Structural Features of Rubber Wood

C.P. Reghu
Rubber Research Institute of India, Kottayam, Kerala

Introduction

The centre of origin of *Hevea brasiliensis*, the para rubber tree, is the Amazon basin and adjacent areas of Brazil. It has also flourished in certain other countries belonging to the American continent such as Bolivia, Peru, Equador, Colombia, Guyana, Surinam and Venezuela. Though ten species of the genus *Hevea* have been reported so far, *Hevea brasiliensis* is the only species being cultivated commercially for natural rubber production.

Sir Henry Wickham, known as the father of natural rubber, made a collection from a very small area near the confluence of River Tapajos and the Amazon (Schultes, 1977). Of the 70,000 seeds he sent in 1876 to Kew Gardens, London, 2700 germinated. From these 1919 were sent to Ceylon (of which 90% survived), 50 to Singapore (none of which survived) and 18 to Java of which 2 survived (Dijikman, 1951). In 1877 another consignment of 22 seedlings was sent to Singapore and all of them survived. These initial planting materials together with other rubber trees grown in Ceylon from the Wickham seedlings were the foundation on which the great Malaysian industry is based (Barlow, 1978). Though various collections were made in the past the fate of those collections is highly controversial as there are no conclusive records to prove that any of them survived at all. Historically, the consensus on the source of the planting material to the South East Asian rubber plantations is that it had originated from the Wickham collections, also referred to the 'Wickham base' and from these, rubber spread to all other Asian countries (Schultes, 1977; Simmonds, 1989).

In 1879, 28 rubber plants were introduced to India from Ceylon and planted in Nilambur, Kerala State. Besides, small consignments reached India during 1880, 1881 and 1886 and were planted on an experimental scale in different parts of southern India (Radhakrishna Pillai, 1980). However, the first commercial plantation of rubber was started in India by European planters in 1902 at Alwaye. The subsequent increase in area under the crop is mainly attributable to the enterprise of a large number of Indian proprietary planters belonging to the former native States of Travancore and Cochin.

Rubber - A source of timber

Rubber tree (*Hevea brasiliensis* [Willd.ex Adr. de Juss.] Muell. Arg.) is a perennial dicotyledonous species belonging to family Euphorbiaceae. The tree has a straight trunk of 3-4 m, attaining 700-1100 mm diameter at breast height with a profusely branched dense canopy. The tree grows to a height of about 30 m. The girth of the trunk may vary from tree to tree depending on clonal and agro-climatic factors. Nevertheless, the trees raised from seedling population normally show a higher girth compared to those raised from bud-grafted planting materials. Over the time, bud grafted plants became common in all the major rubber producing countries as the primary objective has been to obtain higher level of latex yield rather than the timber. This development had serious implications on the yield of timber per tree compared to the availability during the early times as the volume of the timber is directly proportional to the girth of the timber species. It has been estimated that a seedling tree gives 1 m^3 timber and a budded tree gives 0.57 m^3 timber at the time of clear felling, of which 60 per cent is trunk wood and 40 per cent branch wood (Haridasan and Sreenivasan, 1985).

Gross structure of rubber wood

Rubber wood shows the general gross structure of dicotyledonous timber with certain characteristics specific to the species. Based on the density classification (Bosshard, 1966), rubber wood comes under the category of light hardwood.

Rubber Wood Processing and Utilisation in India. (Eds. R. Gnanaharan, George Thomas and K. Damodaran). Science and Technology Entrepreneurs Development Project, Kozhikode, Kerala, pp. 10–18.

The wood is diffuse porous, straight to slightly interlocked grained and medium coarse textured with a characteristic odour of rubber latex when freshly cut. Freshly sawn timber (green wood) is whitish yellow in colour and turns pale cream after drying (Figs. 1, 2,3,4). Usually growth rings are absent or ill-defined in rubber wood and the growth ring like structure displayed in the cross sectional view of the timber are merely false rings which are formed by the distribution pattern of reaction wood (tension wood) fibres in association with apotracheal banded parenchyma (Figs. 1&2) which is a characteristic feature of rubber wood.

