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Original Research Article

Anatomical Characteristics of Some Plant Members of Meliaceae from Assam, India

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Abstract: Anatomical characteristics of wood are important to understand it as a raw material. The present study was carried out to investigate the detailed anatomical characteristics and their relationship with wood density in *Amoora wallichii* King, *Azadirachta indica* A. Juss., *Chukrasia tabularis* A. Juss., *Dysoxylum binectariferum* (Roxb.) Hook.f. ex Bedd. and *Melia azedarach* L. The wood samples were collected from trees with straight bole and uniform crown at breast height. The anatomical characteristics were studied in cross-section, radial longitudinal section, tangential longitudinal section and macerated materials. The present study revealed that wood was diffuse porous with indistinct rings in *A. wallichii* and *D. binectariferum* and distinct rings in *C. tabularis* due to presence of marginal parenchyma bands. Wood was ring porous in *M. azedarach* and semi ring porous in *A. indica*. Solitary, radial multiple of vessels, simple perforation plate, presence of septate fibres, crystals in rays and chambered axial parenchyma cells were the common features among genera. Multiseriate rays were present in *A. indica* and *M. azedarach* whereas rays were uniseriate, biseriate and multiseriate in *A. wallichii*, *C. tabularis* and *D. binectariferum*. The anatomical characteristics exhibited significant variations within genera. The fibre percentage was maximum than vessels, rays and parenchyma. Maximum fibre percentage was present in *A. wallichii* whereas vessels and rays percentage were maximum in *C. tabularis* and *D. binectariferum*. The relationship between anatomical characteristics and wood density was too weak to be significant. The selected genera were moderately heavy to heavy. Thus, these genera can be exploited for different end uses on the basis of their wood density.

Key words: Axial parenchyma, crystals, diffuse porous, radial multiple, vessel-ray pits

Introduction

The family Meliaceae comprises of 51 genera and 620 species and are widely distributed in tropical, subtropical and occasionally in warm temperate regions. Habitat wise, they extend from rain forests and mangrove swamps to semi-deserts (Mabberley *et al.*, 2007). In India, it is represented by about 16 genera and 66 species (Haridasan *et al.*, 1985). The members of this family are both ethnobotanically and ethnomedicinally important. They are rich source of biologically active compounds of commercially interest. The various plant parts of *A. indica* are extensively used in ayurveda, unani and homeopathic medicines (Orwa *et al.*, 2009). Likewise, the leaves of *M. azedarach* are used against skin diseases and the fruits are source of insecticides. It is also grown as an avenue tree for its scented flowers and shade spreading crown. Kaur and Arora (2009) reviewed the medicinal uses of *C. tabularis* along with biopesticidal activities. Whereas, Patel *et al.* (2010) reported a promising anticancerous compound "rohitukine" from the bark of *D. binectariferum*. Kakati *et al.* (2017) investigated the potential of *A. wallichii* seed for production of bio diesel. In addition to this, the family is a source of high quality commercial timbers like *Swietenia* species, *Dysoxylum malabaricum* and *Toona ciliata* in India (Purkayastha, 1992). Most of the workers have highlighted the anatomical characters of taxonomic value in family Meliaceae (Metcalfe and Chalk, 1950; Pennington and Styles, 1975). Patel (1974) made a detailed investigation on wood anatomy of *Dysoxylum spectabile*. Mandang (1993) studied the gross and anatomical features of lesser known species of Meliaceae for assessing the potential of their fibres for pulping. Khaopakro *et al.* (2015) examined anatomical characters of 13 *Aglaia* species and observed variation in both qualitative and quantitative characters.

In India, Pearson and Brown (1932) published anatomical descriptions of few species based on the cross section. Nair (1991) investigated the wood anatomical characters in relation to habitat in *Melia birmonica*, *M. composita*, *Soyamida febrifuga*, *Swietenia mahogoni*, *Azadirachta indica* and *Melia azedarach*. Negi *et al.* (2003) examined distribution pattern of different types and location of crystals in 42 species of Meliaceae housed in Xylarium of FRI, Dehradun. However, there is limited information on wood anatomy of different genera available in Assam. Therefore, the main aim of the present study is to find out the qualitative and quantitative anatomical characteristics in some genera of family Meliaceae and their relationship with wood density.

Materials and methods

Five mature trees with uniform crown and straight bole of each genus namely *Amoora wallichii* King, *Azadirachta indica* A. Juss., *Chukrasia tabularis* A. Juss., *Dysoxylum binectariferum* (Roxb.) Hook. f. ex Bedd. and *Melia azedarach* L.were selected from different forest regions of Assam, India (Table 1). Wood sample of 5cm^3 size was taken from each tree with the help of a chisel and a hammer at breast- height. Collected wood samples were trimmed to 2cm^3 size and were fixed in FAA for 24-48 hours. The samples were preserved in 50% alcohol for further studies. For anatomical investigations, wood sections of 15-25 microns thickness were cut in three planes (cross, tangential longitudinal and radial longitudinal) with the help of a sliding microtome and permanent slides were prepared as per standard laboratory protocol.

The anatomical features of selected woods in three planes were observed under microscope at different magnifications. The anatomical parameters like fibre diameter, fibre wall thickness, vessel diameter, vessel frequency and tissue proportion were determined from cross sections. Ray height, ray width and parenchyma strand from tangential longitudinal sections and inter-vessel pits from radial longitudinal sections were measured. The IAWA list of anatomical features (Wheeler *et al.*, 1989) was followed for terminology, measurements and anatomical features.

