PREPARATION OF MONOGRAPH OF DIFFERENT FIBROUS RAW MATERIALS USED BY INDIAN PAPER INDUSTRY

(MONOGRAPH ON INDIAN PAPERMAKING FIBERS)

(CESS PROJECT)

Based on the work of
Dr. S.V.Subrahmanyam, Dr. Ravi Godiyal,
Mr. Vipul Janbade & Mr. Arvind Sharma

Under the technical guidance of
Dr. A. G. Kulkarni
Director

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CENTRAL PULP & PAPER RESEARCH INSTITUTE
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MONOGRAPH ON INDIAN PAPERMAKING FIBERS

The first paper has seen the light in this world in about A.D. 150 and the inventor was Ts'ai Lun of China. He has claimed to use macerated vegetable fibers from rags, waste hemp fishing nets, young shoots of bamboo and the inner bark of mulberry to form truly felted sheet in a flat porous mould. Japanese acquired this art about five hundred years later. Arabs in A.D.751 set up a mill in Samarkand with the help of captive papermakers from China. Arabs spread it later to Baghdad in A.D. 793, Damascus and Egypt between 10^{th} and 12^{th} centuries, Morocco in A.D.1125 and Spain in A.D. 1156. The art of papermaking spread to France in A.D. 1189, England in A.D.1484 and Scotland in A.D. 1590. It is further spread to Mexico in A.D. 1580 and North America in A.D.1590.

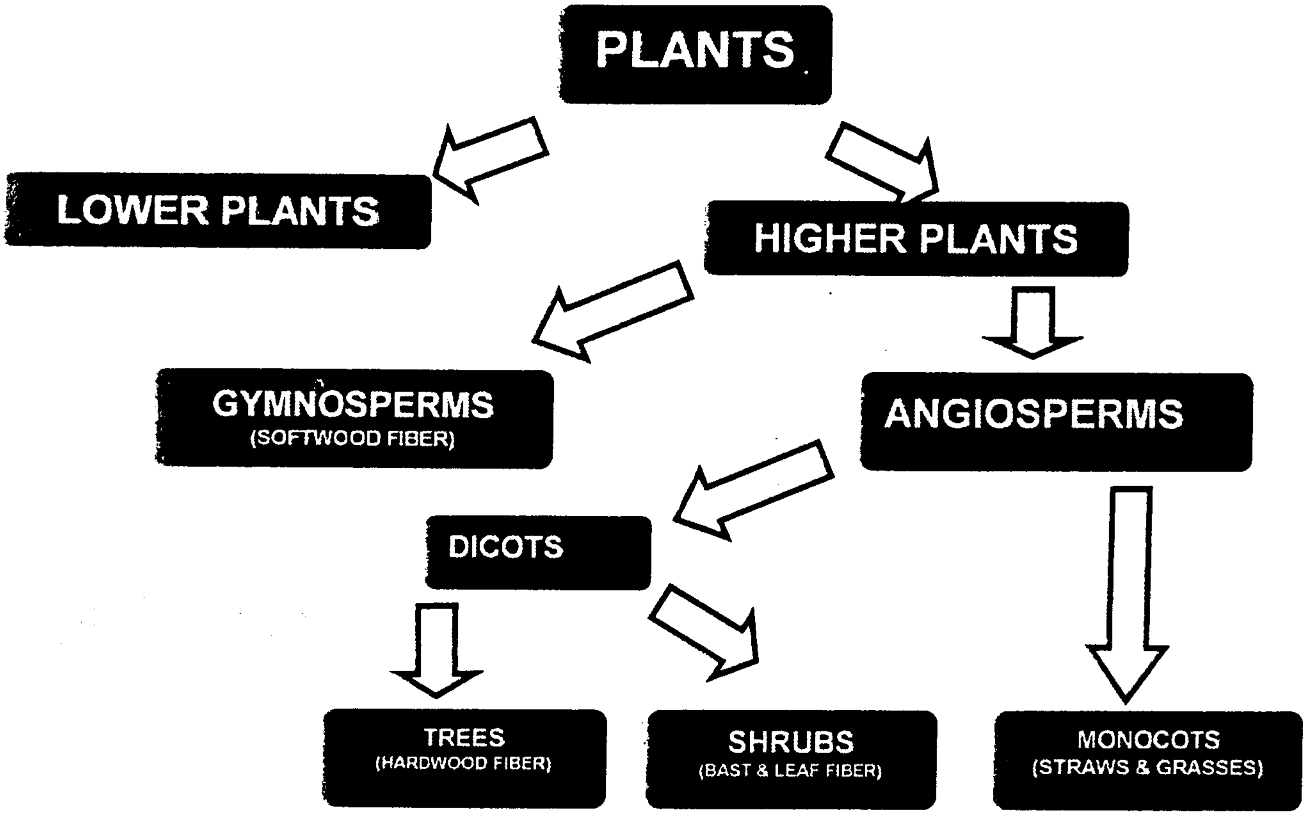
Developments in process chemistry and machinery:

The papermaking remained the same until the end of 18^{th} century. The first Fourdriner machine was invented in principle in A.D.1799 by Nicholas Louis Robert. The Fourdriner machine was successfully introduced by Henry and Sealy in 1804. The important source of fiber was cotton and linen rag along with some straw. The demand for paper continuously increased and the short supply of these fiber sources had often created serious problems for papermakers. After considerable efforts by the chemists, the wood fiber could be extracted using soda process in second half of 19^{th} century. In the mean time, the mechanical wood pulp production was also introduced in 1856.

Current Global pulp and paper scenario shows that most paper is made from wood fibers. Of the total pulp and paper production, wood pulp accounts for about 90% and the rest is derived from vegetable fibers such as seed hairs, bast fibers, grasses and even animal and mineral fibers. Many specialty paper production demands the fibers other than wood. In areas where the wood supply is constraint, the pulp and paper mills use locally available raw materials such as straw, bamboo, bagasse, kenaf, jute etc. Consequently, determination of what fiber has been used in any particular paper, it is important to have means of identifying very specifically a wide variety of different fibers.

Classification of fibrous raw materials:

The vegetable fiber sources are classified as wood fibers and nonwood fibers. The wood fibers are further classified as softwood fibers those are derived from gymnosperm trees and hardwood fibers, which are derived from angiosperm trees.



The non-wood plant (shrubs and grasses) fibers can be grouped into four types based on the botanical part used in making the paper pulp.

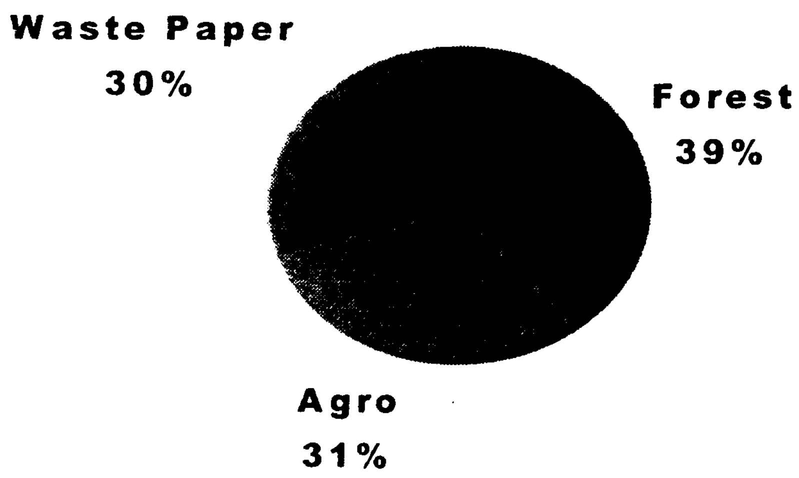
1.	Stalk or culms fiber:	Cereal straws, Grasses, Reeds, Bamboo, Sugarcane(Bagasse).
2.	Bast fibers:	Flax, Jute, Kenaf, Hemp
3.	Leaf fibers:	Sisal, Abaca
4.	Seed hull fibers:	Cotton

Some of these materials such as bast fibers, leaf fibers and seed hull fibers are primarily used for the production of textiles or in case of sugarcane to produce sugar. The term fiber has different meanings in textiles and paper industries. Fiber in textile industry means that fiber removed from the plant mechanically through biological treatment known as retting process. The objective is to obtain a material of greatest possible length for spinning. For example, textile fibers for spinning up to 1.5 to 2 meters long can be obtained from sisal and abaca plant. Even though the textile fiber length in textile terminology is 1.5 meters for sisal fiber, the actual average fiber length is only 3.0 mm from a papermaking point of view.

Papermaking fibers used in Indian Industry:

Indian pulp and paper scenario shows that it uses 39% of forest based fiber, 31% agro residue based fiber and 30% fiber is derived from waste paper. The fibrous raw materials used by Indian paper industry for the production of different varieties of paper comes from different sources like wood, bast, leaf of trees, shrubs, and grasses. The Indian paper industry produces mostly two types of virgin pulps from the fiber sources ie. Chemical pulps through either soda process or kraft process and chemi-mechanical pulps. Each material has distinct morphological characteristics and chemical composition. Morphological features of pulp fiber are the key factor controlling the quality of products during papermaking. The fundamental properties of any pulp fiber are length, diameter/width, and cell wall thickness lumen diameter/width. The derived fiber factor as Runkel ratio, slenderness ratio and coarseness also indicate the fiber behaviour in the papermaking process. The pulps have different types of cell types depending the source.

RAW MATERIAL CONSUMPTION PATTERN IN INDIA



Fibers used in Indian paper industry

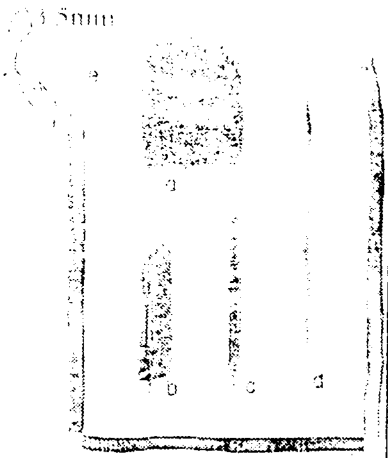
1. Rice straw
2. Wheat straw
3. Bagasse
4. Sarkanda
5. Sabai grass
6. Kans grass
7. Bamboo
8. Reed grass
9. Jute
10. Kenaf
11. Old gunny bags
12. Eucalyptus
13. Casuarina
14. Mango
15. Subabul
16. Popular
17. Imported softwood pulp

Morphology of papermaking cells:

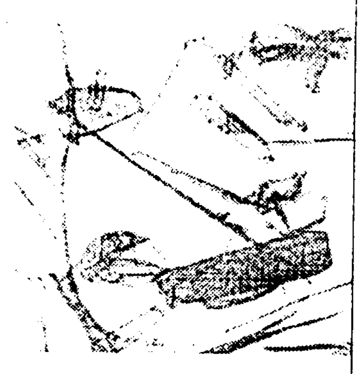
The fibrous raw materials have different tissue composition based on the botanical source. The cells normally found in the paper pulps are fiber tracheids (normally present in softwoods) or fibers (found in all other fibrous raw materials), parenchyma, vessels (found in raw materials other than softwoods and bast fibers) and epidermal cells (mostly found in agro residues). The composition and structure of these different cells determines the papermaking quality of and acceptability of the fiber source.

Fibers: Fibers are the most useful cellulose material in the pulp. These are normally long, flexible and form the basic network (web) in the paper. Fibers contribute to the basic strength of the paper. Fiber is long narrow cell with tapering ends and a central canal known as lumen. The fibers depending upon origin differ significantly. The average fiber length varies from 3.5 mm in softwoods, 0.8-1.2mm in hardwoods, 2-5mm in bast and leafy fibers and 1.0mm to 2.5mm in straws, bagasse and bamboo. Weight proportion of fibers in pulp varies from 95% in softwoods, 65-75% hardwoods and 55-65% in agricultural residues.

Detailed examination of fiber structure by electron microscopy shows the fiber wall exists as four layers surrounding the central canal.



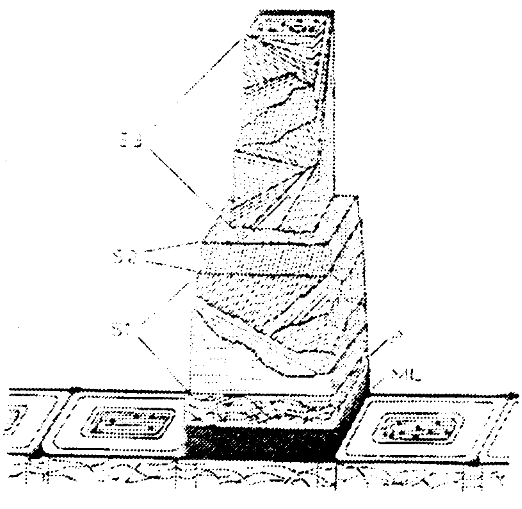
Fibres & Vessels in woods



Fibres and Paranchyma in nonwoods

a, b, c – Vessel elements in Hardwood pulps; d – fibers in hardwood pulps; e – tracheids in softwood pulps	Fibers and Parenchyma in non-woods

The outer most layers are the primary wall is a fine and thin network of cellulose microfibrils embedded in para-crystalline substance. It predominantly has non-cellulosic substance – lignin. Next to primary wall is the secondary wall, which has three principle layers. The outer most secondary wall laye r is S1, followed by middle secondary wall layer S2 that contains bulk of the mature microfibrills. The inner most layer binding the lumen is S3. The middle secondary wall, S2 has special papermaking importance due to its position and constitution in the fiber.



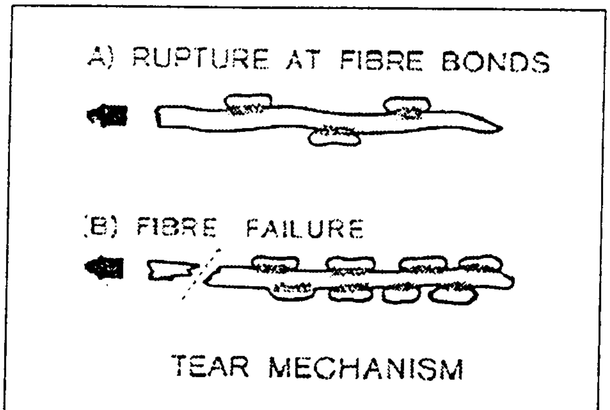
Schematic diagram of fiber wall layers (Curtesy : C.E. Dunning)

The papermaking properties of the fiber are attributed to the various parameters of the fibers such as fiber length, fiber width, fiber wall thickness, and fiber lumen diameter. These primary parameters influence the derived parameters like slenderness ratio, coarseness and Runkel's ratio of the fibers. The submicroscopic parameters of the fibers such as microfibrillar orientation in various layers of fibers have also significant influence on the papermaking.

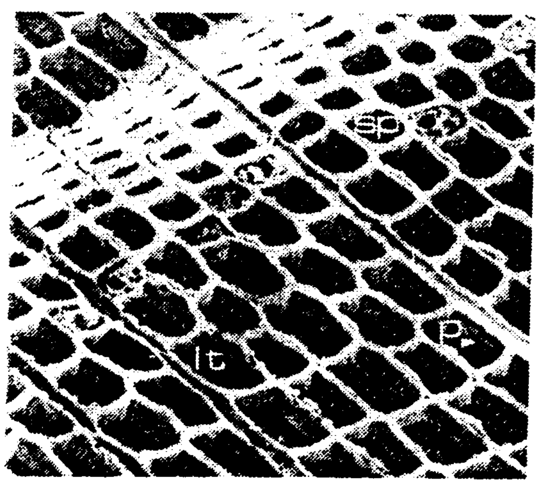
Fiber length: The papermaking pulps have fiber population with varying lengths. The heterogeneity of the fiber population influences the papermaking and the knowledge and understanding of the fiber length distribution is highly essential in predicting the behaviour of a raw material in the papermaking process. Generally, the fiber length is averaged for a source, which is a relatively easy expression and gives a broad idea for comparison purpose. The average fiber length varies from 3.5 mm in softwoods, 0.8-1.2 mm in hardwoods, 2-5 mm in bast and leafy fibers and 1.0 mm to 2.5mm in straws, bagasse and bamboo.

The fibers in a paper web are randomly distributed and depending on the length of the fiber, the number of fiber crossings increase or decrease. If the number of fiber crossings increase due to longer fibers, the web is stronger, thereby having higher wet web strength of the sheet as well as the dry paper strength. The wet web strength is very critical in high-speed machines.

Fiber width: The terms width and diameter of the fibers are normally used for all the practical purposes for the same dimension. In a two-dimensional view of the light microscope, it is not possible to distinguish between width and diameter. The unrefined fibers are normally tubular structures, which become flattened on refining. In the paper web when the fibers cross over randomly, the area of fiber cross over (area of bonding) is influenced by fiber width. If the fibers are wide, then the area per cross over increases where the fibers are held together that contributes to the strength of paper web. For a given fiber length, the fibers with higher fiber width gives higher paper strength due to increased cross over area per fiber. Length to width ratio is known as slenderness of fiber.

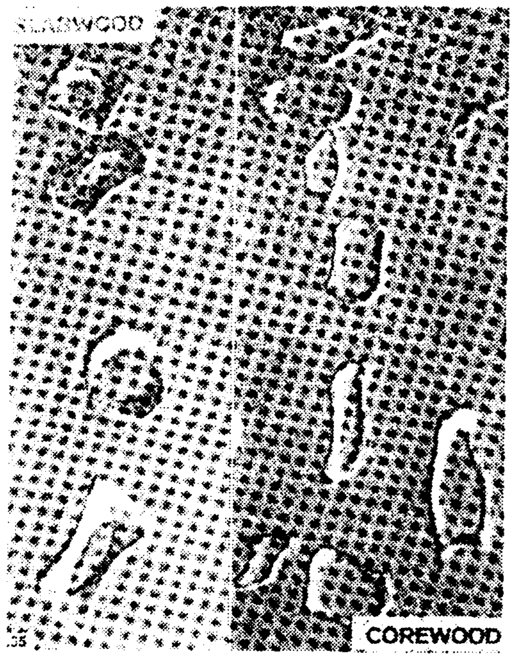


Strength (Tensile, tear and burst) of paper depends on the number of crossings per fiber (Courtesy: Dr.R.P.Kibblewhite)



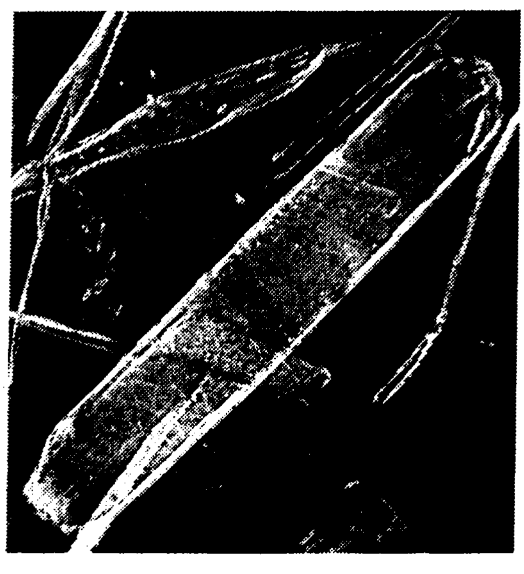
Cross-section of softwood. Note the thick late wood fibers and thin walled early wood fibers (Courtesy: Dr.R.P.Kibblewhite)

Fiber lumen: The central cavity in the fiber is known is fiber lumen, which is void. Depending on the extent of void space, the fiber may flatten (collapsibility) to different extents, as the fiber is refined. Higher the extent of collapsibility then higher is the bonded (contact) area. The fiber lumen is different for different species. The fibers in the same source have different fiber lumen due to seasonal variations in the wood formation. For example the late (winter) wood fibers are have narrower fiber lumen compared to the early (spring) wood fibers. Rind fibers have thicker wall compared to the fibers in vascular bundle s as in bagasse and straws.



Cross section of radiata pine fibers. (Courtesy : Dr.R.P.Kibblewhite

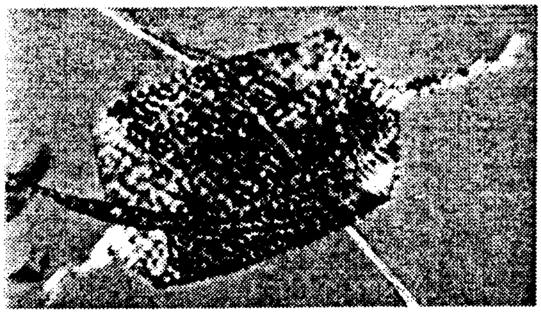
Fiber wall thickness: Fiber wall is specific to a given fiber source. Depending on the fiber wall thickness the fibers' response to refining varies. Fibers with thin cell walls collapse readily. Increase in fiber wall thickness leads to increase in mass per unit length (coarseness) of the fiber. Fibers with higher coarseness are called coarser fibers and with lower coarseness as finer fibers. Fibers of higher coarseness are stiff and difficult to collapse which leads to poor bonding due to less bonding area and lower strength. This will result in increased porosity and surface roughness of the paper. However, the fibers with higher coarseness often give higher tearing strength to the papers. The derivative expression of Runkel's ratio is derived from 2x fiber wall thickness (fiber width excluding lumen in cross sectional view) divided by fiber lumen width.


Parenchyma cell of bagasse

Parenchyma: It is also called as nonfibrous tissue, pith tissue or ground tissue. The parenchyma cells are cellulosic. The dimensions of parenchyma vary with source raw material. They do not contribute to the strength of the paper and often create serious drainage problems affecting the productivity especially in the agricultural residues. The weight percent of parenchyma (nonfibrous) cells is about 5% in softwoods, 25-35% in hardwoods and 30 to 45% agriculture residue pulps. The parenchyma is the source of primary fines in virgin chemical pulp.

Reduction of this nonfibrous tissue especially in nonwoods is a big challenge and wherever it could be effectively reduced, resulted in chemical savings and improved quality of pulp. Raw material pretreatment methods in agro based paper industry are principally targeted to reduce the nonfibrous tissue.

Vessels: The vessel elements are the single units of the vessels. They are spiral shaped in straws, long, narrow and cylindrical in bagasse and bamboo, short, wide and cylindrical with short tail in the hardwoods. They are absent in the softwoods. Wherever they are present they help in the mobility of pulping liquor (penetration) in longitudinal direction of chips. When they are short and wide, they create the vessel pick problem in papers.



Hardwood vessel element

Epidermal cells: The epidermal cells are significantly small cells with serrated margins. They appear either in groups or as singles. Their presence is noticeable in straws and bagasse. The dimensions of the epidermal cells vary with the type of straw.

Epidermal cells of wheat straw

Chemical composition of the fibrous raw materials:

The chemical composition of a fibrous raw material gives a lead in assessing the pulpability of the resource. The fibrous raw materials has the following composition viz. Cellulose, Hemicellulose, Lignin, Extractives, Sugars and Inorganic matter (ash).

Cellulose: Cellulose is a linear polysaccharide of sufficient chain length to be insoluble in water or dilute alkali and acids at room temperature, containing only anhydroglucose units linked together with 1-4 - beta glucosidic bonds and possessing a well ordered structure. Cellulose is a white fibrous material consisting of Carbon, Hydrogen and Oxygen. In its simplest chemical form it is expressed as $(C_6H_{10}O_5)_n$ where the n represents the number of cellulose units. Cellulose molecule is a natural straight chain polymer made out of beta-anhydroglucose units linked together by 1, 4 glycosidic bonds.

The close relationship between cellulose and glucose is established from the effect that mild acid hydrolysis of cellulose causes its conversion to glucose by the addition of one water molecule. The major component of the fibrous raw materials is cellulose. The fiber and paper strength and longevity of the paper depends on the purity of the cellulose. The papers made of cotton lint are said to be permanent papers, as the alpha-cellulose, the purest form of cellulose is to the tune of 95% in the cotton linters. Cellulose has three forms depending on the degree of polymerization (dp). They are alpha-cellulose, beta-cellulose and gamma-cellulose. Wood from softwoods and hardwoods contain about 65% to 75% of cellulose and out of which the alpha-cellulose is about 45% to 55%. The alpha-cellulose is not easily degradable and withstands alkaline and acid treatments of wood during the fiber extraction process i.e. pulping. Hence, knowledge about the quantity and quality of cellulose gives a fair idea about the pulping quality of a fibrous raw material.

Hemicellulose: The non-cellulosic polysaccharides of fibrous raw materials including the related substances such as uronic acids etc. and their substitutents. Hemicelluloses contain mainly sugar units other than glucose units, usually xylose, mannose with small quantities of glucose, galactose, arbinose and rhamnose. The hemicelluloses are nonfibrous with an average D.P. of 150±30and are soluble in dilute caustic soda after the wood has been hydrolysed to form mannose, glucose, galactose, arabinose, and aldobiuronic acids. The quantity of hemicelluloses varies from 10 to 25% depending on the fiber source. They are normally highest in agro residues followed by hardwoods and the softwoods have the lowest quantity. Retention of hemicellulose during the pulping process is important as it improves the pulp yield and contributes to the bonding strength of fibers. The hemicellulose component is an unwanted constituent in the production of dissolving grade pulps. Hence the quantity of hemicellulose is minimized in the raw material prior to pulping using acid-prehydrolysis stage.

Lignin: Lignin is the aromatic polymer of wood consisting of four or more substituted phenylpropane monomers per molecule. Lignin is the cementing material in fiber where the cellulose skeleton is supported by the amorphous lignin. The lignin content varies from ~ 30% in softwoods, 22-27% in hardwoods and 15-22% in agricultural residues. The pulping processes target to remove the lignin to different extents to enable the liberation of fibers.

Extractives: The low molecular compounds of various types, extractible from the fibrous raw materials with water or organic solvents excluding lignin and hemicelluloses. The extractives, which are extraneous components, include aliphatic and aromatic hydrocarbons, terpenes and their derivatives, alcohols, aldehydes, phenols, quinines etc. Some woods contain essential oils, resin acids and sterols whereas others yield tannins and coloring matter. The color, odor, taste or unusual flammability can be attributed to extractives. They may interfere with the pulping process, causes foaming and sometimes causes corrosion.

Ash: The ash content of the fibrous raw materials indicates the presence of inorganics. The quantity of inorganics is in the range of 0.5 to1.0% in softwoods and hardwoods. The inorganics quantity varies from 1 to 2.5% in bamboo and bagasse, 5 to 10% in wheat straw and other grasses and more than 15% in rice straw. The higher inorganic content in the nonwoody fibrous raw material is due to the presence of silica. The presence of silica causes severe problems, especially in the chemical recovery process.

Sugars: The sugars are normally present in the agricultural residues especially in case of bagasse. The presence high quantity of sugars in the raw materials causes problems in storage. It also increases the alkali demand in the pulping process by nutralising substantial quantity of alkali, which would otherwise be used for defibration process.

RICE STRAW

Oriza sativa

Rice is a member of the grass family (Gramineae) and belongs to the genus oryza under tribe oryzeae. Among the cereals,staw has the lowest water use efficiency. Therefore, rice staw can not compete with dry land cereals cerals in area of low rain fall unless irrigation water is readily available from reservoirs, bunds, and the like. On the other hand, the highest yields of traditional varieties have been obtained in regions of cloudless skies. The 38.6 million hectares of Indian agricultural land under rice cultivation in 1977 yielded 42.8 million tons of grain and, as by-products, about 81 million tons of agricultural residues - namely, 66 million tons of rice straw and 15 million tons of husks.

	
Rice Fields	**Transportation to Mill**

The small and medium size paper mills in India make writing and printing paper from rice straw. The random estimates suggest that 4.0 tons of rice straw is produced per ton of rice. The annual production of rice straw is about 80 million tones as Crop production and about 180 million tones is the residue generation as waste. Rice straw is used for fodder and thatching and there fore less quantity was available for paper industry for paper and board production. The crop residue ratio of the Rice straw is about 2.50. Out of this less than 1% is being used by paper industry .

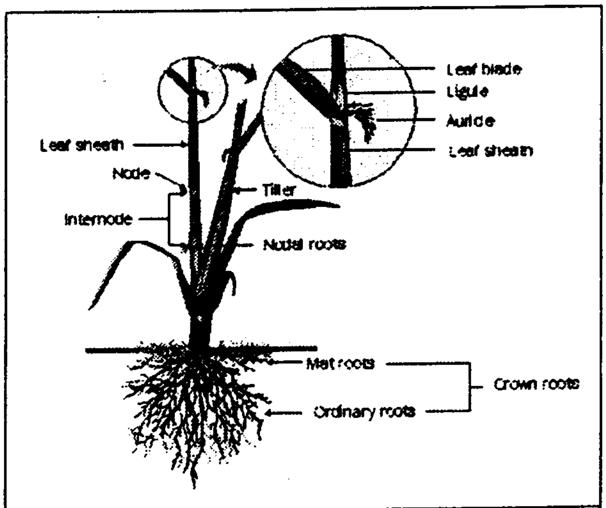
Chemical composition of rice straw:

Se. No	Parameters	Unit	Rice Straw (Punjab)	Rice Straw (MPM)	Rice Straw * (Orissa)
1.	Ash Content	%	20.7	20.2	15.0
2.	Cold Water Solubi lity	%	18.3	16.2	11.0
3.	Hot Water Solubi lity	%	24.8	19.6	13.5
4.	1/10 N NaOH Solubili ty	%	50.2	49.3	44.3
5.	Alcohal Benzene Solubility	%	3.5	3.84	5.90
6.	Pentosan	%	16.7	16.4	20.0
7.	Holocellulose	%	60.9	54.7	70.1
8.	α Cellulose	%	36.4	34.1	-
9.	β Cellulose	%	11.5	11.5	-
10.	χ Cellulose	%	10.8	9.1	-
11.	Acid Insoluble Lignin	%	13.4	19.1	10.0
12.	Acid Soluble Lignin	%	1.0	1.6	-

* IPPTA, September-December, Vol, 21, No.3, Page 15-19,1984

Morphology:

Rice Straw is a heterogenous in nature when compared with wood. Straw consists of stem and leaves. The internodal section is called stalk. It is a hollow tube with an annulus thickness of about 0.5 mm. Typically a stem has 5-7 nodes. The stalk length increases from base to head. It carries the grain. Stem length greatly varies from species to species, genetic mutation within a species, soil condition and climate. The stem is separated at intervals by nodes. At the nodes, a sheath that ends in a leaf blade is formed around the stem. Seed hulls and foreign material is found in straw bales. The agricultural waste after extracting the grains is used in papermaking. It is used in straw boards, cheap grade corrugating, writing a printing paper in admixture with long fiberdpulp.



Rice Straw Plant

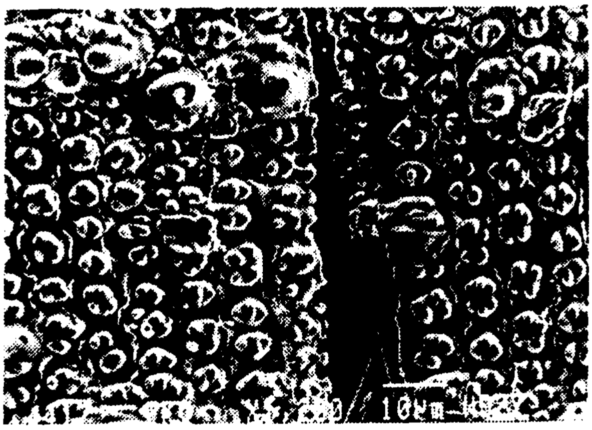
The rice straw fiber varies from 0.26- to 3.1 in length with an average of 1.1 mm and 7-14μm in width (average 11.1 μm). The pulp consists of fibers, parenchyma, vessel epidermal cells and spicules. The fibers are thick walled and pointed ends. The fibers are small than bamboo and bagasse. The parenchyma cells are short or long and rectangular. The vessels are long and narrow. The epidermal cells are conspicuous and abundant with serrated margins often not separated with epidermal peel and have distinct papillae on them. Small-oppressed spicules are present, difficult to observe.

No.	Dimensions	Unit	MPM	Punjab
A	*Properties of fiber:*			
1.	Fiber Length (Weight weighted) (L = 0.20 – 4.0mm)	mm	1.07	0.90
2.	Minimum Fiber Length,	mm	0.40	0.26
3.	Maximum Fiber Length,	mm	2.7	3.1
4.	Mean Fiber width (μ= 7 – 45)	μm	11.1	13.1
5.	Lumen Diameter	μm	2.38	2.8
6.	Cell wall thickness	μm	5.36	4.14
7.	Runkel Ratio		4.50	2.96
8.	Fiber curl index (Weight weighted)(L = 0.50 – 10.0mm)	-	0.144	0.218
9.	Fiber kink index (L = 0.50 – 5.0mm)	1/mm	2.47	2.99
10.	Total kink angle	degree	35.0	45.1
11.	Kinks per mm	1/mm	1.11	1.28
B	*Properties of non-fibrous tissue*			
12.	Length of vessel	μm	198.6	227.1
13.	Width of vessel	μm	36.6	36.6
14.	Length of Parenchyma	μm	83.8	93.6
15.	Width of Parenchyma	μm	28.0	26.7
16.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	64.0	66.6
17.	Length weighted Fines (L = 0.01 – 0.20 mm)	%	25.3	27.7

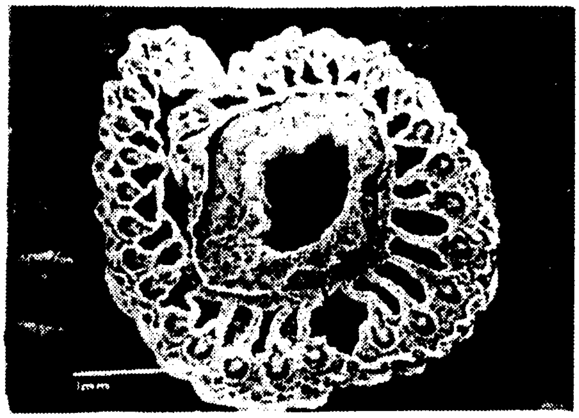
Pulp components:

Under Scanning Electron Microscope the fiber appear more cylindrical as compared to sabai grass, having vitreous silica spread all over its surface thereby giving coarse surface appearance under low magnification. Under the high magnification the fibers show characteristic striations on the longitudinal direction. As separation of individual epidermal cell is difficult, very often the epidermal peels are observed.

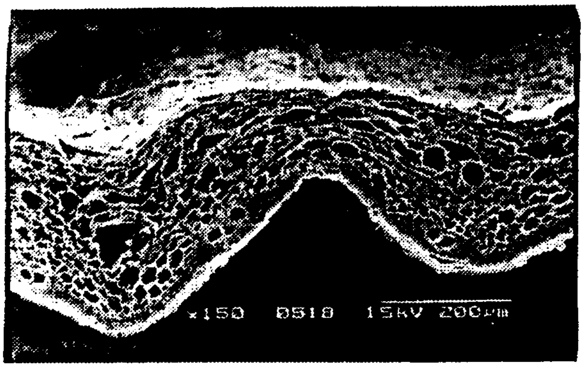
RICE STRAW



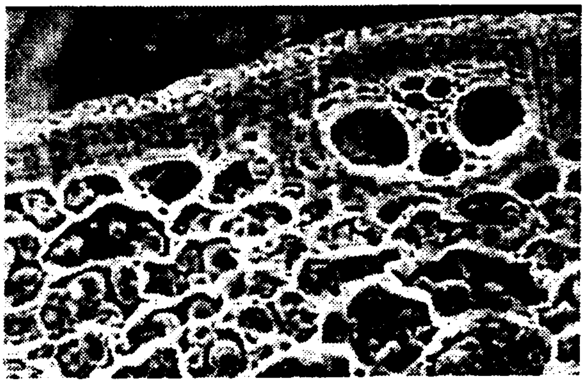
Surface view of rice straw



Sectional view of rice straw



Magnified view of rice straw XS



Magnified view of ground tissue

Rice straw pulp

Magnified view of rice straw pulp

Pulping:

Pulping was carried out using chemical charge 12% & 6% by soda process in the laboratory for the rice straw collected from Punjab, Madhya Baharat and Orissa.

Parameters	Rice Straw (Punjab)	Rice Straw (MPM)	Rice Straw (Orissa)
Raw material O.D.	200 gm	200 gm	200 gm
Cooking chemical, %	12.0	6	6
Bath ratio	1:5	1:5	1:4
Ambient to 100°C	30 min.	30 min.	30 min
100°C to 168°C	100 min.	100 min.	60 min. (140°C)
at 168°C	90 min.	120 min.	90 min (140°C)
Unscreened Pulp yield, %	48.0	57.35	59.4
Reject, %	0.85	1.69	-
Screened Pulp Yield,%	47.1	55.7	-
Kappa No	19.4	26.7	18.2

Bleaching:

The Unbleached Rice straw soda pulp was bleached using CEH bleaching sequence to get brightness 80% ISO.

