A light microscope study of the Parenchymatic cells in some wood and non-wood raw materials

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ABSTRACT

The main raw material for the pulp and paper industry is wood and some suitable non-wood plants.

The anatomy of the fiber containing part of trees from the temperated zone is well known, and extensive studies have been made especially about the fiber properties.

The knowledge about the non-fibrous cells, in general, has been given less interest.

Many unforeseen problems in the pulping process are, however, due to the parenchymatic cells.

The objective of the present study was to focus upon the non-fibrous tissue in some hardwood and non-wood species.

An anatomical difference between tropical and temperated hardwoods is a generally higher proportion of axial parenchyma in tropical hardwoods, up to 50-60%. This can lead to an increase in pulping fines and a potential reduction in drainage on the paper machine.

By a series of micrographs of different hardwoods it is focused upon the non-fibrous tissue, pointing out why some species are less suitable than others.

The structure of jute sticks compared to kenaf sticks is analyzed and finally the difference in the parenchymatic tissue between bamboo and sugar cane.

Introduction

The fibrous content in the stem of trees and some non-wood plants is the main raw-material for the pulp and paper industry.

The stem of a plant performs several important functions :

1. Mechanical support of the body is given mainly by the fibers.
2. Conduction and storing of solutes and food stuffs take place in the parenchymatic tissue.

The parenchymatic tissue consists of living cells of different shape and functions

The amount and shape of the parenchyma cells are adjusted to the botanical requirements of different types of plants.

Typically the parenchyma cells have thin primary walls which are composed of cellulose with pectic compounds, non-cellulosic polysaccharides and hemicelluloses. In some cases, e.g. storage parenchyma these walls may become thicker due to deposition of carbohydrates in the wall. They may undergo sclerosis involving the formation of thick lignified secondary walls, to form sclerides. (Burns).

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Softwood Raw Materials

Softwood raw materials have only about 7% parenchyma cells by volume, and they do not represent a technical problem in the process, except some resin problems in acidic pulps.

The parenchyma cells in softwoods are brick-like thin-walled non-fibrous cells, very small compared to the fibers, and arranged in radial rows. (Fig. 1)

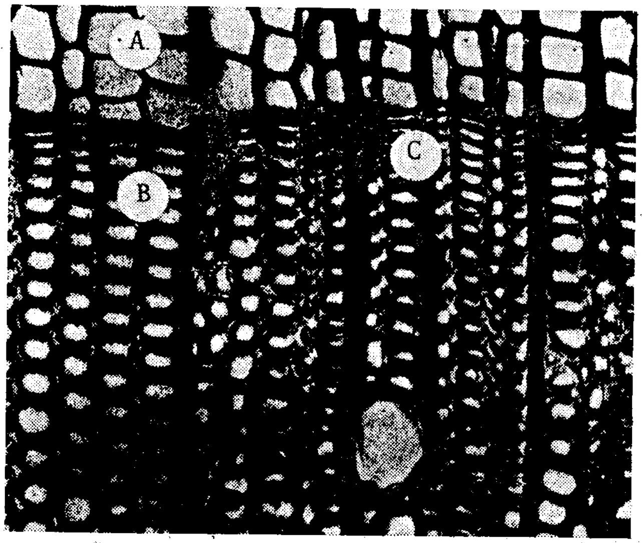

Fig. 1
Transverse section of Larix decidua, (Larch) Magn. 145x

A = Early wood fibers

B = Late wood fibers

C = Rays of parenchyma cells.

Hardwood Raw Materials

The botanical group of hardwoods is much larger than that of softwoods, Hardwoods grow in almost all regions of the world, from temperated to tropical zones. They have to be adaptable to varying growing conditions and have therefore a more complicated anatomy than the softwoods. Hardwoods are mainly rapidly growing trees and consequently they need an effective conduction and storing system. The parenchymatic network is therefore the most specialized tissue in the hardwood.

