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Study of fibre and vessel anatomy of *Grewia tiliaefolia* Vahl

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Abstract

Grewia tiliaefolia Vahl is a deciduous medium sized tree which grows in arid climate. It is used for its edible fruits, fodder and medicine. Anatomical studies were conducted at two year old trees at Forest College and Research Institute, Mettupalayam. One plus tree were selected from each age was felled for the study. Fibre and vessel morphology and its derived indices were observed and evaluated under the image analyzer (Optika). The present study investigated that the increase in anatomical trait from pith to periphery and variation in radial position from pith to periphery. This study concludes that, *Grewia tiliaefolia* is suitable for pulp and paper. Hence it could be commercially exploited for further tree improvement program.

Keywords: *Grewia tiliaefolia,* fibre morphology, vessel, two year old

Introduction

Grewia tiliaefolia Vahl (Dhaman, Thadas) is broad leafed and large flowering plant in the family Malvaceae. *Grewia tiliaefolia* is native to India and found in the sub Himalayan tract from Jamna to Assam and in Central, Western and Southern India. Leaves and twigs are lopped for fodder and wood is used for tool handle.

Wood is one of the abundant biomaterials on earth (Salmen, 2015) [23]. As with the expansion of paper industries in the country, the pulp containing plants are being used to an appreciable extent. The world wood fiber is the original source of over 98% of the fibrous component of paper (Walia, 2013) [26]. The successful conversion of pulp into a marketable product depends on the original fibre characteristics. The anatomical properties have a positive correlation on the strength characteristics of wood (Ocloo and Laing, 2003) [16]. The analysis of fibre characteristics such as fibre length, fibre diameter, lumen width, cell wall thickness and their derived morphological factors became important in estimating pulp quality of fibre (Oluwadare and Ashimiyu, 2007)[18]. Understanding of variations in wood properties with age is not only essential to determine the appropriate age of optimum wood properties desired by the industry but also to predict the effects of reducing rotation on wood quality(Makarand and Vishnu, 2015) [14].

In *Grewia tiliaefolia* species, variation from pith to periphery has needed to be studied for wider knowledge of their effect on quality characteristics. The present study was carried out to determine the variation in anatomical properties from pith to periphery and the suitability of *Grewia tiliaefolia* species for pulp.

Material and method:

The investigations were carried out in the laboratory of Department of Agroforestry, Forest College and Research Institute, Mettupalayam, Tamil Nadu, India.

Collection of sample

The species *Grewia tiliaefolia* was identified from the field of Precision Silviculture and sample trees were felled at stump height of 15-20 cm using power chain saw. About one meter length billets from the felled sample trees were collected for analysis. The billet was debarked, cleaned and labelled for analysis.

The wood samples were subjected to analysis of anatomical properties which are essential to find out the suitability of the wood sample.

Sample preparation
The logs from *Grewia tiliaefolia* tree were felled and prepared into chips using pilot chipper. The wood samples each of dimension 2×2×2 cm^3 were sliced out separately from the *Grewia* species. From these wood samples thin microscope sections of size 15 to 20 µm were taken using 'Yorco rotater microtome' (lip Shaw type). Temporary slides were made by staining these sections with safranin stain and subjected to measurements and photography using image analysis system (Optika). Measurement of various parameters was done using the Optika software.

Maceration
Maceration is done using Jeffrey's method (Lim and Son, 1997). Jeffrey's solution is prepared by mixing equal volumes of 10 percent potassium dichromate and 10 percent nitric acid. Radial chips of wood shavings were taken from the 1 cm^3 wood blocks. These chips were boiled in the maceration fluid for 15-20 mins so that the individual fibres were separated. Then these test tubes were kept for 5-10 mins so that the fibres settled at the bottom. The solution was discarded and the resultant material was thoroughly washed in distilled water until traces of acid were removed. The samples were stained using safranin and mounted on temporary slides using glycerin as the mountant.

Fibre length
Fibre length (µm) was measured from macerated wood samples by measuring both end of the fibre through Optika image analysis software.

Fibre diameter
Diameter (µm) of the fibre was measured from macerated wood samples by measuring cross sectional area through Optika image analysis software.

