>4. Polygonal pores present</td>
<td>Castanopsis</td>
</tr>
<tr>
<td>4. Polygonal pores absent</td>
<td>Lithocarpus, Pasania</td>
</tr>
<tr>
<td>5. Rays homogeneous</td>
<td>Quercus</td>
</tr>
<tr>
<td>5. Rays heterogeneous</td>
<td>Cyclobalanopsis</td>
</tr>
</tbody>
</table>

According to Shimaji (1962), there are some vasicentric tracheids in *Fagus*, but they are scarce and restricted to occasional inconspicuous cells contiguous to vessels. However, Brown and Panshin (1940) did not find such elements in the wood of the American species, *Fagus grandifolia*, and I did not find any in *Fagus hayatae*. On this basis *Fagus* is considered to be the more primitive genus in the Fagaceae. In addition to the lack of vasicentric tracheids, *Fagus* shows other primitive characters such as the polygonal, evenly distributed pores, the oblique perforation plates and
scalariform perforations.

The author has made no attempt to determine phylogenetic relationships among the genera of the Fagaceae. Several proposals, based on various types of evidence, suggest possible interrelationships of the genera in this family. Schottky (1912), on the basis of data from the leaf, the flower and cupula, concluded that the genus *Pasania* is the most advanced, that the genera *Castanea*, *Castanopsis*, *Quercus*, *Cyclobalanopsis* and *Pasania* were derived from a common ancestor, and that divergence of the genus *Fagus* and the ancestor of the other genera occurred early. Schwarz (1936), on the basis of data from the flower, the cupula, the cotyledon, etc. concluded that the *Quercus* is the most advanced, and that all the genera evolved early and followed parallel paths in evolution. Shimaji (1962), on the basis of both external morphology and internal structure, agreed that Schottky's hypothetical relationships were reasonable but he considered that *Quercus* is the most advanced genus, and that *Castanopsis* is more primitive than *Castanea*. The present study offers no new evidence regarding interrelationships among the genera of the Fagaceae, but may suggest possible solutions regarding certain species which have been variously interpreted by different authors. Usually both anatomical and morphological characters are involved in these interpretations.

*Pasania uraiana* is one of the most difficult species to place.
Originally it was described as *Quercus uraiana* by Hayatae (1911) who later (1916) transferred it to *Lithocarpus uraiana*, and it was placed in *Synaedrys* by Koidzumi (1916). Kanehira and Hatushima (1936) treated it under the genus *Shiia*, then transferred it to the genus *Castanopsis* in 1939. Masamune and Tomiya (1947) treated it as the type species of a new genus, *Limlia*. Recent taxonomic studies consider the species in *Pasania*. Shimaji (1962) agreed with Kanehira and Hatushima (1939) that the species belonged in *Castanopsis* on the basis of wood anatomy. This does not agree with his three dimensional model of phylogenetic interrelationship of the groups within the Fagaceae. According to his model, the cupula of *Castanopsis* is enclosed, but the cupula of *Pasania uraiana* is cup-like. Certainly the wood anatomy of this species is very similar to that of *Castanopsis* and quite different from the anatomy of *Pasania* or *Lithocarpus*. The wood resembles most closely that of *Castanopsis carlesii* var. *ses-silis*, except that the walls of the fibers in the latter are somewhat thinner. Thus this species varies from all the species of the genus *Pasania* or *Lithocarpus* in wood anatomical characters, and varies from *Castanopsis* in external morphology. If both anatomical and morphological characters are considered, probably Masamune and Tomiya's placement of this species in the new genus, *Limlia*, is the best solution.

*Pasania formosana* and *Pasania dodoniaefolia* have also been
variously interpreted. Li (1953) treated them as one species under the name of *Pasania formosana* but Lin and Liu (1965) considered them to be separate and distinct species as originally described. A comparison of wood anatomy shows consistent differences between the two species. *Pasania dodoniaefolia* shows distinct growth rings, homogeneous rays, and absence of crystals in the parenchyma cells. *Pasania formosana* shows indistinct growth rings, heterogeneous rays and crystals in parenchyma cells. Thus anatomical evidence supports the earlier morphological evidence used to establish these as two distinct species.

*Castanopsis carlesii* var. *sessilis* was described originally by Hayata (1916) as *Quercus stipitata*, then transferred to *Lithocarpus* by Koidzumi (1925), to *Shiia* by Kudo and Masamune (1930), to *Castanopsis* by Kanehira (1939), and finally treated as a variety of *Castanopsis carlesii* by Nakai (1939), which is currently recognized by Li (1953, 1963) and Lin and Liu (1965). Since *Castanopsis carlesii* has diffuse porous wood, inconspicuous growth rings, pore size transition gradual, while *Castanopsis carlesii* var. *sessilis* has ring porous wood, conspicuous growth rings, pore size transition abrupt, these should be considered as separate species. The best solution would appear to be to reduce *Castanopsis carlesii* var. *sessilis* to synonymy and recognize *Castanopsis stipitata* as the valid name for this species.

