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WOOD ANATOMY OF TREES AND SHRUBS FROM CHINA VII. SAPINDACEAE

by

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SUMMARY

The wood anatomy of 24 species belonging to 18 genera of the Sapindaceae native to China is described. Despite the wood anatomical homogeneity of the Chinese taxa of the family, it is possible to key out individual genera as long as the unknown material is confined to Chinese species. In general, the wood of Sapindaceae is characterised by diffuse-porous vessel distribution, simple perforations, alternate intervessel pits, commonly septate libriform fibres, usually scanty paratracheal parenchyma, mainly uniseriate rays and prismatic crystals common in chambered parenchyma and or fibres. The two taxa from temperate regions are ring-porous.

Key words: Systematic wood anatomy, wood identification, Sapindaceae, Sapindoideae, Dodonaeoideae, China.

INTRODUCTION

The Sapindaceae of China are shrubs, small to large trees and one liana, mainly distributed in the tropical and subtropical regions of the country. In China 22 genera with 48 species are native. These taxa are mainly distributed in the southeastern to the southwestern part, only few occur in the northern part. *Pometia* species are important timber sources, and *Nephelium* and *Litchi* are famous tropical fruit trees.

Table 1 lists the total number of genera and species of the Sapindaceae occurring in China, the number of the species in the world, and the number of species studied wood anatomically for this paper. The table is based on information from Law and Lo (1985), How (1982), and Muller and Leenhouts (1976).

The genus *Lepisanthes* in this study includes *Erioglossum, Aphania* and *Otophora.*

The table shows that over 60% of the genera in China are represented by one species only.

A great number of papers on Sapindaceae wood anatomy have been published since the end of the last century. For a comprehensive survey see Gregory (1994). However, the literature on the wood anatomy of Sapindaceae from China is limited. Moreover, these publications are often restricted to a specific region or to commercial species, respectively.

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Table 1. Enumeration of genera of the Sapindaceae occurring in China.

Subfamily Genus	World Number of species	China Number of species	Number of species studied
Sapindoideae			
Allophylus	190 (1*)	11	1
Amesiodendron	1	1	1
Arytera	25	1	(1)
Cardiospermum	12	1 (liana)	–
Dimocarpus	8	4	1
*Lepisanthes***	24	3	2
Litchi	1	1	1
Mischocarpus	11	3	2
Nephelium	22	3	2
Paranephelium	4	2	–
Pavieasia	1	1	–
Pometia	2	2	1
Sapindus	13	4	2
Xerospermum	2	1	–
Dodonaeoideae			
Delavaya	1	1	1
Dodonaea	60	1	1
Eurycorymbus	1	1	1
Handeliodendron	1	1	1
Harpullia	26	1	1
Koelreuteria	3	3	3
Sinradlkofera	1	1	1
Xanthoceras	1	1	(1)

* According to Leenhouts (1968) only one polymorphic species.

** The genus *Lepisanthes* in this study includes *Erioglossum*, *Aphania* and *Otophora*.

The present study deals with the systematic wood anatomy and microscopic wood identification of the Sapindaceae native to China (Luo 1989; Tang 1973; Yao 1988). Due to the limited number of specimens studied, an ecological wood anatomical survey is hardly feasible. This paper is a contribution to the series on the wood anatomy of trees and shrubs from China. Previous papers in the series were on *Oleaceae* (Baas & Zhang 1986), *Theaceae* (Deng & Baas 1990), *Rosaceae* (Zhang & Baas 1992), *Ulmaceae* (Zhong et al. 1992), *Anacardiaceae* (Dong & Baas 1993), and *Magnoliaceae* (Chen et al. 1993).

MATERIAL AND METHODS

Wood samples were obtained from several institutional wood collections in and outside of China. Unfortunately, most of the wood samples are unvouchered. As far as possible this problem has been remedied by confirming their identity with matching additional authenticated collections by various Chinese botanists (see also Acknowledgements).

Light microscopic studies were carried out using sections and macerations obtained according to standard techniques. The samples for scanning electron microscope were also prepared following the procedure used in previous contributions to the wood anatomy of trees and shrubs in China. Descriptions and determinations of quantitative data are similar to those explained by Baas and Zhang (1986) and also according the IAWA list of microscopic features for hardwood identification (IAWA Committee 1989).

SURVEY OF WOOD ANATOMICAL CHARACTER STATES IN THE SAPINDACEAE FROM CHINA

Growth rings

Growth rings in the Sapindaceae from China are distinct to absent. Growth ring boundaries are marked by following structural changes:

1) Thick-walled and radially flattened latewood fibres versus thin-walled earlywood fibres. This is the major type (Fig. 3, 5, 12, 15).
2) Marginal parenchyma. This is found in *Delavaya, Eurycorymbus, Harpullia, Pometia,* and *Sinradlkofera* (Fig. 19, 27, 32).
3) Marked by difference in vessel diameter between latewood and earlywood (ring-porous) (Fig. 31, 33).

Vessels

Distribution and grouping (Fig. 1, 16, 17, 21, 31, 33) — Sapindaceae are typically diffuse-porous, but are ring-porous and semi-ring-porous in *Koelreuteria*, *Sapindus*, and *Xanthoceras*. In diffuse-porous species the vessels are mainly in radial multiples of 2–5 (8); in ring-porous species the vessels are mainly solitary in earlywood, and in multiples and clusters in latewood.

Frequency and element size (Fig. 1, 10, 19, 28) — Vessel frequency ranges from 2.5 to over 100/mm^2 in the Sapindaceae studied. The large range of variation of vessel frequency is due to the data for two genera. In *Pometia* the vessel frequency is only 2.5/mm^2, in *Handeliodendron* it is over 100/mm^2. In the other genera the vessel frequency ranges from 10–30/mm^2. The average tangential diameter varies from 40 to 230 μm and the average vessel member length from 205 to 695 μm (total range 130–880).

Perforations/shape of vessel members (Fig. 36, 37) — All Sapindaceae have simple perforations. Most vessels have oblique or slightly oblique end walls, only few have horizontal end walls. The vessel members have short to long tails.

Wall pitting (Fig. 37) — The intervessel pits in Sapindaceae are nonvestured, alternate, round to oval, in some genera polygonal. Average horizontal pit chamber diameter ranges from 2 to 9 μm. Vessel-ray and vessel-parenchyma pits are similar to the intervessel pits in size and shape, but half-bordered.

Wall thickness and sculpturing (Fig. 35, 36) — The vessel walls are thin to medium thick. Distinct or fine spiral (helical) thickenings and striations on the vessel walls are found in 50% of the genera.

Tyloses and vessel contents (Fig. 10, 11, 12) — No tyloses were found. Yellow and brown deposits are common. Deposits are not restricted to the vessels, but also occur in the rays.

Fibres (Fig. 1, 2, 18, 20, 26)

The fibres in the Sapindaceae are all libriform. Septate fibres with 1–4 septa are present in most genera, from all septate to some septate. Some genera have non-septate fibres only. Pits are simple and small, mainly in the radial walls, occasionally in the tangential walls. Fibre wall thickness varies from thin- to thick-walled to very thick-walled. Average fibre length ranges from 540–1180 μm (total range 350–1500).

Axial parenchyma (Fig. 3, 10, 11, 17, 19, 22, 26, 27)

The axial parenchyma is mainly scanty paratracheal and occasionally vasicentric. Five genera have marginal parenchyma: *Delavaya*, *Eurycorymbus*, *Harpullia*, *Pometia*, and *Sinradlkofera*. Banded and confluent parenchyma was observed in *Lepisanthes* and *Sapindus*. In *Nephelium* aliform and confluent parenchyma occurs. Various amounts of diffuse parenchyma also occur in *Dodonaea*, *Harpullia, and Nephelium*. Parenchyma absent or very scarce in *Delavaya* and *Handeliodendron*. Most commonly the strands are 3–5 cells long (total range 2–9).

Rays (Fig. 2, 23, 30)

The rays are homogeneous, nearly homogeneous to weakly heterogeneous and occasionally heterogeneous. Transitions between homogeneous (= only procumbent cells) and heterogeneous with many procumbent cells and marginal rows of 1(–3) square and upright cells are most common. Ray frequency ranges from 5 to 19/mm, most commonly 9–12/mm, and is of limited diagnostic value. Rays are exclusively uniseriate, or 1 or 2 cells wide. Only in *Sapindus* rays are 2–4 cells wide and in *Sinradlkofera* bi- and occasionally uniseriate. Ray height varies from 100–960 μm, usually from 300–500 μm.

Crystals (Fig. 6, 7, 9, 14, 20, 24)

Crystals are abundant in the Sapindaceae, but absent in *Handeliodendron* and *Xanthoceras*. The crystals are always prismatic. Crystals mainly occur in chambered parenchyma, but also in rays, fibres and unchambered parenchyma in some genera. The chambers are sometimes enlarged. The crystalliferous chains are 2–50 chambers long. With the light microscope it is often difficult (or even impossible) to be absolutely sure that the crystals occur in parenchyma. For this study crystals are described as in parenchyma unless it is absolutely certain that they are in the fibres. In the

'Generic wood anatomical descriptions', when such cells/strands can only be observed containing crystals, they are referred to as diffuse parenchyma. A detailed study concerning this phenomenon, using different techniques, will be included in a forthcoming worldwide survey of the wood anatomy of the Sapindaceae by Klaassen.

