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Microstructural Properties of *Lantana camara* L. from the Doon Valley and Its Potential as an Alternative Raw Material for the Pulp and Paper Industry

Vishakha Saxena^{1*}, Dheerendra Kumar²

¹Doon (PG) College of Agriculture Science and Technology, Dehradun

²Forest Research Institute, Dehradun, Uttarakhand

*Corresponding Author's Email: vishakhas.fri@gmail.com

Abstract

The present study was carried out to determine the microstructural properties of *Lantana camara* L. in the Doon Valley forest. Wood fiber dimensions such as length, diameter, lumen width, cell wall thickness, runkel ratio, slenderness ratio, and flexibility ratio of *Lantana camara* were investigated from the wood. The morphology of fibers and its fiber indices from this were done with the aim of grading pulp based on fiber morphology in paper manufacturing.

Keywords: *Lantana camara*, Wood Anatomy, Weed, Fiber Length, Derived Indices.

1. Introduction

Lantana camara L. (Verbenaceae family) also known as wild sage, a native of South American tropical forest was introduced to India early in the 19th century. *Lantana camara*, an introduced species by the British has turned itself in to a noxious weed, which has expanded itself in almost all the possible habitats of India. A large part of Indian forest is also encroached by rapidly growing *Lantana*. *Lantana* also causes problems if it invades agricultural areas because of its toxicity to livestock as well as its ability to form dense thickets which if left unchecked can greatly reduce the productivity of farmland. Because of its thorny nature, animal do not eat its leaves. Another problem with *Lantana* is forest gets fire or fire spread due to the wide spread of the shrubs.

But on the other hand it is also beneficial in the improvement of socio-economic status of the backward communities; stem of this weed if treated with sulphate can be also utilized in preparing paper pulp which is used for wrapping, writing and printing paper and manufacturing baskets^{1,2,3}. The demand for wood and wood-based products, including pulp and paper, has increased in India, and wood of many trees is regularly in use for pulp and paper industry. Paper is an important medium for preserving and recording history from time immemorial. It is one of the most versatile and common products of modern societies. The global consumption of paper is 400 million tons per year and expected to increase its consumption to 500 million tons by 2020, while in India, the consumption of paper and paper board is estimated to be double from 10 million tons per year by 2020. Though the soft woods and hardwoods have desirable characteristics of fibers for pulp and paper making, but over exploitation of these woods for different purposes has resulted continuous decline in their production from natural forests. Due to environmental preservation, the use of wood fiber is restricted.



Some paper industries use paper recycling in paper making; however, paper recycling could affect the mechanical and physical properties of paper⁴. Therefore, intensive work has been done on utilization of new alternative resources as raw materials to overcome global shortage of paper. Emerhi⁵ utilized some mangrove species for pulp and paper manufacturing. Naithani and Pande² utilized stem of *Lantana camara* for pulp and paper making.

The present study is done to look out the use of Lantanain paper industry. The present study is done to look out the grading of pulp of *Lantana camara* to understand the paper quality.

2. Material and Method

Twigs of *Lantana camara* was collected from 4 different locations of Dehradun, Uttarakhand (Dhoolkot; Krishna Nagar; Campus of Forest Research Institute; and Selaqui. These 4 healthy mature plants of *Lantana camara* were randomly selected from 4 different locations as mentioned above based on their availability. From each location, one representative sample was obtained from the hardwood of the stem. With this perspective, an attempt has been made to study the wood anatomy and fiber characteristics of *Lantana camara* to see their suitability for pulp and paper making.

For microscopic examination 20-25 µm thick transverse sections, tangential longitudinal

$$R = \frac{2w}{l}$$

$$FP = \frac{L}{d}$$

$$FR = \frac{l}{d}$$

$$CR = \frac{w}{d}$$

Where,

RR=Runkel ratio

FP =Felting power/Slenderness ratio

FR =Flexibility ratio

CR=Coefficient of rigidity

MR=Muhlsteph ratio

FC = Fibrecoarsness

SF = Luce's shape factor

$$MR = \frac{(d^2 - l^2)}{d^2} \times 100$$

$$FC = d^2 - l^2$$

$$SF = \frac{d^2 - l^2}{d^2 + l^2}$$

L = fibre length

l = fibre lumen diameter

d = fibre diameter

w = fibrewall thickness

sections and radial longitudinal sections were cut on Reichert microtome. The sections were stained in Heidenhain's hematoxylin and Safranin and mounted following standard laboratory schedule i.e. passing through grades of alcohol 30%-100% and xylol for making permanent slides. These permanent slides were observed under light microscope according to the feature list given by IAWA (1989)⁶.

