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Wood Anatomical Characteristics of Korean Coniferous and Broad-leaved Trees

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韓國產 針葉樹와 闊葉樹의 木材解剖學的 特性

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요 약

本 연구는 韓國産 針葉樹와 闊葉樹의 木材解剖學的 特性을 考察하기 爲하여 착수하였다. 木材試片, 解離纖維 및 永久스라이드는 서울大學校 수원캠퍼스의 農業生命科學大學, 林産工學科, 木材解剖實驗室에 所藏되어 있는 材料를 利用하였다. 실험재료는 針葉樹 16屬, 31種, 61個體이였으며 闊葉樹 153屬, 286種, 514個體로 全國에서 採取한 材料이다. 肉眼的 特徵의 調査項目으로는 年輪, 心材와 邊材, 放射線, 材色, 香氣와 味 등을 調査하였다. 그리고 顯微鏡的 特徵은 導管, 假導管, 木纖維, 垂直柔細胞와 放射柔細胞, 放射組織의 構造와 細胞間溝 等의 특징을 光學顯微鏡으로 觀察하고 調査하였다. 관찰된 肉眼的·顯微鏡的 特性을 樹種別로 종합하였다. 이 結果에 의하여 韓國産 針葉樹材와 闊葉樹材의 出現特徵率이 계산되었으며 針葉樹材와 闊葉樹材 사이에 나타나는 特徵率을 比較 考察하였다.

Introduction

By the report of the Korea-Manchuria Forestry Handbook (1938) Korean woody plants were classified into 84 families, 241 genera, 667 species, 385

varieties, and 45 formas. Total species of Korea had 1,000 or more tree species in the Korean peninsula.

After the Korean war, our collection work of wood specimens was limited to South Korea, practically the central and southern parts of the Korean peninsula and Cheju island. Ananatomical study of Korean wood was executed about macroscopical and microscopical features by Yamahayashi (1938). This is the first important wood anatomical study. Yamahayashi, N. was a Professor, Suwon Agriculture and Forestry College, former college of Agriculture and Life Sciences of Seoul National University. Thereafter, the studies as another field of wood technology under the Wood Anatomy Laboratory, Department of Forest Products, College of Agriculture and Life Sciences, Seoul National University were executed partially by a few scientists including Lee (1961, 1966, 1984, 1987, 1988, 1989, 1992, 1994, 1995, 1996a, 1996b, 1996c, 1997).

From 1960 to 1994, the laboratory had collected the wood samples of five families, 16 genera and 31 species of coniferous, and 61 families, 153 genera and 286 species included nine varieties and four formas of deciduous trees.

This consolidated report is provided based on the results of the wood anatomical characteristics of coniferous and broad-leaved tree species of Korea. A part of the results and microscopical photographs in the study were reported already by Lee (1994, 1997).

Materials and Methods

Macroscopical …… Examined materials from sample trees and wood specimens about 31 softwood and 286 hardwood species by individual were cut and observed or inspected for the items of annual ring, transition spring to summerwood, sap and heartwood, wood ray, wood texture, intercellular canal, wood color or taste etc. for the softwood and hardwood species.

Microscopical …… In the same positions of every trees, small pieces of one cubic centimeter size for cross, radial and tangential sections were prepared ten blocks per individual. At the same time, the maceration materials of match stick size were also prepared. Sectioned materials were boiled in glycerine and distilled water to soften their hard tissues. Hard materials were treated for six to eight hours and soft materials for four to six hours. Section of materials was performed

by Spencer Sliding Microtome in relatively thick 20 to 30 microns in cross, 15 to 20 microns in radial and tangential sections. The sliced sections were stained by safranin solution, dehydrated with 50% absolute alcohol and finally washed by pure and anhydrous xylol. After clarification, the preparations were mounted in Canada balsam on the slide glass.

For fiber maceration, Schurz method was employed. Materials in test tubes with Schurz's solution were changed into yellowish white and thereafter pure white in color by heating treatment. These white materials were washed and preserved in 30% alcohol.

Vessels; Type of width, wall thickness, arrangement of single pore, multiplying type, number and direction of pore multiple, perforation plate, pit size, arrangement on vessel wall and tyloses occurrence were measured and observed. The vessel element length were measured from the macerated materials. Maximum and minimum sizes by total length method were employed.

Tracheids; In the measurement of tracheid sizes, two methods from the sectional and macerated materials were conducted as the case of vessel element. However, in the study, the maximum and minimum length, width and wall thickness from the macerated materials were measured. For the observations, the arrangement and the size of pit, the spiral thickening of secondary wall and the ray tracheid were observed and measured.

Ray parenchyma cells; To determine the ray quantities on cross section, the ray number occurring within one millimeter tissue was inspected. In tangential section ray types such as uni-, bi-, meta-seriates, and max. and min. values of height or width, and cell layered number in fusiform rays were also measured. In radial section, the homo- or hetero-genus ray of hardwood, and for softwood the ray cross field pitting type described on the diagnostic application of coniferous species in the publications by Brown *et al* (1984), and Kukachka (1960), were observed.

Longitudinal parenchyma cells; Arrangement and occurrence of the parenchyma cells in cross section, and fusi or strandform parenchyma cells in radial section were observed.

Wood fibers; Fiber dimension on the maximum or minimum values of length, width and wall thickness was observed and measured from the sectional and macerated materials.

Intercellular canals; The occurrence and position of vertical or horizontal canals were observed. Radial and tangential diameters of vertical resin canals were measured to inspect the size of canal in cross section.

Appearing feature percentage …… Anatomical data from the observations except the results of measurements were synthesized by species. From these macro and microscopical characteristics with 18 items of softwoods and with 20 items of hardwoods, the appearing features were calculated into percentage by appearing numbers / total species numbers × 100. We named this as the percentage of appearing feature. The figures from the percentages were plotted on coniferous and deciduous species in order to know the appearing frequency of anatomical features in Korean softwoods or Korean hardwoods. They were compared between the softwoods and the hardwoods.

Results and Discussion

The results of wood anatomical characteristics by the investigated macroscopical and microscopical features of Korean coniferous tree (softwood) species were presented in Table 1.

The calculated percentages of appearing feature on anatomical characteristics of 31 Korean softwood species were presented in Table 3. The highest value showed 61.3% (19/31 species) in indenture, next 45.2% (14/31 species) in ray parenchyma end wall nodular, and 41.9% (13/31 species) abrupt transition early to late wood tracheids or resin canal present as same values among 18 observed items. However, the lowest value showed 9.7% (3/31 species) in spiral thickening and in pinoid pitting and next 12.9% (4/31 species) in crystal present among the observed 18 items of anatomical softwood features. Accordingly it was known that in Korean softwoods the highest appearing possibility has in indenture and next ray parenchyma end wall nodular among the 18 items of anatomical features.

The results of wood anatomical characteristics by the investigated macroscopical and microscopical features of Korean broad-leaved tree (hardwood) species were presented in Table 2.

Table 2 was the synthesized features of Korean hardwood species according to the Committee on International Association of Wood Anatomists (1989).

The calculated percentages of appearing feature on anatomical characteristics

of 286 hardwood species growing in Korea were presented in Table 4. By this table the highest value of appearing feature percentage among the 20 observed items of Korean hardwood species is showing 77.3% (221/286 species) in simple perforation and next 67.1% (192/286 species) in diffuse parenchyma, 61.5% (176/286 species) heterogeneous ray, 60.1% (172/286 species) diffuse porous, and 51.4% (147/286 species) spiral thickening in oder. On the contrary, the lowest appearing percentage of anatomical features showed only 1.7% (5/286 species) in figured porous, and next 9.1% (26/286 species) in radial porous, 11.9% (34/286 species) tyloses, 16.1% (46/286 species) confluent and 19.6% (56/286 species) aliform in oder.

Comparing with the appearing feature percentage between Korean softwoods and hardwoods species, higher percentage was appeared in hardwoods than in softwoods.

Based on the percentages of appearing feature from Table 3 and Table 4, Fig. 1 and Fig. 2 were plotted. The percentage of appearing feature of hardwoods had higher tendency than softwoods. This tendency of the results may explain that feature observations of the hardwoods are more easy than those of softwoods.

Conclusions

From the results and discussion of wood anatomical characteristics of Korean coniferous and broad-leaved trees from the appearing feature percentage, it was concluded briefly as follows ;

1. In the calculated percentages of appearing feature of softwoods, the highest percentage was 61.3% in indenture and next 45.2% in ray parenchyma end wall nodular. However, the lowest value was 9.7% in spiral thickening and in pinoid pitting and next 12.9% in crystal present.

2. In the calculated percentages of hardwoods, the highest percentage value was 77.3% in simple perforation plate and next 67.1% in diffuse parenchyma arrangement of vertical parenchyma cells. However, the lowest value was only 1.7% in figured porous wood and next 9.1% in radial porous wood.

3. In general, the percentage of hardwoods were higher tendency than those of softwoods. Accordingly the feature observations of Korean hardwoods are more easy than that of Korean softwoods, based on the percentage of appearing feature.

Summary

This study was carried out to investigate the wood anatomical characteristics of coniferous and broad-leaved trees growing in Korea. The wood specimens, macerated wood fibers, and permanent slides were utilized for the experimental materials stored in Wood Anatomy Laboratory, Department of Forest Products, College of Agriculture and Life Sciences, Seoul National University. Examined materials were 61 individuals, 31 species and 16 genera in coniferous and were 514 individuals, 286 species and 153 genera of hardwood trees. The macroscopical items of the features such as annual rings, sap and heartwoods, wood rays, wood colors, odors and tastes were observed. The macroscopical items of the features such as vessels, tracheids, wood fibers, longitudinal and ray parenchymas, ray constructions, and intercellular canals were examined by light microscope. From the results of the macro- and microscopic features of the species, the anatomical characteristics by the species were synthesized. The appearing feature percentages of Korean softwoods and hardwoods were calculated and investigated.

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Table 1. Anatomical data of coniferous woods growing in Korea

Species	Tracheids			Canals			Rays				Cross-field pits				Paren-chyma		Im-ported	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Ginkgoaceae																		
Ginkgo biloba		+								+					+			
Taxaceae																		
Torreya nucifera			+						+						+			
Taxus cuspidata			+						+						+			
Cephalotaxaceae																		
Cephalotaxus koreana			+						+						+	+		
Pinaceae																		
Abies firma	+							+	+					+				+
Abies holophylla	+							+	+	+				+				
Abies koreana	+							+	+	+				+				
Abies nephrolepis	+							+	+					+				
Tsuga sieboldii	+					+									+			
Picea jezoensis				+	+	+		+	+				+					
Picea koraiensis				+	+			+					+					
Picea excelsa				+	+			+	+				+					+
Larix gmelini var. *principis-rupprechtii*	+	+		+	+	+		+	+				+					
Larix leptolepis	+	+		+	+	+		+	+				+					+
Cedrus deodara								+		+			+	+	+	+	+	+
Pinus koraiensis				+		+					+							
Pinus parviflora				+		+					+							
Pinus strobus				+		+					+							+
Pinus banksiana	+			+		+	+		+			+						+
Pinus taeda	+			+		+	+		+			+						+
Pinus rigida	+			+		+	+					+						+
Pinus densiflora	+			+		+	+				+							
Pinus thunbergii	+			+		+	+				+							
Taxodiaceae																		
Taxodium distichum		+						+						+	+	+	+	+
Metasequoia glyptostroboides		+							+					+	+	+	+	+
Cryptomeria japonica	+								+					+		+		
Cupressaceae																		
Thuja orientalis		+							+					+		+	+	
Chamaecyparis obtusa															+	+		+
Juniperus chinensis								+	+						+	+	+	
Juniperus rigida								+	+						+	+	+	
Juniperus virginiana								+	+						+	+	+	+

1. Abrupt early-latedwood transition, 2. Radial pit two or more rows, 3. Spiral thickening, 4. Resin canal presents, 5. Epithelium walls thick, 6. Ray tracheid presents, 7. Ray tracheid dentates, 8. Ray parenchyma end wall nodular, 9. Indentures, 10. Crystal presents, 11. Windowlike, 12. Pinoid, 13. Piceoid, 14. Taxodioid, 15. Cupressoid, 16. Longitudinal parenchyma presents, 17. Longitudinal parenchyma end wall nodular, 18. Imported species.

