Journal of Plant Resources (2022) **20**(1), 102-112
https://doi.org/10.3126/bdpr.v20i01.56598

Comparative Wood Anatomy of Nepalese Ulmaceae

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Abstract

Wood structure of three Nepalese genus *Ulmus, Celtis* and *Trema* belonging to the family Ulmaceae are described. Altogether 12 wood samples of these three genus are collected from different localities and studied. The study showed ring porous, semi-ring porous or diffuse porous wood. Transition from early wood to late wood was abrupt in ring porous wood. Early wood pores one to three layered. Late wood pores arrangement in dendritic or ulmiform pattern. Perforation plate is simple and inter-vessel pit alternate. Fiber tracheids, tracheids and libriform fibers were non-perforated tracheal elements while wood parenchymatous cell was apotracheal, marginal and paratracheal. Rays were homo-or heterogeneous. *Ulmus* differs from *Celtis* in having ray structure and crystal location. A tentative key is prepared to identify the species based on wood character.

Keywords: Identification, Tentative key, Ulmiform pattern, Vascular tracheid, Wood character

Introduction

Ulmaceae consists of deciduous, semi-deciduous or evergreen trees and shrubs distributing in the tropics, subtropics and temperate regions in both the northern and southern hemispheres (Hooker, 1973). There are 16 genera and about 230 species in the world (Flora of China, 2003). Most of the species are of economic value for either their timber (*Ulmus, Celtis*), wood pulp (*Trema*) or as ornamental tree. Previously the family is treated into two subfamilies, the Ulmoideae and the Celtidoideae. Recently Celtidoideae is treated as a separate family Celtidaceae by many authors suggesting that the genera in the Celtidoideae are more similar to Moraceae than in the Ulmoideae (Chernik, 1975; Grudzinskaya, 1967; Oginuma et al., 1990; Takahashi, 1989; Takao & Tobe, 1990; Tarabayashi, 1991).

In Nepal there are 4 genera and 10 species belonging to family Ulmaceae (Hara et al., 1982). Among them three genera and eight species are examined in the present study. The genera investigated are *Celtis* (2 spp.), *Trema* (3 spp.) and *Ulmus* (3 spp.). While surveying the literature on earlier study dealing with wood anatomy of Ulmaceae, few number of publications by Tippo (1938), Metcalfe & Chalk (1950), Sweitzer (1971), Stern & Sweitzer (1972), Cheng et al. (1980), Person & Brown (1981), Kachroo & Bhat (1982), Yang & Huang Yang (1987), Luo (1989), Wheeler et al. (1989), Zhong et al. (1992), Suzuki et al. (1999) and Joshi (1994) are available.

Wood structure of Nepalese Ulmaceae as a whole is not yet described. So the present study is undertaken to highlight the wood structure of the Ulmaceae native to Nepal and also attempted to prepare a tentative key for the identification of the species based on wood structure.

Materials and Methods

Twelve wood block samples of the genus *Celtis, Trema* and *Ulmus* are collected (Appendix 1 and 2): *Celtis tetrandra* (No. 9194114, No. 9194131, No. 9194150 and No. 9194227), *C. australis* (No. 905), *Trema tomentosa* (No. 9194116), *T. politoria* (No. 9194249), *T. orientalis* (No. 9495082), *Ulmus chumlia* (No. 9194242), *U. lancifolia* (No. 9194250), *U. wallichiana* (No. 9194224 and No. 904). All the samples except two samples no. 904 and no. 905 are collected from West Nepal. The rest two are from Royal Botanical Garden, Kew and National Herbarium Plant Laboratories (KATH), Godawari, Lalitpur. All the voucher specimens have been deposited in KATH. Light microscopic studies of sections and maceration were carried out following the methods of Baas and Xinying (1986). Vessel density, vessel diameter, vessel element length, fiber element length and diameter, ray density, ray height cells and some other characters are measured and compared. A recommendation in the IAWA List of Microscopic Features for Hardwood Identification was followed (International Association of Wood Anatomy [IAWA], 1989).

Results and Discussion

Quantitative wood characters of three genera *Celtis, Trema* and *Ulmus* are given in Appendix 1 and 2. Comparative wood characters are described as follows:

Celtis L.

***C. australis* and *C. tetrandra*:** Growth ring is distinct because of marginal or seemingly parenchymatous bands, inflated multiseriate rays and difference in pore diameter between early wood and late wood. Wood ring porous. Vessel transition from early wood to late wood is abrupt in *C. tetrandra* and gradual in *C. australis*. Early wood pores1-5 in *C. australis* (Figure 1) and 1-3 layered in *C. tetrandra* (Figure 2) oval or round in outline (30-264 µm and 24-200 µm) in radial and tangential diameters, respectively. Late wood pores predominantly in clusters and associated with tracheids forming more or less interrupted wavy bands separated by fibrous tissue. The pore cluster is in diagonal tangential band in *C. tetrandra* (Figure 2) and in tangential festoon-like pattern in *C. australis*. Length of vessel element are short to long (100-912 µm) with end walls horizontal to oblique, and simple perforation plates. Inter-vessel pits are alternate. Pit is polygonal or oval in outline with lenticular apertures and non-vestured. Vessel-ray and vessel-parenchyma pits are horizontally or vertically elongated elliptical in outline (Figure 6), mostly simple or with reduced borders. Spiral thickenings distinctly observed in late wood vessels. Thin-walled and sclerotic tyloses are present (Figure 5), or absent in specimen no. 9194150.