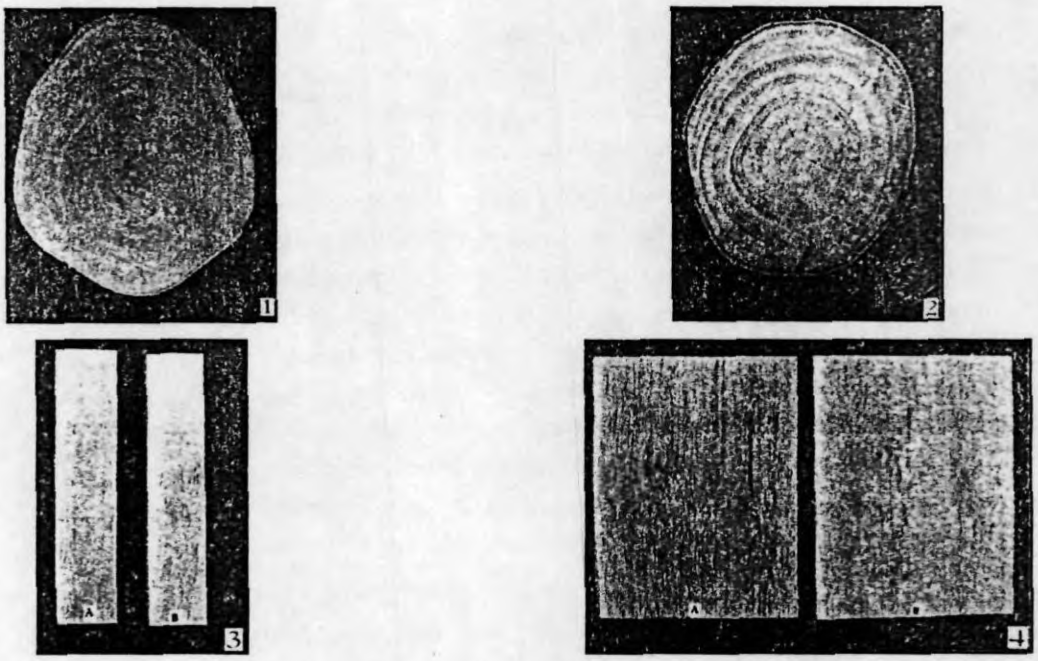

Fig. 1-4 : Rubber wood discs and sawn planks from different clones showing natural colour and tension wood zones (white wooly lustrus arcs).

1. Clone RRII 105 2. Clone GT1

3. Freshly sawn unseasoned planks showing whitish yellow colour. A.RRII 105. B. GT1.

4. Seasoned planks showing pale cream colour. A.RRII 105. B. GT1.

The sapwood is not differentiated from heartwood due to the lack of deposition of pigmented extraneous materials that usually occur during the heartwood formation in other hardwood timber species. Heartwood formation is a long term ageing process in wood where the reserve metabolites get converted into pigmented substances during the course of necrobiosis of storage cells. Though reserve metabolites in the form of soluble sugar, starch, etc., are abundant in rubber wood, the conversion of these materials into heartwood substances does not take place during the course of its economic life span. Hence, heartwood formation is virtually absent in rubber tree and the storage tissue is filled with soluble sugar and starch which in turn is easily attacked by biological agents.

Early wood and late wood formation is not possible in rubber wood even though significant seasonal variation has been reported during the growth phase of the tree (Rao. 1975). This could be due to the long and continuous period of cambial activity associated with the fast growing nature of the tree.

Anatomy of rubber wood

The proportion of timber vary according to the structure and composition of wood elements and may vary even within a tree. Hence, a thorough knowledge about its anatomical characters and alignment of tissues is necessary.

Macroscopic and microscopic examination of wood sections at transverse (T.S), tangential longitudinal (T.L.S) and radial longitudinal (R.L.S) plane displays the dimensional structure of wood and the orientation of wood elements (Fig. 5). Rubber wood is composed of fibres, vessel elements (pores), axial parenchyma and rays distributed in different patterns and proportions as in other hardwood species. Bhat *et al.* (1984) quantified the proportion of elements in rubber wood (Table 1) and concluded that the proportion of wood fibres is moderate in comparison to other fast growing timber species like *Gmelina arborea* and *Eucalyptus* spp.

