Journal homepage: www.scienceletters.researchfloor.org

Contents list available at Journal of e-Science Letters

Journal of e-Science Letters

Original research Article | ISSN :3041-5454

Wood anatomy of *Broussonetia papyrifera and Antiaris toxicaria* of family Moraceae according to IAWA feature list

Ronak Yadav[1*] and Sangeeta Gupta[2]

[1]*Wood Anatomy Discipline, Forest Research Institute, Dehradun, Uttarakhand – 248006, India*
[2]*Wood Anatomy Discipline, Forest Botany Division, Forest Research Institute, Dehradun, Uttarakhand – 248006, India*

ABSTRACT

The present study is based on the wood microstructure of two species i.e., Broussonetia papyrifera L'Herit. ex Vent. and Antiaris toxicaria Lesch. belongs to family Moraceae. These two genera were important for paper making and manufacturing of plywood from ancient times. For making permanent slides an internationally recognised standard procedure is followed and the features were recorded according to list given by IAWA for hardwood identification. Photomicrographs were taken from all three sections to record diagnostic feature of each taxon. A. toxicaria is a diffuse porous wood with aliform and confluent parenchyma; rays are multiseriate with few 1-3 seriate; all septate fibres; polygonal IVPs and presence of prismatic crystals. B. papyrifera is a ring-porous wood with only multiseriate rays; crystals in upright or square ray cells; palisade VRPs; polygonal IVPs and heterocellular rays. For the first time in the Indian context, the wood microstructure of these selected two species were reported according to the feature list of IAWA for hardwood identification.

Keywords: *Moraceae, B. papyrifera, A. toxicaria, IAWA, Wood microstructure, ring porous*

Introduction

The fig family Moraceae consists of monoecious and dioecious trees, shrubs, lianas, and rarely herbs; nearly all possess a milky sap [6]. Today, the members of this family are found all over the world, mainly in tropical and subtropical regions with a few species in temperate areas [10] [17] [18]. It consists of about 38 genera and 1180 species extensively distributed in the warmer parts of the world [4]. In India, the fig family is represented by 9 genera and 140 taxa (125 species and 15 infraspecific taxa) [11]. Out of 9 genera we studied two genera in this present work.

First, *Broussonetia* L'Herit. ex Vent. is a genus of about 7-8 species of trees and large shrubs distributed in Eastern Asia. In India, one introduced species i.e. *Broussonetia papyrifera* is found near Dehradun and irrigated parts of Punjab [14]. Commonly known as paper mulberry, *B. papyrifera* is renowned as a fibrous tree essential to the development of paper making techniques in ancient China around 100 A.D. [2] [9]. This fast-growing dioecious weedy tree species is most likely native to China, Taiwan, and continental Southeast Asia [12]. The species of this genus are used for making paper because of very strong and long fibres in the wood [14]. Of these, only one species found in India was studied for their wood microstructure.

Citation: Ronak Yadav, Sangeeta Gupta (2020). Wood anatomy of *Broussonetia papyrifera and Antiaris toxicaria* of family Moraceae according to IAWA feature list. *Journal of e-Science Letters.*
DOI: https://doi.org/10.51470/eSL.2020.1.6.23

Received 19 September 2020
Revised 27 October 2020
Accepted 18 November 2020
Available Online 14 December 2020

Corresponding Authors: **Ronak Yadav**
Email: **yadavronak2380@gmail.com**

Second, *Antiaris* Lesch. is a genus of 4 species of trees or shrubs distributed in tropical Africa, Madagascar, and Indo-Malayan region of Asia [14]. The genus originally comprised 17 species but [5] reduced and described only four species, as well as pointing out that these four species do not have any essential differences. After a few years of Corner, [2] were combined all species under *A. toxicaria* Lesch. which further lowered the rank into subspecies.Of these only one species (*A. toxicaria*) found in India was studied for their wood anatomy, distributed in the evergreen forest of Western Ghats. The wood is commonly used in making Plywood [14].

This wood microstructure of the genus *Antiaris* has been studied by [8], [16].. In India, [14] provided information about the macrostructure of the genus. It is hard to find any latest literature on the wood anatomy of genus *Broussonetia* except [13], [14] and [15]. [14] have covered General properties, and gross structure with few microstructure properties of Moraceae. However, their work does not cover the complete microstructure details at the species level and is not as per the IAWA list. In this work we provide first time complete description of selected species of two genera of the Moraceae family.

