Natural Rubber : Agromanagement and Crop Processing
Editors : P.J. George and C. Kuruvilla Jacob

Chapter 28

By-products and ancillary sources of income

K. Tharian George, C. P. Reghu and C. R. Nehru

1. INTRODUCTION

The growing commercial exploitation of intercrops, by-products and process wastes in rubber plantations since 1980s represents attempts to maximize net income from natural rubber (NR) cultivation. These attempts assume importance in the backdrop of the emerging trends in the NR sector which consist of an escalation in the prices of material inputs, instability in prices and erosion of relative profit margins. The response, though varied across the major NR producing countries, has been unique in capitalizing on all available opportunities for squeezing unit cost of production and opening up income increasing outlets. In India, income augmenting measures are popular due to certain specific factors such as comparative stability of NR prices and adequate availability of labour (Joseph and George, 1994). The growing popularity of intercrops in the immature phase and standardizing commercial exploitation of by-products and process wastes in the mature phase reflect the efforts to maximize returns.

2. IMMATURE PHASE

In an operational sense, inter-row management during the first three years constitutes an important agronomic component in rubber cultivation. The three options available in inter-row management are (1) establishment of leguminous cover crops, (2) growing short-term intercrops and (3) combining a judicious mix of cover crops and intercrops.

2.1 Cover crops

Cultivation of cover crops, besides reducing input costs of weeding and fertilizer application, also generates a limited income through sale of seeds. *Pueraria phaseoloides*, on an average, yields 30 to 40 kg seeds per ha from the third year till canopy of rubber closes. *Mucuna bracteata* does not produce seeds in the low elevation areas where it is widely cultivated as cover crop in rubber plantations.

2.2 Intercrops

The main objective of growing intercrops in the immature phase of rubber plantations is ancillary income generation. Intercropping is recommended in the first three years of planting as rubber canopy takes two to three years to shade the inter-row areas. It is popular among the smallholders and is normally determined by the asset levels, nature of labour, alternative sources of income, relative agronomic suitability and profitability of the intercrops.

Popular intercrops in India are 'nendran' banana, non-'nendran' banana, pineapple, ginger, turmeric and tapioca. The benefit-cost ratio of intercropping with banana in the first three years of rubber planting ranged from 1.51 to 1.60, with ginger from 0.84 to 3.02 and turmeric from 1.52 to 2.47 (Sreenivasan *et al.*, 1987). An economic analysis of pineapple intercropping in the first three years has shown a benefit cost ratio of 2.27 (Rajasekharan, 1989). The agronomic suitability and economic viability of the crops assume importance in the process of selection. The desirable agronomic practice is simultaneous establishment of both intercrops and cover crops. Such a practice has been found to be operationally feasible only in the case of 'nendran' banana. In a comparative sense, the agronomic advantages of growing 'nendran' banana as an intercrop in rubber plantations are less soil disturbance, prevention of weed growth and relatively large availability of crop residues which is a good source of mulching material for rubber. Intercropping with passion fruit has been reported to be highly profitable in Sri Lanka (Chandrasekara, 1984). In the case of other crops, the benefits of both intercrop and covercrop can be obtained only when both are grown in alternate inter-rows of rubber. Though perennial crops such as coffee, cocoa and pepper were intercropped with rubber on an experimental basis, conclusive evidences for their agronomic suitability and economic viability are not yet available.

3. MATURE PHASE

The major sources of ancillary income in the mature phase of rubber plantations are the three by-products *viz.* rubber seed, rubber honey and rubber wood (Haridasan, 1977).

3.1 Rubber seed

In India, the preliminary attempts for commercial exploitation of rubber seed was initiated by the Khadi and Village Industries Commission (KVIC) in the late 1960s. The two major products processed from rubber seed are rubber seed oil and rubber seed cake. The weight of rubber seed varies from 3 to 5 g, of which about 40 per cent is kernel, 35 per cent shell and 25 per cent moisture. The oil content in dried kernel ranges from 35 to 38 per cent and the recovery rate of seed cake is in the range of 57 to 62 per cent.

3.1.1 Collection and storage

The rubber tree starts producing seeds even before the commencement of tapping. In India, the seed production season is between July and September. The three major factors adversely affecting seed production are powdery mildew disease, abnormal leaf fall disease and severe rainfall. The rubber seed collection in India is unorganized and the commercial exploitation by the planters is not up to the desired extent. The major contributing factors are low price of the seed, prevailing wage rates, structure of the seed market and difficulties in storage. The seeds collected from plantations are often sold to local vendors (Plate 72. a) who sell it to processing units.

