Forest Research
Open Access
ISSN: 2168-9776

Maiti et al., Forest Res 2016, 5:1
DOI: 10.4172/2168-9776.1000166

Research Article Open Access

A Comparative Wood Anatomy of 15 Woody Species in North-eastern Mexico

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Abstract

A preliminary study has been undertaken on wood anatomy of 15 woody species in northeast mexico. There exists large variation among species in wood anatomical traits such as porosity, vessel diameter, its distribution, parenchyma, compactness of ground tissues and fibre cell characteristics. Most of the species are ring to semiring porous viz. *Acacia amentacea, Acacia berlandieri, Acacia shaffneri, Acacia wrightii, and* only few of them are diffuse porous viz. *Diospyros palmeri, Diospyros texana.* Fibre cell characteristics also showed large variations in morphology, size, lumen breadth and in compactness. Most of the species have narrow vessels, *viz.*, *Acacia berlandieri, Acacia shaffneri, Acacia wrightii, Helietta parviflora, and others,* while *Celtis laevigata* and *Caesalpinia mexicana* possessed big sized vessels. Many of the species having narrow vessels are expected to protect the vessels against cavitation during drought and freezing as reported in the literature. Narrow vessels are adaptive traits in xeric habitats. All these wood anatomical traits could be utilized to distinguish species as well as quality determinations of species. The variation in hydraulic systems determine the capacity of water transport among species.

Keywords: Wood anatomy; Hydraulic architecture; Woody species; Variation; Porosity; Vessel size; Fibres

Introduction

Wood is a hard, fibrous structural tissue present in the stems and roots of woody plants. Its main use is for furniture and building construction [1], used as firewood for thousands of years. Wood is composed mainly of three types of cells such as wood fibre cells (sclerenchyma), vessels, and wood parenchyma derived by secondary cambium.

In addition to the basic studies on the growth and development of wood elements, wood anatomical features play important role in the phylogeny of the species and also the adaptive capacity of the species to environmental stresses. Xylem vessel characteristics (such as length, breadth, perforation plate orientation and pits) predict general ecological and phylogenetic trends in wood anatomy, which suggest possible evolutionary tremds on the basis of the xylem vessel and other traits [2-9].

Significant research advances on wood anatomy and its significance in dendrology and application.

A study on anatomy of softwoods and the hardwoods of the world demonstrate characteristic endgrain patterns and intricate motifs (Eric Meier (http://www.wood-database.com/wood-articles/hardwood-anatomy/).

Wood anatomy is used to determine the specific characteristics of species. A comparative study has been undertaken on macroscopic and microscopic anatomical characteristics of five species of the family Rosaceae, *Crateagus mexican*, *Pyrus cummunis*, *Pyrus malus*, *Prunus americana* and *Prunusdomestica.* The results showed similar macro and microscopic characteristics [10]. In another study, it was observed that there exists a large variability in size, cell wall thickness and lumen breadth which may predict the quality and utility of the particular species [11].

Few studies have been undertaken on ultrastructure and biochemical changes in the development of wood elements. Increasing concentrations of ions flowing through the xylem of plants produce rapid, substantial, and reversible decreases in hydraulic resistance. One of the properties of polysaccharide hydrogels is to swell or shrink due to imbibition. When pectin swells, pores in the membranes are pressed, slowing water flow to a trickle. This remarkable control of water movement may allow the plant respond to drought conditions [12].

Interlocked grain causes change in the orientation of axial elements. In a study, vessel and fibre orientations in *Acacia mangium* Wild were compared macroscopically and microscopically to analyse the interlocked grain. A method to print the cylindrical surface of a dry wood disk after bark exfoliation was devised to evaluate the stem axis and circumferential grain fluctuation which revealed circumferential heterogeneity in the vessel orientation. Fibre orientation manifested on some radial splits also was heterogeneous microscopy. They measured fibre orientation angle with reflecting and polarized light microscopy, respectively, and fast Fourier transform. Both vessel and fibre orientations had a similar radial tendency and distinct inversion of the grain. However, the vessel orientation had larger amplitude of change than fibre orientation [13].