GENERIC WOOD ANATOMICAL DESCRIPTION

SUBFAMILY SAPINDOIDEAE

Allophylus L. (Tribe Thouinieae) — Fig. 1, 2

Material studied: *A. cobbe* (L.) Raeusch: Uw 33612.

Shrubs from tropical forests.

Growth rings present, marked by thick-walled and radially flattened latewood fibres. Wood diffuse-porous. Vessels 18 (16–22)/mm^2, 50% solitary, remainder in radial multiples of 2 or 3 (5) and few clusters, oval, tangential diameter 99 (59–140) µm, radial diameter up to 164 µm, walls 5–7 µm thick. Vessel member length 520 (380–645) µm. Perforations simple in oblique end walls. Intervessel pits alternate, round to oval, 6–9 µm. Vessel-ray and vessel-parenchyma pits similar to intervessel pits in size and shape, but half-bordered. Yellow deposits occasionally present.

Libriform fibres 795 (500–970) µm long, all septate with 3 (1–4) septa, thin- to thick-walled, with small simple pits, in the radial walls and occasionally in the tangential walls. Fibre dimorphism present, due to differences in lumen diameter. Fibres with larger lumen, and slightly thinner walls arranged in wavy, more or less concentric bands.

Parenchyma scanty paratracheal to almost vasicentric, in strands of 3–7 cells.

Rays 11 (9–14)/mm, exclusively uniseriate, only a few biseriate in the middle, heterogeneous, composed of procumbent, square and some upright cells, mixed, up to 720 µm (= 34 cells) high. Brown deposits common.

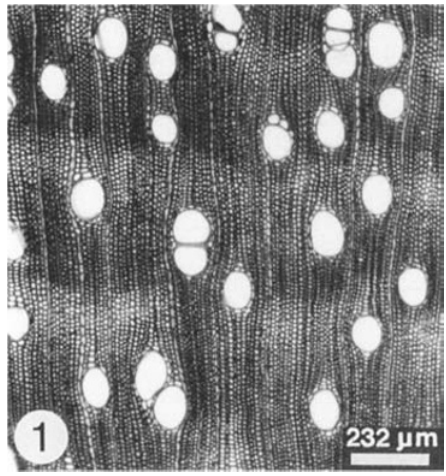
Prismatic crystals in chambered parenchyma, chains of over 20 crystals.

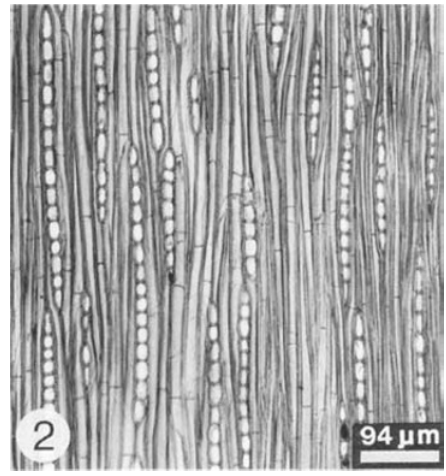
Amesiodendron Hu (Tribe Cupanieae) — Fig. 3, 4

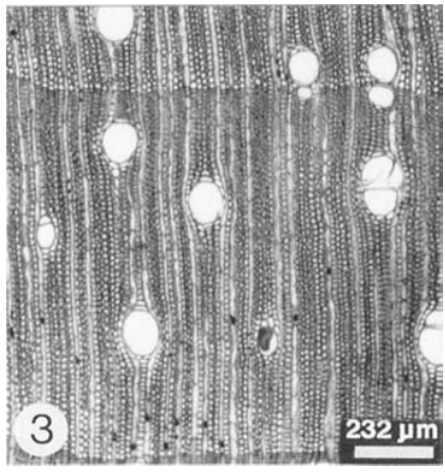
Material studied: *A. chinensis* (Merr.) Hu: Hainan, The Chinese Academy of Forestry, W 11495 (Uw 33596).

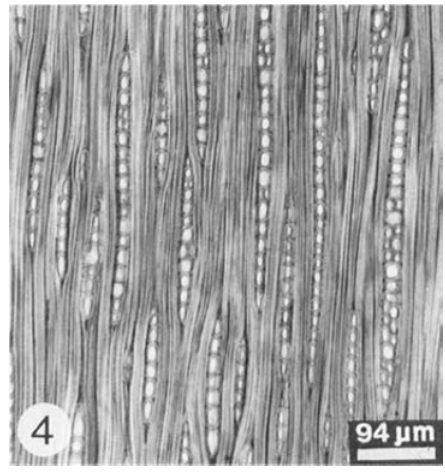
Evergreen trees from tropical and subtropical forests.

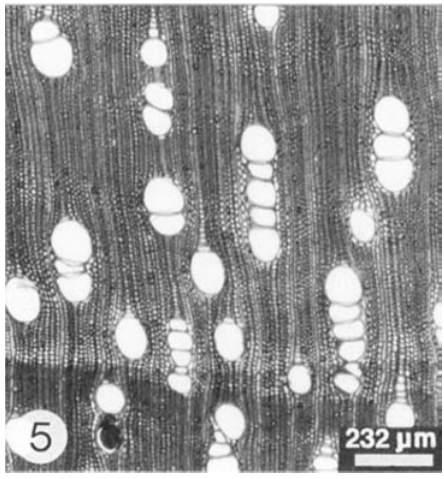
Growth rings distinct, marked by thick-walled and radially flattened latewood fibres. Wood diffuse-porous. Vessels 8 (7–11)/mm^2, 60% solitary, remainder in radial multiples and clusters of 2 or 3, round to oval, tangential diameter 94 (25–140) µm, radial diameter up to 175 µm, walls 3–4 µm thick. Vessel member length 470 (295–765) µm. Perforations simple in oblique end walls. Intervessel pits alternate, round to angular, 3–5 µm. Vessel-ray and vessel-parenchyma pits similar to intervessel pits in size and shape, sometimes large and elongated, but half-bordered. Yellow deposits present. Helical thickenings present.

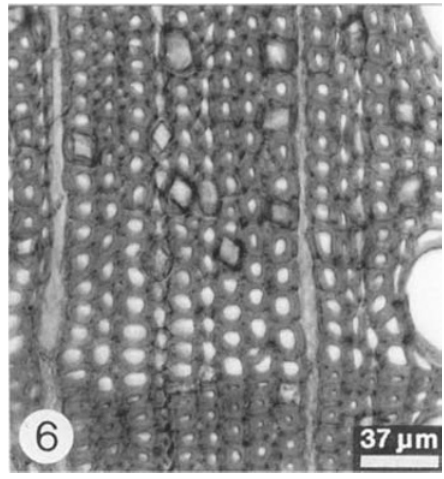












Libriform fibres 990 (617–1352) μm long, partly septate with 1 or 2 septa, very thick-walled, with small simple pits, in the radial walls and occasionally in the tangential walls.

Parenchyma scanty paratracheal, occasionally nearly vasicentric, in strands of 2–8 cells.

Rays 15 (13–17)/mm, mainly uniseriate, occasionally 2- or 3-seriate in the middle, nearly homogeneous, composed of procumbent cells, slightly procumbent cells and very few square cells, up to 720 μm (= 40 cells) high. Brown deposits abundant.

Prismatic crystals present in the ray cells.

Arytera Blume (Tribe Cupanieae) — Fig. 5–7

Material studied: *A. littoralis* Blume: Indonesia, Pieters 3022 (Uw 33606).

Evergreen shrubs or small trees from tropical forests.

Growth rings distinct, marked by thick-walled and radially flattened latewood fibres. Wood diffuse-porous. Vessels 20 (16–33)/mm^2, 20% solitary, mostly in radial multiples of 2–5 (7), round to oval, tangential diameter 99 (53–129) μm, radial diameter up to 128 μm, walls 3–4 μm thick. Vessel member length 525 (325–645) μm. Perforations simple in oblique end walls. Intervessel pits alternate, round to angular, 3–4 μm. Vessel-ray and vessel-parenchyma pits similar to intervessel pits in size and shape, but half-bordered. Brown deposits present.

Libriform fibres 860 (615–1090) μm long, non-septate, but some septate with one septum, thin- to thick-walled with small simple pits, in the radial walls and occasionally in the tangential walls. Fibre dimorphism present, indistinct, in tangential, slightly wavy bands. The fibres in these bands have larger lumens than the ground tissue fibres.

Parenchyma scanty paratracheal, occasionally nearly vasicentric and diffuse, in strands of 3–7 cells.

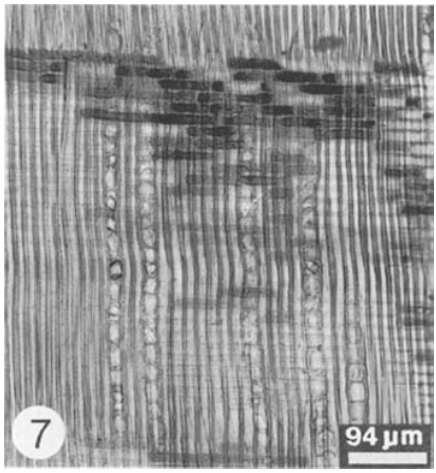
Rays 12 (10–14)/mm, exclusively uniseriate, nearly homogeneous, composed of procumbent cells and some square cells, up to 480 μm (= 30 cells) high. Brown deposits common.