Fresh rubber seeds have high moisture content which makes it difficult to store them without deterioration. Therefore, seeds have to be either sun dried or kiln dried to destroy the fat splitting enzymes present, thereby preventing an increase in the free fatty acid content of the oil. Kernels extracted and properly dried can be kept for four months without deterioration. Fresh rubber seed and its kernel contain about 638 and 749 mg hydrogen cyanide (HCN) per kg. It is reported that storage at room temperature for a minimum period of two months is effective in reducing the HCN content (Narahari and Kothandraman, 1983).

The estimated seed production potential in India is about 150 kg per ha. The production of rubber seed oil and cake for 1997-98 were 2890 and 4710 t respectively (RRII, 1998).

3.1.2 Processing

Although 85 per cent of the area under rubber cultivation in India is in Kerala, the rubber seed processing industry is concentrated in the Virudhunagar district of Tamil Nadu mainly due to favourable weather conditions and availability of unutilized capacity in the groundnut oil processing industry (Haridasan, 1977; George and Joseph, 1992). A recent development in the mode of procurement of rubber seed is collecting the raw material in the form of kernel. The shell is a good source of fuel. At present, about 65 per cent of the raw material is transported to Tamil Nadu in the form of kernel and sun dried to reduce the moisture content.

Although there are three methods (solvent extraction, expeller and rotary) for extracting rubber seed oil, the rotary method (Plate 72. b) is more common. Molasses is required in the extraction of rubber seed oil. Every 100 kg of dried kernel requires 20 to 25 kg of molasses. The recovery of oil and cake varies according to the quality of the kernel, the extent of drying and the extent of molasses used for processing.

A pair of electrically-operated rotary machines can process 250 kg of dried rubber seed kernel per shift of 8 h (Haridasan, 1992).

3.1.3 Rubber seed oil

3.1.3.1 Properties

Rubber seed oil is a semi-drying, light yellowish, non-edible oil free from deposits. The oil consists of 17 to 22 per cent saturated fatty acids and 17 to 82 per cent unsaturated fatty acids. The chemical properties of the oil are given in Table 1 (Bhushan, 1958).

Table 1. Chemical properties of rubber seed oil

Properties	Range
Acid value	4 - 40
Saponification value	190 - 195
Iodine value	132 - 141
Hydroxyl value	12 - 32
Unsaponification (%)	0.5 - 1.0
Refractive index 40°C	1.466 - 1.469
Specific gravity 14/15°C	0.924 - 0.930
Titre (°C)	28 - 32
Fatty acid	**Composition (%)**
Palmitic acid	11
Stearic acid	12
Arachidic acid	1
Oleic acid	17
Linoleic acid	35
Linolenic acid	24

3.1.3.2 Industrial uses

The current industrial use of the seed oil is confined to the soap manufacturing industry (Hardjosuwito and Hoesnan, 1976). Though rubber seed oil can be used as a substitute for linseed oil in the manufacture of paints, the easier availability of linseed oil and its lower price are the major factors preventing a large-scale substitution of linseed oil in the paint manufacturing industry. Epoxidized rubber seed oil is used in the formulation of anti-corrosive coatings, polymer additives and in alkyd resin casting (Vijayagopalan and Gopalakrishnan, 1971).

3.1.4 Rubber seed cake

Rubber seed cake is rich in protein and has been evaluated as a source for cattle and poultry feeds (Amritkumar *et al.*, 1985). The small quantity of HCN present in the cake does not pose any danger to livestock. In India, 50 per cent of the seed cake is reported to be used by the cattle and poultry feed manufacturing industries while the remaining is directly used without blending or mixing. Table 2 gives the chemical composition and nutritive values of rubber seed cake.

Table 2. Chemical composition and nutritive values of rubber seed cake

Component	Nutritive value (%)
Crude protein	29.40
Trace protein	26.10
Ether extract	4.88
Crude fibre	7.05
Total carbohydrate	58.33
Calcium	0.22
Phosphorus	0.76

3.2 Rubber honey

Organized commercial exploitation of honey from rubber plantations in India is a relatively recent development under the auspices of Khadi and Village Industries Commission (KVIC). The estimates on the production of apiary honey provided by KVIC underline the importance of rubber plantations as a source of honey. In the 1980s, the estimated relative share of rubber honey in the total apiary honey production in India was about 40 per cent. The sustained decline in the production of rubber honey since 1990-91 was due to the outbreak of sacbrood disease and in 1993-94 the production was only 550 t, a steep decline from the peak level of 2750 t in 1990-91 (George and Joseph, 1994). As a result of rehabilitation measures, the industry showed signs of revival and the production of rubber honey increased to 1500 t in 1997-98 (RRII, 1998). The rehabilitation measures included the introduction of *Apis mellifera* (Plate 72. c) with a reported average yield of 60 kg per hive per year compared to 19.46 kg per hive per year for the popular Indian honey bee (Plate 72. d), *viz. Apis cerana indica* (Haridasan *et al.*, 1987). On an average, 15 to 20 *A. indica* hives (Plate 72. e) can be placed per ha and the results of a recent survey showed an average yield of 12.1 kg per hive per year for the Indian honey bee (Chandy *et al.*, 1998). Therefore, the mature rubber plantations in India have the potential to produce 67886 t of rubber honey annually, though the extent of exploitation was less than two per cent of the potential during 1996-97.