Fibre wall thickness
Wall thickness (µm) of the fibre was measured from macerated wood samples by measuring thickness of the fibre wall cross sectional area through Optika image analysis software.

Fibre lumen width
Lumen width (µm) of the fibre was measured from macerated wood samples by measuring width of the lumen at cross sectional area through Optika image analysis software.

Derived values (Indices) from fibre dimensions
Four derived values were also calculated using fibre dimensions:

a. Slenderness ratio
Slenderness ratio was calculated using following formula suggested by Varghese *et al.,* (1995).

$$\text{Slenderness ratio} = \frac{\text{Fibre length}}{\text{Fibre diameter}}$$

b. Flexibility Coefficient
Flexibility coefficient was calculated using following formula Suggested by Wangaard (1962).

$$\text{Flexibility Coefficient} = \frac{\text{Fibre lumen width}}{\text{Fibre diameter}} \times 100$$

c. Runkel ratio
Runkel ratio was calculated using following formula Suggested by Runkel (1949).

$$\text{Runkel ratio} = 2 \times \frac{\text{Fibre wall thickness}}{\text{Fibre lumen width}}$$

d. Rigidity Coefficient
Rigidity Coefficient was calculated using following formula Suggested by Tamolang and Wangaard (1961).

$$\text{Rigidity Coefficient} = \frac{\text{Fibre wall thickness}}{\text{Fibre diameter}}$$

Table 1: Fibre Morphology of *Grewia tiliaefolia*

	Pith (µm)	Middle (µm)	Periphery (µm)	Mean (µm)
Fiber length	1151.86	1245.80	1407.78	1268.48
Fiber Diameter	16.10	18.11	20.92	18.96
Fiber Wall thickness	4.6	5.26	5.95	5.32
Fiber Lumen width	12.50	12.85	14.97	13.68

Table 2: Vessel Morphology of *Grewia tiliaefolia*

	Pith (µm)	Middle (µm)	Periphery (µm)	Mean (µm)
Vessel length	164.22	197.3	232.04	197.85
Vessel diameter	129.9	149.49	179.88	153.09

Table 3: Derived indices of *Grewia tiliaefolia*

	Pith (µm)	Middle (µm)	Periphery (µm)	Mean (µm)
Slenderness ratio	71.54	68.79	67.29	69.21
Flexibility ratio	72.37	70.95	71.56	71.63
Runkel ratio	0.57	0.81	0.79	0.78
Rigidity coefficient	0.29	0.29	0.28	0.29

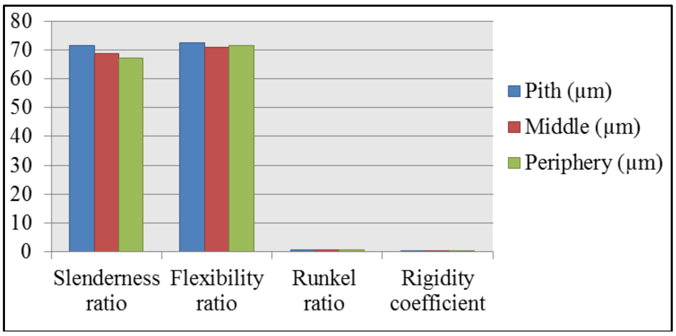

Fig 1: Derived values from fibre dimension of *Grewia tiliaefolia*

Result
Wood Anatomical properties were tested for the wood samples of *Grewia tiliaefolia* at different radial positions.

i. Fibre Morphology
The variation in the fibre morphology was found among different radial position of wood sample. Among the radial position, Pith (1151.86µm) registered higher fibre length followed by Middle (1245.80 µm) and Periphery (1407.78 µm). These results show that fibre length increases from pith to periphery.

The fibre diameter also increases from pith to periphery. Fibre diameter of pith (16.10 µm) registered higher value compared to the middle (18.11µm) and periphery (20.92 µm). The average fibre diameter was 18.96 µm.

In the radial positions (Pith, Middle and Periphery), the mean values of fibre wall thickness was 5.32 µm. The pith (4.6 µm) registered highest fibre wall thickness followed by middle (5.26 µm), and periphery (5.95 µm).