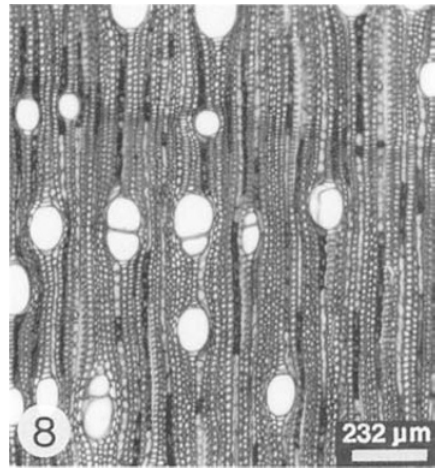
Prismatic crystals present in chambered parenchyma and in septate fibres in chains of over 50 crystals.

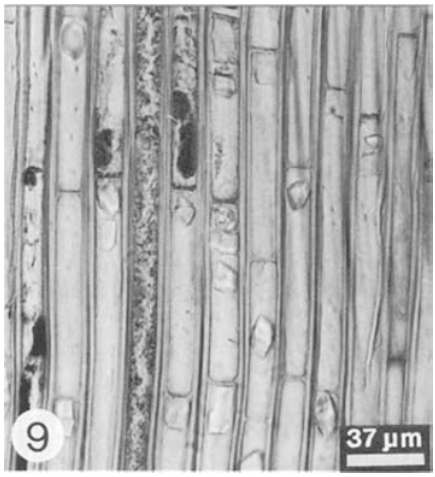
Dimocarpus Lour. (Tribe Nephelieae) — Fig. 8, 9

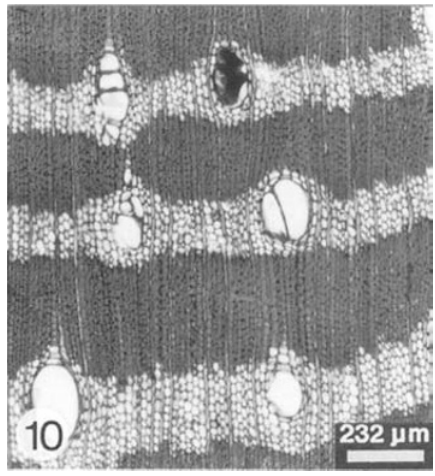
Material studied: *D. longan* Lour.: Hainan, The Chinese Academy of Forestry, W 14608 (Uw 33593); Hainan, Peking University (Uw 33586).

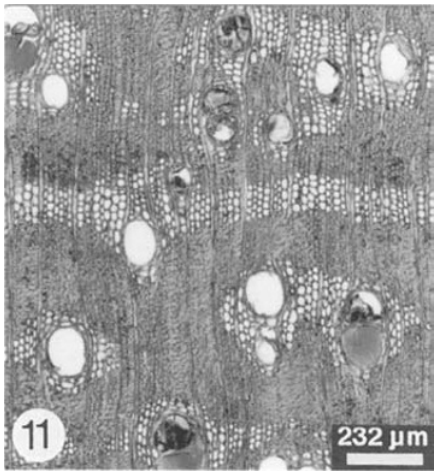
Fig. 1 & 2. *Allophylus cobbe*. – 1: TS, fibre dimorphism. – 2: TLS, septate fibres. — Fig. 3 & 4. *Amesiodendron chinensis*. – 3: TS, growth rings. – 4: TLS, rays uni- and biseriate. — Fig. 5 & 6. *Arytera littoralis*. – 5: TS, vessels in radial multiples. – 6: TS, rhombic crystals.

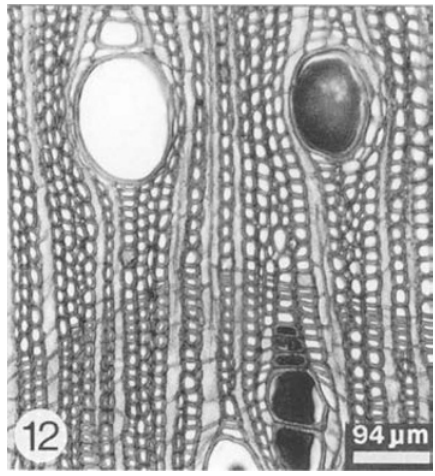












Evergreen trees from tropical forests.

Growth rings present, sometimes faint, marked by flattened latewood fibres. Wood diffuse-porous. Vessels 11–17 (7–35)/mm^2, 23–30% solitary, mostly in radial multiples and irregular clusters of 2–4, round to oval, tangential diameter 87–108 (47–152) μm, radial diameter up to 210 μm, walls 5–7 μm thick. Vessel member length 500–515 (205–675) μm. Perforations simple in oblique end walls. Intervessel pits alternate, round, 2–3 μm. Vessel-ray and vessel-parenchyma pits similar to intervessel pits in size and shape, but half-bordered. Helical thickenings or striations present in vessel element tail. Deposits present but scarce.

Libriform fibres 785–890 (500–1235) μm long, non-septate, and some to many fibres septate with one septum each, thin- to thick-walled with small simple pits, in the radial walls and occasionally in the tangential walls.

Parenchyma scanty paratracheal, occasionally vasicentric, and some diffuse (= with crystals), in strands of 2–5 cells.

Rays 11–19 (10–21)/mm, mainly uniseriate, some biseriate with uniseriate margin, nearly homogeneous, composed of procumbent cells, and some square cells, biseriate part up to 600 μm (= 50 cells) in W 14608; 1400 μm (= 80 cells) in another sample (Uw 33586).

Prismatic crystals abundant in ray cells. In one sample also in fibres and unchambered axial parenchyma.

Lepisanthes Blume (Tribe Lepisantheae) — Fig. 10, 11

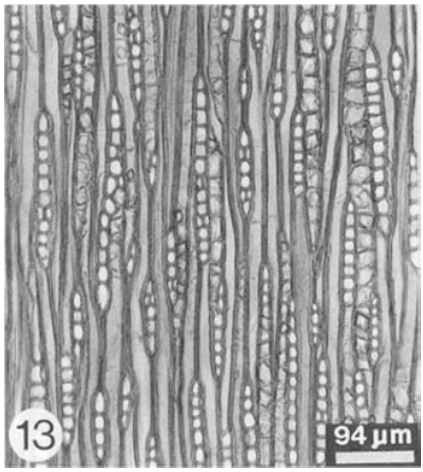
Material studied: *L. rubiginosum* Leenh.: Indonesia, Tjokrosendjojo 12752 (Uw 33611). — *L. senegalensis* Leenh.: Hainan, The Chinese Academy of Forestry, W 14710 (Uw 33595).

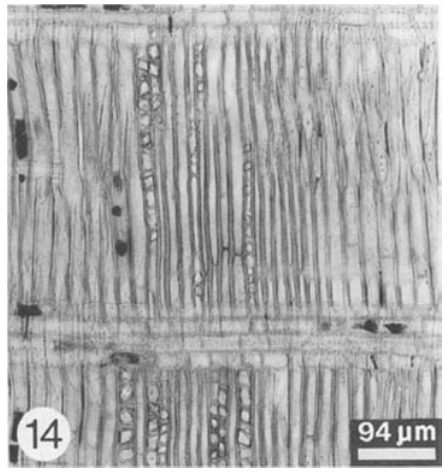
Evergreen shrubs or small trees from tropical forests.

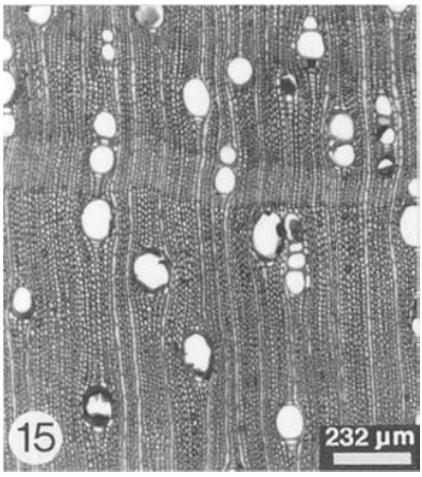
Growth rings absent. Wood diffuse-porous. Vessels 8–11 (6–17)/mm^2, 10–20% solitary, but mostly in radial multiples of 2–5 and few clusters, round to oval, tangential diameter 54–106 (29–164) μm, radial diameter up to 163–234 μm, walls 2–9 μm thick. Vessel member length 430–547 (290–760) μm. Perforations simple in oblique end walls. Intervessel pits alternate, round to angular, 5–9 μm (in *L. senegalensis* 2–4 μm). Vessel-ray and vessel-parenchyma pits similar to intervessel pits in size and shape, some slightly larger, but half-bordered. Yellow to brown deposits present.

