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FROM LATEX TO TIMBER: THE INDIAN PERSPECTIVE

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The attempts to stabilize prices of primary commodities exported from developing countries through policy initiatives by the respective governments were not successful and most of the international commodity agreements collapsed, the latest being the termination of international Natural Rubber Agreement in 1999. In order to face the challenges, attempts to increase the net farm income by exploring commercial potentials of by-products like rubber wood have been initiated. Malaysia led the way with research on evolving latex-timber clones and processing technology for rubber wood since1970. But efforts in this direction in India was rather limited till the 1990s due to the comfortable NR price situation in India as a result of the growing domestic demand and protected market. The major share of the rubber wood available in the country was utilized for low value added products like packing cases in spite of India being a net timber importer.

The rubber wood processing industry in India is affected by constraints like predominance of intermediaries resulting in high raw material cost, absence of vertical integration and lower scales of operation, low levels of capacity utilization and value addition, shrinking supply of good quality raw materials, shortage of working capital, absence of agencies for quality assurance and industrial promotion and problems of market accessibility. These problems can be solved only through strong R & D support and statutory control. The priorities in research should be development of clones with higher latex and timber yield for which wild germplasm can serve as a genetic source. The clones so evolved should have shorter immaturity, good girthing, tolerance to wind, improved timber qualities with more efficient lignin biosynthesis. The developmental priorities should be for formulation of a perspective plan for growth of the industry, setting up agencies for enforcing quality standards and providing market intelligence and other infrastructural assistance for the industry. The Rubber Research Institute of India has already initiated research to develop clones of high latex and quality timber yield. However under the Indian condition it may not be economically feasible to develop exclusively timber yielding clones except in the agro forestry perspective especially for utilization of marginal lands available mostly in the non-traditional rubber growing regions.

INTRODUCTION

The post-colonial period witnessed wide fluctuations and growing uncertainties in the prices of primary commodities exported mainly from the developing countries. In this regard, the futility of international initiatives to stabilise prices at remunerative levels became much more evident from the virtual collapse of all the international commodity agreements (INRA being the latest with its termination on October 13, 1999). The survival strategies adopted by the commodity exporting sectors included attempts to capitalise available opportunities for enhancing net farm income and reduce cost of production. The case of natural rubber (NR) is unique among the important plantation crops, as the net farm income enhancing measures have coincided with the attempts to explore the commercial potential of the major by-product, *viz.*, rubber wood. More importantly, the eco-friendly credentials of rubber plantations, (George and Joseph, 1993; George, 2000; George and Joseph 2002) have given a wider international acceptance for rubber wood as an eco-friendly alternate source of timber, especially since the 1980s. Moreover, it may serve as an additional source of income for the rubber smallholdings, if the commercial potential of rubber wood is effectively utilized. While Malaysia and Thailand have made tremendous strides in the commercial utilisation of rubber wood with greater research and development (R & D) orientation towards development of latex-timber clones (LTC) in Malaysia ever since 1970s India has lagged behind for specific reasons.

This paper is conceived as a theme paper with the prime objective of highlighting the need for a paradigm shift in R & D priorities in India from the unilateral focus on latex production to the joint production of latex and timber. While doing so, the paper analysis some pertinent issues relevant to the Indian context, *viz.*, (a) The reasons for India lagging in the process of commercial exploitation of rubber wood, (b) the need for shift in R & D priorities towards breeding and popularisation of latex-timber clones in India; (c) the current status of rubber wood utilisation in India; and (d) the future R & D priorities facilitating the shift from latex alone production frontier to latex-timber and timber alone production.

STATUS OF RUBBER WOOD IN INDIA

World's supply of rubber wood originates from more than 9.2 million ha of rubber plantations with greater degree of geographical concentration in the South East Asian region, especially, in Malaysia, Thailand, Indonesia, India and China which together account for 87 per cent of the total area under rubber plantations and 78 per cent of the production (IRSG, 2002). While the short-term (1992-97) physical production potential of rubber wood is estimated at 39 million m^3 per year, the long-term production potential is expected to be 52 million m^3 per year by the year 2020 (ITC/UNCTAD/GATT, 1993). The estimated size of the world market for rubber wood - based products is more than US $ 2 billion. However, the current annual rate of industrial utilisation of rubber wood is only about five million cubic metres confining mainly to Malaysia and Thailand together accounting for two million cubic metres.

The efforts to exploit the commercial potential of rubber wood in India have been rather weak in spite of India being a net importer of wood and wood products with a reported import bill worth Rs. 19943.3 million during 1999-2000 (DGCIS, 2000). However, with the dwindling supply of conventional hardwood species, rubber wood has been increasingly utilised for making packing cases, safety matches and plywood industries. The projected availability of rubber wood was 2.1 million cubic metres during 2001-02, of which, stem-wood

Table 1. **Projected availability of rubber wood in India (million m^3)**

Year	Total wood*	Stem-wood	Sawn timber suitable for secondary processing
2000-01	1.60	0.96	0.33
2001-02	2.07	1.24	0.42
2004-05	3.22	1.93	0.64
2005-06	3.19	1.92	0.63
2009-10	4.24	2.54	0.81
2014-15	3.24	1.95	0.60

Source: George and Joseph (2002);
*Includes stem and branch-wood.