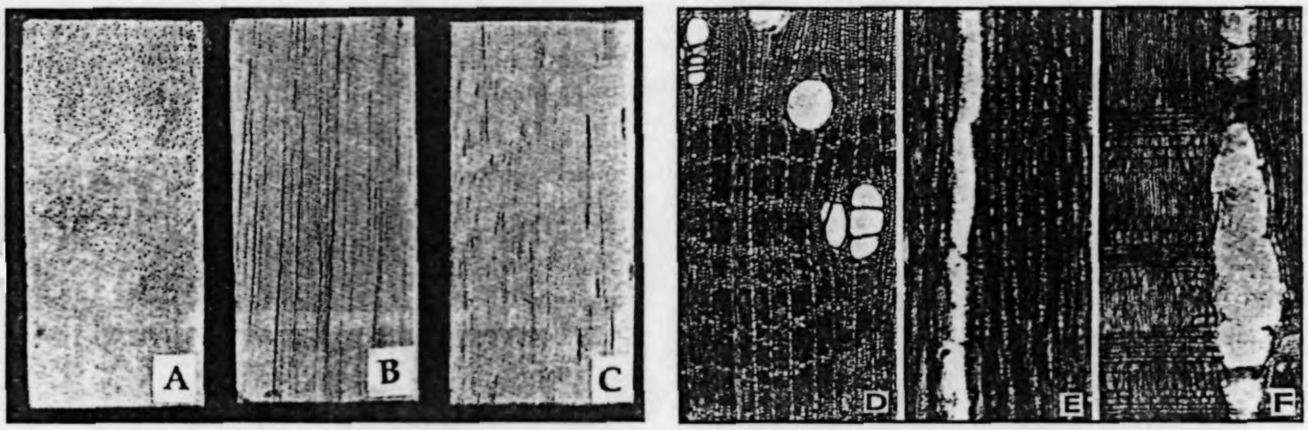

Fig. 5 : Structural features of rubber wood showing the alignment of wood elements at different planes.
A,D : Cross section (C.S).
B,F : Tangential longitudinal section (T.L.S.).
C,F: Radial longitudinal section (R.L.S.)
A to C : Macrophotographs of wood specimens (X 1.3)
D to F : Photomicrographs of wood sections (X 46)

Table 1. Proportion of rubber wood elements and dimension of fibres and vessels

Elements	Proportion (%)	Dimension			
		Length		Width	
		Range	Mean	Range	Mean
Fibres	58.0	1.1-1.4mm	1.19mm	19-27μ	22 μ
Vessels	8.5	154-798 μ	500 μ	70-224 μ	155 μ
Rays	22.0	-	-	-	-
Axial parenchyma	11.5	-	-	-	-

Source: Bhat et al. (1984); Reghu et al. (1989)

Fibres

Fibres are non-septate and belong to the medium group with an average length of 1.1-1.4 mm (Bhat et *al.*, 1984; Reghu *et al.*, 1989). They are square to rectangular in shape and are aligned radially in transverse sections, with an average wall thickness of 3.5 μ. In a mature tree, the length of fibers increases from pith outwards with a decreasing trend near the bark region. Reghu *et al.* (1989) reported significant variation in fibre length at different heights of the tree trunk. The width of fibers ranges from 19-27μ with an average value of 22 μ.

Vessel elements

The diffuse porous nature of rubber wood is caused by the distribution pattern of vessel elements or pores. The structure, alignment and properties of pores also determine the chemical impregnation capacity of rubber wood during preservative treatments.

The vessels are evenly distributed as solitary or radial multiples of 2-3 or rarely more, with 1-4 pores per mm^2. They are moderately large to small, and visible to the naked eye (Figs. 5 A & D). The vessel lines are clearly visible in the longitudinal plane (Figs. 5 B, C, E and F). The vessel members are 154-798 μ in length (mean 500 $\pm$ 46 μ) with a diameter ranging from 70-224 μ (mean 155 $\pm$ 9 μ). The lumen is usually filled with balloon-like parenchymatous structures, called tyloses, formed by the ingrowth of parenchymatous cells towards the vessel lumen through the pit cavities of the vessel walls.

Tylosis: Occurrence of tylosis (Figs. 8 A & B) is a characteristic feature of rubber wood. The presence of tyloses in wood is helpful in checking fungal growth inside the wood during storage but affects the permeability of wood to liquids. However, in rubber wood, the presence of tyloses does not block free entry of wood preservatives. It had long been proved that artificial wounding of bark accelerated tyloses formation in wood of certain other species (Isenberg, 1933; Kramer and Kozlowiski, 1960). In this context it is reasonable to believe that tyloses formation in rubber tree is unavoidable as tapping for rubber latex is a continuous wounding process of the bark which in turn may stimulate the formation of tyloses.