For determination of fiber length, fiber diameter, fiber lumen diameter and vessel length small radial chips of wood samples have been macerated following Schultz's method (30% Nitric acid and a pinch of Potassium chlorate). The same macerated material washed thoroughly with water 2-3 times to remove the acid. The washed material was shaken in the test tube vigorously to separate the different xylem elements *viz.*, fibers, vessels and parenchyma. The macerated material with some water was then transferred to a watch-glass and stained with 2-3 drops of safranin. The material was then mounted on a microscopic slide in glycerin-water (50:50). These micro-slides were observed under light microscope and 25 observations for each parameter were taken. The derived values of fiber dimensions are calculated using the following formulae: -

Data of fiber dimension and their derived values were utilized to determine the fibre quality criteria⁷ following Rachman and Siagian⁷ as described in Table 1.

Table 1. Quality criteria of fibers as raw material for pulp and paper

Criteria	Class I		Class II		Class III	
	Requirement	Score	Requirement	Score	Requirement	Score
Fiber length (μm)	>2000	100	1000-2000	50	<1000	25
Runkel ratio	<0.25	100	0.25-0.50	50	0.50-1.0	25
Slenderness ratio	>90	100	50-90	50	<50	25
Muhlsteph ratio (%)	<30	100	30-60	50	60-80	25
Flexibility ratio	>0.80	100	0.50-0.80	50	<0.50	25
Wall rigidity	<0.10	100	0.10-0.15	50	>0.15	25
Interval	450-600		225-449		<225	
Source: Rachman and Siagian (1976) ⁷						

3. Results and Discussion

3.1. Microscopic Characteristic of *Lantana camara*

Growth rings distinct. Wood diffuses porous with vessels of two distinct diameter classes, solitary, clustered and in radial multiple of 2-3, round to oval. Perforation plate simple (Fig-2). Average tangential diameter of vessel 63 μm , average vessel element length 453 μm . Inter-vessel pits alternate with diameter ranging from 1.25 to 5.0 μm (Fig-2), vessel-ray pits like inter-

vessel pits in shape and size. Fibers non-septate, average fiber length 791 μm , average fiber wall thickness 4 μm , thin walled with distinctly bordered pits to slit-like apertures, average fiber diameter 19 μm . Parenchyma diffuse to diffuse in aggregate and scanty paratracheal. Rays 1-3 seriate, heterogeneous in composition with mostly procumbent, square and upright cells mixed throughout the rays (Fig-1). Average ray height 530 μm , average ray width 42 μm .

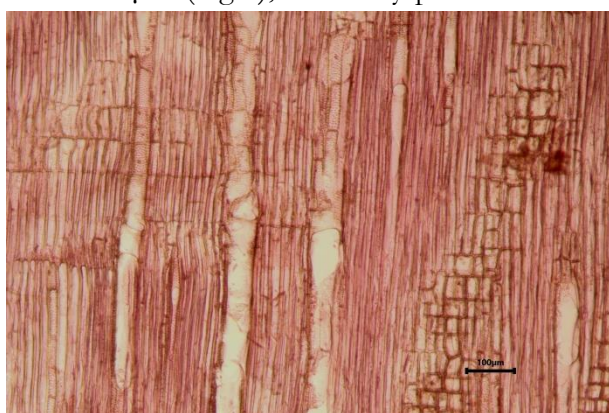


Figure 1. RLS showing heterogeneous with mostly procumbent, square and upright mixed cells.



Figure 2. TLS showing alternate inter vessel pits and simple perforation in vessel.