Table 2. Anatomical data of hardwoods growing in Korea

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Salicaceae																				
Populus davidiana		(+)		+			+				+	+							+	
Populus alba		(+)		+			+					+							+	
Populus maximowiczii		(+)		+			+					+							+	
Populus koreana		(+)		+			+					+							+	
Populus simonii		(+)		+			+					+							+	
Populus nigra var. *italica*		(+)		+			+					+							+	
Populus deltoides		(+)		+			+					+			(+)				+	
Populus alba x *glandulosa*		+		+			+					+							+	
Salix glandulosa	+			+			+					+								+
Salix koreensis	+	(+)		+			+					+								+
Salix matsudana for. *tortuosa*	+	(+)		+			+					+								+
Salix gracilistyla	(+)	(+)		+			+					+								+
Myricaceae																				
Myrica rubra				+				+			+		+	+				+		+
Juglandaceae																				
Platycarya strobilacea	+	(+)	+				+		+	+				+	+					+
Pterocarya stenoptera	(+)		(+)	+			+			+		+		+	+				+	
Juglans mandshurica	+	+		+			+			+		+	+	+					+ ~	
Juglans sinensis	+	+		+			+			+		+	+	+					+ ~	
Betulaceae																				
Betula costata		(+)		+				+			+	+	+	+					+	
Betula schmidtii		(+)		+				+				+	+	+					+ ~	
Betula chinensis		(+)		+				+				+	+	+						+
Betula platyphylla var. *japonica*		(+)		+				+			+	+	+	+					+	
Betula davurica		(+)		+				+			+	+	+	+						+
Alnus japonica		(+)			+			+					+	+					+	
Alnus hirsuta	+	(+)			+			+					+	+				+	+ ~	
Alnus hirsuta var. *sibirica*		(+)			+			+					+	+					+ ~	
Carpinus erosa	+				+			+	+		+	+	+	+				+		+
Carpinus tschonoskii	+				+		+	+					+	+						+
Carpinus laxiflora					+		+	+	+			+	+					+	+	
Carpinus coreana	+				+		+		+			+	+	+				+		+
Carpinus tschonoskii var. *eximia*					+		+					+	+	+				+		+
Corylus heterophylla var. *thunbergii*					+		+	+	+				+	+				+		+
Faguceae																				
Fagus multinervis	(+)	(+)		+			+	+					+	+				+		+
Castanea crenata	+	+	+				+			+			+	+				+	+	
Castanopsis cuspidata var. *sieboldii*	+		+				+			+	+			+	+				+	
Quercus accutissima	+	+	+				+			+	+		+	+	+			+	+	
Quercus variabilis	+	(+)	+				+			+	+		+	+				+	+	
Quercus dentata	+	+	+				+			+	+		+	+				+	+	
Quercus aliena	+	+	+				+			+	+		+	+				+	+	
Quercus mongolica	+	+	+				+			+	+		+	+				+	+	
Quercus serrata	+	+	+				+			+	+		+	+				+	+	
Quercus acuta		(+)			+		+				+		+	+					+	
Quercus myrsinaefolia		(+)			+		+			(+)			+	+					+	
Quercus salicina		(+)			+		+				+		+	+					+	
Ulmaceae																				
Ulmus parvifolia	+	+	+				+		+			+		+	+	+	+	+	+	
Ulmus pumila	+	+	+				+		+			+		+	+			+	+	
Ulmus davidiana var. *japonica*	+	+	+				+		+	+	+	+		+	+			+	+	
Hemiptelea davidii	+	+	+				+		+	+		+			+	+	+			+

(Continued)

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Zelkova serrata	+	+	+				+		+						+	+	+	+		+
Celtis sinensis	+		+				+		+			+			+	+	+			+
Celtis jessoensis	+		+				+		+	+		+			+	+	+			+
Aphananthe aspera		(+)		+			+		+			+		+	+	+	+			+
Moraceae																				
Cudrania tricuspidata	+	+	+				+		+	+	+	+			+	+	+			+
Morus bombycis	+	+	+				+		+	+	+	+			+	+	+			+
Morus alba	+	+	+				+		+	+		+			+	+	+			+
Brossonetia kazinoki	+	(+)	+				+		+				+		+	+	+			+
Ficus carica				+			+			+	+			+	+	+	+			+
Cercidiphyllaceae																				
Cercidiphyllum japonicum		(+)		+				+			+		+							+
Paeonioideae																				
Paeonia suffruticosa	+	+	+					+	+				+					+		+
Berberidaceae																				
Berberis poiretii	+		+				+		+			+		+						+
Berberis koreana	+		+				+		+				+							+
Berberis amurensis	+		+				+		+				+							+
Berberis amurensis var. *latifolia*	+		+				+		+				+						+~	
Nandina domestica			+				+		+				+						+	
Magnoliaceae																				
Liriodendron tulipifera	+	+		+			+	+				+								+
Magonolia sieboldii	+			+				+	+			+							+~	
Magnolia kobus	+			+			+	+				+	+					+	+~	
Magnolia obovata	+	+		+			+	+				+							+~	
Calycanthaceae																				
Calycanthus fertilis						+	+		+				+					+		+
Illiciaceae																				
Illicium religiosum		(+)		+				+					+					+		+
Lauraceae																				
Lindera obstusiloba				+			+	+				+			+	+				+
Lindera glauca				+			+	+							+	+				+
Lindera erythrocarpa		(+)		+			+	+							+	+				+
Cinnamomum camphora	+			+			+	+							+	+				+
Cinnamomum japonium	+			+			+	+							+	(+)				+
Machilus thunbergii	+	+		+			+	+							+	+				+
Machilus thunbergii var. *obovata*	+	+		+			+	+							+	+	(+)			+
Neolitsea sericea	+			+			+	+							+	+	(+)			
Hydrangeaceae																				
Deutzia gracilis				+				+	+				+					+		+
Deutzia glabrata				+				+	+				+	+	(+)					+
Deutzia sieboldiana				+				+	+				+					+		+
Pliladelphus schrenckii	(+)			+				+					+					+		+
Hydrangea paniculata	+	+		+				+					+					+		+
Grossulariaceae																				
Ribes fasciculatum var. *chinense*				+				+	+				+							+
Pittosporaceae																				
Pittosporum tobira				+			+		+		+		+					+		+
Hamamelidaceae																				
Distylium racemosum				+				+			+		+	+						+
Corylopsis glabrascens var. *toroana*				+				+	+				+					+		+

(Continued)

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Hamamelis japonica				+				+					+					+		+
Eucommiaceae																				
Eucommia ulmoides		+		+			+		+				+	+				+	+~	
Platanaceae																				
Platanus orientalis	+	(+)		+			+	+			+		+	+				+	+	
Platanus acerifolia	+	+		+			+	+			+		+	+				+	+	
Platanus occidentalis	+	(+)		+			+	+			+		+	+				+		
Rosaceae																				
Sorbaria sorbifolia var. *stellipila*	+	(+)		+			+						+	+				+	+~	
Spiraea prunifolia var. *simpliciflora*				+			+				+		+					+		+
Spiraea cantoniensis				+			+						+					+		+
Spiraea salicifolia				+			+						+					+	+	
Spiraea prunifolia				+	+		+				+		+					+		+
Physocarpus amurensis				+			+				+		+							+
Stephanandra incisa				+			+						+	+				+	+~	
Rhodotypos scanders		+		+			+						+	+				+	+~	
Rosa multiflora	+		+				+		+				+					+		+
Rosa multiflora var. *platyphylla*		+	+				+						+					+		+
Rosa rugosa			+				+		+				+					+		+
Prinsepia sinensis		+		+			+		+				+					+		+
Prunus mandshurica var. *glabra*	+	+	+				+				+		+					+	+	
Prunus armericana var. *ansu*	+	+	+				+		+		+		+					+		+
Prunus davidiana			(+)	+			+		+				+					+		+
Prunus maackii				+			+		+				+					+		+
Prunus padus	+	+		+			+		+				+					+	+	
Prunus serrulata var. *spontanea*				+			+		+				+					+		+
Prunus pendula for. *ascendens*			(+)	+			+		+		+		+					+		
Prunus sargentii		+	(+)	+			+		+				+					+		+
Prunus leveilleana				+			+		+				+					+		+
Prunus takesimensis		(+)		+			+		+		+		+					+		+
Prunus glandulosa			(+)	+			+		+				+					+		+
Prunus japonica var. *nakaii*			(+)	+			+		+				+					+		+
Crataegus pinnatifida	+			+			+		(+)				+	+				+	+	
Crataegus maximowiczii	+			+			+	(+)					+	+				+	+	
Photinia glabra				+			+				+		+	+				+		+
Eriobotrya japonica				+			+		+		+		+	+				+		+
Raphiolepis umbellata	+			+			+		+		+		+	+				+		+
Chaenomeles sinensis		+		+			+		+		+		+	+				+		+
Chaenomeles lagenaria		+		+			+		+		+		+	+				+		+
Pyracantha angustifolia				+			+		+		+		+					+		+
Malus baccata	+	+		+			+						+	+				+	+	
Malus baccata var. *mandshurica*	+	+		+			+						+	+				+	+~	
Malus sieboldii	+			+			+						+	+				+	+	
Pyrus ussuriensis var. *seoulensis*	+			+			+		+				+	+				+	+	
Pyrus pyrifolia	+			+			+		+				+	+				+	+	
Amelanchier asiatica				+			+		+				+	+				+	+~	
Pourthiaea villosa var. *laevis*	+	(+)	(+)	+			+		(+)				+	+				+		+
Pourthiaea villosa var. *brunnea*	+	(+)		+			+		+				+	+				+		+
Pourthiaea villosa var. *zollingeri*	+	(+)	(+)	+			+		+		+		+	+				+		+

(Continued)

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sorbus commixta	+	(+)		+			+		+		+	+	+	+					+~	
Sorbus alnifolia	+			+			+		+				+	+				+	+	
Mimosaceae																				
Albizia julibrissin	+	+	+				+		+		+	+	+		+	+	+		+	
Caesalpiniaceae																				
Cercis chinensis	+		+				+		+		+	+			+	+	+			+
Gleditsia japonica var. *koraiensis*	+	+	+				+		+		+	+			+	+	+			+
Fabaceae																				
Sophora japonica	+	+	+				+		+		+	+		+	+	+	+		+~	
Echinosophora koreensis		+	+				+		+						+	+	+			+
Maackia amurensis	+	+	+				+		+		+	+			+	+	+			
Maackia amurensis var. *buergeri*	+	+	+				+		+			+	+			+	+			+
Wisteria floribunda	+		+				+		+					+					+~	
Lespedeza cyrtobotrya	+	+	+				+			+	+	+			+	+	+			+
Lespedeza bicolor	+	+	+				+							+	+	+	+			+
Robinia pseudoacacia	+	+	+				+		+	+	+	+			+	+	+		+	
Robinia hispida		+	+				+		+	+	+	+			+	+	+		+~	
Amorpha fruticosa			+				+		+	+	+				+	+	+			+
Rutaceae																				
Zanthoxylum piperitum	+		+	+			+					+						+		+
Evodia daniellii	+		+				+		+		+	+			+	+				+
Evodia officinalis	+		+				+		+		+	+			+	+				+
Phellodendron amurense	+	+	+				+		+		+				+				+	
Poncirus trifoliata				+			+		+		+				+	+	+		+	
Citrus junos				+			+				+			+	+	+	+		+~	
Simaroubaceae																				
Picrasma quassioides	+			+			+					+			+	+	+			+
Ailanthus altissima	+		+				+		(+)			+				+	+	+		+
Meliaceae																				
Cedrela sinensis	+	+	+				+				+					+	+	+		+
Melia azedarach var. *japonica*	+	+	+				+		+			+			+	+	+		+	
Euphorbiaceae																				
Mallotus japonicus	+		+				+			+				+	+					+
Aleurites fordii	+	+	+				+							+	+					+
Securinega suffruticosa	+		+				+						+					+	+~	
Sapium japonicum				(+)	+		+						+	+	+			+		+
Sapium sebiferum				+			+						+	+	+			+		+
Buxaceae																				
Buxus microphylla var. *koreana*				+				+					+	+				+		+
Anacardiaceae																				
Cotinus coggygria	+	+	+				+			+		+	+						+~	
Rhus javanica	+	+	+				+			+		+	+			+	+			+
Rhus trichocarpa	+	+	+				+			+	+	+			+					+
Rhus verniciflua	+	+	+				+			+	+	+				+			+~	
Aquifoliaceae																				
Ilex macropoda					+			+			+		+					+		+
Ilex serrata var. *sieboldii*				+				+			+		+					+		+
Ilex crenata					+			+			+		+					+		+
Ilex cornuta				+	+			+			+		+					+		+
Ilex rotunda					+			+	+		+		+					+		+