Thin slivers of wood taken from radial sides were macerated with Franklin's solution in an oven at 60°C for 24 hours. Temporary slides were prepared in 50% glycerol for measurements and ovservation of fibre length, vessel length, vessel shapes and fibre tips.

Wood density of selected woods was determined by Water displacement method (Smith, 1955).

Standard deviation, Pearson's correlation and univariate analyses were determined by using SPSS 16.0 software.

Table 1. Dimensions and locations of selected species

Sl. No.	Species name	Height (m) (Mean±SD)	Diameter (cm) (Mean±SD)	Co-ordinates: Latitude	Co-ordinates: Longitude	Place
1.	*A. wallichii*	12-14(13±0.31)	280-283(282±1.29)	27° 21´ N 26° 29´N	95° 31´E 90° 36´E	Digboi,Jiadhal
2.	*A. indica*	13-15(14±0.31)	120-123(122±1.29)	27° 29´N 27° 36´N	95° 00´E 94° 35´E	Sissi,Simen
3.	*C. tabularis*	22 -24(23±0.17)	190-193(192±1.29)	26° 19´N 27° 21´N	90° 34´E 95° 50´E	Jiadhal,Katha
4.	*D. binectariferum*	11-14(12±1.26)	88-90(89±1.29)	27° 20´N 26° 07´N	94° 30´E 91° 56´E	Digboi,Lekhapani
5.	*M. azedarach*	11-14(12±1.29)	75-80(77±2.21)	27° 19´N 27° 30´N	95° 46´E 94° 25´E	Katha,Simen

Results

The anatomical and quantitative features of selected species were presented in Figs. 1-5 and Table 2.

Amoora wallichii King

Growth rings - Indistinct, diffuse-porous wood.

Vessels- Mostly solitary, in radial multiples of 2- 4, oval in outline, barrel-shaped to oblong and linear with tail, 125.1-625.5μm (Mean 337.46±111.37μm) in length, 98.99-291.76μm (Mean 166.84±32.55μm) in diameter, vessel frequency 7-19 (Mean 11.46±2.85) per mm^2, simple perforation plate, intervessel pits alternate, small to medium, 5.20-10.40μm (Mean 7.98±1.48μm) in size, vessel ray pits with distinct borders, similar to intervessel pits in size and shape throughout the ray cell.

Fibres – Thin walled, 300.24-1626.4μm (Mean 894.91±238.99μm) long, 13-39μm (Mean 21.98±5.34μm) and 7.8-18.2μm (Mean 11.25±2.69μm) in diameter and lumen diameter, 1.3-14.3μm (Mean 5.36±2.83μm) in wall thickness, septate fibres present.

Parenchyma - Banded, parenchyma bands more than 3 cells wide. Parenchyma strands 2-8 celled.

Rays - Uniseriate, biseriate, rarely multiseriate, mean ray height and ray width 72.94-625.20 μm (Mean 262.91±106.48μm) and 10.42-41.68μm (Mean 13.00±6.15μm), pith flecks present, rays both homocellular and heterocellular, all cells procumbent in homocellular ray, body cells procumbent with two rows of upright and/or square marginal cells in heterocellular ray. Rays 9 - 20 (Mean15.04±2.64) per mm.

