Anatomical characters and identification of Formosan woods with critical remarks from the climatic point of view, with 300 micrographs

Kanehira, Ryozo
Bureau of Productive Industries Government of Formosa Forest Experiment Station : Director

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CHAPTER IV.

SUMMARY AND CRITICAL REMARKS FROM THE CLIMATIC POINT OF VIEW.

I. Occurrence of flavone derivatives in wood.

The occurence of flavone derivatives in plants is almost exclusively limited to the epidermis and peripheral parenchymatous layer of the ærial parts, with few exceptions on record, in which a considerable amount is also found in the bark and the wood, such as in *Myrica rubra, Quercus tinctoria, Morus tinctoria* etc.[1] The author has investigated all indigenous woods described in Chapter II, by producing anthocyanin solution by reduction of flavone derivatives in wood, and has found it very important for diagnostic purposes. The method of reduction is as follows:

5 to 10 cc. of alcoholic extract, prepared by heating the wood chips with alcohol, are acidified by an addition of five to ten drops of concentrated hydrochloric acid. A few cc. of the mixture are received in a test tube with a drop of mercury the size of a pea, and a small amount of metallic magnesium powder. Reduction takes place with a vigorous generation of hydrogen gas whereby the mixture becomes coloured and often intensified by leaving over night. The comparative determination of flavone content is rather difficult and therefore only three grades of colouration have been distinguished. The following is the table showing the occurence of flavone in Formosan woods. ### strongly coloured; ## moderately coloured; # faintly coloured.

Table of flavone content in indigenous woods of Formosa.

TABLE II.

Name of wood	Colour of alcohol extract	Colour of anthocyanin	Intensity of colour
Artocarpus incisa	light yellowish brown	orange red	###
Cudrania javanensis	yellowish brown	„ „	###
Photinia daphniphylloides	light yellowish	scarlet red	###

1) K. SHIBATA (55): *The occurrence and physiological significance of flavone derivatives in plants.*

Name of wood	Colour of alcohol extract	Colour of anthocyanin	Intensity of colour
Premna integrifolia	light yellowish	orange red	###
Prunus campanulata	light yellowish brown	magenta	###
Pseudotsuga Wilsoniana	light yellowish	"	###
Myrica rubra	" "	"	###
Myrica adenophora var. Kusanoi	" "	crimson	###
Calophyllum Inophyllum	light reddish brown	reddish brown	##
Distylium racemosum	" " "	orange red	##
Malus formosana	" " "	" "	##
Stranvæsia niitakayamensis	light yellowish	" "	##
Zelkova formosana	yellowish brown	reddish brown	##
Acacia confusa	" "	dark reddish brown	#
Allophylus timorensis	" "	light yellowish red	#
Engelhardtia formosana	light yellowish brown	light reddish brown	#
Liquidambar formosana	light yellowish	orange red	#
Morus acidosa	" "	" "	# (?)
Premna formosana	" "	" "	#
Rhamnus sp.	" "	light reddish brown	#
Rhododendron Morii	" "	" " "	#
Rhododendron pseudo-chrysanthum	" "	" " "	#
Salix babylonica	" "	light red	#
Salix Warburgii	" "	" "	#

A characteristic feature is the fact that *Pseudotsuga*,[1] excepting all other conifers, contains flavone; it has great value for determination of soft wood; as it is stated later the only genera which contain flavone in coniferous woods in the Japanese Empire are *Larix* and *Pseudotsuga*; both being easily distinguished from other soft woods.

The families of high content of flavone among Formosan woods are *Urticaceæ*, *Rosaceæ*, *Myricaceæ*, *Ericaceæ*, *Verbenaceæ*, *Salicineæ*, *Guttiferæ* and *Hamamelideæ*. *Myricaceæ* and *Ternstrœmiaceæ* are two families which anatomically resemble each other very much but the former is easily distinguished from the latter by the presence of flavone.

1) *Pseudotsuga taxifolia* of America also examined and it contains flavone.

The author investigated flavone content of Japanese and Philippine woods with the following results:

Table of flavone content in Japanese woods.

TABLE III.

Name of wood	Colour of anthocyanin	Intensity of colour
Cercidiphyllum japonicum	magenta	###
Distylium racemosum	crimson	###
Gleditschia japonica	orange red	###
Larix leptolepis	magenta	###
Prunus cerasoides	crimson	###
P. Maximowiczii	magenta	###
P. pseudo-Cerasus (?)	crimson	###
P. serrulatus	"	###
P. Ssiori	magenta	###
Pseudotsuga japonica	"	###
Rhus vernicifera	orange red	###
Robinia pseudacacia	violet red	###
Myrica rubra	" "	##
Prunus Persica var. vulgaris (?)	orange red	##
Salix Caprea	" "	##
Salix Urbaniana	" "	##
Zelkova acuminata	" "	##
Prunus Grayana	" "	#
Rhus javanica	" "	#
R. succedanea var. japonica	" "	#

The families of high flavone content in dicotyledonous woods are *Rosaceæ*, *Anacardiaceæ*, *Urticaceæ*, *Salicineæ*, *Hamamelideæ*, *Leguminosæ*, *Magnoliaceæ* and *Myricaceæ*. A remarkable fact is that *Cercidiphyllum*, an endemic genus of Japan has a high content of flavone and gives very distinct reaction.

Table of flavone content in Philippine woods.

TABLE IV.

Name of woods	Intensity of colour	Colour of anthocyanin
Artocarpus communis	orange red	###
Calophyllum Blancoi	crimson	###
C. Inophyllum	„	###
Carallia integerrima	scarlet	###
Pithecolobium acutiferum	orange red	###
Vitex parviflora	„ „	###
Adenanthera intermedia	violet red	##
Albizzia acle	orange red	##
A. procera	„ „	##
Pithecolobium Saman	„ „	##
Artocarpus Cumingiana	„ „	#
Garcinia Benthami	„ „	#
G. dulce	„ „	#

The families of high flavone content in Philippine woods are *Urticaceæ*, *Guttiferæ*, *Leguminosæ*, *Verbenaceæ* and *Rhizophoreæ*.

From the above tables, the flavone content of wood is rather irregular from the climatic point of view, not showing high percentage of flavone content in the tropics, as it is in the case of flowers, leaves etc. The following is the table showing percentage of flavone content in each country.

