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XYLOTOMIC INVESTIGATIONS OF CONIFEROUS WOODS FROM PAKISTAN

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Abstract

Anatomical features of wood of 15 coniferous species viz., *Abies pindrow* Royle., *Cedrus deodara* (Rox. ex Lamb.) G. Don., *Cupressus arizonica* Greene., *C. funebris* Endl., *C. sempervirens* L., *C. torulosa* D. Don., *Juniperus polycarpos* C. Koch., *Araucaria cookii* R.Br., *Pinus gerardiana* Wall ex Lamb., *P. halepensis* Mill., *P. roxburghii* Sargent., *Picea smithiana* (Wall) Boiss; *P. wallichiana* A.B. Jackson; *Taxus baccata* Zucc., and *Thuja orientalis* L., have been described. Wood characteristics such as variation in growth rings, thickness of early wood and late wood tracheids, presence or absence of parenchyma and its distribution, characteristics of rays and nature and distribution of resin canals in the wood have been presented.

Introduction

Wood is mans oldest source of useful chemicals, his first source of energy and his earliest structural and building material. In the modern civilization wood is useful to man in providing good quality timber and as a source of a wide variety of goods such as resins, gums and as raw material for pulp and paper industry. Coniferous wood commonly known as softwood is regarded as ideal raw material for pulp and paper manufacture because of its high content of alpha cellulose and low lignin content (Mahmood, 1985).

Wood identification is one of the major applications of wood anatomical research because every difference in physical, chemical or mechanical properties of wood finds its origin in anatomical features at microscopic or submicroscopic level (Bass *et al.*, 1976). Data on the anatomical characteristics of coniferous wood has been summarized by Pearson & Brown (1932), Greggus (1955), Zimmermann (1964), Cote. jr (1965), Desh & Dinwoodie (1981), Keating & Bolza (1982) and Ilvessalo-Pfaffli (1995). A comprehensive account of compression wood in gymnosperms is provided by Timell (1986). Conifers comprising of 10 genera and 20 species are the chief forest makers and are the main source of commercial timber in Pakistan (Nasir *et al.*, 1969). No comprehensive work seems to have been done on the Xylotomy of these species. In the present paper distribution, general characteristics of wood and xylotomy of 15 coniferous species viz., *Abies pindrow* Royle, *Araucaria cookii* R.Br. *Cedrus deodara* (Roxb. ex Lamb) G. Don., *Cupressus arizonica* Greene, *C. funebris* Endl., *C. sempervirens* L., *C. torulosa* D. Don., *Juniperus polycarpos C.* Koch, *Picea smithiana* (Wall) Boiss, *Pinus gerardiana* Wall. ex Lamb., *P. halepensis* Miller., *P. roxburghii* Sargent, *P. wallichiana* A.B. Jackson, *Taxus baccata* Zucc., and *Thuja orientalis* L., is described.

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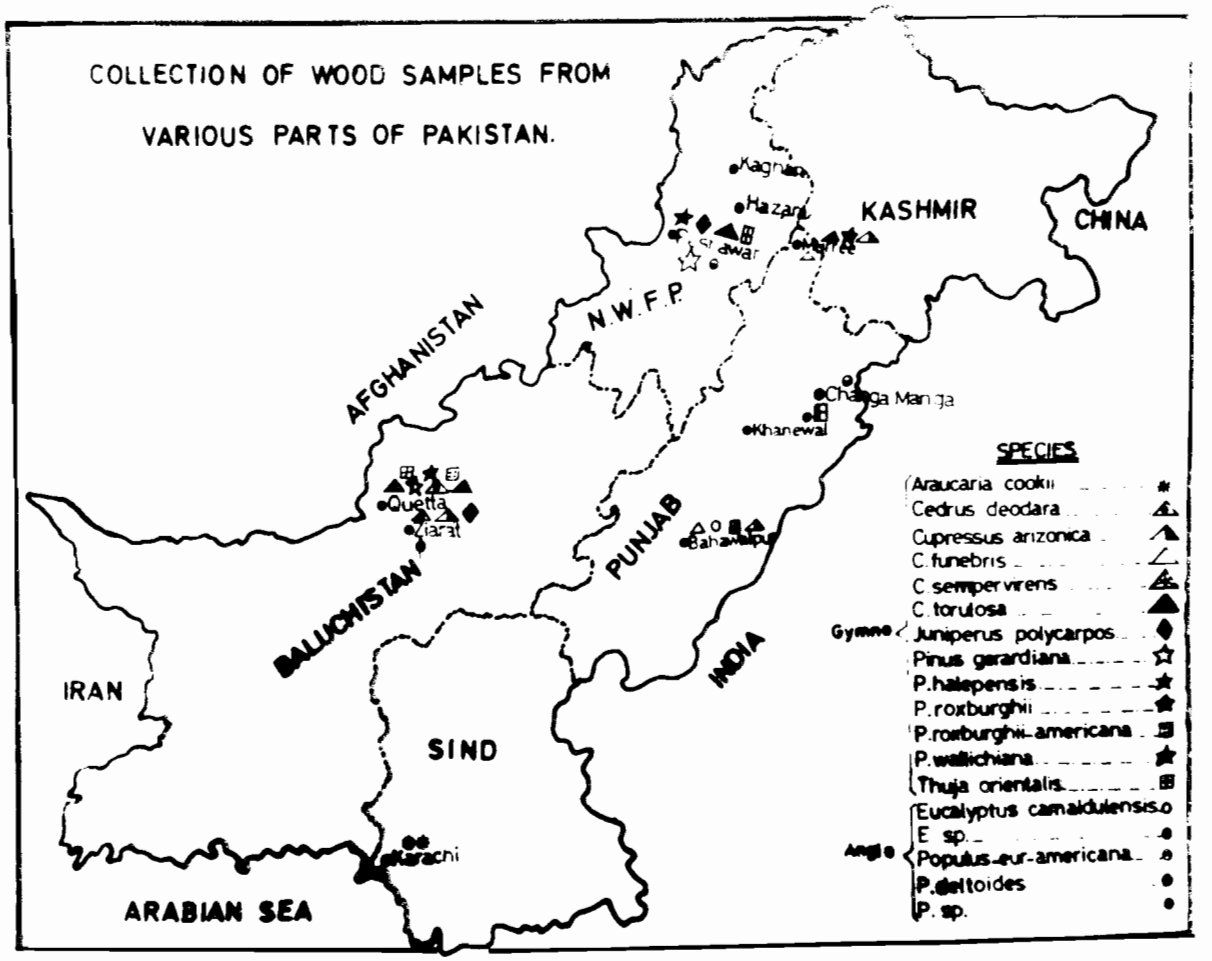


Fig.1. Map of Pakisan showing collection spots of various species.

Materials and Methods

Wood samples from living trees at breast height, were collected from different parts of Pakistan (Fig.1) following the method of Newman (1956). Selected material with sides truly transverse, tangential and radial was converted into cubes of about 2.5 cm. The cubes of dry wood were boiled in 2% KOH before sectioning (Greguss, 1955; Giebel & Dickson, 1976). Transverse, radial and tangential sections were cut on a sliding microtome at 15-30 um and stained with Safranin, Safranin-fast green following Johansen (1940), Greguss (1955) and Gurr (1965). Description of wood characteristics is based on microscopic examination of histological preparations. Terminology and nomenclature used in describing the components of wood and individual cells follow the International Association of Wood Anatomists (IAWA) (1947). Terms used in size classification follow those recommended by Chattaway (1932) and Committee on standardization of terms of cell size, International Association of wood anatomists Anon., (1939).

Results

Details of general features and anatomical characteristics of conierous species are described below:

Abies pindrow Royle

(Fig.2, A,B,C)

Trade or local Name: Fir, Himalayan silver fir, Palundar, Pertel.

Habit and Distribution: An evergreen tall tree, with a narrow cylindrical crown and long straight stem; branches whorled, bark light grey to brown on older plants, silvery on young plants, always fissured; large trees of great size varying from 30-60 m in height and 3.5 m in girth. Common in Himalayas at an elevation of 200-300 m, also found in northern hilly regions of Pakistan on moist rich soils making mix forest with blue pine, spruce, deodar and oaks; pure stands of very rare occurrence.

General characteristics of the wood: White when first exposed, changing its colour to light brown with the passage of time; no difference between sap and heart wood; dark, with somewhat broader striations present along the grain, which become more pronounced with the passage of time; wood lustrous when first exposed, turning dull with the time, working well and smooth with hand and on machine; having no characteristic odour or taste, very light, straight and evengrained with medium fine texture.

Structure of the wood

Growth rings: Distinct, marked by somewhat darker bands of late wood; transition from early wood to late wood gradual.

Tracheids: Medium sized, arranged in definite radial rows without tertiary spirals, 2.0-4.8 mm in length, tangential diameter 42-56 um; early wood tracheids vary in cross section from somewhat squarish to rectangular or somewhat hexagonal, tangential wall thickness 3-5 um; late wood tracheids mostly rectangular with wall thickness 5-7 um; bordered pits on the radial walls arranged in one row, occasionally in biseriate rows; tangential wall pitting present, smaller and scanty than those on the radial walls, occurring in few rows of late wood tracheids, in the early wood 1-2 pits in cross field,

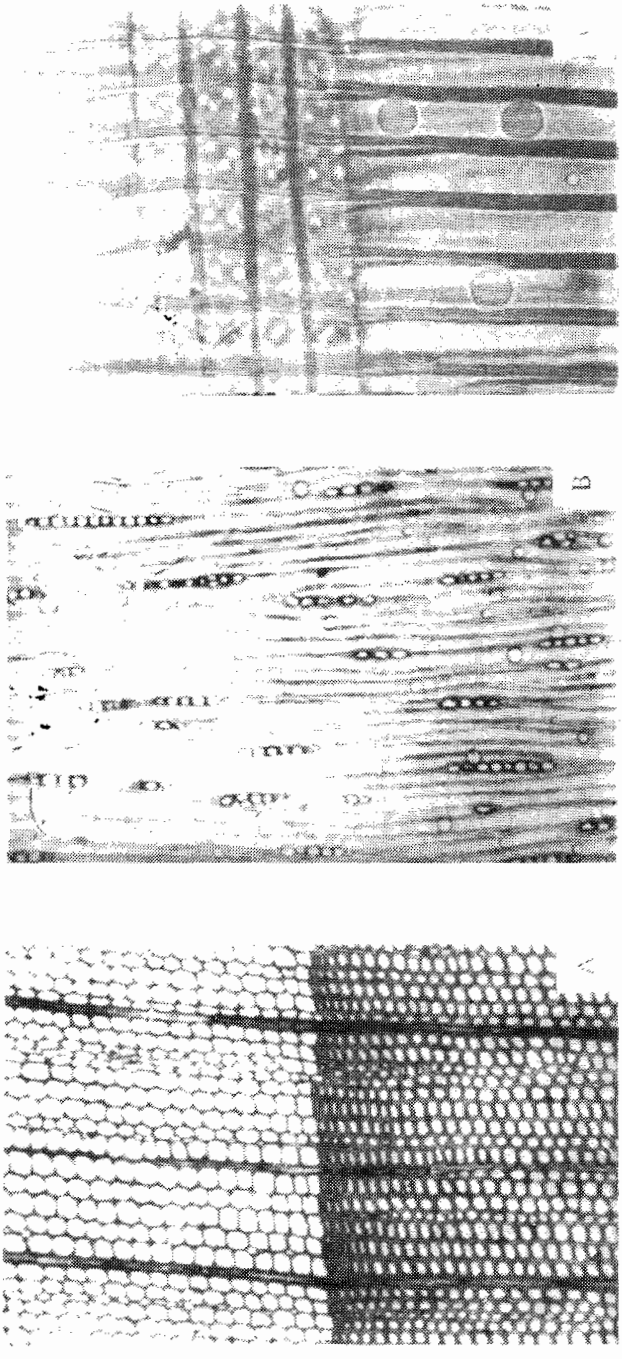


Fig 2.Structure of the wood of *Abies pindrow*. A) T.S. (200x), B) T.L.S. (200x). C) R.L.S. (800x).