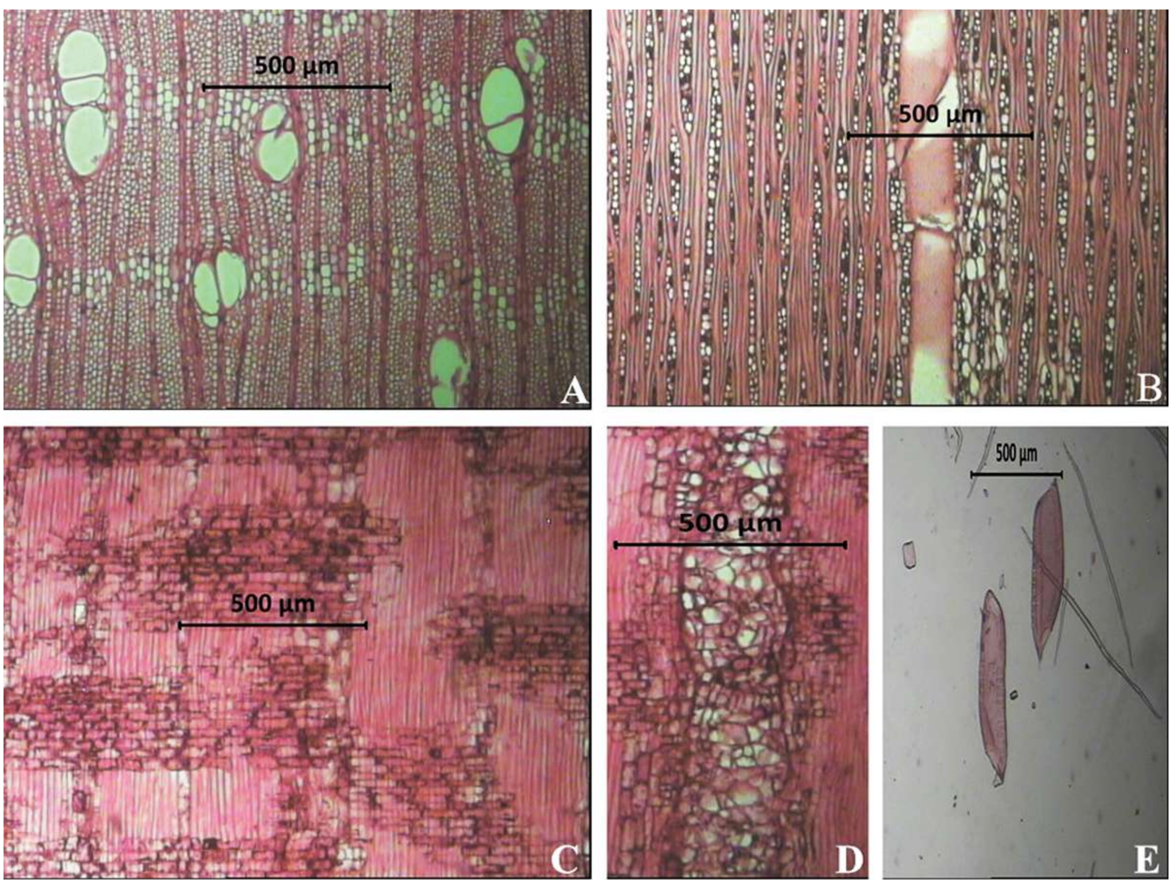

Fig. 1. *Amoora wallichii*: Cross-section showing diffuse-porous wood, vessel solitary and in radial multiple of 2, parenchyma banded (A). Tangential longitudinal section showing uniseriate, biseriate, multiseriate rays and parenchyma strands 3-5 celled (B). Radial longitudinal sections showing homocellular rays of procumbent cells (C) and pith flecks (D). Tube shaped vessels with simple perforation and small tail.

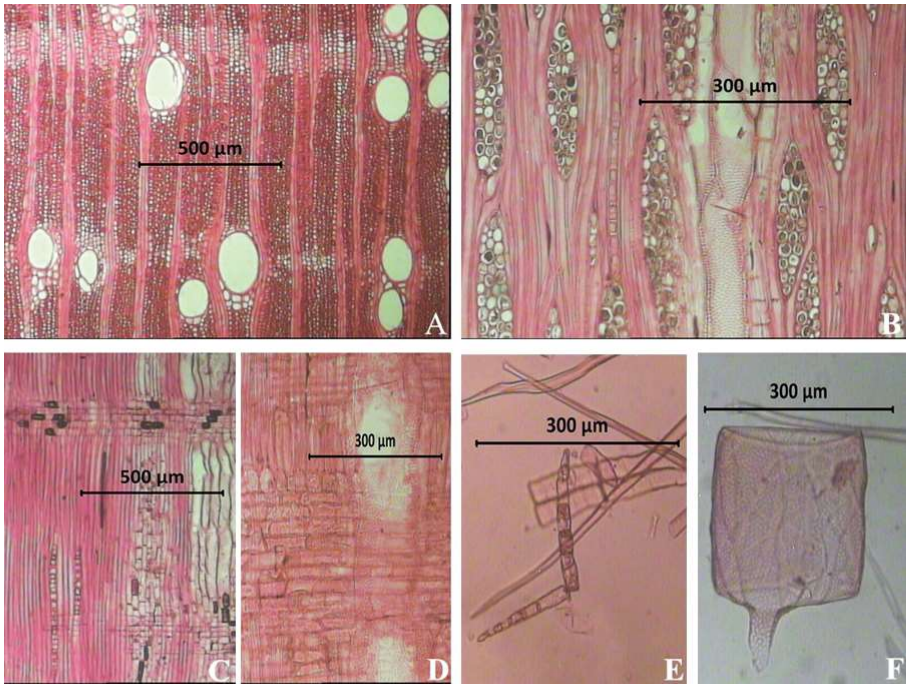

Fig. 2. *Azadirachta indica*: Cross-section showing semi- ring porous wood, vessel solitary, parenchyma unilateral and banded (A). Tangential longitudinal section showing multiseriate rays, intervessel pits alternate, prismatic crystals in fibres and parenchyma strands 3-4 celled (B). Radial longitudinal sections showing homocellular rays of procumbent cells and crystals in fibres (C) and heterocellular rays of procumbent body ray cells with one row of upright and/ or square marginal cells (D). Crystals in chambered axial parenchyma cells (E). Drum shaped vessel with tail on one end (F).