S.No	Parameters	Rice Straw (MPM)	Rice Straw (Orissa)
1.	Kappa no.	26.7	18.2
	Chlorination Stage		
2.	Chlorine added, %	5.88	4.5
3.	Consistency, %	3	3
4.	pH	< 2	< 2
5.	Time, min	30	30
6.	Temperature, °C	Ambient	Ambient
	Alkali Extraction stage		
7.	NaOH , added	2.5	1.5
8.	Consistency, %	8	5
9.	Time, min	60	60
10.	Temperature, °C	60	50
11.	pH	11-12	11-12
	Hypo stage		
12.	Calcium hypochlorite, % added	2.5	2.5
13.	Consistency, %	8	5
14.	Time, min	120	120
15.	Temperature, °C	40 °C	40 °C
16.	pH	9-10	7.1
17.	Residual Cl_2, PPM	85.0	-
18.	Final Pulp Brightness, % ISO	78.7	80.4
19.	Intrinsic viscosity, cm3/gm	378	-
20.	Shrinkage	6.62	-

Properties of rice straw bleached Pulp:

The physical strength properties are in the acceptable range for producing writing and printing grades of paper. It is also suitable for making straw board. Due to high proportion of fines in the pulp, it has low initial freeness unsuitable for any refining.

Sl. No.	Particulars	Rice Straw Punjab (Unbleached)	Rice Straw MPM (Bleached)
1.	Zero Span Tensile Strength	-	7.6
2.	Bauer McNett Classification		
	+ 30	6.6	12.5
	+ 50	10.9	8.8
	+ 100	19.8	29.0
	+ 200	8.7	2.4
	- 200	54.0	47.3

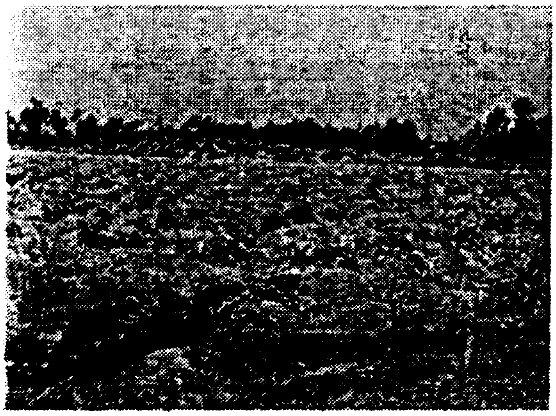
Strength properties of Rice straw pulps

Sl. No.	Properties	Unit	Punjab (Unbleached)	MPM (Bleached)	Orissa (Unbleached)	Orissa (Bleached)
1.	PFI	rev.	0	0	Valley Beater	
2.	Freeness	ml CSF	230	275	270	270
3.	Apparent density	g/cm^3	0.67	0.69	-	-
4.	Burst Index	$kPa\ m^2/g$	2.55	2.0	2.55	2.40
5.	Tensile Index	Nm/g	40.0	33.0	41.1	39.0
6.	Tear Index,	mNm^2/g	4.10	3.40	2.56	3.20
7.	Fold KM	Log	-	0.78	-	-
8.	Bendenstan Smoothness	ml/min	-	1.48	-	-

WHEAT STRAW

Triticum vulgare

The small and medium size paper mills in India make writing and printing paper from wheat straw. The random estimates suggest that 3.0 tons of wheat straw is produced per ton of wheat. The annual production of Wheat straw is about 60 million tones as Crop production and about 90 million tones is the residue generation as waste. Wheat straw is used for fodder and thatching and there fore less quantity was available for paper industry for paper and board production. The crop residue ratio of the wheat straw is about 1.50. Out of this less than 1% is being used by paper industry .



Harvested wheat plants

Preparation of temporary storage piles

Stored wheat plant with grains

Wheat straw after extraction of grains

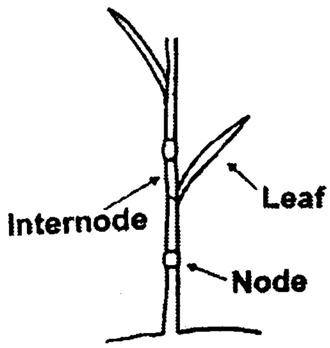
Morphology of wheat straw:

Wheat Straw is a heterogenous in nature when compared with wood. Straw consist of stem and leaves. The internodal section is called stalk. It is a hollow tube with an annulus thickness of about 0.5 mm. Typically a stem has 5-7 nodes. The stalk length increases from base to head. It carries the grain. Stem length greatly varies from species to species, genetic mutation within a species, soil condition and climate. The stem is separated at intervals by nodes. At the nodes, a sheath that ends in a leaf blade is formed around the stem. Seed hulls and foreign material is found in straw bales.

Tissue composition:

Like any botanical tissue, straw consists of cells. A cell has has a multi-corner cross-section. It has a cell wall; inside void portion of cell wall called lumen. The cell wall consist of 80 to 90 % substance on dry basis. The rest 10 to 20 % is deposited within the lumen and consist of sil ica (5-10 %) and extracti ves (5-15 %).

S.No.	Botanical part	Wt %
1.	Internodes	46.7
2.	Blades and sheaths	39.9
3.	Nodes	6.9
4.	Glumes	4.1
5.	Grains	0.2
6.	Foreign matter	2.2



When viewed under the Scanning Electron Microscope the most of the useful fibers located at the outer part of the stem i.e. near the skin with a little area of the fibers being present in the vascular bundle. The parenchyma cells, which constitute mainly fines, occupy about 75 % of the total area. The fibers originating from the out part of internode are thick walled and those coming from the inner part are called thin walled. However, the bulk of the fibers (80%) are from the outer part of stem. The cross section of wheat straw stem will differentiate in to different categories of cell types.

Se. No	Cell Type	Portion, %
1	Fiber	25
2	Paranchyma	75
3	Vessel	3

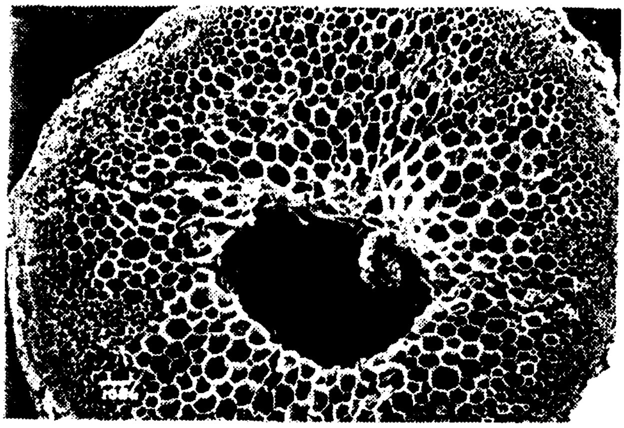
Pulp Components:

The wheat straw is normally converted to chemical pulp using soda process in the Indian paper industry. The pulp contains fibers, parenchyma, vessels, and epidermal cells. The fibers are slender and long and the ends are pointed. The fiber lumen varies from bro ad to narrow. The fibers have an average length of 1.22 mm and the range is from 0.52 to 2.37 mm. The average fiber width is 14.9 microns. The parenchyma is abundant and barrel-shaped. The epidermal cells vary in size and form, sparsely pitted, have more or less serrated margins and appear in either groups or singles. The vessel elements are slender and long.

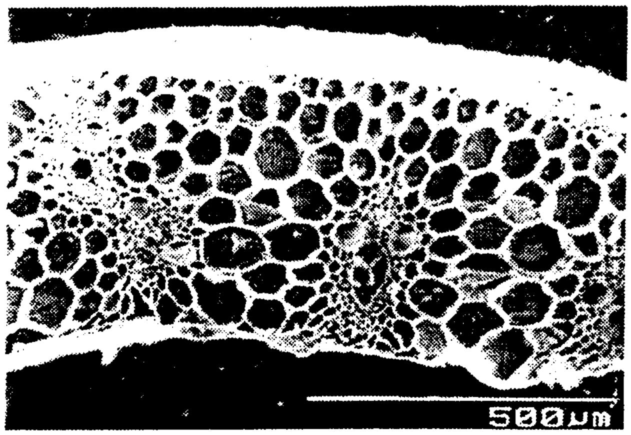
Dimensions of wheat straw pulp components:

No.	Dimensions	Unit	Wheat Straw (Punjab)
A	*Properties of fiber:*		
1.	Fiber Length (Weight weighted) (L = 0.20 - 4.0mm)	mm	1.15
2.	Minimum Fiber Length,	mm	0.26
3.	Maximum Fiber Length,	mm	3.84
4.	Mean Fiber width (μ= 7 - 45)	μm	15.2
5.	Lumen Diameter	μm	3.31
6.	Cell wall thickness	μm	5.95
7.	Runkel Ratio		3.60
8.	Fiber curl index (Weight weighted) (L = 0.50 - 10.0mm)	-	0.136
9.	Fiber kink index (L = 0.50 - 5.0mm)	(1/mm)	2.14
10.	Total kink angle	degrees	39.0
11.	Kinks per mm	(1/mm)	1.02
B	*Properties of non-fibrous tissue*		
12.	Length of vessel	μm	195
13.	Width of vessel	μm	27.2
14.	Length of Parenchyma	μm	193
15.	Width of Parenchyma	μm	44.2
16.	Arithmetic Fines (L = 0.01 - 0.20 mm)	%	56.9
17.	Length weighted Fines (L = 0.01 - 0.20 mm)	%	15.9

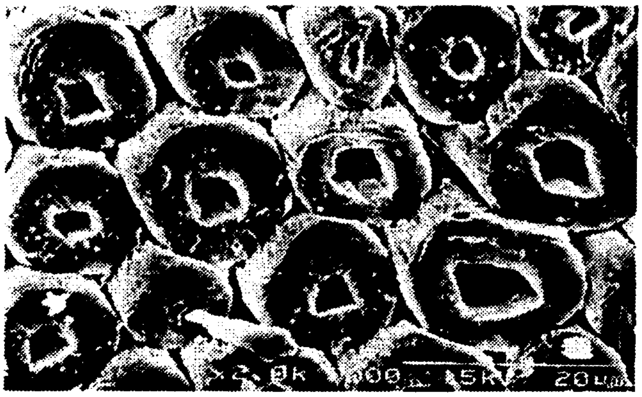
WHEAT STRAW



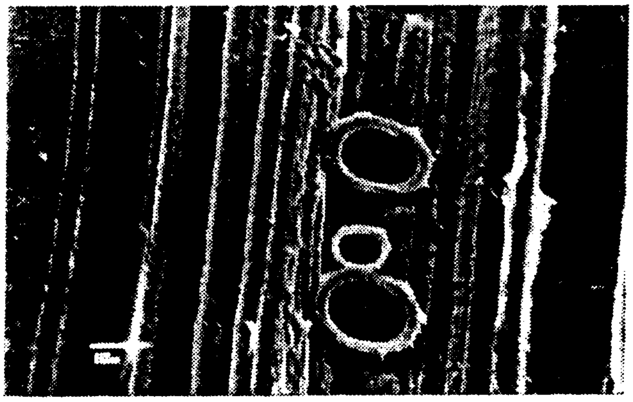
Cross section of wheat straw



Magnified view of XS of wheat straw



Cross section of fibers

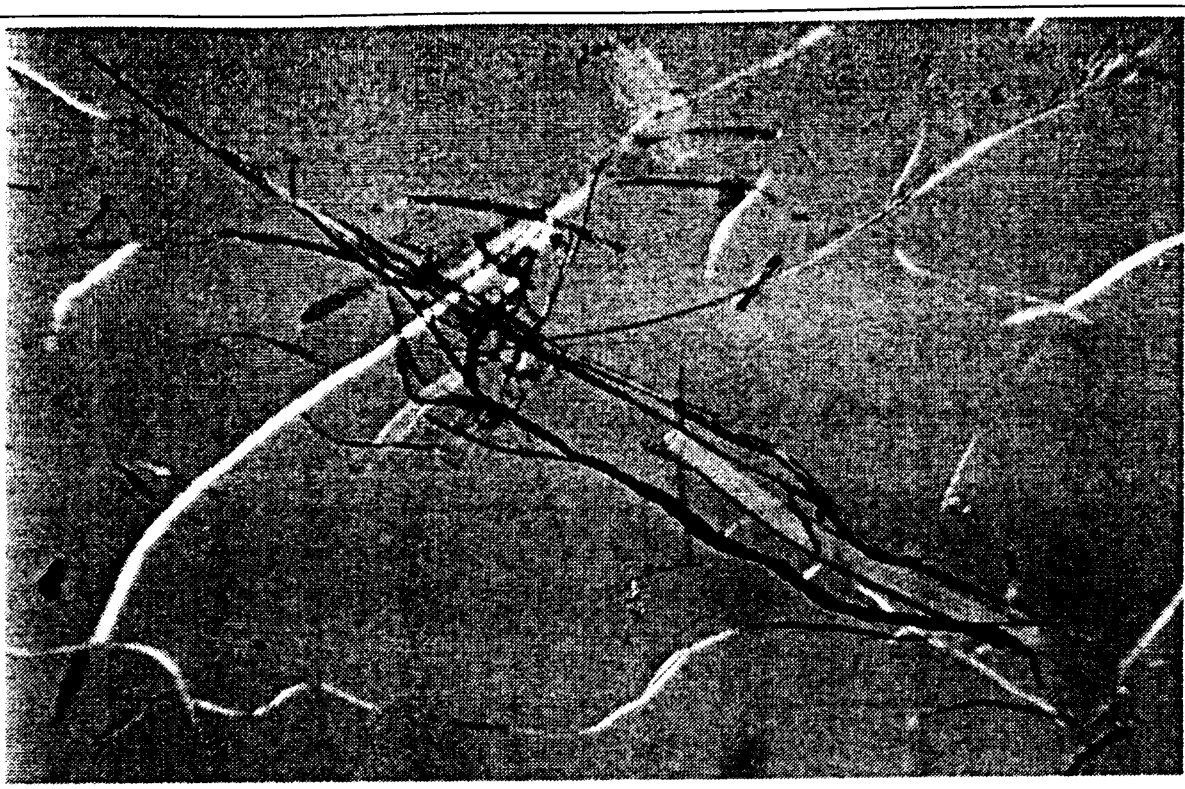


Protoxylem vessels of wheat straw

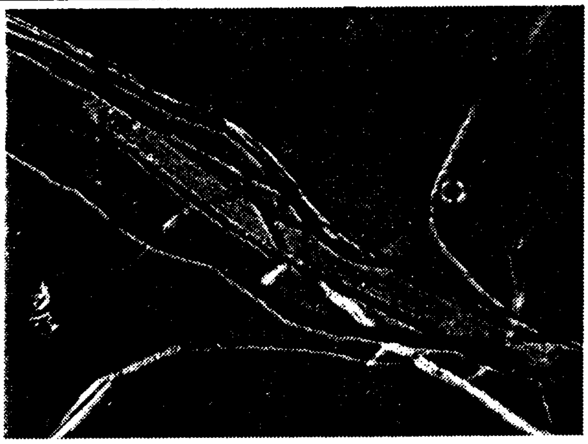
Paper surface showing various cells

Magnified view of fiber crossings

WHEAT STRAW



Wheat straw pulp fibers



Magnified view of vessel and fibers

Magnified view of epidermal cells

Chemical composition of wheat straw:

Se. No	Parameters	Unit	Wheat Straw (Punjab)
1	Ash Content	%	5.7
2	Cold Water Solubility	%	5.4
3	Hot Water Solubility	%	9.6
4	1/10 N NaOH Solubility	%	36.1
5	Alcohol Benzene Solubility	%	2.8
6	Pentosan	%	19.8
7	Holocellulose	%	74.0
8	α Cellulose	%	39.2
9	β Cellulose	%	18.6
10	χ Cellulose	%	16.2
11	Acid Insoluble Lignin	%	19.9
12	Acid Soluble Lignin	%	1.69
	Non-process Elements		
1.	Silica	%	3-5
2.	Chloride	%	0.8-1.0
3.	Potassium	%	1.5-2.0

Pulping:

Despite the open structure of wheat straw, it was observed that alkali consumption to produce a bleachable grade pulp was as high as 16%. The pulp produced had considerable screen rejects. The greater resistance to chemical penetration and also requirement of high chemical dosage for delignification due to the presence of leaf, nodes, sheath and chaff, which escape the raw material cleaning. The total screened yield of the pulp was about 51%. The cooking conditions and resultant pulp quality from wheat straw pulp in laboratory are as follows.

Pulping conditions and pulp properties.

1	Raw material taken in each bomb	200 gm O.D,
2	Cooking chemical, %	16
3	Bath ratio	1:5
4	Ambient to 100°C	30 min.
5	100°C to 168°C	100 min.
6	At 168°C	120 min.
7	Unscreened Pulp yield, %	51.1
8	Reject, %	0.42
9	Screened Pulp yield, %	50.7
10	Kappa No	20.8

Bleaching:

Unbleached wheat straw was bleached using CEH sequence to get a brightness 80%, ISO. Bleaching conditions and properties of wheat straw pulp as given below.

S.No	Parameter	Units	
1.	Kappa No.		20.8
	Chlorination Stage		
2.	Chlorine added	%	4.57
3.	Consistency	%	3
4.	pH		< 2
5.	Time, min	min	30
6.	Temperature	°C	Ambient
	Alkali Extraction stage		
7.	NaOH , added		2.0
8.	Consistency	%	8
9.	Time	min	60
10.	Temperature,	°C	60
11.	pH		11-12
	Hypo stage		
12.	Calcium hypo chlorite added	%	3.0
13.	Consistency	%	8
14.	Time	min	120
15.	Temperature	°C	40
16.	pH		9-10
17.	Final pulp brightness	%	78.9
18.	Intrinsic viscosity	cm3/gm	320

Pulp properties:

Sl. No.	Particulars	Units	Results
1.	Zero Span Tensile Strength (FSI)	Km	11.8
2.	Wet web Tensile Strength		170
3.	Bauer McNett Classification		
	+ 30	%	20.0
	+ 50	%	15.0
	+ 100	%	18.0
	+ 200	%	6.5
	- 200	%	40.5

Strength properties of wheat straw pulp:

Sl. No.	Properties	Units	Results	
1.	PFI	rev	0	500
2.	Freeness	ml, CSF	445	220
3.	Apparent density	g/cm3	0.81	0.87
4.	Burst Index	kPa m2/g	3.45	4.30
5.	Tensile Index	Nm/g	56.0	74.0
6.	Tear Index	mNm2/g	4.20	3.80
7.	Fold Kohler	log	1.68	1.80
8.	Bendtsen Porosity	ml/min	90	10

BAGASSE

Saccharum officinarum

Sugar cane (Saccharum officinarum) residue, commonly known as bagasse is one of the prime papermaking fiber source. About 7.2 million tonnes of bagasse is produced per annum in India. Sugar cane is cultivated in about 4.25 million hectare of agriculture land in India at a yield rate of 70 ton/hectare. Sugar factories crush about 180 million tons of sugar cane per year and the season lasts for 150 to 180 days. Major sugarcane growing states are Utter Pradesh, Maharashtra, Tamilnadu and Karnataka. Bagasse constitutes about 30% of cane processed for production of sugar, which is used as a fuel for cogeneration of steam and power to meet the process requirements. Depending upon the energy efficiency, sugar mills also save bagasse, ranging from 4% to 10% on cane. This spare bagasse is used for production of pulp, paper and particleboard.

Sugar cane in the Field

Bagasse stored in Mill Site

Bagasse is highly bulky and its transportation to the paper mills poses serious problems. Hence, the paper plants, which are situated near the sugar mills, are only able to partly utilize bagasse as a raw material for production of paper. Bagasse is generated from the renewable agriculture source its use in paper industry reduce the dependency of paper industry on forest based fiber and conservation of forests preventing global warming.

As per the Development council India (APFSOS/WP/10) the total bagasse production in 1990 was 7.2 million tons of which 15% was supplies (1.08) million tones) which is equivalent to 0.18 million tons /year paper.

Raw Material:

Bagasse was collected from Shreyans Paper Mill, (Punjab) and Trichy (Chenni). Depithing was carried out in the laboratory.

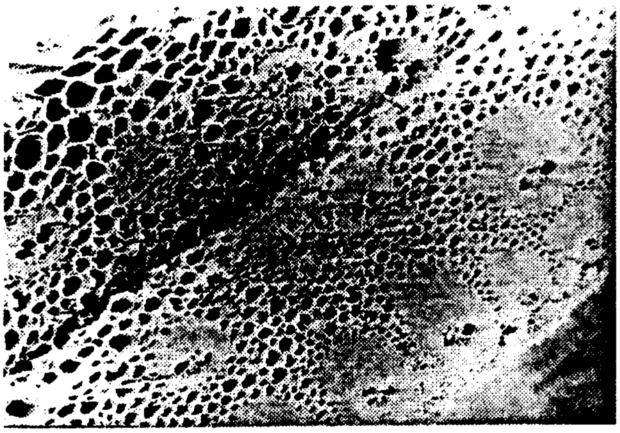
Chemical Composition of raw material:

Se. No	Parameters	Unit	Bagasse (Punjab)	Bagasse (Chenni)
1	Ash Content	%	3.1	2.5
2	Cold Water Solubility	%	1.7	3.0
3	Hot Water Solubility	%	4.4	5.1
4	1/10 N NaOH Solubility	%	35.5	29.9
5.	Alcohol Benzene Solubility	%	2.5	3.0
6.	Pentosans	%	22.7	26.1
7	Holo-cellulose	%	71.5	75.7
8	Alpha Cellulose	%	41.7	40.8
9	Beta Cellulose	%	17.7	24.5
10	Gamma Cellulose	%	12.1	10.4
11	Acid Insoluble Lignin	%	21.2	18.0
12	Acid Soluble Lignin	%	1.3	0.9

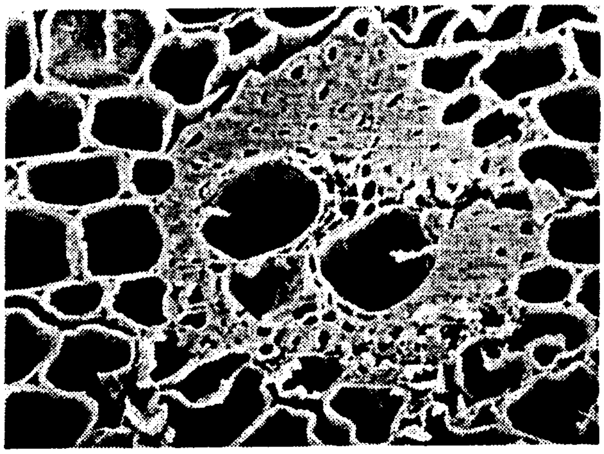
The fibers are obtained from the stem of sugarcane plant after extracting the juice. The fibers in admixtures with some long fibers are used for the manufacture of all types of cheap grade Cultural and industrial paper. The fiber varies 0.3 to 4.0 mm in length and width varies from 10 to 40µm. The wider fibers are thick to thin walled, with straight, pointed tapering ends and relatively more numerous slit like or lenticular pits than in bamboo. Transverse markings similar to those of bamboo are quite common. The wider fibers are usually shorter and comparatively thin walled not frequently with blunt, oblique or forked ends. Parenchyma cells are very abundant, usually appreciably larger than those of bamboo. They are up to 900 µm in length with an average of 358 µm and up to 180 µm in width with an average of 78 µm and serve to distinguish bagasse from bamboo. The parenchyma cells are small to medium sized narrow rectangular and numerous. Vessels are similar to those of bamboo, ranging from 180 to 1600 µm and 30 to 220 µm long and narrow. The epidermal cells somewhat narrow and rectangular with undulating margins are always present but not very common. Stomata may be rarely present.

No.	Dimensions	Unit	Bagasse (Punjab)	Bagasse (Chenni)
A	***Properties of fiber:***			
1.	Fiber Length (Weight weighted) (L = 0.20 - 4.0mm)	mm	1.24	1.52
2.	Minimum Fiber Length,	mm	0.35	0.32
3.	Maximum Fiber Length,	mm	3.62	3.9
4.	Mean Fiber width (μ= 7 - 45)	μm	19.3	21.8
5.	Lumen Diameter	μm	4.07	6.29
6.	Cell wall thickness	μm	7.65	7.76
7.	Runkel Ratio		3.75	2.47
8.	Fiber curl index (W.weighted) (L = 0.50 -10.0mm)	-	0.211	0.181
9.	Fiber kink index (L = 0.50 - 5.0mm)	1/mm	2.52	2.18
10.	Total kink angle	Degrees	47.21	42.0
11.	Kinks per mm	1/mm	1.12	1.06
B	***Properties of non-fibrous tissue***			
12.	Length of vessel	μm	287.5	151.6
13.	Width of vessel	μm	101.4	27.8
14.	Length of Parenchyma	μm	358.5	327.7
15.	Width of Parenchyma	μm	78.2	53.2
16.	Arithmetic Fines (L = 0.01 - 0.20 mm)	%	61.9	58.3
17.	Length weighted Fines (L = 0.01 - 0.20 mm)	%	20.5	17.0

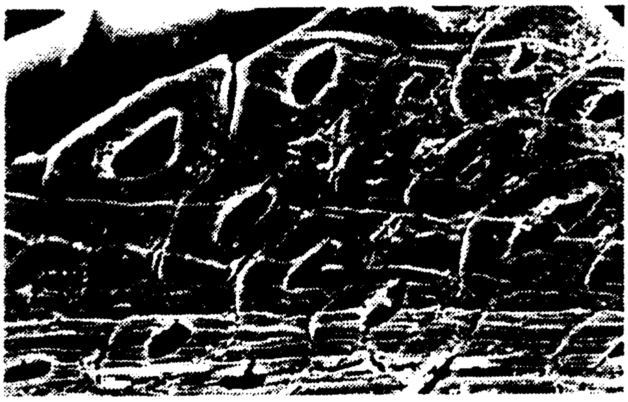
BAGASSE



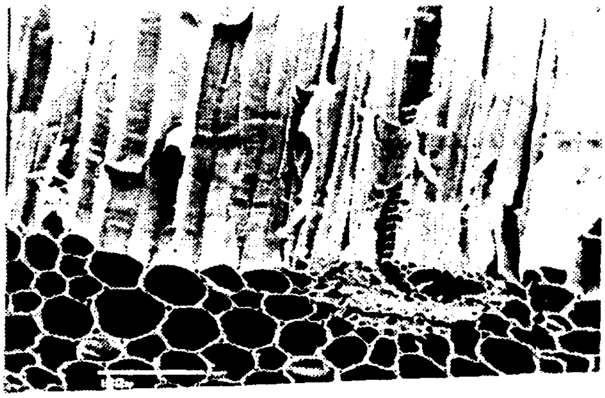
Cross section of bagasse



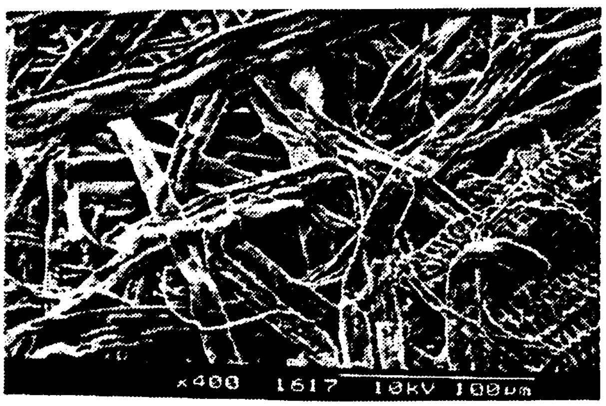
Magnified view of vascular bundle



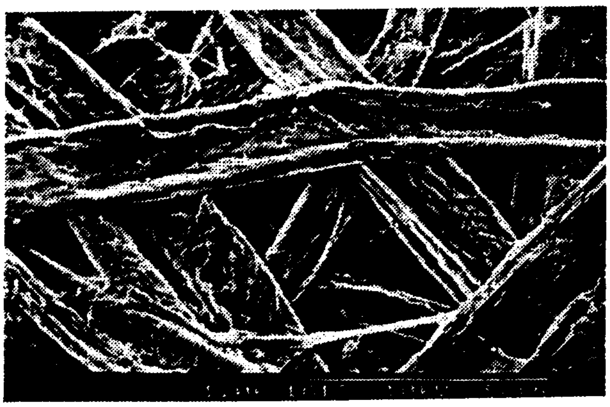
Cross section of fibers



Section showing ground tissue



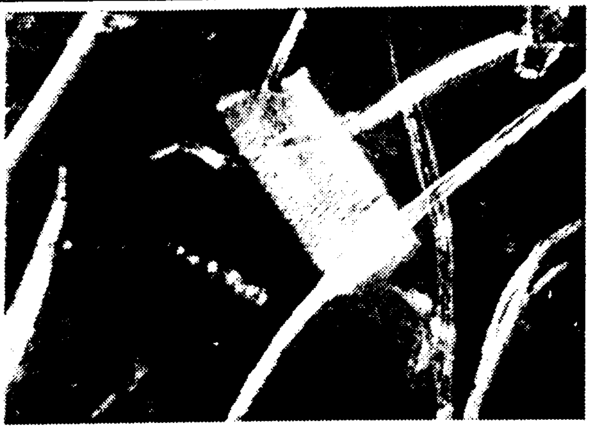
Surface view of paper



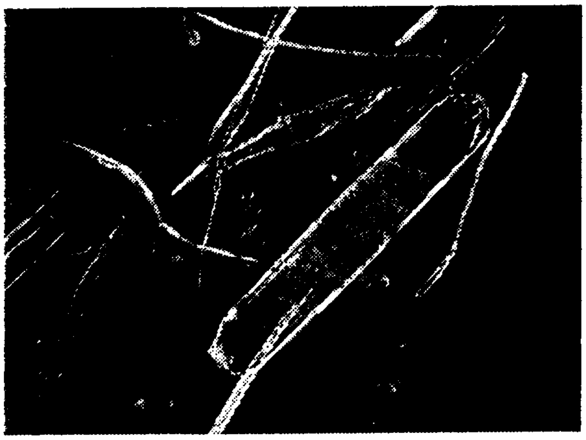
Magnified view of fiber crossings

BAGASSE

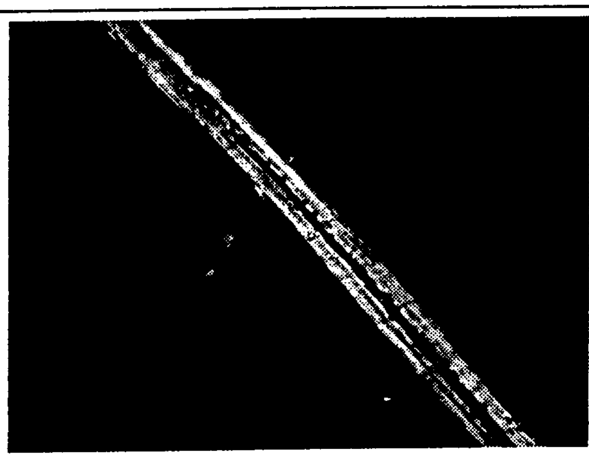
Bagasse pulp component s



Magnified view of vessel element



Prominent parenchyma cells



Enlarged view of fiber, note bright wall and fiber lumen

Pulping:

Pulping experiments were carried out using cooking chemical using 18% and 16% soda process in to obtain bleachable grade pulps of kappa n° around 19 and 11.

1.	Raw material taken in each bomb	200 gm O.D,
2.	Bath ratio	1:5
3.	Ambient to 100°C	30 min.
4.	100°C to 168°C	100 min.
5.	At 168°C	90 min.

Pulping conditions and pulp quality:

S.No	Parameter	Bagasse (Punjab)	Bagasse (NCL)
1.	Cooking chemical, %	18.0	16.0
2.	Unscreened Pulp yield, %	52.2	51.7
3.	Reject, %	1.63	1.84
4.	Screened Pulp yield, %	50.6	49.9
5.	Kappa. no	19.2	10.9

Bleaching:

Unbleached bagasse pulp was bleached using CEH sequence to get targeted brightness 80%, ISO. The conditi ons are given below:

S.No	Parameters	Bagasse (Punjab)
1.	Kappa No.	19.2
	Chlorination Stage	
2.	Chlorine added, %	4.22
3.	Consistency, %	3
4.	pH	<2
5.	Time, min	30
6.	Temperature, °C	Ambient
	Alkali Extraction stage	
7.	NaOH, added	2.0
8.	Consistency, %	8
9.	Time, min	60
10.	Temperature, °C	60
11.	pH	11-12
	Hypo stage	
12.	Calcium hypochlorite, % add ed	2.5
13.	Consistency, %	8
14.	Time, min	120
15.	Temperature, °C	40 °C
16.	pH	9-10
17.	Final pulp brightness, %	80.2
18.	Intrinsic viscosity, cm 3/gm	568

Properties of Bagasse bleached Pulp:

The physical strength properties are in the acceptable range for producing writing and printing grades of paper. It is also suitable for making straw board. Due to high proportion of fines in the pulp, it has low initial freeness unsuitable for any refining However, since the long fiber fraction is also high, the zero-span tensile strength is high indicating the possibility to make good quality writing and printing papers. In spite of being a soda pulp, the strength properties are good. Compared to bamboo, sabai grass yields a stronger and more durabl e pulp.

Pulp properties of Punjab bagasse.

Sl. No.	Particulars	Result
1.	Zero Span Tensile Strength	8.2
2.	Bauer & McNett Classification	
	+30	14.4
	+50	8.6
	+100	39.2
	+200	13.4
	-200	24.4

Characteristics of bagasse paper are high density and tight stiffness, and then it can be used for high-grade printing paper, publishing and stationery. We can find examples such as textbooks, newspapers or toilet papers in overseas countries and catalogs, PPC, paper bags in Japan. Bagasse paper can be recycled like ordinary paper.

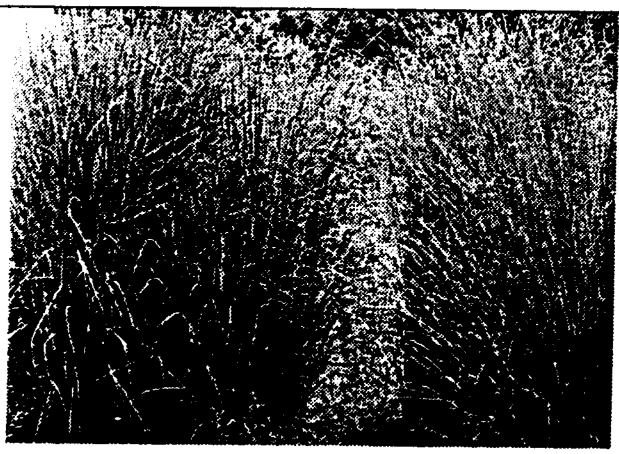
Strength properties of bleached pulp.

Sl. No.	Properties	Unit	Bagasse (Punjab)	
1.	PFI	rev.	0	500
2.	Freeness	mlCSF	485	220
3.	Apparent density,	g/cm^3	0.78	0.90
4.	Burst Index,	kPa m^2/g	2.0	4.0
5.	Tensile Index,	Nm/g	42.0	68.5
6.	Tear Index,	mNm^2/g	4.20	4.10
7.	Fold Kohler	log	1.28	2.01
8.	Bendtsen Porosity	ml/min	220	10

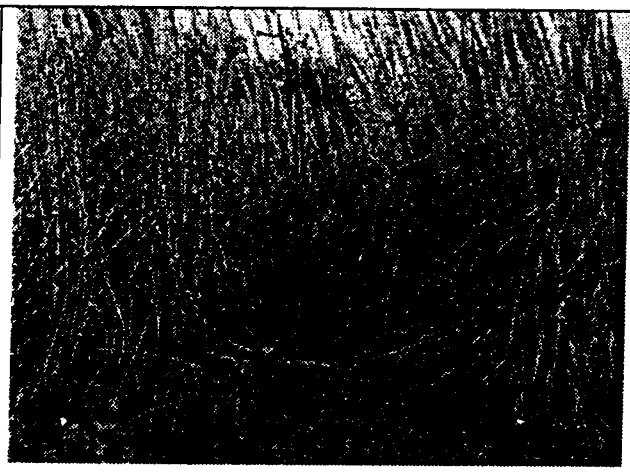
SARKANDA GRASS

Saccharum bengalense

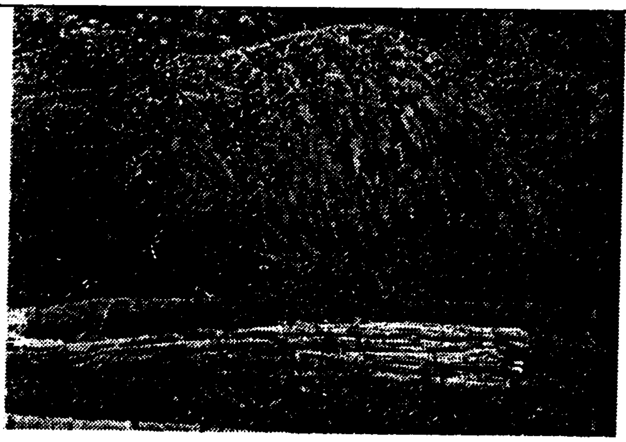
A very large erect grass, growing in clumps with following clumps upto 6 meter tall found mainly in Punjab, Uttar Pradesh, Bihar, Bangal and orissa, growing well on alluvial sandy banks of streams not subjected to water logging. Culms biennial, pale soild, pithy smooth with an inconspicuous growth ring and root zone. Leaves 1-2 meter long and upto 3 cm broad. This species is of great value for fiber extracted from the upper leaf sheaths of the flowering culms. The fiber obtained from sarkanda grass is quite strong and elastic and



Sarkanda Grass in the field



Sarkanda Grass in the field



Sarkanda Grass in bundles

Transporting of Sarkanda grass to Mill

not affected by moisture. It is extensively employed for manufacture of cordage and ropes and for making mats and baskets etc. The leaves are also used for thatching and for purposed of pulp manufactur ing

Source: The wealth of India (Raw Material)

Raw Material:

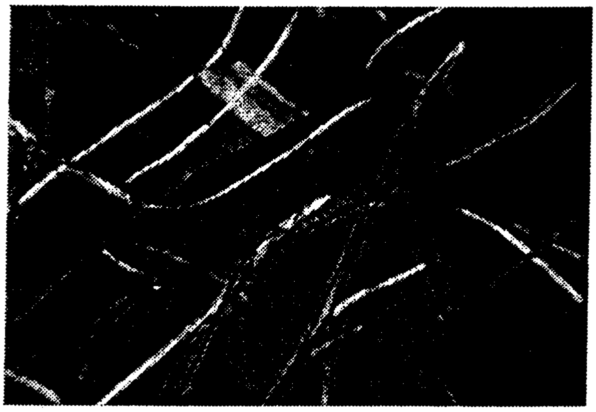
Sarkanda was collected from Shreyans Paper Mill,Punjab.