Material and Methods:

The present study examined the wood samples from two genera of the Moraceae family according to feature list of hardwood identification, housed in the Xylarium of the Forest Research Institute, Dehradun (DDw). The individual specimen details are given in Table 1, along with the accession numbers localities and specific gravity.The wood samples were collected from different parts of erstwhile India (i.e. India before Independence-Myanmar, Pakistan and Bangladesh).

Table 1: list of wood samples under present study

Sr. No.	Species	Acc. No.	Locality	Sp. gr.
1.	*Antiaris toxicaria* Lesch.	DDw 813	Myanmar	0.37
2.	*Antiaris toxicaria* Lesch.	DDw 6614	Western Ghats, Karnataka	0.27
3.	*Broussonetia papyrifera* (L.) L'Hér. ex Vent.	DDw 5677	Lahore, Pakistan	0.42
4.	*Broussonetia papyrifera* (L.) L'Hér. ex Vent.	DDw 5884	Dehradun, Uttarakhand	0.42

A 15-20 µm thick transverse section (TS), tangential longitudinal sections (TLS) and radial longitudinal (RLS) sections were cut with the help of Reichert microtome. The sections were stained with Heidenhain's Haematoxylin and Safranin and passed through grades of alcohol(30-100%)to ensure complete dehydrationand finally mountedin Canada balsam following an internationally recognized standard wood anatomy protocol to prepare-permanent slides. The vessel and fibre quantitative characteristics were determined with Schultz's method in which macerating the radial-chips of wood with 30% Nitric acid and a pinch of potassium chlorate [7]. From the macerated material, 25 measurements for fibre length, diameter and lumen diameter, and 10 measurements for vessel length weretaken and averaged.

For wood microstructure description, the terminology given by the International Association of Wood Anatomists [7] for hardwood identification was followed.Photomicrographs were taken in a Carl Zeiss compound light microscope (Scope.A1.Axio) equipped with Carl Zeiss camerafrom TS, TLS and RLS for the diagnostic features of each taxon.

Results and Discussion

Antiaris toxicaria Lesch

General features- No distinction between heartwood and sapwood, wood white when freshly cut, becoming pale yellow, buff or grayish white on aging; very soft to soft and very light to light (specific gravity 0.27 – 0.37 air dry), Texture coarse; grain interlocked. [14]

Microscopic features

Growth ring- Growth ring either faint or absent.

Vessels- A diffuse porous wood, solitary (40 – 60 %) as well as irregular cluster and short radial multiple of 2-4 vessels; vessel arrangement not specific/ scattered; vessel frequency 3-10 / mm^2, solitary vessel outline round to oval, range of vessel diameter 70-240 µm, vessel member length 300-550 µm, perforations simple. Intervascular pits alternate and the shape of IVPs is polygonal; medium to large size of IVPs with range 8.01-14.69 µm (Fig 1d). Vessel-ray pits are much-reduced border to apparently simple, pits round to angular, vertical (Palisade) or horizontal (Scalariform/gash-like) VRPs; 6.67-24.03µm. Vessel-ray pits are large and not regular shaped. Tyloses are common but occasionally absent. A heartwood vessel contains gums and other deposits (Plate 1, Table 2).

Fibre are septate with simple to minutely bordered fibre pits; fibre thin to thick walled; Range of fibre wall thickness 2-5.34 µm, fibre Lumina 10.68-34.71 µm; fibre length 980-2100 µm; F/V ratio 2.98-4.03 (mean 3.47) (Table 2, Fig 1g-1h)).

Axial parenchyma is paratracheal, vasicentric as thin or fairly thick sheaths round the vessels which become aliform with short to long wings i.e., lozenge aliform and confluent (Fig 1a). Parenchyma with 3-4 and 5-8 cells per strand.