3.2.1 Sources

The honey flow period of rubber plants ranges from January to March and during this period honey bees collect large quantities of nectar from the extrafloral nectaries at

Table 3. Plants for off-season bee forage in rubber plantations

Character	Bee forage plants			
	Antigonon leptopus	*Callistemon lanceolatus*	*Manihot glaziovii*	*Pongamia glabra*
Family	Polygonaceae	Myrtaceae	Euphorbiaceae	Leguminosae
Propagation method	Generative and vegetative	Generative but commonly vegetative (air-layering)	Generative and vegetative (stem cuttings)	Generative
Number of years for maturity	1.5 - 2	3	1	4 - 5
Flowering period *	1 - 12	1 - 12	4 - 11	4 - 6
Peak of flowering *	7 - 9	9 - 10	9 - 11	5 - 6
Pollen (P)/nectar (N) ratings**	P1 N1	P3 N1	P1 N2	N1

* 1 - 12 refer to the months from January to December; ** 1 = major, 2 = medium and 3 = minor source

the tip of the petiole where the leaflets join. Lack of honey flow in rubber during the prolonged dearth period from April to December necessitates alternate bee flora for off-season bee management in rubber plantation based apiaries. The details of flowering and the pollen and nectar potential of four bee forage plants (Table 3) have been identified (Nehru *et al.*, 1990).

3.2.2 Processing

The processing of honey involves indirect heating mainly to prevent fermentation and granulation. The conventional processing methods of heating honey in containers spoils its natural properties by overheating. The new technology developed in India by the Central Bee Research and Training Institute, Pune, is reported to be capable of maintaining the quality of honey by preventing fermentation and delaying granulation (CBRTI, 1986). According to the Bureau of Indian Standards (BIS) specifications, rubber honey is medium grade (Grade A) with an average moisture content of 22 per cent. The important properties of rubber honey are given in Table 4. Apart from honey, other principal hive products are pollen (bee-bread), propolis, beeswax and bee venom which also have industrial uses. The major consuming industries of honey in the domestic market are the ayurvedic and allopathic pharmaceuticals, bakery, confectionery, dairy and tobacco manufacturing.

Table 4. Important properties of rubber honey

Properties	Range	Average
Viscosity (in centipoise) at 27°C	550 - 3800	1358
Specific gravity at 27°C	1.40 - 1.34	1.38
Moisture (%)	21.50 - 25.50	22.00
Reducing sugars	69.08 - 74.80	72.80
Levulose (%)	34.88 - 40.70	37.14
Dextrose (%)	33.57 - 37.97	35.98
Non-reducing sugars (%)	0.78 - 3.14	1.71
Acidity (%)	0.06 - 0.20	0.13
Ash (%)	0.09 - 0.39	0.22
Protein (%)	0.05 - 0.25	0.14
Yeast (million/g)	103.9 - 158.0	139.39

Field level observations on the economics of bee-keeping in rubber plantations indicate that from 15 hives per ha, a production potential of 182 kg can be realized. At the prevailing rate of Rs. 45 per kg for unprocessed honey at the farm gate and giving due allowance for the expenditure on hives, labour and other inputs, the estimated net income is around Rs. 5000 per ha per annum (Chandy *et al.*, 1998).

3.3 Rubber wood

The steady growth in the commercial importance of rubber wood since the 1980s has been influenced by the developments in the world timber market characterized by geographical concentration of demand and supply, uncertainty over the potential sources of supply and efforts to identify environment-friendly types of wood. The emergence of rubber wood (Plate 72. f) as one of the alternatives is an outcome of the sustained research and development efforts since 1970s and its basic nature as a renewable source. The development of processing technologies like standardization of preservative treatment and drying procedures is another important contributing factor. Rubber wood is now extensively used in furniture manufacture, structural applications and interior decoration (Plate 72. g,h). The estimated world market size of rubber wood-based furniture and other items is around US$ 1500 million and the export earnings of Malaysia alone was US$ 655 million in 1995 (MTIB, 1996). The status of rubber wood industry differs among the major NR producers. Malaysia and Thailand are the leading countries in terms of commercial production, consumption and export.

3.3.1 Structural features

Rubber wood is a diffuse porous, light hardwood with straight to slightly interlocking grains and medium coarse texture. The timber is whitish yellow when freshly cut and turns pale cream after drying. The air-dry specific gravity is 0.557 with an average weight of about 515 kg per m^3 at 12 per cent moisture content (Sekhar, 1989). The growth rings are absent or ill-defined (Silva, 1970) 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 tension wood fibres (Reghu *et al.*, 1989a).