TABLE V.

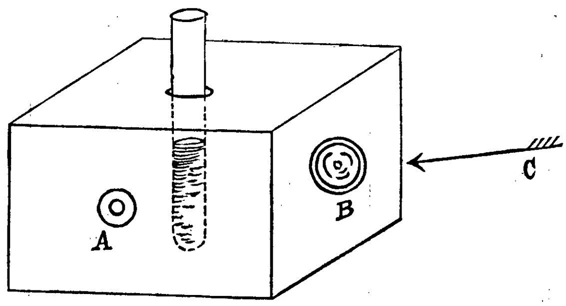
Countries	Number of woods with flavone content	Total number investigated	Percentage
Formosa	24	384	6%
Japan	20	191	11%
Philippine	13	153	%

II. Fluorescence of watery extraction of wood.

The fluorescence of watery extracts of certain species of plants is a familiar fact and especially the fluorescence of the wood extract of *Pterocarpus indicus* is very well known. As Mr. M. FUJIOKA already records in the Report of the Forest Experiment Station, Tokio, No. 15. pp. 47–64, this fluorescence possesses diagnostic value to some degree; it is, however, a rather uncertain criterion and sometimes very difficult to detect unless with some special apparatus.

The present author investigated this phenomenon in all the indigenous woods of Formosa and also those of Japan and Philippines. The method used for detecting fluorescence is as follows:

Take a few grammes of wood chips and put them into an ordinary test tube with water, leaving them for about two weeks or more, during which time the water usually becomes more or less colored; after sufficient extraction, filter off from the chips and examine. If the fluorescence of the extract is very strong it can be detected even in open rooms; if not, put the tube with the



A. eye-hole B. lens C. sun light

extract into a small camera box roughly made of wood, with a small lens in one side; putting the tube in the camera let the the sun light coming through the lens directly fall on the tube and observe it by an eye-hole as shown in the above figure.

The fluorescence is generally intensified by adding ammonia solution, but in some cases it disappears, as with *Vaccinium, Quercus, Ceriops, Acer oblongum* etc.

In the following table, ### indicates pronounced fluorescence evident in the open room; ## more clearly visible in camera; # detected only by camera.

Table of fluorescence of watery extracts of indigenous woods of Formosa.

TABLE VI.

Name of woods	Intensity		Colour of fluorescence
	Watery extract	Adding amm. sol.	
BERBERIDEÆ			
Mahonia tikushiensis	#	#	green
PITTOSPOREÆ			
Pittosporum viburnifolium	—	#	green
TERNSTRŒMIACEÆ			
Adinandra formosana	—	#	blue
A. lasiostyla	#	##	"
Anneslea fragrans var. lanceolata	—	#	indigo
Cleyera ochnacea	#	##	blue
Gordonia axillaris	—	#	green
Saurauja tristyla var. Oldhami	##	##	indigo
Thea shinkœnsis	—	#	"
MALVACEÆ			
Bombax malabaricum	#	##	green
Hibiscus mutabilis	#	#	"
H. tiliaceus	##	###	"
STERCULIACEÆ			
Sterculia luzonica	###	#	blue
RUTACEÆ			
Evodia triphylla	###	###	indigo
Fagara integrifoliola	##	###	blue
Phellodendron Wilsonii	—	#	indigo
Skimmia arisanensis	###	###	"
Zanthoxylum ailanthoides	—	#	"
MELIACEÆ			
Aglaia elliptifolia	#	#	indigo

Name of woods	Intensity		Colour of fluorescence
	Watery extract	Adding amm. sol.	
ILICINEÆ			
Ilex Hanceana	—	#	green
Ilex transarisanensis	—	#	„
SAPINDACEÆ			
Acer Kawakamii	###	###	indigo
A. morrisonense	—	#	„
A. oblongum	##	—	green
A. rubescens	##	##	indigo
A. taiton-motanum	##	##	„
Allophylus timorensis	##	##	green
Pometia pinnata	#	#	„
ANACARDIACEÆ			
Mangifera indica	—	###	green
LEGUMINOSÆ			
Acacia Farnensiana	—	##	indigo
Gleditschia formosana	##	###	green
Leucæna glauca	###	###	„
Ormosia formosana	#	#	„
ROSACEÆ			
Photinia daphniphylloides	#	#	indigo
SAXIFRAGEÆ			
Hydrangea chinensis	###	###	indigo
H. integra	###	###	„
H. Kawakamii	###	##	„
H. longifolia	###	###	„
HAMAMELIDEÆ			
Eustigma oblongifolium	—	#	green
Liquidambar formosana	#	#	indigo
RHIZOPHOREÆ			
Ceriops Candolleana var. Sasakii	##	—	green
COMBRETACEÆ			
Terminalia Catappa	#	##	indigo

Name of woods	Intensity		Colour of fluorescence
	Watery extract	Adding amm. sol.	
MYRTACEÆ			
Psidium Guajava	#	#	green
ARALIACEÆ			
Heptapleurum racemosum	—	#	green
CAPRIFOLIACEÆ			
Viburnum arboricolum	#	—	green
V. luzonicum	—	#	"
V. odoratissimum	#	—	"
RUBIACEÆ			
Diplospora viridiflora	—	#	indigo
Gardenia florida	—	##	green
Nauclea taiwaniana	###	###	"
N. truncata	#	#	"
Randia racemosa	—	#	"
VACCINIACEÆ			
Vaccinium bracteatum	###	—	green
V. caudatifolium	###	—	"
V. randaiense	##	—	"
ERICACEÆ			
Pieris pilosa	—	#	indigo
Rhododendron formosanum	##	##	green
R. Morii	#	##	indigo
R. rubro-pilosum	#	#	green
R. rubro-punctatum	##	##	"
R. Tanakai	#	—	"
MYRSINEÆ			
Rapanea neriifolia	—	#	indigo
SAPOTACEÆ			
Sideroxylon liukiuense	#	—	green
EBENACEÆ			
Diospyros eriantha	—	#	indigo
D. Sasakii	#	#	"

