Comparative Wood Anatomy of Twelve Woody Plant Species in Northeastern Mexico and Its Relation to Taxonomy and Wood Quality

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Abstract

The present study has been undertaken on wood anatomy of 12 woody species at Linares, northeast Mexico. The results show 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 shaffneri, Acacia wrightii,* and *Eysenhardtia polystachya*. Fibre cell characteristics also showed large variations in morphology, size, and lumen breadth. Most of the species have narrow vessels, *viz*., *Acacia shaffneri, Acacia wrightii, Helietta parvifolia,* contained medium sized vessels. Many of the species possess narrow vessels which although impose transport of water but protect the vessels against cavitation during drought and freezing and the species with small narrow vessels mentioned have strategy to adapt both to hot and cold climate against cavitation. All these wood anatomical traits could be utilized to distinguish species as well as quality determinations of species. The variation in hydraulic systems determines the capacity of water transport among species. Besides, these variations in wood anatomical traits such as wood compactness, high density of thick walled wood fibres could be related to good quality of timber for fabrication of strong furniture, on the other hand, the species having broad lumen and thin cell wall could produce good paper pulp which should be confirmed in future study.

Keywords: Anatomy, fibres, porosity, quality, shrubs, trees, variability, wood

1. Introduction

Wood is an important product of woody plants for wood industry and used for furniture and building construction also used for fire wood (Reid et al., 1990). Significant research advances have been undertaken on wood anatomy and its significance in dendrology and application. Few studies have been undertaken on ultra-structural and biochemical changes in the development of wood elements.

A study has been undertaken on vessel and fibre orientations in *Acacia mangium* Willd. Using reflecting and polarized light microscopy, and fast Fourier transform. Both vessel and fiber orientations had a similar radial characteristics and distinct inversion of the grain. However, the vessel orientation showed a larger amplitude of change than fiber orientation (Ogata et al., 2003). The secondary cell wall structure of tension wood of *Laetiaprocera* Poepp. (Flourtiaceae), revealed alternate arrangement of thick and thin layers with S1+S2+S3 using UV microspectrophotometry. It was observed that in the thick secondary wall, cellulose microfibril angle is very low (very close to fibre axis) and cellulose microfibrils 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 (Ruelle et al., 2007).

A study has been undertakem on structural heartwood characteristics of *Prosopis laevigata* (Humb. & Bonpl. *Ex* Willd.) M.C. Johnst., using light microscopy coupled with a digitalized image analysis system. The chemical distribution of lignin and phenolic deposits in the tissue was studied by means of scanning UV microspectrophotometry (UMSP). Monosaccharides were 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%. Subsequent extraction of the soluble compounds was performed with petrolether, acetone/water and methanol/water by accelerated solvent extraction (ASE). Major compounds in acetone/water extracts were identified as (-)-epicatechin, (+)-catechin and taxifolin, and quantitatively determined by liquid chrom (Carrillo et al., 2008). Later, a study undertaken on wood anatomy and ultra structure of the three species of wood of *Prosopis* (*Prosopis vinalillo, Prosopis alba* and *Prosopisnigra*) growing in heterogeneous forest dry Chaqueno Park reveal that the three species show similarity in the structural features of the subfamily Mimosoideae.

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However, the number of vessels/mm^2 showed large variations among species and between individuals of the same species. Using scanning electron microscope, the ornaments in pits and striations on the vessels walls were observed. The variation in striations was shown to be characteristics of the three *Prosopis* species (Bolzon et al., 2010).

Environments play a great role on wood anatomical characters. 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. They observed that environmental changes have caused modifications or adaptations of structural features in dated tree-rings, revealing that growth and development of trees reflects dynamic processes (Wimmer, 2002). Another study on wood anatomy and annual rings of *Prosopis pallida* in the arid and semi-arid lands of the American continent revealed that *P. pallida* has well-differentiated annual growth rings, which is related well with precipitation events associated to El Nino Southern Oscillation phases (Lopez et al., 2005).