Ray parenchyma-Rays are multiseriate 4-10 seriate (frequently 2-5 seriate only), mostly 1-3 cells wide with few number of uniseriate rays; 4-7 rays/ mm.; Uniseriate rays height up to 2-19 cells (80-500 µm) and multiseriate rays have 11-39 ray number of cells (250-930 µm). Rays are both homocellular (All ray cell procumbent) and heterocellular with body ray cell procumbent with one row of upright and/ or square marginal cells. Occasionally few sheath cells present (Table 2, Fig 1b-1c)).

Secretory elements and cambial variants- Laticifers or Radial latex tubes present (Fig 1e).

Mineral inclusions- Prismatic crystals present in procumbent, upright and/ or square ray cells. Crystal present in chambered ray parenchyma cells (Fig 1f).

Table 2- Dimension of Microscopic features of wood of Antiaris toxicaria Lesch.

Microscopic Features		*Antiaris toxicaria* Lesch. (µm)	Microscopic Features		*Antiaris toxicaria* Lesch. (µm)
Vessel Length	**Range**	300 – 550	Ray height (Uniseriate)	**Range**	80 -500
	Mean ± SD	414.11±67.45		**Mean ± SD**	225 ± 114
Vessel Diameter	**Range**	70 – 240	Ray width (Uniseriate)	**Range**	10.68 – 24.02
	Mean ± SD	162.67±47.88		**Mean ± SD**	17.09 ± 3.55
Vessel frequency	**Range**	3 – 10	Ray no. of cells (Uniseriate)	**Range**	2 – 19
	Mean ± SD	6..13±1.73		**Mean ± SD**	8.33 ± 4.39
Inter-vessel pits (IVP)	**Range**	8.01–14.69	Ray height (Multiseriate)	**Range**	250 – 930
	Mean ± SD	11.56±1.81		**Mean ± SD**	512 ± 199.6
Fibre length	**Range**	980-2100	Ray width (Multiseriate)	**Range**	24.03 – 69.42
	Mean ± SD	1442±250		**Mean ± SD**	21.27 ± 8.12
Fibre diameter	**Range**	18.69-37.38	Ray no. of cells (Multiseriate)	**Range**	11 – 39
	Mean ± SD	28.33±5.66		**Mean ± SD**	3 ± 0.9
Fibre wall thickness	**Range**	2-5.34	Ray frequency	**Range**	4 – 7
	Mean ± SD	3.63±0.85		**Mean ± SD**	5.73 ± 0.94
Vessel ray pits VRPs	**Range**	6.68-24.03	**Vulnerability**	26.52	
	Mean ± SD	10.19±1.64	**Mesomorphy**	11263	
F/V ratio	3.30		**VL/VD**	2.61	

Plate 1: Microscopic features of Antiaris toxicaria Lesch.

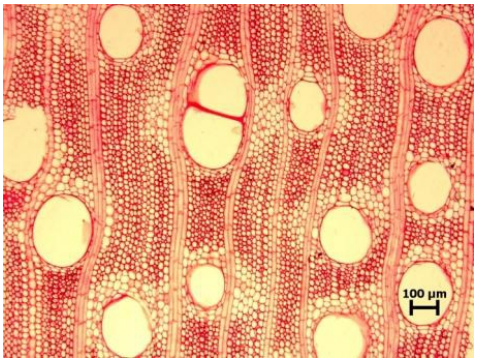

Fig 1a: (Ddw 6614) TS showed diffuse wood porosity and aliform or confluent parenchyma (5x)

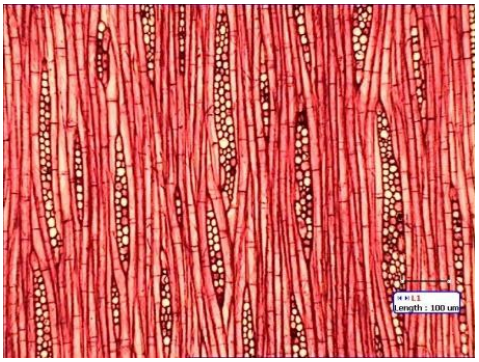

Fig 1b: (Ddw 6614) TLS showed multiseriate rays with some uniseriate (1-3 cell wide), septation in all fibres (5x)