(Continued)

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Celastraceae																				
Euonymus japonicus				+			+		+				+					+	+	
Euonymus alatus				+			+		+				+					+	+	
Euonymus alatus for. *ciliato-dentatus*				+			+		+				+					+	+	
Euonymus sachalinensis				+			+		+				+					+	+	
Euonymus macropterus				+			+		+				+					+	+	
Euonymus trapococus				+			+		+				+					+	+	
Euonymus sieboldianus				+			+		+				+					+	+	
Celastrus orbiculatus	+	+	+				+				+		+		+				+	
Tripterigium regelii	+	+	+				+		+		+				+				+~	
Staphyleaceae																				
Staphylea bumalda				+				+					+					+		+
Euscaphis japonica				+				+					+					+		+
Aceraceae																				
Acer tegmantosum				+			+		+				+					+	+	
Acer tschonoskii var. *rubripes*				+			+		+			+	+					+	+	
Acer ukurunduense	+			+			+		+			+	+						+	
Acer pictum	+			+			+		+		+	+	+					+	+	
Acer ginnala	+			+			+		+		+	+	+					+	+	
Acer palmatum	+			+			+		+		+		+					+	+	
Acer triflorum				+			+		+		+	+	+					+	+	
Acer mandshuricum				+			+		+		+	+	+					+	+	
Hippocastanaceae																				
Aesculus turbinata				+			+		+			+	+						+	
Sapindaceae																				
Koelreuteria paniculata	+		+				+		+		+			+	+	+			+	
Sabiaceae																				
Meliosma myriantha				+	+		+	+			+	+			+			+		+
Meliosma oldhamii				+			+	+				+						+		+
Rhamnaceae																				
Zizyphus jujuba var. *inermis*	+	+		+			+					+		+	+			+		+
Hovenia dulcis	+		+				+				+	+			+	+	+			+
Berchemia berchemiaefolia	+	+	+				+					+			+	+	+			+
Rhamnus davurica	+	+				+	+		+			+	+		+				+	
Vitaceae																				
Parthenocissus tricuspidata	+	(+)	+				+		+		+				+	+	+		+	
Elaeocarpaceae																				
Elaeocarpus sylvestris var. *ellipticus*		(+)		+				+					+	+				+		+
Tiliaceae																				
Tilia amurensis	+				+		+		+				+	+					+	
Tilia taquatii					+		+		+				+						+	
Tilia mandshurica	+				+		+		+			+	+	+					+	
Tilia megaphylla				+			+		+		+	+	+	+					+	
Malvaceae																				
Hibiscus syriacus		+	+				+		+					+	+	+	+			+
Sterculiaceae																				
Firmiana simplex	+	+	+				+							+	+	+	+			+
Actinidiaceae																				
Actinidia arguta		+	+				+		+				+	+				+		+
Theaceae																				
Stewartia koreana				+				+	+				+	+						+
Ternstroemia japonica	+			+				+	+				+					+		+

(Continued)

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Camellia sinensis				+				+					+	+				+		+
Camellia japonica				+				+	(+)				+	+	+			+		+
Cleyera japonica				+				+	+				+	+	+			+		+
Eurya japonica				+				+	+				+	+						+
Eurya emarginata				+				+	+				+	+						+
Flacourticeae																				
Idesia polycarpa				+	+		+				+		+					+		+
Thymelaeaceae																				
Edgeworthia papyrifera	+		+				+		+					+	+					+
Elaeagnaceae																				
Elaeagnus umbellata	+		+				+		+				+	+				+	+	
Lythraceae																				
Lagerstroemia indica			+				+				+		+					+	+	
Punicaceae																				
Punica granatum			+				+				+		+		+					+
Alangiaceae																				
Alangium platanifolium var. *macrophyllum*		(+)	+				+				+		+	+	+	+	+			+
Araliaceae																				
Dendropanax morbifera	+		+				+								+			+		+
Fatsia japonica				+			+	+	+				+					+		+
Kalopanax septemlobus	+	(+)	+				+								+			+		+
Acanthopanax sieboldianum	+	(+)	+				+								+			+		+
Acanthopanax sessiliflorus	+	(+)	+				+											+		+
Acanthopanax senticosus	+	(+)	+				+											+		+
Aralia elata	+	(+)	+				+		+			+			+					+
Cornaceae																				
Aucuba japonica				+	+			+	+				+					+		+
Cornus kousa				+				+					+	+				+		+
Cornus controversa				+				+					+	+				+		+
Cornus alba		(+)		+				+					+	+				+		+
Cornus walteri				+				+					+	+				+		+
Cornus officinalis		(+)		+				+					+	+				+		+
Ericaceae																				
Rhododendron brachycarpum				+				+	+				+					+		+
Rhododendron mucronulatum				+				+	+				+					+		+
Rhododendron mucronulatum var. *ciliatum*				+				+	+				+					+		+
Rhododendron yedoense for. poukhanense				+				+	+				+		+					+
Rhododendron schlippenbachii				+				+	+				+		(+)			+		+
Vaccinium oldhamii				+				+	+				+		+				+	+
Vaccinium koreanum				+				+	+				+						+	
Ebenaceae																				
Diospyros lotus		+		+			+						+		+					+
Diospyros kaki	+	+		+			+						+		+					+
Symplocaceae																				
Symplocos sawafutagi	+			+				+					+	+				+		+
Styracaceae																				
Styrax obassia	+		(+)	+				+					+	+				+		+
Styrax japonica	+			+	+			+					+	+				+		+
Oleaceae																				
Fraxinus mandshurica	+	+	+				+					+			+	+	+		+	
Fraxinus rhynchophylla	+		+				+			+		+			+	+	+		+	
Fraxinus sieboldiana	+		+				+			+		+			+	+	+		+	
Fraxinus americana	+	(+)	+				+					+		+	+	+	+		+	

(Continued)

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Chionanthus retusa	+		+				+		+									+	+	
Ligustrum japonicum			(+)	+			+		+		+		+							+
Ligustrum ovalifolium			(+)	+			+		+		+		+							+
Ligustrum obtusifolium			+				+		+		+		+					+		+
Osmanthus fragrans						+	+		+			+						+		+
Osmanthus heterophylla						+	+		+			+						+		+
Osmanthus latifolius				+		+	+		+			+						+		+
Abeliophyllum distichum		+	(+)	+			+		+				+					+		+
Forsythia koreana			+				+		+				+		+					+
Forsythia ovata			+				+		+				+		+					+
Syringa reticulata var. *mandshurica*	+	(+)	(+)	+			+		+				+					+	+	
Syringa reticulata for. *longifolia*		(+)	(+)	+			+		+				+					+		+
Syringa dilatata		(+)	(+)	+			+		+				+					+		+
Syringa velutina var. *kamibayashii*		(+)	(+)	+			+		+				+					+		+
Apocinaceae																				
Nerium indicum		(+)		+	+		+				+		+					+		+
Verbenaceae																				
Callicarpa japonica				+			+					+	+		+			+		+
Clerodendron trichotomum	+		+				+								+	+	+			+
Vitex negundo var. *incisa*			+				+											+		+
Solanaceae																				
Lycium chinense		(+)	+	+			+		+				+		+				+	
Scrophulariaceae																				
Paulownia coreana	+	(+)	+				+			+					+	+	+		+	
Bignoniaceae																				
Catalap ovata.	+	(+)	+				+		+	+		+			+	+	+		+~	
Catalap bignonioides	+	(+)	+				+		+	+		+			+	+	+		+	
Rubiaceae																				
Gardenia jasminoides for. *grandiflora*				+			+						+	+	+					+
Caprifoliaceae																				
Sambucus williamsii var. *coreana*	+	(+)	+				+						+							+
Sambucus latipinna	+	(+)	+				+						+							+
Viburnum awabuki			(+)	+				+	+				+	+				+		+
Viburnum erosum				+				+	+				+	+	(+)					+
Viburnum sargentii				+				+	+				+		+					+
Viburnum sargentii for. *sterile*				+				+	+				+	+				+		+
Abelia grandiflora		+		+				+	+				+	+				+		+
Weigela florida				+				+					+					+		+
Weigela florida for. *subtricolor*				+				+					+					+		+
Weigela subsessilis				+			(+)	+					+					+		+
Lonicera maackii		+	(+)	+				+	+				+	+				+		+
Lonicera chrysantha			(+)	+				+	+				+	+				+		+
Lonicera tatarica			(+)	+				+	+				+	+				+		+

1. Annual ring somewhat clear or clear, 2. Sap and heartwood presents, 3. Ring porous, 4. Diffuse porous, 5. Radial porous, 6. Figured porous, 7. Simple perforation, 8. Scalariform perforation, 9. Spiral thickening, 10. Tyloses, 11. Crystals, 12. Terminal parenchyma, 13. Diffuse parenchyma, 14. Banded or metatracheal parenchyma, 15. Vasicentric parenchyma, 16. Aliform, 17. Confluent. 18. Pratracheal diffuse parenchyma, 19. Homogeneous ray, 20. Heterogeneous ray, ; ~ means transition. ; (+) Tendency

Table 3. Appearing Percentage of Wood Anatomical Features on Coniferous Tree Species Grown in Korea

Appearing Features	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Percentage (%)	41.9	19.4	9.7	41.9	16.1	38.7	16.1	45.2	61.3	12.9	16.1	9.7	19.4	29	38.7	32.3	22.6	38.7

1. Abrupt early-latedwood transition, 2. Radial pit two or more rows, 3. Spiral thickening, 4. Resin canal presents, 5. Epithelium thick wall, 6. Ray tracheid presents, 7. Ray tracheid dentates, 8. Ray parenchyma end wall nodular, 9. Indenture, 10. Crystal presents, 11. Windowlike, 12. pinoid, 13. Piceoid, 14. Taxodioid, 15. Cupressoid, 16. Longitudinal parenchyma present, 17. Longitudinal parenchyma end wall nodular. 18. Imported species.

Table 4. Appearing Percentage of Wood Anatomical Features on Broad-leaved Tree Species Grown in Korea

Appearing Features	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Percentage (%)	46.9	44.4	39.9	60.1	9.1	1.7	77.3	30.8	51.4	11.9	28.7	30.1	67.1	37.4	31.5	19.6	16.1	54.5	37.4	61.5

1. Annual ring somewhat clear or clear, 2. Sap and heartwood presents, 3. Ring porous, 4. Diffuse porous, 5. Radial porous, 6. Figured porous, 7. Simple perforation, 8. Scalariform perforation, 9. Spiral thickening, 10. Tyloses, 11. Crystal, 12. Terminal parenchyma, 13. Diffuse parenchyma, 14. Banded or metatracheal parenchyma, 15. Vasicentric parenchyma, 16. Aliform, 17. Confluent, 18. Pratracheal diffuse parenchyma, 19. Homogeneous ray, 20. Heterogeneous ray.

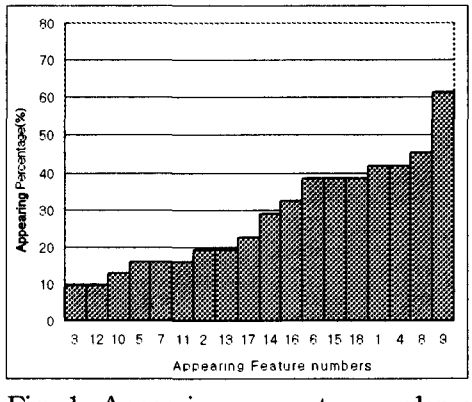

Fig. 1. Appearing percentage order of wood anatomical features on Korean coniferous tree species.