Non-perforated tracheal elements are vascular tracheids and libriform fibers. Vascular tracheids integrating with late wood pores element are abundant and in association with the vessel parenchyma groups. Distinct spiral thickenings are present. Libriform fibers are arranged in patches and alternate with the pores clusters, oval, square or polygonal in cross section and thin to thick-walled (2-4 µm in diameter). Pits small, confined to the radial walls and simple or minutely bordered. Fibers are medium to long (0.4-16 µm). Axial parenchyma are mostly paratracheal, vasicentric, confluent and in concentric narrow to broad bands, with late wood pores and vascular tracheids (Figure 2). Crystals are absent. Rays are heterocellular, uniseriate and multiseriate. Ray density varies from 3-15. Uniseriate rays are 1-18 cells (48-720 µm) in height. Multiseriate rays are 2-9 cells (20-192 µm) in width and 90-1000 µm in height. Uniseriate rays are composed of upright or square cells. Multiseriate rays are composed of procumbent ray cells and uniseriate wings of upright or square cells. Sheath cells are present. Simple crystals are noted in upright or square cells and procumbent cells (Figures 3, 4 and 7).

Cox (1941), Grumbles (1941), Sweitzer (1971) and Wheeler et al. (1989) mentioned diffuse porous wood in evergreen species of *Celtis* and ring porous wood in deciduous species. However, in the evergreen *C. tetrandra* ring porous is found in the present study. Similarly, deciduous or evergreen trees from sub-tropical to tropical regions has semi-ring porous to diffuse porous wood. Marginal parenchyma bands have not been mentioned in the previous wood anatomical description of *Celtis* from China. But later Zhong et al. (1992) mentioned the presence of marginal parenchyma bands in *Celtis* from China. Wheeler et al. (1989) also noted marginal parenchyma bands in *Celtis* from United States. Similarly in the present study of two species of *Celtis,* marginal parenchyma bands are noted. Perforations with vestigial bars is not found in the studied material as Sweitzer (1971) did in the ring porous species.

Trema Lour.

***T. orientalis, T. politoria* and *T. tomentosa*:** Growth ring fairly distinct in *T. tomentosa* (Figure 8 and 9), and *T. orientalis* (Figure 11 an 12), indistinct in *T. politoria* (Figure 10) marked by the differences in fiber wall thickness and diameter. Wood diffuse porous, Pores solitary, radial multiple of 2-4(-7), rarely in cluster multiples of 2-4 and in oblique pairs, oval rarely round in outline, 48-216 µm and 48-168 µm in radial and tangential diameters respectively with thin to thick wall (2-7 µm in diameter). Vessel element length is short (270-330 µm) in *T. politoria* to long 230-700 µm in *T. tomentosa*. Perforation plates are simple with oblique end walls. While inter-vessel pits are non-vestured, alternate, and polygonal or round, and horizontally elliptical with slit like aperture (Figure 13). Vessel-ray and vessel-parenchyma pits with much reduced borders to simple type; a half bordered varying size and shape, small to large, round or angular or horizontally elongated (Figure 14). Spiral thickenings are absent and thin-walled tyloses are present (Figure 11 and 15). Vascular tracheids are absent. Librifom fibers are more or less oval, square rectangular in outline with thin (*T. tomentosa*) to thick (*T. orientalis* and *T. politoria*) wall. Pits are simple to minutely bordered, and confined to the radial walls. Fibers are medium to long (0.3-1.3 µm). Axial parenchyma is scanty paratracheal. Apotracheal parenchyma very rare and diffused (Figure 12). Cells are oval, square, elliptical or tangentially elongated in outline and thin-walled. Crystals are absent. Rays heterocellular, uniseriate and multiseriate (Figure 16). Ray density varies from 3-9. Uniseriate rays 1-16 cells (48-720 µm) in height. Multiseriate rays 1-4 cells (30-108 µm) in width and (144-912 µm) in height and uniseriate rays composed of upright or square cells. Multiseriate rays composed of procumbent body ray cells with marginal upright or square cells. Sheath cells present. Crystals present in *T. politoria* (Figure 14). Perforation present in ray cell of *T. orientalis* and *T. tomentosa* (Figure 16 and 17).