Using UV microspectrophotometry [14] studied the secondary wall structure of the tension wood of *Laetia procera* Poepp. (Flourtiaceae). It was observed that the secondary wall with alternate arrangement of thick and thin layers, possess S1 + S2 + S3 layers. It was observed that in the thick secondary wall, cellulose microfibril angle is very low (very

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Received December 04, 2015; **Accepted** January 07, 2016; **Published** January 11, 2016

Citation: Maiti R, Rodriguez HG, Para AC, Aruna Kumari CH, Sarkar NC (2016) A Comparative Wood Anatomy of 15 Woody Species in North-eastern Mexico. Forest Res 5: 166. doi:10.4172/2168-9776.1000166

close to fibre axis) and cellulose micro fibrils are well organized but in thin layer the cellulose microfibrils are less organized and oriented with a large angle in the axis of the cell. Thick layers are highly lignified.

A study was undertaken on structural heartwood characteristics of *Prosopis laevigata* (Humb. & Bonpl. *Ex* Wild.) M.C. Johnst., using light microscopy coupled with a digitised image analysis system. Average fibre length is 975 µm, the fibres are thick-walled with a single cell wall thickness of 13 µm on average. Average diameter of the vessels which are arranged in non-specific patterns differs significantly between earlywood (116 µm) and latewood (44 µm). The chemical distribution of lignin and phenolic deposits in the tissue was investigated by means of scanning UV microspectrophotometry (UMSP). Monosaccharides were qualitatively and quantitatively determined by borate complex anion exchange chromatography. Holocellulose content ranged between 61.5 and 64.7% and Klason lignin content between 29.8 and 31.4%. [15]. Later, a study was undertaken on wood anatomy and ultrastructure of the 3 species of wood of *Prosopis* growing in heterogeneous forest dry Chaqueño Park. The species studied were: *Prosopis vinalillo, P. alba* and *P.nigra*. The results show that the 3 species are very similar and consistent with the structural features of the subfamily Mimosoideae. However, the number of vessels/ mm^2 was quite variable between species and between individuals of the same species. Samples observed under scanning electron microscope showed displaying ornamentations in pits and striations on the vessels walls. These striations were shown to be characteristics of the 3 *Prosopis* species [16].

Environments play a great role on wood anatomical characters and measured in tree-rings have proved to be useful in dendrochronology. A study was undertaken on wood anatomical features measured in tree-rings in the East-Ore Mountains, Germany in rings of trees grown under severe stresses. It is observed that environmental changes have caused modifications or adaptations of structural features in tree-rings. Overall, wood anatomy reveals clearly that growth and development of trees reflects dynamic processes [17]. Another study on wood antomy and annual rings of *Prosopis pallida* in the arid and semi-arid lands of the American continent revealed that *P. pallida* produced well-differentiated annual growth rings which are related to with precipitation events owing to El Niño Southern Oscillation phases [18].

Wood anatomical traits are found to be related to the adaptation of woody plant to environmental stresses. Various authors reported that the hydraulic architecture of woody plants determine the adaptive strategies to adverse climatic conditions of woody plants [3,6,8,19-28]. From a functional viewpoint, few vessel attributes such as narrow pores and pores multiples acts against cavitation and embolism under hot summer and freezing stress, thereby offering mechanical strength [22,29-33].

A study undertaken on the anatomical heartwood characteristics viz., fiber length (µm), diameter of vessels (µm), and the area of the vessels (µm² revealed that in the locality Linares, Nuevo Leon, Mexico, with higher precipitation and lower temperature the wood showed higher fibre length and higher diameter of the vessels than China, Nuevo Leon [34].

Few studies have been undertaken on wood anatomy of Mediterranean woody species in relation to ecology and ecophysiology.

Various authors stated that the presence of narrow vessels and multiple vessels acts against cavitation during summer stress and winter freezing. Sperry [35] studied patterns in hydraulic architecture and their implications for transport efficiency.

The stem and root wood anatomy of the shrub-*Phlomis fruticosa* (Labiatae) a malacophyllous Mediterranean drought semi-deciduous species [36] has shown that the stem is comprised of diffuse-porous, narrow vessels arranged in tangential bands, vessel elements with oblique simple perforation plates, non-vestured, clustered alternate intervessel pits. It is concluded that though narrow vessels offer high conducting resistance, they are less vulnerable to cavitations, thus providing safety during summer drought and winter freezing. Vessel grouping is a widespread phenomenon in most woody species, especially those from the arid desert flora and Mediterranean species [20,37].