Wood anatomy is used to determine the specific characteristics of species. A comparative study undertaken on macroscopic and microscopic anatomical characteristics of five species of the family Rosaceae, *Crateagus mexican*, *Pyrus cummunis*, *Pyrus malus*, *Prunus americana* and *Prunus domestica, s*howed similar macro and microscopic characteristics (Perez et al., 2008). There exists a large variability in size, cell wall thickness and lumen breadth which may predict the quality and utility of the particular species (Maiti et al., 2015). Recently in a comparative study of wood anatomy of 20 species of Tamaulipan Thorn Scrub, Linares, Northeast of Mexico showing a large variability in porosity, types of parenchyma, ray cells which could be used in the taxonomic determination and quality determination of the species. Wood anatomical traits are found to be related to the adaptation of woody plants to environmental stresses. A study was undertaken on the anatomical heartwood It was observed that in the locality of Linares, Nuevo Leon, Mexico, with higher precipitation and lower temperature the wood showed higher fibre length and higher diameter of the vessels than a the drier site of high temperature (Carrillo-Parra et al., 2013).

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 (Carlquist, 1984; Ewers and Fisher, 1991). The hydraulic architecture of woody plants determines the adaptative strategies to adverse climatic conditions of woody plants (Carlquist, 1989; Zimmermann, 1983; Baas and Carlquist, 1985; Baas and Schweingruber, 1987; Tyree and Ewers, 1991; Tyree et al., 1994; Hacke and Sperry, 2001; Sperry, 2003; Baas et al., 2004). From a functional viewpoint, few vessels attributes such as narrow pores and pores multiples acts against cavitation and embolism under hot summer and freezing stress, thereby offering mechanical strength (Zimmermann, 1982; 1983, Ewers, 1985; Salleo and Lo Gullo, 1993; Hacke et al., 2006; Jacobsen et al., 2007).

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 (2005) studied patterns in hydraulic architecture and their implications for transport efficiency. A study undertaken by Psaras and Sofroniou (2004) on the stem and root wood anatomy of the shrub-*Phlomis fruticosa* (Labiatae) a malacophyllous Mediterranean drought semi-deciduous species revealed 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 (Fahn et al., 1986; Carlquist, 1989). Veronica et al. (2009) studied wood anatomy and hydraulic architecture of stems and twigs of some Mediterranean trees and shrubs along a mesic-xeric gradient. 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) revealed 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 conditions. In Mediterranean-type ecosystems, seasonal dimorphism is an adaptive strategy to save water by developing brachyblasts with xeromorphic summer leaves as opposed to dolichoblasts with more mesomorphic winter leaves. A study undertaken on the seasonal dimorphism in wood anatomy studied (Veronica et al., 2009) 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 broachyblast wood has a higher resistance to implosion due to drought-induced embolism.

The main objective of the paper to study in variability of wood anatomical traits in twelve species of native woody plants at Linares, Northeastern Mexico and its significance and adaptation to drought.

2. Materials and Methods

2.1. Study site

The study was undertaken in the municipality of Linares, Nuevo Leon in Forest Faculty of Universidad Autonoma de

Nuevo Leon (24°47' N; 99°32' O), at sea level of 350 m snm. The type of climate present is subtropical and semiarid condition with hot summer. The average monthly air temperature ranges between 14.7 °C in January to 32 °C in August, although daily common temperatures in summer reach up to 45 °C. The average annual precipitation is about 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 (Cotecoca, 1973, Inegi, 1986).

2.2. Preparation of samples for microscopy

The wood samples were taken from each of five trees from Tamaulipan Thorn Scrub around the Forest Science Faculty. Wood block of size of 2 cm^2, were kept in distilled water for several hours or overnight to soften them for cutting sections with the help of wood microtome at 15 to 20 µm thickness. Transverse, radial and tangential sections were performed. The sections were stained with safranin (1% in water) rapidly for 2 minutes and then washed in distilled water. Then sections were dehydrated with a series of alcohol at 30%, 50%, 70%, 90% and 100%, making two changes of 5 minutes for each treatment. Finally, they were placed on glass slides, covered and fixed with Euparol to make permanent slides. Pictures of these sections mounted were taken with a digital camera fixed on the microscope.

The technique for maceration of wood for observation of wood fibre cells is described by Maiti et al. (2015). A small piece of wood of each species was dipped in concentrated nitric acid and plugged with cotton. Then the test tubes were kept in boiling water bath until the wood pieces started disintegrating. Then, the macerated wood elements were washed several times with distilled water. Thereafter, the macerated fiber cells were stained with safranin (1%) and observed under microscope.