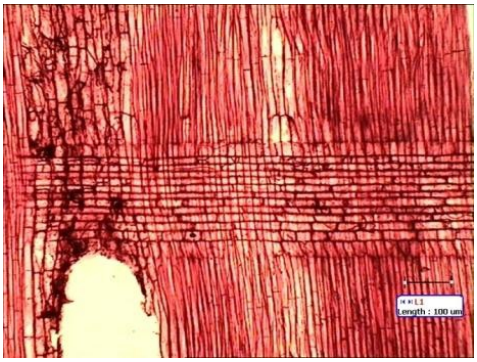

Fig 1c: (Ddw 6614) RLS showed body ray cell procumbent with one rows of upright or square ray cells (5x)

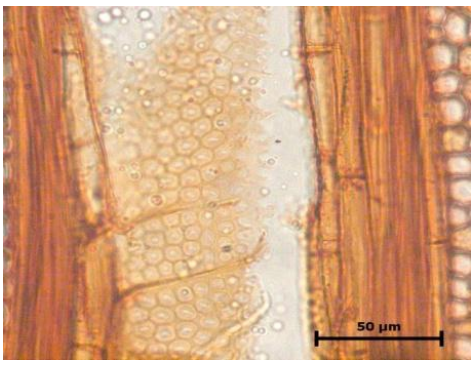

Fig 1d:Antiaris toxicaria (DDw 6614) TLS showed polygonal IVPs (40x)

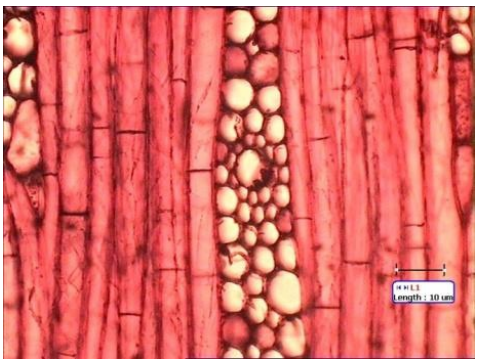

Fig 1e:(DDw 813) TLS showed septate fibres and radially Latex tube (40x)

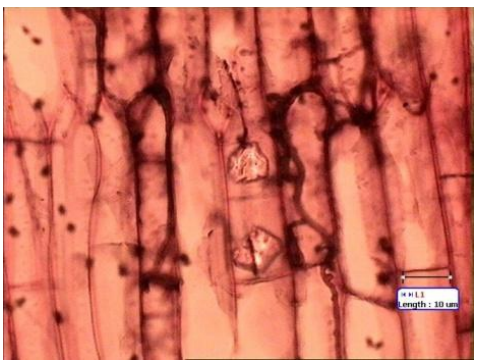

Fig 1f:(DDw 6614) RLS showed prismatic crystal in parenchyma ray cells (40x)

Fig 1g:(DDw 6614) shows fibre length (10x)

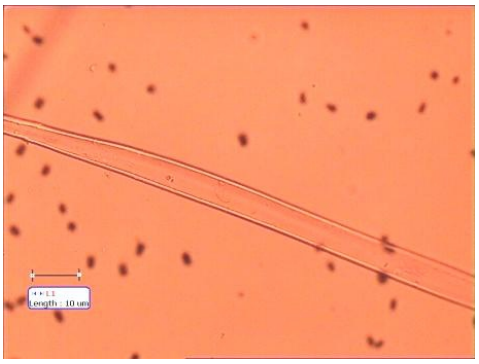

Fig 1h:(DDw 6614) shows fibre diameter (40x)

Fig 1i:(DDw 813) shows vessel length (10x)

***Broussonetia papyrifera* (L.) L'Hér. ex Vent.**

General features- Wood white to grayish white when fresh, whitish brown on exposure, soft and light (sp. gr. 0.42 air dry) straight grained and moderately coarse and uneven textured giving silver-grain on radial surface [14].

Microscopical features

Growth rings-boundaries are distinct due to the demarcation of thick walled fibres.