Chemical composition of raw material.

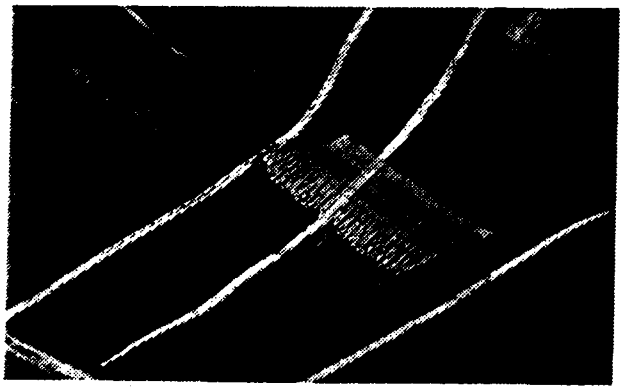
Se. No	Parameters	Unit	Sarkanda
1.	Ash Content	%	8.2
2.	Cold Water Solubility	%	2.6
3.	Hot Water Solubility	%	11.2
4.	1/10 N NaOH Solubility	%	37.3
5.	Alcohal Benzene Solubility	%	3.8
6.	Pentosan	%	20.7
7.	Holocellulose	%	70.4
8.	Alpha Cellulose	%	39.9
9.	Beta Cellulose	%	18.9
10.	Gamma Cellulose	%	11.6
11.	Acid Insoluble Lignin	%	21.0
12.	Acid Soluble Lignin	%	1.92

Morphology

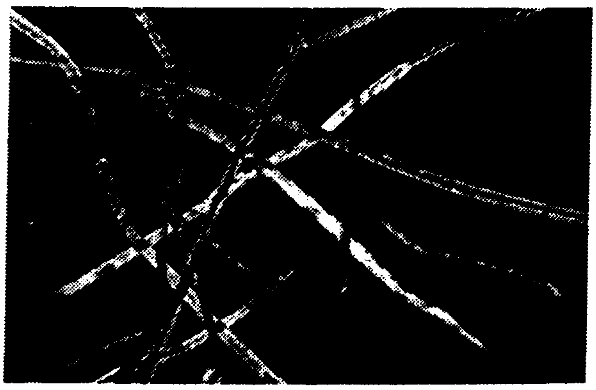
Sarkanda grass pulp components



Sarkanda fibers and vessel element



Magnified view of vessel elements



Enlarged view of fiber

The fiber varies from 0.2- to 3.5 in length (an average of 1.3 mm) and 7 to 40 μm in width (average 15.7 μm). The pulp consists of fibers, parenchyma, and vessel and epidermal cells. The fibers are narrow, long, straight and thick walls and pointed tapering ends and occasional transverse markings. The fibers are narrow than bamboo and bagasse. The parenchyma cells are small to medium sized narrow rectangular and numerous. The vessels are fairly long and narrow. The epidermal cells are numerous, rectangular in shape and conspicuous with serrated margins.

No.	Dimensions	Unit	Sarkanda
A	*Properties of fiber:*		
1.	Fiber Length (Weight weighted) (L = 0.20 – 4.0mm)	mm	1.3
2.	Minimum Fiber Length,	mm	0.50
3.	Maximum Fiber Length,	mm	4.48
4.	Mean Fiber width (μ= 7 – 45)	μm	15.7
5.	Lumen Diameter	μm	4.24
6.	Cell wall thickness	μm	5.72
7.	Runkel Ratio		2.70
8.	Fiber curl index (Length weighted) (L = 0.50 – 10.0mm)	-	0.198
9.	Fiber kink index (L = 0.50 – 5.0mm)	1/mm	2.54
10.	Total kink angle	degrees	46.76
11.	Kinks per mm	1/mm	1.16
B	*Properties of non-fibrous tissue*		
12.	Length of vessel	μm	79.9
13.	Width of vessel	μm	30.1
14.	Length of Parenchyma	μm	141
15.	Width of Parenchyma	μm	31.8
16.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	60.5
17.	Length weighted Fines (L = 0.01 – 0.20 mm)	%	16.5

Pulping:

Pulping experiments were carried out using 18% soda to obtain a pulp of Kappa N° 24.

Pulping conditions and pulp quality:

1.	Raw material O.D	200 gm,
2.	Cooking chemical, % as NaOH	18.0
3.	Bath ratio	1:5
4.	Ambient to 100°C	30 min.
5.	100°C to 168°C	100 min.
6.	At 168°C	90 min.
7.	Unscreened Pulp yield, %	48.7
8.	Reject, %	1.0
9.	Screened Pulp yield, %	47.7
10.	Kappa. no	24.0

Bleaching:

The bleaching was carried out using the CEH sequence with brightness target of 80 %ISO. The pulp was chlorinated using 0.2 Kappa factor.

S.No	Parameter	Sarkanda
1.	Kappa no.	24.0
	Chlorination Stage	
2.	Chlorine added, %	4.84
3.	Consistency, %	3
4.	pH	<2
5.	Time, min	30
6.	Temperature, °C	Ambient
	Alkali Extraction stage	
7.	NaOH , added	2.5
8.	Consistency, %	8
9.	Time, min	60
10.	Temperature, °C	60
11.	pH	11-12
	Hypo stage	
12.	Calcium hypochorite , % added	3.5
13.	Consistency, %	8
14.	Time, min	120
15.	Temperature, °C	40
16.	pH	9-10
17.	Final pulp brightness, %	79.6
18.	Intrinsic viscosity, cm3/gm	356

Pulp properties:

The pulp contains about 30% long fiber fraction that the pulp has potential of higher strength properties. However the pulp has high primary fines proportion, which causes drainage problems.

Sl. No.	Particulars	Result
1.	Zero Span Tensile Strength	9.8
2.	Bauer & McNett Classification	
	+30	21.1
	+50	5.8
	+100	23.6
	+200	20.4
	-200	29.1

Strength properties of Sarkanda bleached pulp:

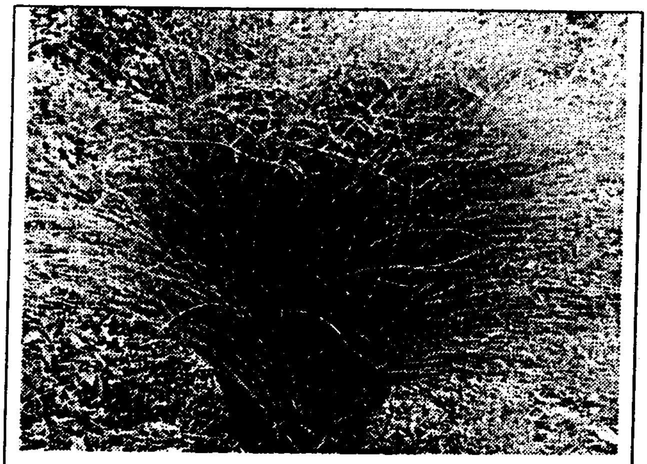
Sl. No.	**Properties**	**Unit**	**Sarkanda Bleached Pulp**		
1.	PFI,	Rev.	0	500	1000
2.	Freeness,	CSF	475	265	150
3.	Apparent density	g/cm^3	0.69	0.75	0.84
4.	Burst Index,	kPa m^2/g	1.50	2.50	3.00
5.	Tensile Index	Nm/g	33.0	50.0	57.5
6.	Tear Index	mNm^2/g	3.70	3.40	3.10
7.	Fold Kohler	log	0.60	0.84	1.14
8.	Bendtsen Porosity	ml/min	1430	210	30

SABAI GRASS

Eulaliopsis binata

Eulaliopsis binata SYN. Ischaemum angustifolium commonly called Sabai, Babui or bhabar, is an important grass species having lot of commercial value. It is a tufted perennial grass of family Gramineae. Apart from being used in papermaking it is used in rope making, which turns is us ed widely in making household furniture and to tie cattle.

Sabai grass is grown in large quantities out side forest area. Sabai grass is perennial grass, 2-5 ft. high erect, slender culms, shiny and woolly at the base. leaves narrow, linear, 3-4 fit long, on piliform peduncles. Seeds black, exceedingly minute and light. The grass is found nearly throught India and is particulary abundant on the dry bare slopes and forest blanks of sub- Himalayam areas. It is common in Bihar, Orissa, Bengal, Central India and Punjab. It occurs to a small extent in Bombay and Madras. Sabai Grass is second only bamboo in importance as raw material for paper manufacture in India. In recent years, the attempts have been made to cultivate the sabai grass on a commercial scale in the forest blanks and waste lands of UP, Bihar and Orissa. The chief areas of cultivation are kheri, Bahriaich and Singhbhum district in Bihar. Sabai grass thrives best on well-drained sandy loams in regions with an annual rainfall of 30-60 inches. It is hardy to both frost and drought, and i s light demander. It can grow on poor soil not subje ct to water logging. Sabai Grass is harvested annually during November- December, but in plantations in UP, and elsewhere two cuttings are taken, the first in August-September and second in November-December. The grass flowers during the cold weather and for purposes of paper manufacture, the grass is cut prior to or during the flowering stage. The yield of the grass varies from 20-75md per acre according to locality, rainfall and intensity of management. Sabai grass when carefully collected free from weeds and foreign matter, forms an excellent material for the production of printing and medium quality writing paper.



Sabai grass

Raw Material:

Sabai Grass was collected from Bhat, Saharanpur

Chemical composition of raw material:

Se. No	Parameters	Unit	Sabai grass
1.	Ash Content	%	5.3
2.	Cold Water Solubility	%	11.4
3.	Hot Water Solubility	%	13.8
4.	1/10 N NaOH Solubility	%	41.0
5.	Alcohal Benzene Solubility	%	3.5
6.	Pentosan	%	17.9
7.	Holocellulose	%	71.2
8.	α Cellulose	%	35.5
9.	β Cellulose	%	21.4
10.	χ Cellulose	%	14.3
11.	Acid Insoluble Lignin	%	23.5
12.	Acid Soluble Lignin	%	1.64

Morphology:

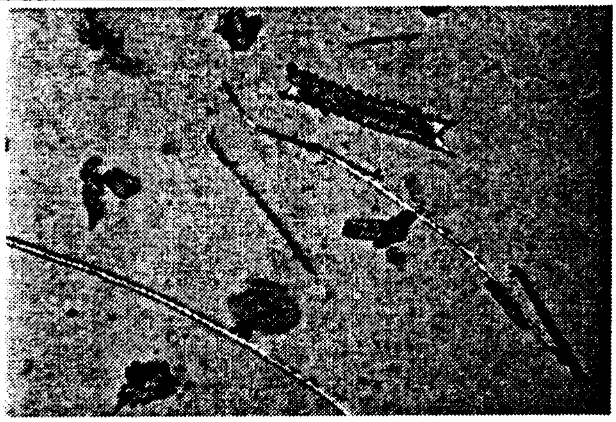
The fibers are derived from the vascular bundles of leaves. The pulp is used for the manufacture of all types of cultural and industrial paper. The fiber varies from 0.4- to 4.4 in length with an average of 1.6 mm and 5-15μm in width (average 13.7 μm). The pulp consists of fibers, parenchyma, and vessel and epidermal cells. The fibers are narrow, long, straight and thick walls and pointed tapering ends and occasional transverse markings. The fibers are narrower than those of bamboo and bagasse. The parenchyma cells are small to medium sized narrow rectangular and numerous. The vessels are fairly long and narrow. The epidermal cells are numerous, rectangular in shape and conspicuous with serrated margins.

No.	Dimensions	Unit	Sabai Grass
A	*Properties of fiber:*		
1.	Fiber Length (Weight weighted) (L = 0.20 - 4.0mm)	mm	1.57
2.	Minimum Fiber Length,	mm	0.35
3.	Maximum Fiber Length,	mm	4.4
4.	Mean Fiber width (μ= 7 – 45)	μm	13.5
5.	Lumen Diameter	μm	1.11
6	Cell wall thickness	μm	6.3
7.	Runkel Ratio		11.4
8.	Fiber curl index (length weighted) (L = 0.50 - 10.0mm)	-	0.162
9.	Fiber kink index (L = 0.50 – 5.0mm)	(1/mm)	2.01
10.	Total kink angle	degrees	41.2
11.	Kinks per mm	(1/mm)	0.99
B	*Properties of non-fibrous tissue*		
12.	Length of vessel	μm	43
13.	Width of vessel	μm	30
14.	Length of Parenchyma	μm	70
15.	Width of Parenchyma	μm	15
16.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	59.7
17.	Length weighted Fines (L = 0.01 – 0.20 mm)	%	14.0

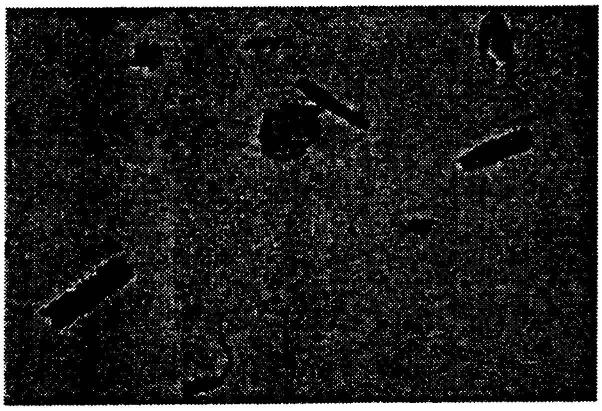
SABAI GRASS

Sabai grass pulp

Magnified view of pulp fiber



Sabai pulp fiber and vessel element



Parenchyma and epidermal cells

Pulping:

Pulping experiments were carried out using cooking chemical using 14% soda process in to obtain pulp of Kappa N° around 18.

Pulping conditions and pulp quality:

S.No	Parameter	Sabai Grass
1.	Raw material O.D.	200 gm
2.	Cooking chemical, % as NaOH	14.0
3.	Bath ratio	1:5
4.	Ambient to 100°C	30 min.
5.	100°C to 168°C	100 min.
6.	At 168°C	90 min.
7.	Unscreened Pulp yield, %	46.0
8.	Reject, %	0.40
9.	Screened Pulp yield, %	45.6
10.	Kappa No	18.6

Bleaching:

The Sabai grass soda pulp was bleached using CEH bleaching sequence to a brightness of 80% ISO.

S.No	Parameters	Sabai Grass
1.	Kappa no.	18.6
	Chlorination Stage	
2.	Chlorine added, %	4.09
3.	Consistency, %	3
4.	pH	<2
5.	Time, min	30
6.	Temperature, oC	Ambient
	Alkali Extraction stage	
7.	NaOH , added	2.0
8.	Consistency, %	8
9.	Time, min	60
10.	Temperature, °C	60
11.	pH	11-12
	Hypo stage	
12.	Calcium hypochorite , % added	2.0
13.	Consistency, %	8
14.	Time, min	120
15.	Temperature, °C	40
16.	pH	9-10
17.	Final pulp brightness, %	81.2
18.	Intrinsic viscosity, cm3/gm	412

Pulp properties:

Sl. No.	Particulars	Result
1.	Zero Span Tensile Strength	12.7
2.	Bauer McNett Classification	
	+30	40.2
	+50	8.5
	+100	2.1
	+200	5.0
	-200	40.0

Physical properties of Sabai Grass bleached Pulp:

Sl. No.	Properties	Unit	Sabai Grass Bleached Pulp		
1.	PFI	rev.	0	500	1000
2.	Freeness	CSF	400	340	300
3.	Apparent density	g/cm^3	0.60	0.61	0.63
4.	Burst Index	$kPa\ m^2/g$	3.90	4.50	4.60
5.	Tensile Index	Nm/g	55.5	58.0	67.5
6.	Tear Index	mNm^2/g	9.40	8.70	7.80
7.	Fold KM	Log	1.98	2.11	2.18
8.	Bendtsan Porosity	ml/min	1690	1590	960

KANS GRASS

(Saccharum spontaneum)

Growing concerns about the rising cost and decreasing supply of bamboo and other forest wood fiber has created a renewed interest in the use of alternative fiber sources in the production of paper products in all over the world. Tree plantations are usually the best option considered to increased wood supply for sustainable development of paper industry in India to meet out the market demand and their higher fiber yield and economic viability. India being an agriculture-based country has availability of agro based raw materials in plenty. This coupled with the shortage of forest based woody raw material, it puts an additional pressure on paper industry to explore and use high proportion of agro based annual plant in there furnish. In order to effectively solve the problem of raw material supply, one major step has been taken by the industry to utilize the unconventional raw materials like bagasse, straw, grasses, and waste paper etc. for making paper.

	
Kans grass field	**Collection of Kans blooms**

Kans Grass (*Saccharum spontaneum*) popularly known as north Indian canes is a perennial grass with slender culms green gray, ivory or white, hard , but very pithy. Kans Grass is mainly found in Himalayas of northern India and extends up to the equatorial regions of java. Kans Grass is a coarse grass normally not relished by cattle and is generally used as fodder only in times of scarcity.

Kans Grass is a perennial grass often hollow in the center, varying in diameter from 5 to15 mm, often rooting at the node, internodes usually long and nodes always thicker than the internodes. Leaves are long, linear, narrow or very narrow, the leaf module or ratio of breadth to length varying from 1:24 to 1:300 or more in the different forms of the species. Culms biennial, pale solid, pithy smooth with an inconspicuou s growth ring and root zone. Leaves 1-2 meter long and up to 3 cm broad. This species is of great value for fiber extracted from the upper leaf sheaths of the flowering culms. The leaves are also used for thatching and for purpose of pulp manufacturing. Keeping its availability and existing utility in view, pulping and papermaking properties of Kans Grass have been evaluated so that it can be exploited for pulp and paper manufacture. Kans Pulp s suitable for production of wrapping, writing printing and greaseproof papers. It is also used for hardboard making. The grass can be used in admixture with other grasses.

Chemical composition of raw material:

Sl. No	Parameters	Unit	Kans Grass
1.	Ash Content	%	6.8
2.	Cold Water Solubility	%	12.6
3.	Hot Water Solubility	%	15.5
4.	1/10 N NaOH Solubility	%	42.2
5.	Alcohol Benzene Solubility	%	4.0
6.	Pentosans	%	15.9
7.	Holocellulose	%	69.2
8.	Alpha Cellulose	%	33.2
9.	Beta Cellulose	%	23.6
10.	Gamma Cellulose	%	12.4
11.	Acid Insoluble Lignin	%	22.4
12.	Acid Soluble Lignin	%	1.6

Morphology :

Kans Grass shows the same diversity of cell type as sarkanda and sabai grass. The fibers are uniform, long and slender with pointed ends. The fiber length ranges from 0.20 mm to 3.90 mm with average length of 1.40 mm. Parenchyma cells are numerous small to large, rectangular to rounded and somewhat larger than sabai grass and their length varies from 22.0 to 312 microns (average 91 μm) and 12 to 98 μm (average 35 μm) in width. Vessels vary from very short to long from 104 μm to 1265 μm (average 489μm) and width various 25 micron to 92 micron (average 38 micron). Epidermal cells are narrow and cylindrical with toothed margins. Epidermal cells' length varies from 57 to 163 μm (average 81 μm) and width from 8 to 16.3 μm (average 13.5 μm).

No.	Dimensions	Unit	Kans Grass
A	*Properties of fiber:*		
1.	Fiber Length (Weight weighted) (L = 0.20 - 5.0mm)	mm	1.4
2.	Minimum Fiber Length,	mm	0.43
3.	Maximum Fiber Length,	mm	3.57
4.	Mean Fiber width (μ= 7 – 35)	μm	15.4
5.	Lumen Diameter	μm	1.14
6.	Cell wall thickness	μm	6.38
7.	Runkel Ratio		11.2
8.	Fiber curl index (length weighted) (L = 0.50 – 5.0mm)	-	0.135
9.	Fiber kink index (L = 0.50 – 5.0mm)	1/mm	1.93
10.	Total kink angle	degree	35.90
11.	Kinks per mm	1/mm	0.93
B	*Properties of non-fibrous tissue*		
12.	Length of vessel	μm	489.0
13.	Width of vessel	μm	38.0
14.	Length of Parenchyma	μm	91.1
15.	Width of Parenchyma	μm	35.0
16.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	55.71
17.	Length weighted Fines (L = 0.01 – 0.20 mm)	%	13.59

Pulping:

Soda Pulping was carried out using chemical charge 16 % as NaOH .. Unbleached pulp of Kappa No. 17.7 was produced.

Pulping conditions and pulp quality:

1.	Raw material	200 gm O.D,
2.	Cooking chemical, %	16.0
3.	Bath ratio	1:5
4.	Ambient to 100°C	30 min.
5.	100°C to 168°C	100 min.
6.	At 168°C	120 min.
7.	Unscreened Pulp yield, %	45.5
8.	Reject, %	0.4
9.	Screened Pulp yield, %	45.1
10.	Kappa No	17.7

Bleaching:

The unbleached Kans grass soda pulp could be bleached using conventional CEH bleaching sequence to get a brightness of 80.0 % ISO.

Sl.no.	Parameters	Unit	Kans Grass
1.	Kappa No.		17.7
	Chlorination Stage		
2.	Chlorine added	%	3.24
3.	Consistency	%	3
4.	PH		< 2
5.	Time	min	30
6.	Temperature	°C	Ambient
	Alkali Extraction stage		
7.	NaOH, added	%	2.0
8.	Consistency	%	8
9.	Time	min	60
10.	Temperature	°C	60
11.	pH		11
	Hypo stage		
12.	Calcium hypochlorite, added	%	2.0
13.	Consistency	%	8
14.	Time	min	120
15.	Temperature	°C	40
16.	PH		9
17.	Final pulp brightness	%	80.9
18.	Intrinsic viscosity	cm^3/gm	379

Properties of pulp:

The pulp contains about 30% long fiber fraction that the pulp has potential for higher strength. However the pulp has high primary fines proportion.

Sl. No.	Particulars	Result
1.	Zero Span Tensile Strength	9.1
2.	Bauer & McNett Classification	
	+30	20.5
	+50	10.8
	+100	24.4
	+200	5.0
	-200	39.3

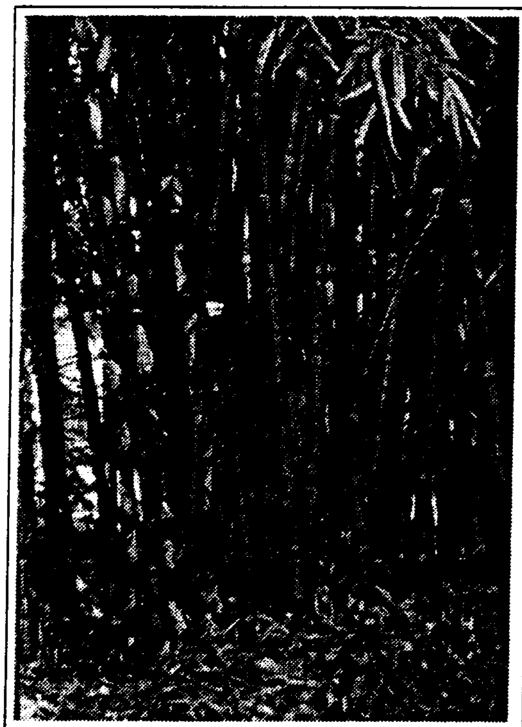
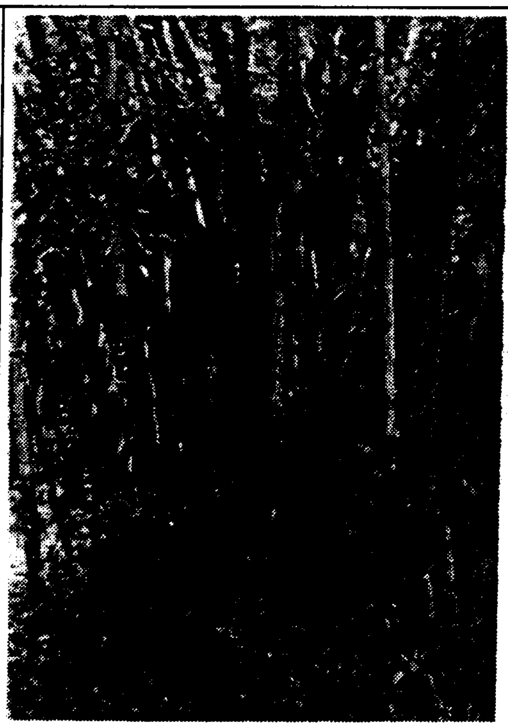
The physical strength properties are in the acceptable range for producing writing and printing grades of paper. Due to high proportion of fines in the pulp, it has low initial freeness unsuitable for any refining (Table 6). However, since the long fiber fraction is also high, the zero-span tensile strength is high indicating the possibility to make good quality writing and printing papers. In spite of being a soda pulp, the strength properties are good.

Strength properties of Kans grass bleached pulp:

Sl. No.	Properties	Units	Kans Bleached Pulp	
1.	PFI	rev.	0	500
2.	Freeness	ml CSF	360	285
3.	Apparent density	g/cm^3	0.78	0.83
4.	Burst Index	kPa m^2/g	3.35	4.30
5.	Tensile Index	Nm/g	55.0	62.0
6.	Tear Index	mNm^2/g	6.50	5.20
7.	Fold Kohler	log	1.78	1.98
8.	Bendtsen Porosity	ml/min	340	130

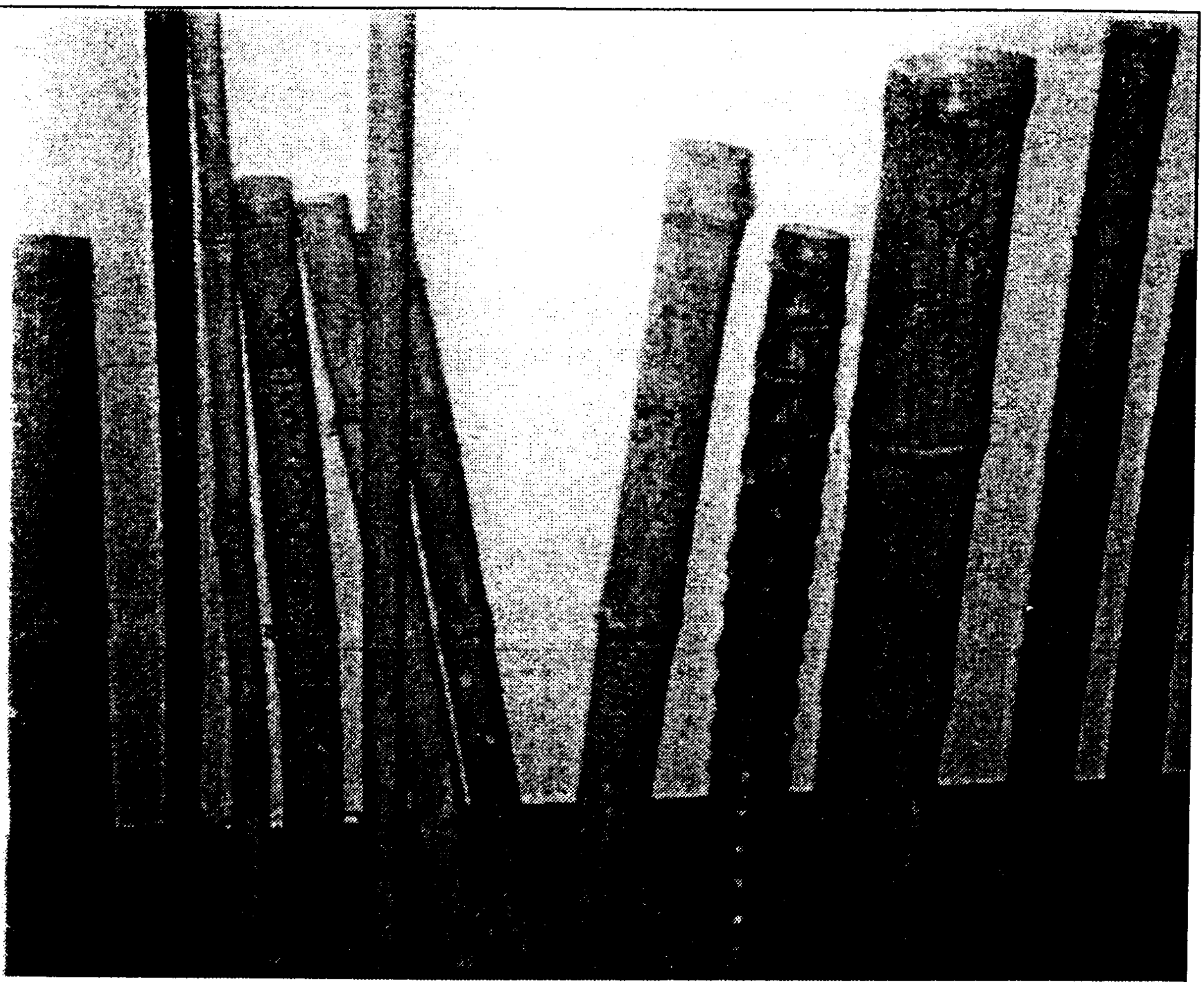
BAMBOO

Bamboo is a perennial, giant, woody grass belonging to the tribe Bambuseae of the well-known family of Gramineae in group angiosperms and the order monocotyledon. The grass family Poaceae (or Gramineae) can be divided into one small subfamily, Centothecoideae, and five large subfamilies, Arundinoideae, Pooideae, Chloridodeae, Panicoideae, and Bambusoideae. In distinction to its name, bamboos are classified under the sub-family Bambusoideae. About 1200-1500 species of 60-70 genera of bamboo are known to exist in the world. More than half of these species grow in Asia, most of them within Japan and Indo-Burmese region, which is considered their area of origin. In India out of 136 species identified, 30 - 40 species are extensively available for economic exploitation. Some examples of bamboo genera are *Bambusa, Chusquea, Dendrocalamus, Phyllostachys, Gigantochloa* and *Schizostachyum*.

Clump of *Bambusa tulda*	Clump of *Bambusa vulgaris*

Bambusa arundinacea is found in Orissa, Assam, Eastern Bangal, South and western India, *B. vulgaris* in Assam; *B. tulda* and *B. balcooa* in Bengal; *Arundinaria aristate* Gamble in eastern Himalayas, *A. weightiaana* in the Nilgiris, , *B. polymorpha* in the upper mixed forests of eastern Bengal and Assam, *Pseudostachyum poltmorphum* in the valleys of eastern Himalayas, Assam and *Dendracalamus strictus* in deciduous forests throughout India. The smaller bamboo species are mostly found in high elevations or temperate latitudes, and the larger ones are abundant in the tropic and subtropic areas. The four major sub-group of bamboo are Arundinarieae, Eubambuseae, Dendrocalameae and Melocanneae. They are restricted to location with a rainfall of 1200 mm to 4000 mm annually and with a temperature between 16°C to 38°C. Atmospheric humidity plays an important role for the growth of bamboo apart from rainfall and temperature. Arundinarieae species grow well in localities with alluvial soils and rocky laterite soils with steep and well-drained slopes. Some of the prominent bamboo species have the following characteristics.



Culms of various bamboo species

Species	Average Height (m)	Internodes, (cm)	Diameter, (cm)
Bambusa arundinacea	26-30	30-40	15-18
Dendracalamus strictus	6-16	30-40	2.5-7.5
Ochlandra species	2-6	60-120	2.5-5.0

Morphology and Growth:

Many species of bamboo exist but the morphology of the cell tissue is almost similar figure 1. Bamboo species flower at regular interval but various species have different flowering periods. Some flower sporadically and some gregariously. The life cycle of different species various from 30 to 60 years. After periodic flowering, seeding and death of bamboo, there will be an interruption of supplies for a period of 8 to 12 years. It is always advisable to have a bamboo crop of different species flowering at different periods. The flowering cycle (in years) in bamboo varies with species viz. *Bambusa bamboo*, (30-40); *Arundinacea falcate, (28-30); Ochlandra travancorica , (28-30); Bambusa polymurpha*, (55-60); *Dendracalmus strictus*, (30-40); *Melocanna bambusoides*, (45); *Bambusa arundinacea*, (32-34); *Bambusa tulda*, (40) represents the general structure of bamboo. Rhizomes and culms are the two important portion of Bamboo. The rhizome is the underground part of the stem and is mostly sympodial or, to a much lesser degree, monopodial. The upper part of stem is known as culms and is used for papermaking. Culm portion of the bamboo tree contains most of the woody material. Most of bamboo culms are cylindrical and hollow, with diameters ranging from 0.25 inch to 12 inches, and height ranging from 1 foot to 120 feet. It is without any bark and has a hard smooth outer skin due to the presence of silica. The culm is complimented by a branching system, sheath, foliage leaves, flowering, fruits and seedlings. Bamboo is distinguishable from one another by the differences of these basic features, along with the growth style of the culm, which is either strictly erect, erect with pendulous tips, ascending, arched or clambering.

Bamboo is a fast growing species and a high yield renewable resource. Bamboo growth depends on species, but generally, all bamboo matures quickly. Bamboo may have 40 to 50 stems in one clump, which adds 10 to 20 culms yearly. Bamboo can reach its maximum height in 4 to 6 months with a daily increment of 15 to 18 cm (5 to 7 inches). Culms take 2 to 6 years to mature, which depends on the species. Bamboo mature in about 3 to 5 years and with a good management of the bamboo resource, the cutting cycle is normally 3 years as its growth is more rapid than any other plant on the plant. Some bamboo species have been observed to surge skyward as fast as 48 inches in one-day. The fast growth characteristic of bamboo is an important incentive for its utilization. Bamboo fiber was conceived to be a pulp making source way back in 1870 by Thomas Routledge, who had carried out research on bamboo in Britain and published data in 1875 and 1879. The soda pulp was first produced in 1905 by R.W.Sundall and later by W. Raitt. Based on the Raitt's process developed at FRI, Government of India passed the Bamboo Paper Industry Protection act in 1925, thereafter the pulp production from bamboo started with 1700 tons in year 1925 increased to 5000 tons in 1932, and the production has increased to phenomenal figures of 67% of pulp production by 1979. The current Bamboo consumption rate by pulp & paper industry in India is in the range of 0.8 to 1.0 million A.D. tons.

	
Transportation of bamboo by train	**Stacking of Bamboo at mill site**

Much of the world's bamboo pulp comes from native forests. Global annual bamboo pulp capacity is now around 1.46 million metric tons, nearly 80% of which is in China and India. Bamboo is extracted from about 60-70 protected forests In India. One of the world's most prolific and fastest-growing plants, bamboo is able to reach maturity in about four years, compared to the typical 25 to 70 years for commercial tree species. The commonly used bamboo species for pulping are *Arundinacea bambusa, Bambusa tulda* (Jati), *Bambusa balcooa* (Bhulka), *Bambusa arundinacea, Bambusa nutans, Bambusa vulgaris, Dendrocalamus gigantica, Dendrocalamus hamiltonii* (Kako), *Dendrocalamus strictus, Melocanna baccifera* (Muli), *Ochlandra species, Oxytenanthera monostigma* and *Oxynanthera parviflora* (Hill Jati).

Thick and thin wall bamboo in stack

Morphology of bamboo remains the same irrespective of the species. Rhizomes and culms are the two important botanical parts in bamboo structure, where the former is underground part of the stem and later is the surface part of the stem. The culms those are apparent stem parts have the papermaking potential. The bamboo culms are cylindrical and hollow, with diameters ranging from 1 cm to 30 cm having height ranging from 0.5 meter to 40 meters. The culms have no bark like the other wood trees, which is an advantage in processing. Bamboo culms can reach its maximum height in 4 to 6 months, but require 2 to 6 years to mature. Tropical climatic conditions influence the extraction of bamboo from forests and its transportation to mill site. As the felling stops for 4 to 5 months, proper storage and preservation of bamboo are important for smooth running of the mills. The extraction of immature culms results in financial losses and the pulp and papermaking characteristics are adversely affected.