2.3. Description of wood anatomical traits

General description is taken on porosity (diffuse porous, semi-ring porous, ring porous), vessel pore size, frequency, diameter, types of perforation plates (straight, inclined).

3. Results and Discussion

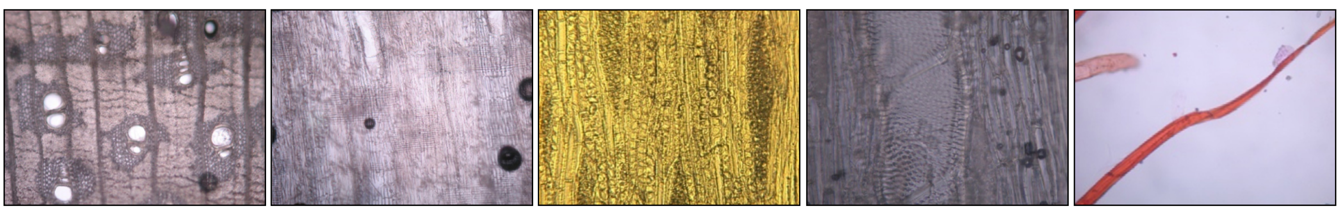
3.1. Description of wood anatomy of some woody species of Northeast Mexico

Microscopic characteristics (transverse section) (N.B. All at 10X except one tangential and fibre cell at 40X)

3.2. Description of wood anatomy of some woody species of Northeast Mexico (Figures 1-12)

3.2.1. Acacia rigidula

Wood semi-ring porous, vessels not numerous, mostly solitary, round to oval in shape, mostly in radial groups of 2 or 3, medium in size, narrow non uniform in size in crossection. Axial parenchyma confluent aliform. Apotracheal parenchyma not distinct, but the presence of tangential band of sclerenchyma distinct. Rays stratified, multi-layered.



Transversal Radial Tangential Tangential (40x) Fibercell 40x

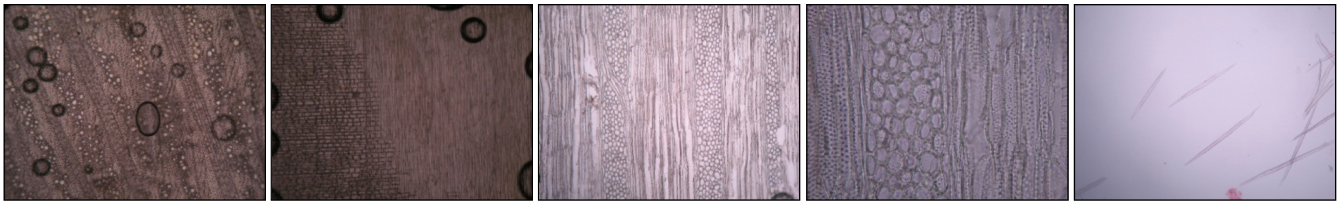
Figure 1: Wood anatomy of *Acacia rigidula*

Transversal Radial Tangential Tangential (40x) Fibercell 40x

Figure 2: Wood anatomy of *Acacia shaffneri*

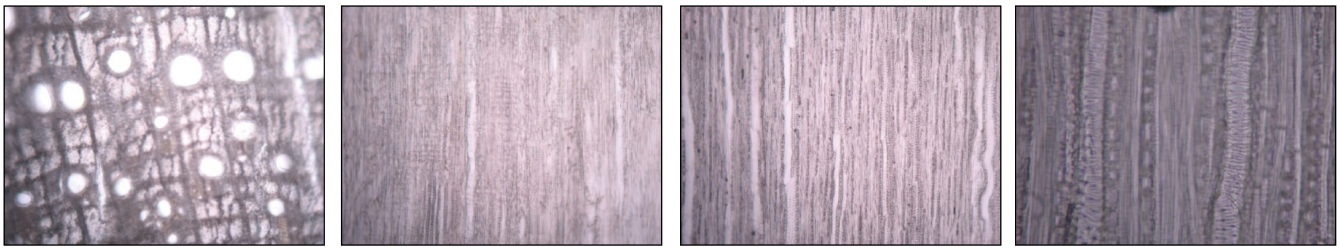
Transversal Radial Tangential Tangential (40x) Fibercell 40x