3-4 um in diameter or even slightly larger in the marginal cells usually 2 or sometimes more occurring one above the other.

Parenchyma: Very scanty, occasionally found in the extreme border of late wood, cells either rectangular of tabular with maximum diameter of 35-45 um, pits present in tangential walls, pit-diameter 4.7 um.

Rays: Fine, hardly visible with naked eyes, unevenly distributed; uniseriate, 1-17 cells high, 14-18 um in width and 350 um in height; ray tracheids absent, tangential walls of ray parenchyma with sieve like pitting, the pits leading laterally to the longitudinal late wood tracheids, ray crossing pits from 2-5 per ray, orbicular or somewhat so, with rounded aperture.

Araucaria cookii **R.Br.**

(Fig.3, A,B,C)

Habit and Distribution: An ever green ornamental plant commonly planted throughout Pakistan as an ornamental tree commonly with branched stem; bark dark brown, rough and thin.

General Characteristics of the Wood: Longitudinal resin canals in the form of dark lines, wood lustrous when first exposed, turn to dull with age; having resinous smell and faint resinous taste.

Structure of Wood

Growth rings: Indistinct, early and late wood also not well differentiated, tangential diameter of late wood tracheids 14-15-18.5 um; pits uniseriate, diameter of pit border 5-8.5 um; shape of pit aperture elliptical, 3-4.5 um long and 1.75-2.5 um wide height of rays 36.3 - 60.5 um and width 9.6-12.1 um; ray cells showed yellowish to brown coloured deposits. Thin septa like resin plugs as shown by Bamber (1979) in *Araucaria klinkii* wood were not seen in *Araucaria cookii*. The shape of pit apertures resembled with *Araucaria* roughly and the structure of rays with *Araucaria humboltlensis* (Greguss, 1955).

Cedrus deodara (Roxb. ex lamb.) D. Don.

(Syn. *C. libani* Var. *deodara* Hook; *Pinus deodara* Roxb.)

(Fig.4, A,B,C)

Trade or Local Name: Deodar, Diar

Habit and Distribution: A very large and tall tree, attaining a great size and reaching to a great age; branches spreading and horizontal, with greyish bark, ends of branches drooping, the tree may attain a great height of upto 60-80 m, but normally 30-50 m in height with average from 2.5-4.0 m. Fairly common at places from 1500-3000 m in Swat, Chitral, Kaghan, Kurram and Azad Kashmir found associated with blue pines and firs but not so common in the Murree Hills. Deodar is the most important tree in Western Himalayas.

General Characteristics of the Wood: Sapwood white; heartwood light yellowish brown which turns completely brown in colour with age; striations inconspicuous and somewhat darker in colouration; dull with characteristic smell and taste; light; straight and even grained with medium fine texture.

Structure of the Wood

Growth rings: Distinct with denser and darker bands of late wood; transition from early to late wood gradual.

Tracheids: Medium fine, arranged in definite radial rows, 1.7-4.4 mm in length, 42-56

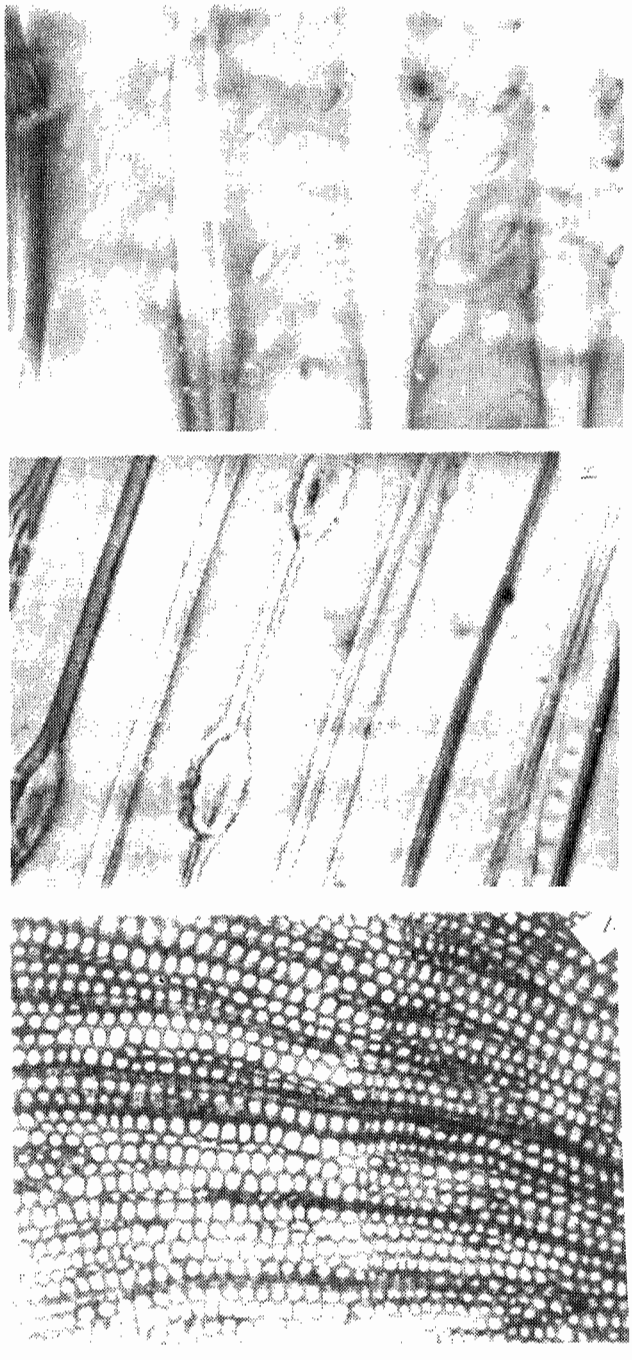


Fig.3.Structure of the wood of *Araucaria cookii*. A) T.S. (200x), B) T.L.S. (800x), C) R.L.S. (2000x).

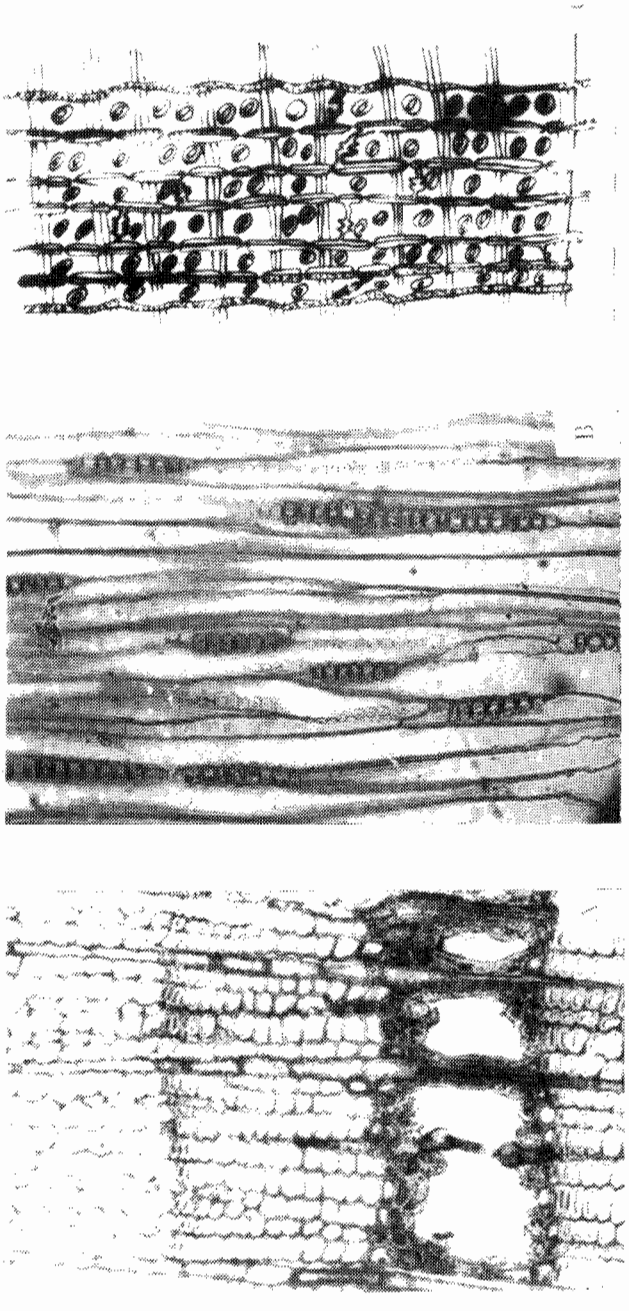


Fig.4.Structure of the wood of *Cedrus deodara*. A) T.S. (200x), B) T.L.C. (800x), C) R.L.S. (400x).

um in diameter, tertiary spiral thickening absent; early wood tracheids vary in cross section from squarish to rectangular or even hexagonal in shape with wall 3-5 um in thickness; late wood tracheids rectangular or hexagonal in early late wood, changing to tabular and gradually becoming comparatively thicker 5-10 um at the outer margin of the ring; bordered pits on radial walls mostly in one row, occasionally biseriate; pits on the tangential walls smaller than those on the radial walls and arranged in one row.