Cheng et al. (1980) and Luo (1989) referred to fibers in *T. orientalis* as fiber tracheid with distinctly bordered pits. Yang and Huang-yang (1987) also reported fiber tracheids in *T. orientalis*. But in the present study, libriform fibers has been observed only with simple to minutely bordered pits which is also observed by Zhong et al (1992) and Joshi (1994). Yang and Huang Yang (1987) described opposite inter-vessel pitting in *T. orientalis.* But Cheng et al. (1985), Zhong et al. (1992) and Luo (1989) observed alternate inter-vessel pits instead of opposite. The present study also shows alternate inter-vessel pit in *T. orientalis.* Zhong et al. (1992) found heterocellular type of rays in *T. orientalis.* But Sweitzer (1971) described uniseriate rays as homocellular with procumbent cells. The result of the present study is similar with that of Zhong et al. (1992) findings.

Similarly, the observation of occasional presence of crystals in axial parenchyma by Cheng et al. (1980) and Luo (1989) and silica in the ray cells by Cheng et al. (1985) have not been noted in the present study and as well as by Sweitzer (1971), Yang and Huang-Yang (1987) and Zhong et al. (1992).

***Ulmus* L.**

***U. chumlia, U. lancifolia* and *U. wallichiana*:** Growth ring distinct (Figure 17, 18 and 19) marked by marginal parenchymatous bands and inflated multiseriate rays and moderate differences in pore diameter. Wood ring porous. Vessels transition from early wood pores to late wood pores are abrupt (Figure 18 and 19). Early wood pore is 1-3 layers, solitary, or in cluster of two, oval or round large in outline 50-312 µm and 50-288 µm in radial and tangential diameters, respectively, and thin to thick walled (2-5 µm). Late wood pores predominantly in clusters and in association with tracheids form a continuous tangential in *U. wallichiana* (Figure 19 and 20) to diagonal wavy bands in *U. chumlia* (Figure 21); small, oval or round in outline. Vessel elements short (157-250 µm). Perforation plates are simple with horizontal to oblique end wall, occasionally in side walls. Inter-vessel pits non-vestured, alternate, polygonal, round or oval with slit like aperture. Vessel-ray and vessel-parenchyma pits are mostly simple or reduced, small and rounded. Spiral thickening distinctly observed in late wood pores but in *U. lancifolia* such thickenings are present in both early and late wood pores. Thin walled tyloses are absent.

Vascular tracheids are abundant in both early wood and late wood pores. It is integrating with late wood pores element and in association with the parenchyma forms a concentric tangential band of late wood pores. Distinct spiral thickenings are present. Librifom fibers are oval, square, and polygonal or radially elongated, thin to thick-walled (2-4 µm diameter). Pits simple to minutely bordered, confined to the radial walls. Fibers are medium to long (0.3-1.7 µm). Axial parenchyma mostly paratracheal, scanty, aliform, abundant in early wood pores and less abundant in late wood pores and mostly marginal to the tangentially aligned clusters or concentric band of late wood pores in *U. wallichiana* (Figure 19). Apotracheal parenchyma is sparse, diffused in the fibrous tract and marginal banded in *U. chumlia* (Figure 18). Marginal parenchyma is absent in *U. wallichiana*. Diamond shaped chambered crystals absent in *U. lancifolia* and present in *U. chumlia* (Figure 21). Rays are homocellular, uniseriate and multiseriate but tendency toward heterocellular in *U. chumlia*. Ray density varies from 5-13. Uniseriate rays are 1-16 cells (40-312 µm) in height. Multiseriate rays are 1-7 cells (20-120 µm) in width and 40-888 mm in height. Uniseriate rays composed of upright or square cells. While multiseriate rays are composed of procumbent body ray cells with uniseriate wings of upright or square cells. Sheath cells present. Simple crystals are present in *U. wallichiana* (Figure 22). Perforated ray cell occur in *U. walichiana* (Figure 23).

Wheeler et al. (1989) and Zhong et al. (1992) also mentioned the presence of marginal parenchyma bands in *U. lanceofolia*. Spiral thickenings was observed in *U. lanceofolia* throughout the body of all vessel elements by Zhong et al. (1992).These characters have also been noted in the present study. Non-enlarged perforated ray cell and chambered crystals are not observed in axial parenchyma of *U. lanceofolia* whereas, Zhong et al. (1992) mentioned the occasional occurrence of non-enlarged perforated ray cell and chambered crystals in axial parenchyma.

General discussion

Ulmaceae are frequently divided into two subfamilies Ulmoideae and Celtoideae. They are sometimes separated into two families Ulmaceae and Celtidaceae (Grudzinskaya, 1967). These subfamilial or familial distinctions are supported by flavonoid chemistry (Giannasi, 1978), pollen morphology (Zavada, 1983) and some anatomical structures (Sweitzer, 1971). Typically, the Ulmoideae have flavonols strictly pinnately veined leaves, and dry fruits; the Celtoideae have glycoflavonols, pinnipalmately veined leaves and drupaceous fruits. In this treatment Ulmus are considered part of the subfamily Ulmoideae; *Celtis* and *Trema* are in subfamily Celtoideae. Chemical similarities between subfamilies include the presence of proanthocyanins with some tannins and scattered mucilaginous cells or canals. Additionally members of the family possess solitary or clustered crystals of calcium carbonate.