Figure 3: Wood anatomy of *Acacia wrightii*



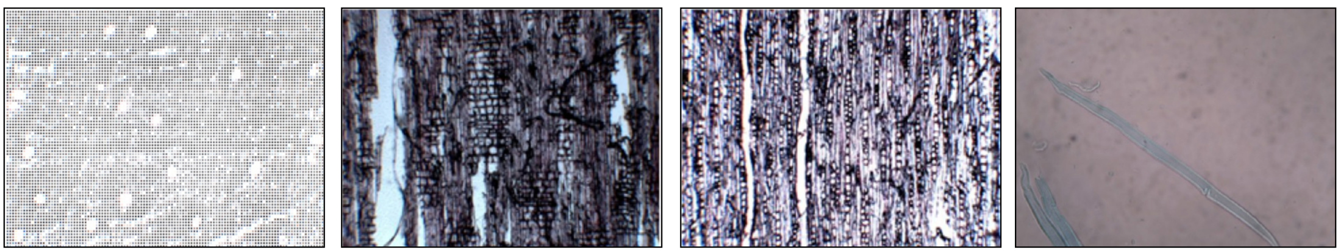
Transversal Radial Tangential Tangential (40x) Fibercell 40x

Figure 4: Wood anatomy of *Berberis chococo*



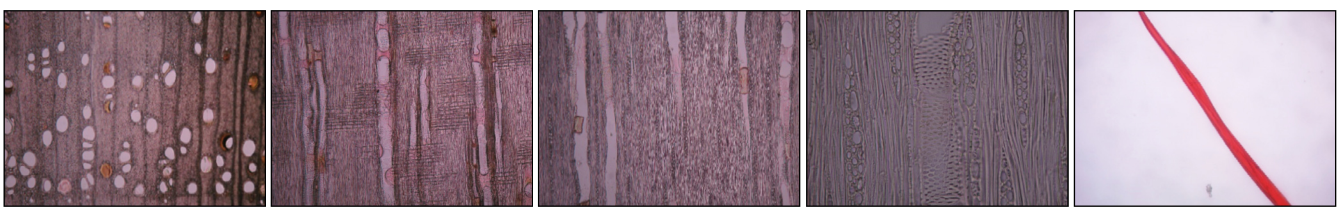
Transversal Radial Tangential Tangential (40x)

Figure 5: Wood anatomy of *Bernardia myricifolia*



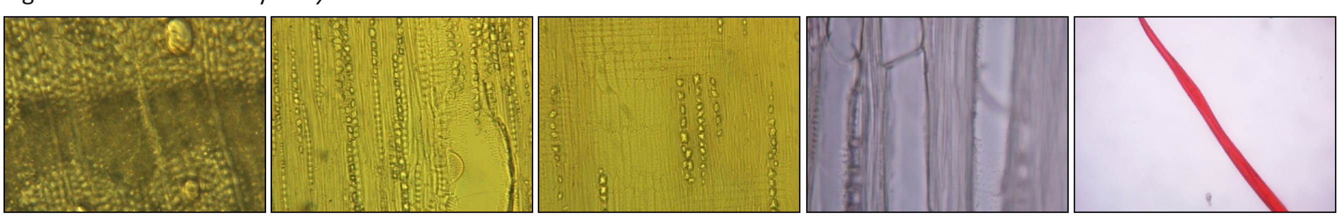
Transversal Radial Tangential Fibercell 40x

Figure 6: Wood anatomy of *Diospyros palmeri*



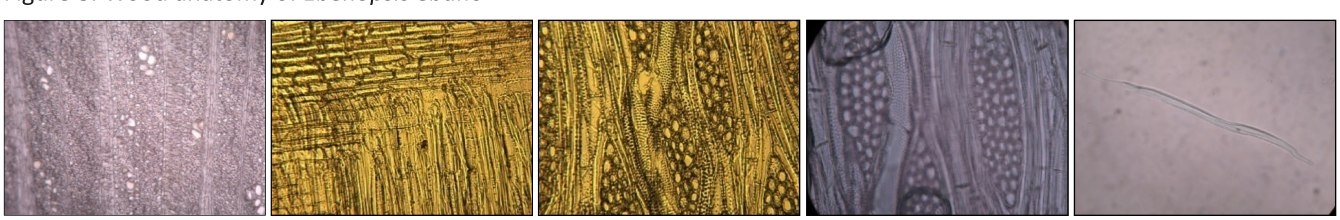
Transversal Radial Tangential Tangential (40x) Fibercell 40x