Parenchyma: Occasional, restricted to outer margin of the growth ring; cells 30-35 um in diameter rectangular to tabular oriented tangentially and inserted in the radial rows of tracheids.

Rays: Fine, not distinct with the naked eye, unevenly, distributed, mostly uniseriate, sometimes biseriate, 14-28 um in width, 700 um in height and 3-40 cells high; ray tracheids relatively low, smooth walled, occurring in horizontal rows on the margin of the ray, with small, bordered pits which lead laterally to the longitudinal tracheids; tangential walls of ray parenchyma with bead like or dentate thickenings, strongly pitted, number of pits on the ray crossing from 2-4 per ray, orbicular to oval.

Resin Canals: Normal resin canals absent; both longitudinal and transverse traumatic canals are present; (i) traumatic longitudinal canals are not of frequent occurrence, schizogenous, usually arranged in tangential bands, giving the appearance of brown lines when seen in cross-section, epithelial cells in 1-2 rows forming a sheath around the canals, orifices of the canal rounded or so; (ii) traumatic transverse canals of very much lesser occurrence than those of the longitudinal traumatic canals, present in the rays, solitary, orifice of the canal oval to lenticular, epithelium from 1-2 cells forming a sheath around the canal.

Cupressus arizonica Greene

(Fig.5, A,B,C)

Trade or Local Name: Cypress

Habit and Distribution: General characteristics are similar to that of *C. funebris*. An ever green medium sized tree, with horizontal branches and slender drooping branchlets. Cultivated in gardens as an ornamental plant in plains and in northern areas of Pakistan.

General characteristics of the wood: Sapwood creamy-white to yellowish-white, heartwood yellowish brown with somewhat darker striations, lustrous when first cut, changes colour with age, smooth to touch with cedary smell and faint cedary taste, light, straight and even grained, with medium fine texture.

Structure of the wood:

Growth rings: Not much distinct, late wood prominent, transition from early wood to late wood abrupt.

Tracheids: Medium fine, arranged in definite radial rows, without tertiary thickening, 1-4 um in length and 25-35 um in diam., early wood tracheids not much defined, tangential wall thickness from 2-3 um, usually rectangular or sometime squarish in shape, intercellular spaces absent in the early wood; late wood tracheids 4-6 rows in radial direction forming narrow band of late wood, tangential wall thickness from 2-4 um, bordered pits in one row on the radial walls of the tracheids from 10-12 um in diameter, tangential wall bordered pits usually present in the late wood tracheids.

Parenchyma: Present, distributed irregularly throughout the ring, horizontal walls with

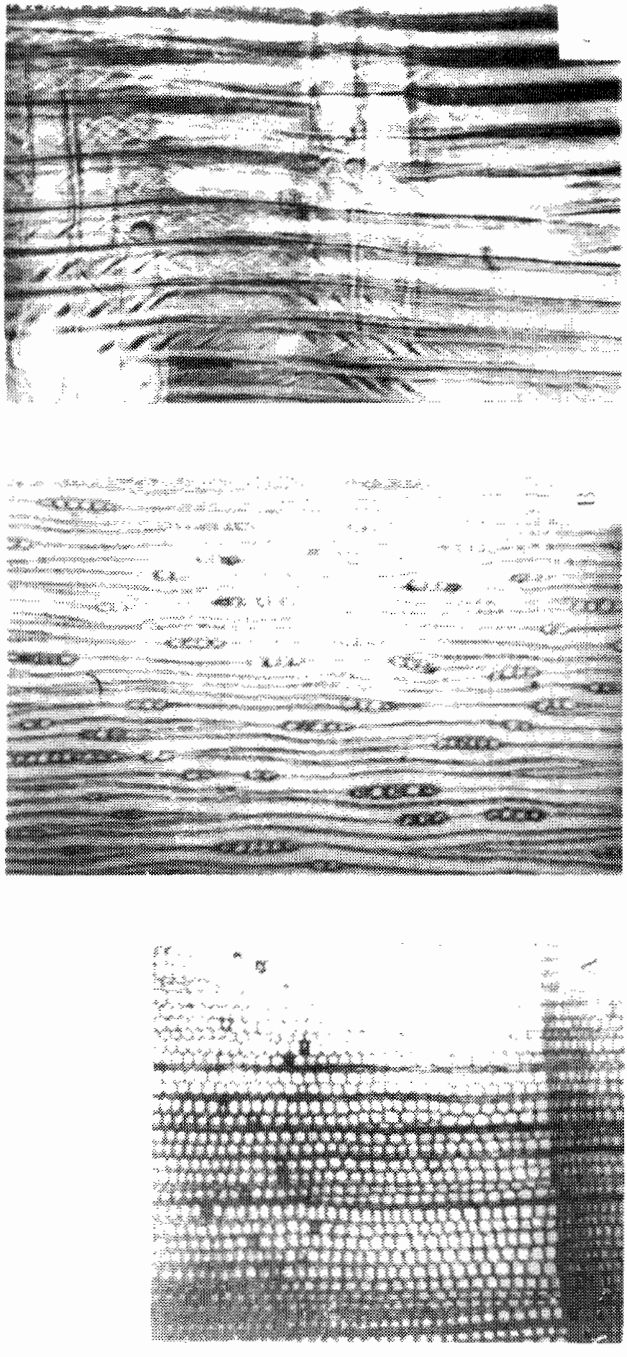


Fig.5. Structure of the wood of *Cupressus arizonica*. A) T.S. (200x), B) T.L.S. (200x), C) R.L.S. (800x).

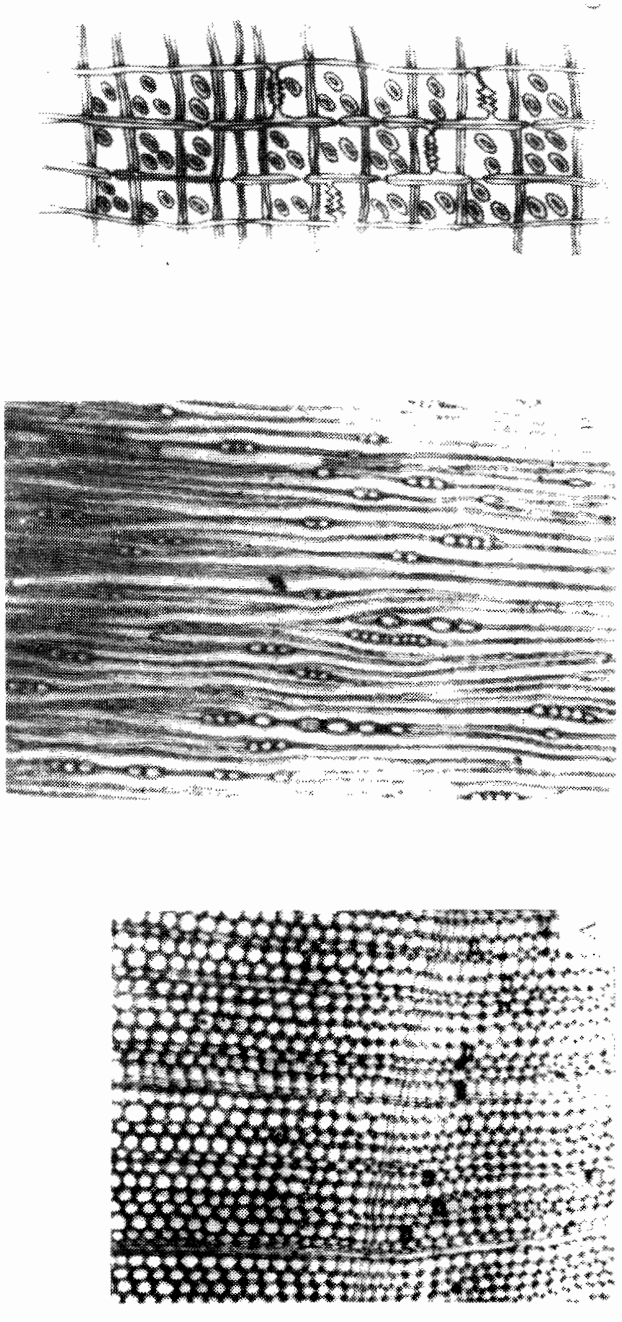


Fig.6. Structure of the wood of *Cupressus funebris*. A) T.S. (200x). B) T.L.S. (200x). C) R.L.S. (800x).

bead like thickening or smooth.
Rays: Fine to very fine, unevenly distributed, uniseriate, 2-9 cells high, sometimes even more, height of ray cells 200 um, ray width from 14-20 um, horizontal walls of ray parenchyma pitted, tangential wall thickness bead like, in the cross field 1-2 pits, 5-7 um in diameter.
Resin canal absent,

Cupressus funebris Endl.

(Fig.6, A,B,C)

Trade or Local Name: Weeping Cypress
Habit and Distribution: An evergreen medium sized tree with horizontal branches and slender and dropping branchlets having greyish brown bark. Weeping cypress, a native of central China, is not very common but is planted in gardens and grave yards and found in a few places generally in the plains of Pakistan.
General characteristics of the wood: Sapwood creamy white to yellowish white, heartwood yellowish brown to light brown, with somewhat darker striations, lustrous when first cut, changes colour with passage of time, smooth to touch, with cedary smell and faint cedary taste, light, straight and even grained, with medium fine texture.
Structure of the wood:
Growth rings: Not much distinct, late wood prominent, transition from early wood to late wood abrupt.
Tracheids: Medium fine, arranged in definite radial rows, without tertiary thickening, 1-4 mm in length and 30-35 um in diam., early wood tracheids very well defined, tangential wall thickness from 1.5-30 um, usually rectangular or sometime squarish or hexagonal in shape, intercellular spaces present in radial direction in the form of a very narrow band; tangential wall thickness of late wood from 3-5.5 um, bordered pits in one row in the radial walls of the tracheids, from 8-15 um in diameter, tangential walls bordered pits from 8-12 um in diam., and present in late wood tracheids.
Parenchyma: Abundant, distributed irregularly throughout the ring, cells solitary or sometimes even in groups, horizontal walls of wood parenchyma with bead like thickening.
Rays: Fine to very fine, unevenly distributed, uniseriate, 1-5 cells high, sometimes even more, height of ray cells 120 um, ray width from 5-12 um, horizontal walls of ray parenchyma sparsely pitted, tangential walls smooth or beadlike structure, pits semi bordered or bordered type in appearance with lenticular or oblique orifice, cross field 2-3 pits with 4-6 um diameter.
Resin canals: Absent,

Cupressus sempervirens L.