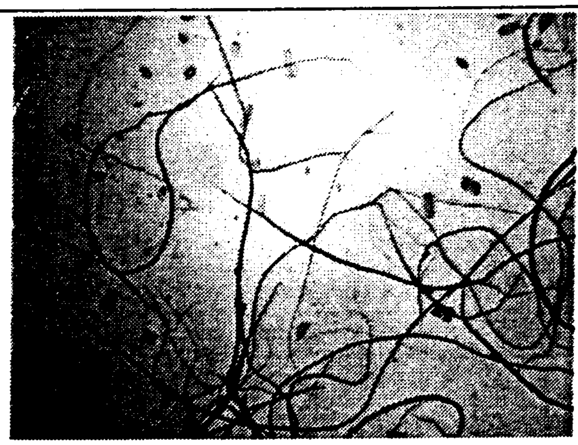
Bamboo culms are extracted from the forests, cut to about two meter length pieces, bundled and stacked, which in turn transported to the interim depots. The freshly extracted bamboos have moisture content ranging from 75% to 50%. From these interim depots, the material is moved by road or rail route to the mill sites. The prolonged storage at the extraction sites leads to serious damage due biological infestations and microbial attack and adversely affects the quality of pulp. It is suggested that there should be concrete paved yards in the mills and the bamboo bundles should be stacked in criss-cross fashion to improve ventilation and drainage of rainwater. The inventory of bamboo storage in a mill should be decided keeping in view the location, infrastructure and production capacities, such that it should not interrupt the sustained supply of bamboo to the mill.

Morphology of Bamboo Culms:

Vascular bundle in ground tissue

Magnified view of fiber cross section

Bamboo chips



Bamboo pulp fibers

The bamboo culms are divided in to segments by nodes. The segments between tow nodes are known as nodes. Outermost cellular layer of bamboo cum is epidermis upon which a waxy layer exists, which gives the smoothness to surface. The fibers appear in layers below the epidermis followed by ground tissue. The vascular bundles, which also contain fibers, are distributed in the ground tissue, which are more closely packed towards the periphery of the stem and scattered towards the inner side in the ground tissue, which causes the differential density of in concentric layers of bamboo. This differential density of bamboo poses biggest challenge to the chip quality management in the chipper house. The bulk density of bamboo chips range between 180 to 250 kg/m^3. The bulk density of bamboo chips can be as low as 120 kg/m^3 in case of immature bamboo. The bamboo fibers are slender and long. The average lengths of the fibers vary between 1.8 mm to 2.5 mm depending upon the species. Similarly, the fiber width varies between 8 μm to 12 μm.

Dimensions and properties of tissues in pulp:

No.	Dimensions	Unit	*B.tulda*	*D. hamiltonii*	*B. balcooa*
A	*Properties of fiber:*				
1.	Fiber Length (Weight weighted) (L = 0.20 – 4.0mm)	mm	1.82	1.96	2.12
2.	Minimum Fiber Length,	mm	0.58	0.47	0.39
3.	Maximum Fiber Length,	mm	5.01	3.5	3.4
4.	Mean Fiber width (μ= 7 – 45)	μm	17.8	17.2	17.2
5.	Lumen Diameter	μm	3.20	3.42	3.67
6.	Cell wall thickness	μm	7.30	6.89	6.76
7.	Runkel Ratio		4.56	4.03	3.68
8.	Fiber curl index (length weighted) (L = 0.50 – 10.0mm)	-	0.176	0.207	0.174
9.	Fiber kink index (L = 0.50 – 5.0mm)	1/mm	1.76	1.93	1.74
10.	Total kink angle	Degrees	44.98	52.34	47.5
11.	Kinks per mm	1/mm	0.84	0.90	0.82
B	*Properties of non-fibrous tissue*				
12.	Length of vessel	μm	286.3	270.2	162.9
13.	Width of vessel	μm	33.5	38.5	58.0
14.	Length of Parenchyma	μm	55.3	69.4	88.0
15.	Width of Parenchyma	μm	30.7	35.5	33.0
16.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	41.7	53.33	32.3
17.	Length weighted Fines (L = 0.01 – 0.20 mm)	%	4.55	6.52	3.09

Chemical composition of raw material:

Se. No	Parameters	Unit	*B.tulda*	*D. hamiltonii*	*B. balcooa*	*M. baccifera*	*NC Hill Bamboo*
1.	Ash Content	%	2.2	2.0	3.6	2.7	2.3
2.	Cold Water Solubility	%	5.1	3.0	3.8	4.0	4.1
3.	Hot Water Solubility	%	7.4	4.0	5.7	4.8	6.5
4.	1/10 N NaOH Solubility	%	21.2	20.3	23.4	25.1	23.2
5.	Alcohal Benzene Solubility	%	2.2	2.2	2.8	2.6	2.1
6.	Pentosan	%	16.2	15.1	15.6	16.5	17.1
7.	Holocellulose	%	75.7	74.9	72.3	73.2	73.5
8.	α Cellulose	%	48.1	47.0	47.1	44.9	44.7
9.	β Cellulose	%	17.6	20.8	13.5	19.7	18.8
10.	χ Cellulose	%	10.1	7.1	11.7	8.6	10.1
11.	Acid insoluble Lignin	%	25.0	25.7	26.8	23.4	23.8
12.	Acid soluble Lignin	%	1.23	1.08	0.98	0.53	0.84

Developments in Bamboo Pulping:

Many of large paper mills in India with 60,000-tpy production capacities are using bamboo with different percentage. Two large mills under HPC Ltd. in North-Eastern India make about 200, 000 tpy paper pulp exclusively from bamboo. Bamboo pulp is capable of fine writing and printing paper standards, offering similar strength, brightness and printability of comparable wood pulp-based papers. Bamboo has it's own papermaking potential, which can hardly be substituted by other raw materials. Bamboo has its maximum resistance to mechanical forces in transverse direction and the smooth surface of the culms; differential density of the culms in concentric layers makes it difficult to achieve clean chipping process. These factors, when the bamboo is not seasoned properly causes more slivers (large chips) and pin chips (botanically vascular strands) and dust (parenchyma cells). This non-uniformity in the chip quality is not a serious problem in batch digestion, but poses serious operational problems when processed in continues digesters due to chocking of the digester screens leading to interruptions in pulping liquor circulation. Nodes in the chips are difficult to pulp as the grain (fibers) and other tissues are intertwined in them causing tightly packing and hinder the pulping liquor penetration.

Bamboo has capillary structures (vessels) running vertically throughout the length in regular distances in the internodes help in pulping liquor movement. These capillaries have air, if the chips are dry and expulsion of air necessary prior pulping process. Steaming of chips would help in expulsion of the entrapped air in the capillaries.

After elaborate and comparative study of pulping processes, it is conclusively established that Kraft process is best suited for pulping of bamboo. Proper choice of pulping process will result in higher pulp yield with low screen rejects by preserving the hemicelluloses. Bamboo pulp is produced using kraft process commercially even today. The pulping temperatures used to be in the range of 165 to 168 °C and the retention time at the maximum temperature is about 2 hours. This process causes darker unbleached pulp with about 700 cm^3/g intrinsic viscosity. The modified processes currently use the pulping temperature in the range of 157 to 160 °C with the retention time to complete the pulping process. The later process improves the unbleached brightness and the strength of the indicated by viscosity in the range of 1200 to 1300 cm^3/g of the pulp. The green bamboo Kraft pulp is difficult to wash due to higher foaming problems and the seasoning of the bamboo helps in reduction of foaming to a significant level..

Pulping Experiment:

Pulping experiments were carried out using cooking chemical using 15 to 17 % as Na_2O with 20% Sulphidity to obtain Kappa N° around 17.

Process conditions:

Raw material	200 gm. (B.D)
Bath ratio	1:3
Ambient to 100 °C	30 min.
100 °C to 165 °C	90 min.
At 165 °C	120 min.

Pulping quality:

Sl. No	Parameter	*B.tulda*	*D. amiltonii*	*M. baccifera*	*NC Hill*	*B. balcooa*
1.	Cooking chemical, %as Na_2O	15	15	17	16	16
2.	Unscreened Pulp yield, %	46.4	47.9	51.0	48.6	43.1
3.	Reject, %	1.4	1.5	-	-	0.8
4.	Screened Pulp Yield, %	45.0	46.4	51.0	48.6	42.3
5.	Kappa No	17.5	16.6	18.4	18.5	17.8

Bleaching:

Bambusa tulda, Dendrocalamus hamiltonii and Bambusa balcooa were bleached using CEpHED sequence to get targeted brightness 80%, ISO. These species cooked with 15%, 15% and 16% as Na_2O respectively. The Kappa of the pulps 17.6, 16.6 and 17.8 were bleached by desired CEpHED sequence to obtain brightness above 80 % ISO.

No.	Parameters	*B.tulda*	*D. hamiltonii*	*M. baccifera*	*NC Hill*	*B. balcooa*
1.	Unbleached pulp Kappa No	17.6	16.6	18.0	18.5	17.8
2.	C - Stage Chlorine added, % Chlorine consumed, %	4.40 4. 25	4.75 4.50	4.5 4.32	4.62 4.37	4.45 4.30
3.	Ep - Stage Alkali applied, % as NaOH H_2O_2 applied %	2.0 0.5	2.0 0.5	2.0 0.5	2.0 0.5	2.0 0.5
4.	H - Stage Hypo applied, % Hypo consumed, % Alkali applied, %	2.0 1.72 0.3	2.0 1.75 0.3	2.0 1.90 0.3	2.0 1.75 0.3	2.0 1.71 0.3
5.	E - Stage Alkali applied, %	0.5	0.5	0.5	0.5	0.5
6.	D - Stage Dioxide applied, % as Cl_2	0.5	0.5	0.5	0.5	0.5
7.	Brightness, % ISO	81.8	82.1	78.5	81.7	82.8
8.	Intrinsic Viscosity cm^3/g	458	448	270	276	412

Bleaching Conditions:	**C**	**Ep**	**H**	**E**	**D**
Reaction Consistency, (%)	3.0	8.0	8.0	10.0	10.0
Reaction Temperature, (°C)	amb	60	40	60	70
Reaction Time, (Min)	30	60	120	60	180

Pulp properties:

The Zero Span Tensile Strength and Bauer Mc Nett fiber classification is carried out for unbleached Bamboo species like ***Bambusa tulda, Dendrocalamus hamiltonii** and* ***Bambusa*** pulps. These pulps contain more of long fiberd fraction (+30).

Sl. No.	Particulars	*B. tulda*	*D. hamiltonii*	*B. balcooa*
1.	Zero Span Tensile Strength	19.1	20.5	19.5
2.	Bauer McNett Classification			
	+12	6.0	6.5	15.0
	+30	72.4	76.7	59.3
	+50	7.2	4.1	3.2
	+100	8.4	9.9	11.5
	+200	0.13	0.2	1.1
	-200	5.7	2.6	9.9

Strength Properties of Bamboos:

Sl. No.	Properties	Unit	Melocanna baccifera						
			Unbleached				Bleached		
1.	PFI	Rev.	0	2000	4000	6000	0	2000	4000
2.	Freeness	CSF	700	550	400	240	680	390	150
3.	Apparent density	g/cm³	0.49	0.62	0.66	0.69	0.51	0.63	0.73
4.	Burst Index	kPa m²/g	1	3	4.2	5.2	0.90	3.1	3.6
5.	Tensile Index,	Nm/g	23	56	69	74	26	60.5	69
6.	Tear Index,	mNm²/g	6	16	14.3	14	6.6	7.4	5.8
7.	Fold KM	log	0.48	1.70	2.20	2.23	0.30	1.38	1.72
8.	Bendtsan porosity	ml/min	>3000	>3000	1040	400	>3000	1380	100

Sl. No.	Properties	Unit	NC Hill Bamboo						
			Unbleached				Bleached		
1.	PFI	Rev.	0	2000	4000	6000	0	2000	4000
2.	Freeness	ml CSF	685	535	385	210	685	380	210
3.	Apparent density	g/cm³	0.47	0.49	0.64	0.69	0.53	0.65	0.74
4.	Burst Index	kPa m²/g	1.0	3.0	4.4	5.2	1.2	3.7	4.1
5.	Tensile Index,	Nm/g	27	58	74	80	26	60.5	69
6.	Tear Index,	mNm²/g	6.4	11.4	9.5	9.0	7	8	7.6
7.	Fold Kohler	log	0.6	1.84	2.01	2.13	0.6	1.85	2.19
8.	Bendtsan porosity	ml/min	>3000	>3000	980	140	>3000	1730	100

OIL PALM

Elaeis guineensis Jacq.

The oil palm tree is a perennial tropical plantation tree, which commonly grows in warm climates at altitudes of less than 1,600 feet above sea level. *Elaeis oleifera* Cortes locally known Noli is native of America and *Elaeis guineensis Jacq.*, known as African oil palm originates from the Gulf of Guinea in West Africa.

Elaeis guineensis grows and produces better crops in permeable soils, which retain moisture, and in areas with a good distribution of rainfall throughout the year. Temperatures of around 79°F without major variations, and a high rate of sunlight are also vital factors. In addition to climate and soil conditions, maximum plantation output capacities depend on the quality of the seed, the rigorous selection of young plants in the nurseries, the preparation of the land for planting the establishment of a cover crop, and fertilization.

Oil Plam Tree

Plantation of Oil Plam Tree

This tree produces one of the most popular edible oils in the world – a versatile oil of superb nutritional value. It is the most prolific of all oil plants and in commercial terms the one which offers major prospects of development. The productive life of oil palm may last more than 50 years but after 20-25 years, the stem reaches a height that makes harvesting difficult. This is usually the time for commercial fields to be replanted.

Oil palm is normally monoic indicating that it has both male and female flowers on the same tree. It produces thousands of fruits, in compact bunches whose weight varies between 10 and 40 kilograms. Each fruit is almost spherical, ovoid or elongated in shape. Generally, the fruit is dark purple, almost black before it ripens and orange red when ripe.

Much care and substantial investment are necessary prior to exploitation. Successful development, therefore, requires an entrepreneurial vision and joint action from organized growers and the State. The design of the plantation with its fields, roads and irrigation channels, and the location of the palm oil mill are key in enhancing the cultivation, maintenance, harvest and transporting of the fruit to the processing site.

Some 40 leaves crown the stately column of the oil palm and as it reaches middle age its leaves spread out - between 10 and 25 feet in length – and almost parallel to the ground. Each leaf has short thorns at its base and about 250 leaflets in an irregular pattern on both sides of the petiole. Thus, these leaflets are not continuous like the tines of a feather. In fact, the irregular appearance of the frond is one of the characteristic features of this species.

Oil Palm	Highest vegetable oil yield per unit area (3-6 t/ha)
Family Species	*Elaeis guineensis* (African Oil Palm) *Elaeis olifera* (American Oil Palm)
Economic Cropping period for oil	25 to 30 years
Climatic requirements	Above 2000 mm distributed rainfed / irrigation Max. temperature : 29 to 36 °C Min. temperature : 24 to 30 °C Sunshine hours : 5 & above
No. of palms / ha	143 (9 x 9 x 9 m triangular)
Nursery period	12 to 18 months
Tree height	20 to 30 m
Leaf production / year	24 to 30
Leaf length	6 to 8 m

The fruit has a single seed – the palm kernel – protected by a wooden endocarp or shell, surrounded by a fleshy mesocarp or pulp. This fruit produces two types of oil: one extracted from the pulp (palm oil) and the other from the kernel (palm kernel oil).

Its stem stands straight in the form of an inverted cone. In the wild, it may grow to heights of one hundred feet and more. The stems of young and adult plants are wrapped in leaves that give them a rather rough appearance. The older trees have smooth stems apart from the scars left by the leaves, which have withered and fallen off.

Primary roots grow downwards from the base of the palm and radiate outwards in a more or less horizontal direction close to the surface of the ground. Their length and depth depend on the type of soil.

The major world producers are Malaysia, Indonesia, Nigeria, Colombia, Thailand, Papua New Guinea, Ivory Coast, Ecuador, Cameroon, D. R. Congo. Oil palm plantations are now taken up in a big way in India for edible oil purpose.

The extensive cultivation of oil palm generates significant quantities of leaf as a byproduct. The leafy material is a good source of fiber for papermaking and the sustained availability of this fiber make it an attractive proposition with economic viability.

Chemical Composition of raw material:

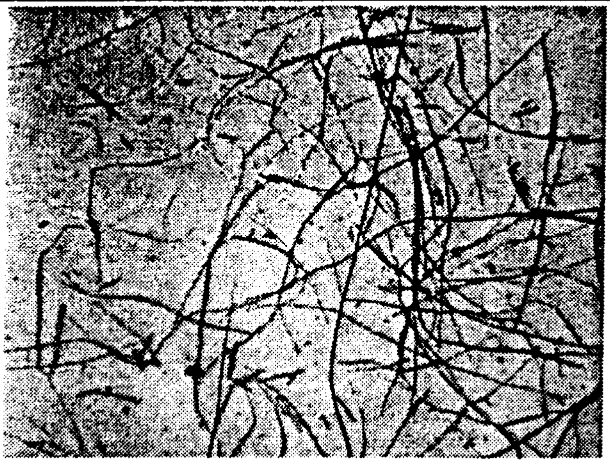
Se. No	Parameters	Unit	Oil Palm Fiber
1.	Ash Content	%	3.6
2.	Cold Water Solubility	%	7.6
3.	Hot Water Solubility	%	8.3
4.	1/10 N NaOH Solubility	%	24.2
5.	Alcohal Benzene Solubility	%	1.3
6.	Holocellulose	%	73.5
7.	α Cellulose	%	44.1
8.	β Cellulose	%	18.4
9.	χ Cellulose	%	11.0
10.	Acid Insoluble Lignin	%	19.0
11.	Acid Soluble Lignin	%	1.9
12.	Pentosans	%	13.7

Morphology Pulp Components:

The fibers are derived from the vascular bundles of leaves. The pulp is used for the manufacture of all types of cultural and industrial paper. The fiber varies from 0.3 to 2.2 in length with an average of 0.8mm and 7-38 μm in width (average 17.5 μm). The pulp consists of fibers, parenchyma, and vessel and epidermal cells. The fibers are narrow, long, straight and thick walls and pointed tapering ends and occasional transverse markings. . The parenchyma cells are small to medium sized narrow rectangular and numerous. The vessels are fairly long and narrow. The epidermal cells are numerous, rectangular and conspicuous with serrated margins.

No.	Dimensions	Unit	Oil Palm
A	*Properties of fiber:*		
1.	Fiber Length (Weight weighted) (L = 0.20 - 4.0mm)	mm	0.77
2.	Minimum Fiber Length,	mm	0.3
3.	Maximum Fiber Length,	mm	2.2
4.	Mean Fiber width (μ= 7 – 45)	µm	17.5
5.	Lumen Diameter	µm	4.8
6.	Cell wall thickness	µm	6.38
7.	Runkel Ratio		2.66
8.	Fiber curl index (length weighted) (L = 0.50 - 10.0mm)	-	0.072
9.	Fiber kink index (L = 0.50 – 5.0mm)	1/mm	1.43
10.	Total kink angle	Degree	20.0
11.	Kinks per mm	1/mm	0.75
B	*Properties of non-fibrous tissue:*		
12.	Length of vessel	µm	322
13.	Width of vessel	µm	88.8
14.	Length of Parenchyma	µm	145.3
15.	Width of Parenchyma	µm	21.0
16.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	45.46
17.	Length weighted Fines (L = 0.01 – 0.20 mm)	%	14.21

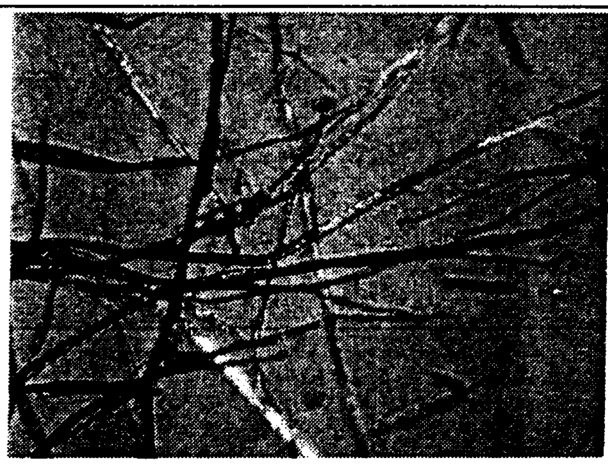
OIL PALM



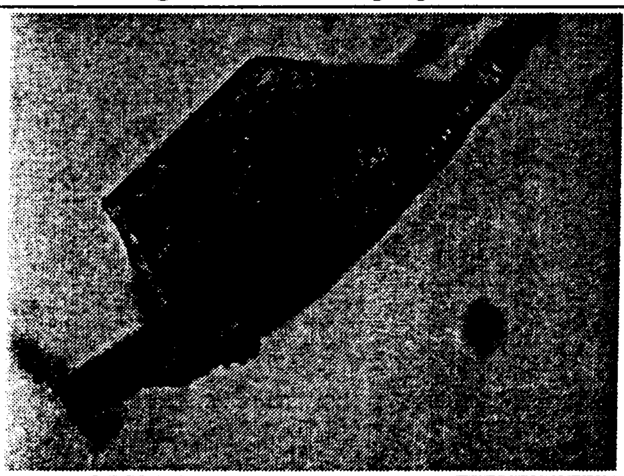
Oil palm Pulp Fibers

Magnified view of Pulp Fibers

Magnified view of pulp fibers



Magnified view of pulp fibers



Vessel of Oil palm Pulp

Fiber and parenchyma

Pulping:

Soda Pulping was carried out using 14% as NaOH, to obtain Kappa No 18.

Pulping conditions and quality of pulp:

S.No.	Particulars	Oil Palm Fiber
1.	Raw material (O.D.)	200 gm.
2.	Cooking chemicals, % as NaOH	18
3.	Bath ratio	1:4
4.	Ambient to 100 °C	30 min
5.	100 °C to 165 °C	90 min
6.	At 165 °C	120 min.
7.	Unscreened Pulp yield, %	50.7
8.	Reject, %	0.78
9.	Screened yield, %	49.9
10.	Kappa number	17.1
11.	Unbleached Pulp Viscosity, cm3/gm	583

Bleaching:

The soda pulp of oil palm fiber has good bleach ability. As conventional sequence CEpH applied to achieve a brightness of 82 ± 2 % ISO.

No.	Parameters	Oil Palm Fiber
1.	Unbleached pulp Kappa No.	 17.1
2.	**C – Stage** Chlorine added, % Chlorine consumed, %	 4.8 4.4
3.	**Ep – Stage** Alkali applied, % as NaOH H_2O_2 applied %	 2.0 0.5
4.	**H – Stage** Hypo applied, %	 1.0
5.	Bleached Yield, %	92.0
6.	Brightness, % ISO	84.0
7.	Intrinsic Viscosity cm^3/g	371

Pulp properties:

Sl. No.	Particulars	Bleached Pulp
1.	Bauer McNett Classification	
	+ 28	19.2
	+ 48	25.6
	+ 100	26.5
	+ 200	1.1
	- 200	27.6

Strength properties of unbleached and bleached pulps:

The unbleached pulp required 1000 PFI rev. to beat pulp to 330 ml CSF. The pulps show the best strength properties at this freeness. As the burst index 4.48, tensile index 61.3 and tear 7.62. Bleached pulp needed 500 rev to beat pulp to 350 ml CSF, Burst at this freeness is 4.24, tensile 5.28 and tear index 6.45.

Strength properties of oil palm pulps:

Sl.	Properties	Unit	Oil Palm Fiber				
			Unbleached			Bleached	
1.	PFI	Rev.	0	500	1000	0	500
2.	Freeness	CSF	560	400	330	520	350
3.	Apparent density	g/cm^3	0.76	0.87	0.88	0.77	0.86
4.	Burst Index	kPa m^2/g	3.16	4.03	4.48	4.02	4.24
5.	Tensile Index,	Nm/g	47.0	52.6	61.3	52.9	58.8
6.	Tear Index,	mNm^2/g	8.05	7.45	7.62	7.55	6.45
7.	Fold Kohler	log	1.77	2.38	2.39	2.0	2.34
8.	Bendtsan porosity	ml/min	1700	320	130	500	130

JUTE

Corchorus olitorius

India is the world's largest producer of jute and allied fibers (1.941 million Metric tons), which accounts for about two third of the world's production (3.092 million Metric tons). The area under jute cultivation is 0.817 million hectares and mesta cultivation is 0.184 million hectares in the year 2001-2002 in India (Source: Min.of Agriculture, Govt. of India).

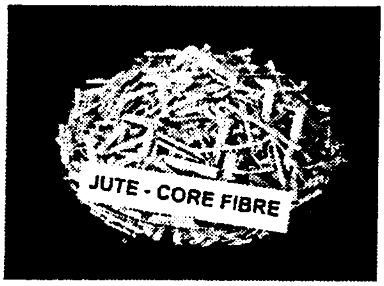
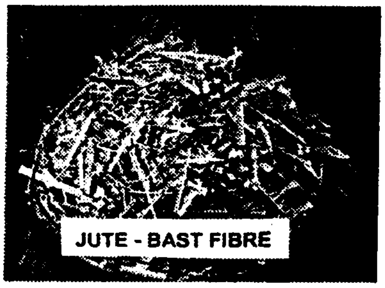
Jute plants are classified into two broad groups i.e. Corchorus capsularis (White jute) and Corchorus olitorius (Tossa jute). Mesta / Kenaf yielding fibers of commerce are similar to jute, constitute a third group. All these four varieties can be considered as one, although it is known that there are marginal variations in their pulping characteristics.

Green Jute in field	Transportation of Green Jute

The Jute advisory board of India's preliminary estimates indicates 8.7% increase in the raw jute crop in the year 2002-2003 and the board has resolved to apprise the Union Ministry of Textiles about the concerns of the jute industry regarding the apprehended decline in mill's consumption and purchase of raw jute in current season which could have far reaching consequences, particularly on jute growers in India. A consistent consumer of jute fibers on a sustained basis will give a boost for increased production by farmers. Jute and allied fibers are used after retting the bark for manufacture of sacks, carpet backing cloth, yarn and other handicraft items. The handicraft items include carpets, soft luggage, decorative fabrics, curtains, blankets, shopping bags and jute composites. The other potential sustained bulk consumer could be pulp and paper industry, provided the right kind of cleaner technology, which can produce specialty and eco grade pulp, is identified for the jute and allied fibers.

Raw material:

The jute plant is an annual plant and grows to a height of 5– 16 feet in height and normally do not have significant branches. Diameter of the stem may reach up to 10 to 20 mm on maturity. The stem portion has two distinct zones viz. bark and core. The bark portion becomes loosely attached to core when the plant is dry. The dry bark is dark brown in color and the core (wood) is pale yellow or cream colored.

		
Chips of Whole Jute	Chips of Jute core wood	Chips of Jute bast

Bast fiber constitutes 36% of the weight in the whole jute, and the balance 64 % is core wood. Bulk density of the whole jute is very low compared to the hardwood and softwood. Bulk density of jute bast fiber is very low compared to core wood. Bulkiness of the raw jute fiber has disadvantages in terms of volumetric loading, throughput etc. Impregnation of chips with liquor also is affected due to high bulkiness, as the chips tend to float.

Sl. No.	Particulars	Whole Jute	Bast	Core
1.	Ratio of Bast and Core, %	-	36	64
2.	Bulk Density, kg/m³	93.4	69.2	110.5

Jute sample in the form of stalks was collected from Barrackpore, Kolkata.

Chemical composition of raw material

The ash content of the bast is higher since the bast portion carries extraneous silica. The holo-cellulose component in the bark is comparatively higher. Higher α - Cellulose content in the bark indicates that the pulp yield levels will be significantly higher and the pulp strength will be superior.

Sl. No.	Particulars	Whole Jute	Bast	Core
1	Ash content, %	3.6	4.4	1.9
2.	Cold Water Solubility, %	4.1	4.5	2.4
3.	Hot Water Solubility, %	4.9	8.6	3.0
4.	1/10 N NaOH Solubility, %	26.2	30.1	23.3
5.	Alcohal Benzene, %	2.7	3.7	2.8
6.	Pentosan, %	15.3	14.6	16.0
7.	Hollocellulose, %	79.5	81.4	75.5
8.	α Cellulose, %	43.5	54.7	36.5
9.	β Cellulose, %	19.9	14.6	25.9
10.	χ Cellulose, %	16.2	12.1	13.1
11.	Klasson Lignin, %	21.1	15.3	24.2
12.	Acid soluble Lignin, %	1.04	1.10	1.20

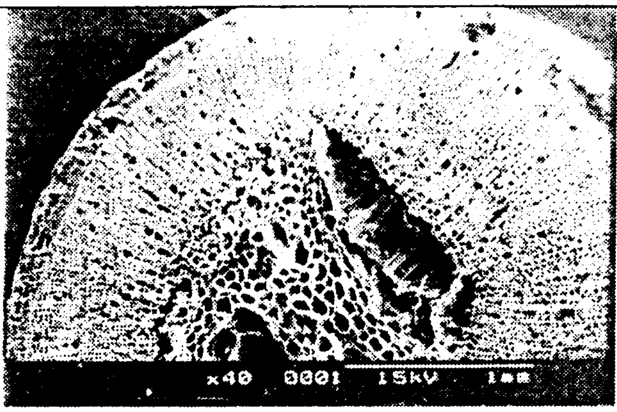
Morphology:

The outer layers (sheath) of stalk are of bast and the fiber from which is used as cordage etc. after retting. The central most core portion is filled with parenchyma tissue, which is termed as pith. The woody tissue located between pith and bast. The fibers from this woody tissue are short and are normally discarded as waste or used as domestic fuel.

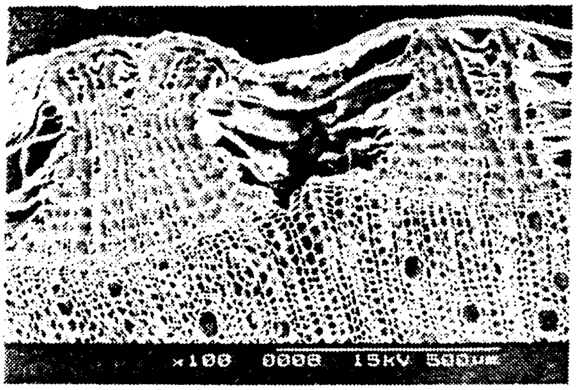
The jute fibers have different dimensions based on the tissue source. The fibers from the bast are long with thick fiber walls. Whereas the fibers from core (wood) are short and relatively thin walled. The average length of the whole jute fiber is 1.01 mm and average width is 18.4 μm.

The diagnostic feature of the jute bast fiber is the irregular width of the broad and well-defined lumen. Sometimes the lumen closes up and is entirely missing for a short distance. The individual fiber is cylindrical with little variation in diameter. The fiber walls are thick and generally smooth, having more or less numerous nodes and cross markings depending upon the mechanical they have received. The fiber ends are slender and pointed. The cross section of the fiber is of polygonal shape with sharply defined angles and a round or oval lumen. The comparative fiber dimensions and properties are recorded in table and Photomicrograph of different fiber of Whole jute; Central core wood (stick) and bast fibers (skin) are given below.

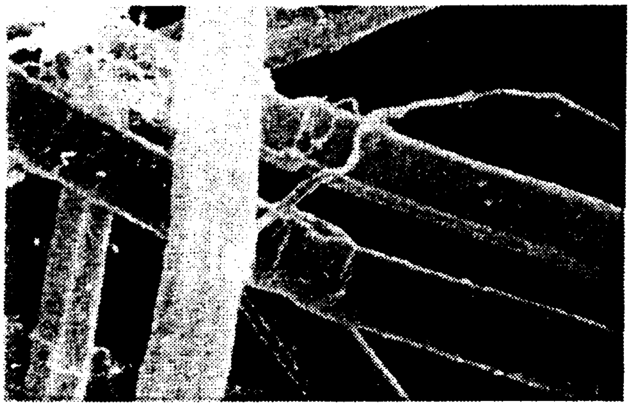
JUTE



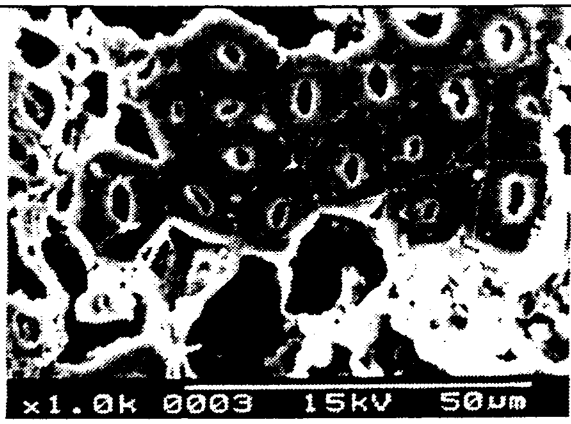
Cross section of Jute stem



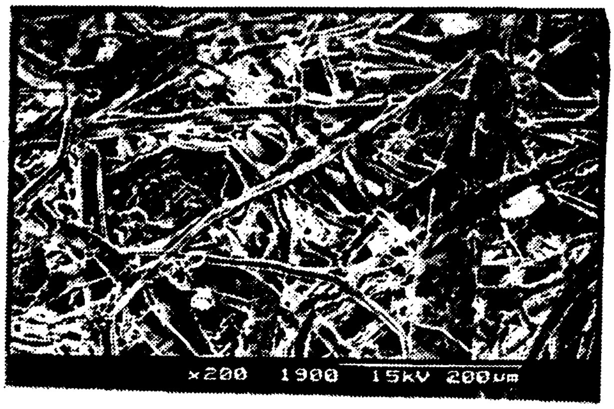
Magnified view of cross section



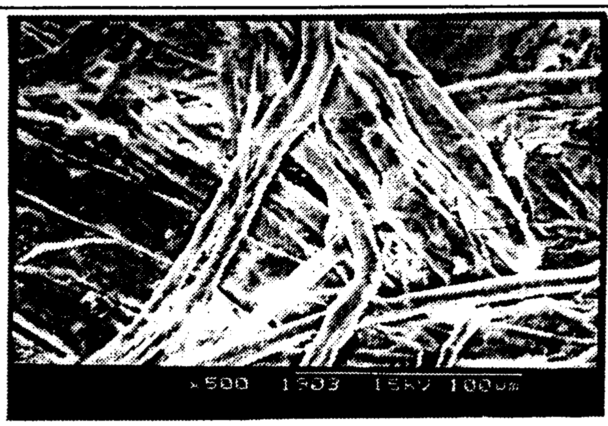
Magnified view of bast fibers



Bast fibers in sectional view



SEM photograph of Fiber Crossing



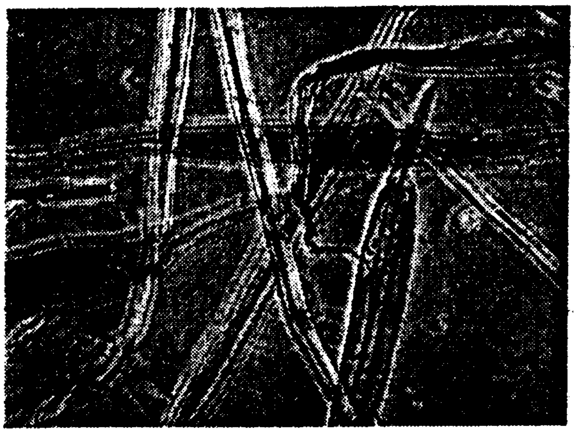
Magnified view of Fiber Crossing

Dimensions and properties of Jute pulp components:

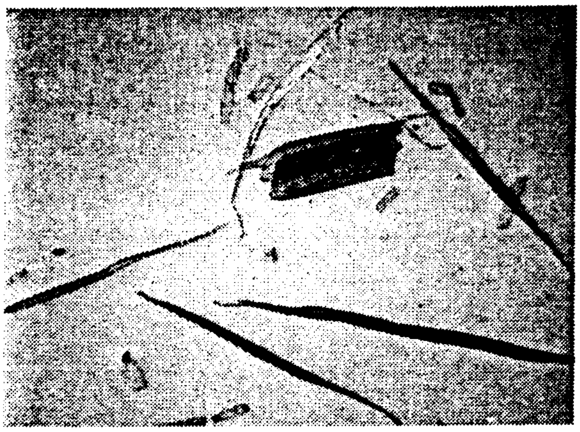
No.	Dimensions	Unit	Whole Jute	Core Fiber	Bast Fiber
A	*Properties of fiber:*				
1.	Fiber Length (Weight weighted) (L = 0.20 – 4.0mm)	mm	1.39	0.69	1.95
2.	Minimum Fiber Length,	mm	0.2	0.2	1.0
3.	Maximum Fiber Length,	mm	4.20	1.0	4.60
4.	Mean Fiber width (μ= 7 – 45)	μm	20.1	21.9	16.4
5.	Lumen Diameter	μm	9.00	-	-
6.	Cell wall thickness	μm	5.35	-	-
7.	Runkel Ratio		1.19	-	-
8.	Fiber curl index (length weighted) (L = 0.50 – 10.0mm)	-	0.077	0.033	0.114
9.	Fiber kink index (L = 0.50 – 5.0mm)	1/mm	0.70	0.44	1.05
10.	Total kink angle	degree	14.23	5.35	30.90
11.	Kinks per mm	1/mm	0.44	0.25	0.54
B	*Properties of non-fibrous tissue*				
12.	Length of vessel	μm	387	-	-
13.	Width of vessel	μm	43.1	-	-
14.	Length of Parenchyma	μm	348.8	-	-
15.	Width of Parenchyma	μm	74.8	-	-
16.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	32.07	33.58	20.87
17.	Length weighted Fines (L = 0.01 – 0.20 mm)	%	5.10	6.86	1.56

JUTE

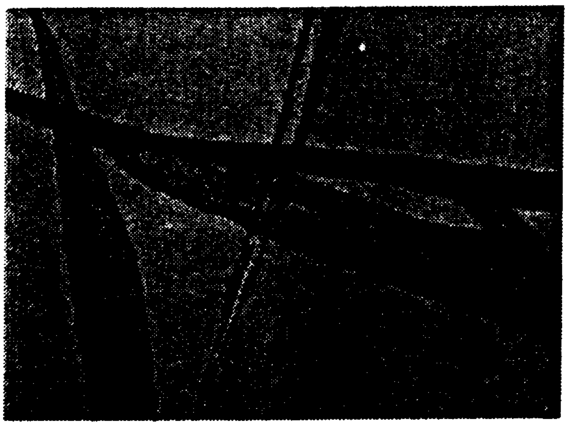
Whole Jute Pulp Fibers



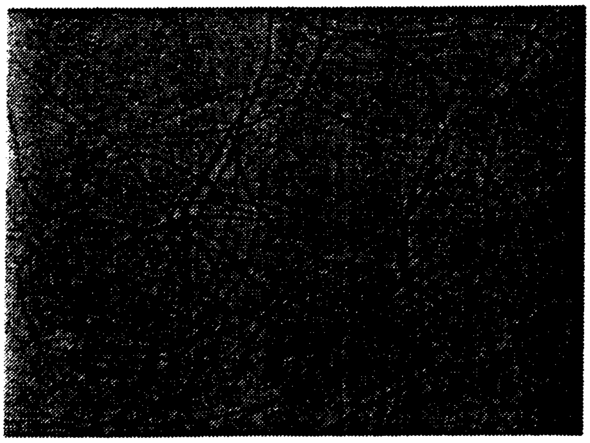
Magnified view of Whole Jute Pulp



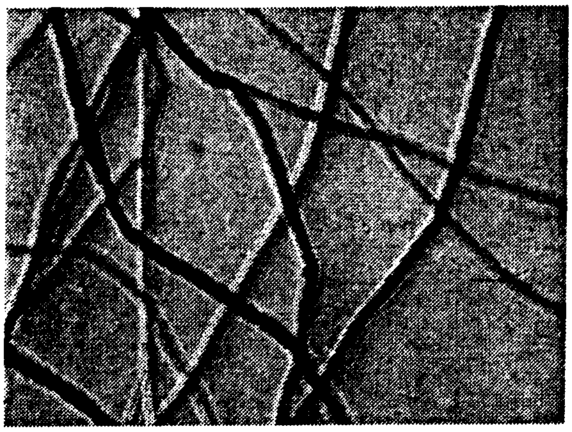
Jute Core wood Pulp Fibers



Magnified view of Jute wood Pulp



Jute Bast Pulp Fibers



Magnified view of Bast Pulp Fibers

Pulping:

The whole jute was pulped using kraft and soda Aq process.