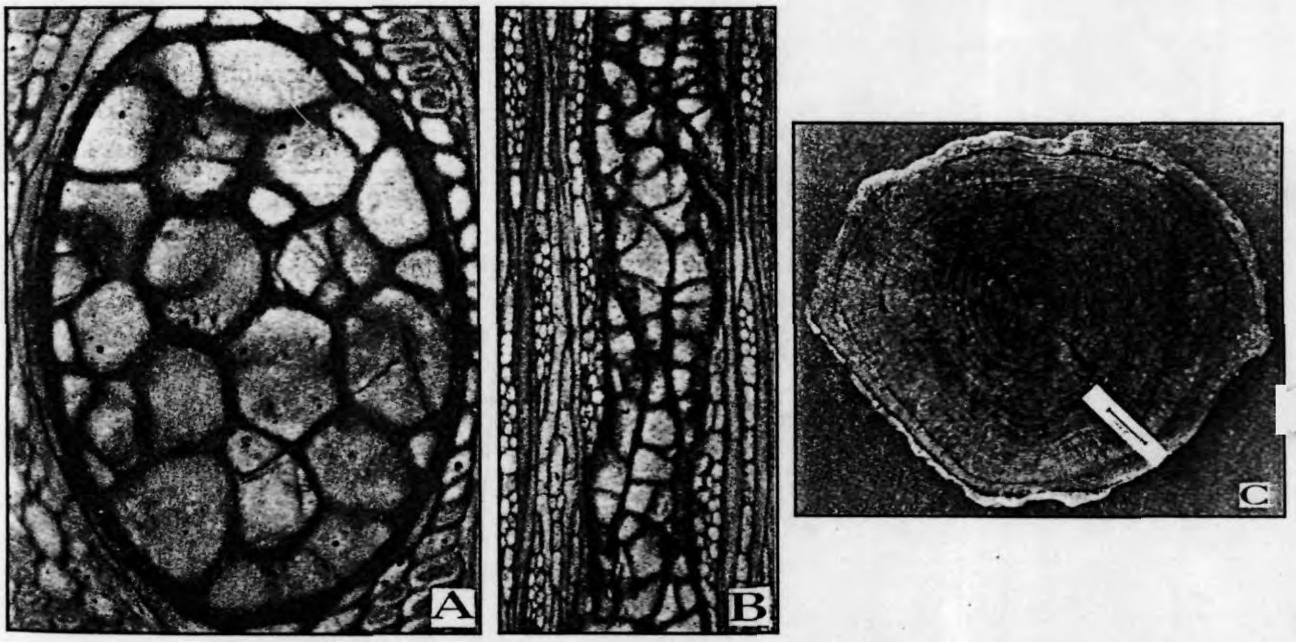

Fig. 8 : Rubber wood showing tylosis formation and discolouration causes by tapping wound.
A. Vessel lumen filled with tyloses (c.s) x 180
B. Tangential view of vessel elements showing tyloses formation. x 112
C. Wood disc showing tapping wound and dis colouration (arrows) in different panels of the tree at different periods of tapping.
Clone - PB 86.

Parenchyma tissue

Axial and ray parenchyma are the parenchyma tissue in wood. They are considered as soft tissues with the main function of storing the reserve metabolites. The axial parenchyma is apotracheal and banded with undulating lines. Scanty paratracheal parenchyma are also found in association with vessel elements. The rays are heterogenous, uni to penta seriate. Both axial and ray cells occasionally have crystal deposits.

While an increase in the proportion of fibres will increase density, an increase in the proportion of soft tissues in wood will reduce the density as a whole. In rubber wood, the higher percentage of soft tissue (33%) reflects its light hardwood nature. Moreover, unlike in other durable hardwood species the soft tissues in rubber wood are almost filled with reserve metabolites, especially in the form of soluble sugar and starch, without any protective quality. Hence, it is highly susceptible to the attack of biological agents and deterioration under natural conditions.