Vessels- Wood ring porous with abrupt transition to the latewood (smaller vessels) or early wood (larger vessels) on the same growth ring, Earlywood vessels are solitary as well as radial multiple of 2-3 vessels, latewood vessels very small grouped into nested near growth ring, vessel arranged diagonally and radially, solitary vessel outline round to oval. The range of diameter of vessels 60-600 µm (mean= 176.78) and vessel member length 300-550 µm. Simple perforation plates; Intervascular pits alternate and the shape of IVPs is polygonal; size of IVPs 6.67-14.69 µm. Vessel-ray pits are much-reduced borders to apparently simple, pits round to angular; VRPs are similar to IVPs in size or shape throughout the ray cell; 5.34-10.68µm. Vessel-ray pits are restricted to marginal rows. Spiral or helical thickening is common in latewood vessels (Table 3, Plate 2, Fig 2a, 2d, 2f).

Fibres are both septate and non-septate with simple to minutely bordered pits; fibre thin to thick-walled. The length of fibres is 893 (490-1300) µm with a walls thickness of 2.98 (2 – 5.12) µm, fibre Lumina 7.68 -33.37 µm; F/V ratio 3.18 (Table 3, Fig 2g).

Axial parenchyma scanty paratracheal; vasicentric, lozenge aliform and confluent; two cells or 3-6 cells per parenchyma strand (Fig 2a).

Ray parenchyma- Rays are mostly multiseriate 4-10 seriates; 2-6 rays per mm. Rays are heterocellular, rays are composed of body ray cells procumbent with one row of upright or square marginal cells and 2-4 rows of upright or square marginal cells. The average height of multiseriate rays is 468.3 µm (200-880 µm) and the average width 57.22 µm (26.7 -93.45 µm) with 9 - 49 cells long. Disjunctive ray parenchyma cells are present. Occasionally few sheath cells present (Table 3, Plate 2, Fig 2b-2c).

Secretory elements and cambial variants- Laticifers or latex tubes present which produce latex.

Mineral inclusion- Prismatic crystals are present in procumbent, upright and square ray cells. Crystal is also present in non-chambered axial parenchyma cells (Fig 2e).

Table 3- Dimension of Microscopic features of Broussonetia papyrifera (L.) L'Hér. ex Vent.

Microscopic Features		*Broussonetia papyrifera* (µm)	Microscopic Features		*Broussonetia papyrifera* (µm)
Vessel length	**Range**	300 – 550	Ray height (Uniseriate)	**Range**	*
	Mean ± SD	414.11±240		**Mean ± SD**	*
Vessel diameter	**Range**	60 - 600	Ray width (Uniseriate)	**Range**	*
	Mean ± SD	176.7 ± 101.9		**Mean ± SD**	*
Vessel frequency	**Range**	**	Ray no. of cells (Uniseriate)	**Range**	*
	Mean ± SD			**Mean ± SD**	*
Inter-vessel pits (IVP)	**Range**	6.67 – 14.69	Ray height (Multi seriate)	**Range**	200 – 880
	Mean ± SD	10.01 ± 1.94		**Mean ± SD**	468.3 ± 178.2
Fibre length	**Range**	490 - 1300	Ray width (Multiseriate)	**Range**	26.7 – 93.45
	Mean ± SD	893 ± 185.85		**Mean ± SD**	57.22 ± 18.6
Fibre diameter	**Range**	12.8 – 40.05	Ray no. of cells (Multiseriate)	**Range**	9 – 49
	Mean ± SD	20.20 ± 5.56		**Mean ± SD**	26.63 ± 10.28
Fibre wall thickness	**Range**	2 – 5.12	Ray frequency	**Range**	2 – 6
	Mean ± SD	2.98 ± 0.81		**Mean ± SD**	4.43 ± 0.94
Vessel ray pits VRPs	**Range**	5.34 – 10.68	**Vulnerability**		**
	Mean ± SD	7.87 ± 1.54	**Mesomorphy**		**
F/V ratio		3.18	**VL/VD**		1.58

*Legends ** Vessel frequency is not computed for ring porous species, *Means there are no uniseriate rays in this species.*

Plate 2- Microscopic features of Broussonetia papyrifera (L.) L'Hér. ex Vent.