Name of woods	Intensity		Colour of fluorescence
	Watery extract	Adding amm. sol.	
OLEACEÆ			
Fraxinus formosana	—	##	indigo
F. insularis	#	#	„
Linociera Cumingiana	#	#	blue
Osmanthus lanceolatus	—	#	indigo
LOGANIACEÆ			
Fagraea Sasakii	—	##	blue
BORAGINEÆ			
Ehretia glaucescens	##	##	blue
VERBENACEÆ			
Premna integrifolia	#	###	green
Vitex heterophylla	—	#	„
LAURINEÆ			
Actinodaphne pedicellata	#	#	violet
Machilus longipaniculata	—	#	green
PROTEACEÆ			
Helicia formosana	#	#	indigo
EUPHORBIACEÆ			
Antidesma kotœnsis	—	#	indigo
Excœcaria Kawakamii	##	##	„
Homonoya riparia	##	###	green
Macaranga dipterocarpifolia	#	—	indigo
Mallotus philippinensis	—	#	
Sapium discolor	#	#	green
URTICACEAE			
Artocarpus incisa	##	###	green
Celtis sinensis	—	#	„
Cudrania javanensis	#	###	„
Ficus Beecheyana	##	—	
F. insularis	#	##	green
F. nervosa	###	###	„
F. retusa	—	#	„
Morus acidosa	—	##	„
Ulmus parvifolia	—	#	„

Name of woods	Intensity		Colour of fluorescence
	Watery extract	Adding amm. sol.	
U. Uyematsui	—	#	green
Zelkova formosana	—	#	"
CUPULIFERÆ			
Quercus gilva	#	—	"
Q. Konishii	##	##	blue
Q. longinux	#	—	"
Q. pseudomyrsinæfolia	#	—	"

III. Lamellated pith.

Lamellated pith is a rather rare occurrence but it is very important for diagnostic purposes, especially in young branches.

The following are the indigenous woods with lamellated pith:

Daphniphyllum glaucescens.[1)]
D. membranaceum.
Heptapleurum racemosum.
Juglans formosana.
Paulownia Kawakami, P. Mikado.
Prinsepia scandens.
Symplocos eriobotriæfolia.

Fatsia papyrifera, Actinidia Championi and *Aucuba japonica,* not further mentioned in this work, have also lamellated pith.

IV. Ripple marks or tier-like structure in dicotyledonous woods.

There are a number of woods which present on longitudinal section fine delicate cross lines of stripes called "ripple marks." This is chiefly due to the arrangement of the rays in longitudinal series, sometimes however to the tier-like ranking of the wood fibers or wood parenchyma. This character is often used for diagnostic purposes as it is easily observed by the unaided eye. The following species are the indigenous woods with ripple marks.

Erythrina indica.
E. corallodendron.
Diospyros Morrisiana.
Heritiera littoralis.
Hibiscus tiliaceus.
Kleinhovia Hospita.

1) Pith solid in *Daphniphyllum glaucencens var. Oldhami.*

Japanese woods with ripple marks are as follows[1]:

Aesculus turbinata. *Diospyros Kaki.*

Diospyros lotus. *Tilia japonica.*

Philippine woods with ripple marks are as follows:

Cumingia philippinensis. *Pterocarpus indicus.*

Dalbergia minahassæ. *P. obovatus.*

Bombycidendron vidalianum. *Pterocymbium tinctorium.*

Heritiera littoralis. *Sterculia oblongata.*

Indigofera Zollingeriana. *Tarrietia sylvatica.*

Pterocarpus echinatus. *Pterospermum niveum.*

The occurrence of ripple marks is more frequent in the Tropics.

V. Intercellular canals in dicotyledonous woods.

Dicotyledonous woods which containing secretory canals are rather confined to tropical or subtropical regions. In the same wood canals are all vertical or axial, in others all horizontal or radial; in the former case they occur only in consequence of injury, while the latter often occur normally.[1] Vertical canals are usually arranged in tangential series producing more or less complete concentric circles on cross section, giving the effect of growth rings.

The following are indigenous woods which contain vertical canals:

Liquidambar formosana. *Sterculia luzonica.*

The horizontal canals somotimes occur irregularly in *Pistacia formosana*; they may be present in the wood of one tree and not in other trees of the same kind.

The following are the indigenous woods which contain horizontal canals:

Buchanania arborescens. *Euphorbia Tirucalli.*

Pistacia formosana.

In *Euyhorbia Tirucalli* and *Pistacia formosana*, the presence of ducts causes the rays to enlarge and become fusiform as in conifers; in other species there is no effect on the shape of the ray.

I) M. Fujioka: Japanese woods with ripple marks. *Journal of Japanese Forestry Association.* No. 349. pp. 9-13.

1) S. J. Record (47): Intercellular canals in Dicotyledonous woods. *Journal of Forestry*, Apl.1 918.

In Philippine woods, a number of species with intercellular canals have been observed by the present author. Besides *Dipterocarpeæ*, which usually have vertical canals, the following are the species containing horizontal canals:

Artocarpus woodii. | *Dracontomelum Cumingianum.*
Buchanania arborescens. | *Koodersiodendron pinnatum.*
Canarium ovatum. | *Santiria nitida.*
Ficus Benthami. | *Spondias pinnata.*

Pygeum Preslii has also vertical canals which arise only in consequense of injury.

VI. Vessels.

(a). ARRANGEMENT OF PORES.

The arrangement of pores is very important for the identification of woods, although from the anatomical point of view it is not proper to rely too much upon it, as it is apt to vary under varying condition; it has however, a great advantage of being discernible by the unaided eye. In tropical regions there are very few of ring-porous woods, since deciduous trees are very rare; the following is the table showing the number of ring-porous woods in each country.

TABLE VII.

Countries.	Formosa.	Japan.	Philippines.
Ring-porous.			
Ever-green.	11	1	3 [1]
Deciduous.	27	45	0
Diffuse-porous.			
Ever-green.	268	39	152
Deciduous.	57	65	0
Total.	363	150	155
Percentage of ring-porous woods.	10.5%	30.7%	1.9%

1) *Calantas* and *Narra* are grouped with the ring-porous woods by FOXWORTHY (18) but according to my own investigation, they are included in the diffuse-porous woods.