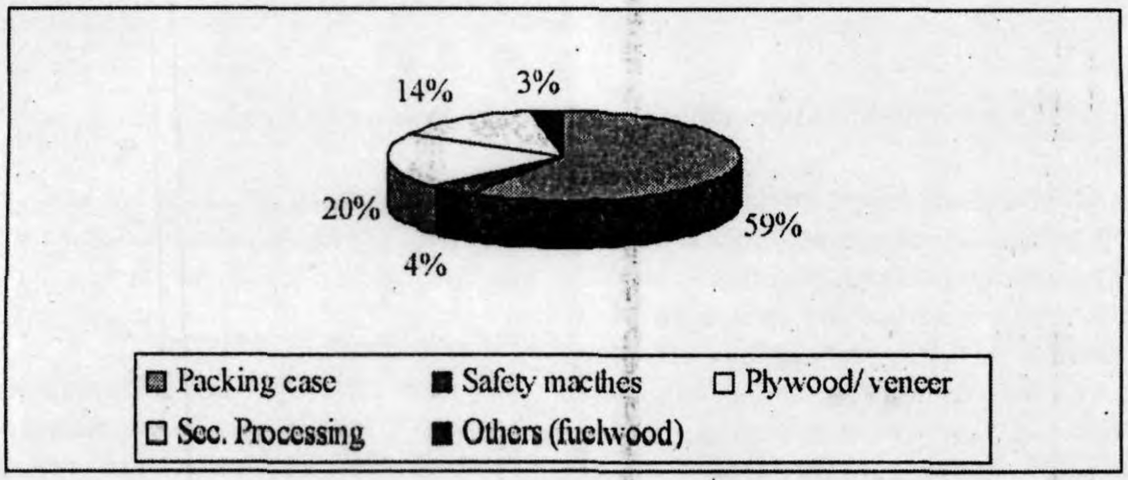

Figure 1. Consumption pattern of stem wood (2001-02)

accounted for 60 per cent and sawn timber suitable for secondary processing constituted 21 per cent (Table 1). The consumption pattern of rubber stem-wood (2001-02) is dominated by packing case sector (59%), followed by plywood industry (20%). Secondary rubber wood processing sector consumes only 14 per cent of the stem-wood produced (Figure 1).

Though secondary processing of rubber wood was started in India as early as 1960s with the establishment of two processing units in Kottayam and Thrissur districts in Kerala, the industrial activity marked significant growth on a commercial scale only during the 1990s. Subsequently, the number of registered rubber wood secondary processing units with pressure impregnation and drying facilities increased from 31 in 1993 to 84 by 2002 with regional concentration in Kerala (68%). Such concentration is due to easy availability of rubber wood as 86 per cent of rubber planted areas is in Kerala and as transportation of rubber wood in log from outside is prohibited. The need for prompt chemical treatment after felling is another factor.

The secondary processing industry has an installed capacity to process about 0.1 million m^3 annually and the extent of capacity utilisation is only around 55 per cent. The sub-optimal levels of capacity utilisation has been due to operational level constraints faced by the industry, which resulted in closure of almost 50 per cent of the registered units.

The operational level constraints, include: (i) absence of a statutory agency to monitor and promote the industry; (ii) absence of vertical integration; (iii) lower levels of capacity utilisation and value addition; (iv) shrinking supply of quality raw material; (v) predominance of intermediaries and the resultant higher raw material procurement cost; (vi) working capital shortage; and (vii) market access issues. A sample survey based on 21 rubber wood processing units in Kerala and Karnataka indicated that the gross value of processed rubber wood during 2000-01was Rs. 150 million of which, the exports was only 22 per cent (Viswanathan, *et al.*, 2003b). The current status of the rubber wood processing industry call for setting up of a promotional agency with R & D support to enforce quality standards as well as formulation of a perspective plan for systematic and regulated growth of the industry (Joseph *et al.*, 1998).

Research and development efforts as well as farm level compulsions to explore the commercial potential of rubber wood for maximising farm income have been rather weak in India till the early 1990s as the thrust was on latex production rubber enjoyed a protected market since independence. However, in the context of the growing process of market integration and uncertainties, it is imperative to explore the commercial potential of rubber wood through appropriate changes in R&D priorities from a long-term policy perspective.

FROM LATEX TO TIMBER: REORIENTING R & D PRIORITIES

The specific reasons that make Indian NR economy to explore the potential of latex-timber clones are: (a) the uncertainties in farm income by singularly focusing on latex yield (b) India being a net importer of timber and timber products; and (c) the growing depletion of the conventional timber species. Moreover, the prevailing unilateral focus on latex production is at stake in view of the biological and agro-climatic constraints on enhancing productivity of NR and the growing market uncertainties (George, 2002).

The income from sale of rubber wood has been indicated the main source for meeting expenditure on replanting in 44 per cent of small holdings in a recent survey. The returns through sale varied from 1.5 to 2 lakh rupees per hectare. However, breeding and development of latex-timber clones call for a thorough overhauling of the existing R & D priorities. In this regard, it will be highly contextual to examine the latex and timber yield potential of prominent clones developed in Malaysia as latex-timber and timber-latex clones, so as to draw certain guidelines specific to the Indian context. It is also important to understand the specific context in which Malaysia started massive programmes for the development of latex-timber clones.

R & D efforts in Malaysia

In sharp contrast to the Indian scenario, Malaysia, Thailand and Indonesia have been primarily NR exporters and were highly exposed to the vagaries of international NR market uncertainties. This situation has provided the required stimuli for exploring additional sources of income from the rubber plantations in these countries. The most critical problem faced by the fast expanding rubber wood-based industries, especially the furniture industry in Malaysia was the insufficient and irregular supply of rubber wood, which stimulated the process of screening, selecting and breeding rubber planting materials with greater potential for production of both latex and timber. Both Malaysia and Thailand have also been successful in penetrating the furniture markets like Japan with their rubber wood furniture. In both the countries, rubber wood accounting for the bulk of the timber raw material used in secondary wood products is now reckoned as crucial to the development of wood products manufacturing industries. Necessary regulations favouring further processing and restricting exports of raw rubber wood has also been imposed. The major institutions involved in the promotion of rubber wood in Malaysia include: Forest Research Institute Malaysia (FRIM), the Malaysian Rubber Board (MRB), Malaysian Timber Industry Board (MTIB) and the Standards and Industrial Research Institute of Malaysia (SIRIM).