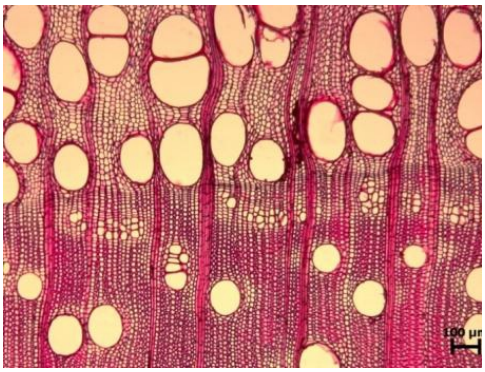

Fig 2a: (DDw 5884) TS showing ring porosity of wood (5x)

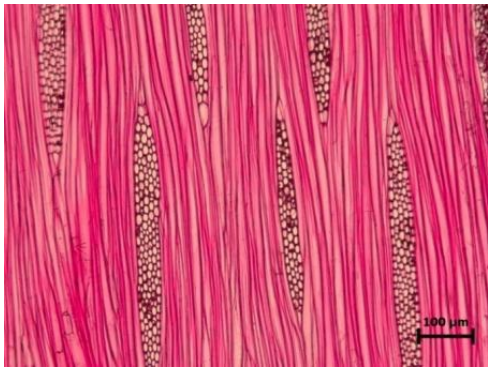

Fig 2b: (Ddw 5884) TLS showing multiseriate rays (10x)

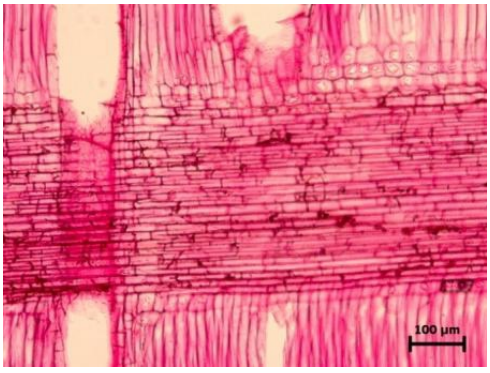

Fig 2c: (Ddw 5677) RLS showing heterocellular rays (10x)

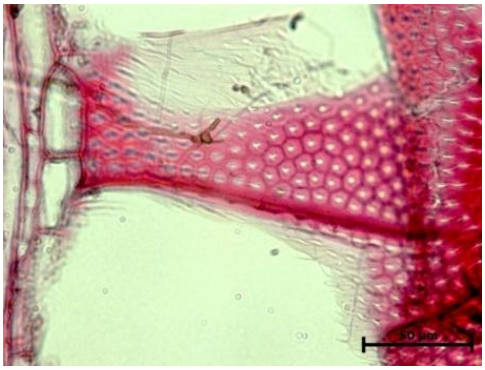

Fig 2d: (Ddw 5677) TLS showing polygonal Inter vessel pits (40x)

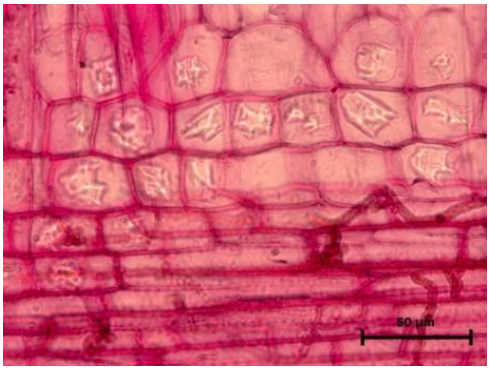

Fig 2e: (Ddw 5884) RLS showing crystals in rows of procumbent, square and upright ray cells (40x)

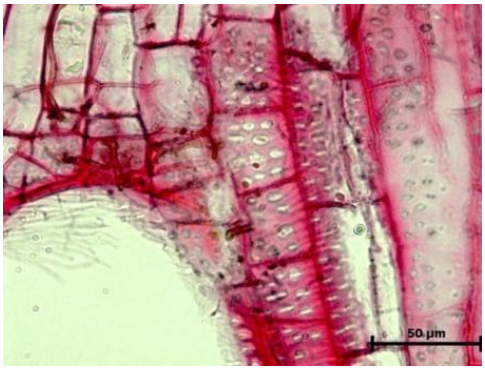

Fig 2f: (Ddw 5884) RLS showing rounded or palisade VRPs (40x)