Figure 7: Wood anatomy of *Eysenhardtia texana*



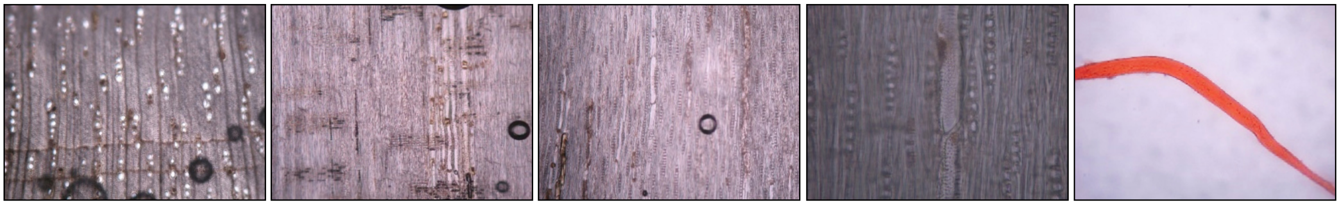
Transversal Tangential Radial Tangential Fibercell 40x

Figure 8: Wood anatomy of *Ebenopsis ebano*



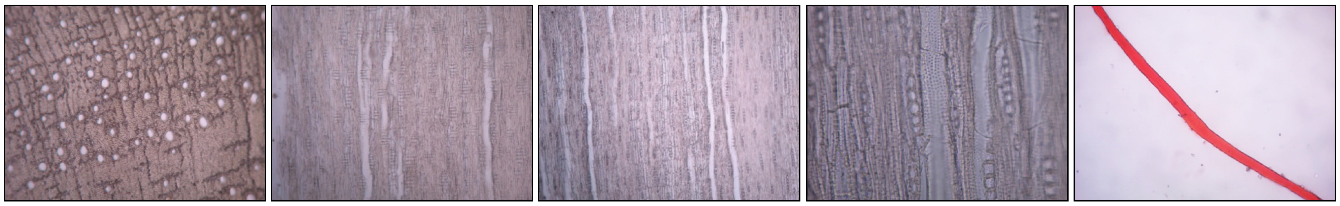
Transversal Radial Tangential Tangential Fibercell 40x

Figure 9: Wood anatomy of *Ehretia anacua*



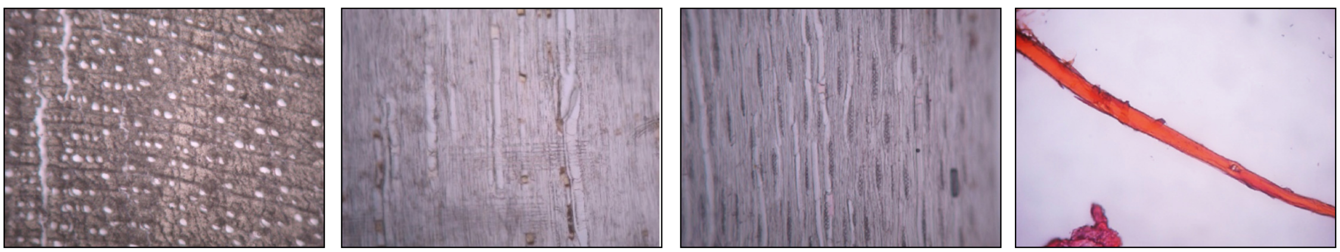
Transversal Radial Tangential Tangential Fibercell 40x

Figure 10: Wood anatomy of *Fraxinus greggii*



Transversal Radial Tangential Tangential Fibercell 40x

Figure 11: Wood anatomy of *Guaiacuman gustifolium*



Transversal Radial Tangential Fibercell 40x

Figure 12: Wood anatomy of *Helietta parvifolia*

Medullary rays medium in breath, narrow, traverse through wood tissue. Wood contains dense contents. Rays uniseriate, not clearly distinct. Vessels short, very much broad more or less with little inclined simple perforation plates, pits elongated, very close, alternate in arrangement. Fibre cells thickwalled, narrow lumened. Wood tissue is compact with thick walled firer. Suitable for strong furniture.