Even the same genus of ring-porous wood in the temperate zone may be diffuse-porous in the tropical zone such as *Fraxinus* and *Kœlreuteria*, which are ring-porous in Japan but often diffuse-porous in Formosa. According to Professor S. KAWAI (37), 54 species out of 200 species of Japanese woods are ring-porous type, that is, 27%.

(b). MAXIMUM NUMBER OF PORES PER UNIT AREA.

Number of pores per unit area is a very important factor in determining species though it is quite variable even in the same tree.

In investigating all species of indigenous woods of Formosa, Japan and Philippines, exclusive of ring-porous woods, the following result is obtained.

TABLE VIII.

Classs	I	II	III	IV	V	Total number investigated
Number of pores per square mm.	1–10	11–30	31–61	61–120	120–more	
Formosa	62 19.5%	98 30.8%	57 17.9%	51 16.1%	50 15.7%	318
Japan	10 9.8%	17 16.7%	26 25.5%	27 26.5%	22 21.5%	102
Philippines	87 57.2%	55 36.2%	7 4.6%	3 2.0%	0 0.0%	152

From this table we come to very important conclusion that in Formosa the wood belonging to Class II comes first, while in Japan III and IV, and in the Philippines Class I comes ahead; in other words, the nearer the tropics the fewer the pores, that is to say tropical woods are more coarse in texture.

Formosan woods belonging to Class I are *Cupiliferæ*, *Leguminosæ* and *Urticaceæ*; to Class II mostly *Laurineæ*, *Leguminosæ*, *Urticaceæ* and *Euphorbiaceæ*; to Class III mostly *Ilicineæ*, *Euphorbiaceæ*; to Class IV *Rosaceæ*; to Class V *Ternstrœmiaceæ*, *Styraceæ*, *Ericaceæ* and *Vacciniaceæ*.

In Philippine woods, species belonging to Class I amount to 57% and none belonging to Class V.

(c). MAXIMUM DIAMETER OF PORES.

The diameter of pores is just as variable as their number, but it has great value for diagnostic purposes. Usually the minimum diameter of pores is about half of the maximum diameter. In general the diameter of pores stands in inverse proportion to the number of pores per unit area, not mentioning many exceptions in cases where wide pith rays occur.

In the following table the species occurring in each country are classified according to the maximum diameter, excluding ring-porous woods.

TABLE IX.

Class	I	II	III	IV	V	VI	Total number investigated
Countries \ Maximum diameter in μ	less than 50μ	$51–100\mu$	$101–150\mu$	$151–200\mu$	$201–300\mu$	more than 300μ	
Formosa	28 8.7%	127 39.3%	79 24.4%	42 13.0%	39 12.1%	8 2.5%	326
Japan	15 14.6%	49 47.6%	22 21.4%	12 11.6%	5 4.8%	0 0.0%	103 [1]
Philippines	1 0.6%	8 5.2%	27 17.8%	34 22.4%	60 39.5%	22 14.5%	152

From the above table, Formosan woods in following order of classes: II, III, IV, V, I, VI; in Japanese woods in order of classes: II, III, I, IV, V, VI; in Philippine woods, in order of classes: V, IV, III, VI, II, I; we come to the conclusion that tropical woods have larger pores than those of the temperate zone[2]; a fact of physiological significance, as the water conducting process is more vigorous in trees of the tropics than in those of the temperate zone.

(d). PERFORATION OF VESSELS.

The type of perforation of vessels is a very important factor for diagnostic purposes. It is principally divided into two: (1) the *simple* and (2) the *scalariform* perforation. There are other various forms, however, though most of them are modifications or malformations of the two principal types. The simple perforation is generally more common than the scalariform, the former being of a superior nature on account of having a higher degree of efficiency in conducting water.

Where the plane of perforation is transverse or only slightly inclined, the simple type is almost invariably found. Where the perforation is inclined it

1) *Trochodendron* and *Osmanthus* excluded.

2) Even in the same species the diameter of pores is larger in the tropics.

may be either simple or scalariform. The opening may be circular, elliptic, or oblong-elliptic.

The elliptical form prevails where the plane of perforation is oblique. As RECORD[1] states, scalariform perforations are never found in large vessels and no ring-porous wood is included; they are usually found in wood with very many pores per unit area and in small vessels.

There are a number of families in which all the genera so far investigated have exclusively simple perforations, for instance, *Leguminosæ*, *Ebenaceæ*, *Tiliaceæ*, *Sterculiaceæ* etc. There are a number of others in which the simple type predominates but the scalariform perforations are occasionally or rarely found, for instance, *Laurineæ;* sometimes the scalariform type predominates and the simple type may occasionally occur, for instance, *Carpinus*.

The following tables are lists of genera of indigenous woods in which vessel perforations are exclusively scalariform (Table X) and having vessel perforations exclusively or predominately simple (Table XI).

Indigenous woods with vessel perforations exclusively scalariform.

TABLE X.

MAGNOLIACEÆ Illicium Michelia Trochodendron	SABIACEÆ Meliosma	CAPRIFOLIACEÆ Viburnum
TERNSTRŒMIACEÆ Adinendra Anneslea Cleyera Eurya Gordonia Saurauja Schima Stachyurus Ternstrœmia Thea	SAXIFRAGEÆ Deutzia Hydrangea Itea	ERICACEÆ Pieris Rhododendron
	HAMAMELIDEÆ Distylium Eustigma Liquidambar	STYRACEÆ Alniphyllum Styrax Symplocos
	RHIZOPHOREÆ Bruguiera Ceriops Rhizophora	MYRISTICEÆ Myristica
ILICINEÆ Ilex	ARALIACEÆ Fatsia Heptapleurum Osmoxylon	EUPHORBIACEÆ Buxus Daphniphyllum
CELASTRINEÆ* Perrottetia		MYRICACEÆ Myrica
SAPINDACEÆ* Turpinia	CORNACEÆ* Cornus	CUPULIFERÆ Alnus

1) loc. cit. p. 136.

*) In some genera with simple perforation.

Indigenous woods with vessel perforations exclusively or predominately simple.

Table XI.