Pulping conditions and quality of pulp:

S.No.	Particulars	Kraft	Soda AQ
1.	Raw material, O.D.	200 gm.	200 gm.
2.	Cooking chemicals, % as Na_2O	16.0	24.0
3.	Anthraquinone, %	-	0.05
3.	Bath ratio	1:4	1:4
4.	Ambient to 100 °C	30 min	30 min
5.	100 °C to 165 °C	90 min	90 min
6.	At 165 °C	90 min.	90 min.
7.	Unscreened Pulp yield, %	49.3	50.7
8.	Reject, %	1.8	0.2
9.	Screened yield, %	47.5	50.5
10.	Kappa number	20.5	18.4

Bleaching:

S.No	Parameters	Unit	Kraft	Soda AQ
1.	Kappa No.		20.5	18.4
	Chlorination Stage			
2.	Chlorine added	%	4.0	3.9
3.	Chlorine Consumed	%	3.5	3.4
4.	Consistency	%	3	3
5.	pH		<2	<2
6.	Time	min	30	30
7.	Temperature	°C	Ambient	Ambient
	Alkali Extraction stage			
8.	NaOH	%	2.0	2.0
9.	Consistency	%	8	8
10.	Time	min	60	60
11.	Temperature	°C	60	60
12.	End pH		12.8	12.8
	Hypo stage			
13.	Calcium hypochorite	%	1.5	1.5
14.	Hypo Consumed	%	1.25	1.25
15.	Consistency	%	8	8
16.	Time	min	120	120
17.	Temperature	°C	40	40
18.	pH		9-10	9-10
19.	Final pulp brightness	%	79.5	78.2
20.	Bleached Yield	%	95.3	96.0
21.	Intrinsic Viscosity	cm^3/gm	410	400

Strength Properties of whole Jute Unbleached Kraft Pulp:

Sl. No.	Properties	Unit	Unbleached kraft Pulp			
1.	PFI	Rev.	0	500	1000	2000
2.	Freeness	ml, CSF	480	335	290	215
3.	Apparent density	g/cm^3	0.66	0.72	0.75	0.80
4.	Burst Index	kPa m^2/g	3.0	5.25	5.70	6.50
5.	Tensile Index	Nm/g	53.5	83.0	105	115
6.	Tear Index	mNm^2/g	11.0	10.1	9.0	8.5
7.	Fold Kohler Molin	log	1.54	2.5	2.66	2.68
8.	Porosity Bendtsen	ml/min.	640	160	90	40

Strength properties of Green Jute bleached Kraft Pulp:

Sl. No.	Properties	Unit	Bleached Kraft Pulp			
1.	PFI	Rev.	0	500	1000	2000
2.	Freeness	ml, CSF	500	370	330	245
3.	Apparent density	g/cm^3	0.69	0.76	0.78	0.80
4.	Burst Index	kPa m^2/g	2.6	5.1	5.3	6.0
5.	Tensile Index	Nm/g	48.5	76	80	81
6.	Tear Index	mNm^2/g	9.7	9.1	8.7	8.4
7.	Fold Kohler Molin	log	1.72	2.72	2.74	2.90
8.	Bendtsen Porosity	ml/min.	400	100	60	30

Strength properties of Jute unbleached Soda Aq Pulp:

Sl. No.	Properties	Unit	Unbleached Soda AQ pulp			
1.	PFI	Rev.	0	1000	2000	3000
2.	Freeness	ml, CSF	610	400	300	250
3.	Apparent density	g/cm^3	0.51	0.64	0.66	0.71
4.	Burst Index	kPa m^2/g	1.1	4.0	4.1	4.8
5.	Tensile Index	Nm/g	21	54.5	57.5	69.5
6.	Tear Index	mNm^2/g	8.1	12.5	16.0	14.1
7.	Fold Kohler Molin	log	0.85	2.55	2.66	3.38
8.	Bendtsen Porosity	ml/min.	2850	440	270	120

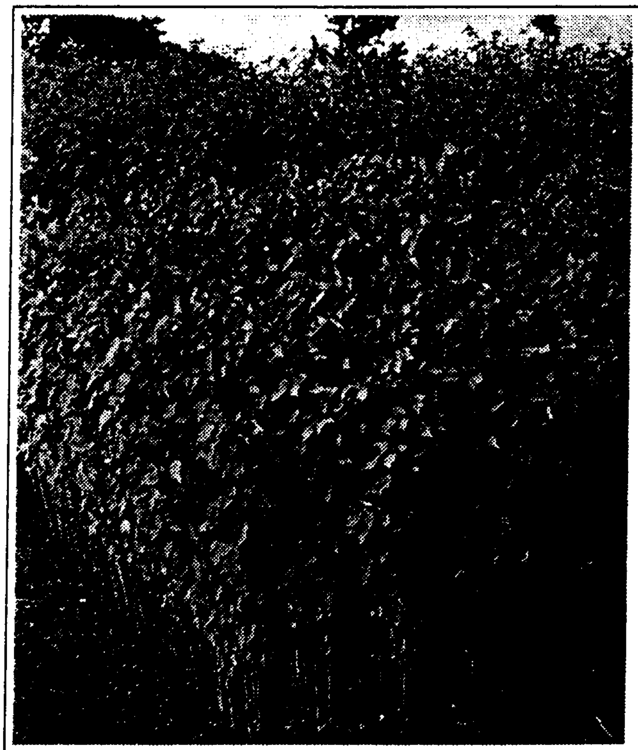
Strength properties green Jute bleached Soda Aq Pulp:

Sl. No.	Properties	Unit	Bleached Soda Aq Pulp		
1.	PFI	Rev.	0	500	1000
2.	Freeness	ml, CSF	440	330	260
3.	Apparent density	g/cm^3	0.69	0.76	0.80
4.	Burst Index	kPa m^2/g	3.8	5.1	4.0
5.	Tensile Index	Nm/g	54	80	77.5
6.	Tear Index	mNm^2/g	9.7	8.7	8.3
7.	Fold Kohler Molin	log	1.79	2.48	2.42
8.	Bendtsen Porosity	ml/min.	300	70	50

KENAF

Hibiscus cannabinus

Worldwide research on alternative raw materials focused attention on agricultural residues and annual plants. Kenaf also called mesta, has been studied as a fiber source in many countries including USA, Philippines and India. In India, Mesta is primarily cultivated as a source of bast fiber and area of cultivation under this crop is around 382.8 thousand hectare as 1000 hectare covered by jute. The gross fiber yield from mesta including 5 thousand bales in the country. It shares 23.7% of the total fiber produced in this country. The present national average of the fiber yield of mesta is 829 kg/hectare while the total green weight of the biomass is around 60 tons/hectare of which 50 tons is moisture. Approximately 4.5 tons of Kenaf bleached chemical paper pulp could be produced from one hectare of mesta cultivation.



Kenaf Plantation

Kenaf (*Hibiscus cannabinus*) has been traditionally grown as a fiber crop for the manufacture of twine and rope. Northern Regional Research Programme, after evaluating over 650 samples of potential fiber crops, found Kenaf as the most promising raw material. Regional Research Laboratory, Jammu conducted trials on some exotic indigenous varieties of Kenaf and found HC-583 variety as most promising under the agro-climatic conditions prevailing in Jammu. Kenaf is an annual crop, which takes about 6 to 8 months for growth. About 13-22 tons of Kenaf can be produced hectare of land. The bast fiber content of Kenaf can range from 18-29%. Since the bast fraction gives a higher pulp yield than the woody component of the stalk, the final pulp should contain 30 to 40% bast pulp. Kenaf may produce pulps with some properties and performance equal to softwood and superior to most hard woods. Kenaf may be used as a blending agent to improve lower quality pulps. Bond paper can be made from Kenaf sulfate pulps blending with wood pulp. Kenaf pulp in the furnish improves strength of the resulting paper and also smoothness, elongation and tensile energy absorption of the bond paper. News print grade paper can be prepared from blends of the bleached Kenaf thermo mechanical pulp containing 15 % Kenaf soda pulp.

Chemical composition of raw materials:

Kenaf bast has high ash content and extractives, which have negative impact on processing the raw material to pulp. The positive aspects of the raw material are the higher Holocellulose and lower lignin content. Lower lignin content normally indicate lower alkali requirement, however the extractives consume significant quantities of alkali due to the acidic nature.

Se. No	Parameters	Unit	Decorticated Kenaf	Kenaf * (Whole Plant)
1.	Ash Content	%	5.07	1.4
2.	Cold Water Solubility	%	9.2	-
3.	Hot Water Solubility	%	12.1	-
4.	N / 10 NaOH Solubility	%	23.8	38.5
5.	Alcohol Benzene Solubility	%	4.12	8.2
6.	Pentosans	%	17.1	17.4
7.	Holocellulose	%	76.4	70.7
8.	α Cellulose	%	41.7	-
9.	β-Cellulose	%	17.9	-
10.	γ-Gamma Cellulose	%	15.8	-
11.	Acid Insoluble Lignin	%	11.7	15.0
12.	Acid Soluble Lignin	%	1.4	1.8

* IPPTA, Apirl-June, Vol, 20, No.2, Page 17-26,1983

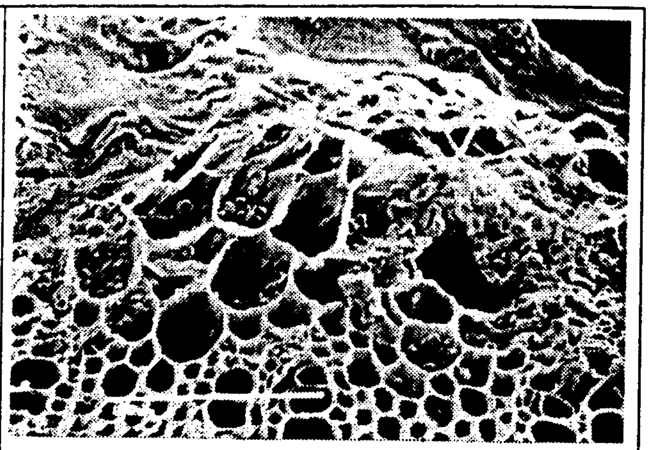
Morphology:

Kenaf grows to height of 2.5 to 4.0 meters in height. The bundles of fibers are obtained from bast/bark of the stalk by retting process. This retted fiber is inferior in quality to that of the jute fiber in terms of surface properties like luster and smoothness, hence normally used for cordage and bagging. The bast is also converted to paper pulp, which contains different tissues like fiber, parenchyma and some vessels. The vessel elements absent in bast, is a contamination due to improper separation of bast from wood. The individual bast fibers are cylindrical with cross markings. Fibers are long with very high length to width ratio. The fiber lumen is narrow and irregular in diameter with some visible constrictions, which may even be discontinuous. Fibers are very thick walled with very high Runkel ratio. Fibers have rounded ends and irregularly thickened.

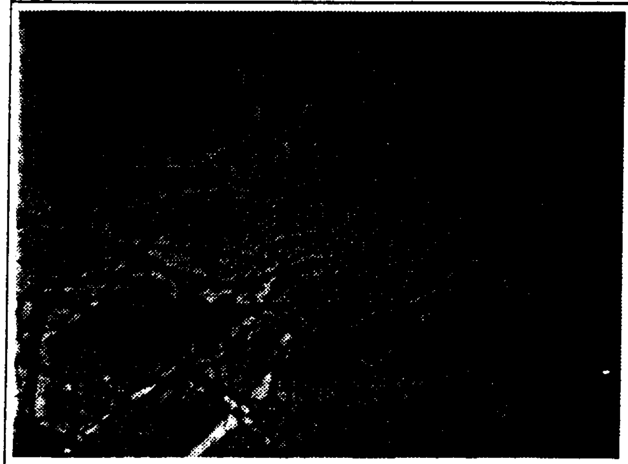
No.	**Dimensions**	**Unit**	**Decorticated Kenaf**
A	*Properties of fiber:*		
1.	Fiber Length (Weight weighted) (L = 0.20 - 4.0mm)	mm	2.48
2.	Minimum Fiber Length,	mm	0.25
3.	Maximum Fiber Length,	mm	5.2
4.	Mean Fiber width (μ= 7 - 45)	μm	19.0
5.	Lumen Diameter	μm	4.95
6.	Cell wall thickness	μm	9.11
7.	Runkel Ratio		3.68
8.	Length to width ratio	-	131
9.	Fiber curl index (length weighted) (L = 0.50 - 10.0mm)	-	0.150
10.	Fiber kink index (L = 0.50 - 5.0mm)	1/mm	1.31
11.	Total kink angle	Degree	44.15
12.	Kinks per mm	1/mm	0.67
B	*Properties of non-fibrous tissue*		
13.	Length of vessel	μm	322
14.	Width of vessel	μm	50
15.	Length of Parenchyma	μm	9.56
16.	Width of Parenchyma	μm	2.23
17.	Arithmetic Fines (L = 0.01 - 0.20 mm)	%	29.8
18.	Length weighted Fines (L = 0.01 - 0.20 mm)	%	1.89

KENAF

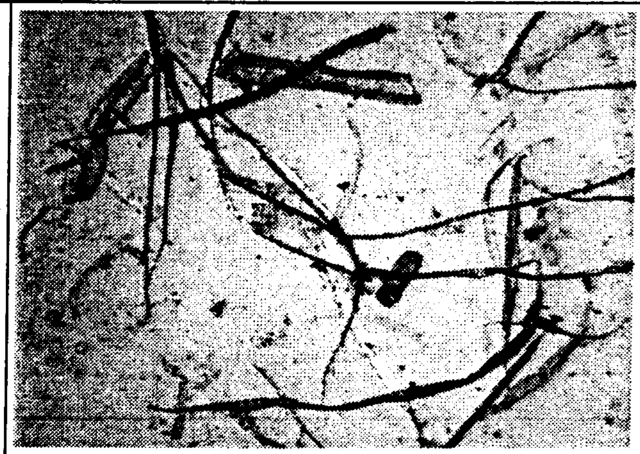
Cross section of Kenaf



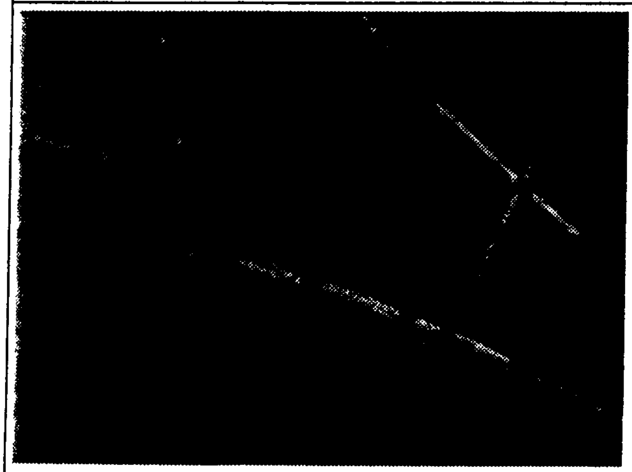
Magnified view of XS of Kenaf



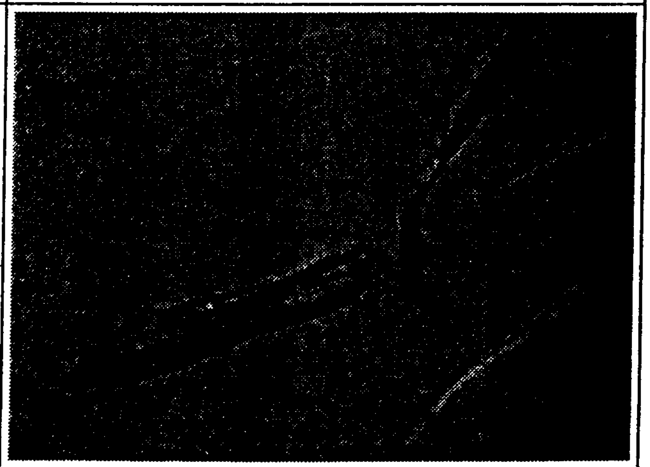
Kenaf Pulp Fibers



Kenaf Fibers and vessel elements



Magnified view of Kenaf fibers



Magnified view of vessel elements

Pulping:

Pulping experiments were carried out using different chemical charges 18% for Decorticated Kenaf and 16 % for Kenaf whole plant as Na_2O.

Pulping condition and properties:

S.No.	Particulars	Unit	Decorticated Kenaf	Kenaf * (Whole Plant)
1.	Raw material taken	gm	200	200
2.	Cooking chemicals	%	18	16.0
3.	Sulfidity of cooking liquor	%	19.5	20
4.	Bath ratio		1:3	1:3
5.	Ambient to 100	°C	30 min	30
6.	100 °C to 165 °C	°C	90 min	100
7.	At 165 °C	°C	120 min	75
8.	Unscreened Pulp yield	%	52.01	45.5
9.	Reject	%	Nil	0.4
10.	Screened yield	%	52.01	45.1
9.	Kappa number		17.0	27.0

Bleaching:

The unbleached Kenaf whole plant and Decorticated Kenaf were bleached using CEH and CEpHH bleaching sequence to get brightness about 80 % ISO.

No.	Parameters	Kenaf (Decorticated)	Kenaf * (Whole Plant)
1.	Unbleached pulp **Kappa No.**	17.0	27.1
2.	**C - Stage** Chlorine added, % Chlorine consumed, %	 3.74 3.60	 5.4 5.3
3.	**Ep - Stage** Alkali applied, % as NaOH H_2O_2 applied %	 2.5 1.0	 2.0 -
4.	**H - Stage** Hypo applied, % Hypo consumed, % Alkali applied, % as buffer	 2.5 2.40 0.3	 1.2 0.91 0.32
5.	**H - Stage** Hypo applied, % Hypo consumed, %	 0.5 0.45	 - -
6.	Brightness, % ISO	82.0	80.3
7.	Intrinsic Viscosity cm^3/g	220	-

Bleaching conditions:	**C**	**Ep**	**H**	**H**
Reaction Consistency, (%)	3.0	8.0	8.0	8.0
Reaction Temperature, (°C)	Ambient	60	40	40
Reaction Time, (Min)	30	60	120	120

Pulp properties:

Sl. No.	**Particulars**	**Unit**	**Kenaf (Decorticated)**	**Kenaf * (Whole Plant)**
1.	Bauer & McNett Classification			
	+ 30	%	80.2	45
	+ 50	%	8.5	14.7
	+ 100	%	3.6	8.8
	+ 200	%	2.6	1.08
	- 200	%	5.1	30.5

Strength properties of unbleached Kenaf Pulp:

Sl. No.	**Properties**	**Unit**	**Kenaf ***				
1.	PFI	Rev.	0	500	1000	2000	4000
2.	Freeness	CSF	525	415	360	275	145
3.	Apparent density	g/cm³	0.70	0.75	0.76	0.79	0.83
4.	Burst Index	kPa m²/g	3.25	5.00	5.20	6.30	6.75
5.	Tensile Index	Nm/g	58.00	81.50	90.50	97.50	98.00
6.	Tear Index	mNm²/g	13.54	11.33	11.13	10.10	9.20
7.	Fold Kohler	log	2.51	2.77	3.28	3.29	3.31
8.	Air res. Gurley	s/100ml	38.5	118	248	611	>1800

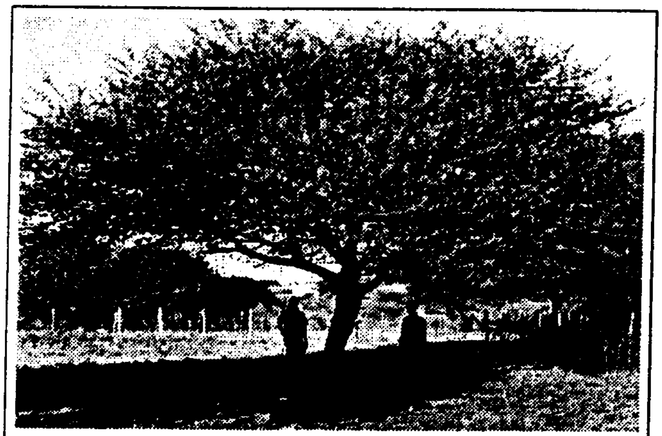
Strength properties of bleached Decorticated Kenaf Pulp:

Sl. No.	**Properties**	**Unit**	**Decorticated Kenaf Pulp**		
1.	PFI	rev.	0	1000	1500
2.	Freeness	CSF	520	430	295
3.	Apparent density	g/cm³	0.52	0.62	0.65
4.	Burst Index	kPa m²/g	3.2	2.9	4.2
5.	Tensile Index	Nm/g	60.0	48.0	72.5
6.	Tear Index	mNm²/g	11.4	10.10	7.80
7.	Fold Kohler	log	1.63	1.53	1.74
8.	Bendtsan porosity	ml/min.	>3000	2580	240

ACACIA

Acacia nilotica (L.) Willd. ex Del. Commonly known as Desi Babul and *Acacia seyal* belong to the family Leguminosae, subfamily Mimosoideae is one of about 135 thorny African Acacia species. Variation is considerable with nine recognized subspecies, three present in the Indian subcontinent and six throughout Africa. They are distinguished by the shape and pubescense of pods and the habit of the tree. Desi babul is drought resistant and prominently grown in dry-lands.

Acacia nilotica is a small tree, 2.5–14 meter tall, significantly variable in many aspects, with branches spreading, bark thin, rough, fissured, deep red-brown. Spines are gray-pubescent, slightly recurved, up to 3 cm long. Leaves are often with 1–2 petiolar glands; pinnae 2–11 (-17) pairs; leaflets 7–25 (-30) pairs, 1.5–7 mm long, 0.5–1.5 mm wide, glabrous or pubescent, apex obtuse; peduncles clustered at nodes of leafy and leafless branchlets; flowers bright yellow, in axillary heads 6–15 mm in diam.; Calyx 1–2 mm long; Corolla 2.5–3.5 mm long. Pods especially variable, linear, indehiscent, 8–17 (-24) cm long, 1.3–2.2 cm broad, straight or curved, glabrous or gray-velvety, turgid, blackish, about 12-seeded; seeds deep blackish-brown, smooth, subcircular, compressed, areole 6–7 mm long, 4.5–5 mm wide. In habit, *A. nilotica* varies from a shrubby tree with wide spreading crowns in savanna habitats (ssp. *subalata, leiocarpa, adstringens, hemispherica* and *kraussiana*), to a 20 meter tree (ssp. *nilotica, tomentosa*, and *indica*) in riverine situations. Ssp. *cupressiformis* has ascending branches like a poplar.



Acacia nilotica Tree

Trees flower in October to December, followed by fruiting in March to June. *Acacia nilotica* is easy to recognize by its bright yellow flowers in round heads, straight stipular spines often slightly deflexed, and dark indehiscent pods compressed over the seeds. Flowering is prolific, and can occur a number of times in a season.

Propagation is by scarified seed. Cover the seeds with very hot water and let soak overnight or until they swell. Pick out those that didn't swell and repeat process with them. Sow swollen seeds immediately in seeding mix, covering with two to three times their thickness. Do not over-water or allow drying out and providing good drainage and bright light. The seeds should germinate within a few weeks with pretreatment or many months without. On the Indian subcontinent, *ssp. indica* forms low altitude dry forests usually on alluvium and black cotton soils. It has been widely planted on farms throughout the plains of the subcontinent. The species grows on saline, alkaline soils, and on those with calcareous pans. Subspecies *hemispherica* is restricted to dry sandy streams beds near Karchi, *ssp. cupressiformis* has similar preferences to *ssp. indica* though is less resilient to weed competition.

It is a pioneer species, easily regenerated from seed. The species can be direct seeded or established by seedlings. in the nursery long poly tubes (20 x 7 cm) should be used so as not to restrict rapid tap root growth. Frequent root pruning is advised. Nursery grown seedlings are usually outplanted after 6 months, but in some cases stay in the nursery up to a year. Establishment varies depending on the site. Seedlings are shade intolerant. In irrigated plantations in the Sind and Punjab, 10-15 seeds are spot sown at 2x3 m spacing on the tops of trenches. They are thinned to 3-4 seedlings after 3-4 months. Further thinning occurs at 5 year intervals. Rotations are 20-25 years. In the Thal desert, Pakistan (250 mm of rain), promising growth resulted from irrigation on a 10 day interval. Growth rates varied considerably depending on the sites, with maximum mean annual increment of 13 m3 /ha at 20 yrs old and 10.5 m3 /ha at 30 years recorded.

Babul (ssp. *indica*) is a popular farm tree of the central plains of India. More recently interest has centered on the fastigiate form (ssp. *cupressiformis*). This subspecies makes an ideal windbreak surrounding fields; its narrow crown shades less than other windbreak species. In India this species is used extensively on degraded saline/alkaline soils, growing on soils up to pH 9, with a soluble salt content below 3%. It also grows well when irrigated with tannery effluent, and colonises waste heaps from coalmines. Over 50,000 hectares of the Indian Chambal ravines have been rehabilitated with *A. nilotica* by aerial seeding and it is one of the 3 most frequently used trees for this purpose.

A. nilotica occurs from sea level to over 2000 m. It withstands extremes of, but is frost tender when young. Annual rainfall varies from 250 - 1500 mm. Trees are generally deciduous during the dry season, though riverine ssp. can be almost evergreen. The species is naturally widespread in the drier areas of Africa, from Senegal to Egypt and down to South Africa, and in Asia from Arabia eastwards to India, Burma and Sri Lanka. Sudan forests are managed on a 20-30 year rotation producing termite resistant timber especially suitable for railway sleepers. In India and Pakistan riverine plantations are managed on a 15-20 year rotation for fuel wood and timber. The dark brown wood is strong, durable, nearly twice as hard as teak, very shock resistant, and is used for construction, tool handles and carts. It is best carved in a green state. It has a high calorific value of 4950 kcal/kg, making excellent fuel wood and quality charcoal. It burns slow with little smoke when dry.

A wide range of pests and diseases affect this species. Of economic importance is the stem borer *Cerostema scabrator* on young plantations in India. *Euproctis lunata* & *E. subnotata* occasionally defoliate patches of forest in Sukkur and Hyderabad. Bruchid beetles attack the seeds, destroying up to 70 %. Fungal rots (Fomes papianus & F. badius) attack unhealthy trees, and powder post beetles (*Sibixylon anale* & *Lyctus africanus*) attack the sapwood of felled timber.

The pods and leaves contain 8% digestible protein [12.4% crude protein], 7.2 MJ/kg energy, and are rich in minerals. In part of its range small stock mainly consume it, but elsewhere it is also very popular with cattle. Pods are used as a supplement to poultry rations in India. Dried pods are particularly sought out by animals on rangelands. In India branches are commonly lopped for fodder. Pods are best fed dry as a supplement, not as a green fodder.

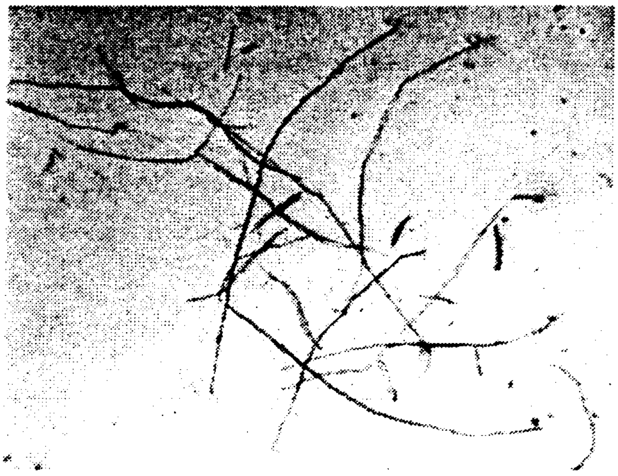
The bark of ssp. *indica* has high levels of tannin (12-20%), which are used for tanning leathers. Ten year old trees yield 35-40 kg of bark. The pods of ssp. *nilotica* have been used for tanning in Egypt for 6,000 years. Subspecies *adstringens* is used for both tanning and dye making. Deseeded pods from ssp. *indica* have 18-27% tannin levels, whereas ssp. *tomentosa* and *nilotica* reach up to 50%. The gum is used in paints and medicines and has been collected for a millennia. It has similar properties to gum arabic (from *A. senegal*) and is frequently used in calico printing in India.

Chemical composition of raw material:

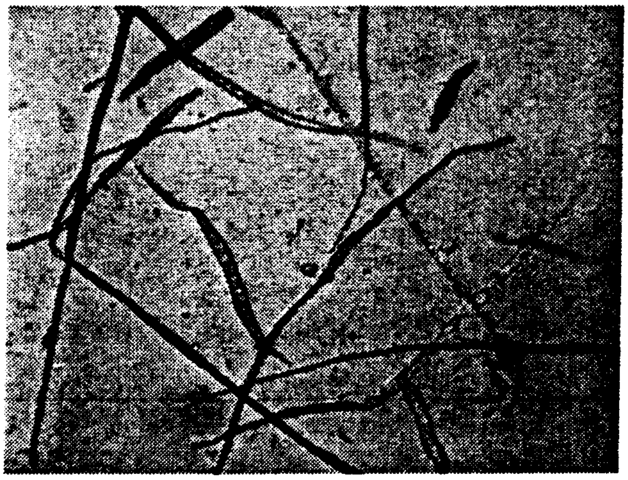
The results of the proximate chemical analysis of the wood chips indicate that it has low ash content, which is a favourable property for its end use as pulpwood. Lower values of solubility in water indicates that the raw material has lower soluble carbohydrate content in chips which has advantages in terms of resistance to degradation and optimal chemical use in pulping process. The extractive content is moderately high, which has its negative share in terms of alkali nutralisation in the pulping process as well as pitch generation. The holocellulose content is significantly higher and with milder pulping conditions the pulp yield levels could be significantly improved. The lignin content in the raw material is reasonable range. The overall analysis indicates that *Acacia nilotica* can be used successfully as a pulpwood raw material.

Se. No	Parameters	Unit	*Acacia nilotica*	*Acacia seyal*
1.	Ash Content	%	0.6	3.92
2.	Cold Water Solubility	%	2.4	8.37
3.	Hot Water Solubility	%	3.8	13.22
4.	1/10 N NaOH Solubility	%	18.0	26.82
5.	Alcohal Benzene Solubility	%	2.68	-
6.	Holocellulose	%	75.9	68.12
7.	α Cellulose	%	44.1	-
8.	β Cellulose	%	18.9	-
9.	χ Cellulose	%	12.8	-
10.	Acid Insoluble Lignin	%	22.8	21.05
11.	Acid Soluble Lignin	%	1.10	-

Morphology of pulp components:



***Acacia nilotica* pulp**



Magnified view of *Acacia nilotica*

No.	Dimensions	Unit	*A.nilotica*
A	*Properties of fiber:*		
1.	Fiber Length (Weight weighted)(L = 0.20 – 4 mm)	mm	1.25
2.	Minimum Fiber Length,	mm	0.2
3.	Maximum Fiber Length,	mm	2.88
4.	Mean Fiber width (μ= 7 – 45)	μm	18.5
5.	Lumen Diameter	μm	6.12
6.	Cell wall thickness	μm	6.2
7.	Runkel Ratio		2.03
8.	Fiber curl index (length weighted) (L = 0.50–10mm)	-	0.087
9.	Fiber kink index (L = 0.50 – 5.0mm)	1/mm	1.46
10.	Total kink angle	Degree	28.71
11.	Kinks per mm	1/mm	0.74

B	*Properties of non-fibrous tissue*		
12.	Length of vessel	μm	220
13.	Width of vessel	μm	24.1
14.	Length of Parenchyma	μm	130
15.	Width of Parenchyma	μm	25.5
16.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	51.02
17.	Length weighted Fines (L = 0.01 – 0.20 mm)	%	7.81

Pulping:

Kraft pulping of Acacia nilotica and Acacia seyal are cooked using 14% & 23 alkali as Na_2O to produce bleachable grade pulp of Kappa No. 22. and 24.8

Pulping Condition and Pulp Quality:

S.No.	Particulars	Acacia nilotica	Acacia Seyal
1.	Raw material, O.D.	300 gm.	300 gm.
2.	Cooking chemicals, %	14	23
3.	Sulphidity	20.1	20.1
4.	Bath ratio	1:3	1:3
5.	Ambient to 100 °C	30 min.	30 min.
6.	100 °C to 165 °C	120 min.	100 min.
7.	At 165 °C	60 min.	120 min.
8.	Unscreened Pulp yield, %	55.3	41.6
9.	Rejects, %	1.8	2.9
10.	Screened pulp yield, %	56.2	38.7
11.	Kappa number	22.2	24.8
12.	Unbleached Pulp Viscosity, cm^3/gm	962	897

Bleaching:

No.	Parameters	*Acacia nilotica*	*Acacia seyal*
1.	Unbleached pulp **Kappa No.**	22.2	24.8
2.	**C – Stage** Chlorine added, % Chlorine consumed, %	4.2 4.0	5.5 4.8
3.	**Ep – Stage** Alkali applied, % as NaOH H_2O_2 applied %	2.0 0.6	2.0 -
4.	**H – Stage** Hypo applied, % Alkali applied, % as buffer	1.5 0.3	2.0 0.3
5.	Bleached Yield, %	95.6	-
6.	Yield on raw material, %	53.7	-

7.	Raw material per ton of OD pulp, Ton	1.87	-
8.	P. C. Number	2.28	2.6
9.	Brightness, % ISO	85.1	83.1
10.	Intrinsic Viscosity cm ^{3}/g	479	476

Bleaching conditions

	C	E_p	H
Reaction Consistency, (%)	3.0	8.0	8.0
Reaction Temperature, (°C)	amb	60	40
Reaction Time, (Min)	30	60	120

Pulp properties:

The Bauer & McNett fiber classification is carried out for both bleached and unbleached pulps. The results indicate that pulp has significant proportion long fiber and the passing 200 fractions is in the reasonable limits as expected for good hardwood species.

Sl. No.	Particulars	Unit	Unbleached Pulp	Bleached Pulp
1.	Bauer McNett Classification			
	+30	%	45.1	52.0
	+50	%	22.0	2.6
	+100	%	15.8	24.5
	+200	%	0.8	1.3
	-200	%	16.3	19.6

Physical strength properties of *Acacia nilotica* (desi babul) pulps:

Physical strength properties of bleached and unbleached pulp are given in the following tables. The unbleached pulp has good initial freeness and it requires 3000 PFI revolutions to develop the pulp to 340 ml CSF. The tensile to tear relation is at the optimal level at this freeness level for unbleached pulp. The pulp shows the best strength properties at this freeness.