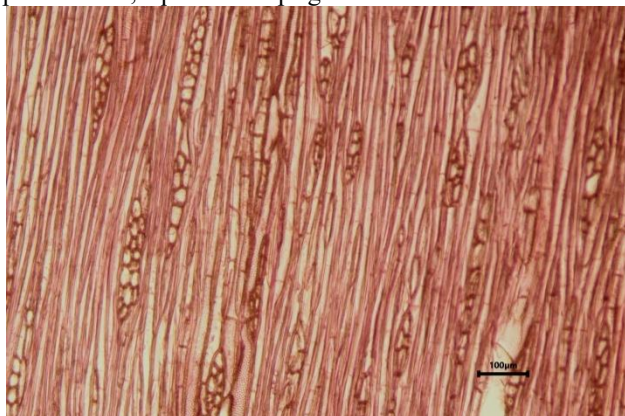


Figure 3. TLS showing rays 1-3 seriate.

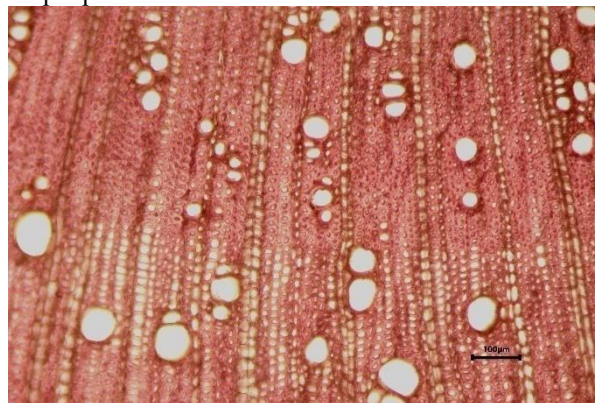


Figure 4. TS showing vessel of two distinct diameter classes, no ring porosity

Table 4. Differential wood anatomical features of *Lantana camara*

S. No.	Sample	VL (μm)	VD (μm)	RW (μm)	RH (μm)	Seration
1	Sample 1	462.67	70	40	507	1-2
2	Sample 2	388.42	82	32.25	747	1-2
3	Sample 3	436.97	52	37.25	439	1-3
4	Sample 4	525.50	49	58	429	1-3
Legends: Vessel length = VL; Vessel diameter = VD; Ray wight = RW; Ray height= RH						

3.2. Morphological features of fibers and vessels

The characteristics of fiber length, fiber diameter and fiber wall thickness are important parameters to estimate pulp quality of fibers in lignocellulose raw materials. The present study shows that mean fiber length of 4 samples of *Lantana camara* varies from 704.93 μm in sample 4 to 850.02 μm in

sample 2; fiber diameter varies from 16.91 μm in sample 3 to 21.82 μm in sample 2; fiber lumen diameter varies from 9.74 μm in sample 1 to 13.36 μm in sample 2 and fiber wall thickness varies from 3.30 μm in sample 3 to 4.39 μm in sample 1. (Table-4)

Table 4. Differential morphological features of fibers of *Lantana camara*

S. No.	Sample	FL (μm)	FD (μm)	LD (μm)	WT (μm)
1	Sample 1	817.53	18.52	9.74	4.39
2	Sample 2	850.02	21.82	13.36	4.23
3	Sample 3	793.97	16.91	10.30	3.30
4	Sample 4	704.93	19.80	11.75	4.03
Legends: Fiber length = FL; Fiber diameter = FD; Fiber lumen diameter = LD; Fiber wall thickness = WT.					

3.3. Derived wood properties

Runkel ratio, slenderness ratio, flexibility coefficient and Luce's shape factor are important derived indices to determine the suitability of material for pulp and paper making. The fibers with Runkel ratio less than 1 are good for paper making because fibers are more flexible, collapse easily and form a paper with large bonded area while, fibers with Runkel's ratio more than 1 are stiff, difficult to collapse and form bulkier paper with less bonded area.^{8,9,10} In the present investigation, the Runkel ratio of selected 4 samples of *Lantana camara* were observed less than 1 and varies from 0.63 μm in sample 2 to 0.90 μm in sample1 (Table 4). From this point of view, fibers of all 4 samples of *Lantana camara* can be considered for pulp and paper making. Felting power or slenderness ratio, a measure of tearing property of pulp in paper making is

determined from fiber length and fiber diameter. The fibers with high felting power are long, thin and have high tearing resistance whereas short and thick fibers have less felting power and tearing resistance. It is reported that felting power of fibrous material more than 33 is considered good for pulp and paper production. All 4 samples have slenderness ratio of more than 33 (Table 4).