BERBERIDEÆ
Berberis
Mahonia

CAPPARIDEÆ
Capparis
Cratæva

BIXINEÆ
Casearia
Idesia
Scolopia

PITTOSPOREÆ
Pittosporum

GUTTIFERÆ
Calophyllum
Garcinia

MALVACEÆ
Bombax
Hibiscus

STERCULIACEÆ
Heritiera
Keinhovia
Pterospermum
Reevesia
Sterculia

TILIACEÆ
Echinocarpus
Elæocarpus
Grewia

GERANIACEÆ
Averrhoa

RUTACEÆ
Acronychia
Clausena
Evodia
Fagara
Murraya
Phellodendron
Skimmia
Zanthoxylum

SIMARUBEÆ
Ailanthus

BURSERACEÆ
Canarium

MELIACEÆ
Aglaia
Chisocheton
Dysoxylum
Melia

OLACINEÆ
Gonocaryum

CELASTRINEÆ*
Euonymus
Otherodendron

RHAMNEÆ
Paliurus
Rhamnus

AMPELIDEÆ
Leea

SAPINDACEÆ*
Acer
Allophylus
Dodonæa
Kœlreuteria
Nephelium
Pometia
Sapindus

ANACARDIACEÆ
Buchanania
Mangifera
Pistacia
Rhus
Semecarpus

CORIARIEÆ
Coriaria

LEGUMINOSÆ
Acacia
Albizzia
Cæsalpinia
Desmodium
Erythrina
Erythrophlœum
Gleditschia
Leucæna
Ormosia
Pongamia

ROSACEÆ
Cotoneaster
Eriobotrya
Malus
Photinia
Prinsepia
Prunus
Raphiolepis
Stranvæsia

COMBRETACEÆ
Lumnitzera
Terminalia

MYRTACEÆ
Barringtonia
Decaspermum
Eugenia
Psidium

MELASTOMACEÆ
Astronia
Blastus

Melastoma

LYTHRARIEÆ
Lagerstrœmia
Pemphis

SAMYDACEÆ
Homalium

ARALIACEÆ*
Aralia
Gilibertia
Oreopanax
Pentapanax

CORNACEÆ
Marlea*

RUBIACEÆ
Chomelia
Diplospora
Gardenia
Morinda
Nauclea
Psychotria
Randia
Timonius
Wendlandia

GOODENOVIEÆ
Scævola

VACCINIACEÆ*
Vaccinium*

MYRSINEÆ
Ardisia
Myrsine

SAPOTACEÆ
Palaquium
Sideroxylon

EBENACEÆ
Diospyros
Maba

OLEACEÆ
Fraxinus
Ligustrum
Linociera
Osmanthus

LOGANIACEÆ
Fagræa

BORAGINEÆ
Cordia
Ehretia
Tournefortia

SCROPHULARINEÆ
Paulownia

BIGNONIACEÆ
Stereospermum

VERBENACEÆ
Avicennia
Callicarpa
Clerodendron
Premna
Vitex

LAURINEÆ*
Actinodaphne*
Beilschmiedia
Cinnamomum*
Cryptocarya*
Lindera*
Litsea
Machilus*
Phœbe
Sassafras
Tetradenia*

HERNANDIACEÆ
Hernandia

PROTEACEÆ
Helicia

THYMELÆACEÆ
Daphne
Wikstrœmia

ELÆAGNACEÆ
Elæagnus

SANTALACEÆ
Champereia

EUPHORBIACEÆ*
Acalypha
Antidesma
Bischoffia
Bridelia
Croton
Euphorbia
Excœcaria
Gelonium
Glochidion
Macaranga
Mallotus
Sapium

URTICACEÆ
Artocarpus
Broussonetia
Celtis
Cudrania
Debregeasia
Ficus
Maoutia
Morus
Pipturus
Trema
Ulmus
Zelkova

JUGLANDEÆ
Engelhardtia
Juglans
Platycarya

CASUARINEÆ
Casuarina

CUPULIFERÆ*
Carpinus*
Castanopsis
Fagus*
Quercus

SALICINEÆ
Salix

* In some genera or species vessels with scalariform perforations.

The following is a table showing the number of genera with scalariform perforations in Formosa, Japan and the Philippines.

TABLE XII.

Number of genera with scalariform perforations.

Countries	Formosa	Japan	Philippines
Number of genera with scalariform perforation	41	28	6
Percentage	19.4%	32.6%	5.7%
Total number of genera investigated	211	86	106

There is an interesting correlation between climatic condition and presence of wood with scalariform perforations. According to the above table the genera of the temperate zone have a higher percentage of vessels with scalariform perforations; thus in the Philippines it is represented by 5.7%, in Formosa by 19.4%, while in Japan by 32.6%.[1] This statement naturally applies to the higher families of dicotyledonous trees predominant in the tropics.

(e). SPIRAL MARKINGS IN VESSELS.

The presence of spiral markings in vessels is a valuable diagnostic feature though it is often of unstable character. Generally vessels of smaller lumen exhibit them to the best advantage. In a given wood all of the vessels may bear spirals or, especially where there is considerable variation in the size, only the smaller vessels may be thus marked; such as *Kœlreuteria formosana, Reevesia formosana, Phellodendron Wilsonii, Ehretia macrophylla, E. acuminata, Pistacia formosana, Elæagnus Thunbergii, Celtis sinensis, C. nervosa, Ulmus Uyematsui, Broussonetia papyrifera, Platycarya strobilacea* etc.

The spirals may exhibit considerable variation in distinctness and number; some are very pronounced (*Ilex, Symolocos, Helicia* etc.), some are indistinct (*Adinandra, Rhododendron* etc.); sometimes few in number (*Echinocarpus, Elæocarpus* etc.) and sometimes numerous (*Acer, Michelia, Mahonia* etc.).

1) Out of 122 genera of indigenous woods of U.S. America, 25 genera (20.5%) have woods with vessel perforations exclusively scalariform. S. J. RECORD (49): pp. 135-136.