De Micco et al. [38] studied wood anatomy and hydraulic architecture of stems and twigs of some Mediterranean trees and shrubs along a mesic-xeric gradient. This study focuses on the anatomy of juvenile and mature wood of some species representative of continuous sequences of Mediterranean vegetation formations according to gradients of water availability, from xeric to relatively mesic: Although some attributes (i.e. porosity and type of imperforate tracheary elements) were similar in young twigs and older rings, other traits (i.e. vessel frequency and size) evidenced the different hydraulic properties of twig and stem wood. The difference between juvenile and mature structures was large in the species of the mesic end of the gradient while it was relatively small in those more xeric. The species showed large variations in wood anatomical traits, most of them are diffuse porous, few semi to ring porous, vessels are narrow resistant to cavitation during drought and freezing.

A study was undertaken on the seasonal dimorphism in wood anatomy studied [39] in Mediterranean subsp *Cistus incanus* has shown that brachyblast wood was safer than dolichoblast and has narrower and more frequent vessels. The measurement of other specific anatomical traits, such as vessel wall thickness, suggested that brachyblast wood has a higher resistance to implosion due to drought-induced embolism.

The present study is undertaken to determine the variability of wood anatomical structure 4s among 15 woody swpecies in Norteastern Mexico and to establish its possible relation with wood quality and utility.

Materials and Methods

The study was undertaken in the municipality of Linares, Nuevo León in Forest Faculty of Universidad Autónoma de Nuevo León (24°47'N; 99°32'E), at sea level of 350 m nm. The type of climate present according to Köppen, modified by Arcía (cited by [40]) is subtropical and semiarid condition with hot summer. The average monthly air temperatures oscillate between 14.7°C in January to 3°C in August, although the common temperature in summer is 45°C. The average annual precipitation is approximately 805 mm with a bimodal distribution. This site is situated in soils which are dark brown deep vertisols. The predominant vegetation is Tamaulipan Thorn Scrub or subtropical thorn scrub [41,42].

Wood samples were collected from Thornscrub forest around the Forest Science Faculty, Linares, UANL. The samples are soaked in water and boiled to soften them. Then, cross and longitudinal sections (15–25 lm thick) were cut with a wood microtome. Depending on xylem structure, the sections are general transversal, radial and tangential. Transversal section was cut perpendicular to the length of trunk. In this plain, is observed the growth rings and its characteristics, breadth of rings, percentage early and late wood and type of transition among them. Rays were largely observed as lines which cross the growth ring in right angle. Other microscopic elements are type of pores, grouping and arrangement of pores, size of pores, size of rays, type of parenchyma, texture, type of transition among soft and heartwood, radial section, perpendicular to the rings. These sections were stained with 2% Safranin-O in water [43] and mounted with Canada Balsam and photographed by a digital camera fixed on to the microscope.

Results and Discussion

In the context of description of wood anatomical characteristics of 15 woody species in the semiarid regions of Northeast Mexico it may be stated that there existed large variation in various wood anatomical traits as well their hydraulic architecture. The specific distinguishable characteristic traits of each of these species are described as follows.

Description of wood anatomy of few woody species of Northeast Mexico

Microscopic characteristics (transverse section) The transverse section of a stem showing organization of primary and secondary xylem of each species is shown in Figure 1.

Wood rings are porous, vessels are not uniform in size, shape. Majority of vessels are solitary, very few are in multiples of 2, oval to rectangularish. Axial parenchyma is paratracheal, parenchyma aliform, confluent. Apotracheal parenchyma aggregated in tangential broad bands. Narrow marginal parenchyma is observed. Medular rays are distinct, little wavy separating radial bands of pores. Sclerenchyma is not abundant. Fibre cells, long with broad lumen, thin walled. Vessels small, truncated with slightly inclined end walls with broad perforation plate, pits round, numerous, alternate in arrangement. Wood tissue compact, seem to be hard associated with thick walled fibre cells and numerous pores (vessels) (Figure 2).