3.2.2. Acacia rigidula

Wood semiring porous, vessels sparse in numbers mostly solitary, round to oval in shape, few in radial groups of 2 or 3, non uniform in size, medium to small. Axial parenchyma aliform confluent. Apotracheal parenchyma in the form of band, scalariform, not clearly distinct, marginal parenchyma is visible. Sclerenchyma in the form of band in tiers. Medullary rays medium in breadth, traverse through wood tissue. Rays in radial section none to many layered. Rays short, mostly mutiseriate, few uniseriate, heterogeneous, cells oval in shape. Vessels medium long, and broad with inclined straight simple perforation plates, pits round, small, alternate in arrangement. Wood tissue is compact with highly thick walled fibre cells; seem to be very hard wood.

3.2.3. Acacia wrightii

Pores diffuse porous, mostly solitary, few in groups of 2 or 3, numerous, non uniform in size. Pores oval in shape, mostly medium in size large, some are very small. Axial parenchyma confluent. Apotracheal parenchyma in the form of broad band, scalariform. Medullary in thickness, transverse 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 perforation plates, pits elongated scalariform alternate in arrangement. Medullary rays wavy. Ray cells stratified, multilayered, stratified. Vessels medium in breadth, truncated with straight perforation plate, pits oval in shape, alternate in arrangement. Fibre cells narrow lumened, thick walled.

3.2.4. Berberis chococo

Wood semiring porous, vessels numerous, arranged in longitudinal groups, very narrow in diameter, round to oval in shape. Axial parenchyma confluent aliform. Apotracheal parenchyma in the form of long mediumly broad band, scalariform, not clearly distinct, marginal parenchyma not distinct. Medullary rays long broad traverse through wood tissue. Rays in radial section non stratified with dense contents. Rays long, broad, multiseriate, several cells in breadth, heterogeneous, cells oval in shape. Vessels medium in length and breadth with inclined simple perforation plate, pits small, round, alternate in arrangement. The tissue is compact with mediumly thick walled fiber cells, profuse vessels, seem to be mediumly hard. Fibre cells moderately thick walled and medium broad lumened.

3.2.5. Bernardia myricifolia

Wood semiring porous, vessels moderate in numbers mostly solitary, round to oval in shape, non uniform in size, mostly large. Axial parenchyma confluent to aliform. Apotracheal parenchyma in the form of broad band, scalariform, and terminal marginal parenchyma is visible. Medullary rays medium in breadth traverse through wood tissue. Rays in radial section non-stratified. Rays long, uniseriate heterogeneous, elongated, widely spaced. Vessels long, narrow with inclined simple perforation plate, slightly broad, more or less with straight simple perforation plates, pits elongated scalariform alternate in arrangement. Wood tissue is moderately compact with mediumly thick walled. Wood is semi-hard for fabrication of furniture; this may be suitable for paper pulp.

3.2.6. Diospyros palmeri

Wood diffuse porous, vessels sparse, mostly solitary, very few in grops, very narrow in diameter, round to oval in shape. Axial parenchyma paratracheal confluent. Apotracheal parenchyma diffused, not clearly distinct, marginal parenchyma not distinct. Medullary rays intercepted by wood tissue. Rays in radial section stratified, multi-layered with dense contents. Rays short, uniseriate, numerous, heterogeneous. Vessels medium in length and breadth with inclined simple perforation plate, pits small, round, alternate in arrangement. Wood tissue loose with profuse parenchyma and thin walled fiber cells, profuse, seem to be soft wood.

3.2.7. Ehretia anacua

Wood diffuse porous, vessels sparse in numbers mostly in pore multiplesy, round to oval in shape, few non-uniform in size, very small. Axial parenchyma confluent aliform. Apotracheal parenchyma in the form of narrow non-scalariform, not clearly distinct, marginal parenchyma is visible. Medullary rays thin traverse through wood tissue. Rays in radial section stratified with dense contents. Rays spindle shaped, many, broad multiseriate several cells in breadth, heterogeneous, cells oval in shape. Vessels short to medium in length, broad, more or less with straight simple perforation plates, pits round, alternate in arrangement. Medullary ray cells stratified multilayered, stratified, pits scalariform, evolutionarily slightly advanced. Fibre cell narrow lumened, thickwalled.Wood tissue is loose with profuse parenchyma, seem to be soft.