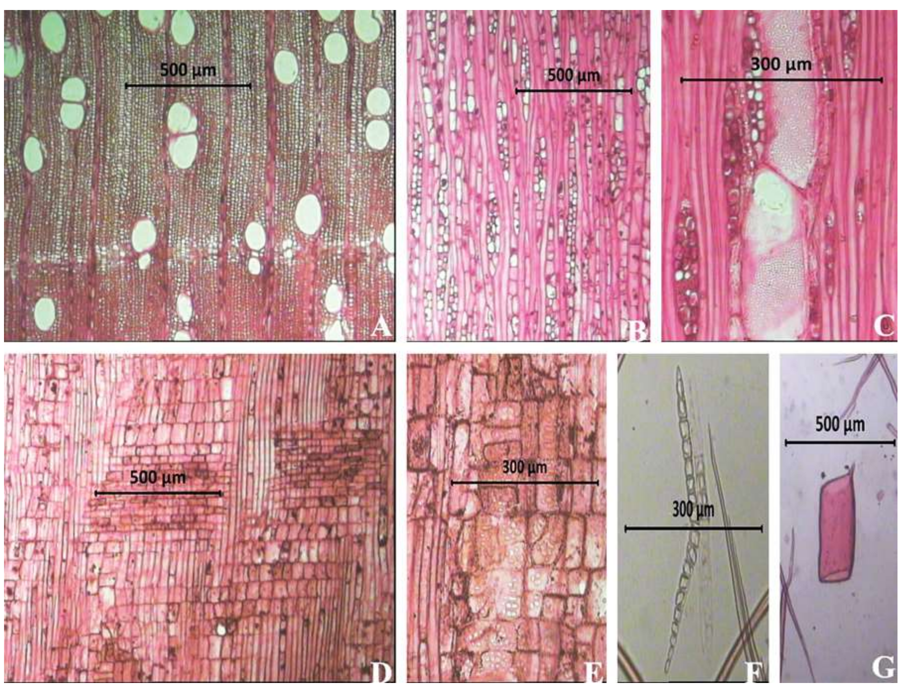

Fig. 3. *Chukrasia tabularis*: Cross-section showing diffuse porous wood, vessel solitary and in radial multiple of 2, parenchyma scanty paratracheal and marginal bands (A). Tangential longitudinal section showing uniseriate, biseriate and multiseriate rays, parenchyma strands 3-7 celled (B) and intervessel pits alternate (C). Radial longitudinal sections showing heterocellular rays of procumbent body ray cells with over 4 rows of upright and/or square marginal cells (D). Vessel-ray pits with much reduced borders to apparently simple, pits rounded or angular (E). Crystals in chambered axial parenchyma cells (F). Tube shaped vessel with tail on both ends (G).

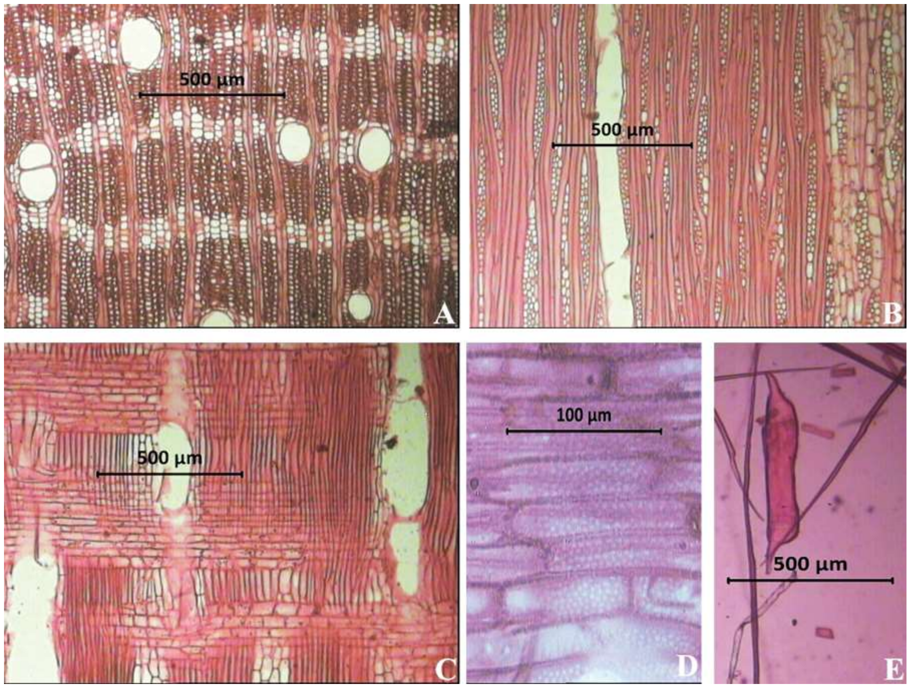

Fig. 4. *Dysoxylum binectariferum*: Cross-section showing diffuse porous wood, vessel solitary and in radial multiple of 2, parenchyma banded (both apotracheal and paratracheal) (A). Tangential longitudinal section showing uniseriate tomultiseriate rays and parenchyma strands 4-9 celled (B). Radial longitudinal sections showing heterocellular rays of procumbent body ray cellswith 1-2 rows of upright and/or and square marginal cells (C) and vessel ray pits with distinct border similar to intervessel pits in size and shape (D). Tube shaped vessels with tails on both ends (E).