The sapwood is not differentiated from heartwood due to lack of deposition of pigmented extraneous materials that usually occur during heartwood formation in other hardwood timber species. Though reserve metabolites in the form of soluble sugar, starch, *etc.* are abundant in rubber wood, conversion of these materials into heartwood substances through long-term ageing process and necrobiosis of storage cells does not take place, mainly due to the fast growing nature of rubber trees. Hence heartwood formation is virtually absent in rubber trees and the storage tissue is always filled with soluble sugar and starch which in turn is easily attacked by fungi, insects, borers, beetles, termites, *etc.* (Kadir and Sudin, 1989). Early wood and late wood differentiation is not possible in rubber due to the long and continuous cambial activity associated with the fast growing tendency.

3.3.2 Anatomical features

Rubber wood is composed of fibres, vessel elements (pores) axial parenchyma and rays in different proportions similar to that of other hardwood species. The fibres are lignified or partially lignified and are 1.1 to 1.5 mm in length (RRIM, 1956; Bhat *et al.*, 1984; Reghu *et al.*, 1989a) and about 22 μm in thickness (Silva, 1970; Reghu *et al.*, 1989a). The vessels are small to moderately large with one to four pores per mm^2. The structure and the distribution pattern of pores enhance the chemical impregnation capacity of rubber wood during preservative treatments. The lumen of the pores is usually filled with balloon-like parenchymatous outgrowths called tyloses which are a characteristic feature of rubber wood. The nature and extent of tylosis formation and their impact on preservative impregnation are still obscure.

3.3.3 Tension wood

Tension wood formation is a common phenomenon in rubber. It is considered as a natural defect or abnormality which creates various problems (Isenberg, 1963; Harlow, 1970). When a tree is felled and freshly cut across, the tension wood zones are clearly visible as white woolly lustrous zones (Plate 73. a). Tension wood is characterized by its unlignified gelatinous fibres (Plate 73. b-d). The proportion of tension wood varies from tree to tree and also with height within a tree (Rao *et al.*, 1983; Reghu *et al.*, 1989a; Sulaiman and Lim, 1992). Sharma and Kukreti (1981) observed 15 to 65 per cent tension wood fibres in the sawn plank of rubber wood.

Tension wood creates a variety of drying, wood working and finishing problems during sawing, planing, machining and finishing of end products (Ipe *et al.*, 1987). Common problems during drying are warping, twisting, collapse, bowing and coupling (Sharma and Kukreti, 1981; Rao *et al.*, 1983; Joseph and Mathew, 1989; Reghu *et al.*, 1989b; Sulaiman and Lim, 1992; Choo and Hashim, 1994).

3.3.4 Physical, mechanical and machining properties

Rubber wood is lignocellulosic and its density is not uniform throughout. The physical and mechanical properties vary along the longitudinal axis that runs in the direction of the grain, radial axis which is perpendicular to the grain in the radial direction and the longitudinal axis perpendicular to the grains (Midon, 1994). The strength of rubber wood in terms of its physical and mechanical properties in comparison to that of teak are presented in Table 5.

Table 5. Physical and mechanical properties of rubber wood in comparison with teak

Property	*Tectona grandis* (Teak)		*Hevea brasiliensis* (Rubber)	
	Fresh	Dry	Fresh	Dry
Moisture content (%)	76.0	12.0	81.2	12.0
Specific gravity	0.596	0.604	0.521	0.557
Weight at given moisture content (kg/m^3)	1053	676	944	515
Static MOR (kg/cm^2)	841	959	437	756
Bending MOE (kg/cm^2)	109.7	119.6	55.6	82.0
Compression (kg/cm^2)				
Parallel to grain	415	532	200	374
Perpendicular to grain	86	101	47	101
Hardness (kg)				
Side	554	512	310	538
End	486	488	309	627
Shear, parallel to grain (kg/cm^2)	94.9	102.3	77.1	113.6
Tension, perpendicular to grain (kg/cm^2)	73.9	62.0	47.4	59.8

MOR = Modulus of rupture; MOE = Modulus of elasticity

Working quality and finish adaptability of rubber wood in comparison with teak indicated that it is suitable for the manufacture of all types of furniture items and bent articles. The working quality index is 130 when teak is taken as 100 (Shukla *et al.*, 1984). Under standard conditions, its adaptability is rated about 94 per cent of teak. The suitability indices of rubber wood on its strength properties in comparison to teak (Shukla and Lal, 1985) are shown in Table 6.