Wood diffuse porous, vessels mostly solitary, round to oval in shape, few in groups of 2 or 3, numerous, contained gummy substance. Non uniform in size. Vessels that are oval in shape, most of them are large, some are very small. Axial parenchyma confluent. Apotracheal parenchyma in the form of broad band, scalariform, marginal parenchyma is visible. Medulary rays thin to broad traverse through wood tissue. Rays short, more or less spindle shaped, mostly 2-3-cells in breadth, few uniseriate, heterogeneous, cells oval in shape. Vessels truncated, broad, short, more or less with straight simple perforation plates, pits elongated scalariform alternate in arrangement. Medullary ray cells stratified, multilayered, stratified, pits oval in shape, alternate in arrangement, evolutionary more advanced. Wood tissue is compact with thick walled fibre cells, profuse vessels, seem to be hard.

The apex of fibre cells is pointed to round, the lumen is somewhat

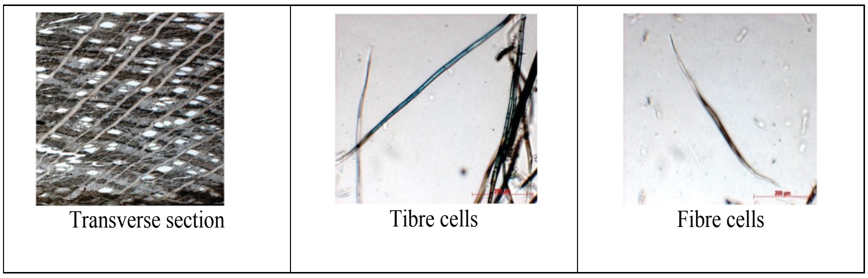

Figure 1: The transverse section of *Acacia amentacea* (10 ×).

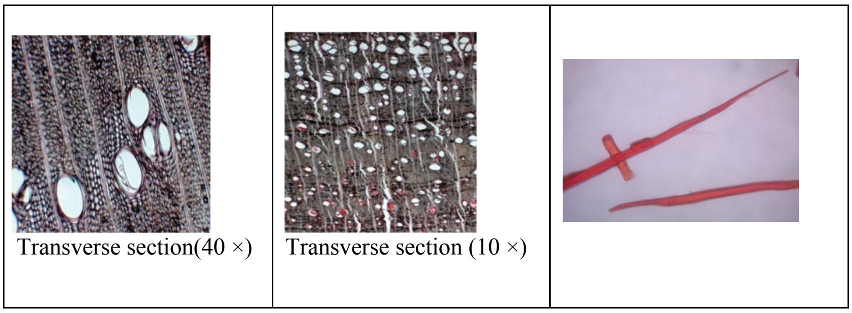

Figure 2: Transverse section of *Acacia berlandieri (*10 ×).

Figure 3: Different sections of *Acacia farnesiana (*10×).

broad, the cell wall is thin, but little lignified. Wood is semi-hard for fabrication of furniture (Figure 3).

Wood diffuse porous, vessels, ovoidal in shape, scanty, mostly solitary, big and small sized. infrequent. Pratracheal parenchyma aliform confluenytric and confluent, surrounded by many cells, apotracheal parenchyma in broad band, scalariform, medullary rays mediumly broad and thin traverse through the wood tissue. Rays spindle shaped short, 2-4 celled broad, heterogeneous, small celled. Rays multiseriate, broad, stratified fibre cells long, pointed, broad lumened with thin wall. Suitable for paper pulp. Vessels broad, short, truncated with straight perforation plate, pits elongated, alternate, evolutionary advanced. Wood tissue compact, hard. Some fiber cells are non-uniform, few are uniform, apex pointed, the lumen is broad, cell wall is mediumly thick but little lignified (Figure 4).

Wood diffuse porous, vessels are narrow, mostly solitary, few of two to three cells, oval in shape, profuse in numbers. Paratracheal parenchyma aliform confluent, apotracheal parenchyma in broad bands, scalariform, medulary rays, mediumly thick traverse through wood tissue. Vessels contained gummy materials. Wood is compact and hard (Figure 5).

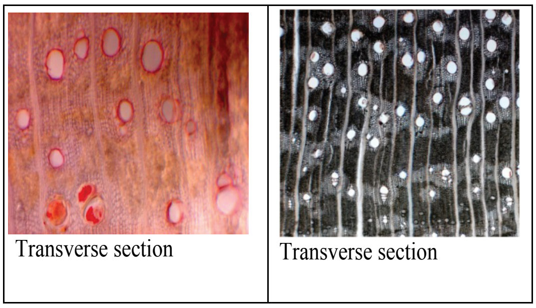

Figure 4: Transverse section of *Acacia shaffneri* (10 ×).