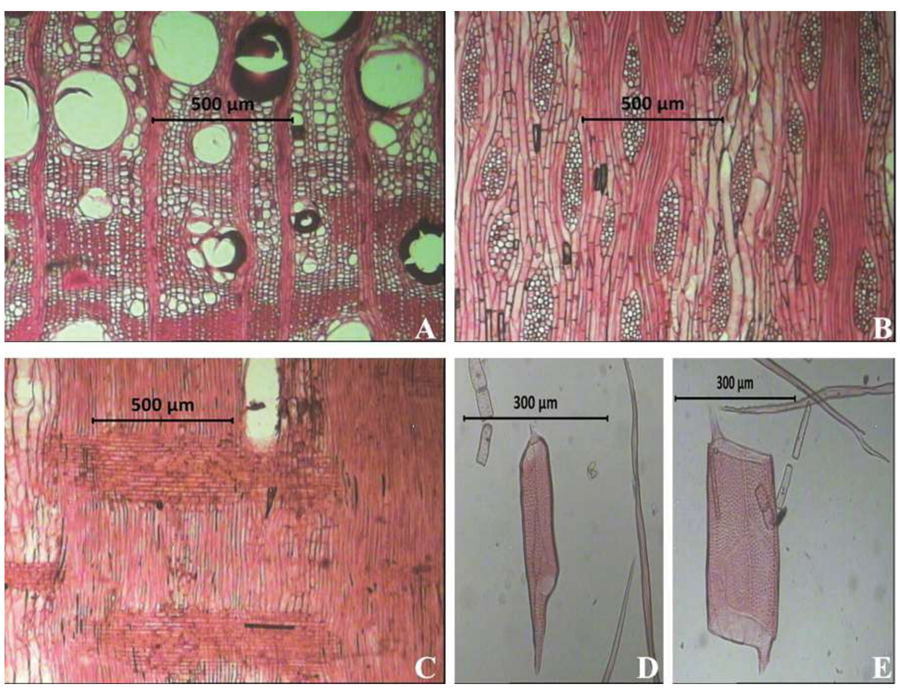

Fig. 5. *Melia azedarach*: Cross-section showing ring porous wood, vessel solitary in early wood and in clusters in late wood, parenchyma diffuse, diffuse - in-aggregate (A). Tangential longitudinal section showing multiseriate rays and parenchyma strands 3-6 celled (B). Radial longitudinal sections showing heterocellular rays of procumbent body ray cellswith 1-2 rows of upright and/or and square marginal cells (C) Tube shaped vessel with short and very long tail (D). Barrel shaped vessel with tail on both ends and a forked fibre (E).

Azadirachta indica A. Juss.

Growth rings - Distinct due to presence of fibres, a semi-ring-porous wood.

Vessels – Mostly solitary, in radial multiples of 4-6, oval to circular in outline, oblong and drum-shaped with tail, 150.12-875.7µm (Mean 317.85±115.62µm) in length, 72.94-296.97µm (Mean 158.17±44.74µm) in diameter in early wood, 68.15-93.78µm (Mean 79.43±6.09µm) in diameter in latewood, vessel frequency 4-6 (Mean 5±1) per mm^2 in early wood, 4-17 (Mean 8±2) per mm^2 in late wood, simple perforation plate, intervessel pits alternate, small to medium, 5.30-13µm (Mean 8.09±2.14µm) in size, vessel- ray pits with distinct borders, similar to intervessel pits in size and shape throughout the ray cell, gummy deposits present.

Fibres - Thin to thick walled, 350.28-1751.8µm (Mean 910.72±231.54µm) long, 13-39 µm (Mean 21.96±5.08µm) and 7.8-20.8µm (Mean 11.25±2.65µm) in diameter and lumen diameter, 1.3-15.6µm (Mean 5.35±2.48µm) in wall thickness, septate fibres present.

Parenchyma - Scanty paratracheal, vasicentric, unilateral paratracheal, banded, parenchyma bands more than 3 cells wide. Parenchyma strands 2-6 celled.

Rays - Mostly multiseriate, rarely uniseriate, biseriate, mean ray height and ray width 125.04-573.1µm (Mean 318.68±83.49µm) and 31.26-104.2µm (Mean 56.26±14.49µm), rays heterocellular, body cells procumbent with two rows of upright and/or square marginal cells. Rays 2 - 10 (Mean 5.36±2.12) per mm.

Mineral inclusions - Prismatic crystals present in procumbent cells of ray, chambered axial parenchyma cells and fibres.

Chukrasia tabularis A. Juss.

Growth rings - Distinct due to presence of marginal parenchyma bands, a diffuse-porous wood.

Vessels - Mostly solitary, in radial multiples of 2-5, oval to circular in outline, drum, barrel- and tube-shaped, with tail, 135.10-3107.30µm (Mean 429.29±281.78µm) in length, 73.64-252.48µm (Mean 131.28±29.93µm) in diameter, vessel frequency 4-22 (Mean 12.62±4.40) per mm^2, simple perforation plate, intervessel pits alternate, medium, 5.20-10.40 (Mean 8±1.99µm) in size, vessel ray pits with distinct borders, similar to intervessel pits in size and shape throughout the ray cell.

Fibres - Thin walled, 270.20-1486.10µm (Mean 848.42±242.18µm) long, 13-57.2µm (Mean 24.46±7.76µm) and 7.8-39 µm (Mean 14.70±4.55µm) in diameter and lumen diameter, 1.3-14.3 µm (Mean 4.87±3.12µm) in wall thickness, septate fibres present.

Parenchyma - Diffuse, scanty paratracheal, vasicentric and in marginal bands, 5-7 cells per parenchyma strand.

Rays - Uniseriate, biseriate, multiseriate, mean ray height and ray width 73.64-368.2µm (Mean 169.66±53.13µm) and 52.60-231.44µm (Mean 110.08±35.86µm), rays both homocellular and heterocellular, all cells were either procumbent or upright or square in homocellular rays, procumbent body ray cells with over 4 rows of upright and/or square marginal cells in heterocellular ray. Also procumbent, square and upright cells were mixed throughout the heterocellular ray. Rays 2-12 (Mean6.62±1.89) per mm.

Mineral inclusions - Prismatic crystals present in upright and/or square cells, procumbent ray cells, in fibres and in chambered axial parenchyma cells.

Dysoxylum binectariferum (Roxb.) Hook.f. ex Bedd.

Growth rings – Indistinct, a diffuse-porous wood.

