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Characterization of Nalita Wood (*Trema orientalis*) as a Source of Fiber for Papermaking

(Part I): Anatomical, morphological and chemical properties

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ABSTRACT

Nalita wood (*Trema orientalis*), one of the fastest growing woods in the world, is characterized anatomical, morphological and chemical properties at annual growth ring level in order to investigate as papermaking raw material. The proportion of fibers and vessel was increased with an increase of growth ring (from pith to bark). The fiber length of Nalita was increased with increasing growth ring, and an average fiber length was about 817 *um*. The average basic density of Nalita was about 0.38 g/cc. The total lignin & holocellulose in Nalita were increased and ash & alcohol-benzene extract decreased from pith to bark. These values were about 23.5 - 24.4 %, 78.1 - 80.1%, 1.04 - 0.92 % and 2.1 - 1.8 %, respectively. The xylan was the predominant sugar in the hemicellulose of Nalita.

***Keyword** : Growth rate, Annual growth ring, Fiber length, Fiber wall thickness, Vessel, Xylan*

1. Introduction

World is expected to consume 80 percent more paper in 2010 than in 1990. The demand of paper and paper products in Bangladesh is about 0.45 million ton, whereas produces only 0.2 million ton per year (1). Therefore, huge amount of foreign currency are being spent for importing paper and paper products. Unfortunately existing pulp and paper industry could not run properly due to inadequate supply of fibrous raw materials. Therefore, it is an utmost need to find out new fibrous raw materials to survive this industry. The forestland in Bangladesh is very limited. On the other hand environmentalists are keeping pressure to stop deforestation. Forestlands are not increasing, but the demand of fibrous raw material is increasing. There are two ways to overcome this situation, one is to utilize annual plant and other is plantation of fast growing tree. The fast growing tree plantations take pressure off natural forests by providing timber and pulpwood. Fast growing tree plantations can also contribute to biodiversity conservation. Research is underway into the level of global subsidies to fast growing plantations. Fast growing tree plantations are intensively managed

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commercial plantations, set in blocks of a single species such as eucalyptus or poplar, which produce industrial round wood at high growth rates and are harvested in less than 20 years. American Horticultural Society (2) listed a few fast growing tree, a few of them are are: Autumn Purple Ash (*Fraxinus angustifolia, syn. Oxycarpa*) is a quick growing seedless ash tree that can gain 2 - 3 ft a year. It is about 40 - 60 ft tall. Scotch Pine (*Pinus sylvestris*) a magnificent tree, tall and stately grows up to 2 ft in a season. It grows in a pyramidal form, and 40 - 75 ft tall. Silver Maple (*Acer saccharinum*) is one of the fastest - growing windbreak trees. It grows 3 ft per year. It is about 80 ft tall with a 50 ft spread. Poplar (*Populus nigra italica*) is an improved variety of the Lombardy Poplar. It is 120 ft tall and 70 ft spread. Hybrid Poplar (*Populus hybrid*) is the fastest growing trees, in good conditions, hybrid poplars shade a 1 story house in three years Hardy and rugged will grow almost anywhere. They thrive even in bitter cold Canadian climate. Eucalyptus spp. esp. (*Eucalyptus gunnii Cider Gum*) are a genus of trees that if left to their own devices that will go to 50 ft.

Recently, a tree has been found of very fast growth rate in the Dhaka region of Bangladesh. Local name of this tree is Nalita (*Trema orientalis*). It was also reported elsewhere as the fastest growing tree (3). The fastest growth occurs in warm, moist areas with consistent temperatures. *T. orientalis* is widely distributed through a range of altitudes in higher rainfall areas. It prefers sites on well-drained, exposed soils without leaf litter, demonstrating an ability to become established on poor or disturbed soil (4). *T. orientalis* is also a nitrogen fixing tree. No report has been found on the chemical, morphological and anatomical properties.

The ultimate end use of wood depends on its properties (physical, chemical morphological and anatomical properties). In this article, an effort has been made to characterize physical, anatomical, morphological and chemical properties in annual growth ring level. Characterization of Nalita wood introduced a new source of fiber for papermaking.