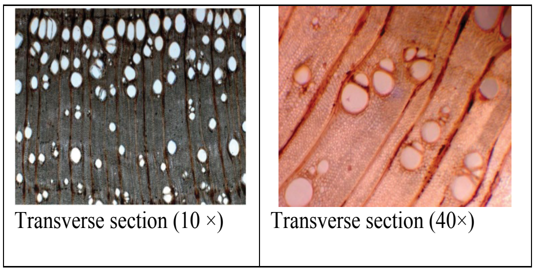

Figure 5: Transverse section of *Acacia wrightii (*10 ×).

Wood diffuse porous, vessels numerous, small sized, oval, some are very small. Wood tissue highly compact revealing that this wood is very hard. Paratracheal parenchyma aliform confluent, apotracheal in bands, scalariform. Rays narrow, long, 2-4 celled, heterogeneous, ray cells non-stratified (Figure 6).

Wood arranged in rings, diffuse porous, vessels few, arranged in groups 3 to 5 cells, ovoidal but compressed. Parenchyma vascicentric aliform. Apotracheal parenchyma in bands. Rays spindle shaped moderately long, maximum 3 to 6 celled in breadth, tapering, heterogeneous, compressed rays spindle shaped, very broad, mutilayered, composed highly compact small round cells, seems to be homogenous. Owing to the profuse quantity of ray and parenchymatous cells, the wood is soft. Rays are multiseriate, non-stratified. Vessels cylindrical, broad, medium in length, pits large, alternate in arrangement (Figure 7).

Wood partially ring porous, vessels are small and numerous, mostly isolated, few in radial groups of 3-4 cells, oval in shape. The vessels arranged in a ring of few cells, mostly in multiple 3-4 cells, large sized, somewhat ovoidal. Wood tissue compact. Paratracheal parenchyma vascicentric, apotracheal parenchyma diffuse. Owing to compact tissue, the wood seems to be very hard. Pratracheal parenchyma vascicentric. Apotracheal parenchyma in bands, somewhat scalariform. Rays uniseriate to biseriate, heterogeneous, short, cells round. Vessels cylindrical, long with oblique perforation plate, pits round, alternate. Vessels broad, long, cylindrical, pits oval, large sized, alternate in arrangement. The apex of fibre cells is pointed, cell wall is medium thick, lumen is thin. Good for soft furniture (Figure 8).

Wood seems to be partially ring porous, vessels arranged in clusters and several of these are of various sizes. Paratracheal parenchyma vascicentric, apotracheal in bands, wood tissue highly compact with profuse sclerenchyma, thereby imparting hardness to wood. Rays are small, mostly bi or tri-seriate, heterogeneous. Wood contained numerous exudates, gums. Wood tissue is loose, probably offering soft wood. The apex of fibre cells pointed with broad lumen, suitable for paper pulp (Figure 9).

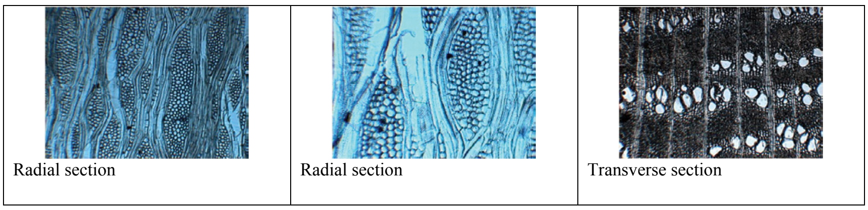

Figure 6: Transverse section of *Cordia boissieri* (10×).

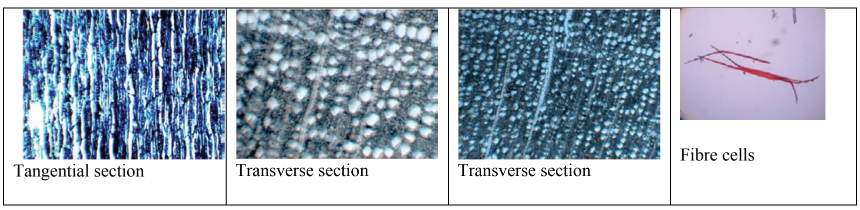

Figure 7: Transverse section of *Helietta parviflora (*10 ×).