By volume the amount of parenchyma cells in hardwood trees from the temperated zone ranges from 10 to 35% by volume. (Fig. 2 and 3.) Many species are in spite of a very high parenchyma content an acceptable short fiber pulp raw-material. (Fig. 4)

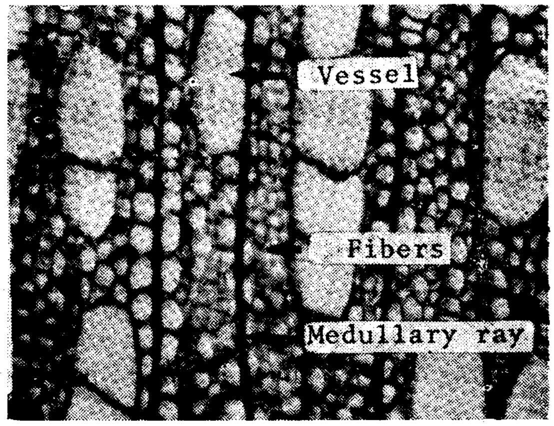

Fig. 2 Magnification 170 X

Transverse section of Poplus spp. (Aspen),

Showing a diffuse porous wood with narrow medullary rays.

13% parenchyma by volume.

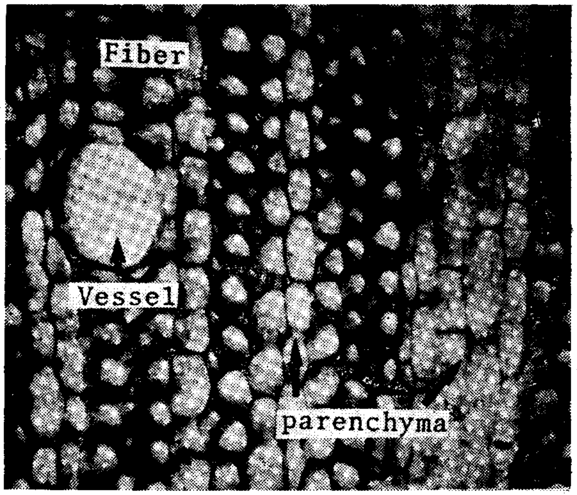

Fig. 3 Magnification 170 X

Transverse section of Fagus spp. (Beech),

Showing a diffuse porous wood with both narrow and wide medullary rays.

32% parenchyma by volume.

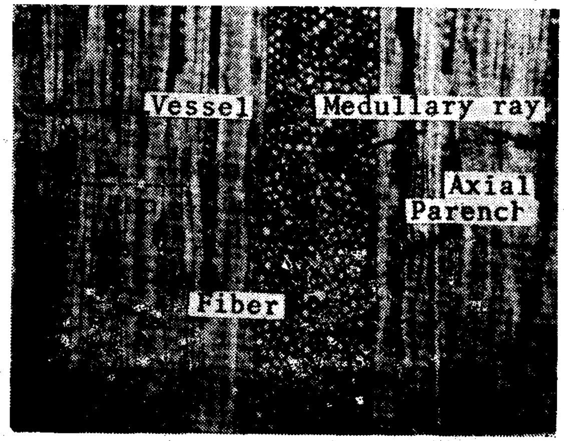

Fig. 4 Magnification 100 X

Tangential section of Fagus spp (Beech),

Here it can clearly be seen that the parenchyma are very small and mainly confined to the rays. The axial parenchyma is limited.

The cells are easy to screen away and Beech is an acceptable raw material.

Among the tropical hardwoods the variations are far more differentiated The percentage of parenchyma can reach up to 50-60% by volume. Normally parenchyma cells are confined to the horizontal rays Tropical hardwoods, however, often have a higher content of axial (longitudinal parenchyma and sometimes a solid network of cells is formed.

A reduced amount of fibrous material in a stem must be compensated by a certain rigidity of the parenchymatic tissue. The cells have to keep their turgor, when this is lost wilting occurs, and the plant dies. Thus the composition of the cell walls is adapted to the reinforcing need of the stem and the cells become more thick-walled.

Many hardwoods have therefore thickened parenchymatic cell walls, making the non-fibrous tissue more resistant to pulping.