2. Materials and Methods

2.1 Raw material

The Nalita trees (*Trema orientalis*) used in this study were collected from the Dhaka region of Bangladesh in March 2003. These trees were debarked and chipped to 1 x 1 x 2 cm size. The wood chips were ground in a Wiley mill and 40 - 60 mesh size was used for chemical analysis.

2.2 Physical, morphological anatomical properties

The basic wood density of trees was determined according to PAPTAC Standard A.8P.

For the measurements of fiber length, we first macerated the wood sample of different ages in a solution containing 1 : 1 HNO_3 and $KClO_3$. A drop of macerated sample was taken in a slide and measured fiber length under a profile projector (Nikon V - 12, Japan). The fiber diameter was measured in an image analyzer.

Three wood blocks of about 1 cm x 1 cm x 1 cm from each annual ring was taken and autoclaved followed by immediate storage in a mixture of equal volumes of glycerin, ethyl alcohol and water till sectioning with sliding microtome. Then permanent slide was prepared and analyzed in an image analyzer. The staining was done by Safranin O. The fiber wall thickness, vessel diameter and percentage of ray, vessel and wood fiber was measured from the transverse section (5). For the image analysis, the lumens of vessel and wood fibers were considered as eclipse shape called "Blob" in the system. The area of the Blob was measured at a selected area of a block in an image. The percentage of vessel and wood fiber area was calculated with the total Blob area divided by total block area (6).

2.3 Chemical analysis

The extractive (T204 om88), carbohydrate (T249 cm00), Klason lignin (T211 om83), acid soluble lignin (UM 250) and ash content (T211 os76) were determined in accordance with Tappi Test Methods.

Holocellulose was determined by treating extractive free wood meal with $NaClO_2$ solution. The pH of the solution was maintained at 4 by adding CH_3COOH-CH_3COONa buffer.

3. Results and Discussion

3.1 Growth rate and physical properties

Figure 1 shows the average growth rate in average height and diameter at breast height (DBH) at a few month intervals. The growth of this tree was exceptionally high, therefore, rate was measured a fter a few month interval. Fig. 1 indicates that the average DBH increased to 21.3 cm at the age of 24 months a fter that the rate of increased was reduced. The average height of tree increased to 13.11 m at 3 months. *Eucaliptus amplifolia* produced 12.8 m height and 17 cm DBH in 53 months in Florida (7). The clone, Capitol Lake was a native clone of *Poplus trichocarpa* had DBH, 8.7 cm and height 15.2 m

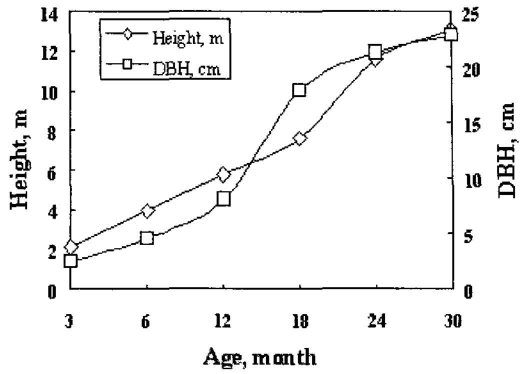

Fig. 1. The growth rate of Nalita tree.

at the 9 years old. Generally, trees whose rotation time is about 15 years are considered fast growing wood. Therefore, it is seen that Nalita is one of the fastest-growing tree. Hence, physical, anatomical, morphological and chemical properties of Nalita were studied. Figure 2 shows the cross section of 3 years Nalita stem. It may be considered as light colored hardwood. The sapwood and heartwood are difficult to distinguishable. Annual ring was hardly visible, which are characteristics of diffuse porous wood.

Table 1 shows the growth ring width and density of Nalita. The width of the growth ring was very high than any other reported fast-growing tree (8). Growth ring width followed an increasing trend with the increase of annual growth ring. It increased to 4.1 cm in the second ring from 1.5 cm in the first ring and again increased from 4.1 cm to in the second ring 4.3 cm in the third ring (Table 1). Most trees showed an increase over a few growth rings from pith followed by decreasing trend (9). In this study, we measured only three growth rings, therefore, our results were consistent with other studied (8).