Sl. No.	Properties	Unit	Unbleached pulp			
1.	PFI	Rev.	0	2000	3000	4000
2.	Freeness	ml,CSF	675	530	340	225
3.	Apparent density	g/cm^3	0.57	0.69	0.74	0.77
4.	Burst Index	kPa m^2/g	1.40	4.60	6.10	5.70
5.	Tensile Index	Nm/g	40.5	80.0	95.0	90.0
6.	Tear Index	mNm^2/g	6.40	8.40	8.10	7.30
7.	Fold Kohler	log	0.60	1.53	2.25	2.20
8.	Bendtsan porosity	ml/min.	>3000	2350	395	25

Physical strength properties of bleached pulps:

The pulp could retain good strength properties even after CE_PH bleaching to an ISO brightness level of 85 %. It indicates that controlled bleaching of *Acacia nilotica* unbleached pulp does not degrade the pulp significantly. The bleached pulp could be developed to 80.5 tensile index with good tearing strength when beaten to about 300 ml CSF.

Sl. No.	Properties	Unit	Bleached pulp			
1.	PFI	Rev.	0	2000	3000	4000
2.	Freeness	ml,CSF	650	460	320	210
3.	Apparent density	g/cm^3	0.62	0.63	076	0.80
4.	Burst Index	kPa m^2/g	1.50	4.00	5.00	6.00
5.	Tensile Index	Nm/g	33.5	54.0	80.5	84.5
6.	Tear Index	mNm^2/g	6.0	7.45	6.5	6.2
7.	Fold Kohler	log	0.84	1.81	2.42	2.56
8.	Bendtsan porosity	ml/min.	>3000	1750	190	37

Physical strength properties of unbleached and bleached Acacia seyal:

Sl. No.	Properties	Unit	Un bleached pulp			
1.	PFI	Rev.	0	2000	4000	5800
2.	Freeness	ml, CSF	685	510	390	320
3.	Apparent density	g/cm^3	0.48	0.61	0.67	0.68
4.	Burst Index	kPa m^2/g	0.7	2.75	3.8	3.9
5.	Tensile Index	Nm/g	17	43	55	55.5
6.	Tear Index	mNm^2/g	2.6	4.9	7.1	6.9
7.	Fold Kohler	log	0.3	1.30	1.52	1.66

Sl. No.	Properties	Unit	Bleached pulp		
1.	PFI	Rev.	0	2000	4000
2.	Freeness	ml, CSF	655	480	315
3.	Apparent density	g/cm^3	0.56	0.68	0.72
4.	Burst Index	kPa m^2/g	1.25	3.30	3.35
5.	Tensile Index	Nm/g	24	47.5	48
6.	Tear Index	mNm^2/g	4.2	5.4	5.9
7.	Fold Kohler	log	0.48	1.34	1.40

CASUARINA

Casuarina equisetifolia Forst.

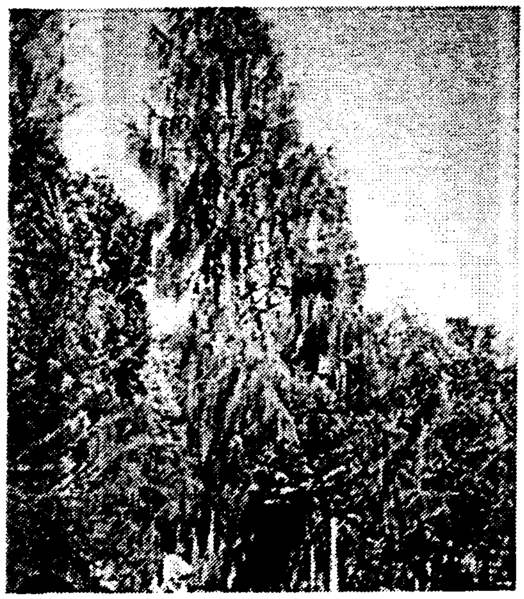
FAMILY: Casuarinaceae

COMMON NAME: whistling-pine, Australian-pine, she-oak, Australian-oak.

Habit: An open-crowned tree 15-20 (-35) m tall, to 1 m in girth. The long slender branchlets are erect or nearly so in the upper part of the tree, and horizontal to somewhat drooping in the lower.

Foliage: The foliage consists of gray-green, wiry, drooping branchlets, 20-30 cm long. Each branchlet has regularly spaced nodes with 6-8 small teeth, which are the tips of the small, scale-like leaves. The leaves arise at the node below and are fused to the branchlet along the internode, making the branchlets longitudinally ridged.

Flowers: *Casuarina* is adapted to wind-pollination and has very small, reduced, unisexual flowers borne in catkins or cones. The flowers are unisexual and the plants are monoecious, with both male and female flowers occuring on the same plant. Male inflorescences are borne at the ends of the branchlets, and appear as a continuation of the branchlet that has become fertile. Each male flower consists of a number of scale-like bracteoles and tepals and one stamen. Female inflorescences are borne on short lateral branches that differ in appearance from the vegetative branchlets. The female inflorescence is a spherical or ovoid head. Each female flower consists of 2 scale-like bracts an an ovary. The styles are reddish and exserted.



Casuarina Tree

Fruit: The fruit is a "cone", 1-2.5 cm long, made up of many flowers. From each flower, the 2 small bracts have become woody and valve-like, and enclose the one-seeded, winged fruit (samara).

Distribution and Habitat: Indigenous to northern and western Australia, Burma through Malesia to Vietnam, Melanesia, and Polynesia. Prefers coastal areas in hot humid climates on dunes and sandy flats.

Propagation

Seedage: Propagation by seed is the most common method of reproduction practiced by farmers. Presowing chemical treatment improves germination. Soaking in 1.5% KNO3 or 7.5% CaOCL2 for 36 hours give a significantly higher percentage germination and vigor index.While survival of uninoculated seedlings is good, growth of uninoculated plants is generally poor. Therefore if seeds are being introduced at a new site, soil must be inoculated with N2 fixing bacteria.

Cuttage: C. equisetifolia exhibits great yield variation under various conditions such as saline or acidic soils. For this reason, though this species is usually propagated be way of seed culture, in these cases vegetative propagation is preferable. Mature softwood stem cuttings treated with an auxin is a simple and inexpensive way to attain good results. Auxin treatment should consist of soaking cuttings in IBA (50 mg/liter) for three hours. Four to six weeks after rooting the cuttings should be inoculated with Frankia cultures. Cuttings respond best April through July.

Raw Material:

Casuarina was collected from ITC Bhadrachalam and J.K.Paper mill (Orissa).

Chemical composition of raw material:

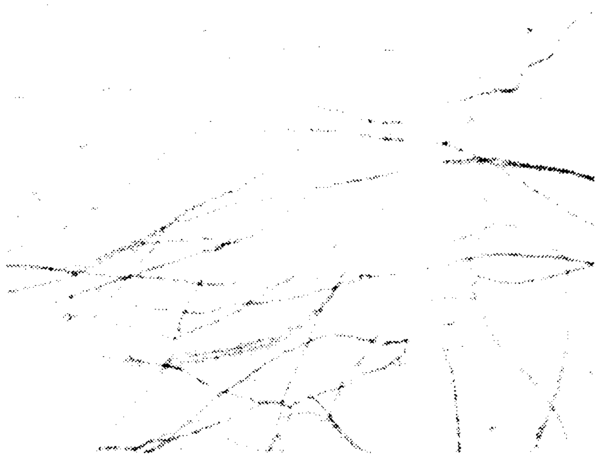
Se. No	Parameters	Unit	Casuarina
1.	Ash Content	%	0.8
2.	Cold Water Solubility	%	1.9
3.	Hot Water Solubility	%	3.23
4.	1/10 N NaOH Solubility	%	11.7
5.	Alcohal Benzene Solubility	%	1.48
6.	Pentosan	%	13.0
7.	Holocellulose	%	78.4
8.	Alpha Cellulose	%	46.2
9.	Beta Cellulose	%	17.7
10.	Gamma Cellulose	%	15.5
11.	Acid Insoluble Lignin	%	24.9
12.	Acid Soluble Lignin	%	0.78

Morphology:

Casuarina pulp like all hardwood pulps, exhibit a greater diversity of cell types than soft wood pulp like indigenous spruce or imported coniferous chemical and mechanical pulps. In the chemical pulp, the different cellular constituents of wood are usually middle lamella or the intercellular cementing substance (that is, lignin) and fragments of torn tissue and entirely absent. The individual fibers measure 0.58 to 1.71 mm (average 0.93 mm) in length and 6 to 38 µm (average 14.5 µm), in width with a relatively broad middle region and somewhat abrupt to gradual tapering pointed ends and are sometimes separated. The parenchyma cells with numerous pits measure 30 to 200 µm (average 131 µm) in length and 15 to 39 µm (average 27µm) in width. Vessel elements vary in length from 203 to 525 µm (average 432 µm) and 56 to 212 µm (average 96.5µm) in width.

No.	Dimensions	Unit	Casurina
A	*Properties of fiber:*		
1.	Fiber Length (Weight weighted) (L = 0.20 – 4.0mm)	mm	0.93
2.	Minimum Fiber Length,	mm	0.58
3.	Maximum Fiber Length,	mm	1.71
4.	Mean Fiber width (7 – 45µm)	µm	14.5
5.	Lumen Diameter	µm	2.80
6.	Cell wall thickness	µm	5.84
7.	Runkel Ratio		4.17
8.	Fiber curl index (length weighted) (L = 0.50 – 10.0mm)	-	0.136
9.	Fiber kink index (L = 0.50 – 5.0mm)	(1/mm)	2.00
10.	Total kink angle	Degrees	34.0
11.	Kinks per mm	(1/mm)	0.94
B	*Properties of non-fibrous tissue*		
12.	Length of vessel	µm	432
13.	Width of vessel	µm	96.5
14.	Length of Parenchyma	µm	131
15.	Width of Parenchyma	µm	27
16.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	26.71
17.	Length weighted Fines (L = 0.01 – 0.20 mm)	%	3.72

CASUARINA

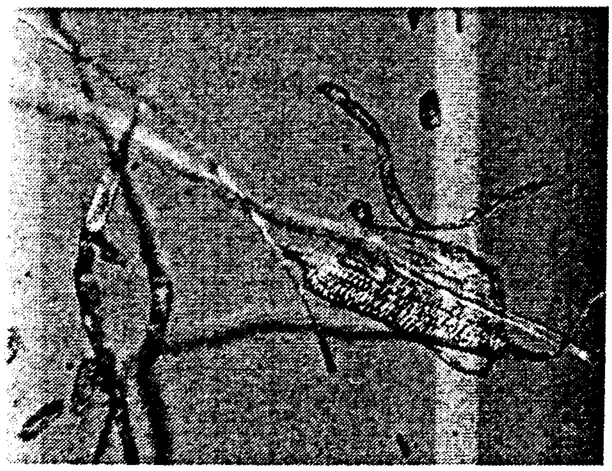


Fibers, vessel and parenchyma tissue

Magnified view of Pulp

Magnified view of pulp fibers

Magnified view of parenchyma



Magnified view of vessel element

Magnified view of vessel element

Pulping:

Pulping experiments were carried out using cooking chemical using 20% & 19.0 as Na_2O in kraft process to obtain pulps of Kappa No. around 21.8 and 16

S.No.	Particulars	Casurina	Casurina (Orissa)
1.	Raw material taken	300 gm.	400 gm.
2.	Cooking chemicals, %	20	19
3.	Sulphidity	25	23
4.	Bath ratio	1:3	1:3
5.	Ambient to 100 °C	30 min.	30 min.
6.	100 °C to 165 °C	100 min.	100 min.
7.	At 165 °C	90 min.	90 min.
8.	Unscreened Pulp yield, %	51.2	44.6
9.	Rejects, %	0.6	0.1
10.	Screened pulp yield, %	50.2	44.5
11.	Kappa number	21.8	16.0

Bleaching:

Sl	Parameters	Casuarina (Orissa)
	Before O_2 Treatment	
1	Kappa number	16.0
2	Brightness ,% ISO	26.2
3	Viscosity ,(cm^3/gm)	673
	After O_2 Treatment	7.8
4	Kappa number	42.4
5	Brightness, % ISO	604
6	Viscosity ,(cm^3/gm)	
	Bleaching sequence	D+C/Eop/D
	D+C, stage	
7	Chlorine added , %	1.46
8	Chlorine dioxide added , %	0.26
	Eop, Stage	
9	NaOH added ,%	2.0
10	Peroxide added , %	0.25
11	Viscosity , (cm^3/gm)	498
	D, stage	
12	Dioxide added as available cl_2 , (%)	
		2.0
13	Bleached pulp Brightness, % ISO	84.5
14	Viscosity , (cm^3/gm)	468
15	Shrinkage , %	6.3

Bleaching Condition:

	O2 Treatment	D+C	Eop	Dioxide
Reaction Consistency , (%)	8.0	3.0	8.0	8.0
Reaction Temperature , (°C)	105	35	70	70
Reaction Time , (Min	45	30	60	120
Oxygen pressure , (kg/cm2)	5.0	--	2.0	--

Pulp properties:

Sl. No.	Particulars	Result
1.	Bauer McNett Classification	
	+ 50	62.9
	+ 70	19.5
	+ 100	4.5
	+ 200	0.4
	- 200	12.7

Strength properties of unbleached Pulp of Casurina:

Sl. No.	Properties	Unit	Casurina Unbleached Pulp			
1.	PFI	Rev.	0	1000	3000	5000
2.	Freeness	ml,CSF	610	540	425	320
3.	Apparent density	g/cm3	0.46	0.56	0.64	0.68
4.	Burst Index	kPa m2/g	1.05	2.40	3.90	4.30
5.	Tensile Index	Nm/g	19.0	36.0	56.0	58.0
6.	Tear Index	mNm2/g	3.80	6.10	8.70	8.30
7.	Fold Kohler	log	0.30	1.00	1.60	1.92
8.	Bendtsan porosity	ml/min.	73000	73000	2520	950

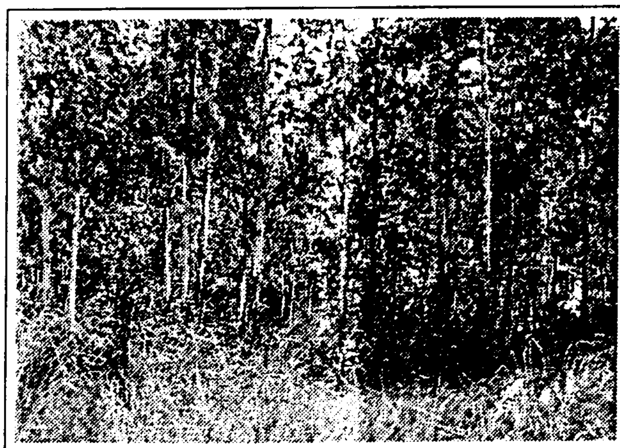
Sl. No.	Properties	Unit	Casurina (Orissa) Unbleached Pulp		
1.	PFI	Rev.	0	4000	5000
2.	Freeness	ml,CSF	620	380	325
3.	Apparent density	g/cm³	0.55	0.70	0.74
4.	Burst Index	kPa m²/g	0.90	3.65	3.70
5.	Tensile Index	Nm/g	23.0	58.0	65.0
6.	Tear Index	mNm²/g	3.15	7.40	7.10
7.	Fold Kohler	log	0.30	1.18	1.58
8.	Bendtsan porosity	ml/min.	73000	1720	1080

Sl. No.	Properties	Unit	Casurina (Orissa) Bleached Pulp		
1.	PFI	Rev.	0	2000	4000
2.	Freeness	ml,CSF	605	435	315
3.	Apparent density	g/cm³	0.55	0.71	0.76
4.	Burst Index	kPa m²/g	1.50	3.10	4.25
5.	Tensile Index	Nm/g	28.0	49.0	62.0
6.	Tear Index	mNm²/g	4.65	6.45	6.85
7.	Fold Kohler	log	0.60	1.11	1.70
8.	Bendtsan porosity	ml/min.	>3000	2280	760

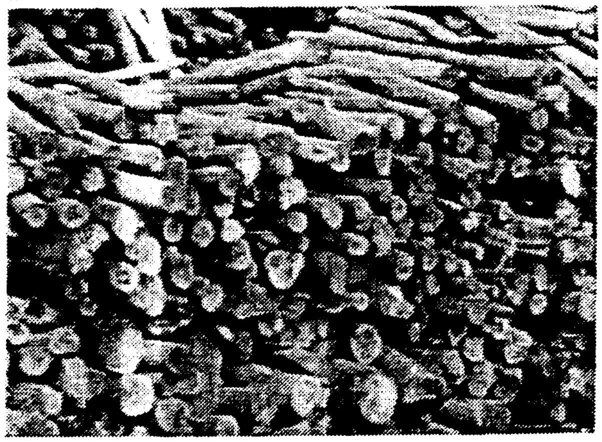
EUCALYPTUS

Eucalyptus tereticornis

Eucalyptus, though are usually consider to be an Australian tree, they are essentially Astro-malayalam with a natural latitudinal range exceeding from 70 to 43 s. several species occur in the land mass of Papua, New Guena to the north of Australia and in some of the island of the eastern part of Indonesia and Philippines. In Australia, it has a generous covering of more than 90%, consisting of 600 species (Hillis, 1991). Because of their astonishing growth characteristic climatic adaptability and wide ranging usefulness, eucalyptuses are increasingly being regarded as almost the most important trees available for men exploitation (Chaturvedi, 1983). Eculyptus as a fiber source is well accepted by papermakers due to specific qualities, such as moderate density, good formation, high bulk, high opacity, moderate bonding properties and good tear. It is accepted for the almost all types of paper with slight modification in pulp and papermaking parameters. A wide range of basic density (300-1000 Kg/m3) is encountered in eucalypts (Kingston and Risdon, 1961). However, eucalyptus with moderate density around 600 Kg/m3 are preferred for pulp and papermaking.



Eucalyptus Plantation



Storage at Mill site

Eucalyptus *tereticornis* is one of the fast growing broad leaf species widely planted throughput India mainly as pulpwood. It is known to grow 2o' in one year coastal area and attain 40 ft. in 7 year. It is expected the yield not less than 10-12 tons per ha. at planning density of 1500 tree/ha. It is sensitive to frost, but grows on well-drained soil receiving an annual rainfall of over 800 mm.

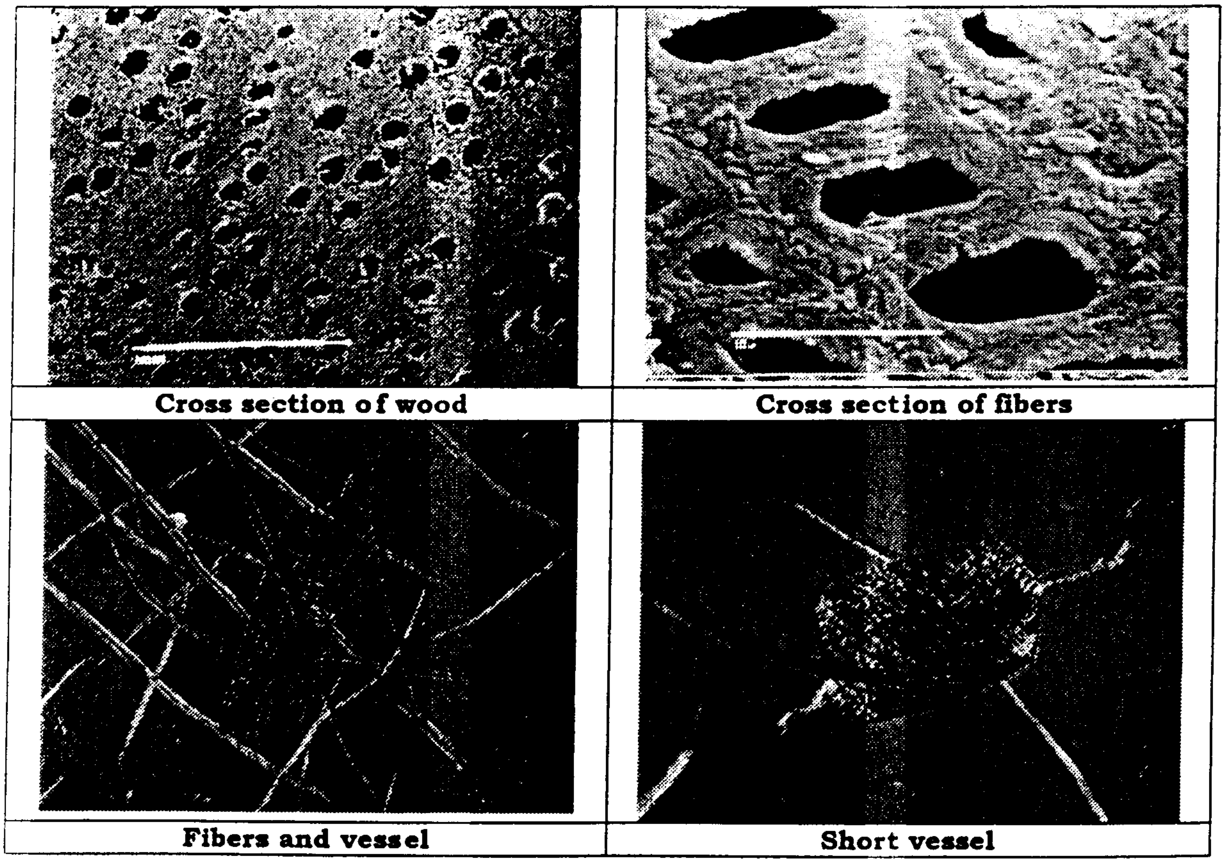
Raw Material:

Eucalpyptus was collected from ITC Bhadrachalam and J.K.Paper mill,Orissa.

Chemical composition of raw materials:

Se. No	Parameters	Unit	Eucalyptus	Eucalyptus (Orissa)
1.	Ash Content	%	0.66	0.24
2.	Cold Water Solubility	%	2.38	1.0
3.	Hot Water Solubility	%	4.31	4.0
4.	1/10 N NaOH Solubility	%	16.83	17.2
5.	Alcohal Benzene Solubility	%	3.00	2.8
6.	Pentosan	%	11.07	-
7.	Holocellulose	%	70.3	68.2
8.	Alpha Cellulose	%	42.6	39.1
9.	Beta Cellulose	%	16.22	17.1
10.	Gamma Cellulose	%	11.48	12.0
11.	Acid Insoluble Lignin	%	27.9	34.7
12.	Acid Soluble Lignin	%	0.58	-

Morphology:



Cross section of wood — Cross section of fibers — Fibers and vessel — Short vessel

Eucalyptus tereticornis used in India both for chemical and mechanical pulps. Eucalyptus pulp like all hardwood pulps, exhibit a greater diversity of cell types than soft wood pulp. The individual fibers measure 0.30 to 1.71 mm (average 0.70 mm) in length and 6 to 40 μm (average 14.2 μm), in width with a relatively broad middle region and abrupt to gradual tapering pointed ends and are sometimes separated. The parenchyma cells with numerous pits measure 30 to 160 μm (average 69 μm) in length and 15 to 40 μm (average 23μm) in width. Vessel elements vary in length from 200 to 500 μm (average 360μm) and 70 to 200 μm (average140 μm) in width.

Se.No.	Dimensions	Unit	Eucalyptus
A	*Properties of fiber:*		
1.	Fiber Length (Weight weighted) (L = 0.20 - 4.0mm)	mm	0.65
2.	Minimum Fiber Length,	mm	0.31
3.	Maximum Fiber Length,	mm	1.71
4.	Mean Fiber width (μ= 7 - 45)	μm	14.2
5.	Lumen Diameter	μm	3.40
6.	Cell wall thickness	μm	5.4
7.	Runkel Ratio		3.18
8.	Fiber curl index (Weight weighted) L = 0.50 - 10.0mm)	-	0.142
9.	Fiber kink index (L = 0.50 - 5.0mm)	1/mm	2.15
10	Total kink angle	Degree	29.93
11	Kinks per mm	1/mm	0.98
B	*Properties of non-fibrous tissue*		
12.	Length of vessel	μm	360
13.	Width of vessel	μm	140
14.	Length of Parenchyma	μm	69.0
15.	Width of Parenchyma	μm	23.0
16.	Arithmetic Fines (L = 0.01 - 0.20 mm)	%	25.59
17.	Length weighted Fines (L = 0.01 - 0.20 mm)	%	5.34

Pulping:

Pulping experiments were carried out using Kraft cooking using 16% and 24% as Na_2O process to obtain bleachable grade pulps of Kappa N° around 22 and 17.2.

Pulping conditions and pulp quality:

S.No.	Particulars	Eucalyptus	Eucalyptus (Orissa)
1.	Raw material taken	300 gm.	200 gm
2.	Cooking chemicals, %	16	24
3.	Sulphidity	25	22
4.	Bath ratio	1:3	1:4
5.	Ambient to 100 °C	30 min.	30min
6.	100 °C to 165 °C	100 min.	120 min.
7.	At 165 °C	60 min.	90 min.
8.	Unscreened Pulp yield, %	46.0	40.0
9.	Rejects,%	0.11	0.7
10.	Screened Pulp yield, %	45.9	39.3
11.	Kappa number	21.8	17.2
12.	Unbleached Pulp Viscosity, cm^3/gm	602	490

Oxygen treatment of Eucalytus (orissa) pulp:

Sl.	Particulars	Results
1	Initial kappa number	17.25
2	Initial pulp brightness %	27.3
3	Initial pulp viscosity cm^3/g	490
	Oxygen treatment	
4	NaOH added, %	2
5	Peroxide added	0.8
6	Initial pH	12.4
7	Final pH, at 35 °C	10.6
8	Kappa number	7.8
9	Pulp brightness %	49.0
10	Intrinsic Viscosity, cm^3/g	380
11	Yield, %	98.0

Oxygen treatment condition:

Pulp consistency	10%
Sodium hydroxide charged	2.0 %
Oxygen pressure	3 bar
Treatment temp.	95 °C
Treatment time	60 minutes

Bleaching optimization of oxygen treated Eucalyptus (Orissa) pulp:

S.No.	Parameters	Results
1.	Unbleached pulp Kappa number	17.25
2.	Intrinsic Viscosity (cm3/g	490
3.	O2-Del.Stage	
4.	**Kappa after O-Del.**	7.2
5.	Intrinsic Viscosity (cm3/g)	380
6.	Brightness after O2 delignification,%ISO	49
	Chlorination /Dioxide Stage	
7.	Chlorine added, as avl. Chlorine, %	1.75
8.	Dioxide added.%	0.53
	Extraction stage (Eop)	
9.	NaOH added,%	2.0
10.	Peroxide added, %	0.8
11.	Oxygen pressure, bar	1.0
12	Eop stage brightness, %ISO	80.0
13.	Eop stage Viscosity (cm3/g)	266
	Dioxide Stage	
14.	Dioxide added, %	0.80
15.	Dioxide consumed, %	0.76
16.	Brightness, %ISO	90
17.	Bleached yield, %	97.5
18.	Viscosity.cm3/g	259

Conditions for different stages of Bleaching:

	C/D	Eop	Hypo
Consistency (%)	3.0	10.0	8.0
Reaction time (min)	60	120	120
Reaction temp (°C)	50	70	40
Oxygen pressure, bar	--	1	--

Pulp properties:

Sl. No.	Particulars	Unbleached Eucalyptus pulp	Bleached Eucalyptus pulp (Orissa)
1.	Bauer McNett Classification		
	+ 50	40	0.3
	+ 70	38	57.7
	+ 100	6.2	27.1
	+ 200	2.8	7.8
	- 200	11	7.1

Strength properties of unbleached Pulp of Eucalyptus:

Sl. No.	Properties	Unit	Eucalyptus Unbleached Pulp		
1.	PFI	Rev.	0	1000	2000
2.	Freeness	ml,CSF	500	385	330
3.	Apparent density	g/cm^3	0.61	0.72	0.73
4.	Burst Index	$kPa\ m^2/g$	2.20	4.90	5.70
5.	Tensile Index	Nm/g	37.0	68.0	69.0
6.	Tear Index	mNm^2/g	5.30	7.60	7.35
7.	Fold Kohler	log	1.07	1.94	2.12
8.	Bendtsan porosity	ml/min.	2690	880	470

Strength properties of unbleached Pulp of Eucalyptus (Orissa):

Sl. No.	Properties	Unit	Eucalyptus (orissa) Unbleached Pulp		
1.	PFI	Rev.	0	2000	4000
2.	Freeness	ml,CSF	550	440	360
3.	Apparent density	g/cm^3	0.58	0.67	0.71
4.	Burst Index	$kPa\ m^2/g$	1.30	3.50	3.70
5.	Tensile Index	Nm/g	34.0	57.0	62.5
6.	Tear Index	mNm^2/g	0.60	6.40	7.30
7.	Fold Kohler	log	0.60	1.76	1.93
8.	Bendtsan porosity	ml/min.	>3000	2660	1490

Strength properties of Bleached Pulp of Eucalyptus (Orissa):

Sl. No.	Properties	Unit	Eucalyptus (Orissa) bleached Pulp		
1.	PFI	Rev.	0	1000	2000
2.	Freeness	ml,CSF	450	390	320
3.	Apparent density	g/cm^3	0.60	0.70	0.75
4.	Burst Index	$kPa\ m^2/g$	1.70	2.40	3.00
5.	Tensile Index	Nm/g	30.5	37.5	45.0
6.	Tear Index	mNm^2/g	1.90	6.70	5.00
7.	Fold Kohler	log	1.00	1.27	1.34
8.	Bendtsan porosity	ml/min.	>3000	3000	1650

MANGO

Mangifera indica Linnaeus

Mango, a large evergreen tree to 20 m tall with a dark green, umbrella-shaped crown belongs to the family Anacardiaceae. The leaves are alternate, simple, leathery, oblong-lanceolate, 29-30 cm long X 3-5 cm wide on flowering branches, up to 50 cm on sterile branches. The young leaves are red, aging to shiny dark green above, and lighter below, with yellow or white venation.

The inflorescence is a much-branched panicle bearing many very small (4 mm) greenish white or pinkish flowers. Both male and bisexual flowers are borne on the same tree. The flowers are radially symmetrical, and usually have 5 petals, streaked with red. There is usually only 1 fertile stamen per flower; the 4 other stamens are sterile. The flower has a conspicuous 5-lobed disk between the petals and stamens. The fruit is an irregularly egg-shaped and slightly compressed fleshy drupe, 8-12 (-30) cm long, attached at the broadest end on a pendulous stalk. The skin is smooth greem greenish-yellow, sometimes tinged with red. The underlying yellow-orange flesh varies in quality from soft, sweet, juicy and fiber-free in high-quality selected varieties to resinous and fibrous in wild seedlings. The single, compressed-ovoid seed is encased in the white fibrous inner layer of the fruit.

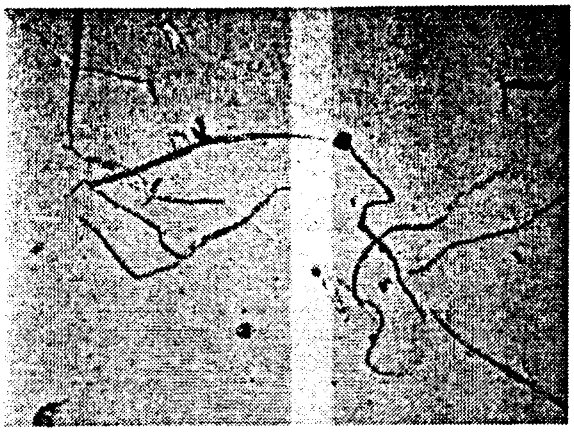
Mango is indigenous to India and Burma where it still grows in the wild also. Mangos had been distributed via cultivation throughout the Indian subcontinent, which eventually spread to all tropical regions of the world and naturalized. The tree grows best at elevations from 0-1200 m. with a pronounced rainy season for vegetative growth and dry season for flowering and fruiting, and on well-drained soils ranging in pH from 5.5 to 7.5. Mangos are propagated from seed and seedlings take 6 or more years to come into bearing than vegetative propagules of a reproductively mature tree. Mango is primarily grown for fruits and the wood of mature trees is used as timber. The timber waste finds its way to the paper industry.

Chemical composition of raw material:

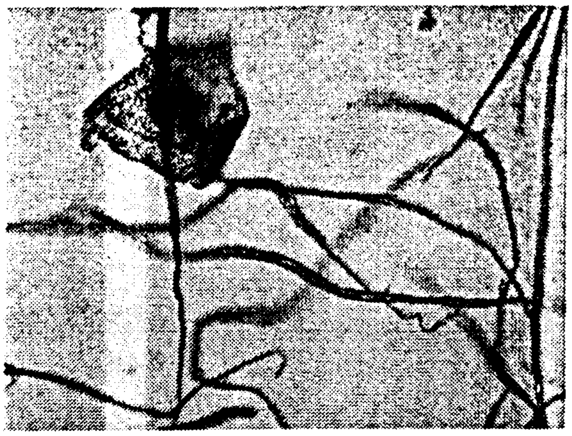
Se. No	Parameters	Unit	Mango
1.	Ash Content	%	1.5
2.	Cold Water Solubility	%	6.74
3.	Hot Water Solubility	%	9.64
4.	1/10 N NaOH Solubility	%	21.3
5.	Alcohal Benzene Solubility	%	2.81
6.	Pentosan	%	11.96
7.	Holocellulose	%	74.7
8.	Alpha Cellulose	%	45.5
9.	Beta Cellulose	%	18.5
10.	Gamma Cellulose	%	10.6
11.	Acid Insoluble Lignin	%	22.8
12.	Acid Soluble Lignin	%	0.97

Morphology:

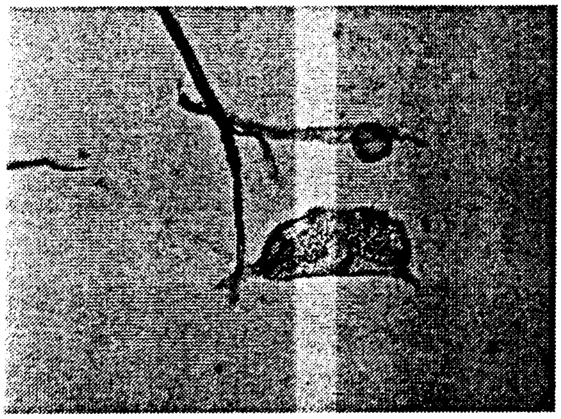
No.	Dimensions	Unit	Mango
A	*Properties of fiber:*		
1.	Fiber Length (Weight weighted) (L = 0.20 – 4.0mm)	mm	0.77
2.	Minimum Fiber Length,	mm	0.24
3.	Maximum Fiber Length,	mm	1.9
4.	Mean Fiber width (μ= 7 – 45)	μm	15.0
5.	Lumen Diameter	μm	4.2
6.	Cell wall thickness	μm	5.4
7.	Runkel Ratio		2.57
8.	Fiber curl index (length weighted)(L = 0.50 – 10.0mm)	-	0.111
9.	Fiber kink index (L = 0.50 – 5.0mm)	1/mm	1.78
10.	Total kink angle	degree	25.89
11.	Kinks per mm	1/mm	0.86
B	*Properties of non-fibrous tissue*		
12.	Length of vessel	μm	219
13.	Width of vessel	μm	54.3
14.	Length of Parenchyma	μm	92.6
15.	Width of Parenchyma	μm	28.4
16.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	27.01
17.	Length weighted Fines (L = 0.01 – 0.20 mm)	%	4.71



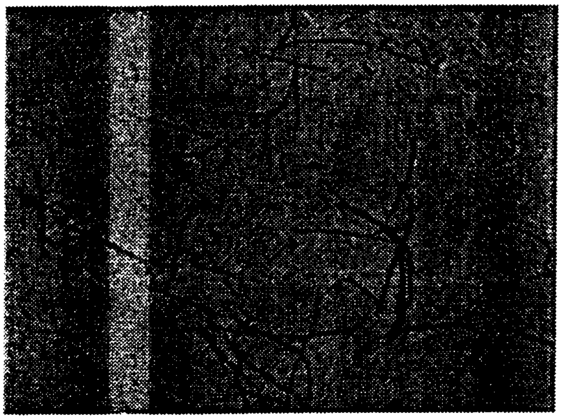
Magnified view of Mango Pulp



Magnified view of Mango Pulp



Magnified view of Mango Pulp



Magnified view of Mango Pulp

Pulping:

Pulping experiments were carried out using cooking chemical using 21% as Na_2O Kraft process in to obtain pulps of kappa N° around 25.5.