(Fig.7, A,B,C)

Trade or Local Name: Saru, Cypress.
Habit and Distribution: An evergreen ornamental tall tree with narrow cylindrical and fastigiate branches, stem fluted, having greyish brown thin bark, older trees attain a size of 8-12 m in height and 0.5-1.0 m in girth. Found in northern areas and is also cultivated as ornamental tree throughout Pakistan.
General characteristics of the wood: Sapwood white to yellowish white; heartwood light brown to yellowish brown with fine darker striations; lustrous when first exposed, with

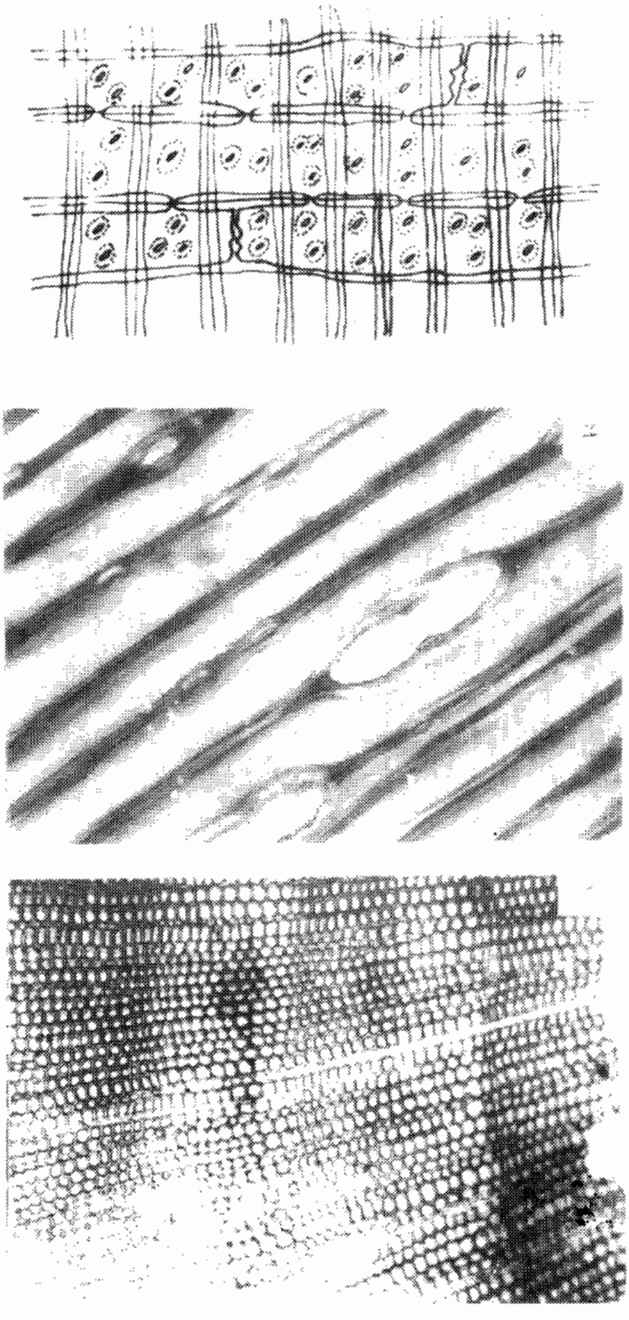


Fig. 7. Structure of the wood of *Cupressus sempervirens*. A) T.S. (800x), B) T.L.S. (800x), C) R.L.S. (400x).

smooth feel, cedary smell and faint cedary taste; light, straight grained with medium fine texture.

Structure of Wood

Growth rings: Indistinct, early and late wood also not markedly distinct.

Tracheids: Medium fine, arranged in definite radial rows, without spiral thickenings, tangential walls abundantly pitted, generally in the late wood; pits readily visible, circular or short-elliptic, 5-8 um in diam., aperture lenticular or slit like, usually oblique in orientation, early wood tracheids quite uniform in shape and size.

Parenchyma: Cells thin walled; clearly differentiated from the thin walled tracheids, occurring along or near to the outer edges of the growth rings, usually formed in the late wood; sometimes arranged in radial rows forming tangential plates.

Rays: Not distinct with naked eyes; very fine, unevenly distributed; uniseriate, 13-20 um in width and 20-250 um in length, 2-20 cells in height:

Resin canals: Absent

Cupressus torulosa **D. Don**

(Fig.8, A,B,C)

Trade or Local Name: Himalayan Cypress.

Habit and Distribution: An ever green very large and tall tree with spreading branches; branchlets drooping, quadrangular having greyish brown thick bark. The trees vary in height and girth, in very favourable localities the trees attain a size of 30-40 m in height and 2-3 m in girth. Found in the hilly regions of northern areas of Pakistan and is also cultivated as ornamental tree elsewhere in the plains.

General Characteristics of the Wood: Sapwood creamy-white to yellowish-white; heartwood yellowish brown to light brown, with fine and darker striations marking the growth increments; lustrous when first cut, changes after age, very smooth to touch, with cedary smell and faint cedary taste, light, straight and even-grained with medium fine texture.

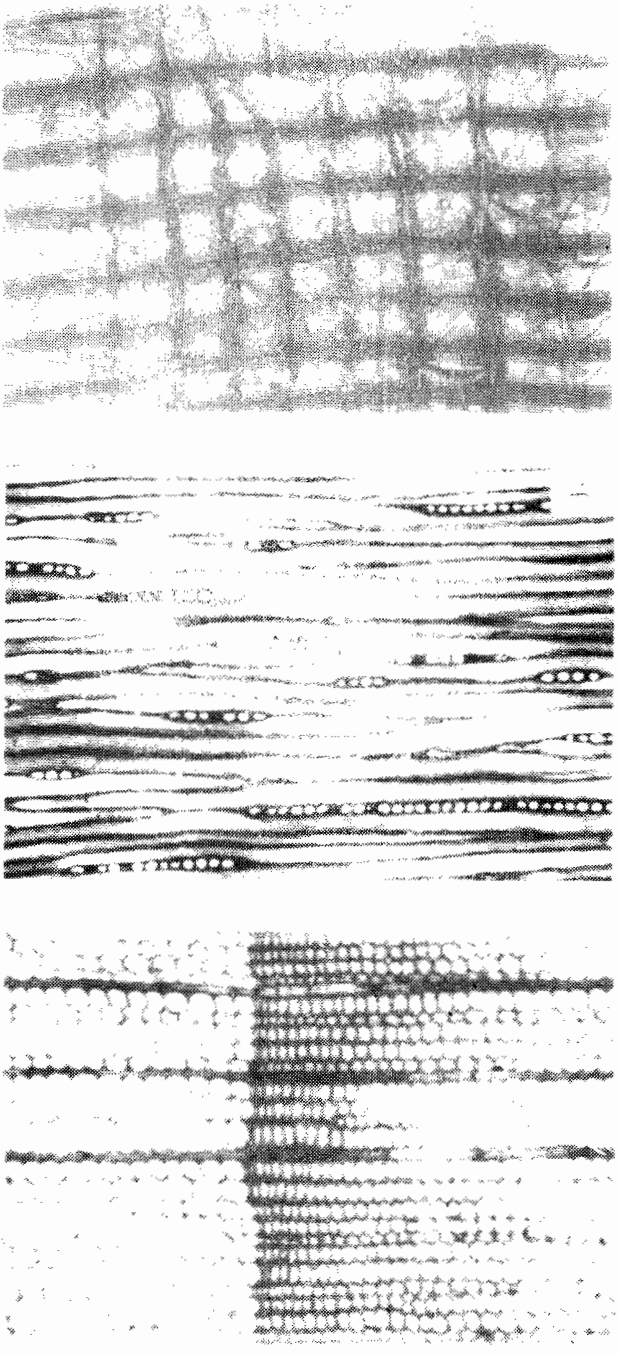
Structure of the Wood:

Growth rings: Distinct, late wood is clearly identified by sharp defined lines in the outer margins, transition from early wood to late wood abrupt.

Tracheids: Medium fine, arranged in definite radial rows, without tertiary thickening; 1.2-4.1 mm in length and 28-35 um in diam., early wood tracheids very well defined, tangential wall thickness 2-3 um, usually rectangular sometimes squarish or hexagonal in shape, intercellular spaces present in the early wood; late wood tracheids in the form of sharply defined narrow bands demarcating the boundary of the annual ring, tangential wall thickness 3-5 um; bordered pits in one row on the radial walls of the tracheids, 9-14 um in diam., bordered pits in tangential wall 4-7 um in diam., and present in the late wood tracheids, pits of tangential walls uniseriate and smaller than those of radial walls.

Parenchyma: Abundant, distributed irregularly throughout the ring, sometimes terminal, both metatracheal diffused and matatracheal zonate appearing as clearly defined bands; cells 35-42 um, solitary or some times in groups of 2-4.

Rays: Fine to very fine, not visible to naked eyes, unevenly distributed, uniseriate, 14-22 um wide and 240 um in height, 1-22 cells along the height; horizontal walls of ray parenchyma smooth, tangential walls with bead like thickenings, walls thick to medium



Figs 5. Structure of the wood of *Cupressus torulosa*. A. T.S. (200x). B. T.L.S. (200x). C. R.L.S. (800x).

thick; pits present, connecting the rays to longitudinal early wood tracheids, 2-4 per ray crossing, semi bordered or bordered type in appearance, with lenticular or oblique orifice.

Resin canals: Absent

Juniperus polycarpos C. Koch.
(Syn. *Juniperus macropoda* Boiss)
(Fig.9, A,B,C)

Trade or Local Name: Juniper, Pencil Cedar

Habit and Distribution: Medium sized tree, trunk usually not straight, bark reddish brown, smooth, branches low, irregular and very knotty, height 1-5 m and 1-3 m in girth. It usually forms open forests in Balochistan and the dry inner valleys in Chitral, Kurram, Gilgit and Baltistan from 2000-4000 m.

General Characteristics of the Wood: Sapwood yellowish-white, heartwood dull red to reddish-brown, turns to deep brown after aging, mottling present along the grain which denote growth increment, lustrous or dull, easy to work, with characteristic cedary odour and taste, very light, straight grained with fine and even texture.

Structure of the Wood:

Growth rings: Distinct, with clear darker bands of dense summer wood, transition from early wood to late wood absent.