Spiral markings seem to be influenced by climatic conditions and in the tropics there are very few species with spirals in vessels. Among the Philippine woods investigated by the author, there are only five species which have spiral markings in vessels; even in the same genus there may be spirals present in the temperate zone but absent in the tropics: f.i. two *Elæocarpus* of Formosa have spirals but there are none in the Philippine species, and while the Japanese *Gleditschia* has spirals, no spirals are to be seen in the Formosan species of the same genus. This feature is also noted by Dr. J. W. Moll; he says in his "Micrographie des Holzes" II, in page 263, "Das Verhalten der spiraligen Verdickungen, nämlich das Fehlen derselben bei der javanischen Species und das Vorhandensein bei der Species unserses Klimas stimmt ganz gut mit der Tatsache dass ich solche spiraligen Verdickungen bis jetzt in den javanischen Hölzern bei sehr viel weniger Species gefunden habe als man für europaeische Species angegeben findet. "Auch in den Familien wo man sie für mehrere Species angegeben findet, habe ich sie nur in äusserst seltenen Fällen gefunden."

Table XIII.

Indigenous woods with spiral markings or striations in vessels.

MAGNOLIACEÆ Michelia BERBERIDEÆ Berberis Mahonia BIXINEÆ (Casearia) (Scolopia) PITTOSPOREÆ Pittosporum* TERNSTRŒMIACEÆ Adinandra Stachyurus STERCULIACEÆ Reevesia	TILIACEÆ Echinocarpus Elæocarpus RUTACEÆ (Evodia) Phellodendron MELIACEÆ (Melia) ILICINEÆ Ilex CELASTRINEÆ Euonymus* RHAMNEÆ Rhamnus* SAPINDACEÆ Acer	Kœlreuteria (Pometia) Sapindus Turpinia ANACARDIACEÆ Pistacia ROSACEÆ Eriobotrya Prunus* SAXIFRAGEÆ Deutzia* Hydrangea* HAMAMELIDEÆ Liquidambar ARALIACEÆ Heptapleurum*

Oreopanax	VERBENACEÆ (Vitex)	ELÆAGNACEÆ Elæagnus*
VACCINIACEÆ Vaccinium	LAURINEÆ (Beilschmiedia) (Cinnamomum)* (Tetradenia)*	URTICACEÆ Broussonetia Celtis* Ulmus
ERICACEÆ Rhododendron		
STYRACEÆ Symplocos	PROTEACEÆ Helicia	JUGLANDEÆ Platycarya
BORAGINEÆ Ehretia	THYMELÆACEÆ Daphne	CUPULIFERÆ Carpinus*

TABLE XIV.

Japanese woods with spiral markings or striations in vessels.

MAGNOLIACEÆ Michelia	ANACARDIACEÆ Rhus	OLEACEÆ Ligustrum Osmanthus
BERBERIDEÆ Berberis	LEGUMINOSÆ* Maackia Gleditschia Robinia	BORAGINEÆ Ehretia
STERCULIACEÆ Sterculia		LAURINEÆ (Litsea)
TILIACEÆ Tilia	ROSACEÆ Amelanchier Eriobotrya Photinia Prunus* Pirus	URTICACEÆ Celtis Morus Ulmus Zelkova
RUTACEÆ Phellodendron		
MELIACEÆ Melia		
ILICINEÆ Ilex	CORNACEÆ Aucuba	JUGLANDEÆ Platycarya
CELASTRINEÆ Euonymus	CAPRIFOLIACEÆ Viburnum*	CUPULIFERÆ (Carpinus) Ostrya
SAPINDACEÆ Acer Aesculus	ERICACEÆ Enkianthus	SALICINEÆ Populus

Philippine woods with spiral markings or striations in vessels.

(Garcinia) Melia (Toona) (Phœbe) (Aporosa)

* Indicates some species without spirals. Striations in bracket.

The following table shows the percentage of genera having vessels with spirals in each country.

TABLE XV.

Number of genera with vessels having spirals.

Countries	Formosa	Japan	Philippines
Number of genera with spirals in vessels.	47.	35.	5.
Percentage to total genera investigated.	22.3%	40.7%	4.7%

According to RECORD,[1] there are 47 out of 122 genera of American woods with spirals in the vessels; this is about 38.5%.

(f). CHARACTER OF PITTING IN VESSELS.

The character of pitting between adjacent vessels is an important factor for diagnostic purposes. The pits between vessels can be divided into groups: *bordered pits* and *scalariform bordered pits*; in the first group, arrangement of pits, size, contour of border and nature of aperture are very important features. The scalariform bordered pits usually occur in vessels with scalariform perforation, but sometimes also in vessels with simple perforation (as in *Leea* and *Blastus*).

Formosan woods with scalariform bordered pits in vessels are as follows:

TABLE XVI.

MAGNOLIACEÆ	HAMAMELIDEÆ	Heptapleurum
Illicium	Distylium (?)	Osmoxylon
Michelia	Eustigma	
Trochodendron[2]	Liquidambar	CAPRIFOLIACEÆ
		Viburnum
CELASTRINEÆ	RHIZOPHOREÆ	
Perrottetia	Bruguiera	STYRACEÆ
	Ceriops	Symplocos
AMPELIDEÆ		
Leea*	MELASTOMACEÆ	EUPHORBIACEÆ
	Blastus*	Daphniphyllum
SAXIFRAGEÆ		
Itea	ARALIACEÆ	
Hydrangea	Fatsia	

* Perforation of vessels simple. 1) loc. cit. 2) Trachlids

(e). VESSEL CONTENT.

The presence of tyloses or various deposits such as gum, resins, lime etc. in vessels sometimes serves for diagnostic purposes but it is generally of too variable for dependable results. *Cudrania javanensis*, *Morus acidosa* of Formosan species are very remarkable on account of their well-developed tyloses and so are the Philippine species *Vatica mangachapoi* and *Mimusops parviflora*, as well as the Japanese species *Robinia pseudacacia*.

VII. Wood fibers.

Wood fibers are the principal element of the wood. Arrangement of fibers, their diameter, thickness of wall, length, spiral thickenings, pits in walls and septa, are not only important for diagnostic purposes but have a close relation to the character of the wood. When the fibers are arranged regularly in radial direction, the wood is generally easy to split; fibers with large cavities and thin walls make the wood light, if they have a small diameter and thick walls, the wood becomes close textured,[1] other things being equal, and also the content of gummy or resinours substance in cavities makes the wood durable.

(a). MAXIMUM DIAMETER OF FIBERS.

The following table shows the percentage of the species arranged according to the diameter of the fibers in five classes:

TABLE XVII.