Ceiba pentandra (Kapok) from Burma has been tried for high yield pulping (Yuzana Bo Ni and Nadeem Kausar, Norad project 1987), but was found most unsuitable because of the complicated morphology. A compact network of large axial parenchyma cells are surrounding the fibers and the medullary rays. (Fig. 5 and 6). Large clusters of cells have to be removed and a very low yield can be obtained.

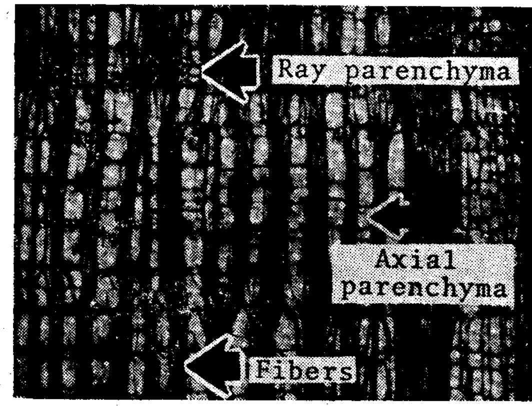

Fig. 5

Radial section of Ceiba pentandra. (Kapok)

The ray parenchyma are smaller and fewer in number than the axial parenchyma.

Magn. 60 X

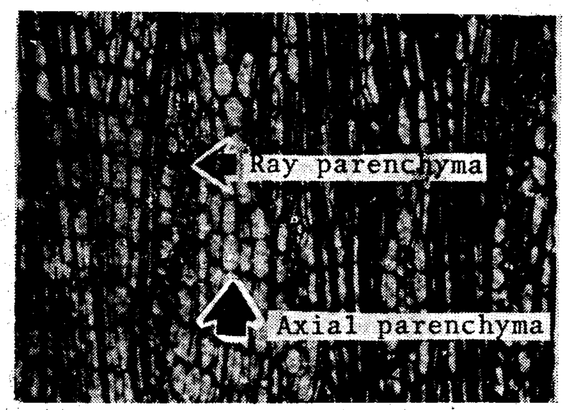

Fig. 6

Tangential section of Ceiba pentandra. (Kapok)

The parenchyma tissue is very compact and the fiber content is low.

Magn. 60 X

Inclusions in parenchyma cells

The cells of parenchyma frequently contain inclusions; these materials may be crystals, silica, and numerous materials of complex chemical nature, including gums, resins, tannins, oils latex, colouring matters, and nitro genous materials, such as alcaloids. Carbohydrates, usually in the form of starch grains, are also common, particulary in the sapwood of the stem. Crystals, mostly of calcium oxalate, are quite common, both in the longitudinal parenchyma and in the ray cells. (Panshin 1964)