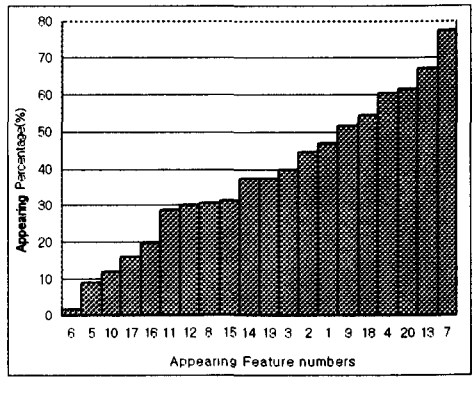

Fig. 2. Appearing percentage order of wood anatomical features on Korean broad-leaved tree species.

Selected Photographs of Korean Wood Structure

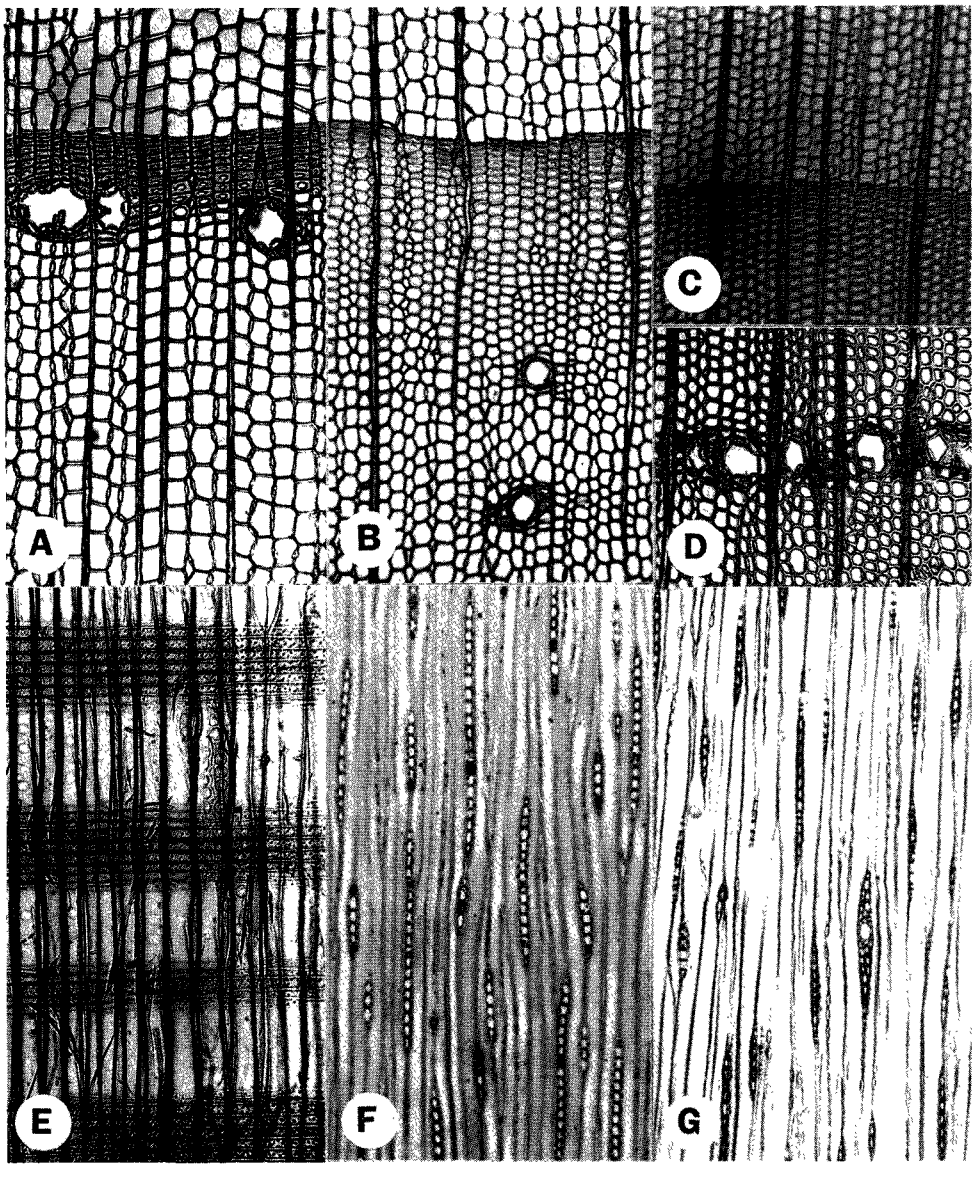

Photo. 1. A : *Larix gmelini var. principis-rupprechtii*, cross section (×100), B : *Larix leptolepis*, cross section (×50), C : *Cedrus deodara*, cross section (×100), D : *Cedrus deodara*, cross section, traumatic resin canal (×100), E : *Larix letolepis*, radial section (×100), F : *Cedrus deodara*, tangential section (×100), G : *Larix leptolepis*, tangential section (×100).

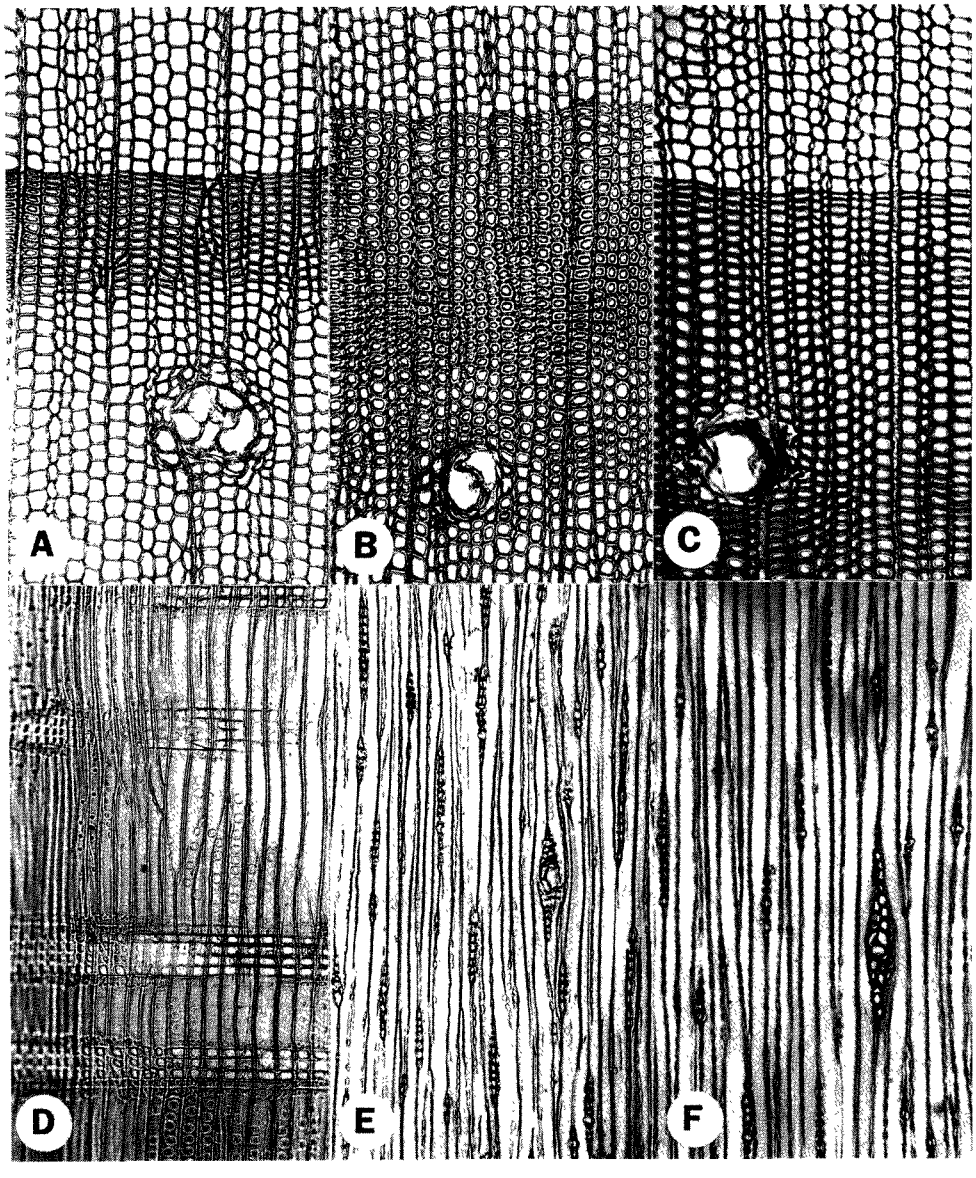

Photo. 2. A : *Pinus densiflora*, cross section (×100), B : *Pinus thunbergii*, cross setion (×100), C : *Pinus rigida*, cross section (×100), D : *Pinus thunbergii*, radial section (×100), E : *Pinus densiflora*, tangential section (×100), F : *Pinus thunbergii*, tangential section (×100).

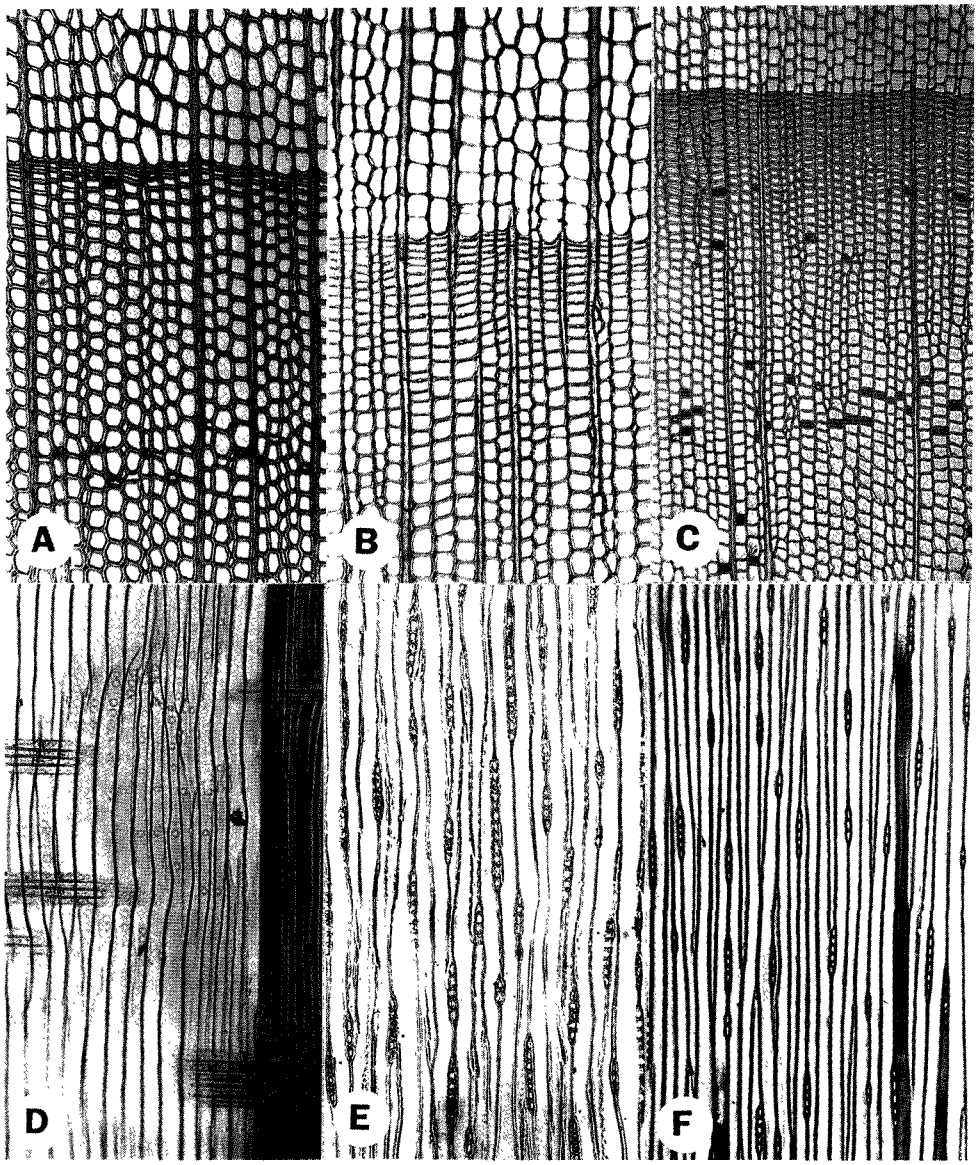

Photo. 3. A : *Taxodium distichum*, cross section (×100), B : *Metasequoia glyptostroboides*, cross section (×100), C : *Cryptomeria japonica*, cross section (×100), D : *Cryptomeria japonica*, radial section (×100), E : *Taxodium distichum*, tangential section (×100), F : *Cryptomeria japonica*, tangential section (×100).