Vessels – Mostly solitary, in radial multiples of 2-3, oval to circular in outline, drum, barrel and tube shaped, with or without tail, 175.14-1075.86µm (Mean 593.07±170.34µm) in length, 88.57-432.43µm (Mean 207.81±75.32µm) in diameter, vessel frequency 4-14 (Mean 8.76±2.76) per mm^2, simple perforation plate, intervessel pits alternate, medium, 5.2-10.4 µm (Mean 6.55±1.56µm) in size, vessel ray pits with distinct borders, similar to intervessel pits in size and shape throughout the ray cell.

Fibres - Thin walled, 500.4-2376.9µm (Mean 1324.65±357.62µm) long, 18.2-52µm (Mean 31.22±6.82µm) and 7.8-26µm (Mean 13.20±4.06µm) in diameter and lumen diameter, 1.3-20.8µm (Mean 9.00±3.44µm) in wall thickness, septate fibres present.

Parenchyma - Vasicentric, banded (both apotracheal and paratracheal) bands more than three cells wide. Parenchyma strands 2-10 celled.

Table 2. Quantitative features of selected genera of family Meliaceae

Parameters	*A. wallichii*	*A. indica*	*C. tabularis*	*D. binectariferum*	*M. azedarach*
FL(μm)(Mean±SD)	(894.91±238.99)	(910.72±231.54)	(848.42±242.18)	(1324.65±357.62)	(914.13±205.72)
FD(μm)(Mean±SD)	(21.98±5.34)	(21.96±5.08)	(24.46±7.76)	(31.22±6.82)	(23.12±5.56)
FLD(μm)(Mean±SD)	(11.25±2.69)	(11.25±2.65)	(14.70±4.55)	(13.20±4.06)	(12.23±3.47)
FWT(μm)(Mean±SD)	(5.36±2.83)	(5.35±2.48)	(4.87±3.12)	(9.00±3.44)	(5.44±3.02)
VL(μm)(Mean±SD)	(337.46±111.37)	(317.85±115.62)	(429.29±281.78)	(593.07±170.34)	(291.23±68.84)
VD(μm)(Mean±SD)	(166.84±32.55)	(79.43±6.09)	(131.28±29.93)	(200.81±75.32)	(98.55±9.28)
IVP(μm)(Mean±SD)	(7.98±1.48)	(8.09±2.14)	(8.00±1.99)	(6.55±1.56)	(7.11±1.58)
VF/mm^2(Mean±SD)	(11..46±2.85)	(8±2)	(12.62±4.40)	(8.76±2.76)	(7.71±1.82)
APS(μm)(Mean±SD)	(3.56±1.33)	(3.56±1.08)	(3.10±0.97)	(4.45±1.74)	(3.74±1.54)
RH(μm)(Mean±SD)	(262.91±106.48)	(318.68±83.49)	(169.66±53.13)	(375.20±204.04)	(338.85±83.97)
RW(μm)(Mean±SD)	(13.00±6.15)	(56.26±14.49)	(110.08±35.86)	(46.26±18.45)	(59.26±16.44)
RF/mm (Mean±SD)	(15.04±2.64)	(5.36±2.12)	(6.62±1.89)	(8.64±1.78)	(4.06±1.07)

FL- Fibre length; FD- Fibre diameter; FLD- Fibre lumen diameter; FWT- Fibre wall thickness; VL- Vessel length; VD- Vessel diameter; IVP- Inter vessel pits; VF- Vessel frequency; APS- Axial parenchyma strand; RH- Ray height; RW- Ray frequency; RF- Ray frequency

Table 3. Analysis of variance of anatomical characteristics in selected genera **(F value)**

Parameters	*A. wallichii*	*A. indica*	*C. tabularis*	*D. binectariferum*	*M. azedarach*
FL	3.89*	5.08**	0.53 ns	0.63 ns	1.01 ns
FD	0.68 ns	2.66*	25.48**	0.65 ns	7.70**
FLD	3.79*	2.95*	13.24**	9.22**	9.03**
FWT	2.08 ns	1.60 ns	7.99**	1.85 ns	1.43 ns
VL	3.91*	4.22**	0.68 ns	7.13**	2.42*
VD	5.93**	22.82**	50.69**	41.25**	14.47**
IVP	3.33*	2.11 ns	4.61**	3.17*	39.43**
VF	0.62 ns	5.11**	1.82 ns	2.94*	0.18 ns
APS	157.33 ns	.951 ns	0.61 ns	0.64 ns	0.37 ns
RH	5.15**	6.78**	75.24**	11.98**	2.54*
RW	37.39**	2.28 ns	46.07**	18.64**	27.50**
RF	0.02 ns	36.55**	0.32 ns	0.11 ns	0.10 ns

The level of significance used are ns = non- significant, * = significant at $P \leq 0.05$ level,**= highly significant at $P \leq 0.01$ level

FL- Fibre length; FD- Fibre diameter; FLD- Fibre lumen diameter; FWT- Fibre wall thickness

VL- Vessel length; VD- Vessel diameter; IVP- Inter vessel pits; VF- Vessel frequency;

APS- Axial parenchyma strand; RH- Ray height; RW- Ray frequency; RF- Ray frequency

Table 4. Tissue proportion and wood density of selected genera of family Meliaceae

Sl. No.	Species	Fibre (%)	Vessel (%)	Ray (%)	Parenchyma (%)	Wood density (gm/cc) (Mean±SD)
1.	*A. wallichii*	62	16	18	4	0.68-0.72(0.70±0.01)
2.	*A. indica*	60	16	17	7	0.80-0.83(0.81±0.01)
3.	*C. tabularis*	47	30	16	7	0.64-0.67(0.65±0.01)
4.	*D. binectariferum*	50	16	26	8	0.68-0.71(0.69±0.01)
5.	*M. azedarach*	56	20	16	8	0.67-0.71(0.69±0.01)