Tracheids: Fine, arranged radially in definite rows, from 1.8-2.6 mm in length and 32-38 mm in tangential diameter. Some rows of tracheids especially those present adjacent to the rays, conspicuously larger than the remaining tracheids, usually without tertiary thickening; early wood tracheids uniform in distribution squarish to hexagonal or somewhat rectangular at the margin of the ring, uniform in size and shape, with wall thickness from 2-4 um with intercellular spaces; late wood tracheids forming narrow band at the margin, delineating the growth ring, tabular, arranged tangentially, wall thickness 5-7 um; bordered pits in tangential walls of tracheids, 7-19 um in diam., much smaller than those on radial walls, radial walls pits in one row and 9-15 um in diameter.

Parenchyma: Abundant, irregularly distributed, sometimes even wanting, usually present at the outer margin of the ring, metatracheal and diffused, cells solitary or sometimes 2-3 contiguous in the tangential plane, tabular, tangential 25-32 um diam., heartwood cells with redish brown gummy deposit.

Rays: Fine, hardly visible with naked eyes, unevenly distributed, 5-7 per mm, uniseriate, 13-17 um, 1-10 cells in height, sometimes even upto 16 cells in height, ray tracheids not observed, ray parenchyma thick walled, ray cells 15-20 um high, 6-15 um in width, horizontal tangential walls of ray cells highly pitted, pits leading laterally to the longitudinal spring wood tracheids, orbicular, semi bordered, with lenticular, oblique orifices; tangential walls, sometime with 4-5 bead like thickenings, pit aperture from 2-4 um in diameter.

Resin canals: Absent

Picea smithiana (Wall) Boiss.
(Syn. *P. morinda* Link, *Pinus smithiana* Wall)
(Fig.10, A,B,C)

Trade or Local Name: Himalayan Spruce, Kachal.

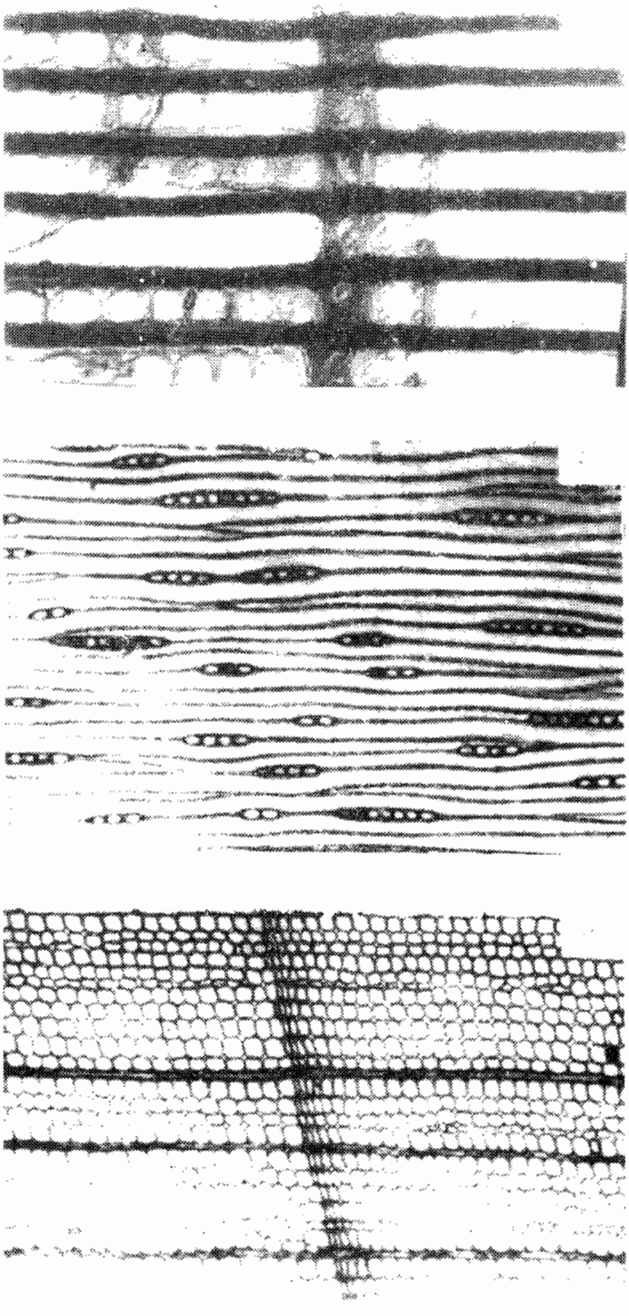


Fig. 9. Structure of the wood of *Juniperus polycarpos*. A) T.S. (200x), B) T.L.S. (200x), C) R.L.S. (800x).

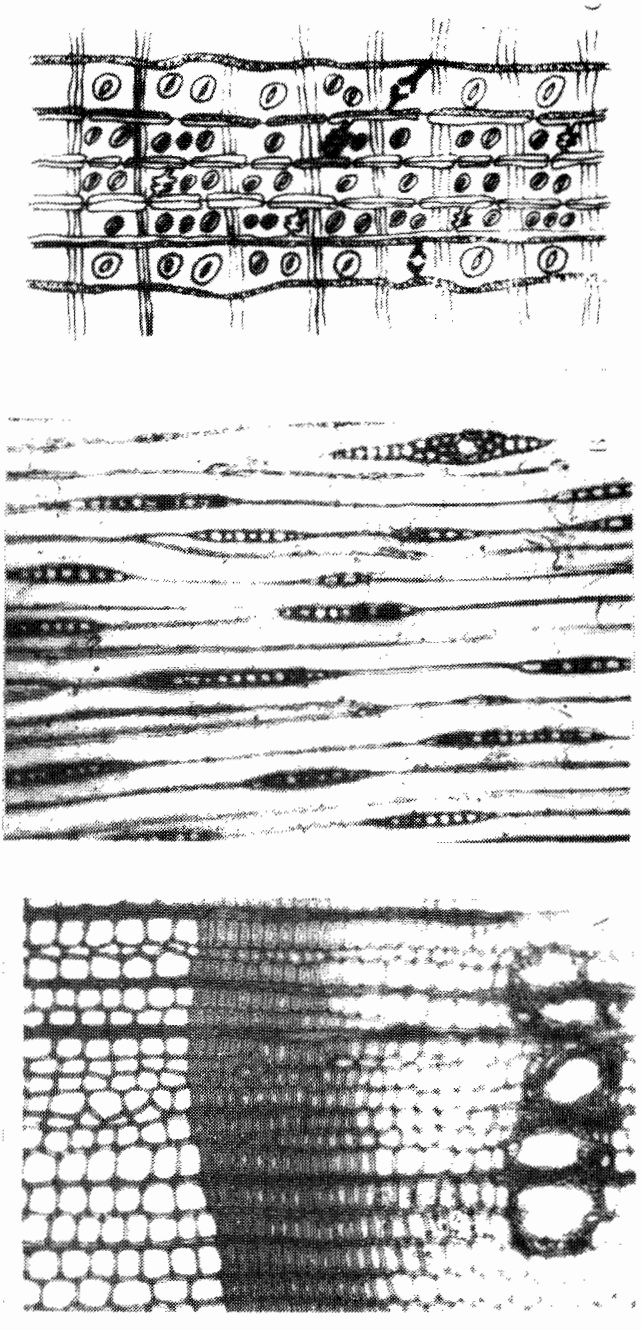


Fig.10. Structure of the wood of *Picea smithiana*. A) T.S. (200x), B) T.L.S. (200x), C) R.L.S. (400x).

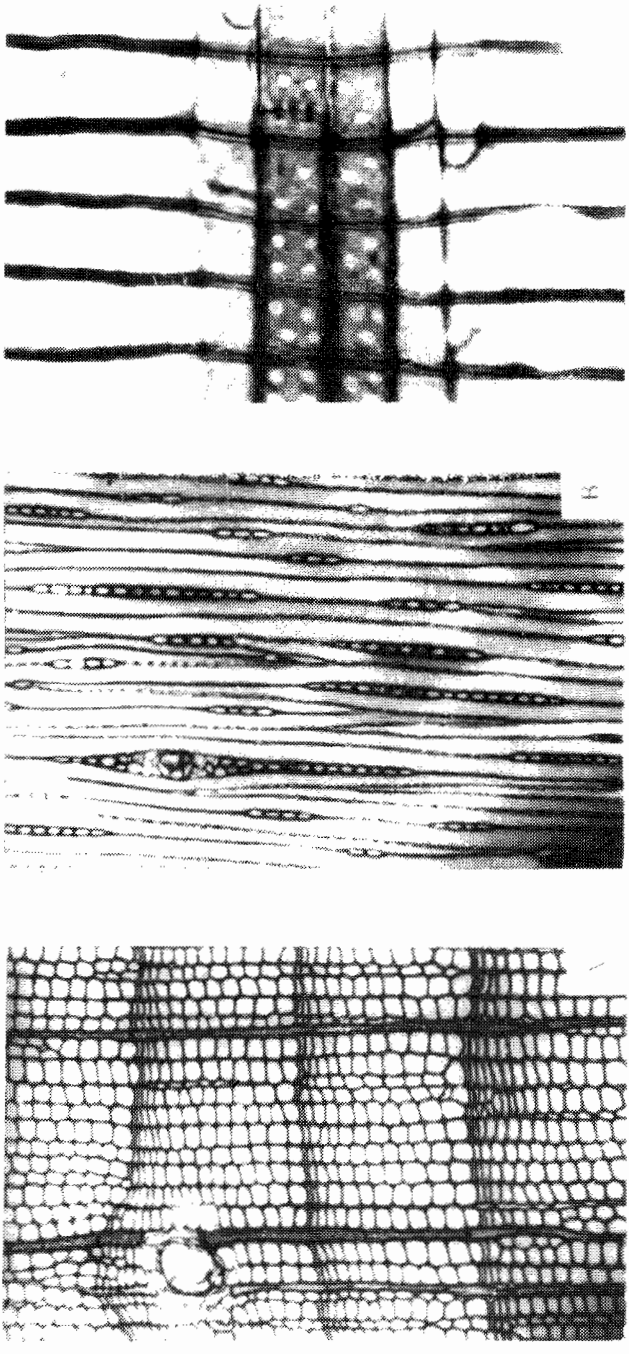


Fig. 11 Structure of the wood of *Pinus gerardiana*. A) T.S. (200x), B) T.L.C. (200x), C) R.L.S. (800x).

Habit and Distribution: A very large and tall tree with whorled and drooping branches and hanging branchlets, possessing greyish-brown bark which peals off in plate like scales; the tree with 10-23m clean bole may attain a great height upto 50 m or even more (60-70); with a usual girth from 2.5-3.0 m, (occasionally 6-8 m). Found extensively in northern areas of Pakistan, especially in Kaghan, Swat, Dir, Chitral, Kurram, Gilgit Agency and Azad Kashmir at elevation of 200-3300 m, also scattered in Murree Hills and Gullies.