Although Ulmaceae as a family are diverse in wood anatomy, there are many characters pervading the entire group. These include mostly exclusively simple perforations, alternate, non-vestured inter-vessel pits, relatively short vessel elements and fibers; non-septate fibers with simple to minutely bordered pits confined to the radial walls; mainly paratracheal parenchyma; rays rarely higher than 1 mm. However, two subfamilies, the Ulmoideae and Celtidoideae of the family Ulmaceae can be distinguished on the basis of differences in wood anatomy, mainly in ray structure. Genera in the Ulmoideae have exclusively homocellular rays or a mixture of homocellular and heterocellular rays, while genera in the Celtidoideae have heterocellular rays. Sheath cells are absent from the Ulmoideae, but are present in some Celtidoideae, particularly in the wider rays. The genus *Ulmus* of Ulmoideae have vessel-ray parenchyma pits similar to or slightly smaller than the intervessel pits, while the genus *Celtis* and *Trema* of Celtidoideae have vessel-ray parenchyma pits of varying size and shape. However, the promotion of the two sub families to family level as suggested by Grudzinskaya (1967) and Chernik (1975, 1980, 1981, 1982) is not supported by wood anatomy, because of the many anatomical characters common to both sub families.

The Ulmaceae, particularly the Ulmoideae, should be considered specialized in their wood anatomy. The characters include mostly simple perforation plates, alternate inter vessel pits, relatively short vessel elements and fiber, rays with a tendency to homogeneity, axial parenchyma occurring in groups (aliform, confluent, confluent-banded, marginal bands). Vessels are in a wavy tangential to diagonal pattern and associated with vascular tracheids in many species and storied structure in some species. Wood anatomy does not support Giannassi's (1986) suggestions based on flavanoid chemistry that Ulmoideae are primitive and relative to Celtidoideae. Because the genus *Trema* (Celtidoideae) have the most primitive wood anatomy of any of the Ulamceae as their rays are totally heterocellular, and they have the longest vessel elements. This study supports the generally accepted placement of Ulmaceae in the order Urticales. The Ulmaceae, especially the Celtidoideae resemble Moraceae in their wood anatomy, the features listed above as characteristic of the Ulmaceae also occur in the Moraceae (Tippo, 1938; Metcalfe & Chalk, 1950). An effort is done to prepare a tentative key for the identification of the genera of Ulmaceae native to Nepal.

Generic wood anatomical key to Nepalese Ulmaceae

A. Wood ring porous, rays heterocellular, sheath cells present. ***Celtis***

- **A1**. Transition from early to late wood abrupt. ***C. tetrandra***
- **A2**. Transition from early wood to late wood gradual. ***C. australis***

B. Wood ring porous or diffuse porous, rays homocellular, sheath cells absent. ***Ulmus***

- **B1**. Wood ring porous, crystal present, tyloses absent or present.
  - **b1**. Tyloses absent, marginal parenchyma present. Crystal present in axial parenchyma. ***U. chumlai***
  - **b2.** Tyloses present, marginal parenchyma absent, crystals present in ray cells. ***U. wallichiana***
- **B2**. Wood diffuse porous and crystal absent. ***U. lancifolia***

C. Wood diffuse porous, vascular tracheid absent, spiral thickening absent, rays heterocellular. ***Trema***

- **C1**. Tyloses present and crystal absent. ***T. orientalis***
- **C2**. Tyloses present or absent, simple crystal present in ray cell.
  - **c1.** Tyloses absent, vessel element length short, marginal ray cell 1-8. ***T. politorai***
  - **c2.** Tyloses present, vessel element length long, marginal ray cell 1-4. ***T. tomentosa***

Conclusion

Wood structure of eight species of *Celtis, Trema* and *Ulmus* native to Nepal is characterized by, 1) exclusively simple perforation plates, 2) alternate non-vestured inter-vessel pits, 3) relatively short vessel elements and fibers, 4) non-septate fibers with simple to minutely bordered pits, 5) mainly paratracheal parenchyma, 6) medium to large rays.

Acknowledgements

I would like to thank Dr. Lokendra Raj Sharma, former Director General, Department of Plant Resources, for his valuable suggestion and Dr. Shushim Ranjan Baral, former Chief, National Herbarium and Plant Laboratory for giving facilities in the laboratory. I am very much grateful to Prof. Dr. Mitsuo Suzuki, Tohoku University, Japan for providing the wood samples and going through the manuscript.