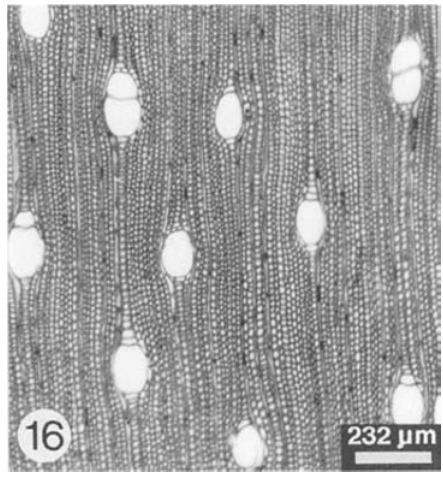
Libriform fibres 1055–1428 (590–1880) μm long, non-septate and septate with one septum, very thick-walled with small simple pits, in the radial walls and occasionally in the tangential walls.

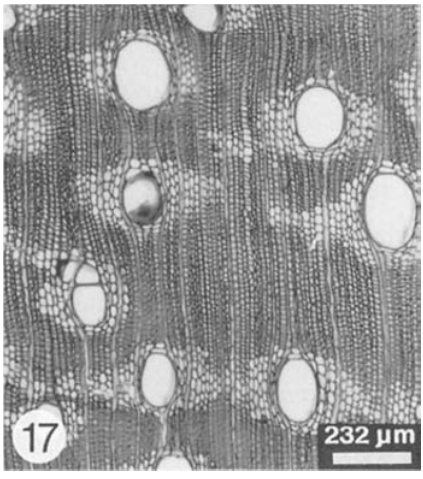
Fig. 7. *Arytera littoralis*; RLS, chains of rhombic crystals. — Fig. 8 & 9. *Dimocarpus longan*. – 8: TS, vessels diffuse, parenchyma scarce. – 9: RLS, rhombic crystals. — Fig. 10 & 11. *Lepisanthes rubiginosum*. – 10: TS, tangential bands of parenchyma. – 11: TS, various types of parenchyma. — Fig. 12. *Litchi chinensis*, TS, growth ring border.

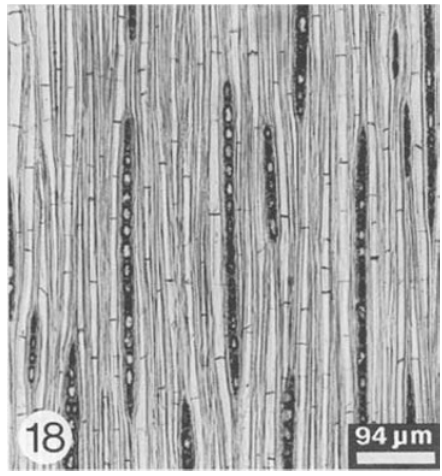












Parenchyma banded, aliform-confluent and sometimes diffuse, 3(1–5) bands/mm, wavy, usually including the vessels, bands 3–10 cells wide, in strands of 3–8 cells.

Rays 8–14 (6–16)/mm, exclusively uniseriate, but 1- or 2-seriate in *L. senegalensis*, homogeneous, composed of procumbent cells, up to 700–800 μm (= 46 cells). Yellow deposits present.

Prismatic crystals present in axial chambered parenchyma strands, chains up to over 15–20 crystals. The crystalliferous strands mainly located on the border between parenchyma and fibres.

Litchi Sonn. (Tribe Nephelieae) — Fig. 12–14

Material studied: *L. chinensis* Sonn.: Hainan, the Chinese Academy of Forestry, W 11434 (Uw 33590); Hainan, Peking University (Uw 33587).

Evergreen trees from tropical or subtropical region.

Growth rings distinct, marked by flattened latewood fibres. Wood diffuse-porous. Vessels 9–19 (5–29)/mm^2, 30–35% solitary, mostly in radial multiples and irregular clusters of 2–4 (5), round to oval, tangential diameter 96–125 (59–160) μm, radial diameter up to 210 μm, walls 4–7 μm thick. Vessel member length 400–695 (265–880) μm. Perforations simple in horizontal to oblique end walls. Intervessel pits alternate, round to oval, 2–3 μm. Vessel-ray and vessel-parenchyma pits similar to intervessel pits in size and shape, but half-bordered. Striation patterns present in vessel element tails. Deposits fill the vessels of one sample (Uw 33587).

Libriform fibres 590–1150 (380–1645) μm long, septate and non-septate, with 1–3 septa, thin- to thick-walled with small simple pits, in the radial walls and occasionally in the tangential walls. Brown deposits common.

Parenchyma scanty paratracheal, occasionally vasicentric, in strands of 4 or 5 (3–6) cells.

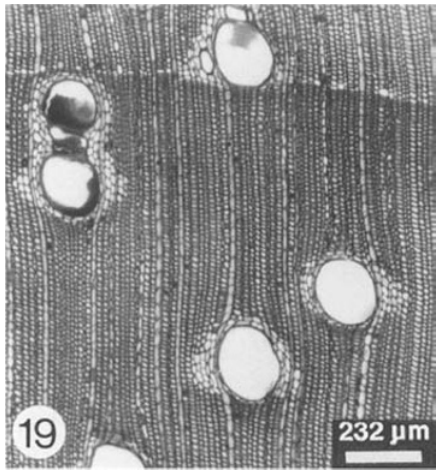
Rays 9–15 (7–17)/mm, mostly uniseriate, also biseriate, nearly homogeneous, composed of procumbent cells, and some square cells, up to 500 μm (= 28 cells).

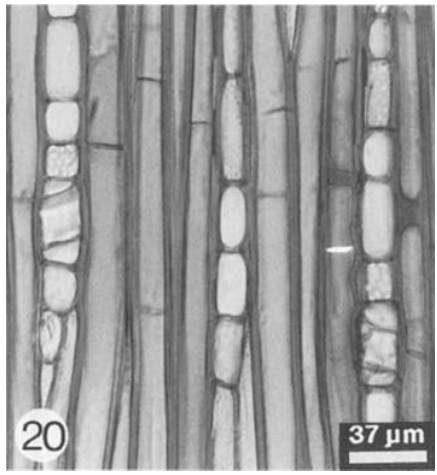
Prismatic crystals present in ray cells and chambered parenchyma, in chains over 30 crystals. Especially located in growth ring boundaries.

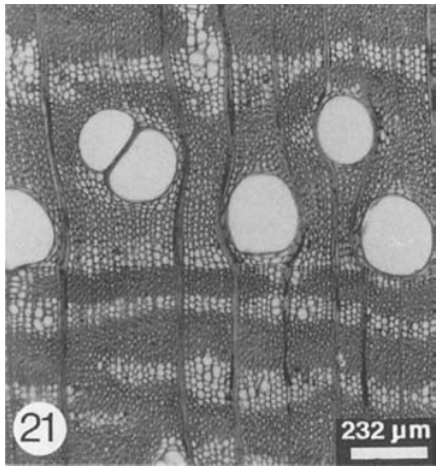
Mischocarpus Blume (Tribe Cupanieae) — Fig. 15, 16.

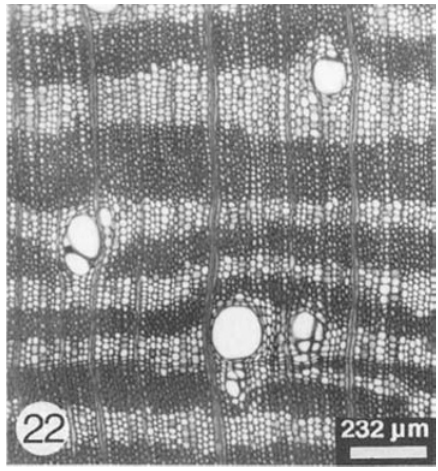
Material studied: *M. pentapetalus* (Rox.) Radlk.: Forestry Research Institute of Guangdong Province, W 1680 (Uw 33598); H.L. Lo, Academiae Sinicae Canton (Uw 33609). — *M. sundaicus* Blume: Agriculture University of South China, W 0598 (Uw 33599).

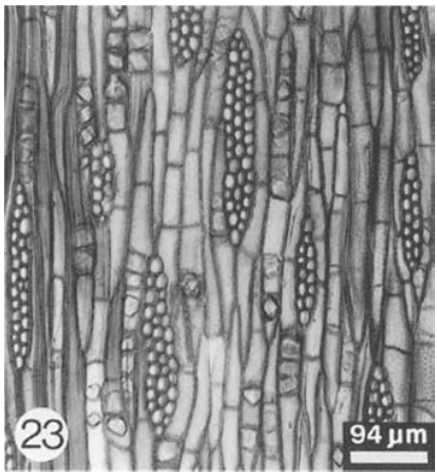
Fig. 13 & 14. *Litchi chinensis*. – 13: TLS, chains of rhombic crystals. – 14: RLS, chains of rhombic crystals. — Fig. 15. *Mischocarpus sundaicus*, TS, growth ring border. — Fig. 16. *Mischocarpus pentapetalus*, TS, growth ring border absent. — Fig. 17 & 18. *Nephelium lappaceum*. – 17: TS, aliform and confluent parenchyma. – 18: TLS, uniseriate rays and septate fibres.