The Malaysian R&D efforts in developing rubber wood-based value-added products and the subsequent development of LTC with higher latex and timber yield

Table 2. **Timber yield of RRIM 900 series clones in Malaysia**

Clone	Age (years)	Bole volume (m^3/tree)	Canopy volume (m^3/tree)	Total volume (m^3/tree)	Timber volume (m^3/ha)	Latex yield (kg/ha)
RRIM 908	22	0.51	0.51	1.02	255	1315
RRIM 910	22	0.76	0.57	1.33	333	1641
RRIM 912	22	0.75	0.75	1.50	375	2055
RRIM 913	22	0.50	0.50	1.00	250	2181
RRIM 918	22	0.66	0.66	1.32	330	1956
RRIM 921	22	0.63	0.63	1.26	315	1391
RRIM 922	22	0.63	0.32	0.95	238	1710
RRIM 928	21	0.59	0.15	0.74	185	3181
RRIM 929	21	0.60	0.60	1.20	300	3277
RRIM 931	20	0.68	0.68	1.36	340	2172
RRIM 932	20	0.46	0.23	0.69	173	1795
RRIM 936	20	0.49	0.25	0.74	185	2146

Sources: Estimated from *Planters Bulletin*, (1995); Ong *et al.*, (1995)

potential (Ong, *et al.*, 1995) are indeed commendable. In Malaysia's specific context, the alternate combinations of latex and timber production mainly include the twin options, *viz.*, (a) establishment of LTC plantations with higher production of timber and latex; and (b) establishment of rubber wood plantation solely for the extraction of rubber wood (Hassan, 2002). Currently, the Malaysian strategies include: (i) replanting with latex-timber clones of RRIM 2000 series (from 2001 to 2022), which have shorter replanting cycle of 14-17 years with potential timber yield of 0.81 to 1.87 m^3 per tree (MRB, 1998), and (ii) the promotion of LTC in reforestation/ agro-forestry programmes.

The prominent clones identified to be suitable for latex and timber production are the PB 200 and 300 series and RRIM 900 and 2000 series (Arshad, *et al.*, 1995; Arshad and Othman, 1996). Of the RRIM 900 series, 12 clones showed potential for timber production. At an average age of 21 years, the average timber volume reported was 1.09 m^3 per tree with a bole volume of 0.61 m^3 per tree (Table 2). In the case of RRIM 2000 series, nine clones were identified as

Table 3. **Latex and timber yield of RRIM 2000 series clones in Malaysia**

Clone	Age (years)	Bole volume (m^3/tree)	Canopy volume (m^3/tree)	Total volume (m^3/tree)	Timber volume (m^3/ha)	Latex yield (kg/ha)
RRIM 2001	17	0.41	0.82	1.23	357	2850
RRIM 2002	17	0.44	0.66	1.10	218	2348
RRIM 2008	14	0.33	0.99	1.32	342	2686
RRIM 2009	14	0.34	0.34	0.68	127	2277
RRIM 2014	14	0.53	0.80	1.33	192	2007
RRIM 2015	14	0.43	0.87	1.30	357	2760
RRIM 2016	14	0.43	0.85	1.28	308	2582
RRIM 2017	14	0.36	0.63	0.99	182	2261
RRIM 2020	14	0.37	0.63	1.00	179	2232

Sources: Estimated from *Planters' Bulletin*, (1995); Ong *et al.*, (1995).

Table 4. **Variability in latex and timber yield of LTC in Malaysia**

Clone	Age (years)	Bole volume (m³ / tree)	Canopy volume (m³ / tree)	Total volume (m³ / tree)	Timber vol. per ha (m³)	Latex yield (kg./ha)
RRIM 900 series						
Mean	21	0.61	0.49	1.09	273.13	2068
CV (%)	4.16	16.49	41.06	25.14	27.24	29.71
RRIM 2000 series						
Mean	15	0.40	0.73	1.14	251.4	2445
CV (%)	9.02	15.45	26.07	19.10	35.58	11.65

Sources: Estimated from *Planters Bulletin*, (1995); Ong *et al.*, (1995)

having greater potential for both latex and timber production (Table 3). The clone RRIM 2001 has occupied premier position in terms of both timber volume (356.70 m^3 per ha) and latex yield (2850 kg/ ha) compared to other clones. The clones differed in terms of variability in bole and canopy volumes as indicated by the highest coefficient of variation in canopy volume (26 %) compared to bole volume (15 %).

While the variability in bole volume has been modest between both the series of the clones, there was significant variation in canopy wood volume (41 %) and total timber volume (25 %) and latex yield per ha (29 %) in the case of RRIM 900 series (Table 4) and timber volume per ha in the case of RRIM 2000 series (36%). In general, RRIM 2000 series clones have been found to be more consistent in terms of latex and timber yield profiles. However, it is important to note that the canopy volume of the RRIM 2000 series (0.73 m^3/ tree) has been found to be significantly higher than that of RRIM 900 series (0.49 m^3/tree).

Research agenda for India

The proposed multi-disciplinary R & D agenda for India should be focused towards (a) identifying genotypes with higher latex and timber yield potential with the attributes of shorter immaturity period, good girthing on tapping and tolerance to wind damage (b) screening and early selection of *Hevea* germplasm for qualitative and quantitative timber traits (c) improvement of timber quality and durability, enhancement of lignification and also reduction in the incidence of tension wood (d) undertaking the comparative feasibility analysis of alternate combinations of latex-timber clones in different agro-climatic settings (e) setting up of a promotional and regulatory agency with R & D support to revive the ailing rubber wood manufacturing units and strengthen their value added manufacturing base coupled with mechanisms to regulate the role of intermediaries in the primary market and monitor quality standards and provide market intelligence (f) formulation of a perspective plan for the regulated growth of the rubber wood based industry.