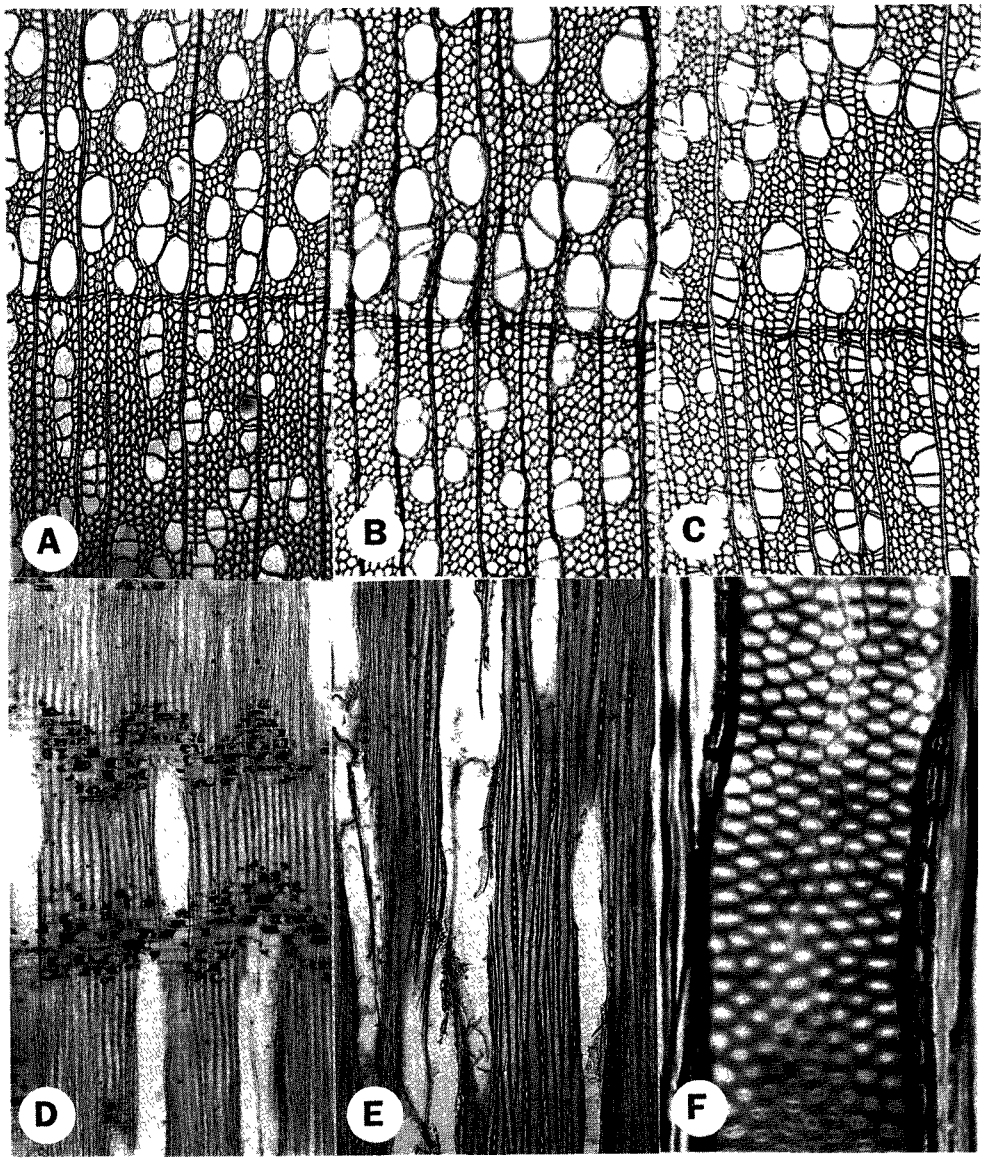

Photo. 4. A : *Populus davidiana,* cross section (×100), B : *Populus alba* x *glandulosa,* cross section (×100), C : *Populus maximowiczii,* cross section (×100), D : *Populus nigra* var. *italica,* radial section (×100), E : *Populus deltoides,* tangential section (×100), F : *Populus alba* x *glandulosa,* tangential section (×100).

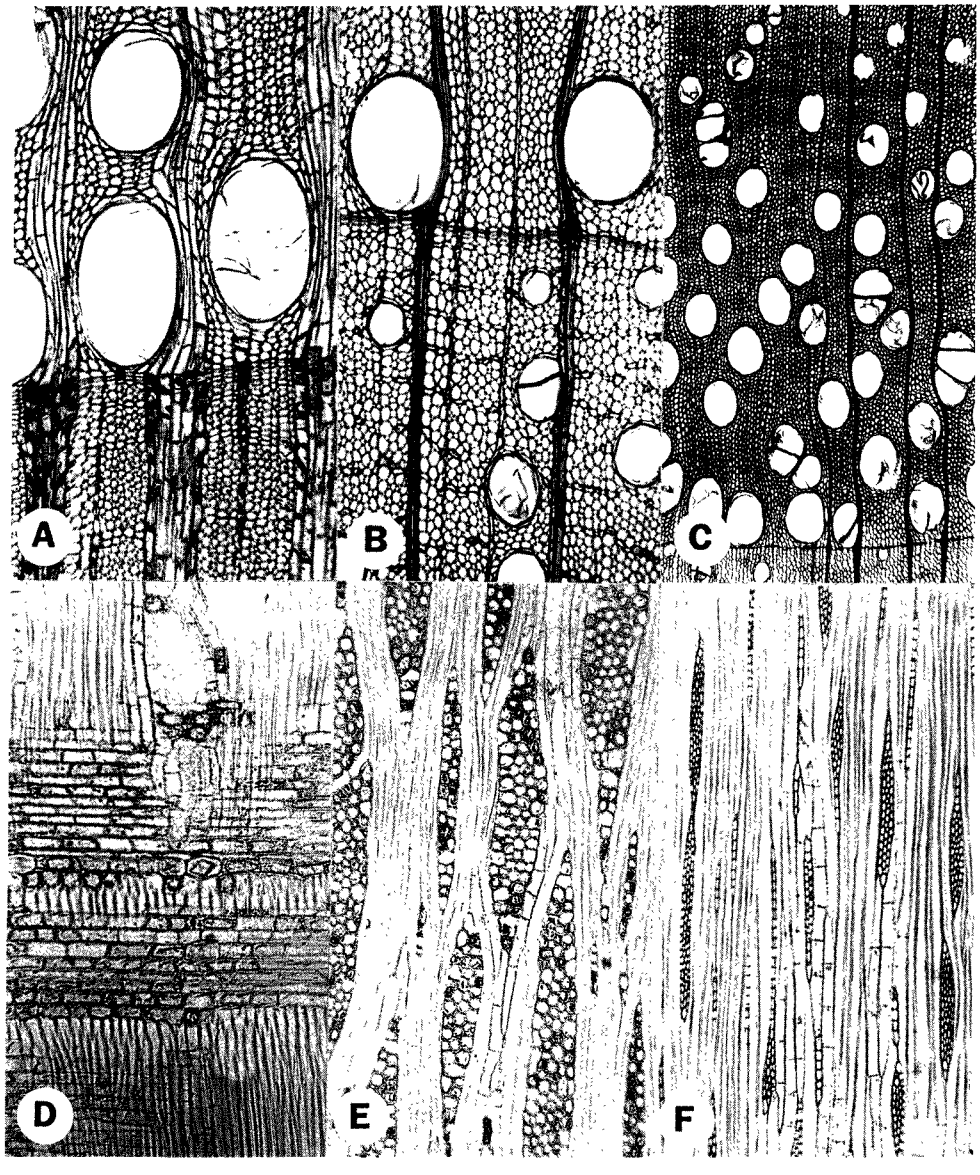

Photo. 5. A : *Platycarya strobilacea,* cross section (×100), B : *Juglans mandshurica,* cross section (×100), C : *Juglans sinensis,* cross section (×50), D : *Platycarya strobilacea,* radial section (×100), E : *Platycarya strobilacea,* tangential section (×100), F : *Juglans mandshurica,* tangential section (×100).

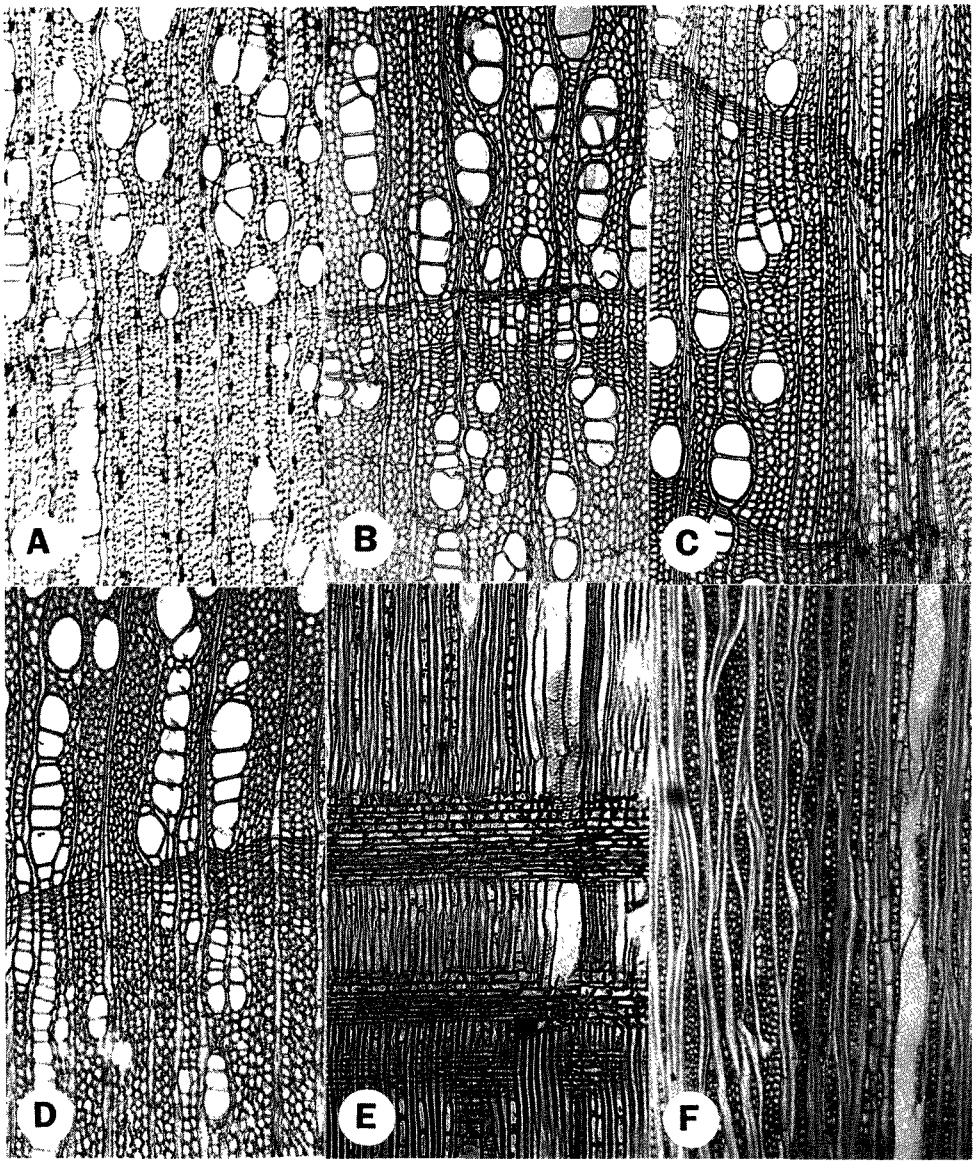

Photo. 6. A : *Carpinus erosa,* cross section (×100), B : *Carpinus tschonoskii,* cross section (×100), C : *Carpinus laxiflora,* cross section (×100), D : *Carpinus tschonoskii* var. *eximia,* cross section (×100), E : *Carpinus coreana,* tangential section (×100), F : *Carpinus laxiflora,* tangential section (×100).