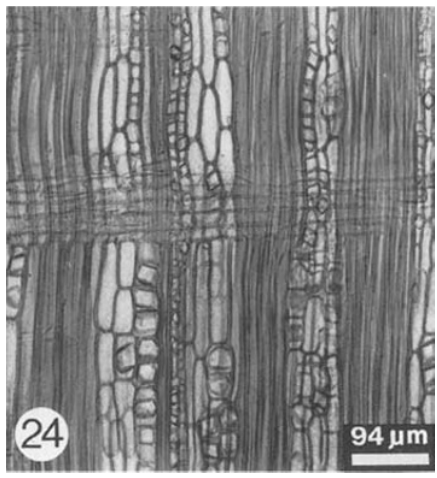












Evergreen trees and small trees from tropical forests.

Growth rings distinct to indistinct, marked by thick-walled and radially flattened latewood fibres versus thin-walled earlywood fibres. Wood diffuse-porous. Vessels 8–21 (5–28)/mm^2, 30% solitary, mostly in radial multiples of 2 or 3, up to 6 in *M. sundaicus*, round to oval, tangential diameter 70–98 (35–123) μm, radial diameter up to 168 μm, walls 3–4 μm thick. Vessel member length 379–628 (125–772) μm. Perforations simple in oblique end walls. Intervessel pits alternate, round to oval, 3–5 μm. Vessel-ray and vessel-parenchyma pits similar to intervessel pits in size and shape, but half-bordered. Yellow deposits common in *M. sundaicus*.

Libriform fibres 764–985 (323–1323) μm long, all septate with 2 septa, thin- to thick-walled with small simple pits, in the radial walls and occasionally in the tangential walls.

Parenchyma (scanty) paratracheal, diffuse (= with crystals) in *M. sundaicus*, in strands of 2–4 cells.

Rays 9–15 (7–18)/mm, exclusively uniseriate, few with a biseriate part in the middle, nearly homogeneous, composed of procumbent cells, and some square cells, up to 400–480 μm (= 23–27 cells) high. Brown deposits abundant.

Prismatic crystals present in chambered parenchyma, in chains over 20 crystals.

Nephelium L. (Tribe Nephelieae) — Fig. 17, 18

Material studied: *N. lappaceum* L.: Hainan, The Chinese Academy of Forestry, W 13121 (Uw 33591); Hainan, Peking University (Uw 33588; Uw 33651).

Evergreen trees from tropical forests.

Growth rings indistinct to faint, marked by difference in the fibre lumen of earlywood and latewood, in one sample also marked by the presence of marginal parenchyma. Wood diffuse-porous. Vessels 7–12 (4–18)/mm^2, 20–25% solitary, mostly in radial multiples and few clusters of 2–4, round to oval, tangential diameter 126–132 (76–188) μm, radial diameter up to 246 μm, walls 3–7 μm thick. Vessel member length 585–635 (325–765) μm. Perforations simple in oblique end walls. Intervessel pits alternate, round to oval, (3–)4–5 μm. Vessel-ray and vessel-parenchyma pits similar to intervessel pits in size and shape, but half-bordered. Striations present. Brown deposits present.

Libriform fibres 1035–1125 (590–1560) μm long, non-septate and only few septate with 1–4 septa, thin- to thick-walled with small simple pits, in the radial walls and occasionally in the tangential walls.

Parenchyma aliform and confluent, occasionally marginal and sometimes diffuse, in strands of 4–7 cells.

Fig. 19 & 20. *Pometia pinnata*. – 19: TS, marginal parenchyma. – 20: TLS, rhombic crystals in the ray cells. — Fig. 21. *Sapindus saponaria*, TS, wood ring-porous. — Fig. 22–24. *Sapindus rarak*. – 22: TS, wood diffuse-porous. – 23: TLS, multiseriate rays. – 24: RLS, rhombic crystals.

Rays 9–11 (6–13)/mm, exclusively uniseriate, homogeneous, composed of procumbent cells, up to 350–560 µm (= 17–26 cells) high. Brown deposits abundant.

Prismatic crystals present in chambered axial parenchyma, in chains of 5 to over 15 crystals.

Pometia Forst. (Tribe Nephelieae) — Fig. 19, 20

Material studied: *P. pinnata* Forst.: Sudo Tw 11551 (Uw 33614). — *P. tomentosa* (Blume) Teijsm. & Binn.: Yunnan, The Chinese Academy of Forestry, W 17240 (Uw 33592).

Evergreen trees from tropical forests.

Growth rings distinct, marked by radially flattened latewood fibres and marginal parenchyma. Wood diffuse-porous. Vessels 2–4 (1–7)/mm^2. In *P. pinnata* 60% solitary, in *P. tomentosa* 23% solitary, remainder in radial multiples of 2–4, round to oval, tangential diameter 172–182 (88–235) µm, radial diameter up to 294 µm, walls 5–6 µm thick. Vessel member length 690 (440–880) µm in *P. pinnata*, 495 (325–645) µm in *P. tomentosa*. Perforations simple in oblique end walls. Intervessel pits alternate, round, 4–5 µm. Vessel-ray and vessel-parenchyma pits similar to intervessel pits in size and shape, but half-bordered. Striations present. Brown deposits present.

Libriform fibres 1085–1180 (560–1500) µm long, all septate with one septum, thin-walled with small simple pits, in the radial walls and occasionally in the tangential walls.

Parenchyma vasicentric as complete circular sheath of 1–3 cells, sometimes also aliform (lozenge type), and marginal bands, 1–5 cells wide, in strands of 3–7 cells.

Rays 8–9 (6–13)/mm, mainly uniseriate, some biseriate, heterogeneous, mainly procumbent, but also square and upright cells mixed throughout the rays, or as marginal rows, up to 600–960 µm (= 25–35 cells) high. Brown deposits abundant in ray cells of one sample.

Prismatic crystals present in ray cells, predominantly in square/upright cells, few in procumbent cells.

Sapindus L. (Tribe Sapindeae) — Fig. 21–24, 37

Material studied: *S. rarak* DC.: Yunnan, Academiae Sinicae (Uw 33687). — *S. saponaria* L.: Hainan, Peking University (Uw 33589); Hubei, the Chinese Academy of Forestry (Uw 33597).

Deciduous trees from tropical, subtropical and temperate regions.

Growth rings distinct in *S. saponaria*, marked by larger vessels in the earlywood; faint in *S. rarak*. Wood ring-porous in *S. saponaria*; semi-ring-porous in *S. rarak*. Vessels in *S. saponaria* 5 (4–7)/mm^2 in earlywood and 31–35 (26–40)/mm^2 in latewood; 8 (3–13)/mm^2 in *S. rarak*. Distribution in *S. saponaria* mainly solitary in the earlywood, and mainly in irregular clusters of 3–6 (10) in the latewood; in *S. rarak* 20% solitary with remainder in irregular multiples of 2–4. Vessels round to slightly oval, tangential diameter in *S. saponaria* very variable, 200–250 (160–330) µm in the earlywood and 15–50 µm in the latewood; in *S. rarak* 95 (50–145) µm, in both species

the radial diameter is slightly larger or equal, walls 3–7 μm thick. Vessel member length 240–280 (150–380) μm in *S. saponaria* and 380 (235–530) μm in *S. rarak*. Perforation simple in horizontal to oblique end walls. Intervessel pits alternate, polygonal to occasionally round, 4–7 μm. Vessel-ray and vessel-parenchyma pits similar, but half-bordered. Helical thickening present in the narrow vessels of both species. Yellowish brown deposits scarce in *S. rarak*.

Libriform fibres 1005–1060 (530–1705) μm long, mainly septate with 1–3 septa, thin- to thick-walled, with small simple pits, on the radial walls and occasionally on the tangential walls.

Parenchyma confluent or in wavy paratracheal bands, very few diffuse (= with crystals); bands 3–10 cells wide, 3–5/mm. Strands of 3 or 4 (5) cells.

Rays 5 (4–8)/mm, multiseriates 2 or 3 (4) cells wide and occasionally also uniseriate, homogeneous, composed of procumbent and weakly procumbent cells, up to 100–480 μm (= 6–35 cells) high.

Prismatic crystals abundant, in chambered crystalliferous axial parenchyma strands, chains 5 to over 20. In many cases the crystalliferous strands are situated in parenchyma cells next to the libriform fibres.

Subfamily Dodonaeoideae

Delavaya Franch. (Tribe Harpullieae) — Fig. 25

Material studied: *D. toxocarpa* Franch.: Guangxi, The Chinese Academy of Forestry, W 16028 (Uw 33654); Guangxi, H.L. Lo 1991-03, Academiae Sinicae Canton.

Small trees or shrubs from the southwestern part of China.

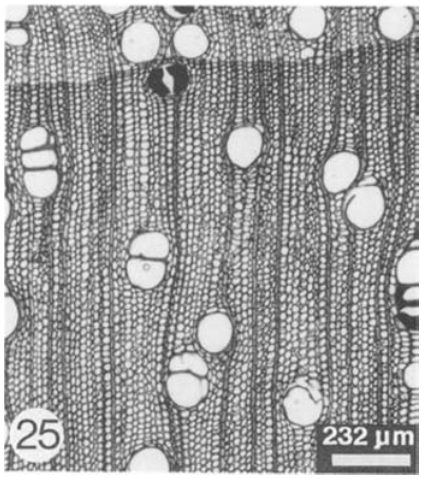
Growth rings distinct to faint, marked by difference in vessel diameter and marginal parenchyma. Wood diffuse-porous. Vessels 16–32 (21–46)/mm^2, 10–45% solitary, mostly in radial multiples of 2–4 (8), round to oval, tangential diameter 80–120 (35–150) μm, radial diameter up to 140 μm, walls 4–6 μm thick. Vessel member length 475 (385–585) μm. Perforations simple in horizontal to oblique end walls. Intervessel pits alternate, 4–6 μm. Vessel-ray and vessel-parenchyma pits similar to intervessel pits in size and shape, but half-bordered. Fine helical thickenings present in some vessels.