Class	I	II	III	IV	V	Total number
Countries \ Maximum diameter of fibers	01–6μ	17–25μ	26–32μ	33–40μ	41μ-more	investigated
Formosa Number of species.	93	195	54	17	3	362
Percent.	25.7%	53.9%	14.9%	4.7%	0.8%	
Japan Number of species.	42	82	25	1	0	150
Percent..	28.0%	54.7%	16.7%	0.6%	0.0%	
Philippines Number of species.	23	95	29	4	4	155
Percent.	14.9%	61.2%	18.7%	2.6%	2.6%	

1) *Lignum vitæ* which is considered to be the hardest and heaviest of all woods has a diameter of fibers of 10–12μ, with walls 4μ thick (author's own measurement).

In the Formosan and Japanese woods, diameter of fibers is arranged in order of classes, II, I, III, IV, V, and in the Philippine woods, in order of classes, II, III, I, IV, V.

This shows some tendency to have larger cavities in the tropics.

(b). THICKNESS OF WALL.

The following table shows the species grouped in respect to thickness of wall of fibers.

TABLE XVIII.

Class	I	II	III	IV	V	VI	Total number
Countries \ Thickness of wall	1–2μ	3μ	4μ	5μ	6–7μ	8μ-more	investigated
Formosa							
Number of species	50	115	123	36	25	12	361
Percent	13.8%	32.1%	34.0%	9.9%	3.3%	6.9%	
Japan							
Number of species	15	61	48	17	7	1	149
Percent	10.1%	40.9%	32.2%	11.4%	4.7%	0.7%	
Philippines							
Number of species	10	41	60	11	15	18	155
Percent	6.4%	26.5%	38.7%	7.1%	9.7%	11.6%	

In Formosan woods the classes appear in the order of III, II, I, IV, VI, V; in Japanese woods it is II, III, IV, I, V, VI; in Philippine woods III, II, VI, V, IV, I.

This shows some tendency to have thicker walls in the tropics.

(c). SEPTA OF FIBERS.

The septa of fibers often serve for diagnostic purposes.

The following is a list of genera with septate fibers.

TABLE XIX.

BIXINEÆ Scolopia PITTOSPOREÆ Pittosporum BURSERACEÆ *Canarium* MELIACEÆ Aglaia* Chisocheton CELASTRINEÆ Perrottetia RHAMNEÆ Rhamnus* AMPELIDEÆ Leea SAPINDACEÆ Allophylus Dodonæa Pometia Sapindus *Nephelium* SABIACEÆ Meliosma ANACARDIACEÆ Buchanania	LEGUMINOSÆ Cæsalpinia *Leucæna* SAXIFRAGEÆ Deutzia Hydrangea MYRTACEÆ Eugenia* MELASTOMACEÆ Astronia Blastus Melastoma LYTHRARIEÆ Lagerstrœmia SAMYDACEÆ Homalium ARALIACEÆ Aralia Fatsia Heptapleurum Oreopanax Osmoxylon Pentapanax MYRSINEÆ Ardisia STYRACEÆ Symplocos*	OLEACEÆ Fraxinus* Ligustrum BORAGINEÆ Ehretia* VERBENACEÆ Callicarpa Premna* LAURINEÆ Cryptocarya Lindera* Tetradenia* EUPHORBIACEÆ Antidesma Bischoffia Euphorbia Glochidion Mallotus* URTICACEÆ Debregeasia Ficus Maoutia JUGLANDEÆ Juglans CUPULIFERÆ Alnus

(d). SPIRAL MAKING IN FIBERS.

This is very important for diagnostic purposes. *Ilex* and *Symplocos* are almost always marked with spirals in fibers, other genera often sporadically.

The following are the Formosan genera with spirals in fibers:

TABLE XX.

TERNSTRŒMIACEÆ Stachyurus (sometimes) ILICINEÆ Ilex (always) SAXIFRAGEÆ Deutzia (sometimes)	CAPRIFOLIACEÆ Viburum propinquum (sometimes) STYRACEÆ Symplocos (nearly always)	BORAGINEÆ Ehretia glaucescens (spirals in part) ELÆAGNACEÆ Elæagnus (rarely)

* Indicates some of the species non-septate.

The following are the Japanese genera with spirals in fibers.

TABLE XXI.

ILICINEÆ Ilex (always)	SAXIFRAGEÆ Deutzia	STYRACEÆ Symplocos
CELASTRINEÆ Euonymus (nearly always)	CAPRIFOLIACEÆ Viburum Awabucki	ELAEAGNACEÆ Elæagnus longipes (?)

(e). CONTENTS IN FIBER CAVITIES.

Fibers sometimes contain some gummy or resinous substance in cavities; it occurs more frequently in heart-wood and more in tropical woods. In Philippine woods such as *Xylocarpus, Adenanthera, Albizzia, Maba,* in Formosan woods such as *Leea, Sapindus, Rhizophora, Ligustrum, Pipturus,* are remarkable genera which have contents in the cavities, but very few such cases occur in Japanese woods.

Hard woods in the tropics such as *Lignum vitæ* and *Aquillaria Agallocha* usually have gummy substance in the cavities.

VIII. Wood parenchyma.

(a). ARRANGEMENT.

The arrangement of wood parenchyma is a very important feature in classifying woods. It is generally divided into four groups: (1) *paratracheal,* (2) *metatracheal,* (3) *terminal* and (4) *scattered;* the terminal is a form of (2); (1) and (4) occur in most woods and from the diagnostic point of view (2) is most important.

The percentage of species with metatracheal and terminal parenchyma in each country is as follows:

TABLE XXII.

Arrangement \ Countries	Formosa	Japan	Philippines
Number of species with metatracheal parenchyma.	155	51	94
Percentage to total species investigated.	43.0%	34.0%	60.6%
Number of species with terminal parenchyma.	29	35	0
Percentage to total species investigated.	8.0%	23.3%	0.0%

Metatracheal parenchyma occurs most frequently in tropical woods; in Philippine 60.6%, in Formosa 42.4%, in Japan 34.0%, while terminal parenchyma mostly occurs in the temperate zone.

(b). CONTENT OF CRYSTALS IN PARENCHYMA CELLS.