There are many species in the Fagaceae that would be
extremely difficult to identify only on the basis of wood anatomy. The difference between any two species is very slight. For instance, the major difference between Castanea crenata and Castanea mollisima is the presence or absence of scalariform perforations in the late wood; between Castanopsis formosana and Castanopsis stellatospina, and also between Quercus variabilis and Quercus acutissima is only the arrangement of xylem parenchyma; between Lithocarpus amygdalifolius and Pasania nantoensis is only the presence or absence of tyloses in the heartwood; and between Pasania kawakamii and Pasania dodoniaefolia is only the shape of the pit aperture.

My observations differ in several minor ways from those of earlier workers on wood anatomy of the Fagaceae. Shimaji (1962) recorded the occurrence of vasicentric tracheids in Fagus including Fagus hayatae and Fagus grandifolia. The tracheids were described as few and inconspicuous. Brown and Panshin (1940) did not report such elements in Fagus grandifolia and the author did not observe any in Fagus hayatae. Shimaji (1962) described the vessel distribution of Castanopsis hystrix as radial porous and that of Quercus acutissima as ring porous. On the basis of the samples studied by me, these woods are ring porous and semidiffuse porous, respectively. Other minor differences in descriptions of characteristics of various xylem elements have been found. Such variations are expected, and the smaller the sample examined, the greater will
be the differences reported by various workers. Carlquist (1961) has stated that there are numerous variations related to environment, to location within the plant, to maturation or age of tissue, and additional variations among individuals. On the other hand, similarities in wood anatomy in different species are not indicative necessarily of close genetic relationship. This is due to the fact that parallel specialization of the tissues may have occurred independently (Bailey, 1944).

Evidence from wood anatomy of dicotyledons has proved to play an important role with reference to taxonomy and phylogeny. The lines of specialization of the various structural features have been better established for the xylem than for any other single tissue, and have been used to clarify taxonomic affinities by many anatomists (Bailey, 1954; Carlquist, 1961; Metcalfe and Chalk, 1950). If the range of variation of each character of wood anatomy has been understood, and the origin of the parallel specialization of certain tissue has been found, wood anatomy will offer more significant contributions to the clarification of taxonomic affinities.


15. Masamune, G. Three species of Formosan plants which should be included in the genus Shiia Makino. Botanical Magazine (Tokyo) 44:405-406. 1930.


APPENDIX FIGURES

Each species is illustrated by (a) cross (b) radial and (c) tangential sections, X 60

<table>
<thead>
<tr>
<th>Species</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fagus hayatae</td>
<td>73</td>
</tr>
<tr>
<td>Castanea crenata</td>
<td>73</td>
</tr>
<tr>
<td>Castanea mollissima</td>
<td>74</td>
</tr>
<tr>
<td>Castanopsis carlesii</td>
<td>74</td>
</tr>
<tr>
<td>Castanopsis carlesii var. sessilis</td>
<td>75</td>
</tr>
<tr>
<td>Castanopsis subacuminata</td>
<td>75</td>
</tr>
<tr>
<td>Castanopsis formosana</td>
<td>76</td>
</tr>
<tr>
<td>Castanopsis hystrix</td>
<td>76</td>
</tr>
<tr>
<td>Castanopsis kawakamii</td>
<td>77</td>
</tr>
<tr>
<td>Castanopsis kusanoi</td>
<td>77</td>
</tr>
<tr>
<td>Castanopsis stellatospina</td>
<td>78</td>
</tr>
<tr>
<td>Lithocarpus amygdalifolius</td>
<td>78</td>
</tr>
<tr>
<td>Lithocarpus castanopsisisfolius</td>
<td>79</td>
</tr>
<tr>
<td>Pasania kodaihoensis</td>
<td>79</td>
</tr>
<tr>
<td>Pasania konishii</td>
<td>80</td>
</tr>
<tr>
<td>Pasania brevicaudata</td>
<td>80</td>
</tr>
<tr>
<td>Pasania uraiana</td>
<td>81</td>
</tr>
<tr>
<td>Pasania kawakamii</td>
<td>81</td>
</tr>
<tr>
<td>Pasania dodoniaefolia</td>
<td>82</td>
</tr>
</tbody>
</table>
20. *Pasania randaiensis* 82
21. *Pasania formosana* 83
22. *Pasania ternaticupula* 83
23. *Pasania nantoensis* 84
24. *Quercus variabilis* 84
25. *Quercus acutissima* 85
26. *Quercus phillyraeoides* 85
27. *Quercus semicarpifolia sub sp. glabra* 86
28. *Cyclobalanopsis pachyloma* 86
29. *Cyclobalanopsis morii* 87
30. *Cyclobalanopsis championii* 87
31. *Cyclobalanopsis gilva* 88
32. *Cyclobalanopsis stenophylloides* 88
33. *Cyclobalanopsis glauca* 89
34. *Cyclobalanopsis longinux* 89
35. *Cyclobalanopsis globosa* 90