Latex and timber: Policy options and comparative feasibility analysis

Any shift in priorities from latex to timber in the Indian context should necessarily be preceded by comparative feasibility analysis, higher timber output is possible only at the expense of the harvest index, which may lead to substantial reduction in the quantity/ volume of latex produced. This raises the important issue of feasibility of alternate combinations of latex-timber clones in India as the small and marginal growers dominate (98 % of the holdings and 83% of the area) the production sector. This also underlies the need for a sensitivity analysis of different combinations of latex and timber production in India *vis a vis* Malaysia. The sensitivity analysis based on the twin options of latex and wood extraction and wood extraction only in the case of Malaysia indicated that the option involving both latex and wood extraction provided higher net returns compared to the option involving only wood extraction (Table 5). The analysis also showed that the return on investment on the option of both latex and wood extraction is much higher with an internal rate of return (IRR) of 13.7 per cent compared with 12.8 per cent in the case of the wood extraction only. Moreover, the net present value (NPV) of investment at 10 per cent discount for the 2000 ha forest plantation was RM 7.7 million and RM 5.8 million respectively. But, the benefit cost ratio (BCR) in the option of latex and wood extraction (1.20) has been found to be lower than the wood extraction only (1.29), which may be explained in terms of the higher input intensity involved in the latex production and extraction.

Table 5. **Return on investment for short-cycle rubber forest plantation in Malaysia**

Expenditure/ returns	Option 1: Latex and wood extraction	Option 2: Wood extraction only
Total revenue (RM Million)	192.87	134.22
Total expenditure (RM Million)	108.64	51.66
Net revenue (RM Million)	84.23	82.56
NPV at 10 % (RM Million)	7.70	5.80
IRR	13.70	12.80
B/C Ratio	1.20	1.29

Source: Hassan, 2002

A pioneering study on the feasibility of growing latex-timber clones in India, showed that planting of clones with higher timber potential is not highly rewarding as a 20 per cent decrease or loss in latex yield is not compensated even by a 100 per cent increase in timber potential (George and Joseph, 1996). However, it is important to develop clones with shorter life cycle with higher latex and timber yield suitable for the small holdings. Though it is not desirable to promote latex-timber clones in India on a wider scale, planting recommendations favouring latex-timber clones with shorter life cycle may be popularised in an agro-forestry perspective especially for marginal lands, non-traditional regions where latex productivity is lower and for areas within the traditional regions where shortage of tappers poses problems. The major policy options worth considering in this regard are: (a) different combinations of latex and timber plantations; (b) different life cycles of rubber plantations; and (c) harvesting timber without the option of tapping. However, the third option appears to be impractical in view of the specific characteristics of the NR production sector, viz. dominance of small and marginal growers.

R & D PROGRAMME ON LATEX : TIMBER CLONES IN INDIA

In this context, it is important to recapitulate the R & D programmes being initiated by the Rubber Research Institute of India (RRII) towards breeding and selection of *Hevea* clones with higher latex yield and timber output. The RRII has already initiated studies on the possibility of direct of wild *Hevea* germplasm for timber production and on the timber yield potential of the existing *Hevea* clones for selection of parental clones in breeding programmes.

Timber potentialities of *hevea* clones

The volumetric yield of *Hevea* logs per unit area planted may vary due to the differences in agro-management practices,

Table 6. **Clone-wise timber yield and actual utilizable volume**

Clone	Total log volume		Utilizable volume (m^3)	Average girth (cm)	Variability in girth (CV %)
	(m^3/ tree)	(m^3/ha)			
Irradiated	0.45	112	0.24	97	23
RRIM 600	0.67	167	0.37	111	19
RRII 200 series	0.77	193	0.43	116	18
Total	0.71	176	0.39	109	20

Source: Viswanathan *et al*., (2003a)

agro-climatic conditions, variety of clones, initial planting density, casualty due to wind and other damage, genetic and physiological characters of the tree, method of logging, *etc*. The average timber yield varies across rubber planting regions from 140 to 200 m^3 /ha., based on the manner in which plantations are managed (ITC/ UNCTAD/ GATT, 1993). It is estimated that in India, the yield of green wood (including branches of more 5 cm girth) per hectare is of the order of 180 m^3 in the estates sector and 150 m^3 in the smallholdings (Joseph and George, 1996). In Malaysia, the green wood yield is estimated at 190 m^3 and 180 m^3 respectively (Arshad, *et al*., 1995). In India, the volume of timber available from a seedling tree is estimated at one m^3 compared to 0.57 m^3 from a budgrafted tree with a clear bole volume of 60 per cent and branch-wood volume of 40 per cent.

A pioneering study was undertaken to estimate the timber yield potential of *Hevea* clones grown in a traditional rubber growing region in India (Viswanathan *et al*., 2003a). The study included three clones, *viz*., irradiated clones, RRII 200 series (RRII 201 to RRII 208) and RRIM 600 covering a total population of 1058 trees (Table 6). Among the three clones, the total log volume was found to be the highest for RRII 200 series (193 m^3 per ha) followed by RRIM 600 (167 m^3 per ha) and the irradiated clones (112 m^3 per ha).