Tension wood

Tension wood is considered as a defect and it is an abnormal structure of wood. The degree of modification of wood anatomy involved in tension wood formation is extremely variable within and between tree species (Necesany, 1958). The tension wood fibres are partially lignified unlike normal wood fibres which are lignified.

In rubber tree, the formation of tension wood is a common phenomenon. Its impact on rubber tree architecture has been studied extensively by Fisher and Stevenson (1981). Out of the 18 tree architectural models reported, rubber tree comes under Rauh's model where the orientation of axes takes place due to the angle of inclination caused by the movement of canopy, wind blow and gravitational response, resulting in the initiation of tension wood formation on the lower side of the inclined axes and later forms on the other zones of the axes. According to the above phenomenon, the distribution of tension wood is not restricted to a specific zone of the axes in rubber tree unlike in other hardwood species where its formation is usually limited to the upper side of the leaning stems and branches.

Distribution pattern of tension wood

Based on the distribution pattern, tension wood has been classified into (i) compact tension wood and (ii) Diffuse tension wood. In the former type, the tension wood fibres are concentrated in a particular region of the tree axis in the form of compact arcs or bands, whereas in the latter type, the fibers are scattered singly or in small groups among the normal wood fibres (Fig. 6 A). When the tree is felled and freshly cross cut, the compact arcs are clearly visible even to naked eye as white 'wooly' lustrous zones (Figs. 1 & 2). However, in diffuse types the fibres are recognised only with the aid of a microscope after staining wood sections with specific stains. The presence of compact tension wood in association with the apotracheal banded undulating parenchyma is exhibited in the growth ring-like structure in rubber wood (Fig. 6 A).

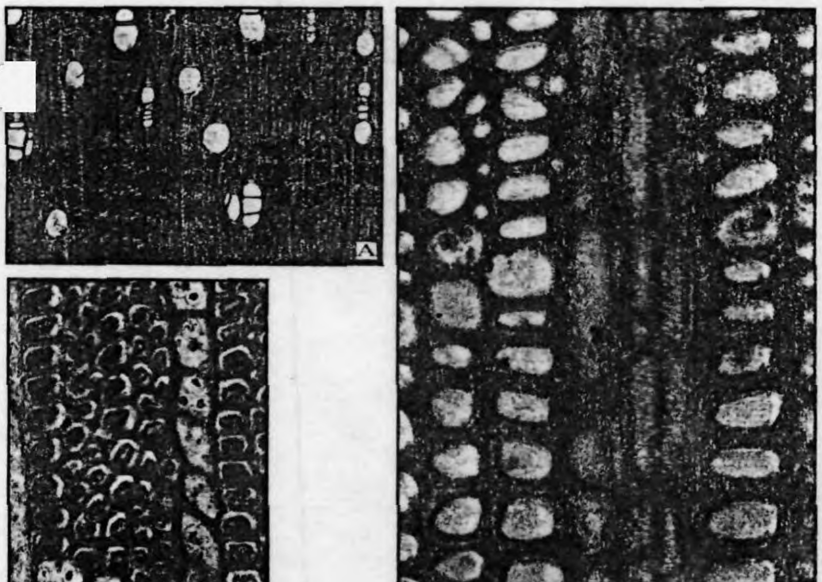

Fig. 6: Cross section of rubber wood (stained with Toluidine blue 'O') showing the distribution pattern of tension wood and normal wood fibres.

A. Compact tension wood formed as continuous bands (dense violet coloured bands), and discrete groups of diffuse tension wood fibres (arrows) among normal wood fibres. X 46.

B. Unlignified gelatinous layer of tension wood fibres (G-fibres) showing convolutions and detachment from the adjacent walls. X 320.