Table 6. Suitability indices of rubber wood

Property	Suitability index*
Weight (12% moisture content)	93
Strength as beam	62
Stiffness as beam	77
Suitability as post	52
Shock resistance	75
Retention of shape	77
Shear	92
Hardness	74
Splitting coefficient	75

Source : Shukla *et al.*, 1984 * When suitability index of teakwood is 100

Sawing, machining and planing of rubber wood is easy but turning is slightly difficult (Shukla *et al.*, 1984; Rao *et al.*, 1993). Rubber wood has become an important source of raw material for the manufacture of panel products such as particle board, block board, medium density fibre board, *etc.* (Yusoff, 1994) because of its excellent physical properties.

3.3.5 Processing

The processing of rubber wood consists of two stages, *viz.* preservative impregnation and drying. The basic objective of preservative treatment is to protect rubber wood from biodeterioration caused by various biological agents.

The preservative treatments are classified into (1) short-term or temporary protection and (2) long-term or permanent protection. The method adopted for temporary protection is dip treatment using a number of wood preservatives comprising insecticides and fungicides or mixtures of both. In long-term preservative protection, the wood preservatives are allowed to penetrate deep into the timber by providing maximum dry salt retention and complete preservative penetration. This can be achieved by two methods (1) dip diffusion process and (2) pressure impregnation process.

3.3.5.1 Dip diffusion process

It is also known as boron diffusion process and should be carried out only on freshly sawn timber having more than 50 per cent moisture content. The process consists of dipping or immersion of freshly-sawn timber for an adequate period in a mixture of boric acid and borax in water (Gnanaharan and Mathew, 1982; Gnanaharan and Damodaran, 1993). The duration of immersion in the preservative solution varies depending on the thickness of the planks (Gnanaharan, 1982; Tam and Singh, 1987) and the size of the timber. This treatment gives a dry salt retention of 5 kg per m^3 and 12 mm penetration (Gnanaharan, 1996). The boric acid-borax solution alone does not protect rubber wood from sap stain fungal attack. To protect from fungal staining, a fungicide has to be added to the solution for which sodium pentachlorophenate (NaPCP) at 0.5 to 1.0 per cent concentration is proved to be the most effective (Gnanaharan, 1983; Jose *et al.*, 1989). Though the diffusion treatment process is economically viable, the treated timber can be used only for indoor wood working purposes as the boron compounds are leachable.

3.3.5.2 Pressure impregnation

Pressure treatment is the popular and comparatively more effective method of rubber wood preservation. In this method, deeper and more uniform penetration and retention of preservatives can be achieved. The two types of pressure treatment methods are vacuum pressure method (Bethel process) and oscillating pressure method (OPM).

The principle involved in the vacuum pressure method is the impregnation of preservatives into the wood by creating vacuum and pressure. The treatment is carried out in steel pressure cylinders or vessels having provisions for measuring temperature, vacuum and pressure. This treatment can be done for freshly-sawn timber as well as partially dried (25 to 30% moisture content) timber. However, partially-dried timber ensures maximum penetration and retention of preservatives. The most common types of preservatives used in this process are : (1) copper-chrome-arsenic (CCA) consisting of copper sulphate, potassium or sodium dichromate and arsenic pentoxide, (2) copper-chrome-boric (CCB) consisting of copper sulphate, sodium or potassium dichromate and boric acid and borax (Hong and Liew, 1989; Gnanaharan and Damodaran, 1993). The details of pressure impregnation plants and installation are available in IS 2683 (BIS, 1966).

The oscillating pressure method (OPM) is only a variation of the vacuum pressure process and employs rapidly alternating cycles of vacuum and pressure. This method is more complex than the conventional vacuum pressure method as it requires automated plant equipments for introducing 10 to 15 cycles of vacuum and pressure for 10 min within a total treatment time of 2 h. This method is widely adopted for rubber wood treatment in Malaysia and the other rubber producing countries (Dahlan *et al.*, 1994).

Vacuum pressure impregnation of a special class of chemicals called vinyl monomers having different colours into rubber wood and its polymerization through gamma irradiation is another method (Kaderkutty, 1989). The wood processed by this method is known as rubber wood polymer composites. This method enhances the physical and mechanical properties as well as provides different permanent stains to wood. The durability of the wood is also enhanced considerably in this process.

3.3.6 Drying

The main purpose of drying is to adjust the moisture level in the timber to the level of equilibrium moisture content (EMC) so as to prevent the timber from absorption or desorption of moisture leading to distortions and dimensional variations in the end products.

The two methods of drying are air-drying and kiln-drying. The removal of moisture from timber through controlled temperature and humidity constitutes the basis of kiln-drying. The permissible moisture content in the wood depends on the end use and the locality where it is used. The details on the moisture content for different end uses are described in IS 287 (BIS, 1973). Drying is the most critical of all the processing operations as rubber wood contains a large quantity of tension wood.