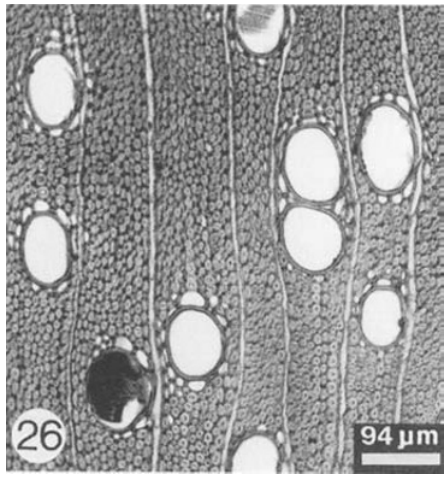
Libriform fibres 745 (610–1055) μm long, all septate with 1–3 septa, thin- to medium thick-walled with small simple pits in the radial walls and occasionally in the tangential walls.

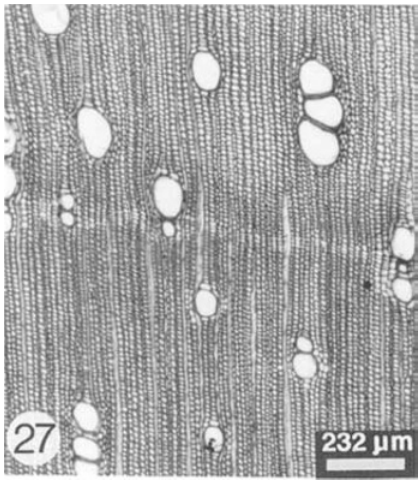
Parenchyma very scarce, diffuse (= with crystals), scanty paratracheal, and marginal.

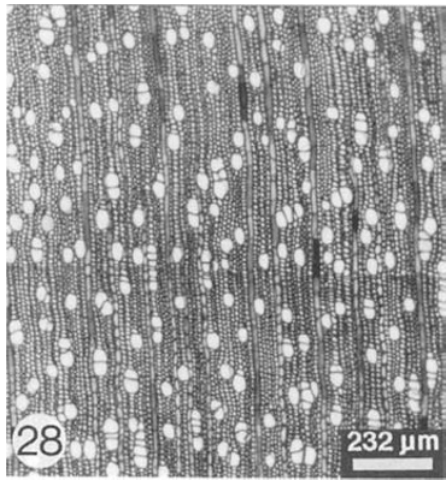
Rays 12 (11–14)/mm, exclusively uniseriate, heterogeneous, composed of procumbent cells with (marginal rows of) square or upright cells, up to 505 μm (= 26 cells) high.

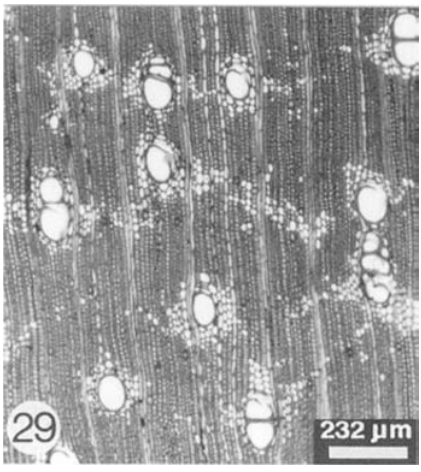
Prismatic crystals present in chambered parenchyma, in chains, over 20 crystals, and in the ray cells of one sample.

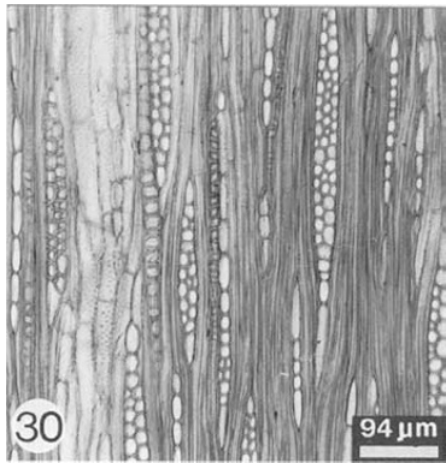












Dodonaea Miller (Tribe Dodonaeae) — Fig. 26

Material studied: *D. viscosa* Jacq.: Forest Research Institute of Guangdong Province, W 0933 (Uw 10427); Hawaii, W.L. Stern USw 25983 (Uw 33600).

Shrubs or small trees from tropical and subtropical regions.

Growth rings very faint, usually absent. Wood diffuse-porous. Vessels 21–34/mm^2, 40–50% solitary, with remainder in radial multiples of 2–5, round to oval, tangential diameter 65 (35–105) μm, radial diameter up to 129 μm, walls 4–5 μm thick. Vessel member length 260–460 (130–600) μm. Perforations simple in horizontal or oblique end walls. Intervessel pits alternate, round, 3–6 μm. Vessel-ray and vessel-parenchyma pits similar to intervessel pits in size and shape, but half-bordered. Brown deposits common.

Libriform fibres 600–770 (351–970) μm long, non-septate, very thick-walled with small simple pits, in the radial walls and occasionally in the tangential walls.

Parenchyma scanty paratracheal, occasionally nearly vasicentric to faint aliform and diffuse (= with crystals), in strands of 2–4 cells.

Rays 9–10 (6–13)/mm, mainly uniseriate, also biseriate, heterogeneous, composed of procumbent and a marginal row of square cells, up to 600 μm (= 40 cells) high.

Prismatic crystals present in chambered parenchyma, chains over 25 crystals.

Eurycorymbus Hand.-Mazz. (Tribe Harpullieae) — Fig. 27

Material studied: *E. cavaleriei* Rehd. & Hand.-Mazz.: South China Agriculture University (Uw 33602).

Deciduous trees only found in southern part of China.

Growth rings distinct, marked by thick-walled and radially flattened latewood fibres, the presence of marginal parenchyma and a slight difference in diameter of the vessels. Wood diffuse-porous. Vessels 10 (7–15)/mm^2, 50% solitary, with remainder in radial multiples of 2 or 3, round to oval, tangential diameter 95 (60–130) μm, radial diameter up to 175 μm, walls 7–9 μm thick. Vessel member length 447 (255–620) μm. Perforations simple in oblique end walls. Intervessel pits alternate, round, 3–4 μm. Vessel-ray and vessel-parenchyma pits similar to intervessel pits in size and shape, but half-bordered. Striations present. Yellow deposits present.

Libriform fibres 694 (375–935) μm long, partly septate with 1–3 septa, thin- to thick-walled with small simple pits, in the radial walls and occasionally in the tangential walls.

Parenchyma scanty paratracheal and vasicentric, occasionally aliform, marginal bands of 2–6 cells wide, in strands of 3–5 cells.

Fig. 25. *Delavaya toxocarpa*, TS, wood diffuse-porous. — Fig. 26. *Dodonaea viscosa*, TS, parenchyma scanty paratracheal. — Fig. 27. *Eurycorymbus cavaleriei*, TS, marginal parenchyma. — Fig. 28. *Handeliodendron bodinieri*, TS, wood diffuse-porous, over 100 vessels per mm2. — Fig. 29 & 30. *Harpullia cupanioides*. – 29: TS, various types of parenchyma. – 30: TLS, multiseriate rays and chains of rhombic crystals.

Rays 9 (7–13)/mm, uniseriate and biseriate, nearly homogeneous, composed of procumbent cells and occasionally a marginal row of square or upright cells, up to 550 µm (= 35 cells) high.

Prismatic crystals present in chambered parenchyma, chains over 10 crystals.

Handeliodendron Rehd. (Tribe Harpullieae) — Fig. 28, 36

Material studied: *H. bodinieri* (Lévl.) Rehd.: The Chinese Academy of Forestry, W 16128 (Uw 33653).

Deciduous trees or shrubs only found in the southern part of China.

Growth rings faint, marked by radially flattened latewood fibres and a row with more vessels per sq.mm. Wood diffuse-porous. Vessels more than 100/mm^2, 30% solitary, mostly in radial multiples of 2–4, round to oval, tangential diameter 40 (24–62) µm, radial diameter up to 67 µm, walls 1.5 µm thick. Vessel member length 451 (245–575) µm. Perforations simple in oblique end walls. Intervessel pits alternate, polygonal, 5–6 µm in diameter. Vessel-ray and vessel-parenchyma pits similar to intervessel pits in size and shape, but half-bordered. Helical thickenings present.

Libriform fibres 700 (505–960) µm long, non-septate, thin- to thick-walled with small simple pits in the radial walls and occasionally in the tangential walls.