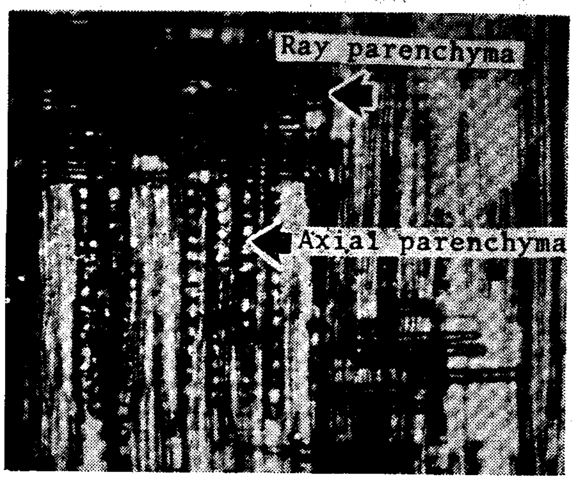

Fig. 7 Radial section of Leucaena. Magn. 75 X

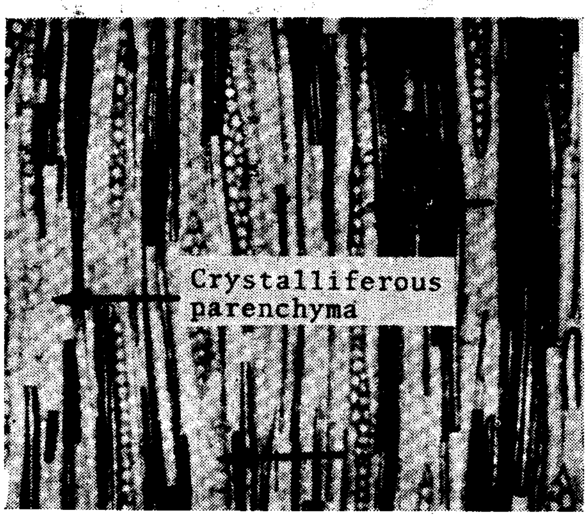

Fig. 8 Tangential section of Leucaena. Magn. 75 X

Leucaena leucocephala (Tanzania) is found to be suitable for unbleached and bleached kraft pulping (G. P. Reuben, Norad-project 1992).

Leucaena is a nitrogen fixing tree. The nitrogenous substance is stored in axial crystalliferous xylary parenchymatic cells. Figs. 7—8.

The cooking conditions were compared to Eucalyptus spp. from Tanzania.

Leucaena needed tough cooking conditions and consumed more chemicals to remove the crystalliferous parenchyma cells. Some unbroken cells could still be seen in the unbleached pulp. (Fig. 9). Most extractives were, however; removed during bleaching.

Fig. 9 Unbleached pulp of Leucaena, showing fibers and unseparated axial cells.

Pulping of mixed hardwoods means a blend of various species with a very different botanical structure. The problems to the pulpmaker are often related to the parenchymatic tissue.

For improvement of the pulp quality it is nessecary to exclude the most unsuitable species before pulping.

Botanical knowledge about the trees in the local forest is very important to make this evaluation possible.

It is a notable fact that the tropical hardwood species most commonly used for plantations have a law content of mainly thin-walled parenchyma (Acacia, Albizia, Eucalyptus etc).

This is a deliberate choice made by experience and knowledge of a suitable pulping raw material.

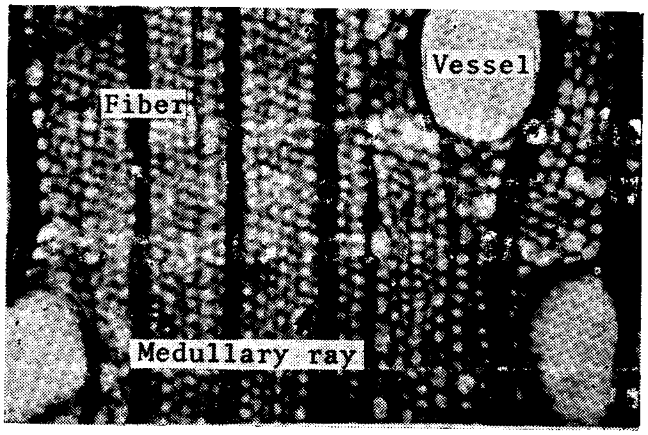

Fig. 10
Transverse section of Eucalyptus spp.
The medullary rays are only one layer wide.
No axial parenchyma is present.
Magnification 170 X

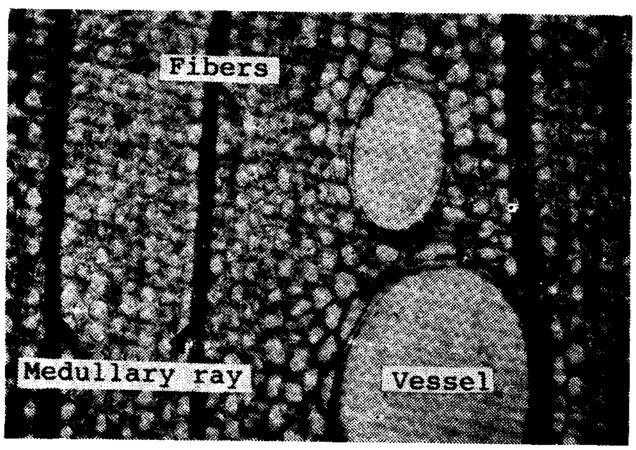

Fig. 11
Transverse section of Acacia mangium
Fibers with an open lumen.
Some large vessels and a law content of parenchyma.
Magnification 170 X

Non-Wood Raw Materials

Problems related to the parenchymatic cells in non-wood raw materials are well known, but basic information about the anatomical structure of these plants is still not sufficiently documented.