Density is perhaps the oldest and most widely used criterion for evaluating quality of wood and its strength properties. Table 1 indicates that wood density of Nalita was increased slightly with number of growth

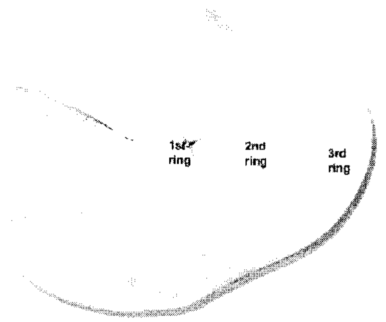

Fig. 2. Cross-section of 3 years Nalita wood stem.

ring (from pith to bark). Similar results are reported in the elsewhere (9). It was increasing from 0.32 g/cc at the first ring to 0.38 g/cc in the third ring. This value was little bit lower for chemical pulpwood. Very fast growth of Nalita may be the reason of lower density. Fast growth is associated with the high percentage of juvenile wood. The density of juvenile wood is lower than mature wood. The average density of loblolly pine was range from 0.36 to 0.45 for juvenile wood and 0.42 to 0.64 for mature wood (10). Numerous investigations conducted on the Southern pines and other Pinus species have conclusively demonstrated that the wide growth ring was likely associated with the lower density of wood (10). Some reports on the relation of wood density to age (distance from pith to bark) were consistent. Some workers found that density was increased with age (11, 12), whereas other suggested a decrease or a decrease followed by increase.

Table 1. Growth ring width and density of Nalita wood

Annual growth ring	Growth ring width, cm	Density, g/cc
First	1.5	0.32
Second	4.1	0.36
Third	4.3	0.38

3.2 Anatomical properties

Table 2 shows the tissue proportion of Nalita. The results showed that the proportion of fiber and vessel was increased and ray decreased with an increase of growth ring (from pith to bark). These results were consistent with the results of *A. excelsa* Jacob (5). The increasing tendency of vessel proportion toward the bark was also observed in *Shorea leprosule* and *S. parvifolia* by Bosmin (13), and *Quercus garryara* Dougl by Lei *et al.* (14). The highest proportion of fiber was 71.4 % at the 3rd annual growth ring and lowest 66.3 % at the first ring. The highest value of ray was 19.6 % at the first annual ring and lowest value was 13.2 % at the third ring. *Castanea crenata* showed similar decreasing trend with increasing growth ring until 6-7th growth ring (15). Generally relative proportion of ray gradually increased until it reach to a certain growth ring and then stabilize. Fast grown wood has more ray than slow grown wood. In oaks, the ray volume some time exceeds 30 % (16). The majority of the ray parenchyma cells were bi- and triseriate, two and three cells in width (Fig. 3). The shape of parenchyma cells was brick like (Fig. 3).

Fiber length is of special importance to the

Table 2. Average tissue proportion and its dimension of Nalita wood

	Annual ring		
	First	Second	Third
Vessel, %	14.1	14.9	15.4
Ray, %	19.6	18.0	13.2
Fiber, %	66.3	67.1	71.4
Vessel diameter, *um*	115.0	112.0	112.0
No. of vessel mm^{-2}	12.7	11.2	9.4
Fiber length, *um*	697.0	829.0	925.0
Fiber diameter, *um*	25.9	26.1	23.9
Fiber wall thickness *um*	1.94	2.24	2.43