Fibre lumen width recorded significant difference among different radial positions of the wood. Fibre lumen width values for pith, middle and periphery was 12.50 µm, 12.85 µm and 14.97 µm respectively. The average Fibre lumen width was 13.68 µm (Table 1).

ii. Vessel morphology

This experiment showed variation in the vessel length among different radial positions of the wood. The average vessel length was 197.85µm. The pith (164.22µm) exhibited highest value vessel length followed by Middle (197.3µm) and Periphery (232.04 µm). The mean vessel diameter of the radial position (Pith, Middle and Periphery) was 153.09µm. Pith (129.9 µm) recorded highest vessel diameter compared to the Middle (149.49µm) and Periphery (179.88 µm). It was noticed that the vessel length and diameter increased from inner heartwood to outer heartwood (Table 2).

iii. Derived Values (Indices) from Fibre Dimensions

By dividing cell wall thickness by lumen diameter, Runkel classification value was obtained. The Runkel ratio of *Grewia tiliaefolia* was 0.74 µm, 0.81 µm and 0.79 µm at Pith, Middle and Periphery respectively. The average Runkel ratio was 0.78 µm.

Flexibility coefficient is the measure of fibre flexibility. The maximum value of flexibility coefficient was 72.37 µm (Pith) followed 70.95 µm (Middle) and 71.56 µm (Periphery). This results shows that pith's wood fibre was more flexible than other radial direction.

The slenderness ratio of this species found highest in pith (71.54 µm) and the lowest in

Periphery (67.29 µm) compared to the average slenderness ratio (69.21 µm). The middle was 68.79 µm.

In *Grewia tiliaefolia* wood fibres, the rigidity coefficient ranged between 0.29µm (Pith) to 0.28 (Periphery). The average rigidity coefficient was 0.29. The current study recorded that the rigidity coefficient increases with increase in radial direction (Pith, Middle and Periphery) (Table 3).

Fig 2: Fibre (Pith) **Fig 3:** Fibre (Middle) **Fig 4:** Fibre (Periphery)

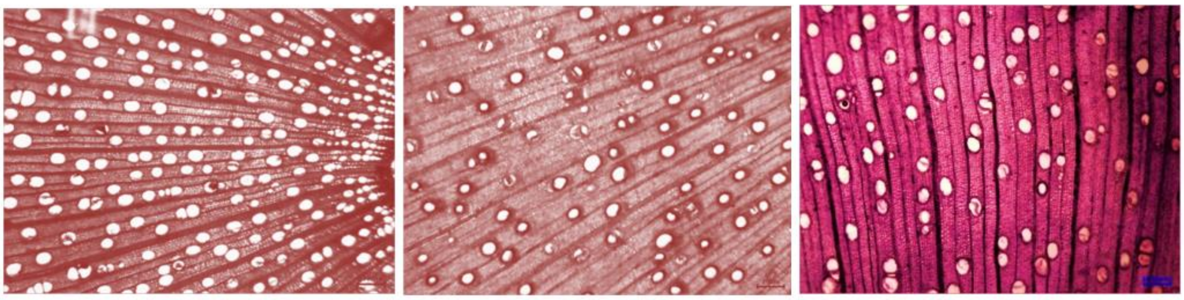

Fig 5: Vessel (Pith) **Fig 6:** Vessel (middle) **Fig 7:** Vessel (Peryphery)

Fig 2-7: Shows the fiber and vessel morphology of *Grewia tiliaefolia* species observed under image analyzer (Optika)