Flexibility ratio is one of the important derived indices to determine strength properties of paper and is governed by lumen diameter and fiber diameter. It determines the degree of fiber bonding in paper sheet. The values for hardwood and softwoods are 0.55-0.70 and 0.75 respectively. The fibers having flexibility ratio more than 0.75 and between 0.50-0.75 are considered as highly elastic. In the present study the flexibility ratio varies from 0.45 (sample 2) to

0.57 (sample 1). It indicates that fibers of sample 2, 3 and 4 are not flexible and do not satisfy the requirement for their suitability for pulp and paper making, while fibers of sample 1 having the value 0.57 may be elastic enough to use in pulp and papermaking (Table 4). Fibers with high coefficient of rigidity reflect the higher density. Panshin and de Zeeuw¹¹ mentioned that high fiber density correlated positively to pulp yield. In addition, the resulting fiber will also produce a sheet of paper with high opacity, more rugged,

larger dimension and high tear strength. The present study shows that the coefficient of rigidity varies from 0.19 in sample 2 to 0.24 in sample 1.

Wood fibers with a high Muhlsteph ratio exhibit a smaller surface area, and therefore the bonding area and contact between the fiber decreases. This causes the lowering of tensile strength and crack resistance of resulting paper. Value for Muhlsteph ratio varies from 62.48 in sample 1 to 72.32 in sample 1 (Table 5).

Table-5. Differentially derived wood properties						
S. No.	Sample	R. R.	F.P.	F.R.	C.R.	M.R.
1	Sample 1	0.90	44.16	0.57	0.24	72.32
2	Sample 2	0.63	38.96	0.45	0.19	62.48
3	Sample 3	0.64	46.97	0.46	0.20	62.85
4	Sample 4	0.68	35.60	0.48	0.20	64.78
Legends: Runkel ratio = R.R.; Felting power = F.P.; Flexibility ratio = F.R.; Coefficient of rigidity = C.R.; Muhlsteph ratio = M.R.						

3.5. Assessment of fiber quality

All the samples assessed for the fiber quality in table 5 and scored according to Rachman and Siagian⁷. According to the overall analyzed parameters (fiber length, Runkel ratio, felting power, flexibility ratio, coefficient of rigidity and Muhlsteph ratio), fiber of all four samples of *Lantana camara* belonged to quality class III. Fibers with quality class II have moderate in tear resistance, crack resistance, and tensile strength, since they are easily flattened during pulp sheet forming⁷. Therefore, this species is recommended to be used as raw material for pulp and paper.

4. Conclusion

In this study, the wood of *Lantana camara* had been proven to be a source of raw material for pulp and paper industries due to the quality of its fiber characteristics and this study indicates that fibers of all four samples of *Lantana camara* can be used in papermaking as those are falling in category III of quality criteria for fibers. It is quite

beneficial to us if we can use this invasive species industrially.

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Authors' Contribution

VS: Study design, Conceptualization, interpretation, drafting of manuscript. **DK:** Analysis of data, Literature review, editing of manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest related to this review work.

Data Availability Statement

The data supporting the findings of this study are available within the article. Additional data related to this study are available from the corresponding author upon reasonable request.

Use of AI Statement

The author(s) utilized Gemini (developed by Google) and Grammarly during the writing process to enhance language clarity, correct spelling, and grammatical errors, and ensure appropriate formatting in alignment with *PhytoTalks* journal specifications. These tools were used strictly for language refinement and editing; no original scientific content or data interpretation was generated by the AI. The final manuscript was thoroughly reviewed and approved by the author(s), who remain fully accountable for its contents.

Ethical Approval

Ethical approval was not required for this study.

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