3.2.8. Eysenhardtia texana

Wood semi-ring to ring porous, vessels numerous, mostly isolated. Few in radial bands of two or more cells, vessel round to oval in shape, non uniform in size in crossection. Axial parenchyma paratracheal. Apotracheal parenchyma in the form of long tiers, scalariform. Medullary rays narrow, traverse through wood tissue. Ray cells multi-layered, non-stratified. Rays mediumly long, not profuse, multiseriate, heterogeneous. Vessels medium in length, broad with inclined to truncated, simple perforation plates, pits round, very close, small, alternate in arrangement. Fiber cells broad lumened and thickwalled. Wood tissue is compact with moderately thick walled fibre cells, seem to be mediumly hard.

3.2.9. Ebenopsis ebano

Wood diffuse porous, semi-ring porous, mostly solitary, round to oval in shape, few in radial groups of 2 or 3, very small in size, narrow, non uniform in size in crossection. Axial parenchyma confluent aliform. Apotracheal parenchyma in the form of narrow band, scalariform, marginal parenchyma, terminal parenchyma visible. Medullary rays narrow, intercepted by wood tissue. Wood contains dense contents. Rays mediumly long, not profuse, uniseriate long, heterogeneous, cells rectangular in shape. Vessels medium in length and breadth, more or less with little inclined simple perforation plates, very close, small, alternate in arrangement. Fibrecells broad lumened, thinwalled, suitable for paper pulp.Wood tissue is compact with mediumly thick walled fiber, suitable for strong furniture.

3.2.10. Fraxinus greggii

Wood semi-ring porous, vessels numerous, narrow, few solitary, many in radial group of several vessels, non uniform in size, mostly small. Axial parenchyma paratracheal. Apotracheal parenchyma in the form of long narrow band, scalariform, marginal parenchyma is not distinct. Medullary rays thin, traverse through wood tissue. Annual ring distinct. Rays in radial section stratified with dense contents. Rays short, uniseriate of large cells, homogeneos, cells oval in shape. Vessels medium in length, slightly inclined simple perforation plates, pits round, oval, alternate in arrangement. Wood tissue is compact with thin walled fibre cells, profuse vessels, seem to be hard. Fiber cells broad lumened and thinwalled. Wood is hard for fabrication of furniture, this may be suitable for paper pulp.

3.2.11. Guaiacum angustifolium

Wood diffuse porous, vessels numerous, narrow, mostly isolated. Few in radial bands of two, vessel round to oval in shape, non uniform in size in cross section, narrow vessels. Axial parenchyma confluent aliform. Apotracheal parenchyma in the form of short bands, scalariform. Medullary rays not distinct. Rays mediumly long, not narro inclined to truncated, with simple perforation plates, pits round, very close, small, alternate in arrangement. Wood tissue is compact with mediumly thick walled fiber cells, seem to be semi-hard. Fibre cells mediumly thickwalled but broad lumened, may be suitable for paper pulp.

3.2.12. Helietta parvifolia

Wood diffuse porous, vessels numerous, very narrow, mostly isolated, vessel round to oval in shape, non uniform in size in crossection, distributed in the form of stars. Axial parenchyma paratracheal. Apotracheal parenchyma diffused, medullary rays not distinct. Rays mediumly long, not profuse, uniseriate, heterogenous long, consisting of elongated cells. Vessels medium in length, narrow, mostly inclined to simple perforation plates, pits round, very close, small, alternate in arrangement. Wood tissue compact with mediumly thickwalled fiber cells, seem to be mediumly hard.

3.3. Variability in flora

The study on wood anatomy of twelve woody tree species at Linres, northeastern Mexico, has shown wide variability with respect to wood porosity, intensity of vessels, their diameter, orientation, and type of wood parenchyma, paratraceal and apotracheal, as well as fibre cell characteristics. Species may be distinguished on the basis of various wood anatomical trits which coincide with other studies (Perez et al., 2008). The woody plant species also showed variability in xylem vessel characteristics such as length, vessel, perforation plate inclination and types pits which determine the evolutionary trend as suggested by Carlquist and others mentioned already. In addition, it is assumed that wood anatomy could predict the adaptation of woody plants to environmental stresses and quality of timbers (Maiti and Rodriguez, 2015).