Discussion

i. Fibre morphology

The Fibre morphology *viz*., Fiber length, Fiber diameter, Fiber wall thickness and Fiber lumen width were observed in *Grewia tiliaefolia* wood samples. The fibre morphology traits are increase from inner wood to outer wood in this species. The same line (Jorge *et al*., 2000) [10] found that with increase in age there was an increase in fibre morphology traits from inner wood to outer wood. The radial variation of these traits showed an increasing trend from pith to the periphery although of small magnitude. The observed increase in these traits associated with the increasing radial position (pith to periphery) of the tree may be due to the many molecular and physiological changes that occur in the vascular cambium as well as the increase in the wood cell wall thickness during the tree aging process (Plomion *et al*., 2001 and Roger *et al*., 2007) [20]. The mean cell wall thickness obtained in the radial position was increased from pith to periphery of wood. It also increases from inner wood to outer wood. Current findings are in concurrence with studies on *Tectona grandis (*Izekor and Fuwape, 2011) [9] and Thorn less Bamboo (Krishnakumar *et al*., 2019) [11]. The increase in cell wall thickness if *Gmelina arborea* to changes in cell size that are associated with annual and periodical growth cycles (Akachuku., 1982) [1].

In the present study, the fibre lumen width ranged from12.50µm (pith) to 14.97µm (Periphery). This showed that fibre lumen width decreases with radial direction with outer wood to inner wood, which may be attributed to the increase in the length of fibre initial associated with increasing age of the cambium (Jorge *et al*., 2000) [10]. The observed differences in lumen width with increasing age of the tree may also be due to increase in cell size and physiological development of the wood as the tree grows in girth. The positive relationship reported between variations in lumen width of the cambium. Fibre lumen width increased from inner wood to the outer wood at any particular height. Generally, the trend of variations in fibre lumen width showed a decrease from base to top and an increase from inner wood to outer wood (Roger *et al.*, 2007) [20].

ii. Vessel morphology

There was an increase in vessel length and vessel diameter from pith to periphery. The sap wood of *Grewia tiliaefolia* had possessed wider vessels in the periphery region compared to pith and this was due to the fact the sap wood is physiologically active tissue of wood and its responsible for translocation of sap. Thus, they showed relatively larger vessels.

The vessel length and vessel diameter were interrelated and also significantly varied from pith to periphery (Krishnakumar et al., 2017 and Rao *et al*., 2003) [12, 19]. On the other hand, in *Myracrodruon urundeuva*, the vessel frequency decreased towards bark whereas, the vessel diameter increased (Florsheim *et al*., 1999) [6]. The increase in vessel length and vessel diameter from pith to periphery of *A. odorantissima* (Anoop *et al*., 2005) [2] and *S. saman* (Sahu, 2005) [21] are also in conformity with the results of current study.

iii. Derived Values (Indices) from Fibre Dimensions

Generally, the acceptable value for slenderness ratio of papermaking fibres are more than 33 (Xu et al., 2006) [27]. By referring to this value and morphological properties of *Grewia tiliaefolia* wood fibre, they are suitable to be used for timber as well as pulp and papermaking.

Slenderness ratio of this species is 69.21, which was comparable to *Eucalyptus alba* slenderness ratio value (Dutt and Tyagi, 2011) [4]. This is partly because short and thin fibres are readily collapsed to double walled ribbons and produce good surface contact and fibre to fibre bonding (Ogbonnaya *et al.*, 1997) [17]. Fibre diameter and wall thickness governs the fibre flexibility. A decrease in these variables, which are measures of the flexibility and wet plasticity of fibres, results in higher degree of conformability, which gives rise to a product of a higher density, due to its higher density leads to fixing this species into timber industry. This gives good physical strength properties. Therefore, the furnitures made from *Grewia tiliaefolia* samples are expected to have an increased mechanical strength and thus be more suitable for timber and packaging purposes (Saikia *et al.*, 1997 and Neto *et al.*, 1996) [22 and 15]. Similar result was recorded in *Acacia auriculiformis* wood (Shukla *et al.*, 2007) [24]. The Derived Values (Indices) from Fibre Dimensions are furnished in figure 1.

The fibres with good flexibility are expected to have positive effect on making timber products like furniture. Generally, there are four different types of fibers which are classified under flexibility ratio (Istas *et al.*, 1954; Bektas *et al.*, 1999) [8, 3]:

1. High elastic fibres having elasticity coefficient greater than 75.
2. Elastic fibres having elasticity ratio between50 to 75.
3. Rigid fibres having elasticity ratio between30 to 50.
4. High rigid fibres having elasticity ratio less than 30.