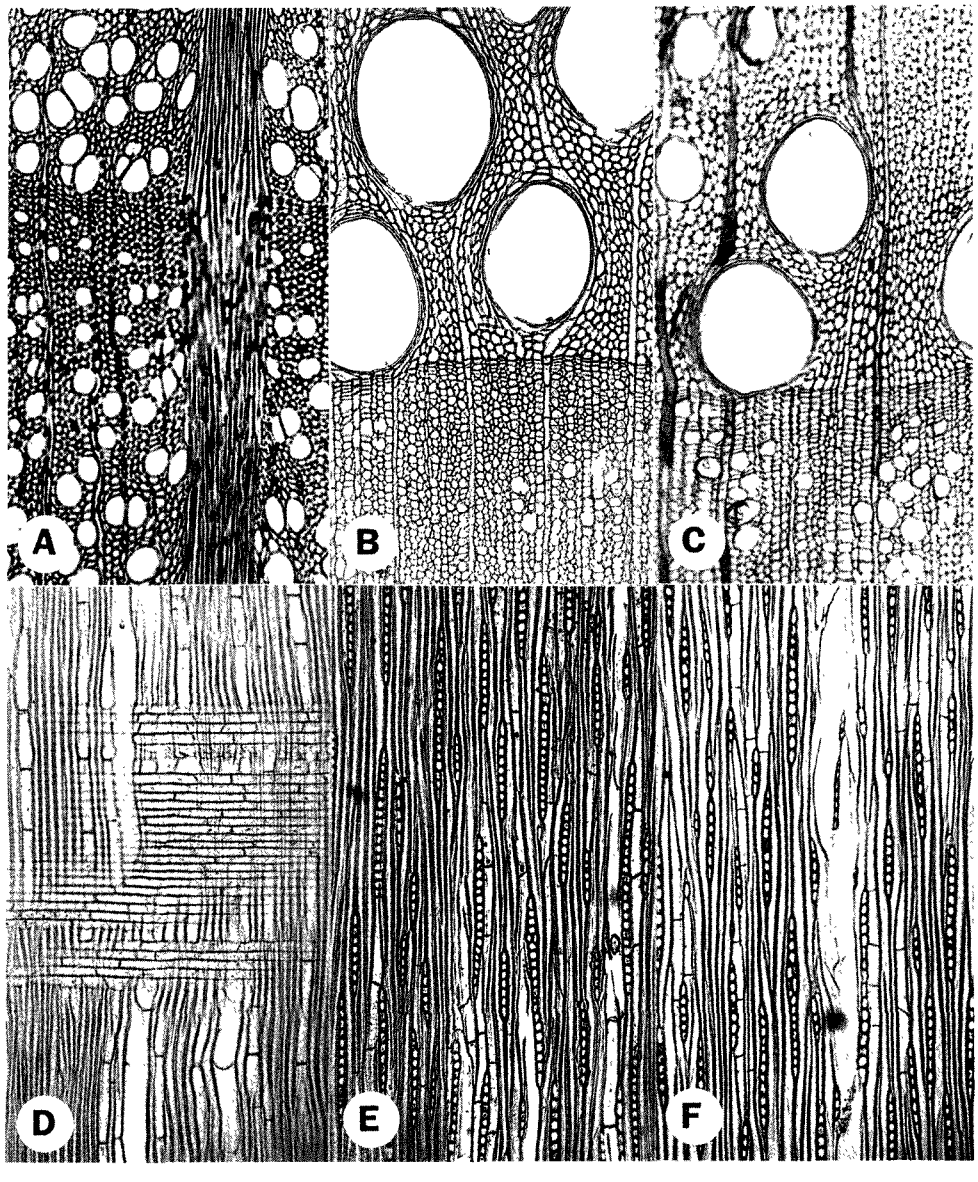

Photo. 7. A : *Fagus multinervis*, cross section (×100), B : *Castanea crenata*, cross section (×100), C : *Castanopsis cuspidata* var. *sieboldii*, cross section (×100), D : *Castanea crenata*, radial section (×100), E : *Castanea crenata*, tangential section (×100), F : *Castanopsis cuspidata* var. *sieboldii*, tangential section (×100).

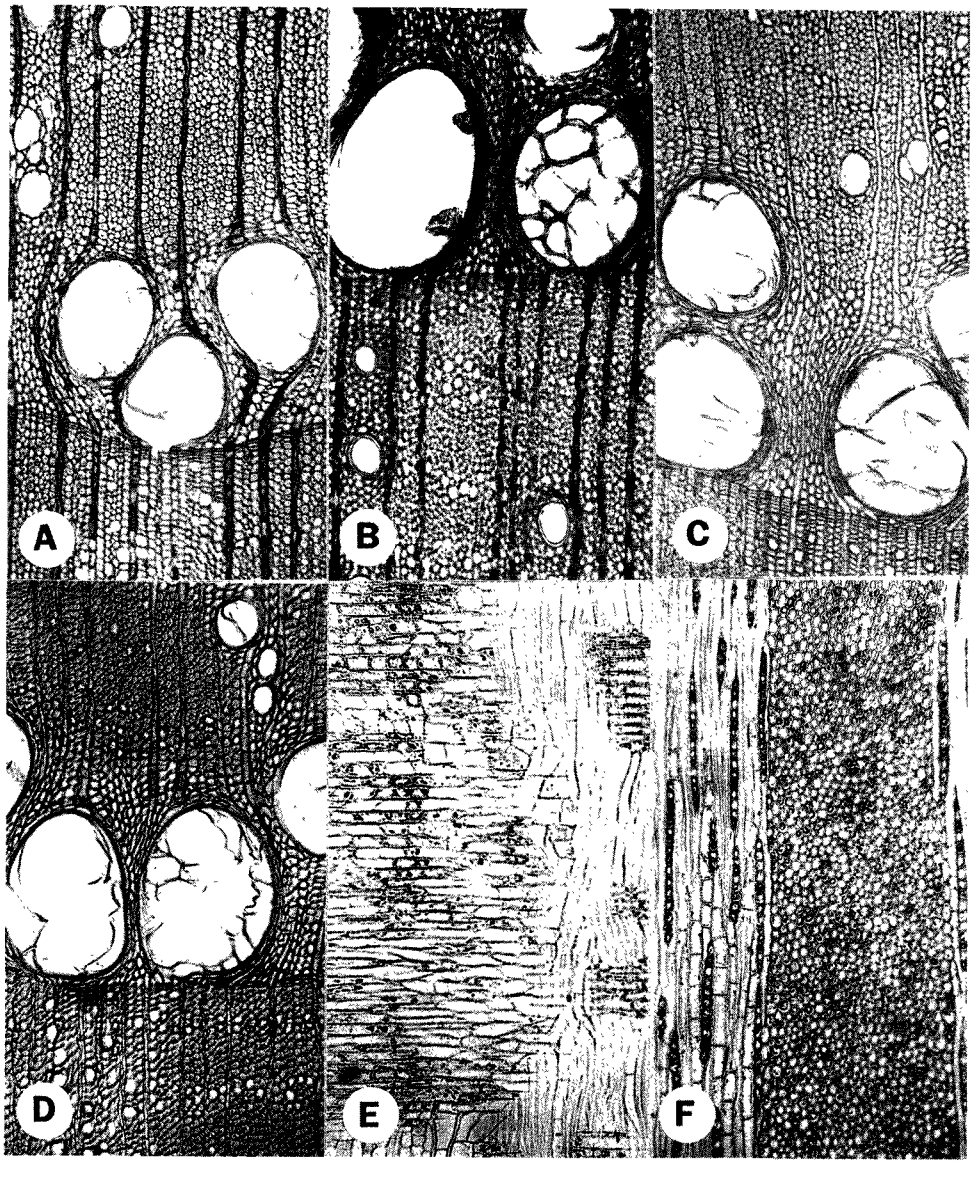

Photo. 8. A : *Quercus accutissima,* cross section (×100), B : *Quercus variabilis,* cross section (×100), C : *Quercus dentata,* cross section (×100), D : *Quercus mongolica,* cross section (×100), E : *Quercus serrata,* radial section (×100), F : *Quercus dentata,* tangential section (×100).

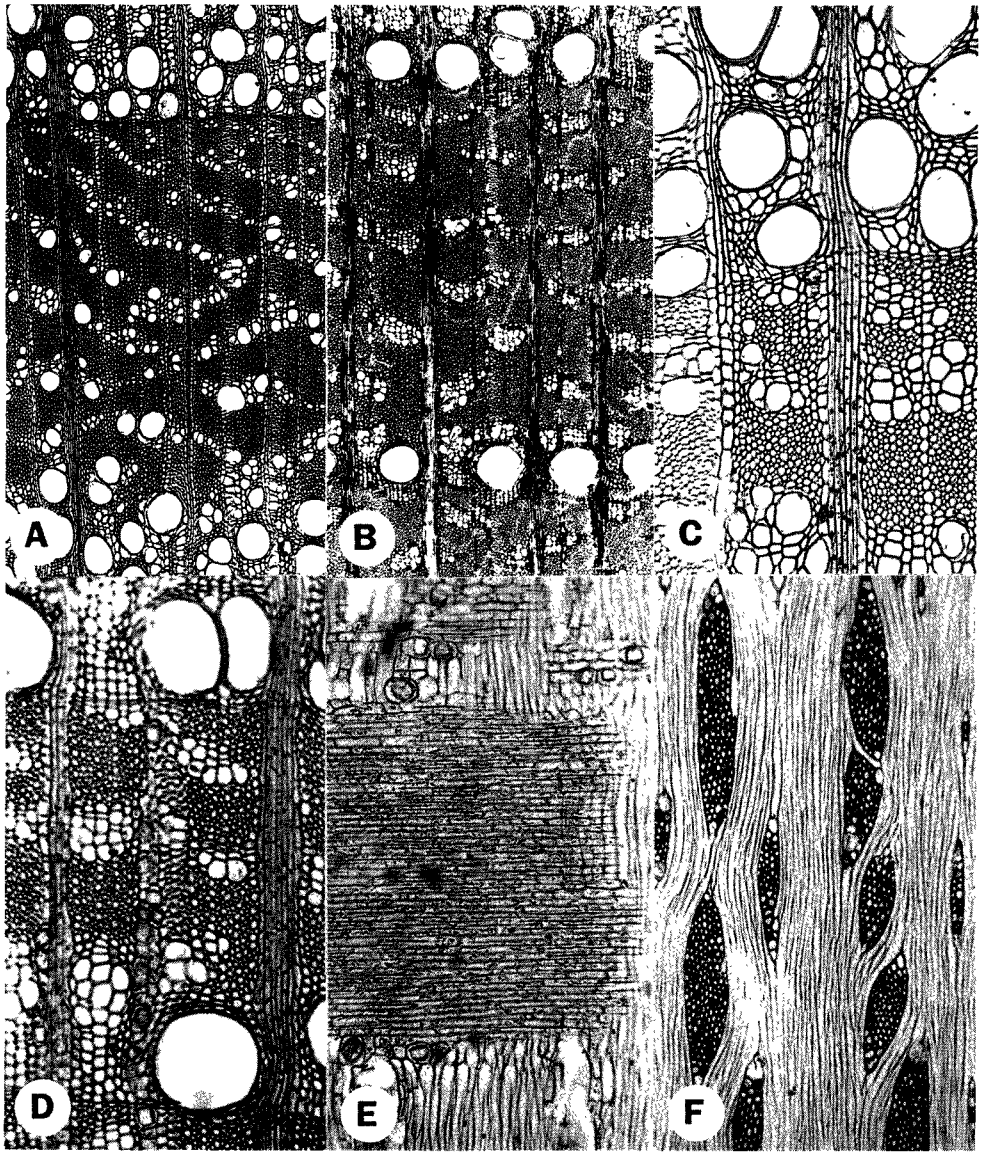

Photo. 9. A : *Hemiptelea davidii,* cross section (×50), B : *Zelkova serrata,* cross section (×50), C : *Hemiptelea davidii,* cross section (×100), D : *Zelkova serrata,* cross section (×100), E : *Zelkova serrata,* radial section (×100), F : *Zelkova serrata,* tangential section (×100).