Table 5. Relationship between wood density and anatomical characteristics in members of family Meliaceae

Parameters	*A. wallichii*	*A. indica*	*C. tabularis*	*D. binectariferum*	*M. azedarach*
FL	-0.189 ns	-0.023 ns	-0.094 ns	0.003 ns	-0.172 ns
FD	-0.429 ns	-0.331 ns	0.206 ns	-0.236 ns	0.666 ns
FLD	-0.517 ns	-0.792 ns	0.004 ns	-0.295 ns	0.742 ns
FWT	0.120 ns	0.134 ns	0.374 ns	0.207 ns	0.334 ns
VL	0.254 ns	0.331 ns	-0.395 ns	-0.241 ns	0.509 ns
VD	0.737 ns	-0.216 ns	0.310 ns	-0.680 ns	0.681 ns
RH	-0.591 ns	0.110 ns	0.464 ns	0.641 ns	0.847 ns
RW	-0.644 ns	0.838 ns	0.355 ns	0.740 ns	0.334 ns

The level of significance used are ns = non- significant

Rays - Uniseriate, biseriate, multiseriate, mean ray height and ray width 41.68-1094.1µm (Mean 375.20±204.04µm) and 10.42-83.36µm (Mean 46.26±18.45µm), rays both homocellular and heterocellular, all ray cells procumbent in homocellular rays, body cells procumbent with one - two rows of upright and/or square marginal cells in heterocellular ray. Rays 6 - 14 (Mean 8.64 ±1.78) per mm.

Mineral inclusions - Prismatic crystals present in upright/or square marginal cells of ray, in chambered axial parenchyma cells.

Melia azedarach L.

Growth rings - Distinct, a ring-porous wood.

Vessels - Mostly solitary in early wood, and clusters in latewood, circular in outline, drum, barrel and tube shaped with tail, 150.12-625.5µm (Mean 291.23±68.84µm) in length, 98.99-250.08µm (Mean 165.30±33.69µm) in diameter in early wood, 78.15-109.41 µm (Mean 98.55±9.28µm) in diameter in latewood, vessel frequency 4-8 (Mean 6±1) per mm^2 in early wood, 4-12 (Mean 7.71 ±1.82) per mm^2 in late wood, simple perforation plates, intervessel pits alternate, medium, 5.2 – 10.4µm (Mean 7.11±1.58µm) in size, vessel ray pits with distinct borders, similar to intervessel pits in size and shape throughout the ray cell, gummy deposits present.

Fibres - Thin to thick walled, 500.4-1501.2µm (Mean 914.13±205.72µm) long, 10.4-41.6µm (Mean 23.12±5.56µm) and 5.2-20.8µm (Mean 12.23±3.47µm) in diameter and lumen diameter, 2.6-15.6µm (Mean 5.44±3.02µm) in wall thickness, septate and forked fibres present.

Parenchyma - Vasicentric, banded, bands more than three cells wide, 2-10 cells per parenchyma strand.

Rays - Mostly multiseriate, rarely uniseriate, biseriate, mean ray height and ray width 125.04-583.52µm (Mean 338.85±83.97µm) and 20.84-104.2µm (Mean 59.26±16.44µm), rays both homocellular and heterocellular, all cells procumbent in homocellular ray, body ray cells procumbent with two rows of upright and/or square marginal cells in heterocellular ray. Rays 2 -7 (Mean 4.06±1.07) per mm.

Mineral inclusions - Prismatic crystals present in procumbent ray cells and chambered axial parenchyma.

Analysis of variance was carried out to see the variation in anatomical characteristics within genera. The results presented in Table 3 showed that statistically significant variation existed for fibre length in *A. indica* and *A. wallichii* and for fibre diameter in *C. tabularis* and *M. azedarach*. There was a statistically significant variation in fibre lumen diameter in all species except *D. binectariferum*. Fibre wall thickness variation was non-significant in all species except *C. tabularis*. The vessel parameters namely vessel length, vessel diameter and intervessel pits exhibited statistically significant differences in all species except vessel length in *C. tabularis*, intervessel pits in *A. indica*. Similar non-significant variation existed in vessel frequency of selected species except *A. indica* and *D. binectariferum*. Axial parenchyma strand varied non-significantly for all species. There was significant variation in ray height for all species.

The results presented in Table 4 showed that fibre percentage was maximum than other tissue in selected species. Maximum fibre percentage was observed in *A. wallichii* followed by A. indica, *M. azedarach*, *D. binectariferum* and

C. tabularis. The vessel and ray percentage were maximum in *C. tabularis* and *D. binectariferum*. The results presented in Table 5 showed that the relationship between wood density and all anatomical characteristics like fibre length, fibre diameter, fibre lumen diameter, fibre wall thickness, vessel length, vessel diameter, ray height and ray width was too weak to be significant.