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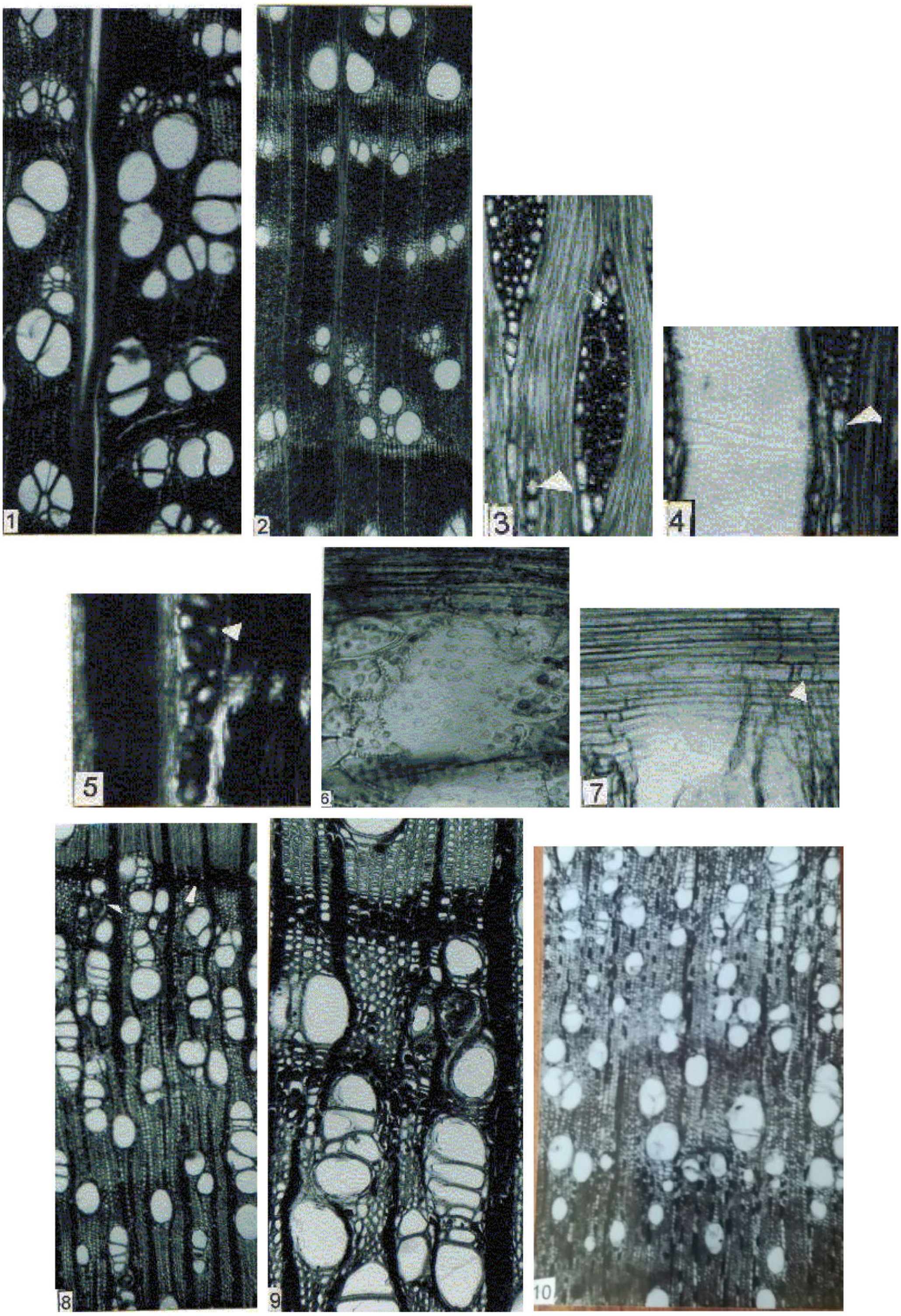

Figure 1&2(40X): .Cross section of *C. australis* (sp.no. 905) and *C. Tetrandra* (sp.no.9194227) showing early wood pores and distribution pattern of late wood pores, **Figure 3(100X):** Tangential section of *C. tetrandra* (sp.no. 9194150) showing crystals and sheath cells in ray cell, **Figure 4(100X):** Tangential section of *C. australis* (sp.no.905) showing crystals in ray cell, **Figure 5(100X):** Radial section of *C. tetrandra* (sp.no.9194114) showing tyloses in pores, **Figure 6(400X):** Radial section of *C. tetrandra* (sp.no.9194150) showing vessel parenchyma pit,ray vessel pit and procumbent ray cell, **Figure 7(100X):** Radial section of *C. australis* (sp.no.905)showing homogeneous ray cell and crystal, **Figure 8&9(40X&400X):** Cross section of *T. tomentosa* showing growth ring, diffuse porous wood, radial pores and tyloses, **Figure 10(40X):** Cross section of *T. politoria* (sp.no.9194249) showing indistinct growth ring and diffuse porous wood