The parenchymatic tissue in non-wood plants is gradually changing during growth and cells are given various botanical functions. Thus cells of quite different chemical composition and dimensions can be found in the structure of the stem. This heterogenity of the cells in non-wood is causing very special pulping and screening conditions.

Jute-Kenaf (Mesta)

Jute and Kenaf are annual dicotyledonous plants, grown mainly because of the long phloem fibers. The woody core (the stick) is however, also a fiber source for papermaking, not fully utilized. The fibers are flexible but slightly shorter than hardwood fibers.

The sticks of kenaf and jute have a different anatomical structure. The kenaf stick is softer and more easy to break up in a pulping process than jute. The difference is mainly due to the amount and composition of the parenchyma cells.

In jute stick the ray cells have about the same diameter and cell wall thickness as the fibers, giving the whole structure a woody character. Fig. 12 Kraft pulping of jute stick have been studied by Ni Ni Myaing and Than Lwin Oo, Norad project 1989.

Kenaf has medullary rays composed of several layers of thin-walled cells, larger in diameter than the fibers. (Fig. 13.) In the kenaf stick these separate layers of strong fibers and a week parenchymatic tissue are more easy to attack in a pulping process. Thus the bast and the core can be processed in one operation.

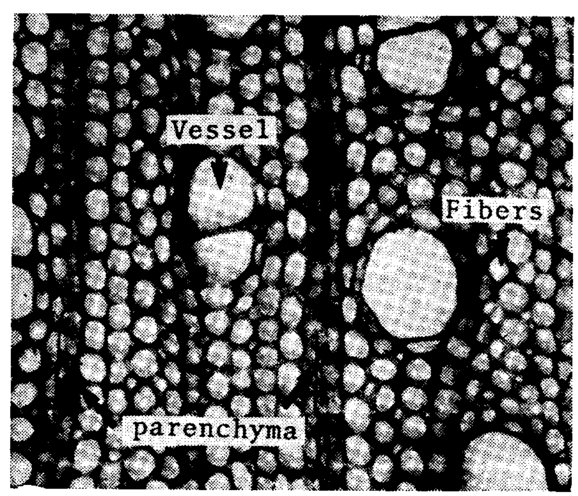

Fig. 12 Transverse section of
Jute stick
Magn. 200 X

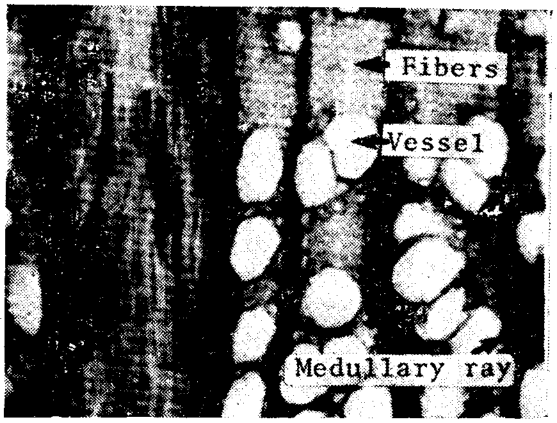

Fig. 13 Transverse section of
Kenaf stick
Magn. 200 X

Bamboo—Sugar cane

These are two raw materials commonly used by the pulp industry. They are monocotyledonous plants belonging to the large grass family. The fibrous material is concentrated in vascular bundles. The two species have very different botanical composition.

Bamboo is extremely rapid growing and tall and need a very strong stem. Sugar cane has a stem with scattered fiber bundles in a tissue of sugarstoring cells and needs in addition only surrounding support and protection. The nature has organized this difference mainly by differentiation of the parenchymatic tissue.