Reghu *et al*., (2002 a) have compared the latex and timber yield potential of RRII

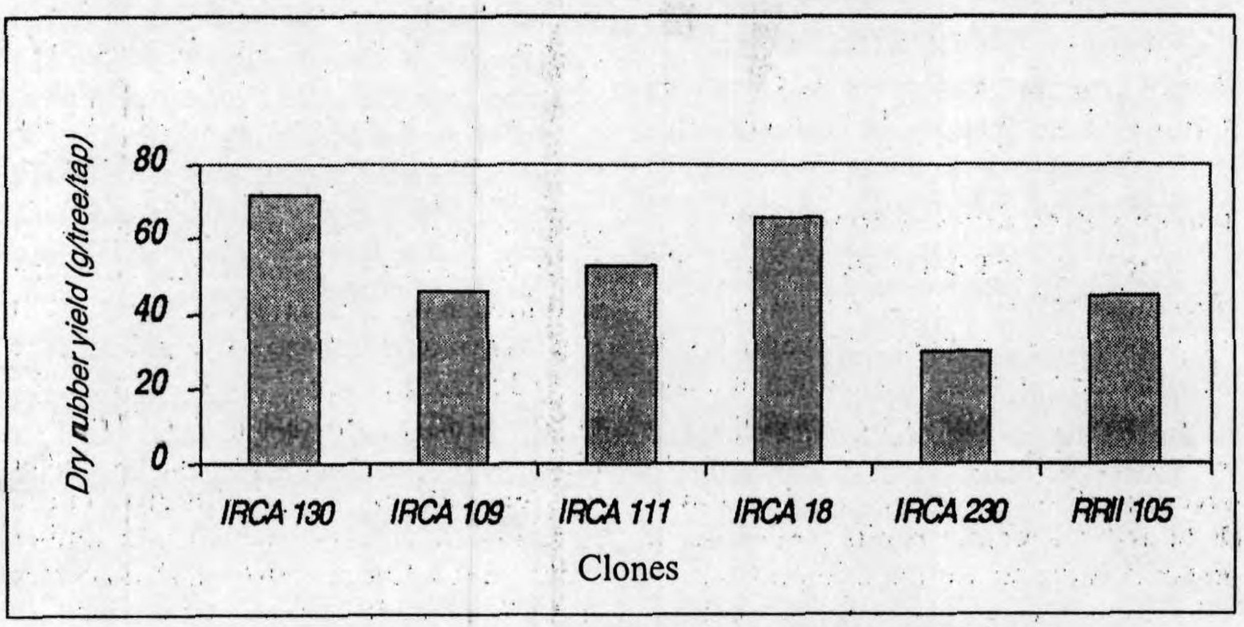

Figure 2. Comparison of latex yield of IRCA clones with that of RRII 105

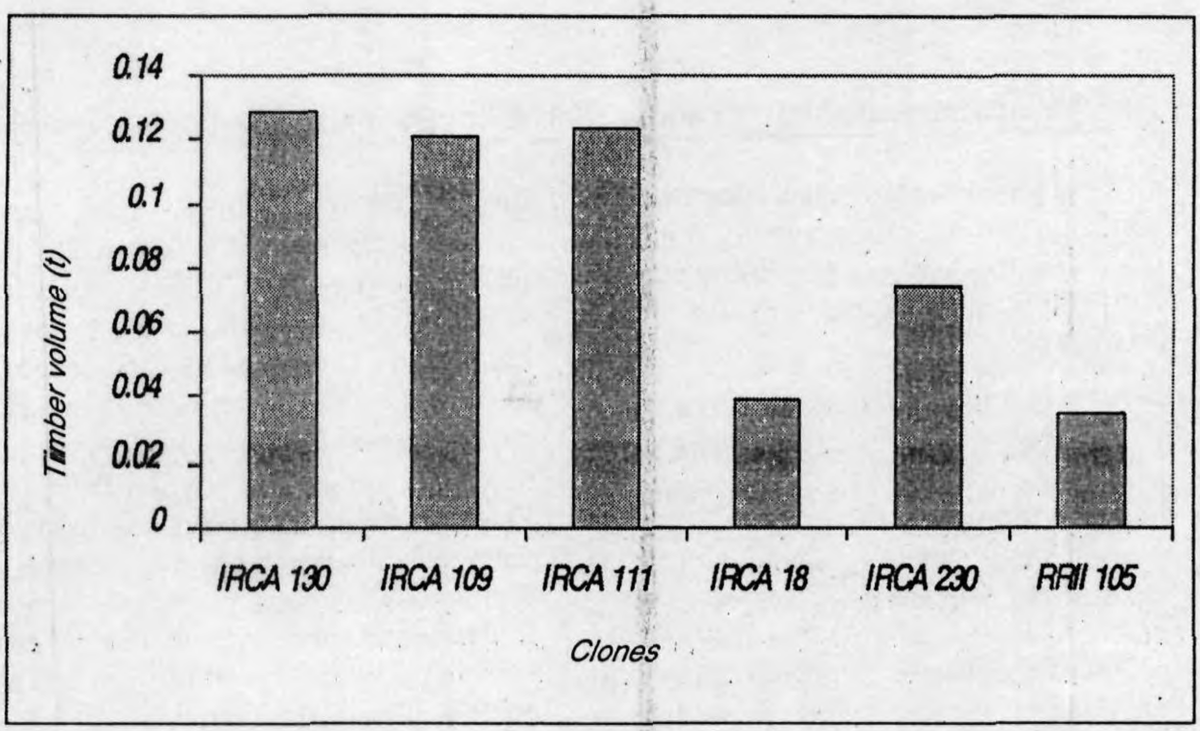

Figure 3. Comparison of timber yield of IRCA clones with that of RRII 105

105 with some of the IRCA clones grown in India, at the age of nine years (Figures 2 and 3). While the clones IRCA 130 and IRCA 18 have higher latex yield over RRII 105, the clones IRCA 109 and IRCA 111 are almost comparable with RRII 105 (Figure 2). However, the timber yield of RRII 105 has been found to be lower than all the IRCA clones (Figure 3).