Parenchyma very scarce, few strands at growth ring borders.

Rays 10 (7–12)/mm, exclusively uniseriate, heterogeneous, composed of procumbent cells and marginal rows of square and/or upright cells, usually 1 cell high, up to 300 µm (= 11 cells). Brown deposits common.

Crystals absent.

Harpullia Roxb. (Tribe Harpullieae) — Fig. 29, 30

Material studied: *H. cupanioides* (Blanco) Roxb.: Forestry Research Institute of Guangdong Province, W 0147 (Uw 33601).

Trees from tropical region.

Growth rings absent to faint, if present marked by marginal parenchyma of 1 cell wide. Wood diffuse-porous. Vessels 13 (8–17)/mm^2, 28% solitary, mostly in radial multiples of 2–4, round to oval, tangential diameter 94 (47–129) µm, radial diameter up to 177 µm, walls 6–7 µm thick. Vessel member length 503 (210–700) µm. Perforations simple in horizontal to slightly oblique end walls. Intervessel pits alternate, round, 6–8 µm. Vessel-ray and vessel-parenchyma pits similar to intervessel pits in size and shape, but half-bordered. Yellow deposits present.

Libriform fibres 895 (470–1145) µm long, non-septate, thin- to thick-walled with small simple pits, in the radial walls and occasionally in the tangential walls.

Parenchyma diffuse (= with crystals), scanty paratracheal, vasicentric and winged-aliform, sometimes marginal, in strands of 4–7 cells.

Rays 9 (7–14)/mm, 1 or 2 cells wide, heterogeneous, composed of procumbent cells with 1 or 2 rows of square to upright marginal cells, up to 450–660 µm (= 25–35 cells) high.

Prismatic crystals present in chambered axial parenchyma, in chains over 30 crystals.

Koelreuteria Laxm. (Tribe Koelreuterieae) — Fig. 31

Material studied: *K. bipinnata* Franch.: Guangdong, The Chinese Academy of Forestry, W 17044 (Uw 33594). — *K. elegans* Laxm.: Taiwan, Lw 17395 (Uw 33615). — *K. paniculata* Laxm.: District of Columbia, Smithson. Inst. 1527 (Uw 7223).

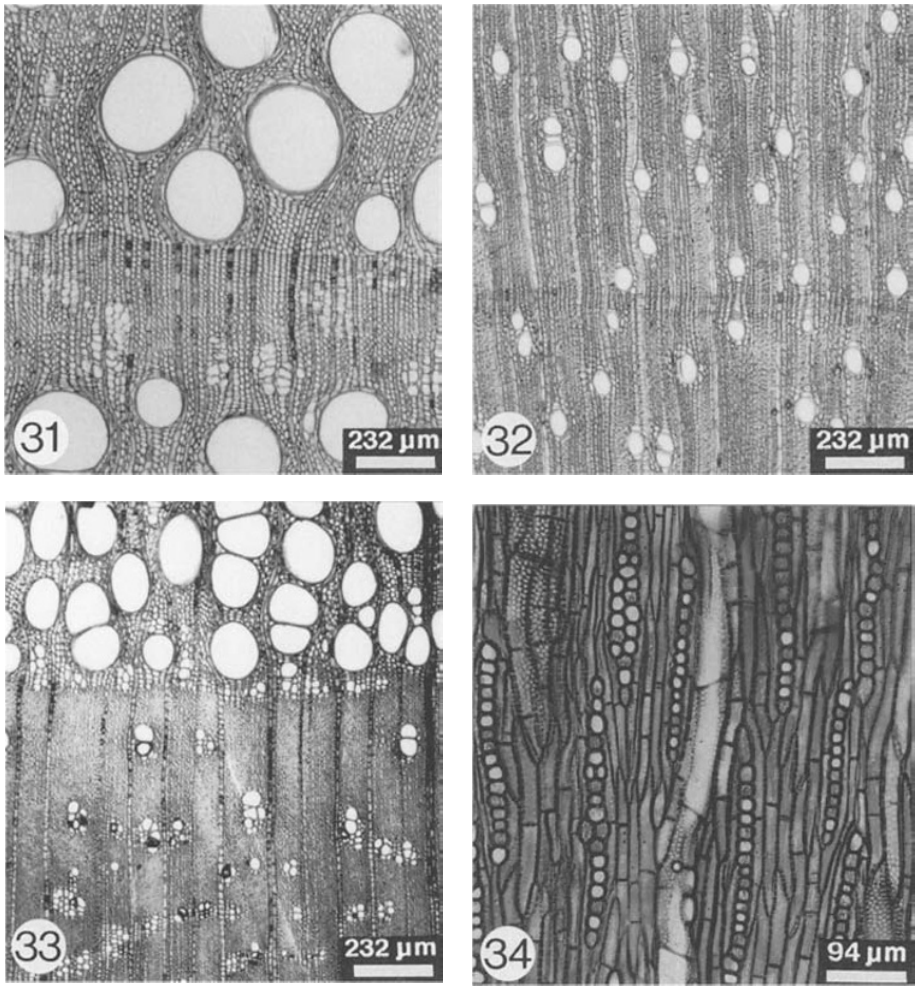


Fig. 31. *Koelreuteria bipinnata*, TS, wood ring-porous. — Fig. 32. *Sinradlkofera minus*, TS, wood diffuse-porous. — Fig. 33 & 34. *Xanthoceras sorbifolium* (cult.). – 33: TS, wood ring-porous. – 34: TLS, rays uni- and biseriate.

Deciduous trees or shrubs from tropical, subtropical and temperate regions.

Growth rings distinct, marked by radial flattened latewood fibres and much larger vessels in the earlywood and marginal parenchyma. Wood ring-porous. Vessels in earlywood mainly solitary in *K. bipinnata* and *K. elegans*; in irregular clusters of 2 or 3 in *K. paniculata*. In the latewood in radial multiples of 2–10, round to oval, tangential diameter in the earlywood 175–230 (88–323) μm; in the latewood 25–35 μm, radial diameter up to 270 μm, walls 3–9 μm thick. Vessel member length 280–345 (185–435) μm. Perforations simple in horizontal or oblique end walls. Intervessel pits alternate, round to angular, 8–9 μm. Vessel-ray and vessel-parenchyma pits similar to intervessel pits, in size and shape, but half-bordered. Helical thickenings present in small vessels.

Libriform fibres 795–990 (350–1175) μm long, all septate with one septum, thin- to thick-walled with small simple pits in the radial walls and occasionally in the tangential walls.

Parenchyma scanty paratracheal, occasionally nearly vasicentric in *K. elegans* and marginal, in strands of 2–9 cells.

Rays 12–15 (10–17)/mm, uniseriate, only few biseriate rays, nearly homogeneous, composed of procumbent cells, and some square cells; up to 300–410 μm (= 15–20 cells) high.

Prismatic crystals few to abundant in ray cells.

Sinradlkofera Gagnep. (Tribe Koelreuterieae) — Fig. 32, 35

Material studied: *B. minus* (Hemsl.) T. Chen: Guangxi, Academiae Sinicae Canton (Uw 33685).

Evergreen small trees found in southwestern to southern parts of China.

Growth rings distinct, marked by radially flattened latewood fibres and the presence of marginal parenchyma. Wood diffuse-porous. Vessels 26 (20–29)/mm^2, 60% solitary, with remainder in radial multiples of 2 or 3, round to oval, tangential diameter 44 (24–62) μm, radial diameter up to 81 μm, walls 3–5 μm thick. Vessel member length 444 (305–610) μm. Perforations simple in oblique end walls. Intervessel pits alternate, round, 2–3 μm. Vessel-ray and vessel-parenchyma pits similar to intervessel pits in size and shape but half-bordered. Striations present. Yellow deposits present but scarce.

Libriform fibres 829 (530–1115) μm long, non-septate, thin- to thick-walled with small simple pits in the radial walls and occasionally in the tangential walls.

Parenchyma scanty paratracheal and vasicentric, apotracheal as marginal bands of 1–3 cells wide, and diffuse (= with crystals) in strands of 3–8 cells.

Rays 10 (7–12)/mm, biseriate and occasionally uniseriate, heterogeneous, composed of procumbent cells and 1–3 marginal rows of square and upright cells, up to 460 μm (= 28 cells) high.

Prismatic crystals present in chambered parenchyma, usually 1 crystal per chamber, sometimes up to 4 crystals per chamber, in chains, over 20 crystals.