3.3.7 Production and consumption

3.3.7.1 Production

Among the major NR producing countries, the rubber wood processing and the downstream products manufacturing sector are relatively more developed in Malaysia and Thailand compared to Indonesia, India and Sri Lanka, in terms of scale of operation, level of technology employed, variety of products manufactured and the pattern and volume of exports. The primary and secondary processing of rubber wood in India is concentrated in Kerala which accounts for more than 85 per cent of rubber-planted area in the country.

India is the fourth largest natural rubber producing country in the world with a planted area of around 0.53 million ha. The current estimated average production of rubber wood is 150 and 180 m^3 per ha in the smallholding and estate sectors respectively. The annual gross availability of rubber wood is 1.27 million m^3 during 1997-98 and the projected estimate for 2010 is 4.24 million m^3 (George and Joseph, 1999). The stem wood constitutes 60 per cent of the total timber yield. The remaining 40 per cent is branch wood. Sawn timber suitable for secondary processing amounts to 35 per cent of the stem wood.

The primary market of rubber wood in India is mainly based at Kottayam, Perumbavoor, Ollur and Nilambur in Kerala. This primary market is characterized by the presence of intermediaries consisting of timber traders in the plantation belts and brokers in the auction centres. The peak period of supply is from January to May. The decrease in supply during the monsoon months pushes the prices up by 10 to 15 per cent. The farm gate price of rubber wood logs is only 55 per cent of the terminal market price (Joseph and George, 1996).

3.3.7.2 Consumption

While the stem portion is used for different industrial applications, the branch wood is almost entirely consumed as firewood by households and small-scale industrial units. Stem wood is mainly consumed for production of packing cases. Other industrial uses are for plywood, veneers, safety matches and for secondary processing (Table 7).

Table 7. Consumption of stem rubber wood in India (1997-98)

Industrial use	Girth range (cm)	Relative share (%)
Packing case	37.5 - 62.5	58.5
Plywood/veneers	62.5 and above	24.5
Safety matches	62.5 and above	3.0
Secondary processing	75.0 and above	12.0
Others	–	2.0

Source : Joseph *et al.*, 1999

Activated carbon and white charcoal from rubber wood are other potential products for use in the chemical industry. There are around 1000 saw mills in Kerala dealing mainly or exclusively in rubber wood with an average procurement of 2100 t per year. Most of the units are small-scale with an average installed capacity of 5.5 m^3 per shift. The reported average recovery rate is higher (64%) compared to the normal range (35 - 50%), as the sawn timber is mainly used for making packing cases. There are around 180 rubber wood veneer processing units out of which 36 units have their own facilities for manufacturing plywood. The units with indigenous lathes have a capacity of 10 t per shift while those with imported lathes have a capacity of 25 t per shift and the average recovery rate is 74 per cent (Joseph and George, 1996). Though extensively used for splints and veneers of safety matches during early 1980s when conventional softwood species were costly and in short supply, rubber wood is less preferred at present for these end uses and its share has come down from 13.3 per cent in 1984-85 to three per cent in 1997-98 (Joseph *et al.*, 1999). There are 50 secondary processing units, mostly set up during early 1990s. These units depend mainly on indigenous technology and the average annual installed capacity of the industry is 1115 m^3 per annum. The preferred preservative is CCB. The sawing and seasoning rejections were high (46 and 25% respectively). Only 43 per cent of the units have downstream manufacturing facilities and the products are generally less value-added items (Viswanathan *et al.*, 1998). The industry is oriented towards internal market. The relative share of export is marginal compared to other NR producing countries.

REFERENCES

Amritkumar, M.N., Sundaresan, K. and Sampath, S.R. (1985). Effect of replacing cotton seed cake by rubber seed cake in concentrate of cows on yield and composition of milk. *Indian Journal of Animal Sciences*, 55(12) : 1064-1070.

Bhat, K.M., Bhat, K.V. and Damodaran, T.K. (1984). Some wood and bark properties of *Hevea brasiliensis*. *Journal of Tree Sciences*, 182 : 40-66.

Bhushan, D.C. (1958). Rubber seed and its oil. *Indian Oil Seeds Journal*, 2(3) : 35-37.

BIS (1966). Guide for installation of pressure impregnation plants for timber. IS 2683, Bureau of Indian Standards, New Delhi.

BIS (1973). Recommendations for maximum permissible moisture content for timber used for different purposes. IS 287, Bureau of Indian Standards, New Delhi.

CBRTI (1986). Personal communication, Central Bee Research and Training Institute, Pune.

Chandrasekara, L.B. (1984). Intercropping *Hevea* replanting during the immature period. *Proceedings of the International Rubber Conference*, 1984, Colombo, Sri Lanka, 1(2): 390-391.

Chandy, B., Joseph, T. and Mohanakumar, S. (1998). Commercial exploitation of rubber honey in India : Report of a sample survey. *Rubber Board Bulletin*, 27(3) : 9-15.