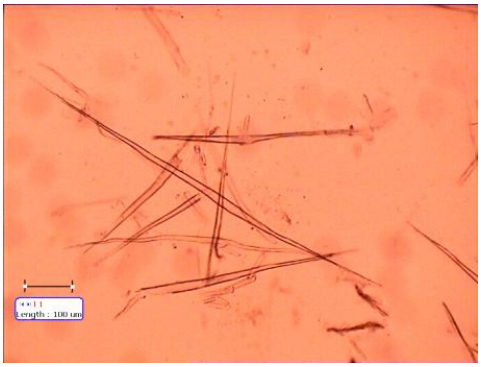

Fig 2g: (DDw 5677) Fibre length (10X)

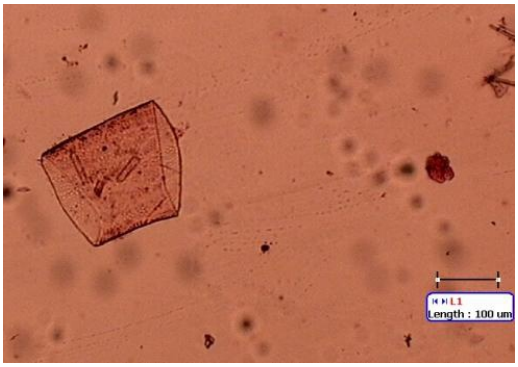

Fig 2h: (DDw 5884) Vessel length (10x)

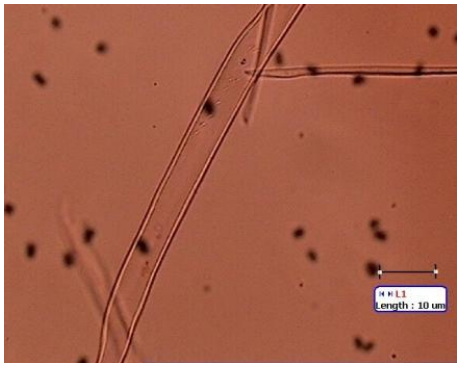

Fig 2i: (DDw 5677) Fibre diameter (40X

The previous literature on the wood anatomy of the selected genera has not covered the features as per IAWA list either based on the gross structure or macrostructure of wood. So, it is hard to find any latest literature on the wood microstructure of the selected species except [8], [13], [14], [15] and [16]. There is the presence of septate fibres in *Antiaris toxicaria* within the present study, which are also reported by [8]. [16] provided information about the distribution of septate fibres within all members of Olmedieae have presence of septate fibres, African genus *Antiaris* placed in Olmedieae by [3] which were also followed by the presence of septate fibre in the genus *Antiaris*. All the qualitative wood microscopic features in present study of genus *Antiaris* were found to be similar with [8] findings except variations in quantitative data which is may be due to environmental influences.

B. papyrifera genus has similar features with findings of [15] and present study in their qualitative wood features which is constant or fixed. However, variations observed in quantitative wood features i.e., maximum vessel length in present study was 550 µm reported maximum length of vessel element was 315 µm in the species of this genus. Maximum fibre length was 490 – 1300 µm and multiseriate ray height was 200 - 880µm in present study while [15] reported fibre length to be 570 – 1150 µm and height of multiseriate rays was 410 – 510 µmin this genus. According to [15] only non-septate fibres are present in this genus but the present works reported both septate and non septate fibre.

Conclusion

An investigation of selected species of the family Moraceae revealed that particular genus has their own prominent characteristics of wood identification. *Broussonetia* is a genera commonly known as paper mulberry have ring porosity in its wood while *Antiaris* genus has diffuse porosity in their wood. *A. toxicaria* is recognized on the basis of septate fibres, all fibres of this taxon show septation while *B. papyrifera* is wood is identified on the basis of absence of 1-3 seriate rays and have only multiseriate rays. The recorded wood anatomical traits are used to differentiate these selected genera from the other genera of the Moraceae family. In the present study the wood microstructure of selected species is reported first time in Indian context as per IAWA.

Acknowledgement

The corresponding author is thankful to the head of the Botany Division and Incharge of Wood Anatomy Discipline, FRI, Dehradun for access the wood samples from the Xylarium. I am grateful to staff of wood anatomy discipline and my colleague Ms Mamta Yadav for their support during writing the manuscript.

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