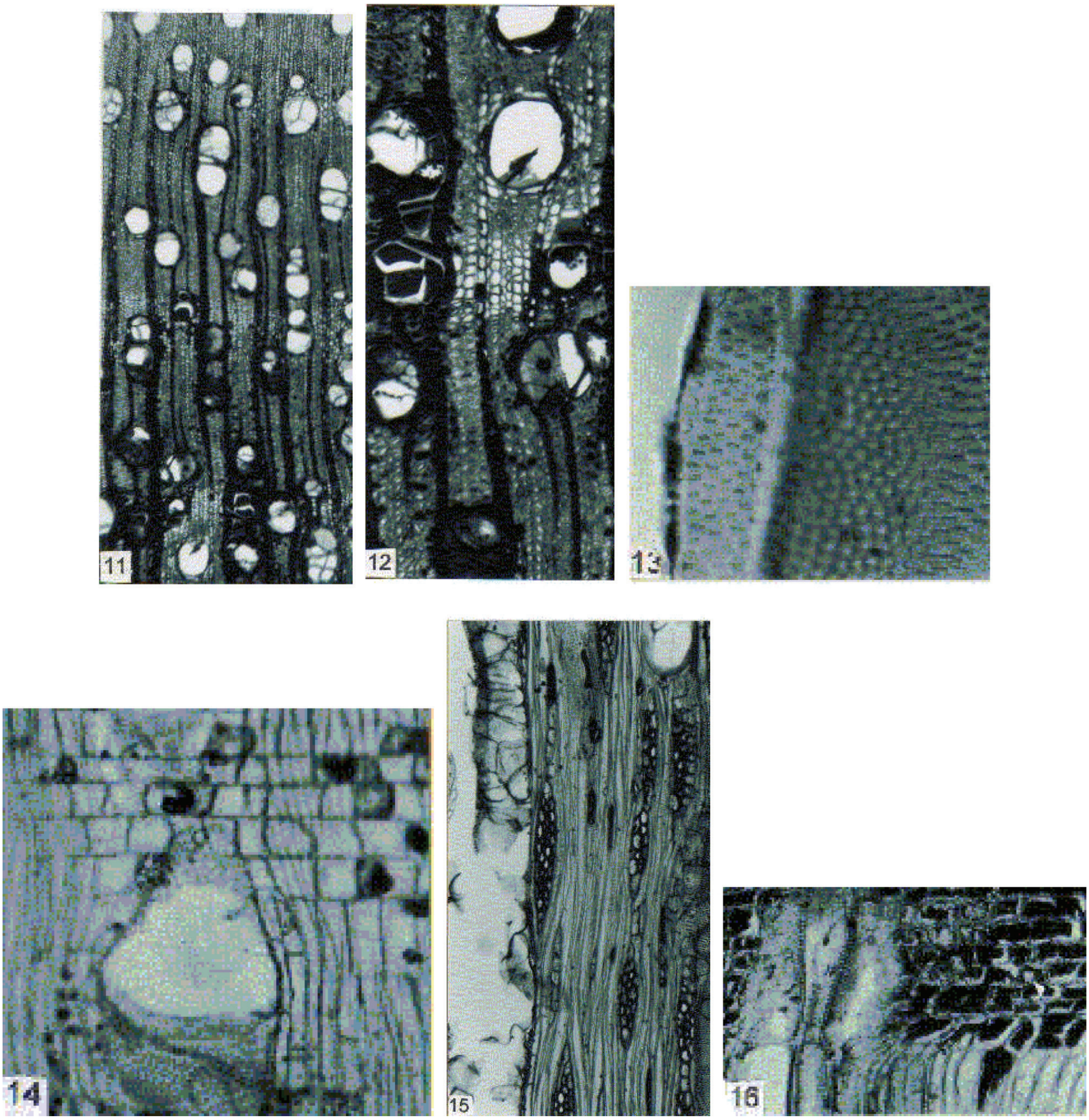

Figure 11&12(40X&100X): Cross section of *T. orientalis* (sp.no.9495082) showing diffuse porous wood, tyloses, confluent vescicentric paratracheal parenchyma and fairly distinct growth ring, **Figure 13(400X):** Tangential section of *T. tomentosa* (sp. no.9194116)showing alternate vessel pit, **Figure 14(100X):** RLS of *T. politoria* (sp.no.9194249) crystal in upright ray cell, **Figure 15&16(100X):** Tangential section and Radial section of *T. tomentosa* (sp.no.9194116) showing tyloses and crystals in ray cell and heterocellular and perforated ray cell