In bamboo the characteristic vascular bundles are reinforced by formation of extra xylary bundles The fibrous material is bound together with a very strong network of thick-walled parenchymatic cells, giving the stem the additional rigidity. It is a great advantage for the pulp makers that these cells are small and rather uniformed in size.

A transverse section of sugar cane shows two separate zones. The dense rind where the most valuable fiber bundles are found and the central part mainly containing sugar storing cells. The parenchyma cells in the center are large and thin-walled, In the rind they become gradually smaller and the cell wall becomes sclerified. This difference in dimentions and wall thickness creates the wellknown screening problems of bagasse.

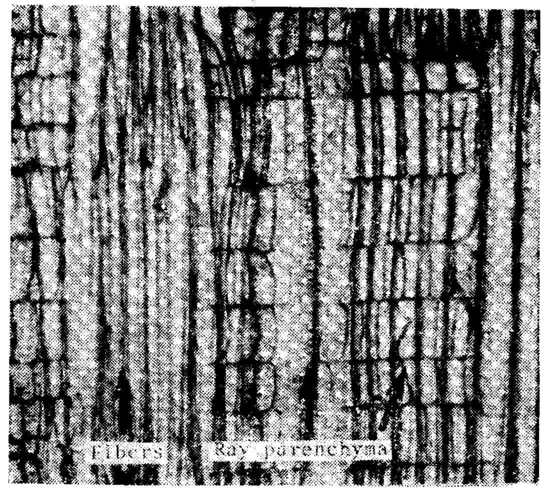

Fig. 14
Radial section of Jute stick, showing a strong network of parenchyma.
Magn. 160 X

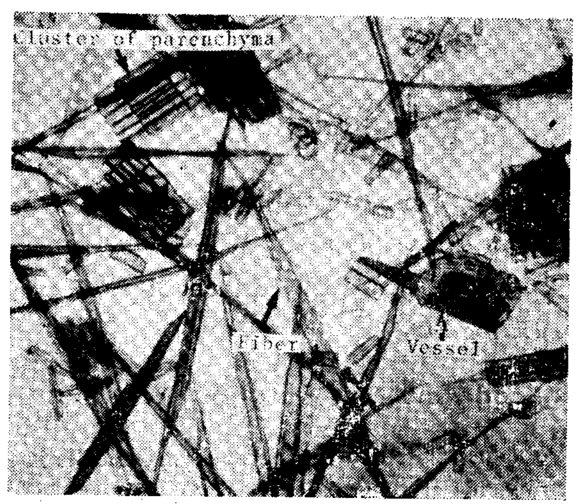

Fig. 15
Jute stick kraft pulp
Magn 70 X
Klusters of parenchyma are still present.

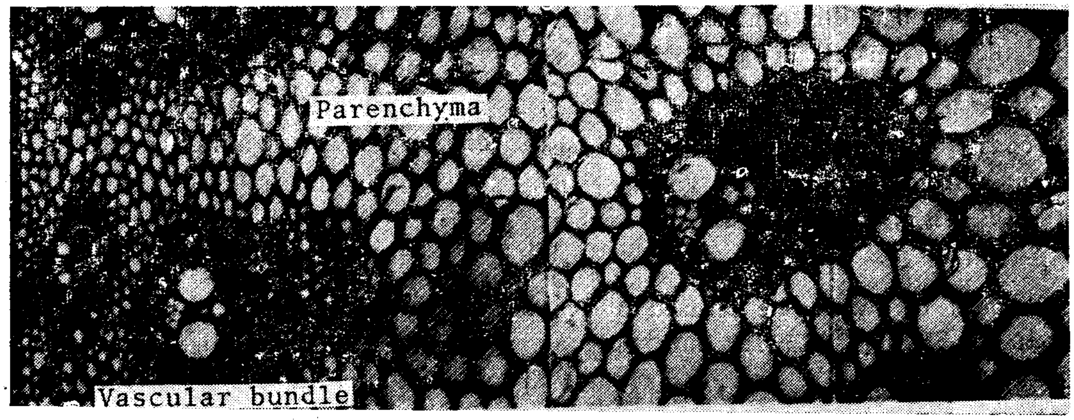

Fig 16 Sugar cane. Cross sectional view of the rind zone.