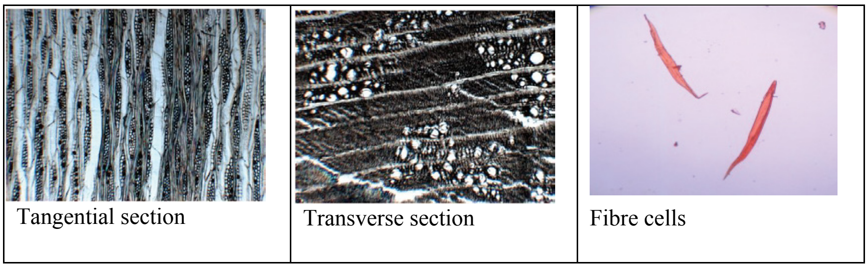

Figure 8: Transverse section of *Condalia hookeri* (10 ×).

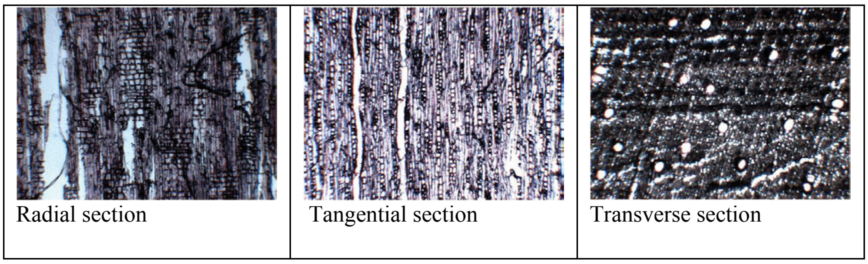

Figure 9: Different section of *Diospyros palmeri* (10 ×).

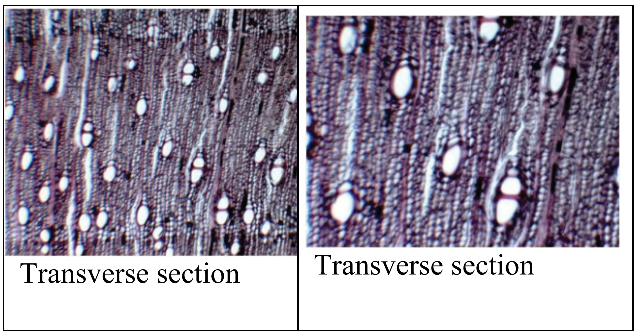

Figure 10: Transverse section of *Xanthoxyllum fagara* (10 ×).

Wood diffuse porous, vessels are oval or compressed. Parenchyma paratracheal vascicentric. Apotracheal parenchyma diffuse, terminal parenchyma present, fibres profuse, thereby imparting wood to be very hard. Rays numerous, mostly uniseriate, few biseriate composed of heterogenous ovoidal cells (Figure 10).

Wood appears to be semi-ring porous to ring porous. Vessels few, ovoid, not many, soltitary mostly few in radial groups of 2-3 cells, ovoidal in shape. Paratracheal parenchyma, vascicentric. Apotracheal parenchyma, scalariform. Terminal parenchyma present near the annual ring. Apotracheal parenchyma, aggregated. Wood is composed of mostly soft parenchymatous tissue, thereby, imparting soft wood nature. Rays short mostly uniseriate or 2-3 seriate, heterogenous (Figure 11).

Wood diffuse porous, vessels numerous, round, solitary, few in groups of 2-3. Paratracheal parenchyma, vascicentric. Apotracheal parenchyma scalariform in bands. Ray numerous, uniseriate, seems to be homogeneous of rectangularish cells. Vessels mediumly long with slightly inclined perforation plate. Wood tissue loose, probably producing soft wood (Figure 12).

Wood ring porous, Vessels scanty, mostly solitary, few in radial ring of 2 cells, separated by by long medullary rays. Paratracheal parenchyma vascicentric. Apotracheal parenchyma scalariform. Wood tissue is semi-compact imparting semi-hard wood nature (Figure 13).