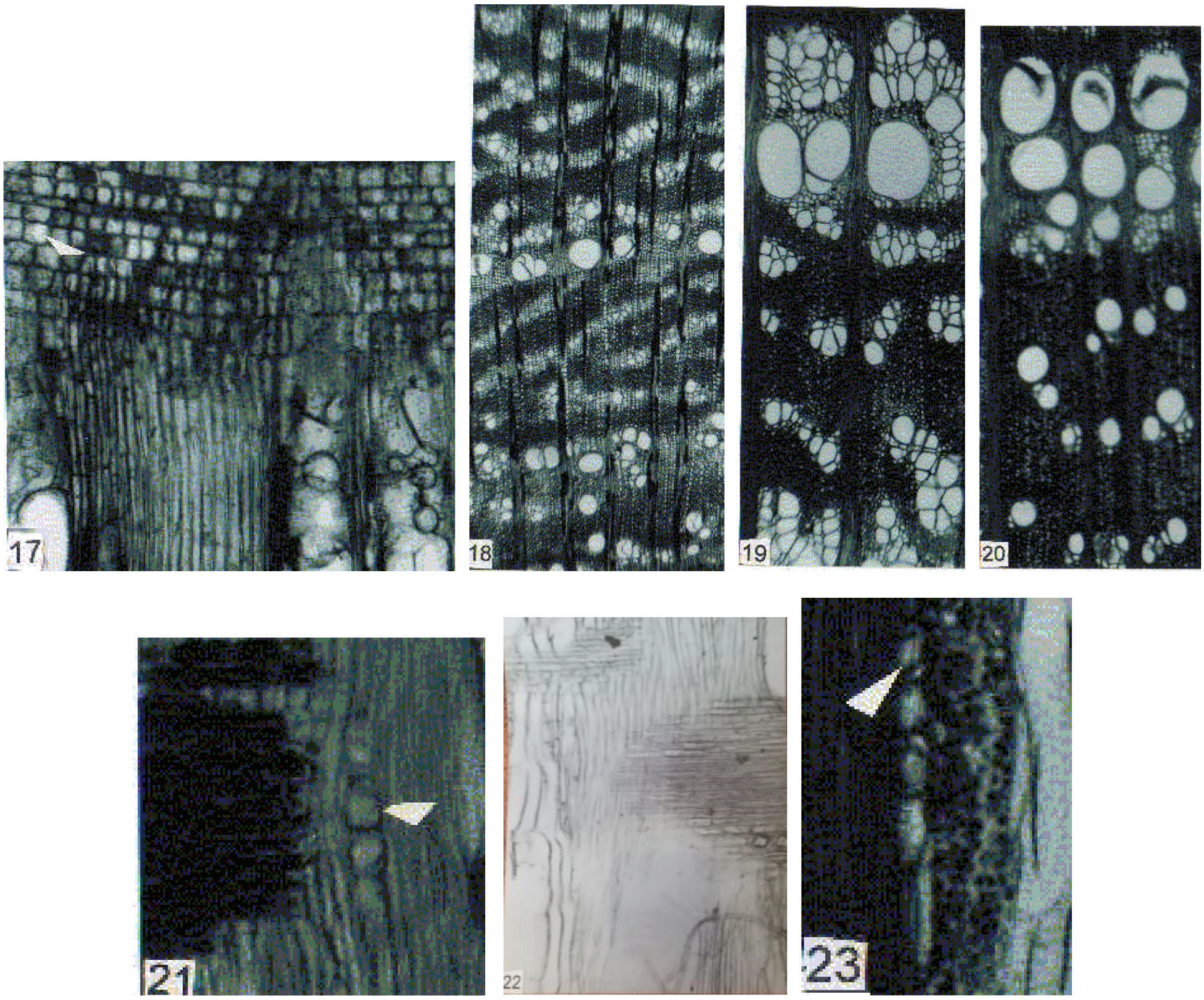

Figure 17(100X): Radial section of *T. orientalis* (sp.no.9495082)showing tyloses and perforated ray cell, **Figure 18(40X):** Cross section of *U. chumlai* (sp.no.9194242) showing dendritic arrangement of late wood pores, **Figure 19(40X):** Cross section of *U. wallichiana* (sp.no.9194224) showing festoon like tangential band of late wood pores and single layer of early wood pore, **Figure 20(40X):** Cross section of *U. wallichiana* (sp.no.904) showing three layer of early wood pore and its tangential pattern of distribution, **Figure 21(10X):** Radial section of *U. chumlai* (sp.no.9194242) showing chambered crystal in axial parenchyma, **Figure 22 (100X):** Radial section of *U. wallichiana* (sp.no. 904) showing crystal in procumbent ray cell, **Figure 23 (199X):** Tangential section of *U. walliochiana* (sp.no.9194224) showing crystal in ray cell

Appendix 1 : Quantitative wood characters of some species of the genus *Celtis, Trema* and *Ulmus* of the family Ulmaceae