General Characteristics of the Wood: White when first cut, turning to greyish brown with age, true heartwood absent but in older trees the wood towards the butt had some distinct colouration, particularly the inner portion, which is not infrequently dull red; lustrous when freshly cut, becoming dull with passage of time; easy to work with hand or on machine, without characteristic odour or taste; light and even grained with medium fine and even texture.

Structure of the wood

Growth rings: Distinct marked by denser late wood band at the termination of growth rings, transition from early to late wood gradual.

Tracheids: Medium fine, arranged in characteristic radial rows with inconspicuous tertiary spiral thickening, 1.5-4.6 mm in length, tangential diameter 42-50 um; early wood tracheids vary in cross section from squarish to hexagonal, rarely rectangular, 2-3 um thick; late wood tracheids mostly rectangular, changing to tabular and thick walled towards periphery of the rings, wall 4-7 um thick; bordered pits arranged in one row on the radial walls of the tracheids, sometimes in rows of two, tangential walls of tracheids with bordered pits mainly in the late wood, uniseriate and smaller in diameter than those of the radial walls.

Paranchyma: True parenchyma absent; epithelial cells surrounding the resin canals relatively thick walled (3-5 um).

Rays: Very fine, not distinct by naked eyes, distributed unevenly, ray of two types; (i) narrow rays numerous and uniseriate, 14-18 um in width, 280 um in height, and 3-24 cells high (ii) broader rays, occasional and sparse, uniseriate, 35-45 um in width, 350 um in height; ray tracheids marginal, in 1-2 horizontal rows, with orbicular bordered pits leading laterally to the longitudinal tracheids; ray parenchyma strongly pitted, 2-4 per ray crossing, varies from oval to lenticular, semi bordered.

Resin oanals: Both longitudinal and transverse resin canals present, scanty and minute, surrounded by some what thick walled epithelial cells, mostly located in the transition zone and late wood, (i) longitudinal canals very irregular, solitary or in groups of two, in cross-section they are circular or so, 112 um in diam., (ii) transverse canals, small solitary occurring in the fusiform rays surrounded by a sheath of uniseriate epithelial cells, orifice 10-14um in diameter.

***Pinus gerardiana* Wall**

(Fig.11, A,B,C)

Trade of Local Name: Chilghoza pine, chilghoza.

Habit and Distribution: A medium sized tree, with cylindrical straight stem, reaching to a height of 18-25 m with 1-2 m girth, spreading at the top, with irregular branches, having thin greyish bark. Found in the inner dry valleys of Chitral, Kurram, Upper Swat, near Astor and is common in Balochistan.

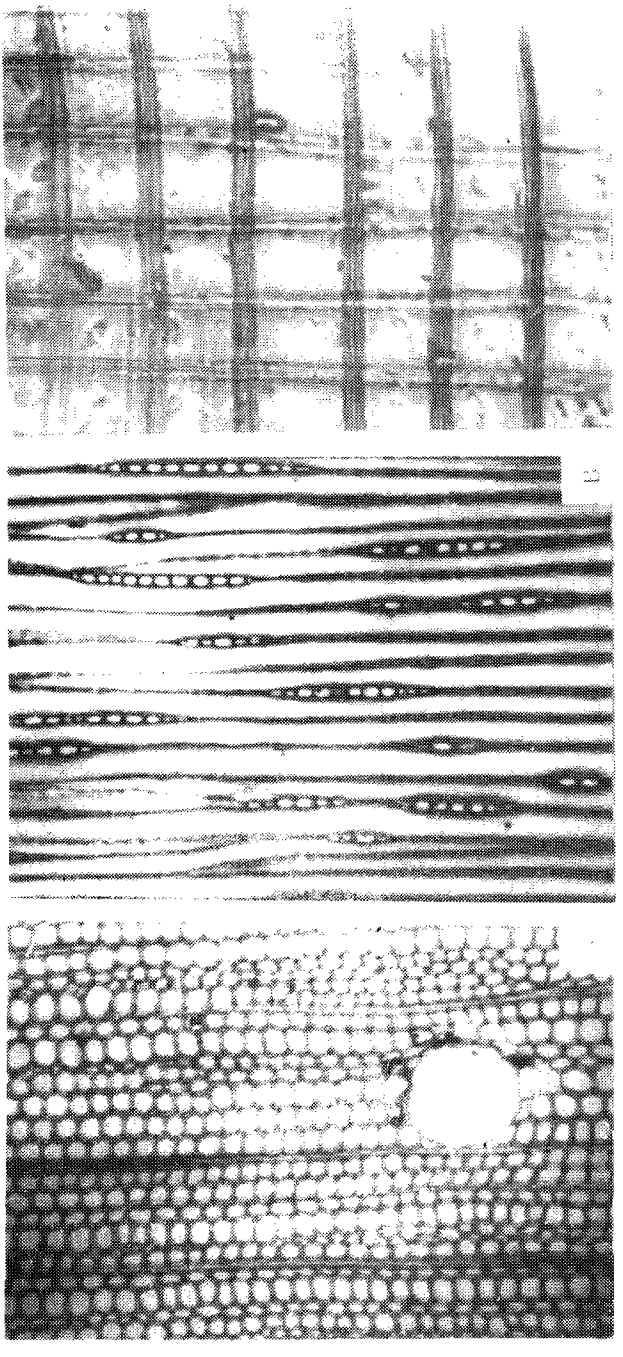


Fig. 12 Structure of the wood of *Pinus halepensis*. A) T.S. (200x), B) T.L.S. (200x), C) R.L.S. (400x).

General Characteristics of the wood: Sapwood white to creamy white, heartwood light red when first cut turning to dull red or reddish brown with passage of time, with darker striations; resin canals present; lustrous to somewhat dull with resinous odour and taste, straight to nearly straight and unevenly grained, medium and coarse textured.
Structure of the wood:
Growth rings: Distinct, transition from early wood to late wood gradual, early wood and late wood bands in different rings about equal in width.
Tracheids: Arranged in definite radial rows, measuring from 2.0-58 mm in length, 40-52 um in diam., early wood tracheids squarish or somewhat hexagonal in cross section, without intercellular spaces. Early wood tracheid wall much thinner than that of late wood tracheids and wide lumened. Late wood tracheids thick walled from 5-7 um, with narrow lumen. No bordered pits in tangential walls of tracheids, very fine oblique striations usually confined to late wood present in the wall of longitudinal tracheids.
Parenchyma: Absent
Rays: Fine, not distinct with maked eyes, unevenly distributed, mostly uniseriate, sometimes biseriate, ray tracheids of two types, (i) Narrow rays numerous than broader rays, 1-20 cells high, 500 um in height and 6-14 um in width, (ii) broader rays lesser in number and fusiform in shape, 380 um in height and 38-52 um in width, 25 cells high, ray cells in cross section mostly long elliptic in single row rays and square or rectangular in the taller rays; thin walled parenchyma and thick walled parenchyma form the rays, the later very rare, the thick horizontal walls have simple pits.
Resin canals: Abundant both longitudinal and transverse, surrounded by thin walled epithelial cells, longitudinal canals irregularly distributed mostly confined to the late wood boundary, mostly occurring singly, having one to many cells thick layer of epithelial cells.

***Pinus halepensis* Mill.**

(Fig.12, A,B,C)

Trade or Local Name: Quetta Pine
Habit and Distribution: A medium sized tree with cylindrical straight stem reaching to a height of 20-32 m with 1-2.5 m girth; bark rough, greyish and 2-4 cm in thickness; exotic species introduced from Europe and West Asia; widely cultivated in Balochistan, also cultivated in Swat and Islamabad, reported from Zeran Village in Kurram and Torkham; one of the fast growing pines of Pakistan.
General Characteristics of the wood: Sapwood white to creamy white; heartwood light red when first exposed turning to light reddish brown with age; with light dark striations; resin canals on longitudinal side in the form of darker lines, lustrous or so when first cut, becoming dull, with passage of time, with resinous taste, straight to nearly straight and unevenly grained with medium fine texture.
Structure of the wood:
Growth rings: Distinct, the walls of early wood and late wood tracheids lack differentiation; thick walled tracheids may be present, but not confined to the late wood.
Tracheids: Medium fine, variable in shape, sometimes provided with intercellular spaces, arranged in radial rows, tangential walls of the last late tracheids posses few pits which are quite large (10-20 um) with aperture circular, or short and eye shaped;

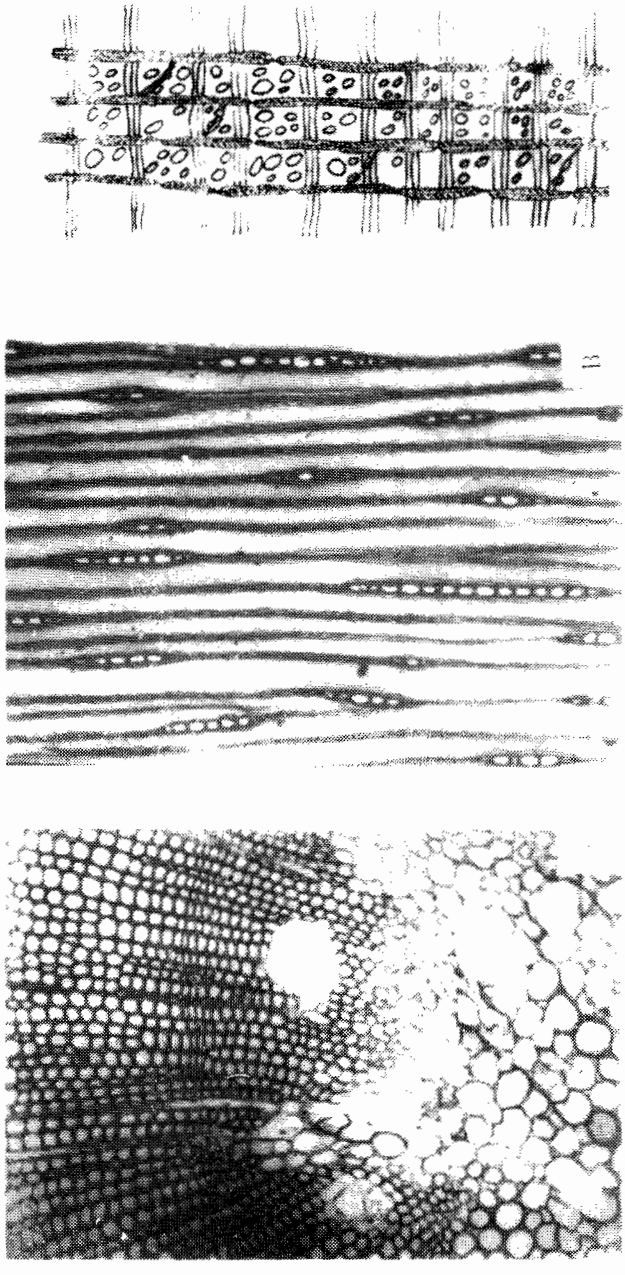


Fig.13.Structure of the wood of *Pinus roxburghii*. A) T.S. (200x), B) T.L.S. (200x), C) R.L.S. (400x)

pits in the radial walls of tracheids uniseriate, pit pairing absent.
Parenchyma: Absent
Rays: Very fine, not distinct with naked eyes, unevenly distributed; fusiform, uniseriate, occasionally biseriate when transverse resin canals present; uniseriate ray consisting of 4-21 cells, measuring 104-520 um in height and 15-26 um in width; biseriate ray comprising 5-13 cells, 250-325 um in height and 26-32 um in width.
Resin canal: Both longitudinal and transverse enclosed by thin walled epithelial cells; (i) longitudinal canals large unevenly distributed, solitary, 91-104 um in diam., (ii) transverse canals comparatively smaller than the longitudinal ones, very sparse and inserted in the fusiform wood rays, 38-56 um in diameter.