Wood semi-ring porous. Vessels numerous, not uniform in size, round to oval in shape. Parenchyma seems to be partially vascicentric, The presence of profuse ground tissue seems to make the wood very soft. The fiber cells are uniform, apex is pointed, cell wall is thin, the lumen is little broad, suitable for paper.

The anatomical studies of these fifteen woody tree species of north eastern Mexico, has shown the existence of wide variability. Most of the species are ring to semiring porous viz. *Acacia amentacea, Acacia berlandieri, Acacia shaffneri, Acacia wrightii, Cordia boissieri, Helietta parviflora, Condalia hookeri, Xanthoxylum fagara, Celtis pallida, Celtis laevigata, Caesalpinia mexicana, Eysenhardtia polystachya*; only few of them are diffuse porous viz. *Diospyros palmeri, Diospyros texana.*

Fibre cell characteristics also showed large variations in morphology, size, lumen breadth on the basis of which the species are recommended for its utility such as furniture [44]. On the basis of compactness we recommended species as soft and hard wood. With respect to vessel size, most of the species have narrow vessels, *viz.*,

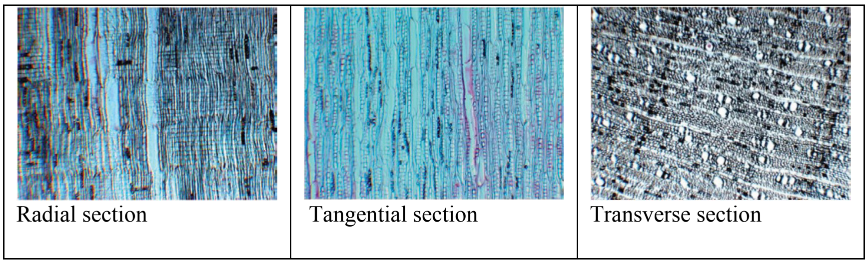

Figure 11: Different Section of *Diospyros texana* (10 ×).

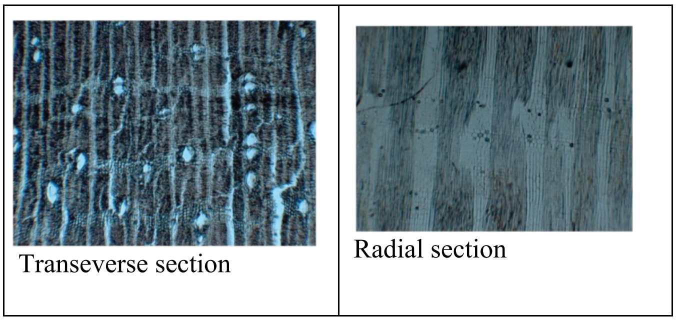

Figure 12: Transeverse section and Radial section of *Celtis pallida* (10 ×).

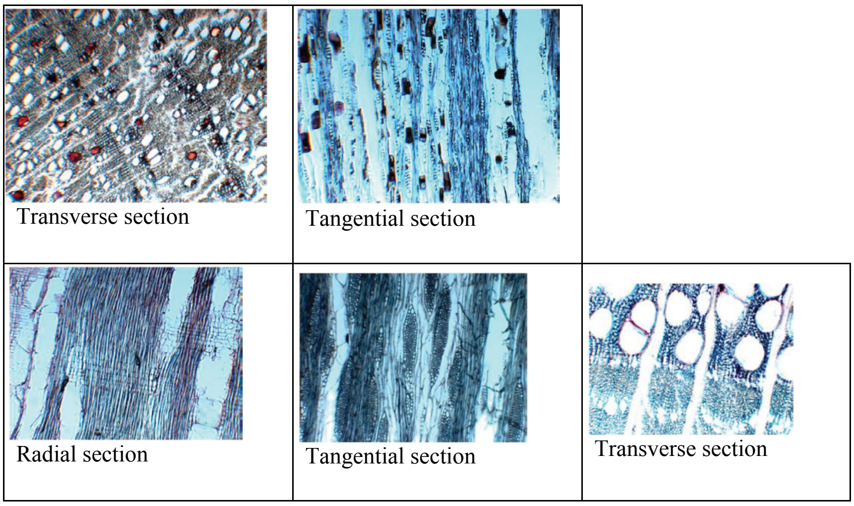

Figure 13: Different section of *Celtis laevigata* (10 ×) and *Eysenhardtia polystachya* (10 ×).