Timber potentialities of germplasm

The 1981 IRRDB collection of wild *Hevea* germplasm was confined to three different eco-geographical provenances of the Amazon basin *viz.* Acre, Rondonia and Mato grosso. The eco-geographical preference of this crop can be expected to have a profound influence on the growth (bole and branching) habits pertaining to timber production potential. In general, the wild accessions are poor latex yielders. However, preliminary screening indicated the potentiality of several accessions in having desirable timber characteristics. Crossing high yielding Wickham clones with selected wild accessions showed promising results with improved girth and yield performance of the progenies (Benong *et al.*, 2002).

Twenty vigorous wild accessions have been reported from Malaysia (Nasaruddin, *et al.*, 2002) with the total timber volume ranging from 1.4 m^3 to 2.5 m^3 at the age of 14 years. Similarly, 28 accessions have been identified in Indonesia (Daslin, *et al.*, 2002) with a clear bole volume ranging from 0.92 m^3 to 2.56 m^3 per tree at the age of 13 to 16 years. Studies initiated at RRII have identified 19 potential accessions as timber yielders (Reghu, *et al.*, 2002b). These selections have been planted in a timber evaluation trial along with 6 wickham clones at the Regional Research station, Padiyoor, Kerala. The preliminary results revealed that all these genotypes have vigorous growth and girthing pattern compared to Wickham clones Hence there is a possibility of direct use of potential genotypes for timber production.

Structure and properties of *Hevea* wood

Rubber tree (*Hevea brasiliensis)* is a perennial dicotyledonous species belonging to the family Euphorbiaceae. The tree has a straight trunk of 3-4 m, attaining 70 – 110 cm diameter at breast height with a profusely branched dense canopy. The tree grows 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 material. Over time, bud grafted plants have replaced seedling derived trees in all the major rubber producing countries and this practice had serious implications on the per tree timber yield as the volume of the timber is directly proportional to the girth of the timber species. Rubber trees with desirably large stem diameters and longer boles with less branching (branching at higher elevations from the ground) gives higher timber yield and reduces the wood wastes generated at the time of tree felling, logging and sawing.

Gross structure

Rubber wood has a gross structure of dicotyledonous timber with certain characteristics specific to the species. Based on density (Bosshard, 1966), rubber wood is classified under the category of light hardwood. 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. Growth rings are usually absent or ill defined in rubber wood. The concentric markings, which resemble growth rings combined with the large vessel elements, give the timber an attractive appearance with clear figure on the longitudinal surface of the wood. Heartwood formation is virtually absent in rubber tree and the storage wood tissue is filled with soluble sugar and starch, which under it vulnerable to attack by biological agents.

Anatomy

Rubber wood composes of fibres, vessel elements (pores), axial parenchyma and rays distributed in different patterns and proportions as in other hardwood species. Table 7 depicts the proportion of wood elements in rubber wood .The proportion of fibres in rubber wood is moderate in comparison to other fast growing timber species such as *Gmelina arborea* and *Eucalyptus* spp.

Fibres are non-septate and belong to the

Table 7. **Proportion and dimension of rubber wood elements**

Element	Proportion (%)	Dimension: Length Range (mm)	Dimension: Length Mean (mm)	Dimension: Width Range (mm)	Dimension: Width Mean (mm)
Fibres	58.0	1.100 - 1.400	1.19	0.019 - 0.027	0.022
Vessels	8.5	0.015 - 0.798	0.05	0.070 - 0.224	0.155
Rays	22.0	-	-	-	-
Axial parenchyma	11.5				

Source: Bhat *et al*., (1984); Reghu *et al*., (1989) medium group with an average length of 1.19 mm, average width of 0.022 mm and wall thickness of 0.0035 mm. In mature trees, the fibre length increases from pith outwards. Reghu *et al.*, (1989) reported that significant variation in fibre length was observed at different heights of the tree trunk. The vessel elements are evenly distributed as solitary or radial multiples of 2 to 3 or rarely more, with 1 to 4 pores per mm^2. These are moderately large to small, and visible to the naked eye. The vessel lines are clearly visible in the longitudinal plane. The lumen is usually filled with balloon-like parenchymatous structures, called tyloses, formed by the in growth of parenchymatous cells towards the vessel lumen through the pit cavities of the vessel walls. The diffuse porous nature of rubber wood is caused by the distribution pattern of pores or vessel elements. The structure, alignment and properties of pores also determine the chemical impregnation capacity of rubber wood during preservative treatments. The parenchymatuous tissue in wood axial and ray parenchyma which are considered as soft tissue with the main function of storing the reserve metabolites.

While an increase in the proportion of fibres increases density, an increase in the proportion of soft tissue in wood reduces it. In rubber wood , the higher percentage of soft tissue (33%) reflects its light hardwood nature. Moreover, unlike in durable hardwood species the soft tissue 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 that cause deterioration under natural conditions. However, the structural and anatomical characteristics of rubber wood enable wood preservatives to penetrate, impregnate and protect it from biological deterioration.

Tension wood formation

Tension wood is considered as a natural defect and it is an abnormal structure of wood. The formation of tension wood is a common phenomenon In rubber tree. The distribution of tension wood is not restricted to the 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. 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 fibres are scattered singly or in small groups among the normal wood fibres. When the tree is felled and freshly cross cut, the compact arcs are clearly visible even to naked eye as white 'wooly' lustrous zones. However, in diffuse type, the fibres are recognised only with the aid of a microscope after staining wood sections with specific stains.

Clonal variability

The proportion of tension wood in rubber trees vary from clone to clone, tree to tree and even within trees at different height levels from base to top of the tree bole. Significant clonal variability was observed in the proportion of tensionwood in the mature (Ani, and Lim 1992) and immature growth phases of the tree. Of the six clones studied (Francis and Reghu, unpublished) in their mature stage, PB 260 had the maximum proportion of tensionwood (40.2%), followed by RRII 105 (28.3%), RRIM 600 (26.5%) and PB 86 (26%). The clone Tjir and GT 1 had lowest percentage share of tensionwood, *viz.,* 16.8 and 19 per cent respectively (Figure 4).