According to this classification, flexibility coefficient of *Grewia tiliaefolia*, ranged from 0.34 to 0.66, which fall under high elastic fibres and this indicated that this species is suitable for secondary timber. On other studies about hardwoods, elasticity coefficient was found as 43.30 for plane (Bektas *et al.*, 1999) [3], 45.20 for eucalyptus (Hus *et al.*, 1975) [7], 41.00 for *Carpinus orientalis* (Tank, 1978) [25] and 46.37 for Robinia (Liao *et al.*, 1981) [13] and it was found that this species is likely in uniformity with other hardwoods in terms of elasticity coefficient. Examining this information given, it seems that fibres from this species were similar to other hardwood fibres.

The fibres of *Grewia tiliaefolia* is rigid and more flexible with high slenderness ratio due to high cell wall thickness with narrow lumen also have Runkel ratio more than 1.0 will be stiffer, more flexible. The product made from this type of fibres will be bulky, coarse surfaced and containing a large amount of void volume (Dutt and Tyagi, 2011) [19]. On the contrary to this, fibres from this species had moderate rigidity coefficient and suitable for timber production. Similarly in *Eucalyptus grandis*, *Eucalyptus alba* and *Eucalyptus tereticornis*. By dividing cell wall thickness by lumen diameter, Runkel classification value was obtained (Dutt and Tyagi, 2011) [4]. When Runkel proportion is greater than 1, it indicates that a fiber has thick wall and cellulose obtained from this type of fiber is less suitable for timber; when it is equal to 1, it specifies that a cell wall has medium thickness and cellulose obtained from this type fiber is suitable for plywood. When the rate is less than 1, it points out that a cell wall is thin and cellulose obtained from this fiber is the most suitable for production of paper (Eroglu, 1980; Xu *et al.*, 2006) [5, 27]. Runkel value of this species indicates, suitable for timber and according to the Runkel classification, they fall under thick wall fibers group. Depending on all of these, it is possible to conclude that *Grewia tiliaefolia* wood fibers are more preferable for secondary timber production.

Conclusion

The wood anatomical characterization of *Grewia tiliaefolia* gives an idea about the morphology of fiber length, fiber diameter, fibre lumen width, cell wall thickness, vessel diameter and vessel height and derived values from fiber dimension which indicates that the *Grewia tiliaefolia* are suitable for making paper. It has been verified from the above observed values of fibre morphology that *Grewia tiliaefolia* species are in the normal range for hardwoods. Thus, it can be concluded that *Grewia tiliaefolia* is well suited to produce pulp and paper.

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Reference

1. Akachuku AE. University of Ibadan, Nigeria. Agric. Research Bulletin. 1980; 1(2):5-6.
2. Anoop EV, F Antony, KV Bhat, LA Davis, LC Babu. Anatomical key for the identification of important timbers of Kerala. Kerala State Council for Science and Technology and Environment, Thiruvananthapuram, 2005, 126.
3. Bektas I, A Tutus, H Eroglu. A study of the suitability of Calabrian pine (*Pinus brutiaten*) for pulp and paper manufacture. Turk. J Agric. For. 1999; 23:589-599.
4. Dutt D, CH Tyagi. Comparison of various eucalyptus species for their morphological, chemical, pulp and paper making characteristics. Indian J Chem. Tech. 2011; 18:145-151.