Most of the species have diffuse porous wood, but very few ring to semiring porous viz. *Acacia rigidula, A. shaffneri, Bernardia myricifolia, Fraxinus gregii.* Most of the species possess narrow vessels viz. *Acacia* spp.*, Bernardia myricifolia, Eysenhardtia texana, Ebenopsis ebano, Berberis chococo, Diospyros palmeri, Ehretia anacua, Fraxinus gregii, Guiacuman gustifolium, Helietta parviflora.* Few species have medium to narrow vessels such as *Ebenopsis ebano, Eysenhardtia texana, Acacia rigidula* while.*Bernardia myricifolia* possesses bigger vessels. The species having narrow vessels mentioned have capacity of resistance to cavitation and embolism exposed to hot summer and cold winter in semiarid Northeastern Mexico, similar to those in Mediterranean climates as discussed by several authors (Zimmermann, 1982; 1983; Ewers, 1985).

Similar to the present study the variability in wood anatomical traits have been reported by other authors (Isaías et al., 1998; Carmen de la Paz Perez Olvera et al., 2006,Pérez et al., 2008; Veronica et al., 2009; Silvia et al., 2010 Moises Aguilar-Alcantara et al., 2014).

Wood fibre characteristics of different species studied also showed large variations in morphology, size, lumen breadth on the basis of which the species are recommended for its utility such as furniture (Maiti et al., 2015). In this respect woody plant species having wood fibre cells with broad lumen and thin cell wall could be related to good paper pulp quality such as *Ebenopsis ebano, Ehretia anacua, Guiacum angustifolium.* Therefore, wood anatomical traits could predict the quality and utility of the timbers and also adaptation of the species to adverse environments (Maiti and Rodriguez, 2015). On the basis of compactness we recommended species as soft and hard wood.

The variations of hydraulic architecture may be related to the adaptive strategies to adverse climatic conditions of woody plants, suggested by various authors (Carlquist, 1989; Baas et al., 2004). From a functional viewpoint, various studies have discussed vessel pore size affecting conductivity, vulnerability to cavitation and mechanical strength (Zimmermann, 1983; Ewers, 1985; Salleo and Lo Gullo, 1993; Jacobsen et al., 2007). 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 (Psaras and Sofronieu, 2004; Veronica et al., 2009; De Micco et al., 2008). 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 ^{o}C separated cold climate of winter season with temperature going below to 5 ^{o}C. It has been reported that vessel grouping is a widespread phenomenon in most woody species, especially those from the arid desert and Mediterranean flora (Fahn et al., 1986; Carlquist, 1984; 1989). In this respect Jacobsen et al. (2007) reported that xylem density and anatomical traits correlate with water stress in 17 evergreen shrubs species of the Mediterranean-type climate region of South Africa. They stated that minimum seasonal pressure potential, $P_{(min)}$, xylem specific conductivity (K), stem strength against breakage (modulus of rupture, MOR), xylem density, theoretical vessel implosion resistance and several fibre and vessel anatomical traits were measured. More negative P_{min} was associated with having greater xylem density, and there was no relationship between P_{min} and traits associated with increased water transport efficiency. Xylem density integrates many xylem traits related to water stress tolerance. Xylem density may be an integral trait for predicting the impact of climate change on evergreen shrubs. Therefore, the species with small narrow vessels, solitary or in groups mentioned have strategy to adapt both to hot and cold climate against cavitation and embolism as mentioned by various authors. The species having big vessel diameter may be susceptible to drought such as *Celtis pallida,* or they may have deep root system for adaptation to semiarid climates in northeast Mexico.

3.4. Relation with wood quality

The variation of wood anatomical traits could be used in identification of the species and quality determination of the timer. The species having compact wood, high amount of thick walled wood fibres could be related to strong wood for strong furniture such as *Acacia rigidula, A, shaffneri, Fraxinas greggii, Helieta parvifolia.* The species having fibre cells with broad lumen, thin cell wall could be useful for good paper pulp for fabrication of paper such as *Fraxinas greggii, Gguicum angustifolia.*

4. Conclusion

Significant variability was observed in the wood anatomical traits of the species under the study. The wood anatomical traits such as wood compactness, high density of thick walled wood fibres, lumen and cell wall thickness can be utilized to formulate the plans for utilization of the species in question. Also selection of species according to the use can be made in forestry based industries.

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