Choo, K.T. and Hashim, W.S. (1994). Seasoning of rubber wood. In: *Rubber Wood Processing and Utilisation* (Eds. L.T. Hong and H.C. Sim). Forest Research Institute of Malaysia, Kuala Lumpur, pp.105-119.

Dahlan, M.J., Hong, L.T., Mohamad, A. and Wong, A.H.H. (1994). Preservation of rubber wood. In: *Rubber Wood : Processing and Utilisation* (Eds. L.T. Hong and H.C. Sim). Forest Research Institute of Malaysia, Kuala Lumpur, pp. 85-103.

George, K.T. and Joseph, T. (1992). Rubber based industralisation in Kerala : An assessment of missed linkages. *Economic and Political Weekly*, 27(1&2) : 47-56.

George, K.T. and Joseph, T. (1994). Commercial exploitation of rubber honey in India : A preliminary assessment. Rubber Research Institute of India, (Unpublished Monograph).

George, K.T. and Joseph, T. (1999). Rubber wood production and utilisation in India. *Handbook on Rubber Wood* (Eds. R. Gnanaharan, K. Tharian George and K. Damodaran). Science and Technology Entrepreneurship Development, Calicut (In press).

Gnanaharan, R.(1982). A simplified boron diffusion treatment for rubber wood. *The International Journal of Wood Preservation*, 2 : 169-172

Gnanaharan, R. (1983). Preliminary note on the fungal problem of rubber wood. Document No. IRG/WP/3246, International Research Group on Wood Preservation, Sweden.

Gnanaharan, R. (1996). Technical properties and specifications for Indian rubber wood. In: *Global Forum on Investment Opportunities in the Indian Rubber Wood Industry*. Indian Rubber Wood Task Force, Cochin, pp. 113-123.

Gnanaharan, R. and Dhamodaran, T.K. (1993). Mechanical properties of rubber wood from a thirtyfive year old plantation in Central Kerala, India. *Journal of Tropical Forest Science*, **6** : 136 -140.

Gnanaharan, R. and Mathew, G. (1982). Preservative treatment of rubber wood (*Hevea brasiliensis*). *Research Report, Kerala Forest Research Institute*, **15** : 1-16.

Hardjosuwito, B. and Hoesnan, A. (1976). Rubber seed oil analysis and its possible use. *Merara Perkebunan*, **44** : 225-229.

Haridasan, V. (1977). Utilisation of rubber seeds in India. *Rubber Board Bulletin*, **14**(1&2) : 19-24.

Haridasan, V. (1992). Ancillary income from rubber plantations. In: *Natural Rubber : Biology, Cultivation and Technology* (Eds. M.R. Sethuraj and N.M. Mathew). Elsevier, Amsterdam, pp. 561-567.

Haridasan, V., Jayarathnam, K. and Nehru, C.R. (1987). Honey from rubber plantation : A study of its potential. *Rubber Board Bulletin*, **23**(1) : 18-21.

Harlow, W.M. (1970). Inside wood : Masterpiece of nature. American Association, New York.

Hong, L.T. and Liew, C.C.K. (1989). Protection of rubber wood timber : Impregnation with boron preservative. Document No.IRG/WP/3551. International Research Group on Wood Preservation, Sweden.

Ipe, V.C., Reghu, C.P. and Haridasan, V. (1987). Rubber wood consuming units in Kerala: Technical facilities and problems. *Rubber Board Bulletin*, **23**(1) : 22-25.

Isenberg, I.H. (1963). The structure of wood. In: *The Chemistry of Wood* (Ed. B.L. Browning). Inter Science Publishers. John Wiley, New York.

Jose, V.T., Rajalakshmy, V.K., Jayarathnam, K. and Nehru, C.R. (1989). Preliminary studies on the preservation of rubber wood by diffusiion treatment. *Rubber Board Bulletin*, **25**(2) : 11-16.

Joseph, S. and Mathew, N.M. (1989). Use of rubber wood for the manufacture of safety matches. *Rubber Board Bulletin*, **25**(2) : 19-20.

Joseph, T. and George, K.T. (1994). Commercial exploitation of ancillary rubber products. *Economic and Political Weekly*, **29**(8):413-415.

Joseph, T. and George, K. T. (1996). Primary processing of rubber wood in Kerala : Report of a sample survey. *Wood News*, **5** : 39-43.

Joseph, T., George, K.T. and Viswanathan, P. K. (1999). Production and utilisation of rubber (*Hevea*) wood in India. *Plantation Timbers and Bamboo : The Proceedings* (Eds. K. Damodaran *et al.*). Indian Plywood Industries Research and Training Institute, Bangalore, pp. 151-157.

Kaderkutty, A.K. (1989). Rubber wood : Polymer composite by gamma-radiation processing. *Rubber Board Bulletin*, **25**(1) : 5-6.