Pinus roxburghii Sargent
(Syn. *P. longifolia* Roxb.).
(Fig.13, A,B,C)

Trade or Local Name: Chir, Chil.
Habit and Distribution: A tall and evergreen tree with whorled branches, the size varies according to localities. In favourable localities it grows to a maximum height of 45 m and 3-4 m in girth. Bark rough 2-5 cm thick. Found in north western hilly regions of Pakistan at an elevation of 600-1500 m. Common in Murree Hills, Swat, Azad Kashmir, Dir and Hazara.
General characteristics of the wood: Sapwood white to creamy white; heartwood light red when first cut, turning to light reddish brown with passage of time, with dark reddish striations; in longitudinal side resin canals form dark lines; lustrous to somewhat dull, with resinous odour and faint resinous taste, straight to nearly straight and uneven-grained, medium and coarse textured.
Structure of the wood
Growth rings: Distinct, transition from early wood to late wood abrupt forming darker bands of denser late wood.
Tracheids: Arranged in definite radial rows, measuring from 1.8-5.7 mm in length, without tertiary spirals; early wood tracheids rectangular to squarish or somewhat hexagonal in transverse section; without intercellular spaces; thickness of tracheid wall 3,0-5.5 um; early wood tracheid wall much thinner than late wood tracheid and wide lumened; late wood tracheid thick walled from 9-13 um thick with narrow lumen, sometimes paired on the radial walls of the early wood tracheids; tangential pitting absent in some of the latewood tracheids.
Parenchyma: Absent
Rays: Fine, not distinct with naked eyes, unevenly distributed, with ray tracheids of two types: (i) narrow rays numerous than the broader rays, uniseriate, from 20-450 um in height with 1-15 cells along the height, 13-25 um in width; (ii) broader rays less in number and fusiform in shape, 60-450 um in height and 42-60 um in width, ray tracheids marginal and frequently interspersed in horizontal lines; marginal tracheids 1-2 or 1-3 rows.
Resin Canals: Abundant, both longitudinal and transverse, surrounded by thin-walled epithelium, longitudinal canals irregularly scattered and mostly found in the middle and outer portions of the ring, mostly occurring singly having 1-many cells thick epithelium; transverse canals are similar to the longitudinal canals but smaller, solitary,

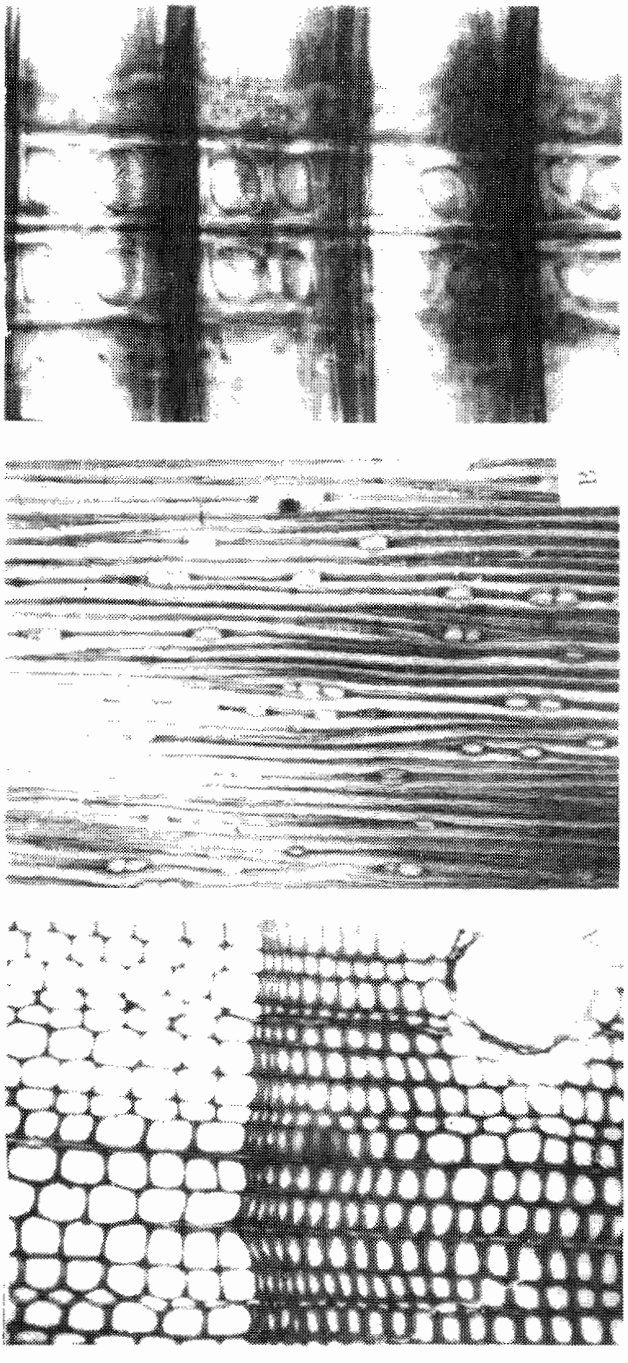


Fig.14.Structure of the wood of *Pinus wallichiana*. A) T.S. (200x), B) T.L.S. (200x), C) R.L.S. (800x).

present between the fusiform rays, epithelium 1-2 cells in thickness.

Pinus wallichiana A. B. Jackson

(Syn. *P. excelsa* Wall., *P. griffithii* Mc Clelland)

(Fig.14, A,B,C)

Trade or local Name: Kail, Blue Pine.

A large and ever green tree with glaucous foliage and whorled branching, stem cylindrical and straight reaching to a height of 28-36 m with 2-3.5 m in girth; bark rough, not thick, greyish in colouration. Found in Murree Hills, Azad Kashmir, Kaghan, Gilgit, Swat, Dir and Chitral regions.

General characteristics of the wood: Sapwood white to yellowish - white; heartwood light pinkish red to light red, with light dark striations; longitudinal resin canals in the form of darker lines; lustrous when first exposed, turning dull with age; having resinous smell and faint resinous taste; straight and fairly even-grained, with medium fine texture.

Structure of the wood:

Growth rings: Distinct, fairly wide uneven, late wood much wider than early wood.

Tracheids: Medium fine, 2.2 5.00 mm in length, arranged in radial rows measuring 42-55 um in tangential diam., without tertiary spirals; late wood tracheids thick-walled, 4-8 um in thickness, rectangular or tabular in transverse section, without intercellular spaces; early wood tracheids thin-walled 2-4 um in thickness, squarish to rectangular or somewhat hexagonal in transverse section without intercellular spaces; transition from early to late wood gradual; bordered pits in the form of one row on the radial walls of the tracheids; tangential pitting in the last few rows of late wood tracheids; tangential wall pitting much smaller than on the radial walls; pit aperture of narrow tracheids oblique and lenticular invariably included, uniseriate.

Parenchyma: Absent, the epithelial cells surrounding the resin canals are not supposed to be true longitudinal parenchyma.

Rays: Very fine, not distinct with naked eyes, unevenly distributed; 2-10 cells along ray height; rays of two types: (i) broader rays sparse and fusiform, 42-55 um in width and 300-340 um in height; (ii) narrow rays larger in number than the broader rays, uniseriate 10-18 um in width and 150-220 um in height with 1-14 cells along the height; ray tracheids marginal and interspersed, arranged in horizontal rows, empty.

Resin canals: Both longitudinal and transverse; surrounded by thin-walled epithelium; longitudinal canals mostly present in the middle portion of the ring and irregularly distributed, generally occurring singly, epthelium 1-5 cells thick, resin canal 120-200 um in diam., transverse canals smaller as compared to the longitudinal canals, solitary and inserted in the fusiform wood rays, 39-55 um in diam., eptithelium 1-2 cell thick.

Taxus baccata Linn.

(Fig.15, A,B,C)

Trade or local Name: Yew

Habit and Distribution: A large tree with dense and irregularly spreading branches; stem irregular with little clean bole; bark reddish brown, thin and scaly; tree 6-20 m tall varying from 1.5-2.0 m in girth. Found in shady moist forests in Himalayas at an elevation of 1800-3000 m.