Pulping conditions and pulp quality

S.No.	Particulars	Mango
1.	Raw material taken	300 gm.
2.	Cooking chemicals, %	21
3.	Sulphidity	25
4.	Bath ratio	1:3
5.	Ambient to 100 °C	30 min.
6.	100 °C to 165 °C	100 min.
7.	At 165 °C	60 min.
8.	Unscreened Pulp yield, %	47.4
9.	Rejects, %	0.5
10.	Screened Pulp yield, %	46.9
11.	Kappa number	25.5

Pulp properties:

Sl. No.	Particulars	Result
1.	**Bauer McNett Classification**	
	+ 50	55.6
	+ 70	25.7
	+ 100	4.6
	+ 200	0.9
	- 200	12.2

Strength properties of unbleached Pulp:

The unbleached pulp is required 3000 PFI rev. to beat pulp to 305 ml csf. The pulps show the best strength properties at this freeness. As the burst index ix 5.20, tensile index 78.0 and tear 6. 8.

Sl. No.	Properties	Unit	Mango Unbleached Pulp		
1.	PFI	Rev.	0	1000	3000
2.	Freeness	ml,CSF	590	410	305
3.	Apparent density	g/cm^3	0.55	0.67	0.75
4.	Burst Index	kPa m^2/g	1.6	4.05	5.20
5.	Tensile Index	Nm/g	30.0	57.0	78.0
6.	Tear Index	mNm^2/g	4.3	6.70	6.80
7.	Fold Kohler	log	0.70	1.51	2.26
8.	Bendtsan porosity	ml/min.	>3000	1600	360

SUBABUL

Leucaena leucocephala

Subabul is also known as leucaena or ipil-ipil. It had its origin from Mexico and is now widely spread throughout the tropical and subtropical countries of the world. It is a perennial hardy evergreen shrub. It has deep and strong taproot and even the seedlings are deep rooted. The leaves are bipinnate, 15 to 20 cm long with 10 to 15 pairs of pinnate leaves. Inflorescence is globular and the flowers are white. There are four types of Subabul:

Hawaiian type: The plants are short bushy and remarkably drought tolerant. It is suited to hilly terrains in drought prone areas. It is a prolific seed producer and is good for fodder purpose. K-341 is a Hawaiian variety.

Salvador type: Tall, tree like and fast growing having maximum annual biomass production. Possesses large leaves, pods and seeds than Hawaiian types. Responds to high fertilization. Variety K-8 is useful for fodder.

Peru: Tall and extensively branching type and is ideal for fodder purpose.

Cunningham: It is a cross between Salvador and Peru types.

Subabul is best suited for warm regions and grows well between 22 and 30°C in regions of 500 to 2000 mm annual rainfall. Because of its strong and deep root system, the tree is highly drought resistant. It is restricted to elevations below 500 m but it withstands variations in rainfall, sunlight, windstorm, slight frost and drought. It cannot withstand waterlogging. It requires a deep well drained neutral soil and can tolerate saline and acid soil. It can also be grown in steep slopes, hilly terrains, gravelly areas and sandy loams. Planting of seedlings can be done with the onset of rains in May-June or Sept-October. Seed viability is high, but the hard seed coat posses dormancy. To hasten germination seeds are to be dipped in concentrated sulfuric acid for four minutes and then washed or put in hot water at 80°C for four minutes. Sundry the seeds afterwards for about one hour before sowing.

A seed rate of 3-4 kg/ha is recommended. Sowing is preferably done during February-March in a nursery or polythene bags or in situ at 2-3 cm depth. Give irrigation if there is no rain. Seedlings (1.5 to 3 months old with 6-8 leaves) are planted in the main field. A spacing of 1 x 0.1 m is recommended for a pure crop of fodder, 1.5 x 0.2 m for planting in boundaries and borders of coconut gardens and 2 x 0.2 m when raised along boundaries. It can grow under a wide range of conditions as a range plant, roadside plant, in pastures etc. The land should be, however, cleared of bushes, ploughed and leveled before sowing.

A basal application of $N:P_2O_5:K_2O$ at the rate of 20:50:30 kg/ha is recommended. Since the early growth of the crop is slow, the tender plants are to be protected from aggressive weeds. Two or three inter-row cultivation is essential to check weeds in early life. Once established, even vigorous grasses seldom smother the plants. Leucaena combines well with many grasses like guinea, pangola, dinanath, Hybrid Napier etc.

Subabul is a highly nutritious leguminous tree fodder with 27-34 per cent protein. The fodder is rich in carotene and vitamin A. Pro-vitamin A content is the highest among all plant species. The foliage contains an uncommon amino acid, mimosine, which is toxic to non-ruminants at levels of about 10% of the diet.

Subabul starts flowering at 125-150 days after planting. First cutting is done after 5-6 months at a height of 70-80 cm from the ground level at a time when the plants reach a height of 1.5-1.75 m. Subsequent harvests can be made at 50-60 days interval depending on the re-growth. When planted in boundaries, the main shoot is not cut; only side branches are cut for fodder, leaving the top three branches. In gravelly soil and in low rainfall areas, a yield of 25-30 tonnes per ha per year may be obtained. The irrigated crop may produce 100 t/ha of green fodder per year in seven to eight cuttings.

Farm & Social Forestry Outcomes:

Achievements in all three initiatives have been very encouraging.

Research and Development: 86 fast growing and high yielding, disease resistant clones are being produced on a commercial scale. The productivity of 'Bhadrachalam' clones ranges between 20-58 m3/hectare/year, which is 3 to 9 times more productive than normal seedlings. 23 site-specific clones (includes 86) adapted to problematic alkaline and saline soils have also been developed so far.

a) Farm Forestry: The commercial viability of these clones & subabul-selected varieties is evident from the fact that since 1992, 6,372 farmers have become our partners and planted over 10,000 hectares.
b) Social Forestry: Since its inception in 2001-02 covered 2,500 poor tribal farmers converted 1730 hectares of private wastelands into productive farmlands and planted 4.5 million saplings of different species.

c) Environment: Apart from other well-known consequences of such a large-scale greening effort, these plantations have the potential to sequester 0.58 million tonnes of carbon, thus mitigating GHGs.

d) Farm Incomes: Average net gains to farmers is about Rs.25,000/hectare/year (US$ 520) under rainfed condition and Rs.40,000/hectare/year (US$ 833) with irrigation on a 4 year rotation cycle which is significantly higher than most other cash crops in our operational area, and at much lower risks.

Pollution prevention:

By promoting the planting of nearly 45 million plants, the project has increased the green cover in the country over 13,000 hectares. Apart from the innumerable benefits of such large-scale afforestation, it directly contributes to in-situ moisture conservation, groundwater recharge and significant reduction in topsoil losses due to wind and water erosion.

This plant population has the potential to sequester 0.58 million tonnes of carbon thus helping in the reduction of Green House Gas (GHG) and conservation of natural forest resources. This 0.58 million tonnes of carbon is approx. worth US$ 1.7 million at the rate of US$ 3 per metric tonne.

Over 7,000 rural households having access to their own woody biomass, they can meet most of their fuelwood requirements in-house through loppings, cuttings and pruning. To this extent therefore, existing public forests are protected from wanton destruction by rural households in search of fuelwood. As a result of the leaf-litter from multi-species plantations and the promotion of leguminous inter-crops between rows, depleted soils are constantly getting enriched, making these farmlands more productive. In the near future, the increase in soil fertility will lead to a decline in fertiliser and pesticide consumption, thus reducing the pollution of groundwater sources through leaching of such chemicals.

Raw Material:

Subabul was collected from ITC Bhadrachalam and J.K.Paper mill, Orissa.

Chemical composition of raw material:

Se. No	Parameters	Unit	Subabul
1.	Ash Content	%	0.65
2.	Cold Water Solubility	%	2.10
3.	Hot Water Solubility	%	4.7

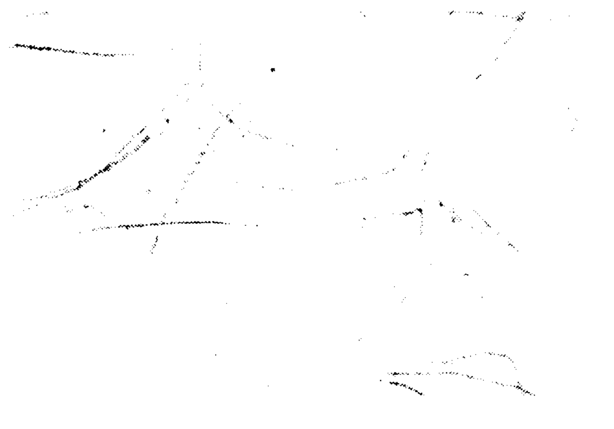
4.	1/10 N NaOH Solubility	%	16.1
5.	Alcohal Benzene Solubility	%	2.3
6.	Pentosan	%	13.0
7.	Holocellulose	%	75.2
8.	Alpha Cellulose	%	40.4
9.	Beta Cellulose	%	21.1
10.	Gamma Cellulose	%	13.7
11.	Acid Insoluble Lignin	%	24.3
12.	Acid Soluble Lignin	%	0.68

Morphological Features:

Subabul is a hard wood, exhibit a greater diversity of cell types than soft wood pulp. The individual fibers measure 0.22 to 2.0 mm (average 1.00 mm) in length and 6 to 38 μm (average 20.1 μm), in width with a relatively broad middle region and somewhat abrupt to gradual tapering pointed ends and are sometimes separated. The parenchyma cells with numerous pits measure 30 to 200 μm (average 122.4μm) in length and 15 to 39 μm (average 25.5μm) in width. Vessel elements vary in length from 203 to 525 μm (average 297 μm) with an average width of 31μm.

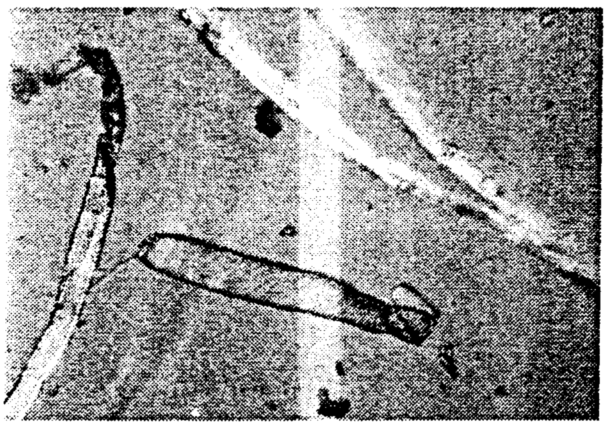
No.	Dimensions	Unit	Subabul
A	*Properties of fiber:*		
1.	Fiber Length (Weight weighted) (L = 0.20 – 4.0mm)	mm	1.02
2.	Minimum Fiber Length,	mm	0.22
3.	Maximum Fiber Length,	mm	2.0
4.	Mean Fiber width (μ= 7 – 45)	μm	20.1
5.	Lumen Diameter	μm	9.18
6.	Cell wall thickness	μm	5.46
7.	Runkel Ratio		1.19
8.	Fiber curl index (Weight weighted)(L = 0.50 – 10.0mm)	-	0.108
9.	Fiber kink index (L = 0.50 – 5.0mm)	1/mm	1.62
10.	Total kink angle	degree	28.86
11.	Kinks per mm	1/mm	0.76
B	*Properties of non-fibrous tissue*		
12.	Length of vessel	μm	297
13.	Width of vessel	μm	31
14.	Length of Parenchyma	μm	122.4
15.	Width of Parenchyma	μm	25.5
16.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	27.37
17.	Length weighted Fines (L = 0.01 – 0.20 mm)	%	3.83

SUBABUL



Subabul Pulp Fibers

Magnified view of Subabul Pulp



Parenchyma tissue

Vessel element and fibers

Pulping:

Pulping experiments were carried out using cooking chemical using 20% & 21% as Na_2o kraft process in to obtain b leachable grade pulps of kappa n° 21.6. & 17.6

Pulping conditions and pulp quality:

S.No.	Particulars	Subabul	Subabul (Orissa)
1.	Raw material	300 gm.	300gm
2.	Cooking chemicals, %Na_2O	22	21
3.	Sulphidity	25	23
4.	Bath ratio	1:3	1:3
5.	Ambient to 100 °C	30 min.	30
6.	100 °C to 165 °C	90 min.	100
7.	At 165 °C	60 min.	120
8.	Unscreened Pulp yield, %	51.8	44.5
9.	Rejects, %	2.1	0.17
10.	Screened Pulp yield, %	49.7	44.3
11.	Kappa number	21.8	17.6
12	Unbleached Pulp Viscosity, cp	25	-

BLEACHING RESPONSE OF SUBABUL (B) PULP:

Sl.	Parameters	Results
	Before O_2 Treatment	
1.	Kappa number	17.6
2.	Brightness, % ISO	26.6
	After O_2 Treatment	
3.	Kappa number	8.0
4.	Brightness, % ISO	41.0
5.	Shrinkage , %	4.31
6.	Viscosity , cm^3/g	500.2
	Bleaching sequence	
	D+C, stage	
7.	Chlorine added ,%	1.5
8.	Chlorine dioxide added, %	0.26
	Eop, Stage	
9.	NaOH added, %	2.5
10.	Peroxide added, %	0.35
11.	Viscosity , cm^3/g	363.5
	D, stage	
12.	Chlorine dioxide added as Cl_2, (%)	2.0
13.	Brightness, % ISO	83.6
14.	Viscosity , cm^3/g	361

Bleaching Conditions:

	O_2 Treatment	**D+C**	**Eop**	**Dioxide**
Reaction Consistency, (%)	10.0	10.0/3.0	10.0	10.0
Reaction Temperature, (°C)	105	Ambient	80	80
Reaction Time, (Min	45	45	60	180
Oxygen pressure, (kg/cm2)	5.0	--	2.0	--

Pulp properties:

Sl. No.	**Particulars**	**Result**
1.	Bauer McNett Classification	
	+ 50	56.0
	+ 70	27.7
	+ 100	3.5
	+ 200	3.1
	- 200	9.7

Physical Strength properties of unbleached Pulp of Subabul:

Sl. No.	Properties	Unit	Subabul Unbleached Pulp		
1.	PFI	Rev.	0	2000	4000
2.	Freeness	ml,CSF	615	465	320
3.	Apparent density	g/cm³	0.65	0.79	0.83
4.	Burst Index	kPa m²/g	1.50	4.35	5.70
5.	Tensile Index	Nm/g	39.0	74.5	73.0
6.	Tear Index	mNm²/g	5.60	9.15	9.20
7.	Fold Kohler	log	1.04	2.25	2.40
8.	Bendtsan porosity	ml/min.	2970	660	170

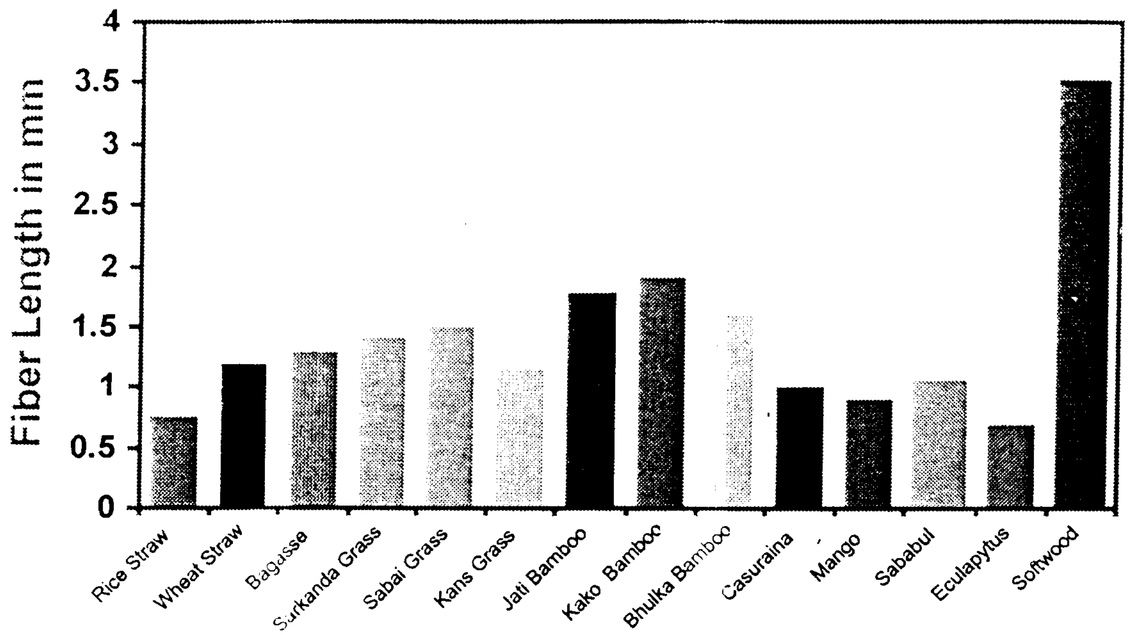
Physical Strength properties of unbleached Pulp of Subabul :

Sl. No.	Properties	Unit	Subabul Orissa Unbleached Pulp		
1.	PFI	Rev.	0	2000	4000
2.	Freeness	ml,CSF	610	435	300
3.	Apparent density	g/cm³	0.60	0.77	0.80
4.	Burst Index	kPa m²/g	1.60	3.95	4.65
5.	Tensile Index	Nm/g	33.5	64.0	73.0
6.	Tear Index	mNm²/g	5.45	6.70	6.25
7.	Fold Kohler	log	0.60	1.38	1.86
8.	Bendtsan porosity	ml/min.	3000	530	110

Physical Strength properties of Bleached Pulp of Subabul:

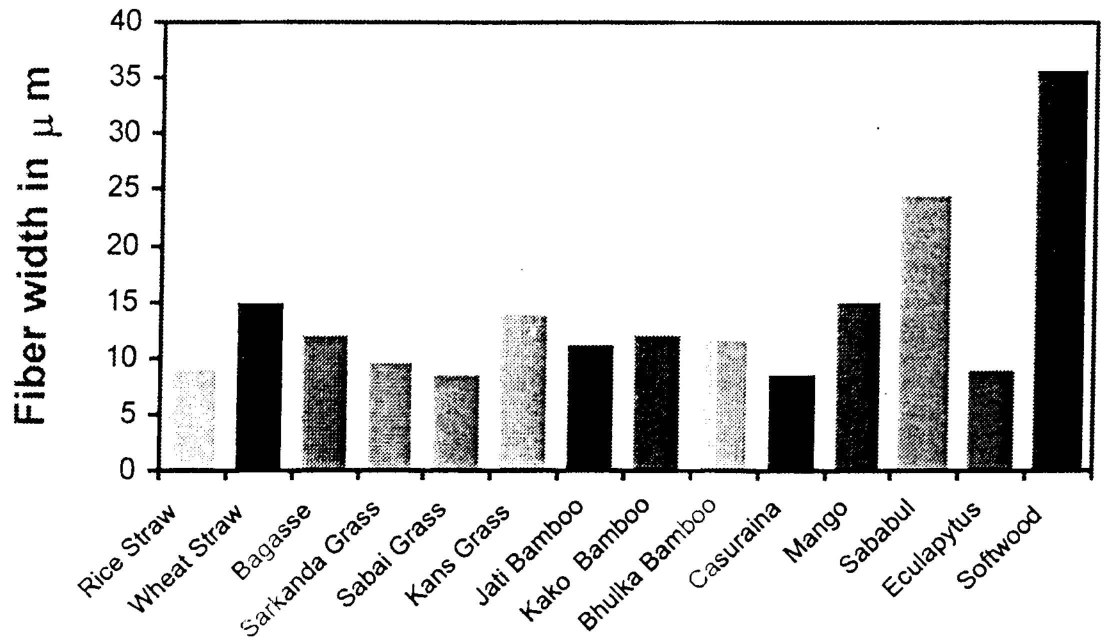
Sl. No.	Properties	Unit	Subabul Orissa Bleached Pulp		
1.	PFI	Rev.	0	2000	3000
2.	Freeness	ml,CSF	550	350	320
3.	Apparent density	g/cm³	0.66	0.80	0.84
4.	Burst Index	kPa m²/g	2.05	4.50	4.55
5.	Tensile Index	Nm/g	33.0	64.5	65.0
6.	Tear Index	mNm²/g	5.75	6.2	6.0
7.	Fold Kohler	log	0.78	1.32	1.48
8.	Bendtsan porosity	ml/min.	2800	470	190

FIBER LENGTH OF DIFFERENT FIBEROUS RAW MATERIALS



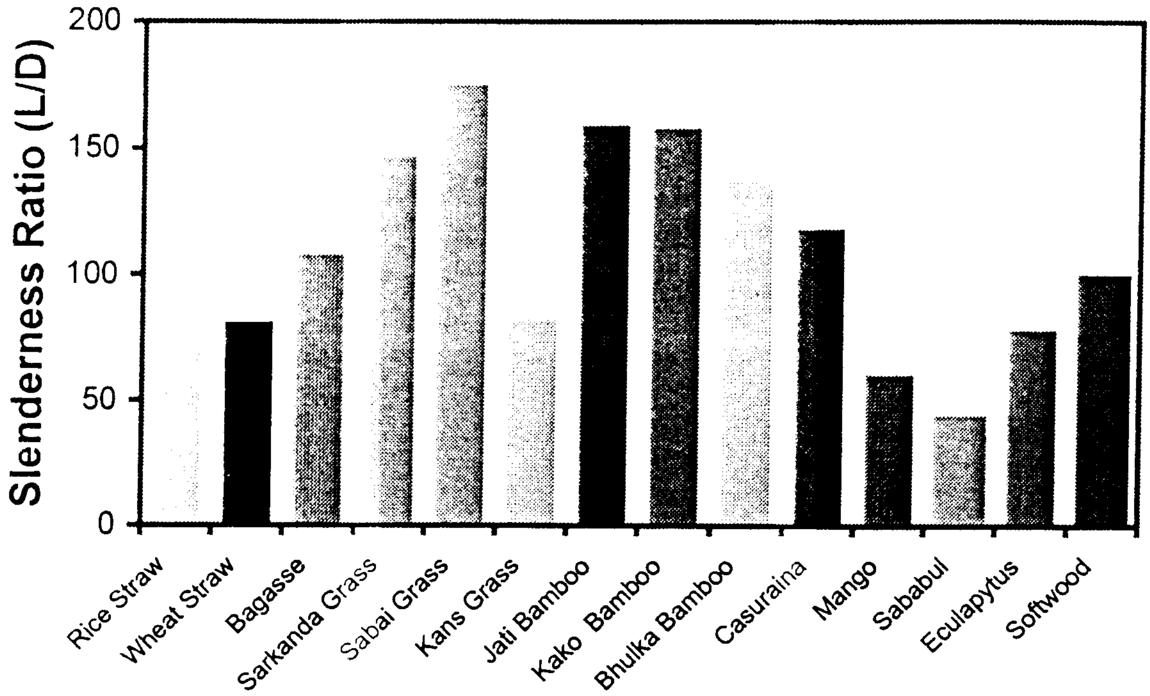
Fiber length is one of the major factors that influence the paper strength. It is one single major factor influencing the Wet web tensile strength that contributes to the runnability. In a paper web the number of fiber crossings per fiber proportionally increases with fiber length, thereby increases the tearing strength of the paper.

FIBER WIDTH OF DIFFERENT FIBEROUS RAW MATERIALS



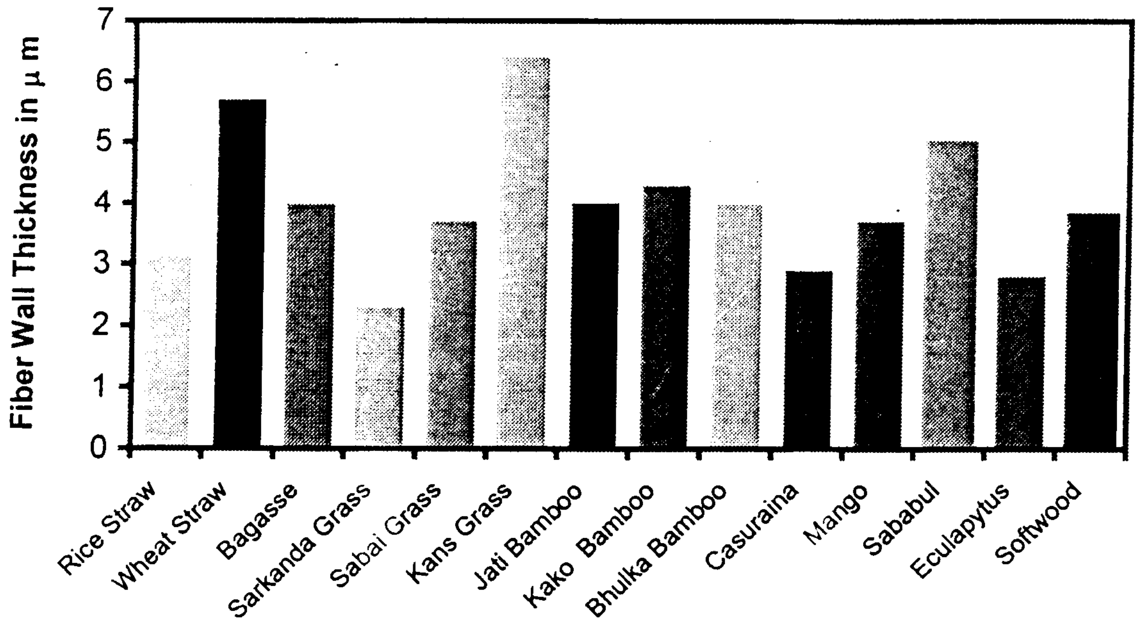
Fiber width influences the area of bonding. At a given fiber length, increase in fiber width increases the fiber bonding area which has direct impact on tensile, tear and bursting strength of paper.

SLENDERNESS OF FIBERS OF DIFFERENT FIBEROUS RAW MATERIALS

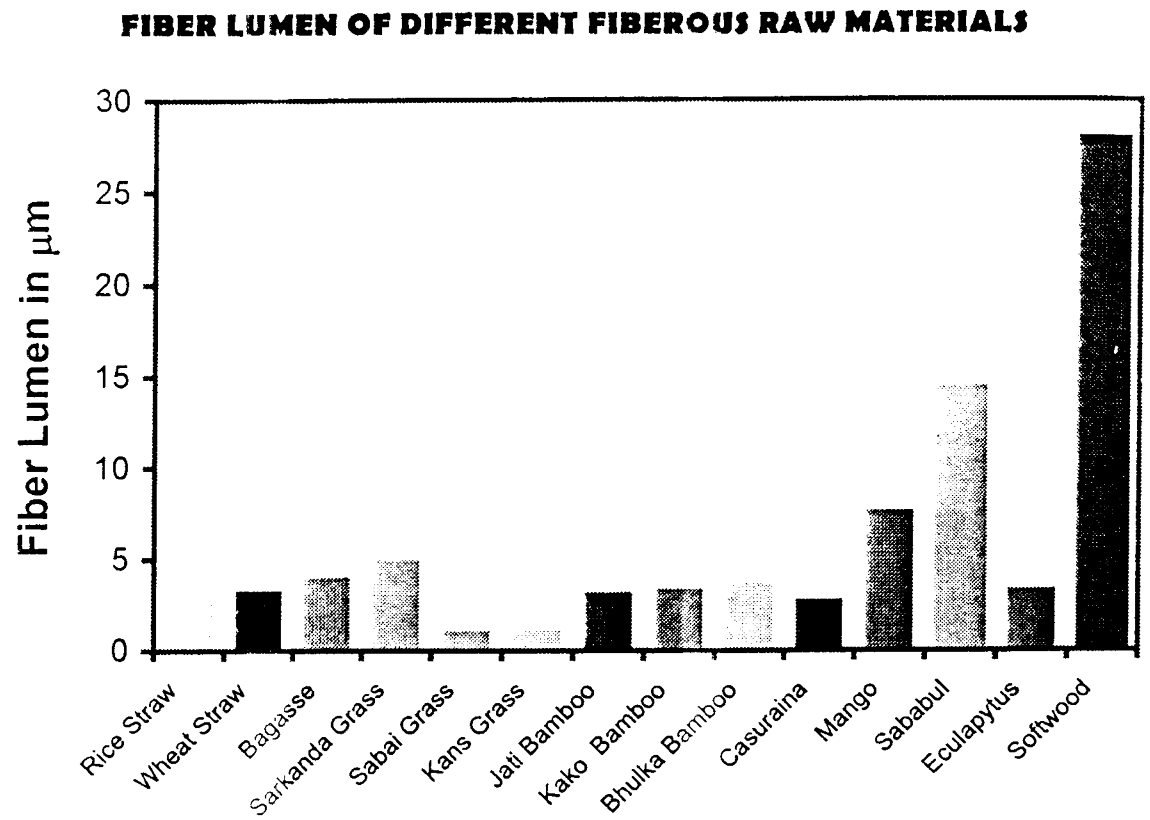


Slenderness of the fiber is derived from Length of fiber divided by width of the fiber.

FIBER WALL THICKNESS OF DIFFERENT FIBEROUS RAW MATERIALS



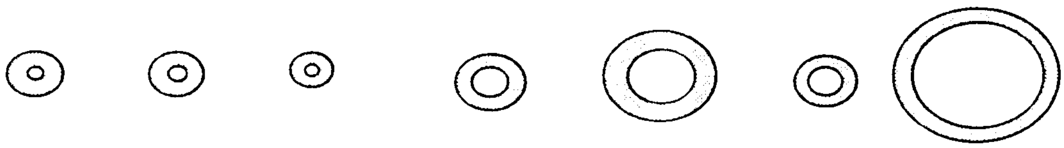
Fiber wall thickness indicates the mass of the wall material per unit length of the fiber. As the wall thickness increases, the fibers are difficult to collapse in the refining treatment. The paper strength was found to improve with increasing fiber length and decreasing wall fraction (only to certain extent) (Rydholm).



Fiber lumen influences the collapsibility and conformability of the fibers. Collapsibility of the fibers improves the area of fiber bonding as the contact area increases.

COMPARATIVE CROSS SECTIONAL DIMENSIONS OF DIFFERENT FIBERS

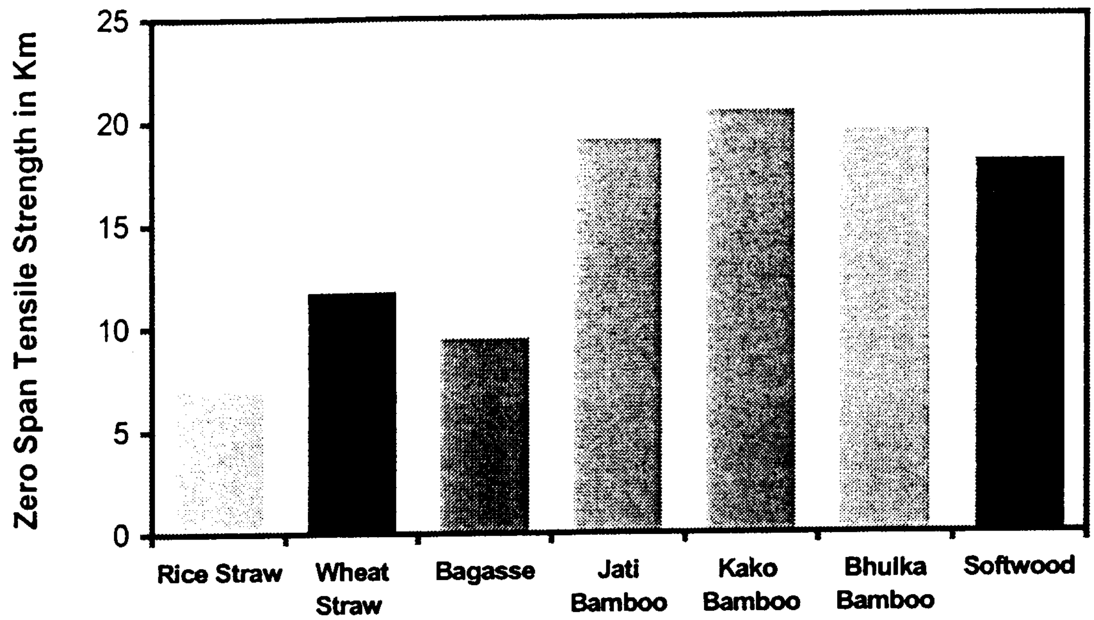
	Rice Straw	Wheat Straw	Bagasse	Sarkanda Grass	Sabai Grass	Kans Grass	Jati Bamboo
Fiber diameter, µm	11.1	15.2	21.8	15.7	13.5	15.4	17.8
Fiber Lumen, µm	2.3	3.3	6.3	4.2	1.1	1.1	3.2
Wall Thickness, µm	5.4	6.0	7.8	5.7	6.3	6.4	7.3



	Kako Bamboo	Bhulka Bamboo	Casuraina	Mango	Subabul	E.Hybrid	Softwood
Fiber diameter, µm	17.2	17.2	14.5	15.0	20.1	14.2	40.0
Fiber Lumen, µm	3.4	3.7	2.8	4.2	9.2	3.4	28.0
Wall Thickness, µm	6.9	6.8	5.8	5.4	5.5	5.4	6.0

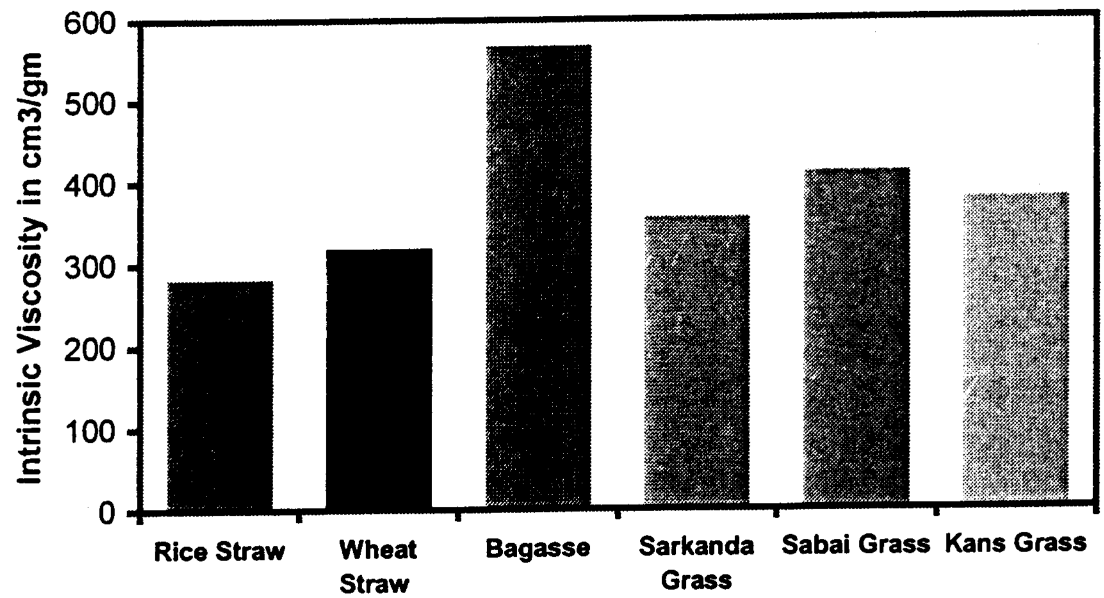
The coarseness was found to influence the bulk with an exponent of –0.3, burst with – 1.0, tensile strength with – 0.6, and tearing strength with – 0.3 (Rydholm)

FIBER STRENGTH INDEX OF DIFFERENT FIBEROUS RAW MATERIALS

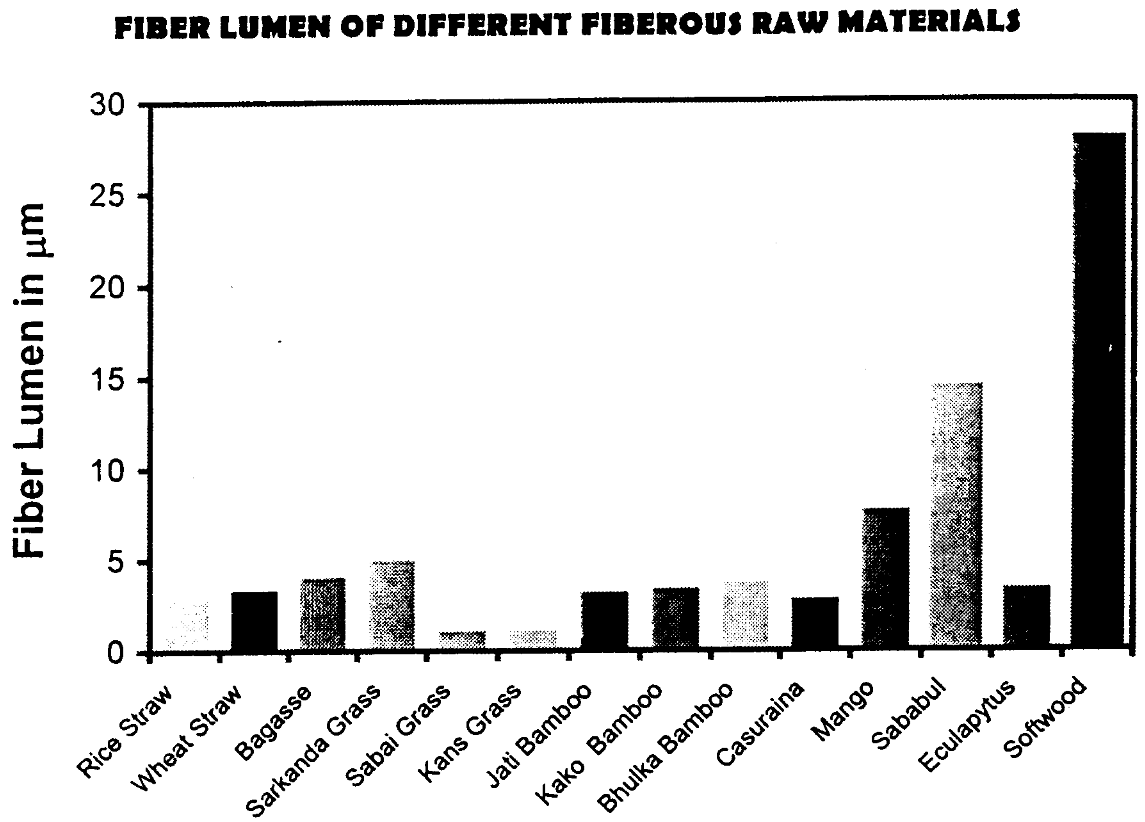


Fiber strength index (FSI) indicates the intrinsic strength of the individual fiber. Fibers with good FSI will show better strength properties, provided the fibers have reasonable length and width those are responsible for the tensile and tearing strength of the papers.