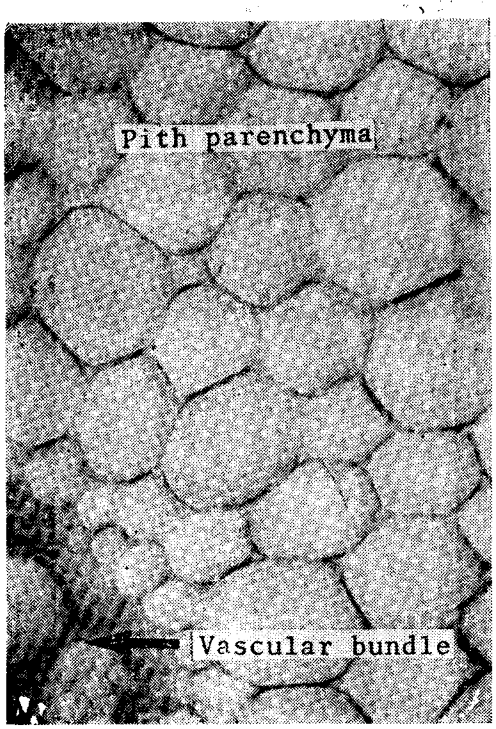

Fig. 17 Sugar cane
Cross sectional view of
the pith zone
Magnification 200 X

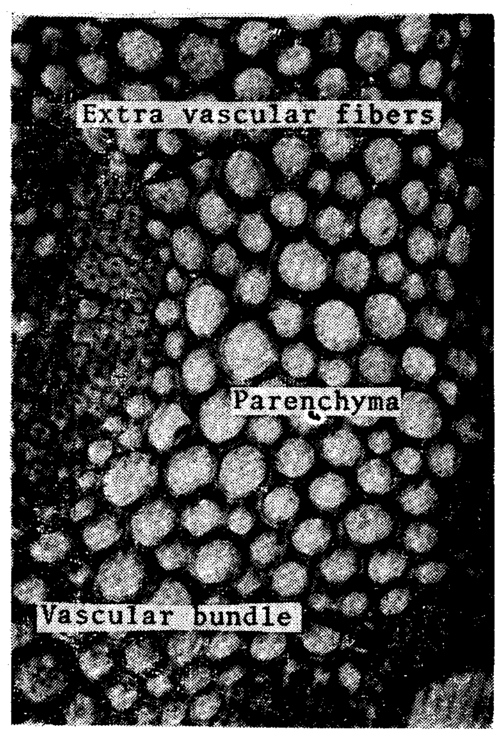

Fig. 18 Bamboo
Cross sectional view
Magnification 200 X

Conclusion :

The parenchyma cell wall is complex and varies with the species, the cells can contain lignified secondary walls.

In hardwoods from the temperated zone the parenchyma ranges from 10 to 35% by volume. In some tropical species it may comprise an appreciable volume of the wood, at times more than 50%.

Domestic tropical hardwoods are selected to have a low content of parenchyma, from less than 10% to about 18% by volume.

Tropical hardwoods have a more complicated cellular morphology and a higher proportion of axial parenchyma.

Axial parenchyma cells are often larger and have thicker walls than radial parenchyma, and therefore more difficult to attack in the pulping process.

Jute stick has thick-walled parenchyma and a more woody character than the core of kenaf (mesta).

The parenchyma cells in kenaf are larger than in jute, forming rays of several layers, thus the structure becomes softer and easier to break down.

Bamboo has a very strong parenchymatic tissue, formed by relatively small thick-walled cells. The dimensions of the cells are almost uniformed, compared to sugar cane.

Sugar cane on the other hand has a variety of parenchyma cells. Both the wall thickness and the dimensions vary within the plant stem causing well-known screening problems. The parenchyma cells in the rind zone are thick-walled and difficult to attack, only the cells in the pith zone are thin-walled and easy to depith.

Botanical knowledge is important for correct utilization of the different raw materials. especially in blends of species.

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