General characteristics of the wood: Sapwood white to dirty white, heartwood varying

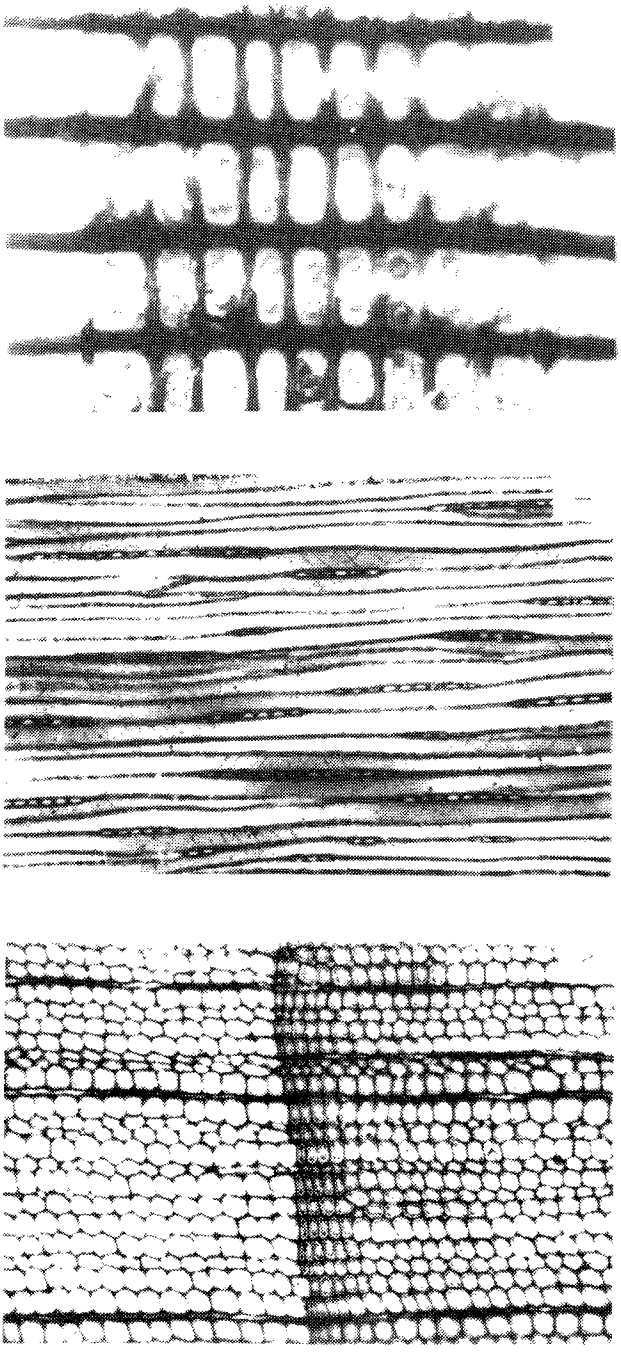


Fig.15.Structure of the wood of *Taxus baccata*. A) T.S. (200x). B) T.L.C. (800x). C) R.L.S. (800x)

in colouration, mostly reddish-brown, marked by lighter and darker streaks; lustrous to dull, working well both with tool and on machine giving rise to a smooth finish, without characteristic odour or taste, straight to somewhat interlocked grains, with fine and uneven texture.

Structure of the wood:

Growth rings: Distinct, marked by clear and distinct dark lines on the outer margin, transition from early to late wood abrupt, particularly at the extreme outer portions.

Tracheids: Fine, arranged in very characteristic radial rows, 1.5-3.0 mm in length, 35-42 um in diam., with tertiary spiral thickening in both early and late wood; in cross section the early wood tracheids somewhat thick walled (3-5 um) varying in shape from squarish to somewhat hexagonal or even sometime rectangular; late wood tracheids thick walled (4-6 um) rectangular and at the outer margin of the ring somewhat much compressed, between the two rays the outer margin of the growth ring is somewhat bent outward; in the radial walls the bordered pits are arranged in one row, with varying distance, pits in tangential walls not in one row, smaller than those of radial wall pitting present in the late wood tracheids.

Parenchyma: Not much abundant, irregular in distribution, relatively abundant in the outer margin, sometimes terminal, metatracheal-diffused and metatracheal-zonate, somewhat clear bands, cells solitary or in groups of 1-3.

Rays: Fine, not distinct with the naked eye, unevenly distributed, uniseriate, occasionally biseriate, 14-20 um in width and 464 um in height, 2-21 cells long the height; ray tracheids absent; medium thick-walled, ray crossing pits from 1-4 (mostly 1-2), semi bordered, with lenticular oblique orifice.

Resin canals: Absent.

***Thuja orientalis* Linn.**

(Syn. *Biota orientalis* (Linn.) Endl., *Platycladus orientalis* (Linn.) Spach.

(Fig.16, A,B,C)

Trade or Local Name: Thuja, Morphankh.

Habit and Distribution: A small cultivated tree with branched stem, branchlets flattened in vertical planes; bark dark-brown, rough and thin, 2-8 mm in thickness. The species is a native of China and Japan and is commonly planted throughout Pakistan in the plains and the foot hills as an ornamental tree.

General characteristics of the wood: It is not a wood yielding species. Sapwood white to creamy white heartwood reddish brown to dark brown, with light dark striations; sweet smelling and without any taste, straight grained with fine texture.

Structure of the wood:

Growth rings: Slightly distinct, late wood somewhat narrow than early wood.

Tracheids: In transverse section angular or with round corners having intercellular spaces between them; pits frequently visible on the tangential walls; on radial walls of tracheids bordered pits present, uniseriate in the late wood tracheids and sometimes biseriate in the early wood tracheids; early wood pits have circular apertures while late wood pits have eye-shaped apertures.

Parenchyma: Predominantly present in late wood, sometimes present in early wood, circular or elliptic pits on horizontal walls.

Rays: Very fine, not distinct with naked eyes, unevenly distributed, uniseriate rarely

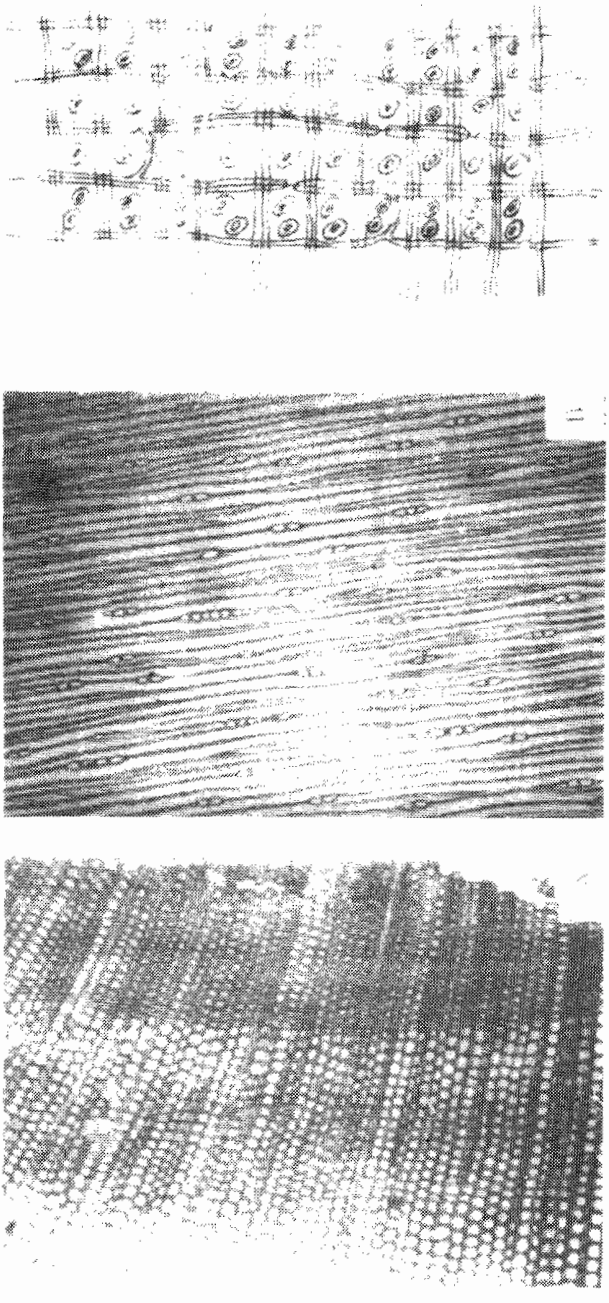


Fig.16.Structure of the wood of *Thuja orientalis*. A) T.S. (200x). B) T.L.S. (200x). C) R.L.S. (400x).

biseriate consisting of only lignified parenchyma ray 2-6 cells high measuring 20-80 um in length and 10-15 um in width.
Resin canals: Absent

Discussion

Observations on the wood anatomy of the species examined showed characteristic features which is typical of coniferous wood as described by Pearson & Brown (1932), Greguss (1955) and Jane (1956). Distinct growth rings were present in *A. pindrow*, *C. deodara*, *C. torulosa*, *J. polycarpos*, *P. smithiana*, *P. gerardiana*, *P. halepensis*, *P. roxburghii*, *P. wallichiana* and *T. baccata*. Growth rings were not much distinct in *C. arizonica* and *C. funebris*, slightly distinct in *T. orientalis* and indistinct in *C. sempervirens* and *A. cookii*.

Parenchyma was present in secondary xylem of *C. sempervirens* and *T. orientalis* while abundantly distributed in *C. funebris*, *C. torulosa* and *J. polycarpos*. It was both metatracheal diffused and metatracheal zonate appearing as clearly defined band. It was less abundant in *T. baccata* and very scanty in *A. pindrow*. True parenchyma was absent in *P. smithiana*, however it was occasionally observed in *C. deodara* and *Pinus* spp.

Transition from early to late wood was abrupt in *C. arizonica, C. funebris, C. torulosa, P. roxburghii* and *T. baccata* while it was gradual in *A. pindrow, C. deodara, P. smithiana, P. geradiana* and *J. polycarpos*. Late wood traheids in *P. wallichiana* possessed thick walled cells whereas the early wood tracheids were thin walled. They varied in their wall thickness to such an extent that walls of late wood tracheids were twice the thickness of early wood tracheids. This is in contrast to the report of Greguss (1955) who found lack of appreciable difference in wall thickness of early and late wood tracheids in *P. wallichiana*. Rays were not distinct with naked eyes in all the coniferous species examined. The rays were fine and unevenly distributed. Generally they were uniseriate as in other softwoods. Biseriate rays were not observed in *A. pindrow*, which is contrary to the findings of Kucera & Bosshard (1975) who observed biseriate rays in *A. alba*. Two types of rays were observed in *Pinus* spp. and *Picea smithiana* where narrow rays were present in large number than broad rays. Rays were many cells high in *Pinus* spp., and *C. deodara* and were fairly long. Rays were composed of few cells in *T. orientalis* while these were relatively smaller in rest of the species. Resin canals were present in *Pinus* spp., and *Picea smithiana* and absent in *C. arizonica, C. funebris, J. polycarpos, A. pindrow, C. torulosa, T. baccata, C. sempervirens* and *T. orientalis*. Both longitudinal and transverse canals were present. Transverse canals were smaller than the longitudinal and were surrounded by a sheath of thin walled epithelial cells. Longitudinal canals were mostly confined to the boundary of the late wood. Normal resin canals were absent in *C. deodara* and instead longitudinal and transverse traumatic canals were present. Transverse traumatic canals were less frequent than longitudinal traumatic canals.

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