The quantification of diffuse tension wood is extremely difficult due to random distribution of tension wood fibres among the normal wood fibres. The occurance of 15-68 % tension wood in random samples of three rubber wood logs (Sharma and Kukreti, 1981) and 15-65 per cent tension wood in different longitudinal samples taken from the same tree and different trees (Rao *et al.*, 1983) has been reported.

Structural features 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 microfibrills, which gives its characteristic gelatinous nature. In rubber wood the third layer of the secondary wall is unlignified and usually shows partial or total detachment from the adjacent walls (Reghu, 1998; 2002).

Wood working problems due to tensionwood

The abnormal structure and peculiar properties of tension wood fibres result in various wood working problems depending on the distribution and quantity of tension wood formed. The major problems associated with the incidence of tension wood at different stages of rubber wood processing are:

(i.) While cutting and sawing, the G layer tends to detach from the adjacent walls (due to the low level of lignification and lack of adhesion between the G-layer and other cell wall layers), and frequently form convoluted masses in the fibre lumen . This in turn sticks to the saw and disturbs its free movement.

(ii.) During peeling, green wood often produce rough and 'wooly' surface as the fibres tend to be partly torn out.

(iii.) While planning and finishing the tension wood zone always depicts a rough surface which will make the end products less attractive.

(iv.) Due to low level of lignification, the longitudinal shrinkage of tension wood fibre during drying is very severe and causes uncontrollable distortions. Major drying defects caused by tension wood are warping in the form of twisting, bowing, cupping, collapse, springing etc. which in turn results in dimensional instability of sawn planks and associated machining problems.

As the impact of tension wood on various applications of rubber wood is unpredictable, appropriate technology development through coordinated research is essential for quality improvement of rubber wood from a long-term perspective.

Lignin biosynthesis studies for improving timber quality

The potential of rubber timber for various industrial applications has been well established. However, some inherent demerits of rubber wood prevent its acceptability for specific end uses. Major limitations preventing the wide utilization of rubber wood for industrial applications are:

(i.) High proportion of unlignified or partially lignified tension wood fibers and low level of lignification in normal fibers leading to considerable reduction in the strength properties, high level of distortions, shrinkage, diamensional instability and high incidence of wind damage in the field.

(ii.) High susceptibility to biological deterioration due to the high content of reserve metabolies in the form of soluble sugar and starch.

(iii.)Low level of polyphenolic conversion of reserve metabolites making rubber wood less durable.

It has already been reported that the increase in lignin biosynthesis in living trees facilitates the improvement of quality and durability of timber by enhancing physical, chemical and mechanical properties in addition to protecting them from biological deterioration (Boudet, 2000). Lignins are phenolic polymers of the cellwall and its functional significance has been mainly associated with mechanical support, defence mechanisms and strengthening of plant tissue. Above all, the high deposition of lignin bio-polymer into the cellwall provide re-inforcement and confers new properties such as resistance to biodegradation (Boudet, 2000).

In this context, RRII has initiated lignin biosynthesis studies with the objective of improving quality and durability of rubber timber. The protocol for the localisation and quantification of key enzyme markers in *Hevea* pertaining to lignin biosynthesis and for the estimation of wood lignin has been developed. Preliminary studies on the lignification pattern in certain *Hevea* clones revealed significant clonal variability. The rapid identification and quantification of enzyme markers pertaining to lignin biosynthesis in rubber tree for speedy and effective screening of a large number of potential genotypes having desirable timber quality traits is being undertaken. This would ultimately result in enhanced utilisation of rubber wood for various industrial applications by eliminating and/ or minimising the major demerits caused by low level of lignification and biological deterioration, thus facilitating further value addition of rubber timber.

CONCLUSION

The new research agenda as highlighted in this paper calls for a systematic and realistic analysis of the varying degrees of grower responses to replanting, the influence of income from rubberwood on further plantation investments, the age at which trees are harvested and the timber yield potential of various clones in different agro-climatic environments. This is of prime importance as the rubber wood would from an important source of income to the small and marginal farmer in the context of fluctuating rubber prices. It is also important to undertake in depth studies in a multi-disciplinary perspective for identifying genotypes with higher latex and timber yield potential; screening and early selection of *Hevea* germplasm for qualitative and quantitative timber traits; evolving latex-timber and timber clones with the attributes of shorter immature cycle, good girthing on tapping, tolerance to wind damage; and improving timber qualities including durability.

REFERENCES

Ani, S. and Lim, S.C. (1992). Wood quality study of rubber wood at different ages and clones. *Report on Properties and Utilization of Rubber wood from Trees of Different Age Groups, FRIM, Kepong*, pp. 39-50.

Arshad, N.L.B. and Othman, R.B. (1996). Rubber plantations as a timber resource. *The Planter* **72**: (846): 79.

Arshad, N.L.B. and Othman, R.B. and Rahman.

(1995). *Hevea* wood availability in Peninsular Malaysia. *Planters' Bulletin*, **224 & 225**: 73 - 83.

Benong, M; Othman, R; Ghani, Z.A. and Mohd. Nasarudin, A.M. (2202). Status on the evaluation and utilisationof the 1981 IRRDB Hevea germplasm. *IRRDB Joint Workshop on Plant Breeding, Agronomy and Socio-Economics*, 28 August to 7 September, 2002, Malaysia and Indonesia.

Bhat, K.M., Bhat, K.V., Damodaran, T.K. and Rugmini, P. (1984). Some wood and bark properties of *Hevea brasiliensis*. *Journal of Tree Sciences*, **3**: 40-46.