Discussion

The woods in selected members of family Meliaceae were diffuse-porous with distinct and indistinct growth rings, semi-ring-porous and ring-porous. Diffuse-porous woods with indistinct growth rings were present in *Amoora wallichii* and *Dysoxylum binectariferum* and growth rings were demarcated by marginal bands of parenchyma in *Chukrasia tabularis*. The other genera *Azadirachta indica* and *Melia azedarach* were semi-ring-porous and ring-porous. Solitary vessels, (except latewood vessel of *M. azedarach*) simple perforation plates, inter-vessel pits alternate, small to medium and vessel ray pits with distinct borders; similar to intervessel pits in size and shape were the common features present in all genera. Most of the features are in agreement with the findings of other workers (Metcalfe and Chalk, 1950; Patel, 1974; Pennington and Styles, 1975). Gummy deposits were present in vessels of *A. indica* and *M. azedarach* only.

A perusal of literature reveals that family Meliaceae has vasicentric, confluent to banded axial parenchyma (Ogata *et al.*, 2008; Khaopakro *et al.*, 2015). Various types of parenchyma like scanty paratracheal, vasicentric, diffuse, banded (both apotracheal and paratracheal) were observed in the present study which shows that more than one type of parenchyma may be present in the same genus. Rays were mostly multiseriate, both homocellular and heterocellular. The homocellular rays consisted of procumbent cells in all selected genera except *C. tabularis*. In this genus, homocellular rays composed of either procumbent cells or upright cells or square cells and heterocellular rays with procumbent body ray cells with square and /or upright cells mixed throughout the rays were reported. So far, there is no report of cellular composition of rays of the genera taken for the present study.

The presence of prismatic crystals in chambered axial parenchyma cells have been reported by many researchers (Metcalfe and Chalk, 1950; Patel, 1974; Negi *et al.*, 2003 and Khaopakro *et al.*, 2015). In the present study, prismatic crystals were present in chambered axial parenchyma (*C. tabularis*, *D. binectariferum* and *M. azedarach*), fibres (*A. indica* and *C. tabularis*), procumbent ray cells (*D. binectariferum*, *A. indica* and *M. azedarach*) and procumbent, square and upright ray cells in *C. tabularis*. Hence, it is in agreement with the findings of these workers.

Wheeler *et al.* (1989) proposed three categories for fibre length and fibre wall thickness. The categories of fibre length are ≤900μm, 900-1600 μm and ≥1600 μm and very thin walled, thin to thick walled and very thick walled for fibre wall thickness. Vessel diameter was categorized as ≤50 μm, 50-100 μm, 100-200 μm and ≥200 μm. In the present study, fibre length of all selected genera was in the range of 900-1600 μm except *Amoora wallichii* and *Chukrasia tabularis*. Vessel diameter was in range of 100-200μm except *A. indica*. The fibres were mostly thin walled. Similar results were obtained in other genera of this family by Metcalfe and Chalk,1950; Khaopakro *et al.*, 2015. However, there is no report on other selected parameters in the literature.

Wood characteristics are highly variable within a tree, among trees of same species, between populations of a species growing in a locality and between populations of species growing in different geographical areas (Zobel and Talbert, 1984). Among wood characteristics, fibres length, vessel length and their dimensions are under strong genetic control and show variation within and among trees (Zobel and van Buijtenen, 1989). Most of the anatomical characteristics show highly significant variations and contrary to the findings of Pande *et al.* 2007a, 2007b; 2009. Samples of selected genera collected from different sites may be the cause of highly significant variation in anatomical characteristics.

The relative proportion of various cell types present in wood varies from species to species. Also, the proportion of different cell types in wood with their dimensions are important not only in hydraulic conductivity, toughness and flexibility of living trees but also in permeability, density, mechanical strength properties and end uses of wood. All selected genera had higher percentage of fibres than other tissues like other hardwoods and corroborates the findings of Sharma *et al.*, 2011a, 2011b; Singh *et al.*, 2019.

Wood density, a complex functional trait in hardwoods, is comprised of properties of wood elements like vessels, fibres and parenchyma (Fortunel *et al.*, 2014). In the present study, the range of wood density in all selected genera was 0.65-0.81 gm/cc. The higher fibre percentage and presence of more extractives in the rays may attribute to highest wood density in *A. indica*. According to Wheeler *et al.* (1989), the wood having wood density less than 0.40 gm/cc is light wood, between 0.40 to 0.75 gm/cc is moderately heavy wood and above 0.75 gm/cc is heavy wood. The present study shows that *A. wallichii, C. tabularis, D. binectariferum* and *M. azedarach* are moderately heavy woods whereas *A. indica* is a heavy wood.

Anatomical characteristics like fibre wall thickness, vessel frequency, vessel diameter, vessel grouping, ray height and ray width etc. govern the wood density (Fujiwara *et al.*, 1991; Fujiwara, 1992). On the other hand, Fortunel *et al.* (2014) reported that wood density is independent of vessel traits and determined by fibre traits only. Several studies have shown the conflicting results on relationship between wood density and anatomical characteristics (Pande *et al.*, 2008; Sreevani and Rao, 2014 Zheng and Cabrera, 2013; Zieminska *et al.* 2013). The relationship of wood density with all anatomical characteristics was too weak to be significant which may be due to differences in age of the selected trees, location and samples taken from sapwood for the investigation.

Conclusions

Most of the qualitative anatomical features were similar in all selected genera. Growth rings were indistinct in *A. wallichii* and *D. binectariferum*. Both apotracheal and paratracheal banded parenchyma was present in *D. binectariferum*. Rays were mostly multiseriate in *A. indica* and *M. azedarach*. Crystals were absent in *A. wallichii*. However, the genera differ from one another in their quantitative anatomical features. All selected genera are moderately heavy except *A. indica* and are most suitable for different end uses.

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