C. Lignified normal wood fibres. X 320.

Proportion of tension wood

The proportion of tension wood in rubber wood varies from tree to tree and within the same tree along the length of trunk depending on the influence of the environmental factors where it grows. The quantification of tension wood is extremely difficult due to random distribution of diffuse tension wood fibers among the normal wood fibres. Panikkar (1971) reported the occurrence of tension wood in *Hevea brasiliensis*. Sharma and Kukreti (1981) reported 15-68 per cent tension wood in random samples of three rubber wood logs. Vijendra Rao *et al.* (1983) studied the proportion of tension wood in rubber wood and found that tension wood varied in different samples taken longitudinally from the same tree and between different trees and its proportion (compact and defuse tension wood) ranges from 15-65 per cent. Reghu *et al.* (1989) observed a gradual increase in tension wood proportion from base to top of the tree trunk of two trees (Clone PB 86) at the age of 35 years. The proportion ranged from 8-36 per cent (Table 2). Ani Sulaiman and Lim (1992) from Malaysia studied the percentage of tension wood in two clones (PB 260 and RRIM 600) at different ages and height positions of rubber tree and found that RRIM 600 had a lower percentage (30) whereas PB 260 had 40 per cent. T[illegible] proportion of tension wood in PB 260 increased with height whereas a decrease with height was noticed in RRIM 600 (Table 3).

Table 2. Proportion (%) of normal wood and tension wood (compact tension wood) at different height levels of rubber tree (clone PB 86) at 35 years of age

Height levels (m)	Tree No. 1		Tree No. 2	
	Normal wood	Tension wood	Normal wood	Tension wood
0.6	91.55	8.45	88.50	11.50
2.1	70.63	29.37	66.78	33.22
3.6	64.36	35.64	63.88	36.12

Source: Reghu et al. (1989)

Table 3. Proportion (%) of tension wood in rubber wood at various ages and tree heights

Clone	PB 260				RRIM 600			
Age (Year)	Bottom	Middle	Top	Mean	Bottom	Middle	Top	Mean
3	35	40	57	44	-	-	-	-
8	27	29	37	30	42	33	25	33
14	49	36	52	45	-	-	-	-
24	-	-	-	-	39	29	25	30

Source : Ani Sulaiman and Lim (1992)

Structure of tension wood fibres

Anatomically tension wood differs from normal wood in many of its properties and most of these differences are mainly associated with its fibre structure. Tension wood fibres are specialised fibres called gelatinous fibres (G-fibres) where one of the layers of the secondary wall is unlignified and made up of crystalline cellulosic microfibrils which gives its characteristic gelatinous nature. In rubber wood the third layer of the secondary wall is unlignified (Vijendra Rao *et al.*, 1983) with a fibre wall structure of P + S1 + S2 + S3(G) as shown in Figure 7.

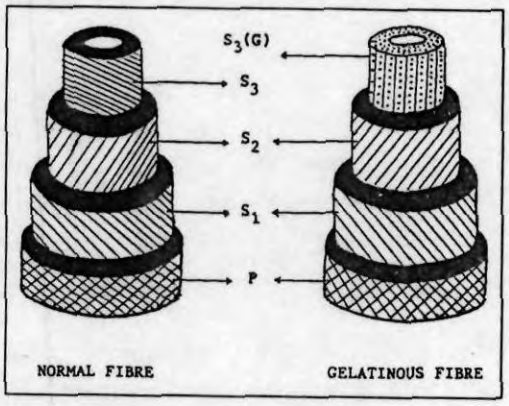

Fig. 7 : Diagrammatic representation of the organisation of fibre walls in normal and tension wood fibres in rubber wood.
P- Primary wall
S1, S2, S3 - Secondary wall layers (lignified)
S3 (G) - Third layer of the secondary wall (unlignified gelatinous layer).

where P - Primary wall (lignified)

S_1, S_2 - secondary wall (lignified)

S_3 (G) - third layer of the secondary wall (unlignified and gelatinous)

The G-layer usually remains intact with the non-gelatinous wall or shows partial or total detachment and appears as a dense mass in the fibre lumen (Fig. 6 B).

Defects of rubber wood

The defects or de-merits of rubber wood can be broadly grouped into five.

(i) Natural defects

(ii) Machining defects

(iii) Seasoning or drying defects

(iv) Tapping marks

(v) Biological defects

1. Natural defects

Tension wood, knots, juvenile wood and taper are generally considered as the natural defects in rubber wood. The incidence of tension wood in rubber wood has given rise to various problems at different stages of processing and utilization. The major problems are associated with machining, seasoning and finishing properties depending on the distribution and quantity of tension wood formed.

Knot : The left-over portions of the branches present in the main trunk after cutting the branches are called knots. Ho (1992) reported the frequency of knots on the sawn timber from the clones PB 260 and RRIM 600 at the age of 3,8,14 and 24 years. The study revealed that more than 56 per cent of the sawn boards were free from knots in older trees and less then 30 per cent of the boards in 3-year-old trees were free from knots.