The presence of chambered parenchyma cells with crystals of calcium oxalate depends rather on physiological and oecological causes, trees growing in coral regions generally seeming to contain crystals of calcium. Crystals may occur also in ray parenchyma cells. In the Philippines, limestone deposits often crystalized by volcanic action, occur scattered throughout the islands, especially along the coast and there are many species of trees with crystals in parenchyma cells.

The following is a table showing percentage of species with crystals in wood parenchyma and ray parenchyma cells.

TABLE XXIII.

Countries / Number of species	Formosa	Japan	Philipines
Crystals in wood parenchyma cells	35	12	28
Crystals in ray parenchyma cells	37	7	23
Total	72	19	51
Percentage to total number of species investigated	19.8%	12.7%	32.9%

(c). SCHIZOGENOUS CAVITIES IN WOOD AND RAY PARENCHYMA.

Secretory cells are chiefly confined to *Laurineæ* and a few other genera; in *Laurineæ*, they occur mostly in *Cinnamomum* and contain essential oil. In *Champereia manillana* cystolith-like structures occur and they contain crystals of calcium oxalate.

IX. Pith rays.

Pith rays are very important factor for diagnotic purposes. They are divided into two kinds: according to the shape of the cells they may be either *homogeneous* or *heterogeneous,* and according to the arrangement of ray cells they may be either (1) *high rays* or (2) *ordinary rays;* (1) includes the rays higher than 1 mm. and (2) includes the rays less than 1 mm. in height.

There are still other kinds of pith rays: *broad* rays and *compound* or *aggregate* rays but these are confined to special genera such as *Quercus, Alnus* etc.

(a). HOMOGENEOUS RAYS.

TABLE XXIV.

List of indigenous genera with homogeneous rays.

CAPPARIDEÆ	LEGUMINOSÆ	EUPHORBIACEÆ
Capparis	Acacia	Acalypha*
Cratæva	Albizzia	Sapium*
	Desmodium	
RUTACEÆ	Erythrina*	URTICACEÆ
Clausena	Erythrophlœum	Broussonetia
Evodia*	Gleditschia	Cudrania
Fagara*	*Leucæna*	Ulmus
Murraya		Zelkova*
Phellodendron	MELASTOMACEÆ	
Zanthoxylum	Blastus†	JUGLANDEÆ
	Melastoma†	Juglans
SIMARUBEÆ		Platycarya
Ailanthus*	BORAGINEÆ	
	Ehretia*	CASUARINEÆ
MELIACEÆ		*Casuarina*
Aglaia*	VERBENACEÆ	
Melia	Vitex	CUPULIFERÆ
		Alnus
SAPINDACEÆ	HERNANDIACEÆ	Castanopsis
Acer	Hernandia	Fagus*
Kœlreuteria		Quercus*
Nephelium	ELÆAGNACEÆ	
Pometia*	Elæagnus*	
Sapindus		

(b). WIDTH OF PITH RAYS

The width of pith rays has a close relation to the character of the wood. Woods with wide rays are generally soft and light.

* nearly homogeneous. † mostly of upright cells.

Uniseriate rays and biseriate in part are very important features for diagnostic purposes. The pith rays in hard woods of the tropics such as Santal wood, *Lignum vitæ* and Iron wood (*Eusideroxylon Zwagerii*) are all uniseriate. Uniseriate rays seem to occur more frequently in the tropics.

TABLE XXV.

List of indigenous genera with uniseriate rays.

CAPPARIDEÆ Capparis GUTTIFERÆ Calophyllum TERNSTRŒMIACEÆ Adinandra Schima Stachyurus RUTACEÆ Acronychia Murraya Skimmia MELIACEÆ Aglaia Dysoxylum CELASTRINEÆ Euonymus* SAPINDACEÆ Allophylus Dodonæa Kœlreuteria	*Nephelium* Pometia ANACARDIACEÆ Buchanania LEGUMINOSÆ Erythrophlœum ROSACEÆ Stranvæsia (Pirus) HAMAMELIDEÆ Eustigma COMBRETACEÆ Lumnitzera* MYRTACEÆ Psidium MELASTOMACEÆ Astronia Blastus Melastoma	LYTHRARIEÆ Lagerstrœmia Pemphis SAPOTACEÆ Sideroxylon EBENACEÆ Diospyros Maba LOGANIACEÆ Fagræa* EUPHORBIACEÆ Euphorbia* Glochidion Mallotus Sapium JUGLANDEÆ Engelhardtia SALICINEÆ Salix*

* always uniseriate; without asterisk sometimes biseriate in part.

(c). High Rays.

Table XXVI.

List of Formosan genera with high rays excluding *Cupuliferæ*.

MAGNOLIACEÆ Trochodendron BERBERIDEÆ Berberis Mahonia TERNSTRŒMIACEÆ Saurauja Ternstrœmia MALVACEÆ Hibiscus Bombax OLACINEÆ Gonocaryum AMPELIDEÆ Leea	CORIARIEÆ Coriaria SABIACEÆ Meliosma SAXIFRAGEÆ Deutzia Hydrangea RHIZOPHOREÆ Ceriops Bruguiera Rhizophora ARALIACEÆ Osmoxylon CORNACEÆ Marlea	GOODENOVIEÆ Scævola MYRSINEÆ Ardisia Myrsine PROTEACEÆ Helicia ELÆAGNACEÆ Elæagnus EUPHORBIACEÆ Bischoffia URTICACEÆ Debregeasia

Summary.

1. Investigation of flavone content in wood is very important for diagnostic purposes.
2. Ripple marks occur more frequently in woods of the tropical zone than in those of the temperate zone.
3. Intercellular canals occur only in woods of the tropics.
4. Number of pores per unit area gradually decreases toward the tropics but the diameter of pores follows an inverse course; in other words tropical woods are coarser in texture than those of the temperate zone.
5. Scalariform perforation of vessels occurs more frequently in the tropics than in the temperate zone; this shows that tropical trees to be of higher order.
6. Spiral thickenings in vessels occur more frequently in the temperate zone than in the tropical zone.
7. Ring-porous woods are more numerous in the temperate zone than in the tropics; in conformity with a higher percentage of deciduous trees.
8. Wood fibers have usually thicker walls and larger diameter in tropical woods than in those of the temperate zone.
9. Metatracheal parenchyma is more frequent in the tropics than in the temperate zone.