INTRINSIC VISCOSITY OF PULPS OF DIFFERENT FIBEROUS RAW MATERIALS



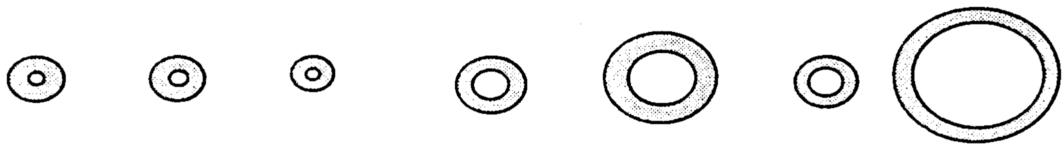
Intrinsic viscosity of the pulps gives an indication of degree of polymerization (DP) of cellulose. Changes in DP value to lower side indicate the loss in strength of the paper as the pulp is subjected to various pulping and bleaching processes.



Fiber lumen influences the collapsibility and conformability of the fibers. Collapsibility of the fibers improves the area of fiber bonding as the contact area increases.

COMPARATIVE CROSS SECTIONAL DIMENSIONS OF DIFFERENT FIBERS

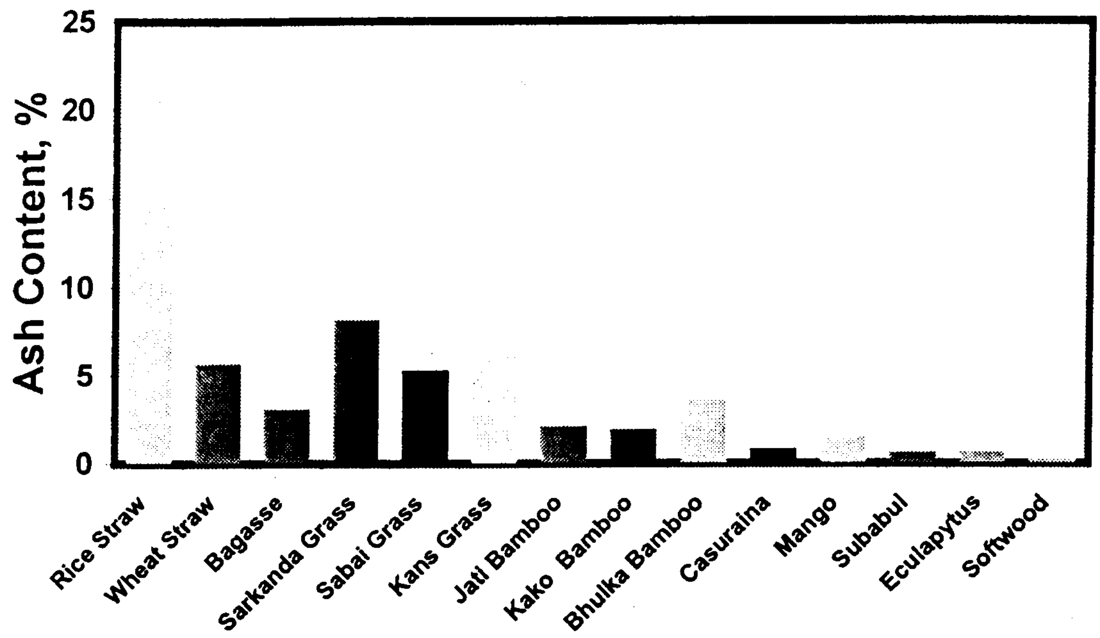
	Rice Straw	Wheat Straw	Bagasse	Sarkanda Grass	Sabai Grass	Kans Grass	Jati Bamboo
Fiber diameter, µm	11.1	15.2	21.8	15.7	13.5	15.4	17.8
Fiber Lumen, µm	2.3	3.3	6.3	4.2	1.1	1.1	3.2
Wall Thickness, µm	5.4	6.0	7.8	5.7	6.3	6.4	7.3



	Kake Bamboo	Bhulka Bamboo	Casuraina	Mango	Subabul	E.Hybrid	Softwood
Fiber diameter, µm	17.2	17.2	14.5	15.0	20.1	14.2	40.0
Fiber Lumen, µm	3.4	3.7	2.8	4.2	9.2	3.4	28.0
Wall Thickness, µm	6.9	6.8	5.8	5.4	5.5	5.4	6.0

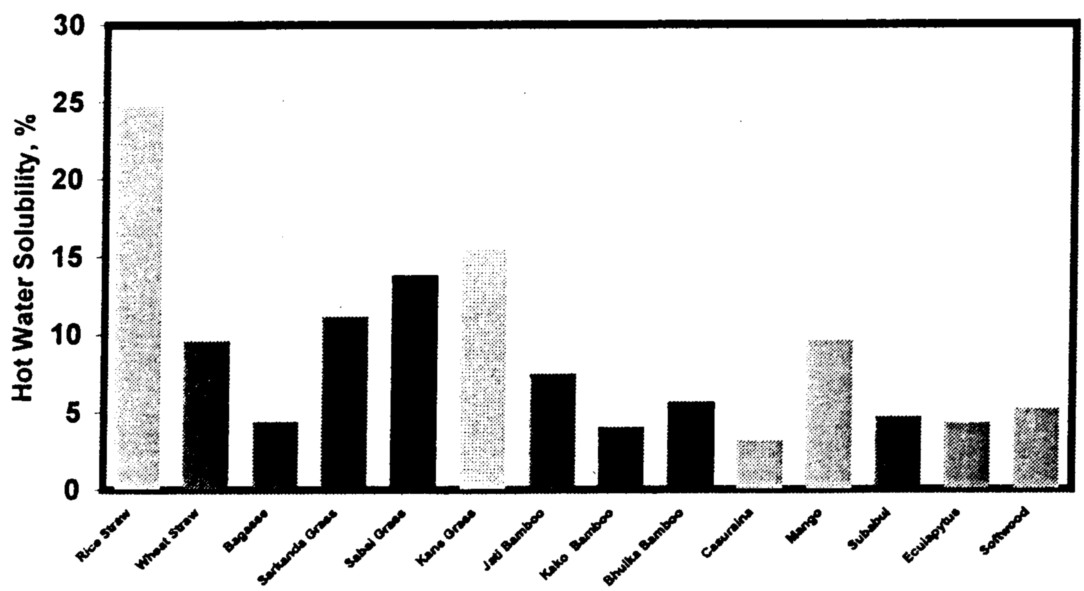
The coarseness was found to influence the bulk with an exponent of –0.3, burst with – 1.0, tensile strength with – 0.6, and tearing strength with – 0.3 (Rydholm)

ASH CONTENT IN DIFFERENT FIBEROUS RAW MATERIALS



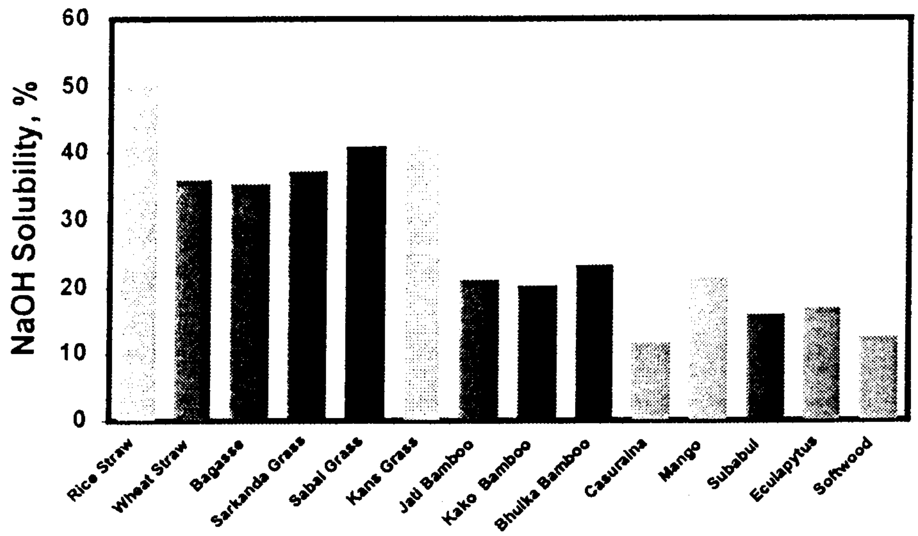
Ash content is the inorganic content present in the raw materials. Inorganic content is very low in the wood based raw materials. The higher ash content in agro based raw materials is due to presence of silica. Silica also consumes considerable quantity of alkali during the pulping process.

HOT WATER SOLUBILITY OF DIFFERENT FIBEROUS RAW MATERIALS



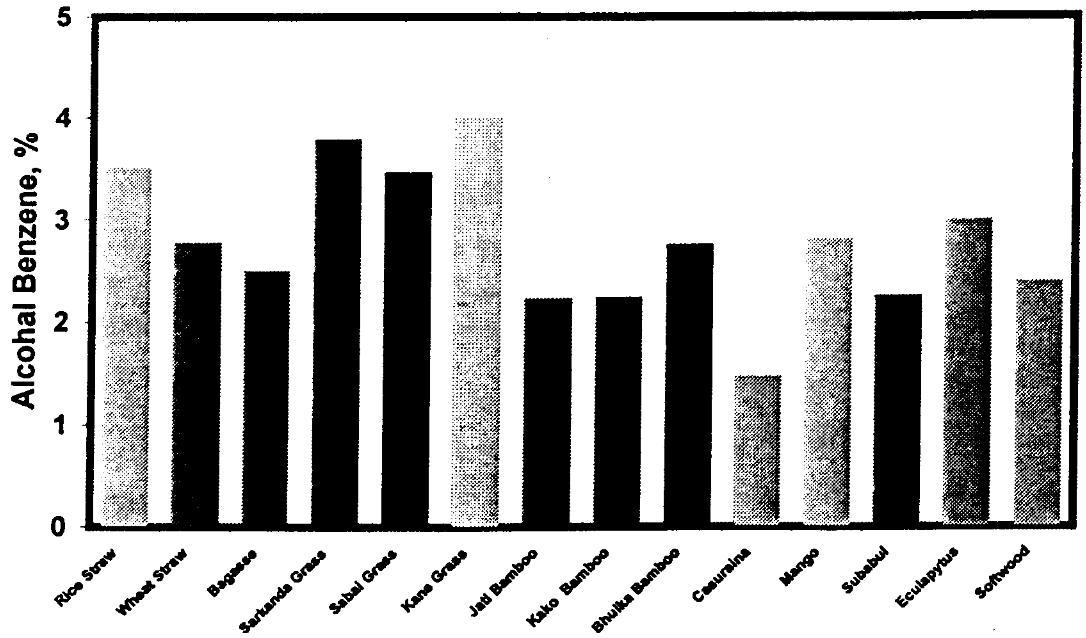
Water solubility of the raw materials indicate the presence of freely soluble materials like carbohydrates, tannins etc. This is an undesirable component of the fibrous raw material keeping the pulping chemical requirements in view.

N/10 NaOH SOLUBILITY OF DIFFERENT FIBEROUS RAW MATERIALS



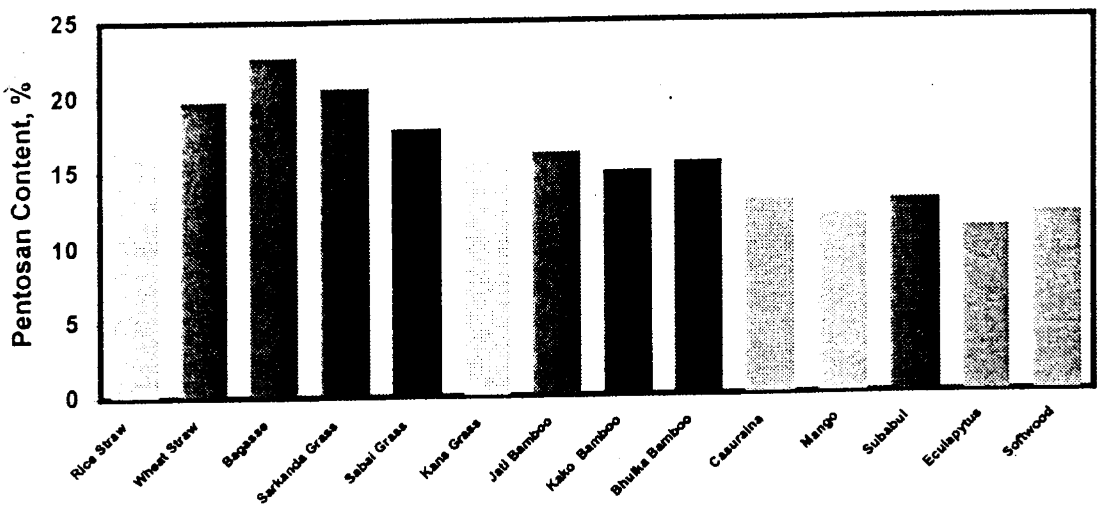
Mild alkali solubility of the raw material indicates the easily degradable content in the raw materials. This value influences the degradation of the raw material during the storage. The degradation (physical and microbial) is faster in the raw materials having higher soluble material. The degradation has two fold effect, the loss in quantity and quality of the raw material.

EXTRACTIVES IN DIFFERENT FIBEROUS RAW MATERIALS



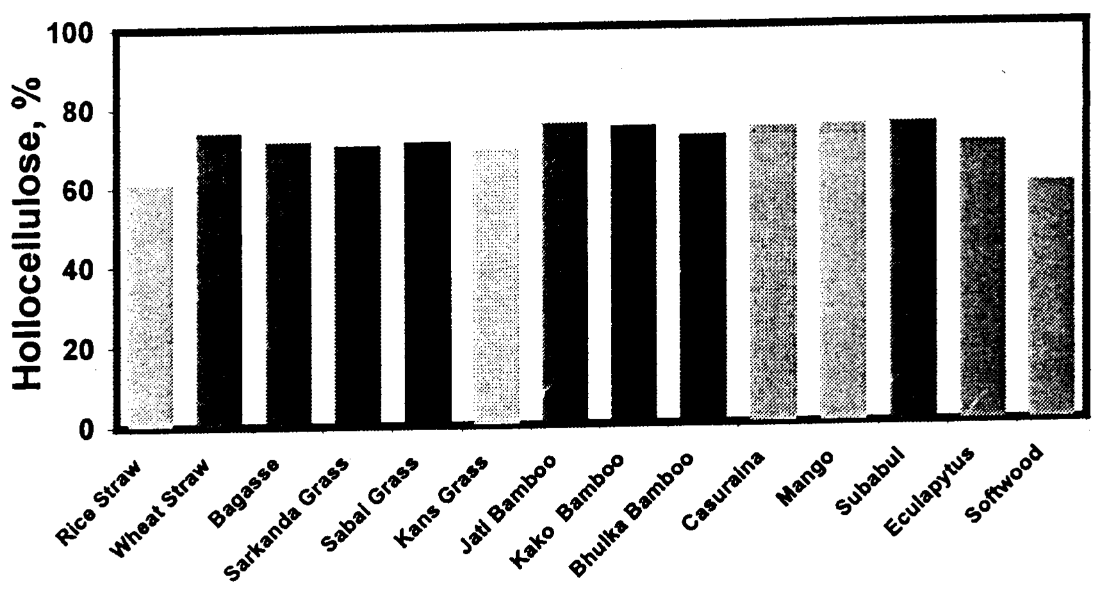
The extractives, which are extraneous components, include aliphatic and aromatic hydrocarbons, terpenes and their derivatives, alcohols, aldehydes, phenols, quinines etc. They may interfere with the pulping process, causes foaming and sometimes causes corrosion.

PENTOSAN CONTENT IN DIFFERENT FIBEROUS RAW MATERIALS



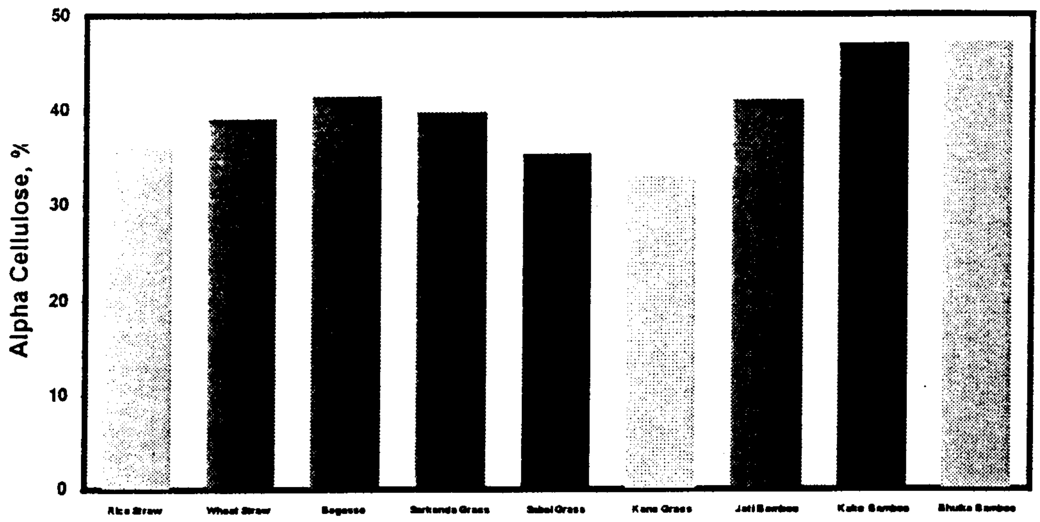
The non-cellulose polysaccharides of fibrous raw materials including the related substances such as uronic acids etc. and their substitutents. In the paper pulps, it helps in the fiber bonding and there is a fair correlation between hemicellulose content and paper strength expressed as tensile and bursting strength. Their presence in pulp are responsible for ease in beating of pulp.

HOLOCELLULOSE IN DIFFERENT FIBEROUS RAW MATERIALS



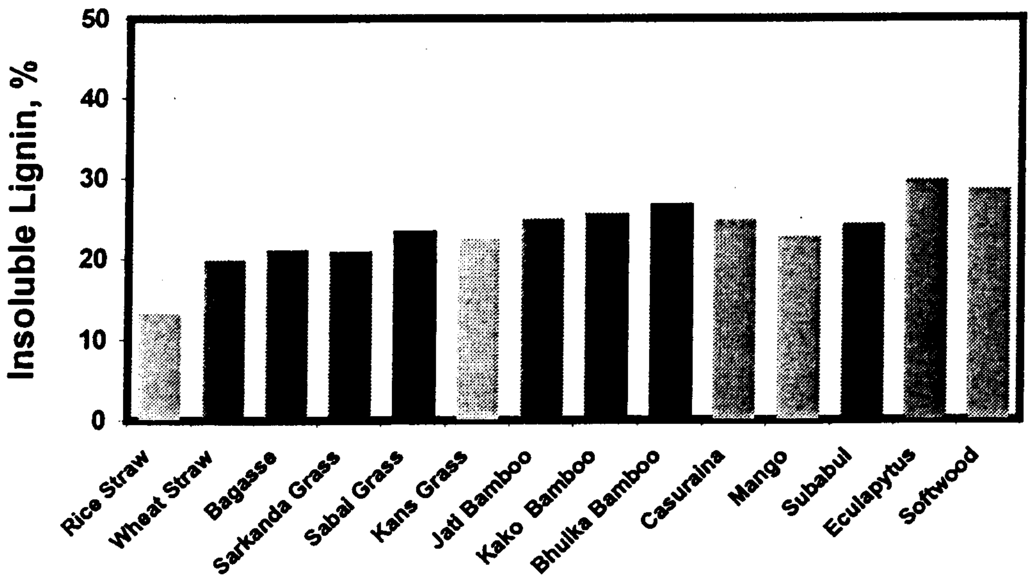
The total cellulose component in the raw material. It includes low molecular polysaccharides as well as straight-chained high DP cellulose. The yield of the chemical pulps mainly depends on holocellulose. The process variables influence the yield of the pulps by preserving the total polysaccharides to different degrees.

α – CELLULOSE IN DIFFERENT FIBEROUS RAW MATERIALS



High molecular weight cellulose is known as alpha cellulose. The fiber and paper strength and longevity of the paper depends on the purity of the cellulose. The alpha-cellulose is not easily degradable and withstands alkaline and acid treatments of wood during the fiber extraction process i.e. pulping.

KLASON LIGNIN IN DIFFERENT FIBEROUS RAW MATERIALS



Lignin is the aromatic polymer of wood consisting of four or more substituted phenylpropane monomers per molecule. The pulping processes target to remove the lignin to different extents to enable the liberation of fibers.

FURNISH REQUIREMENTS FOR VARIOUS GRADES OF PAPER AND BOARD

Paper or Board	Pulp Type	Contribution to Paper Furnish
Printing & Writing Paper		
Chemical Pulp	Softwood, bamboo Kraft Hardwood Kraft	Reinforcement Opacity, formation
	Softwood Sulfite Hardwood Sulfite	Reinforcement, opacity, general purpose Filler Pulp, Opacity, Formation
	Agro-residue Kraft & Soda	Filler Pulp, Opacity, Formation
Mechanical Pulp	Mechanical (bleached)	Opacity, Printability, Dominating Component
Newsprint	Softwood & Bamboo Kraft Mechanical	Reinforcement Main component, bleaching in case of dark wood or improved paper quality
Tissue	Various Chemical Pulps CTMP	Softness, absorption Absorption, Bulk
Packaging paper	Softwood, Bamboo Kraft	Strength (tensile strength, stretch and bursting strength)
Container Board and box board	Chemical Pulps	Appearance, printability, surface strength, z-strength
	CTMP, TMP	Bulk, stiffness

Contribution of fiber source to various paper properties

Agriculture Residues			Hardwood Chemical Pulp	Softwood Chemical Pulp	Mechanical Pulp
Straw & Bagasse	**Bamboo & Reed**	**Bast fiber**			
1. Formation 2. Opacity (expect Bagasse)	1. Strength 2. Runnability 3. Opacity 4. Bulk	1. Runnability 2. Fineness	1. Formation 2. Opacity 3. Surface smoothness	1. Strength 2. Runnability	1. Opacity 2. Bulk 3. Surface and pore structure for printability

ANNEXURE I

METHODS OF TESTS FOR FIBER ANALYSIS OF PAPER AND BOARD

Introduction:

Fibers are the basic component of a paper, and determination of fiber composition is essential in characterization of the paper. The methods of fiber analysis make possible the identification of the kinds of fibers present and determination of their relative amounts. The identification of fibers depends principally on the application of stains as they produce a variety of colors depending on the source.
Knowledge of fiber dimensions is very important since they help in identification of source. The dimensions of fibers and other pulp components influence the papermaking properties and have practical utility in the papermaking process.

Material Methods:

Apparatus

Dropper: About 10-cm long and 8-mm inner diameter, fitted with a rubber bulb and graduated to deliver 0. 5 ml.

Warming plate: electric, with level top having a black mat finish and with a control to keep the temperature of the surface at 50 to 600C.

Dissecting needles: preferably of platinum-iridium alloy or stain- less steel.

Microscope: Binocular compound microscope with a graduated mechanical stage, abbe condenser and optical equipment consisting of two eyepieces of x10 magnification is recommended for routine observations. Additional accessories like phase contrast and polarizing illumination systems will be of great help in identification of special features of fibers.

Projection Microscope: Any suitable projection microscope having x50, x100, x 200 and x400 magnifications may be used for case of measurements.

Testing Procedures:

Sampling: The sample should be representative of the whole of the material. Portions (total about 0. 2 g) are torn from the paper or paperboard to provide a representative sample. The sample is defibered by one of the fol- lowing procedures.

Preparation of sample: Sample may be placed in a beaker of 2 litre capacity and covered with one litre distilled water. It is heated gently to 70-80°C on a hot plate. After 20-30 minutes the beaker is removed from the hot plate and is allowed to cool. Volume of the water is raised to 2 lit. and the contents of the beaker are transferred to an electrically operated disintegrater having smooth edges with blunt blades. Fibers are thoroughly dispersed and while the fiber suspension is still in motion, one litre of the suspension of fibers is transferred to a graduated cylinder. Remaining one litre fiber suspension is discarded. The volume of the above one litre fiber suspension is again raised to 2 litre to give a fiber concentration of .05%. Fiber suspension is agitated again to ensure uniform consistency. One litre of above fiber suspension is discarded and t the remaining suspension of fibers is added one litre of water to give a consistency of 0.0125%. it is now ready for preparing microscopic slides.

NOTE : Selection of the proper consistency of fiber suspension may vary from raw material to raw material. A fiber concentration varying from 0.05% to .01% is suitable for the preparation of slides.

Preparation of slides: Parallel lines are drawn 25mm from each end of the slides (75mm x 25mm) with a glass marking pencil. The lines retain the fiber suspension within the 25 mm square. Any dust or lint is removed from the slides and these are placed on a warming hot plate, maintained at 50-60°C. the flask containing the defibered sample is vigorously shaken, and a portion of it withdrawn immediately with the wide mouthed dropper (id = 0.5 cm.) 0.5 ml. of the suspension is deposited on the centre of the slide. The water in the slides is allowed to evaporate until the fibers are barely suspended, then the fibers are distributed evenly with a dissecting needle. The slides are left on the hot plate until they are completely dry.

Selection of the proper consistency of fiber suspension for the preparation of slides: To choose the proper consistency of the fiber suspension for the preparation of slides, the slides are prepared at different consistencies e.g. 0.05%, 0.025% and 0.0125%. It is observed that 0.125% consistency of fiber suspension is most suitable for the preparation of slides from indigenous fiber sources. It fulfils the basic requirement of a properly prepared slide where the fibers are distributed evenly at low density on the slide and individual fibers can be examined. Slides prepared with fiber concentration of .05%.& 25% resulted in dense slides and it is difficult to examine each fiber. Selection of final consistency for preparation of slide differs from the consistency of 0.5% as mentioned in Tappi Standard T 401-05074. The difference is due to the nature and dimensions of the softwood fiber from hardwood and agricultural residue fibers as encountered in the Indian Paper Industry.

Staining: The C stain is suggested for general analysis. The 'C' stain (2-3 drops) is applied to the fibers on slide and cover glass is placed over it with care to avoid inclusion of air bubbles. The slide is allowed to stand for 1 to 2 minutes and the surplus stain is drained off the slides by bringing it into contact with a blotting paper.

Identification: The stained slide is placed in position on the stage of the microscope. For illumination, a 15-W "daylight" fluorescent tube, placed 10 to 12 in. from the mirror of the microscope, is recommended. The slide is examined for the different fibers, with attention given also to morphological characteristics. It is often desirable to prepare slides of authentic fibers for comparison with the sample. Following magnifications are recommended for observation of various pulp components and their measurement.

Particulars	Magnifications
Fiber length	x 50
Fiber width	x 125, x 480
Parenchyma cells, Epidermal cells and Vessels	x 125, x 480

Determination of fiber length: For the determination of fiber length and fiber diameter the slides are prepared at consistency lower than 0.125%. It is found that 0.01% consistency is suitable for determination of fiber dimensions. At this consistency no more than 75 fibers are distributed on the slide and it is easy to determine the dimensions of each fiber appearing on the slide. Fiber dimensions of more than 300 fibers are recorded for each type of pulp.

Determination of length and width of various morphological parts of fibrous raw materials: Length and width of various morphological parts of the given pulps may be determined to use it as a diagnostic feature of the pulp when present in unknown furnish. Since these morphological parts viz. Parenchyma cells, epidermal cells and vessels are sometimes very small, it is necessary to use high magnifications for the determination of their dimensions. The following table shows the various magnifications used in their measurements.

Weight factor determination: Determination of the weight factor involved investigation of the different pulp types appearing on the microscopic slide after developing colour with a proper stain. The following two methods are examined to count number of fibers on the slide

1. **Pointer method**
2. **Square method**

Pointer method: The stained slide is placed in position on the stage of the microscope. The pointer is moved with the mechanical stage so that the pointer is 2-3 mm from a top corner of the cover glass. The field is moved horizontally and the fibers of each kind are counted and recorded as they passed the pointer. Alternately separate passes may be made for each kind; provided care is taken to see that, the slide is not shifted even to the slightest extent either upward or downward. When all the fibers in one line are counted, the stage is moved 5 mm vertically; the fibers are counted similarly in the second line. The fibers are counted in five separate lines each 5mm apart.

If a single fiber passed the pointer more than once, it is counted each time. If the fiber followed the centre for some distance, it is counted only one fiber. Fragments below 100 μ are ignored but large fragments are added together mentally to give the equivalent of a whole fiber.

Square method: To check and prove the validity of pointer method, a square method is also tried which makes it possible to count the total number of fibers appearing for each kind on the slide. For case of counting, the cover glass is divided into nine equal squares. The fibers are stained with 'C' stain and the total fibers of each kind appearing in each square are counted and added up for all the nine squares.

After assigning an arbitrary value of unity for rag, wt. Factor of the given pulp is determined by the above two methods. Within experimental error and tolerance allowed both the methods relate well to each other and give similar values for weight factor. However for practical purposes the pointer method is quicker and hence this method is followed for subsequent determination.

Calculation:

The number count of each kind of fiber is multiplied by its respective weight factor to obtain the weighted count. The fiber composition for each kind of fiber is found from

$$\text{Fiber composition (\%)} = \frac{\text{Weighted count}}{\text{Total weighted count}} \times 100$$

Report:

Both fields on the slide are counted. If the results for the two fields vary for any type of fiber by more than the tolerances given below, one or more additional fields should be prepared and the average of results from all fields reported.

Percentage of Total	**Tolerance, %**
< 20 and > 80	+2
20 - 30 and 70 -80	+3
30 - 40 and 60 -70	+4
40 - 60	+5

The results are usually reported to the nearest 1%. A percentage of less than 2% is reported as a "trace.

Additional information, if any:

Fibers from different sources differ markedly in average weight per fiber. Use of a factor is necessary for calculating the percentage by weight for each kind of fiber. Whenever possible, the factor should be determined for the actual pulps used in the sample being analyzed. if this is not possible, the analyst should determine the factors for each type of pulp he is likely to encounter. The factors given in Table were determined by different individuals and agencies and should be used only as a guide when better factors are not available.

COLORS PRODUCED BY 'C' STAIN

Ground wood	vivid yellowish orange

Softwood pulps

Sulfite

Raw	Vivid yellow
Medium cooked	Light greenish yellow
Well cooked	Pinkish gray
Bleached	Light purplish gray to weak red-purp
High alpha	
Unbleached	Very pale brown to brownish gray
Bleached	Moderate reddish orange to dusky red

Sulfate

Raw	Weak greenish yellow
Medium and well cooked	Strong yellowish brown to moderate yellowish green and dark greenish gray
Bleached	Dark bluish gray to dusky purple

Hardwood pulps

Sulfite

Unbleached	Pale yellow-green
Bleached	Weak purplish blue to light purplish gray
High alpha Bleached	Moderate reddish orange to dusky red
Soda, sulfate, and neutral sulfite Unbleached Bleached	 Weak blue-green to dusky blue-green and reddish gray Dusky blue to dusky purple
Rag	Moderate reddish orange
Abaca (manila fiber) Raw Unbleached and bleached	 light greenish yellow yellowish gray to weak blue and medium gray
Jute Unbleached Bleached	 vivid yellowish orange light yellow-green
Straw, bamboo, bagasse, flax burds, and esparto Raw Unbleached and bleached	 Light yellow to weak greenish yellow Light greenish gray to dark bluish gray and medium purplish gray
Japanese fibers Gampi and mitsumata Kozo	 Light greenish yellow to light bluish Pinkish gray

PREPARATION OF 'C' STAIN

Solutions:

Aluminum chloride solution: AIC13- 6H20 (about 40 g) is dissolved in water (100 ml) to make a solution of 1. 15 specific gravity at 28'C.

Calcium chloride solution: CaCI2 (about 100 g) is dissolved in water (150 ml) to make a solution of 1.36 specific gravity at 28'C.

Zinc chloride solution: Water (about 25 ml) is added to dry ZnCL2 (50 g) to make a solution of 1. 80 specific gravity it 28'C. (Fused reagent- grade sticks in sealed bottles or crystals should be used; ZnCI2 from a previously opened bottle should not be used.)

Iodide-iodine solution: Dry potassium iodide (0. 90 g) and dry iodine (0.65 g) are dissolved in water (50 ml). The reagents are mixed and crushed together with a little water, and water is added slowly with stirring until the solution is complete.
Solution 1 (20 ml), solution 2 (10 ml), and solution 3 (10 ml) are mixed thoroughly; then solution 4 (12.5 ml) is added and mixed well. The mixture is poured into a tall, narrow vessel and placed in the dark. After 12 to 24 hr, when the precipitate has settled, the clear portion of the solution is pipetted off into a dark bottle and a leaf of iodine is added.

NOTE: The solution should be kept in the dark when not in use. Fresh stain should be made every 2 or 3 months. The C stain is very sensitive to slight differences in composition, and care should be taken in its preparation and use. The solutions should be of the exact specific gravity specified and measured accurately with graduated pipets. Dark-colored, glass-stoppered dropping/bottles, preferably wrapped with black paper, should be used as containers.

WEIGHT FACTORS OF WOOD AND NON-WOOD FIBERS

Sl.	Fiber type	IS:528 5-1998	CPPRI	TAPPI	SCAN G4:90	BROWNING
1.	Rag	1.00				1.00
2.	Rag (cotton, flax & hemp)				1.00	
3.	Cotton linters			1.25	1.25	1.25
4.	Bamboo, ubld & ble sulfate, sulfite &soda	0.78				
5.	Bamboo pulp				0.55	
6.	Sabai grass, ubld & bld soda	0.48				
7.	Bagasse, unbld soda	1.20				
8.	Bagasse, unbld for boards		0.75	0.90		0.90
9.	Bagasse ubld & bld for papers			0.80	0.75	0.80
10.	Straw for board			0.65	0.60	0.65
11.	Straw bleached			0.35	0.35	0.35
12.	Wheat straw unbleached		0.69			
13.	Wheat straw bleached		0.55			
14.	Rice straw unbleached		0.47			
15.	Rice straw bleached		0.43			
16.	Khar grass bleached		0.43			
17.	Khai grass bleached		0.44			
18.	Flax and Ramie bleached			0.50		0.50
19.	Flax pulp				0.80	
20.	Flax shives				0.40	
21.	Hemp unbleached soda	1.13				
22.	Esparto			0.50	0.50	0.50
23.	Abacca and Jute			0.55	0.55	0.55
24.	Jute unbleached		0.40			
25.	Jute stic unbleached sulfate	0.40				
26.	Sisal			0.60	0.60	0.60
27.	Indian spruce mechanical	1.40				
28.	Imported coniferous ubld & bld sulfate	1.04				
29.	Softwood ubld & bld sulfite & kraft			0.90		0.90
30.	Western hemlock			1.20		1.20
31.	Douglas fir			1.50		1.50
32.	Southern pine			1.55		1.55
33.	Alfa northern			0.70		0.70
34.	Alfa southern			1.50		1.50
35.	Softwood chemical pulps bleached				0.90	
36.	Softwood chemical pulps unbleached				1.00	
37.	Douglas fir inland variety				0.90	

38.	Douglas fir coastal variety				1.40	
39.	Southern yellow pine				1.40	
40.	Radiata pine				1.20	
41.	Softwood dissolving grade pulps				0.85	
42.	Softwood semi-chemical sulfite pulps				1.40	
43.	Softwood TMP				1.70	
44.	Softwood CTMP				2.00	
45.	Ground wood depending on its fineness			1.30	1.30	1.30
46.	Eucalyptus teretecornis bleached		0.30			
47.	Eucalyptus teretecornis bleached		0.28			
48.	Salai unbld & bld sulfate	1.16				
49.	Salai ubld & bld mechanical	1.40				
50.	Hardwood soda, sulfate or sulfite			0.60		0.60
51.	Gum			1.00		1.00
52.	Alfa northern			0.50		0.55
53.	Birch, Aspen, Poplar, Beech				0.50	
54.	Maple, Willow, Hickory				0.40	
55.	Sweet gum, Black tupelo, Tulip, Poplar				0.80	
56.	Eucalyptus, Oak				0.45	
57.	Hardwood semi-chemical Birch				0.90	
58.	Hardwood semi-chemical gums				1.30	
59.	Hardwood mechanical pulps				0.90	
60.	Wool				3.10	