Juvenile wood : The wood produced in young trees, the wood formed during the early years of older trees and the wood of most branches are generally referred to as juvenile wood. When a tree is mature the wood formed in the outer zone is termed as mature wood. Juvenile wood is different from mature wood in many respects such as cell size, fibre wall thickness, microfibrillar orientation, proportion of wood elements, ring width, etc. The proportion of juvenile wood is an important factor determining the quality of sawn timber especially for ascertaining the processing problems. Bhat et al. (1984) reported the presence of juvenile wood in rubber tree up to about 90 mm radius from the inner pith with variation in its fibre length and basic density.

Taper : The reduction in the diameter of the tree or log from base upwards is termed as taper which is considered as a defect when the conical form is pronounced. The extent of taper varies with age of the tree, influence of environmental factors and cultural operations. Rubber trees raised from seedling population show a tapering trunk from base to top whereas bud grafted trees always produce cylindrical trunks. Though taper creates certain practical problems during stacking, transporting and sawing of timber, in general, it is not reported as a serious problem in rubber wood.

2. Machining defects

The abnormal structure and peculiar properties of the gelatinous fibres in tension wood result in various woodworking and machining problems. While cutting and sawing, the G-layer tends to detach from the adjacent walls due to lack of adhesion between the G-layer and other cell wall layers, and frequently from convoluted masses in the fibre lumen or pulled out. This in turn sticks to the saw blade and disturbs its free movement. Tension wood zone always depicts a rough surface while planing and finishing which will make the end products less attractive. During peeling, green wood often produces rough and wooly surface as the fibres tend to be partly torn out.

3. Seasoning defects

The seasoning defects related to the structural features of rubber wood are mainly associated with the quantity of tension wood formed. As the G-layer is unlignified, longitudinal shrinkage of tension wood fibre is very severe during drying and causes uncontrollable distortions. Major seasoning or drying defects caused by tension wood are warping in the form of twisting, bowing, cupping, collapse, springing, etc. which in turn will result in dimensional instability of sawn planks and associated machining problems.

4. Tapping marks

Bark is the most important part of the rubber tree where latex is formed. It is the tissue formed outside the cambium. Mature bark has an outer protective zone called cork consisting of layers of stone cells, an inner soft zone called soft bast and an intermediate hard region termed as hard bast. The soft bast consists of functional latex vessels, sieve tubes, phloem rays and axial parenchyma. Due to the abundance of stone cells the latex vessels in the hard bast region are discontinuous and usually non-functional.

Tapping is a process which involves controlled wounding and excision of bark tissue. On tapping, a thin layer of bark consisting of the hard bast and soft base is removed, leaving a thin layer of the innermost region of the soft bast along with the intact cambium, called residual bark. In the hands of an inexperienced tapper the tapping knife happens to injure the cambial cells, and sometimes even the wood tissue, which creates permanent marks known as tapping marks associated with callus formation. The injured wood portion becomes defective and discoloured (Fig. 6 C at arrows). In plywood and veneer industry these tapping marks create serious problems and thereby the recovery is very poor.

5. Biological defects

Rubber wood is a perishable timber and highly susceptible to biological deterioration. The high carbohydrate (soluble sugar and starch) reserves deposited in the parenchyma are the major factors governing the susceptibility to biological agents. This defect affecting the durability of rubber wood can be properly controlled by adopting appropriate preservative treatments.

Conclusion

The major limitations of rubber wood for industrial applications are high susceptibility to insects and fungal attack and incidence of tension wood. Substituting rubber wood in place of other quality timber resources necessitates improvement of its quality and durability. The structural and anatomical characteristics of rubber wood enable wood preservatives to penetrate, impregnate and protect it from biological deterioration. However, the nature, quantity and extent of tension wood fibres adversely affect the machining, seasoning and physical (shrinkage) properties of rubber wood to a great extent.

To evaluate a rubber tree as a potential source of timber for various end uses, tension wood has to be taken into account. Avoiding tension wood formation in rubber tree is not possible, but to control its deleterious effects is essential. As the impact of tension wood on various applications of rubber wood is unpredictable, appropriate technology development through coordinated research is essential from a long term perspective.