Name of the Plants	Specimen No.	Altitude (m)	Pore character (µm)			Length	pit (µm)	Pore density	Libriform Fiber (µmµmµm)				Parenchyma cells (µm)			cells/strand
			RD	TD	Wall				RD	TD	Length	Wall	RD	TD	wall	
Celtis australis	905	1440	120-264	96-192	2.4-5.0	114-200	2.4-5.0	-	10.0-22	.7.0-19	456-1369	2.4-6.0	14-29	10.0-29	1.2	3.0-6.0
Celtis tetrandra	9194114	1120	48-188	24-144	5.0-10	288-912	5.0-10	35-42	14	10	600-1400	2.4-4	15	24	1.2	3-6.0
	9194131	900	30-240	90-200	2.4-7	100-280	5-7.0	27-35	12	12	650-1350	2.5	22	20	1.2	2-8.0
	9194150	1420	36-186	24-120	2.5	130-300	5-7.0	13-29	11	10	800-1600	2.5-4	15	13	1.2	2.0-9.0
	9194227	2370	90-170	80-170	2.4	180-400	5.0-10	11.0-19	12	10	480-1440	2.5	16	22	1.2	2.0-5.0
Trema orientalis	9495082	1560	48-168	48-100	2.4	144-456	7.0-10	12.0-23	10.0-24	7.0-19	576-912	2.4-3.6	7.0-24	7.0-24	1.2	2.0-6.0
Trema tomentosa	9194116	1060	60-216	48-168	2.4-7	230-700	5.0-10	9.0-25	16	15	350-1160	1-2.4	20	22	1.2	2.0-8.0
Trema politoria	9194249	1500	90-190	60-140	2.0-5.0	270-330	5.0-12	11.0-18	16	14	440-1300	2.4-5	16	22	1.2	2.0-5.0
Ulmus chumlia	9194242	1530	50-170	50-160	2.5	130-350	11.o-18	-	10	10	300-1200	1.2-2.4	15	13	1.2	2.0-5.0
Ulmus lancifolia	9194250	1370	144-288	144-288	2.4	130-300	2.4-5.0	-	22	22	600-1590	2.4	13	22	1.2	3.0-4.0
Ulmus wallichiana	9194224	2470	190-312	144-264	2.5	200-350	10	-	5	25	350-1250	3.6	20	30	1.2	1.0-5.0
	904	1440	120-264	96-192	2.4-2.5	144-200	7.9-12	-	10.0-29	10.0-19	925-1750	2.4-4.0	19-38	19-38	1.2	2.0-8.0

Note: RD = Radial diameter; TD = Tangential diameter; VD = Vertical diameter; V/Par.= Vessel parenchyma pit; R/V = Ray vessel pit

Appendix 2 : Quantitative wood characters of some species of the genus *Celtis, Trema* and *Ulmus* of the family Ulmaceae

Name of the Plants	V/par. Pit (µm)	Uniseriate rays		Multiseriate rays (µm)		Ray density	R/Vpit (µm)	Upright cells (µm)			Procumbent cells (µm)		
		cells	Ht.(µm)	width	height			RD	VD	TD	RD	VD	TD
Celtis australis	2.4-17	1.0-13	48-528	76-192	288-2400	9.0-11.0	2.4-18	19-67	24-71	10.0-15	38-161	14-29	8.0-15
Celtis tetrandra	5.0-24	2-6.0	120-240	24-48	168-720	15-Sep	5.0-17	15-50	20-40	10.0-20	40-130	10.0-25	8.0-15
	5.0-12	1-6.0	50-200	30-90	150-750	5-Mar	5.0-12	10.0-40	20-70	10.0-40	30-180	10.0-30	8.0-20
	3.0-7.0	1.0-18	60-400	20-80	90-1000	10.0-12.0	3.0-16	25-40	30-60	10.0-20	40-240	15-30	10.0-15
	10.0-20	1.0-16	48-720	48-72	144-912	4.0-9.0	5.0-20	15-20	20-60	12.0-20	40-150	10.0-20	10.0-20
Trema orientalis	5.0-22	1.0-9.0	72-360	30-50	144-840	3.0-5.0	5.0-22	20-40	35-199	10.0-20	30-7-	15-30	10.0-15
Trema tomentosa	5.0-10.0	2.0-5.0	72-168	48-108	168-552	6.0-8.0	4.0-12.0	15-40	20-100	8.0-20	30-80	20-30	8.0-15
Trema politoria	10.0-20	1.0-16	48-720	48-72	144-912	4.0-9.0	5.0-20	20-30	20-160	10.0-30	20-100	20-50	10.0-30
Ulmus chumlia	3.0-7.0	1.0-7.0	40-140	20-100	140-400	6.0-13	3.0-7.0	15-30	20-60	10.0-15	40-300	10.0-30	10.0-30
Ulmus lancifolia	5.0-7.0	1.0-9.0	50-110	20-120	40-620	5.0-12.0	5.0-7.0	10.0-20	10.0-30	8.0-10.0	20-200	10.0-30	10.0-15
Ulmus wallichiana	5.0-10.0	2.0-10.0	72-288	24-96	96-888	8.0-11.0	10.0-15	20-60	20-70	10.0-15	50-210	10.0-30	10.0-30
	5.0-10.0	3.0-16	120-312	48-96	95-888	7.0-11.0	5.0-12.0	-	-	-	29-304	10.0-19	10.0-25

Note: RD = Radial diameter; TD = Tangential diameter; VD = Vertical diameter; V/Par.= Vessel parenchyma pit; R/V = Ray vessel pit