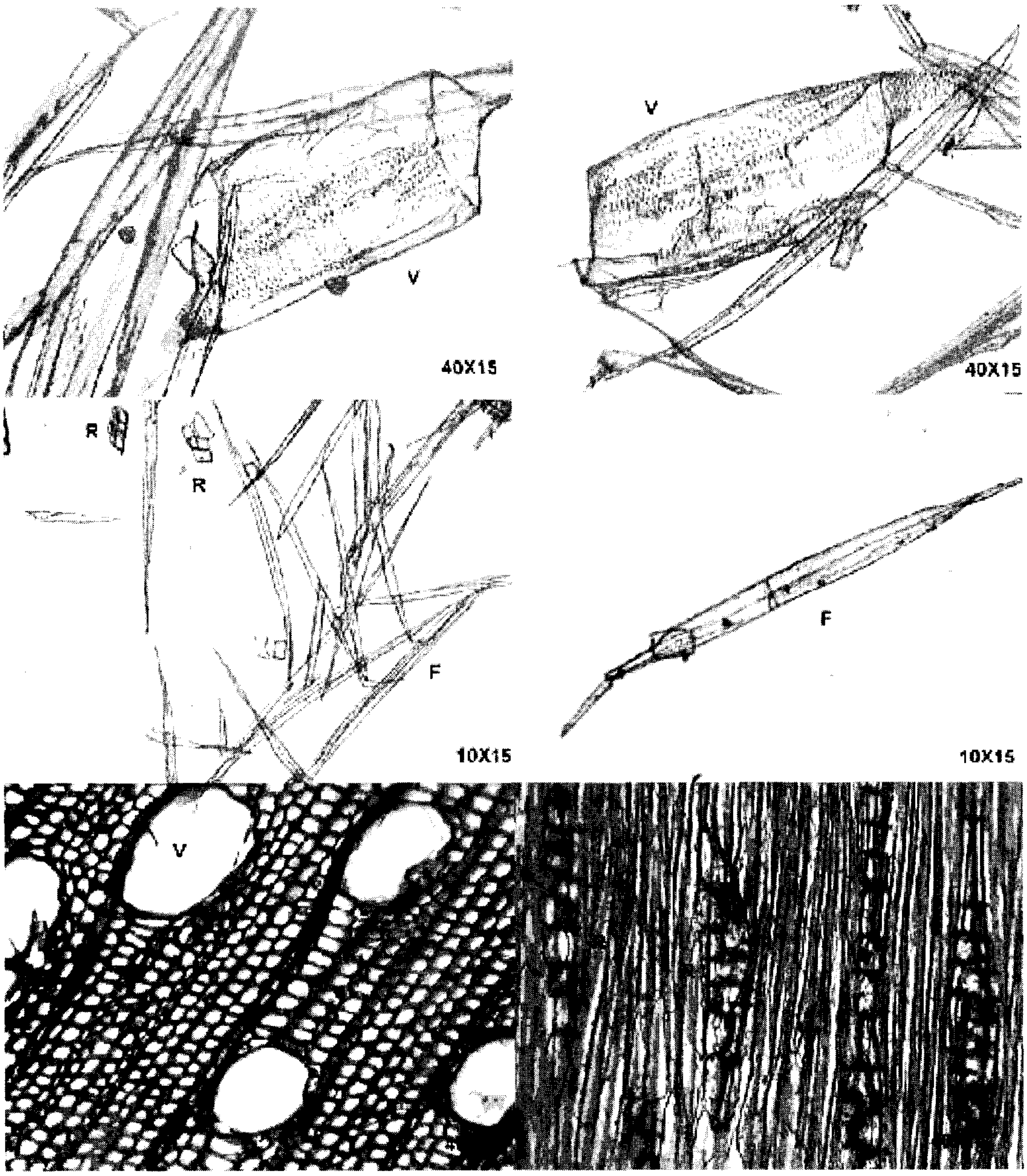

Fig. 3. The vessel, fiber and ray parenchyma of Nalita wood.
(V-vessel, P- parenchyma, F-fiber, R - Ray)

pulp and paper industry, and for this reason extensive literature exists concerning its variation within and among tree. Fiber length increased significantly from first ring to third ring (from pith to bark) (Table 2). It is known that the fiber length depends upon the length of cambial initial and on the amount of intrusive growth they differentiate (17). Therefore, fiber length increases with age. The average fiber length was increase from 697 *um* at the first to 925 *um* at the third annual ring. Sahri *et al* (5) showed that large and medium diameter trees have longer fibers than the small diameter. Kennedy and Smith noted (18) that fiber length is longer in better sites. Fast-grown sprout had shorter fibers than slow grown. Research demonstrated that the fiber length in species or clone increased with distance from pith to bark (19, 20). The fiber length range was almost similar to *Acacia megium* and other tropical hardwood (21).