Bosshard, H.H. (1966). Notes on the biology of heartwood formation. *IAWA News Bulletin*, **1**: 11-14.

Boudet, A.M. (2000) Lignins and lignification: selected issues. *Plant Physiology and Biochemistry*, **38**(1/2): 81-96.

Daslin, A., Sekhar, W. and Irwan, S. (2002) Report on the evaluation and utilization of the 1981 IRRDB Hevea germplasm in Indonesia. *IRRDB Joint Workshop on Plant Breeding, Agronomy and Socio-Economics*, 28 August to 7 September, 2002, Malaysia and Indonesia.

DGCIS (2000). Monthly statistics on foreign trade:2 Imports. Directorate general of commercial Intelligence and Statistics, Ministry of Commerce, Government of India, Calcutta.

Francis, M and Reghu, C.P. (2002). Structural studies on tension wood of *Hevea brasiliensis* with special emphasis on clonal variability. Rubber Research Institute of India, Kottayam (unpublished).

George, K.T. (2000). Exploring new frontiers of environment conservation: The case of rubber plantations, In: *Tropical Forestry Research: Challenges in the New Millennium*. (Eds. Varma, R.V., Bhat, K.V., Muralidharan, E.M., and J.K. Sharma). *Proceedings of the International Symposium*, 2-4 August, 2000 at Kerala Forest Research Institute, Peechi, Kerala, India, pp. 267-272.

George, K.T. (2000). Research programmes in Economics Division: A review. *Paper presented at the Rubber Planters' Conference*, 21-23 November 2002, Rubber Research Institute of India, Kottayam.

George, K.T. and Joseph, T. (1993). Untapped market potential and comparative advantage of a by-product: The case of rubber wood processing industry in India. *Wood News*, 3(3): 6 - 10

George, K.T. and Joseph, T. (1996). The economics of rubber wood production in India: A cost benefit analysis on the constraints and potential. *Proceedings of the Global Forum on Investiment Opportunities in the Indian Rubber Wood Industry*, 19-21 March 1996, Cochin, Kerala, pp. 135-141.

George, K.T. and Joseph, T. (2002). Rubber wood production and utilisation in India, In: *Rubber Wood Processing and Utilization in India*. (Eds. R. Gnanaharan, K. Tharian George,. and K. Damodaran). Science and Technology Entrepreneurship Development Project, Kozhikode, Kerala, India, Ganesh Publications Pvt. Ltd., Bangalore, pp. 1-9.

Hassan, Mohamad Johari b. Mohamad (2002). Viability of rubber forest plantation. *IRRDB Joint Workshop on Plant Breeding, Agronomy and Socio-Economics*, 28 August to 7 September, 2002, Malaysia and Indonesia.

IRSG (2002). *Rubber Statistical Bulletin*, *57* (2), November, International Rubber Study Group, U.K.

ITC/ UNCTAD/ GATT (1993). Rubber wood: A study of the world development potential, market study. International Trade Centre, UNCTAD/GATT, Geneva.

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

Joseph, T., George, K.T. and Viswanathan, P.K. (1998). Production and utilization of rubber (Hevea) wood in India. *Proceedings of the*

National Seminar on Plantation Timbers and Bamboo, 23-24 July 1998 , IPIRTI, Bangalore, India, pp. 151-57.

Malaysian Rubber Board (1998). Revised rubber strategy: Key areas for action, Malayasian Rubber Board, Kuala Lumpur.

Nasaruddin, M.A., Othman, R., Benong, M. and Ghani, Z.A. (2002). Overview of the IRRDB 1981 *Hevea* germplasm collection. *IRRDB Joint Workshop on Plant Breeding, Agronomy and Socio-Economics*, 28 August to 7 September, 2002, Malaysia and Indonesia.

Ong, S.H., Othman, R, Aziz, M ZA, Hashim, O, Benong, M and Ghani, MNA (1995). RRIM planting recommendations 1995-1997, In: *Ensuring Sustainability and Competitiveness of the NR Industry* (Eds. Kadir S.A. Abdul Aziz). *Proceedings of the Rubber Growers' Conference*, 17-19 July 1995, Kuala Lumpur, Malaysia, pp. 9-39.

Reghu, C.P. (1998). Rubber tree: A potential source of timber. *Rubber Board Bulletin*, **27**(3): 2-8.

Reghu, C.P. (2002). Structural features of rubber wood, In: *Rubber Wood Processing and Utilization in India*. (Eds. R. Gnanaharan, K. Tharian George, and K. Damodaran). Science and Technology Entrepreneurship Development Project, Kozhikode, Kerala, India, Ganesh Publications Pvt. Ltd., Bangalore, India, pp. 10-18.

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

Reghu, C.P. Abraham, S.T., Rao, G.P., Madhavan, J. and Varghese, Y.A. (2002 a). Evaluation of IRCA clones. Rubber Research Institute of India, Kottayam. (unpublished).

Reghu, C.P. Abraham, S.T. and Varghese, Y.A. (2002 b). Screening of *Hevea* germplasm for timber- latex traits . Rubber Research Institute of India, Kottayam. (unpublished).

Rubber Board (2002). Indian Rubber Statistics, Vol. 25, Rubber Board , Kottayam, Kerala.

Sharma, S.N. and Kukreti. (1981). Seasoning behaviour of rubber wood: An underutilized non-conventional timber resource. *Journal of Timber Development Association of India*, **27** (2): 19-29.

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.

Viswanathan, P.K., George, K.T. and Joseph, T. (2003a). Timber yield potential of *Hevea* clones in India: A preliminary assessment, *The Planter*, **79** (925): 253-261.

Viswanathan, P.K., George, K.T. and Joseph, T. (2003b). Policy paper on rubber wood. Rubber Research Institute of India, Kottayam, Kerala (unpublished). ■