Acacia berlandieri, Acacia shaffneri, Acacia wrightii, Helietta parviflora, Cordia boissieri, *Diospyros palmeri*, *Celtis laevigata*, *Eysenhardtia polystachya, Xanthoxyllum fagara*. *Celtis pallida* contained medium sized vessels, while *Celtis laevigata* and *Caesalpinia mexicana* possessed big sized vessels. Recently Maiti [11] reported large variation in fibre cell morphology and its dimentions ampng 30 species of woody plants in Northeastrn Mexican and its possible relation to wood quality and its utility. In another study they interpreted that wood anatomy could predict wood quality [45].

With respect to variations of hydraulic architecture, various authors have emphasized the role of hydraulic architecture of woody plants in the adaptive strategies to adverse climatic conditions of woody plants [3,6,8,19-27]. From a functional viewpoint, various studies have discussed vessel pore size affecting conductivity, vulnerability to cavitation and mechanical strength [46]. The present study coincides with the observation with these authors that many of the species possess narrow vessels which although impose transport of water but protect the vessels against cavitation during drought and freezing. This has been observed in the Mediterranean climates where plants were exposed to hot dry climate separated by hard winter as have been reported by few authors [47]. Similar to the climatic conditions in the Mediterranean regions the climatic condition in Northeast Mexico where the trees are exposed to hot dry summer with temperature raising to more than 40°C separated cold climate of winter season with temperature going below to 5°C. It has been reported that vessel grouping is a widespread phenomenon in most woody species, especially those from the arid desert flora and Mediterranean species [48]. Therefore the species with small narrow vessels mentioned have strategy to adapt both to hot and

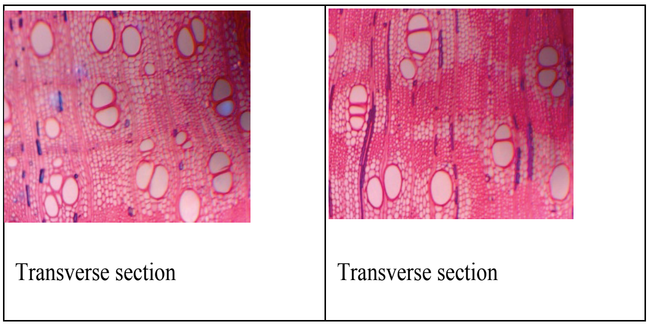

Figure 14: Transverse section of *Caesalpinia Mexicana* (10 ×).

cold climate against cavitation. The species having big vessel diameter may be susceptible to drought such as *Celtis pallida, Caesalpinia mexicana* or they may have deep root system for adaptation to semiarid climates in northeast Mexico.

Conclusions and Research needs

Our preliminary study on wood anatomy of 16 woody species in Northeastern Mexicio indicates that there exists large variability in wood anatomical traits which can be related in the species identification and quality determinations of the species. There is also large variability in the morphology, length, wall lignification of fibre cell in the woods among species. The intensity of lignification contribute to the strength and high quality timber for furniture, soft wood containing high amount of parenchymatous tissue and thin walled fibre cells for fabrication soft furniture, fences. Woods having fibre cells with broad lumen and thin wall could be suitable for the manufacture of paper documented in the literature. Therefore, there is a great necessity to evaluate the wood anatomical structures of trees in a forest and classify them for their suitability of various uses on the basis of wood anatomical structure. The selected wood of a particular species could be tested for its physical and chemical properties in a wood technology laboratory for its confirmation (Figure 15).

Wood ring porous traversed by broad medullary rays. Vessels solitary, few of 2 cells. Paratracheal parenchyma vascicentric. Apotracheal parenchyma in the form of bands. Marginal parenchyma few. The presence of profuse parenchyma imparts softness to the wood, not suitable for furniture. Rays are broad mostly multiseriate, heterogeneous. Vessels mediumly long with slightly inclined perforation plate.

Wood semi-ring to diffuse porous, large sized, mostly solitary, few in groups of 2. Parenchyma is aliform to confluent. Apotracheal parenchyma aggregated. Wood is composed numerous soft tissue, thereby, imparting softness to the wood. Rays are uniseriate, homogenous. The fiber cells are uniform, wide, mediumly long, apex pointed, lumen broad, uniform. Cell wall is thin. Good for paper pulp.

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