Figure 3 shows the vessel, fibers and ray cells of Nalita. Vessels are a typical hardwood sample is often large enough in diameter. Vessel diameter of Nalita was about 11 *um* and it was not changed significantly with an increase of annual ring as shown in Table 2. The number of vessel mm^{-2} was decreased from 12.7 at the first ring to 9.4 at the third ring. Vessels were perforated. The wall of vessels was conpiocusly pitted. Some vessels were truncated in both ends and some were tail in one or both ends. The fiber wall thickness at the third annual ring was about 2.43 *um*, which was comparable to maple (22). Nalita is the fastest growing wood. Therefore, it contains high proportion of springwood. The cell wall of springwood is relatively thin than summerwood.

3.3 Chemical properties

Table 3 shows the chemical composition of Nalita. The lignin content of Nalita was between 23.5 - 24.4 %. This value was slightly higher than that of poplar clones, which are one of the fastest growing-wood (8). The lignin content was increased with annual growth ring (Table 3). As compared to *Acacia mangium* (21), the Nalita showed low alcohol-benzene extract at about 2 %. The holocellulose content was increased from 78.1 at the first annual ring to 80.1 at the third annual ring. The ash content of Nalita was little bit higher than that of poplar clones (8). Table 3 also shows the carbohydrate composition of Nalita. Xylan was the predominant component in hemicellulose of Nalita followed by arabinan and mannan. The glucan and xylan percentage were increased from 40.4 to 49.7 % and 13.9 to 15.0 % from the first annual ring to third annual ring, respectively, at the same time arabinan and glactan decreased from 1.5 to

Table 3. Chemical properties of Nalita wood at the growth ring level

Annual ring		First	Second	Third
Ash, %		1.04	0.96	0.92
Alcohol-benzene extract, %		2.1	1.9	1.9
Lignin, %	Klason	21.8	22.0	22.6
	Acid soluble	1.7	1.8	1.8
	Total	23.5	23.8	24.4
Hollocellulose, %		78.1	79.2	80.1
Carbohydrate, %	Glucan	40.4	48.6	49.7
	Xylan	13.9	14.1	15.0
	Arabinan	1.5	0.6	0.5
	Mannan	1.2	0.8	0.8
	Glactan	1.0	0.6	0.6

0.5 % and 1.0 to 0.6 %, respectively.

4. Conclusions

The growth rate of Nalita was very fast. The Nalita was a diffuse porous-wood, its annual growth ring was hardly distinguishable. The basic wood density of Nalita was about 0.38 g/cc. The percentage of fiber, fiber length and fiber wall thickness were increased with increasing annual growth ring. The fiber length and wall thickness were reached to 925 *um* and 2.43 *um*, respectively at the third year, which are comparable to other fast growing wood. The lignin and holocellulose were increased with annual growth ring. The xylan was the predominant sugar of hemicellulose in Nalita. This wood may be an alternative of traditional pulpwood. Therefore, the pulping study of this wood would be done in our next investigation.