5. Eroglu H. Investigating possibilities of obtaining wood pulp from wheat straw by O2-NaOH method. Ph.D. Thesis, Karadeniz Technical University, 1980.
6. Florsheim SMB, FM Tomazello, L Spegiurin. Variations in dimensions from pith to the bark and from stem base to the top in the trees of "aroeira" *Myracrodruon urundeuva* F.F and A.F. Allemao (Ancardiaceae) II. Vessels and rays. Rev. Inst. Forestall (Portuguese). 1999; 11(2):159-171.
7. Hus S, T Tank, E Goksal. Considering Eucalyptus (*E. camaldulensis* Dehn). Wood which grow in Turkey (in Tarsus-Karabacak) morphologically and opportunities for evaluating semi chemical cellulose in paper industry. Tubitak Publications, USA, 1975.
8. Istas JR, R Heremans, EL, Roekelboom Caracteres Generaux, De Bois Feuillus, Du Congo Belge En Relation Avec Leur Utilization Dans I 'industrie Des Pates A Papier: Etude Detaillee De Quelques Essences. Gembloux: INEAC, 1954; (Serie Technique, No. 43).
9. Izekor DN, JA Fuwape. Variations in the anatomical characteristics of plantation grown *Tectona grandis* wood in Edo State, Nigeria. Scholars Research Library. Arch. App. Sci. Res. 2011; 3(1):83-90.
10. Jorge F, T Quilho, H Pereira. IAWA Journal. 2000; 21(1):41-48.
11. Krishnakumar N, Kanna SU, Parthiban KT. Principal Component Analysis in Biometric, Pulp Quality and Anatomical Properties of Thronless Bamboo (*Bambusa balcooa*). International Journal of Environment and Climate Change. 2019, 350-355.
12. Krishnakumar N, Umesh Kanna S, Parthiban KT. Anatomical Properties of Two Thornless Bamboos (*Bambusa balcooa* and *Bambusa vulgaris*). Global journal of bioscience and biotechnology. 2017; 6(2):328-331.
13. Liao PY, ZL Hu, WL Ji, LQ Wang, JY Quan. Studies on the chemical components, fiber dimensions and pulping properties of sixteen species of fast growing wood. J Nanjing Technol. Col. For Prod. 1981; 4:16-25.
14. Makarand, Vishnu, Anatomical properties of *Anthocephalus cadamba* (Roxb.) Miq. at five different ages, Indian journal of forestry. 2015; 38(4):323-326
15. Neto P, D Fradinho, MA Coimbra, F Domingues, D Evtuguin A. Silvestre and J.A.S. Cavaleiro. Indian Crops Prod. 1996; 5:189-196.
16. Ocloo JK, E Laing. Correlation of relative density and strength properties with anatomical properties of the wood of Ghana *Celtis* species. Discovery and Innovation. 2003; 15(314):186-197.
17. Ogbonnaya CI, HR Macauley, MC Nwalozie, DJM Annerose. Indian Crop Prod. 1997; 7:9-18.
18. Oluwadare AO, Ashimiyu OS. The relationship between fibre characteristics and pulp-sheet properties of *Leucaena leucocephala* (Lam.) De Wit. Middle-East journal of scientific research. 2007; 2(2):63-68.
19. Rao RV, S Shashikala, P Sreevani. Variation in basic density and anatomical properties of *Eucalyptus tereticornis* clones. J Trop. Forest Prod. 2003; 9(1-2):59-67.
20. Roger MR, TF Mario, CA Edwin. Madera y Bosques. 2007; 13(2):3-13.
21. Sahu VK. Wood property profile of rose wood (*Dalbergia latifolia* Roxb.), Ceylon rose wood (*Albizzia odoratissima* (*Linn.f.)* Benth.) and rain tree (*Samanea saman* (*Jacq*.) Merr.).Kerala Agricultural University. M.Sc. Thesis, 2005.
22. Saikia CN, T Goswami, F Ali. Evaluation of pulp and paper making characteristics of certain fast growing plants. Wood Sci. Technol. 1997; 31(6):467-475.
23. Salmén L. Wood morphology and properties from molecular perspectives. Annals of forest science. 2015; 72(6):679-684.
24. Shukla SR, RV Rao, SK Sharma, P Kumar, R Sudheendra, S Shashikala *et al*. Physical and mechanical properties of plantation-grown *Acacia auriculiformis* of three different ages. Australian Forestry, 2007; 70(2): 86-92.
25. Tank T. Evaluating Beech and Hornbeam species in Turkey by Natural Sulfate Semi Chemical (NSSC) Method. Istanbul University, Istanbul, 1978.
26. Walia YK. Chemical and physical analysis of *Morus nigra* (Black mulberry) for its pulpability. Asian J of Adv. Basic Sci. 2013; 1(1):40-44.
27. Xu F, XC Zhong, RC Sun, Q Lu. Anatomy, ultra-structure and lignin distribution in cell wall of *Caragana Korshinskii*. Indian Crops Prod. 2006; 24:186-193.