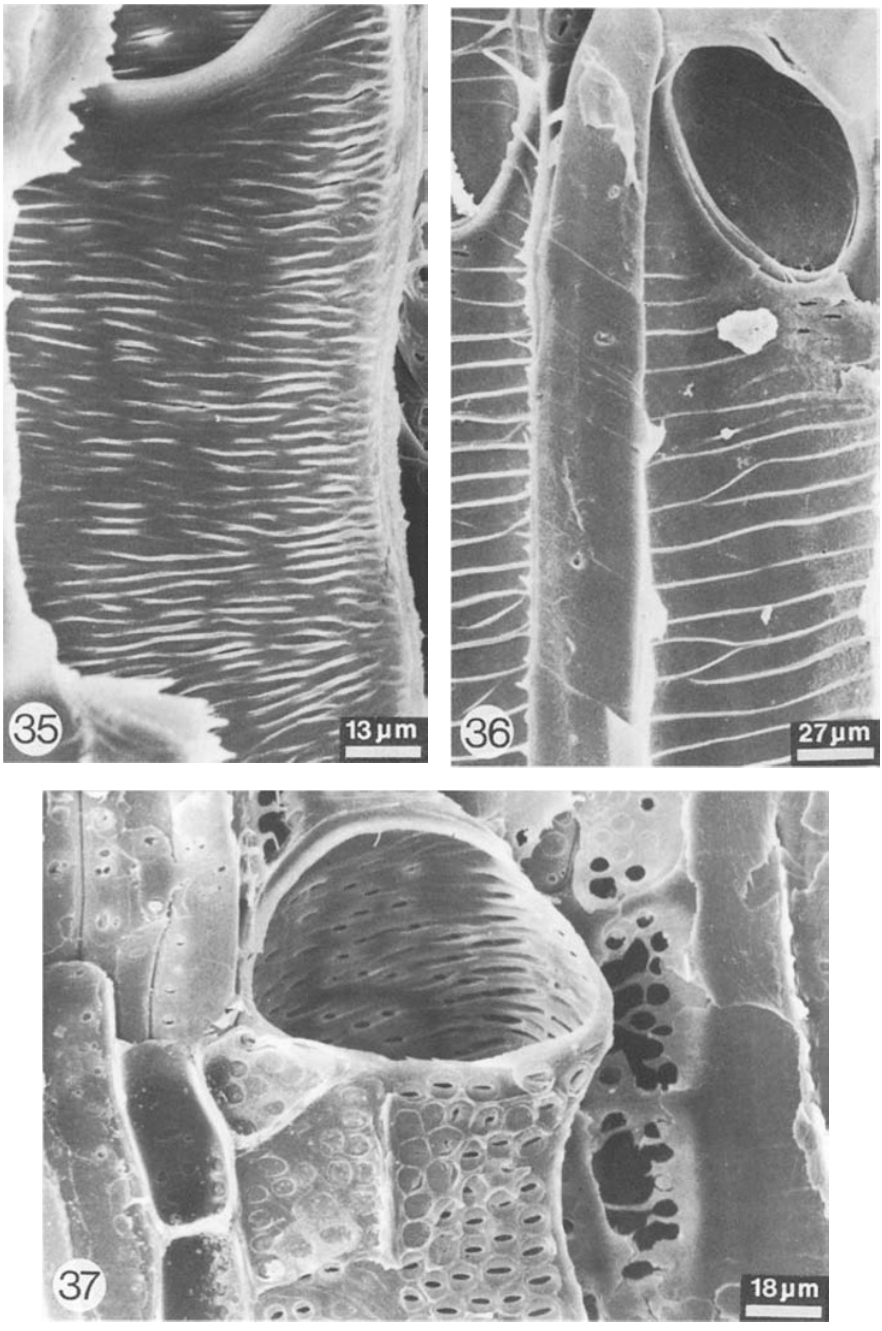


Fig. 35. *Sinradlkofera minus*, SEM, weak vessel wall thickenings. — Fig. 36. *Handeliodendron bodinieri*, SEM, clear vessel wall thickenings with wide spaced rims and a simple perforation plate. — Fig. 37. *Sapindus rarak*, SEM, simple perforation plate and alternate pattern, pits non-vestured.

Xanthoceras Bunge (Tribe Harpullieae) — Fig. 33, 34

Material studied: *X. sorbifolium* Bunge: Cantonspark s.n., Netherlands. Cultivated, sample of 1 cm diameter (Un 393).

Shrubs or small trees from northern part of China and Korea.

Growth rings distinct, marked by radially flattened latewood fibres and the difference in latewood and earlywood vessel diameter. Wood ring-porous, 40% solitary, mostly in radial multiples of 2 or 3, round to oval, tangential diameter in earlywood 87 (67–119) μm; in latewood 35 (19–71) μm, radial diameter up to 152 μm, walls 3–5 μm thick. Vessel member length 203 (130–315) μm. Perforations simple in oblique end walls. Intervessel pits alternate, round to angular, 6–8 μm. Vessel-ray and vessel-parenchyma pits similar to intervessel pits in size and shape, but half-bordered. Helical thickenings present in wide/small vessels. Brown deposits common.

Libriform fibres 542 (350–805) μm long, non-septate, thin-walled in earlywood, thick-walled in latewood, with small simple pits in the radial walls and occasionally in the tangential walls.

Parenchyma scanty paratracheal, and marginal, in strands of 2–4 cells.

Rays 8 (7–10)/mm, uni-, sometimes biseriate, heterogeneous, composed of procumbent, square and upright cells up to 720 μm (= 46 cells) high. Brown deposits common.

DISCUSSION

Compared with the total number of species of the Sapindaceae in the world (about 1400), the number of species occurring in China is few (55). Based on the studies of the materials available for this study, the following comments can be made:

1) Despite variation in a number of quantitative and qualitative features, the Chinese representatives of the Sapindaceae are wood anatomically homogeneous, characterised by simple perforations, alternate intervessel pits, vessel-ray and vessel-parenchyma pits similar to the intervessel pits, but half-bordered, libriform fibres only, septate fibres present, rays 1 or 2 cells wide and prismatic crystals common.
2) Most species of Sapindaceae of China are restricted to tropical and subtropical regions. The species from subtropical and temperate regions tend to be ring-porous and semi-ring-porous, while the species in tropical regions are diffuse-porous.
3) Helical thickenings are much more common and conspicuous (= thicker) in temperate species than in tropical taxa.
4) This study mostly confirms earlier wood anatomical studies of the Sapindaceae (Luo 1989; Metcalfe & Chalk 1950; Meylan & Butterfield 1978; Patel 1975; Record 1945; Record & Hess 1943; Solereder 1908; Tang 1973; Yamabayashi 1936; Yao 1988), but there are some differences. This study did not find bordered fibre pits (Yao 1988) or storied structure (Carlquist 1975). Tyloses are reported from China as common in the family (Tang 1973), but in our material tyloses are lacking, only organic deposits often exist in vessels and rays. Helical thickening was reported only in *Sapindus* and *Koelreuteria* (Record & Hess 1943), but we observed helical thickenings or striations in most Chinese species. Septate fibres have been described

for almost all species (Solereder 1908), but we did not observe septate fibres in *Sinradlkofera*, *Dodonaea* (Kanehira, 1921, mentioned *Dodonaea* only sometimes has septate fibres), *Handeliodendron*, *Harpullia*, and *Xanthoceras*.

Generic wood anatomical key to the Sapindaceae from China

1a. Wood ring-porous or semi-ring-porous 2
b. Wood diffuse-porous 4
2a. Rays multiseriate, parenchyma banded ..... *Sapindus*
b. Rays uniseriate or partly biseriate, parenchyma bands absent 3
3a. At least part of the fibres septate ..... *Koelreuteria*
b. All fibres non-septate ..... *Xanthoceras*
4a. Parenchyma predominantly scanty paratracheal, sometimes vasicentric or absent 12
b. Parenchyma aliform, confluent, banded and/or marginal 5
5a. Fibres non-septate only 6
b. Fibres non-septate and septate, occasionally very few 8
6a. Vessels with helical thickenings/striations ..... *Sinradlkofera*
b. Vessels without helical thickenings/striations 7
7a. Intervessel pits 6–8 μm; parenchyma scanty paratracheal, vasicentric and winged-aliform ..... *Harpullia*
b. Intervessel pits 3–6 μm; parenchyma scanty paratracheal, occasionally nearly vasicentric to faint aliform ..... *Dodonaea*
8a. Vessels without helical thickenings/striations ..... *Lepisanthes*
b. Vessels with helical thickenings/striations 9
9a. Prismatic crystals in ray cells ..... *Pometia*
b. Prismatic crystals in chambered axial parenchyma 10
10a. Rays exclusively uniseriate ..... *Nephelium*
b. Rays not exclusively uniseriate 11
11a. Rays uniseriate and biseriate, 9 per mm ..... *Eurycorymbus*
b. Rays multiseriate, 2–3 (4) cells wide, 5 per mm ..... *Sapindus*
12a. Intervessel pits 6–9 μm, fibre dimorphism present ..... *Allophylus*
b. Intervessel pits 1–5 (6) μm, fibre dimorphism absent 13
13a. Prismatic crystals present in ray cells, sometimes very sporadically) 14
b. Prismatic crystals absent from the ray cells 16
14a. Intervessel pits 2–3 μm ..... *Litchi / Dimocarpus*
b. Intervessel pits 3–6 μm 15
15a. Prismatic crystals in axial elements ..... *Delavaya*
b. Prismatic crystals in ray cells only ..... *Amesiodendron*
16a. Fibres non-septate only 17
b. Fibres all or in part septate ..... *Arytera, Mischocarpus* (all), *Delavaya* (all)
17a. Rays multiseriate, vessel with fine closely spaced helical wall sculpturing, prismatic crystals in chambered parenchyma ..... *Sinradlkofera*
b. Rays uniseriate, vessels with distinct widely spaced helical vessel wall thickenings, prismatic crystals absent ..... *Handeliodendron*

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