Literature Cited

1. Gupta, R.C., "A report on the Bangladesh pulp and paper industry" 82(3): 93 (1999).
2. American Horticultural Society www.english-gardening.com/Plants/fast_growing_tree.htm (2003)
3. Regional Soil Conservation Unit (RSCU). A Selection of Useful Trees and Shrubs for Tanzania. Dra ft. Nairobi. (1992).
4. FAO, Rome. Forest Division, Tanzania Ministry of Lands, Natural Resources and Tourism. Trees for Village Forestry. The Ministry, Dares Salaam (1986).
5. Sahri, M.H., Boupha, L., Nobuchi, T., Choh S.H. and Jusoh M.Z., "Anatomical Propertoes and Their Variations in Planted Azadirachta exxelsa (Jack) Jacobs". New Horizons in Wood Anatomy. Ed. Y.S.Kim Chonnam Nat'l Univ.Press Kwangju p.54 (2000).
6. Park, S.J., and Jung, K.H., "Identification of *Betula* species in dry archaeological woodeen plates, Tripitaka Koreana. Anatomical Propertoes and Their Variations in Planted Azadirachta exxelsa (Jack) Jacobs". New Horizons in Wood Anatomy. Ed. Y.S.Kim Chonnam Nat'l Univ.Press Kwangju p.24 (2000).
7. Rockwood, D.L., Dinus, R.J., Kramer, J.M., and MacDonough, T.J., "Genetic variation in wood, pulping and paper properties of *Eucalyptus amplifolia* and *E. grandis* grown In Florida, USA", CRC for Temperate Hardwood Forestry- IUFRO, Hobert, p.53-59 (1995).
8. Law, K.N., Rioux, S., and Valave, J.L., "Wood and paper properties of short rotation poplar clones" Tappi J. 83(5): 1, (2000).
9. Cown, D.J., and Ball, R.D., "Wood densitometry of 10 *Pinus radiata* families at seven contrasting sites: influfence of tree age, site, and genotype". New Zealand Journal of Forest Sience 31(1): 88-100 (2001).
10. Zobel, B.J., "Three rings-per-inch dense southern pine can it be developed (*P. taeda*, ring width, specific gravity, uniformity, geographic location, fertilization, general heredity, parental specific gravity)", Journal of Forestry. 70: 333, (1972).
11. Boyce, S. G., and Kaeiser, M., "Environment and genetic variability in the length of fibers of eastern cottonwood", Tappi J. 44(5):363 (1961).
12. Curro, P., "Technological investigations on the wood of some Euro-American poplar hybrid-Physical and mechanical properties", Agr. For. Exp. Centre 3,Italy (1960).
13. Bosman, M.T.M., Kort, D.I., Genderen, M.K.V., and Baas, P., Radial variation in wood properties of naturally and plantation grown light red merenti. IAWA J. 15,111-120. (1994).
14. Lei, H., Milota, R.M., and Gartner, "Between and within-tree variation in the anatomy and specific gravity of wood in Oregon white oak". IAWA J. 17(4): 445-461 (1996).
15. Han, S.K., and Soh, Y.W., New Horizons in Wood Anatomy. Ed. Y.S.Kim Chonnam NationalUniversity Press Kwangju p.111-116 (2000).
16. Seppo, K., "Forest Resources and Sustainable

Management" Papermaking Science and Technology series 2. TAPPI PRESS and PI, Finland p.150 (1998).

17. Bailey, I.W., 1920. "The cambium and its derivative tissues. II: size varialtion of cambium initials in gymnosperms and angiosperms", Am J. Bot. 7, 355-367 (1920).
18. Kennedy, R.W., and Smith, J.H., "The effect of some genetic and environmental factors on wood quality in poplar", Pulp Pap. Mag. Can. 60, 35-136 (1959).
19. Bendtsen, B.A., and Sen ft, J., "Mechanocal andantomical properties in individual growth rings of plantation-grown eastern cottonwood and lolobolly pine", Wood Fiber Sci. 18(1):23-28(1986).
20. DeBell, J. D., Gartner, B.L., and DeBell, S. D., "Fiber length in young hybrid poplus stems grown at extremely different rate", Can. J. For. Res. 28:603-608 (1989).
21. Law, K.N., and Daud, W.R.W., 2000. " CMP and CTMP of a fast-growing tropical wood: *Acacia mangium*", Tappi J. 83(7): 1-7 (2000).
22. Francis, R.C., Hausch, D.L., Granzow, S.G., Makkonen, H.P., and Kamdem, D.P., "Fiber yield for fully bleached kra ft pulps from black locust (*R. pseudoacacia*) and silver maple (*A. saccharium*)", Holz als Roh- und Werkstoff 59: 49-52 (2001).