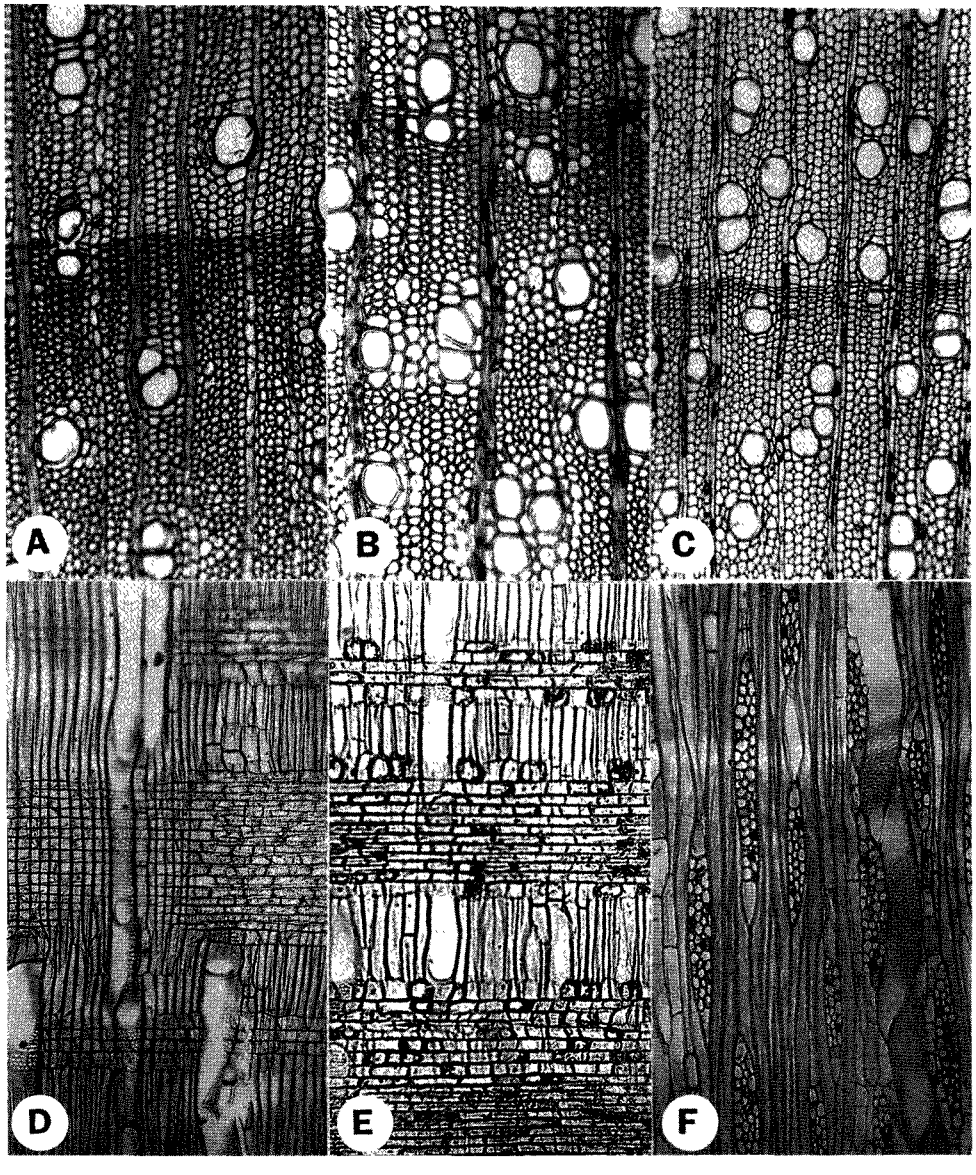

Photo. 10. A : *Machilus thunbergii,* cross section (×100), B : *Machilus thunbergii* var. *obovata,* cross section (×100), C : *Neolitsea sericea,* cross section (×100), D : *Machilus thunbergii,* radial section (×50), E : *Neolitsea sericea,* radial section (×100), F : *Machilus thunbergii* var. *obovata,* tangential section (×100).

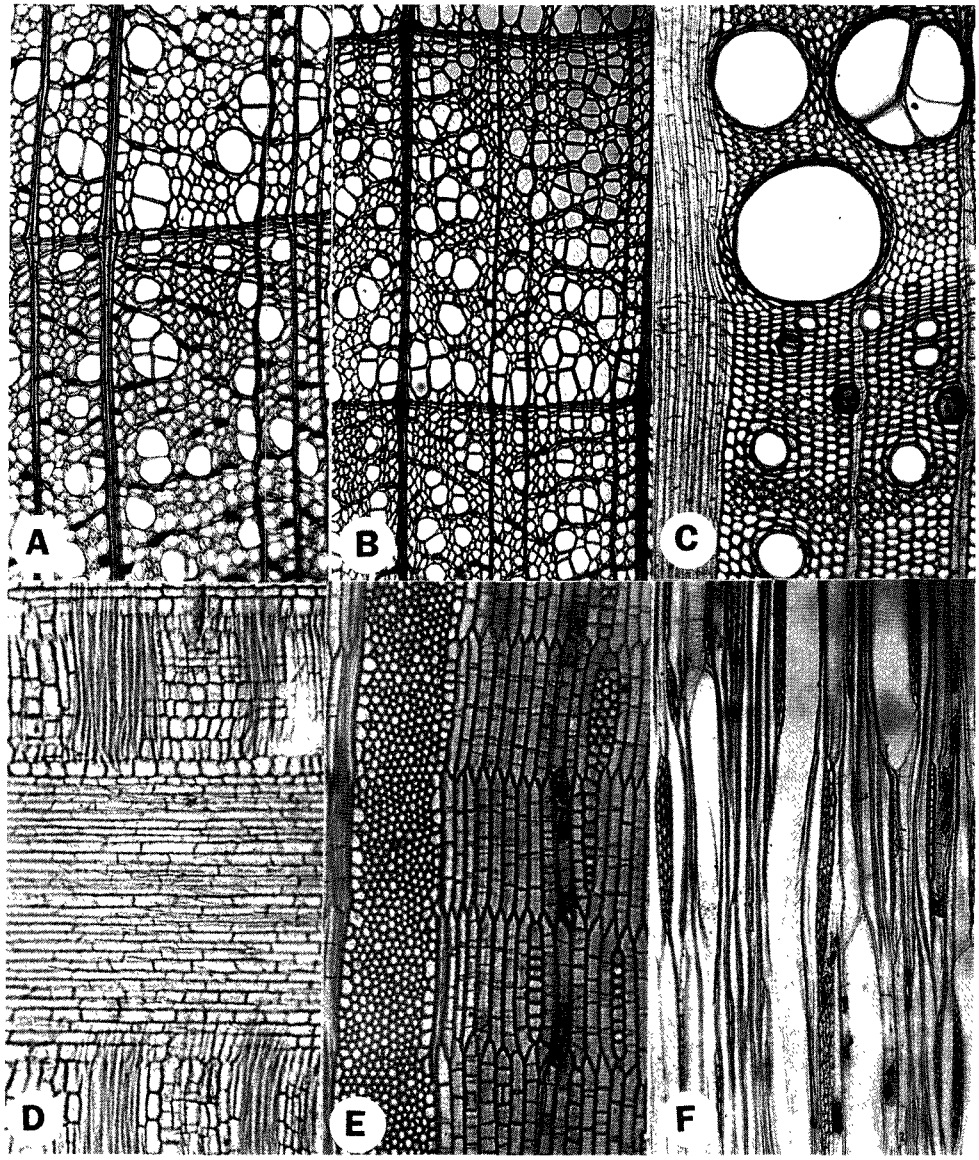

Photo. 11. A : *Tilia amurensis,* cross section (×100), B : *Tilia megaphylla,* cross section (×100), C : *Firmiana simplex,* cross section (×100), D : *Firmiana simplex,* radial section (×100), E : *Firmiana simplex,* tangential section (×100), F : *Tilia amurensis,* tangential section (×100).

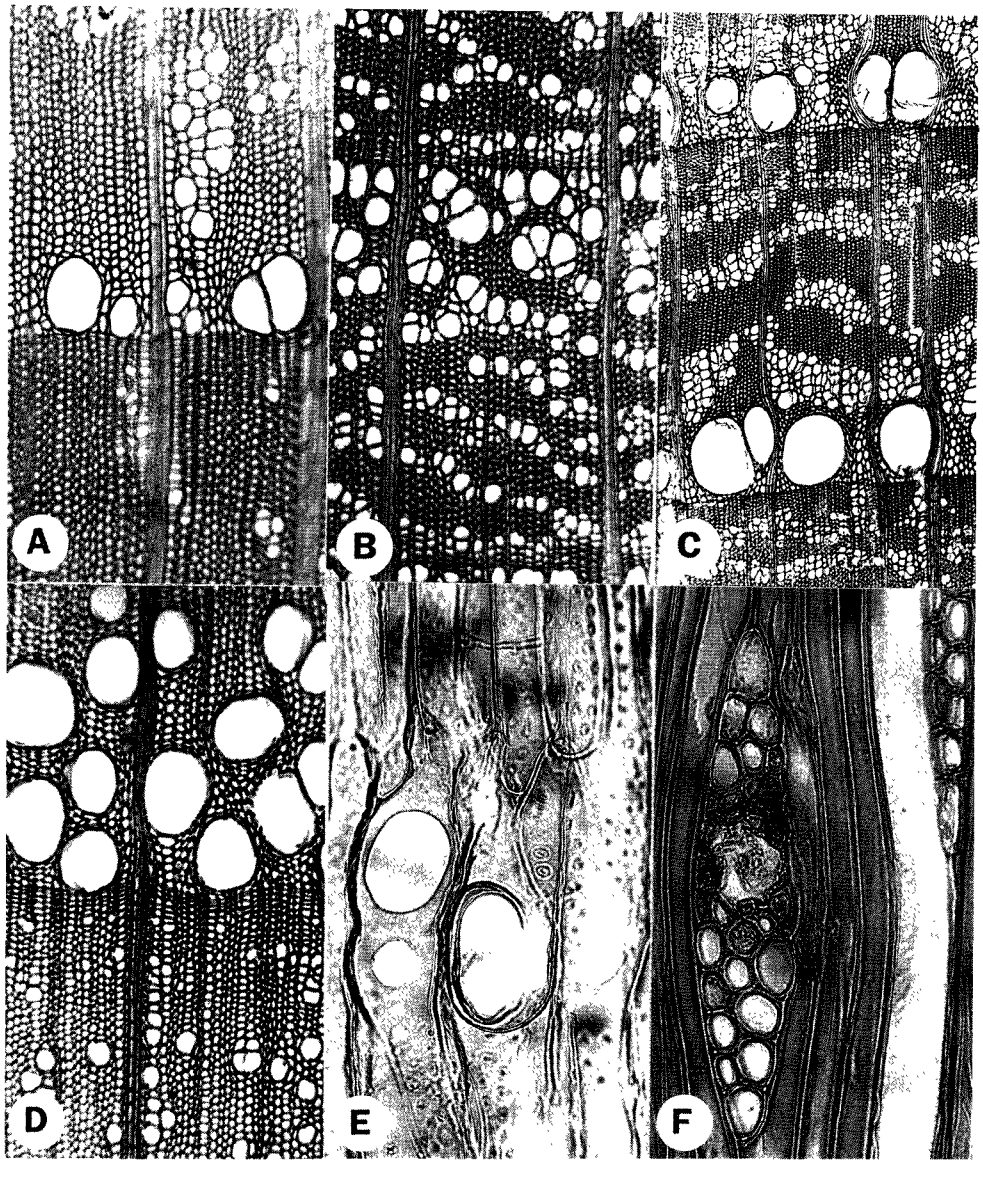

Photo. 12. A : *Dendropanax morbifera,* cross section (×100), B : *Acanthopanax senticosus,* cross section (×100), C : *Kalopanax septemlobus,* cross section (×50), D : *Aralia elata*, cross section (×100), E : *Kalopanax septemlobus*, radial section simple perforation (×400), F : *Dendropanax morbifera*, tangential section horizontal resin canal (×400).