Kadir, A.A. and Sudin, R. (1989). Carbohydrate in rubber wood (*Hevea brasiliensis* Muell. Arg.). *Holzforchung*, **43** : 173-178.

Midon, M.S.(1994). Physical and mechanical properties of rubber wood. In : *Rubber Wood : Processing and Utilisation* (Eds. L.T. Hong and H.C. Sim). Forest Research Institute of Malaysia, Kuala Lumpur, pp. 27-36.

MTIB (1996). Personal Communication, Malaysian Timber Industry Board, Kuala Lumpur.

Narahari, D. and Kothandaraman, P. (1983). Influence of processing and storage on hydrogen cyanide and tannin contents of para rubber seed and its products. *Animal Feed Science and Technology*, **9** : 319-324.

Nehru, C.R., Thankamani, S., Jayarathnam, K. and Joseph, P.M.L. (1990). Nectar and pollen plants for extending the flow period in rubber growing areas of India. *Rubber Board Bulletin*, **25**(3) : 5-6.

Rajasekharan, P. (1989). Pineapple intercropping in the first three years of rubber planting in smallholdings : An economic analysis. *Indian Journal of Natural Rubber Research*, **2**(2) : 118-124.

Rao, K.P.V., Kamala, B.S. and Srinivasan, V.V.(1993). A note on the suitability of rubber wood (*Hevea brasiliensis*) for handicrafts. *Journal of Timber Development Association of India*, **39**(3) : 38-42.

Rao, V.R., Dayal, R. and Sharma, B. (1983). Studies on the nature and pattern of distribution of tension wood in *Hevea brasiliensis* Muell. Arg. (Rubber wood). *Indian Forester*, **109**(5): 286-291.

Reghu, C.P., Premakumari, D. and Panikkar, A.O.N. (1989a). Wood anatomy of *Hevea brasiliensis* (Willd. ex Adr. de Juss.) Muell. Arg. : 1. Distribution pattern of tension wood and dimensional variation of wood fibres. *Indian Journal of Natural Rubber Research*, 2(1) : 27-37.

Reghu, C.P., Premakumari, D. and Panikkar, A.O.N. (1989b). An account of tension wood with special reference to *Hevea brasiliensis*. *Rubber Board Bulletin*, **25**(2) : 21-30.

RRII (1998). Annual report 1997-98. Rubber Research Institute of India, Kottayam (In Press).

RRIM (1956). Rubber wood as a raw material for paper pulp or building material. *Planters' Bulletin*, **23** : 58-63.

Sekhar, A.C. (1989). Rubber wood : Production and utilisation. Rubber Research Institute of India, Kottayam, pp. 224.

Sharma, S.N. and Kukreti, D.P. (1981). Seasoning behaviour of rubber wood : An under utilized non-conventional timber resource. *Journal of Timber Development Association of India*, **27** : 19-29.

Shukla, K.S., Bhatnagar, R.C. and Pant, B.C. (1984). A note on the working quality and finishing adaptability of rubber wood (*Hevea brasiliensis*). *Indian Forester*, **110** : 490-496.

Shukla, N.M. and Lal, M. (1985). Physical and mechanical properties of *Hevea brasiliensis* (Rubber wood) from Kerala. *Journal of Timber Development Association of India*, **31**(2): 27-30.

Silva, S.S. (1970). Industrial utilisation of rubber wood for wood based panel products. *RRIC Bulletin*, 5(3&4) : 40-53.

Sreenivasan, K.G., Ipe, C.V., Haridasan, V. and Mathew, M. (1987). Economics of inter cropping in the first three years among new / replanted rubber. *Rubber Board Bulletin*, **23**(1) : 13-17.

Sulaiman, A. and Lim, S.C. (1992). Wood quality study of rubber wood at different age and clones. Report on properties and utilisation of rubber wood from trees of different age groups. Forest Research Institute of Malaysia, Kuala Lumpur, pp. 39-50.

Tam, M.K. and Singh, D.K. (1987). Preservation treatment of rubber wood by dip-diffusion. *Proceedings of Second Rubber Wood Utilisation Seminar*, 1985, Kuala Lumpur, Malaysia, pp. 140-145.

Vijayagopalan, K. and Gopalakrishnan, K.S. (1971). Epoxidisation of rubber seed oil. *Rubber Board Bulletin*, **11** : 52-54.

Viswanathan, P. K., Joseph, T. and George, K. T. (1998). Rubber wood processing industry in India : An analysis on the commercial exploitation and operational level constraints, *Thirteenth Symposium on Plantation Crops*, 1998, Coimbatore, India.

Yusoff, M.N.M. (1994). Panel products from rubber wood : Particle board, block board and medium density fibre board. In : *Rubber Wood: Processing and Utilisation* (Eds. L.T. Hong and H.C.Sim), Forest Research Institute of Malaysia, Kuala Lumpur, pp. 185-200.