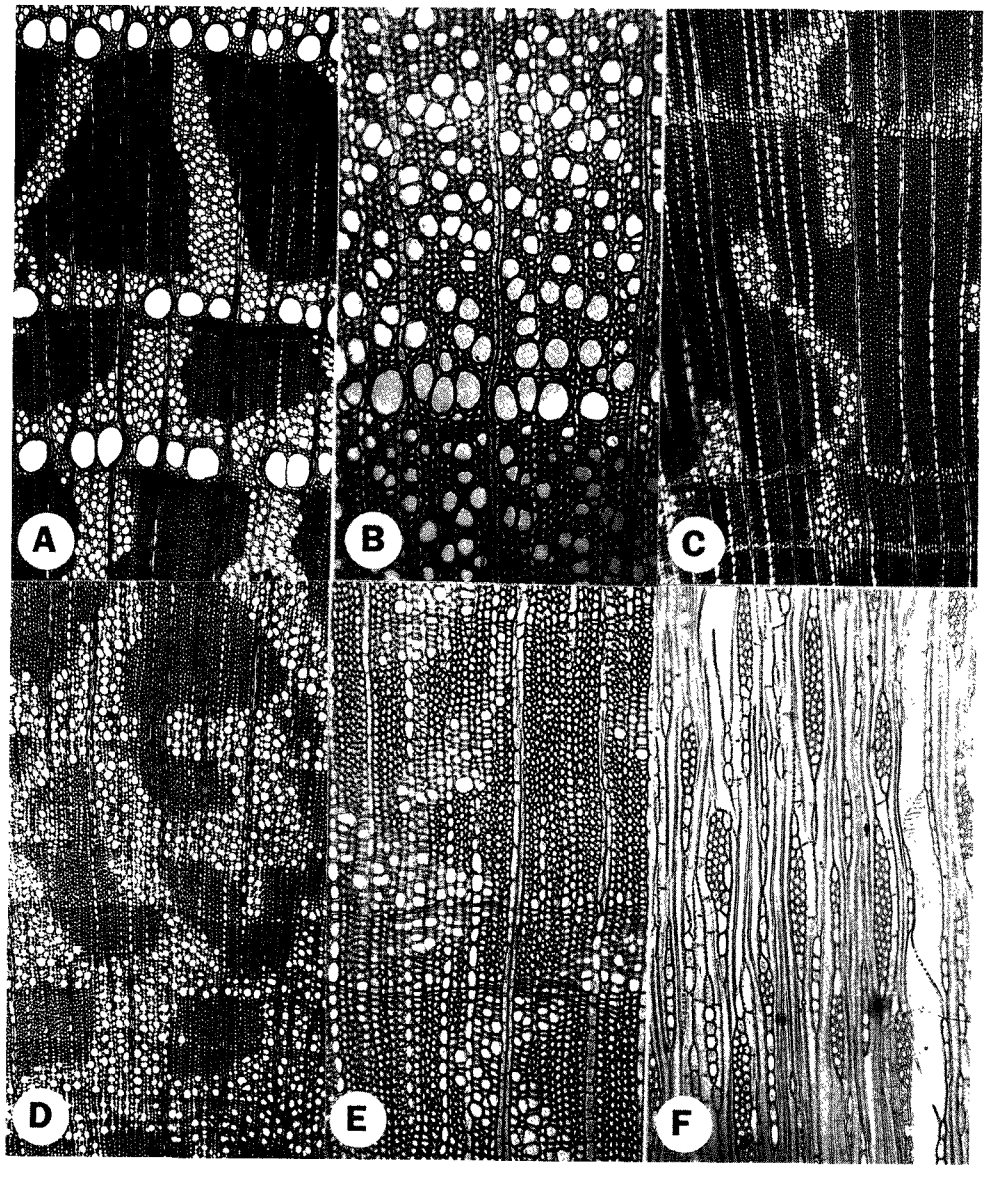

Photo. 13. A : *Chionanthus retusus*, cross section (×50), B : *Ligustrum japonicum*, cross section (×100), C : *Osmanthus latifolius*, cross section (×50), D : *Osmanthus fragrans*, cross section (×50), E : *Osmanthus heterophylla*, cross section (×50), F : *Ligustrum obtusifolium*, tangential section (×100).

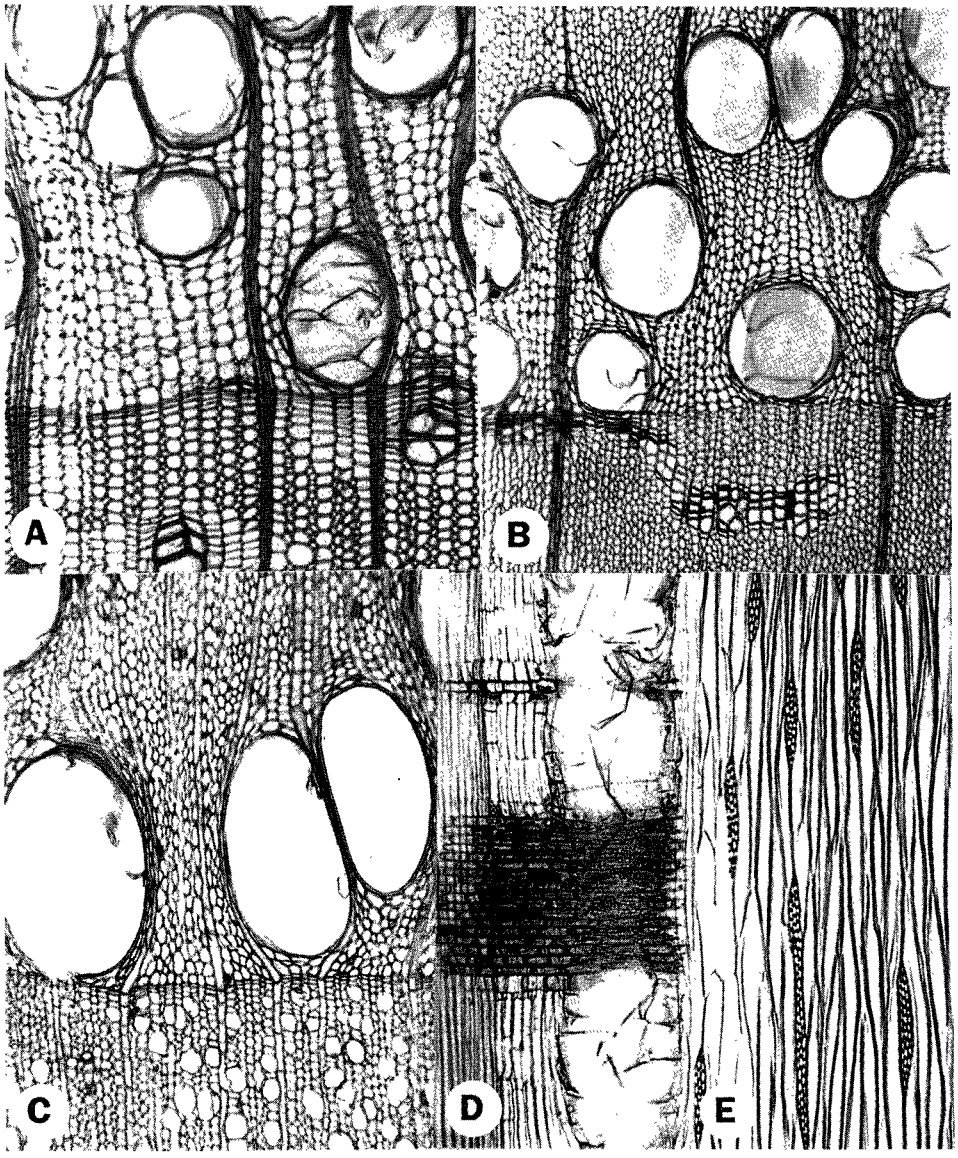

Photo. 14. A : *Paulownia coreana,* cross section (×50), B : *Catalap ovata,* cross section (×100), C : *Catalap bignonioides,* cross section (×100), D : *Catalap ovata,* radial section (×100), E : *Paulownia coreana,* tangential section (×100).

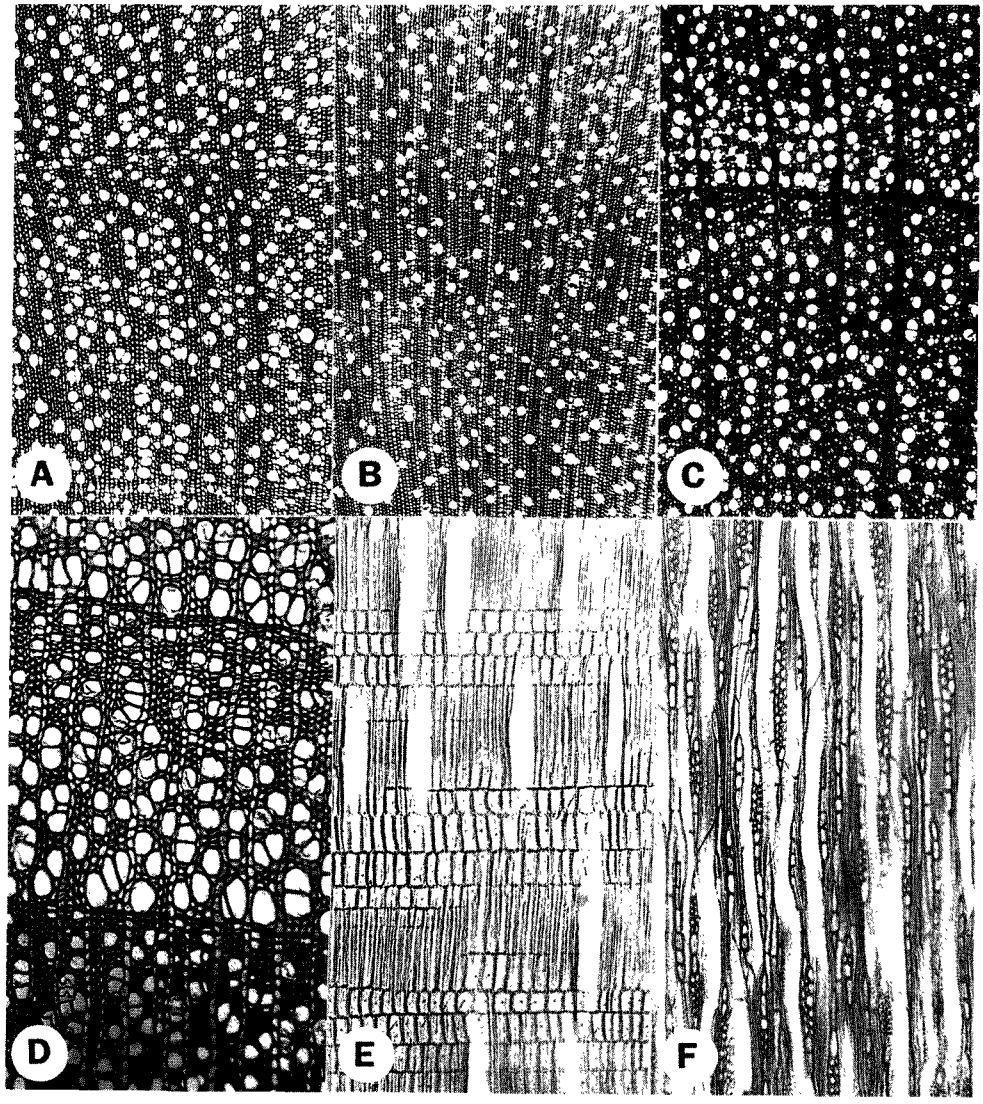

Photo. 15. A : *Weigela florida* for. *subtricolor*, cross section (×50), B : *Weigela florida*, cross section (×50), C : *Lonicera chrysantha*, cross section (×50), D : *Lonicera tatarica*, cross section (×100), E : *Weigela florida*, radial section (×100), F : *Lonicera tatarica*, tangential section (×100).