

**Forest Management:** Definitions, Good Practices and Certification.

## Further Reading

- Anonymous (1950) *The Wealth of India- Industrial Series*, Publication and Information Directorate, pp. 242–271. New Delhi, India: CSIR.
- Anonymous (1972) *Indian Forest Utilization*. Dehradun, India: Forest Research Institutes and Colleges.
- Anonymous (1973) *Processing of Natural Rubber*. FAO Agricultural Services Bulletin, no. 20 Rome: Food and Agriculture Organization.
- Balick MJ (ed.) (1988) *The palm-tree of life: biology, utilization and conservation*. *Advances in Economic Botany* 6: 1–282.
- Balick MJ and Beck HT (eds) (1990) *Useful Palms of the World: A Synoptic Bibliography*. New York: Columbia University Press.
- Basu SK and Chakraverty RK (1994) *A Manual of Cultivated Palms in India*. Calcutta, India: Botanical Survey of India.
- Chaudhari DC (1995) *Manual of Rill Method of Resin Tapping from Pines*. Dehradun, India: Indian Council of Forestry Research and Education.
- Coppen JJW (1995) *Gums, Resins and Latexes of Plant Origin*. Rome: Food and Agriculture Organization.
- Corner EJH (1966) *The Natural History of Palms*. Berkeley, CA: University of California Press.
- Data on Agriculture/Agricultural Production-Primary Crops/Natural Rubber*. FAOSTAT- FAO statistical databases. Available online at: <http://apps.fao.org>.
- Hillis WE (1987) *Heartwood and Tree Exudates*. Berlin: Springer-Verlag.
- Howes FN (1949) *Vegetable Gums and Resins*. Waltham, MA: Chronica Botanica.
- Johnson DV (1998) *Tropical Palms*. Rome: Food and Agriculture Organization.
- Jones DL (1995) *Palms Throughout the World*. Washington, DC: Smithsonian Institution Press.
- Mantell CL (1950) *The natural hard resins: their botany, sources and utilization*. *Economic Botany* 4: 203–242.

socioeconomic development of the producing countries. Until the start of World War II natural rubber was the sole supply of an elastic material. Since the 1950s it has had to compete with a variety of oil-derived synthetic rubbers; nevertheless natural rubber has managed to establish good markets in products that require natural rubber's specific properties. The obvious environmental advantages which natural rubber possesses over the synthetic rubbers have never translated into financial advantage: both kinds have for decades suffered, like most industrial raw materials and agricultural commodities, from poor prices. Despite this, producing natural rubber remains the main and often the sole source of family income for millions of small farmers around the world.

## History

Natural rubber is found in the form of latex in at least 2000 species of plants: these include *Hevea* spp., *Manihot*, and *Castilloa* from tropical America; *Landolphia* and *Funtumia* from Africa; and *Guayule* from Russia. There is only one rubber-bearing species of commercial significance – *Hevea brasiliensis* – a native of the Amazonian (mainly Brazilian) rainforest.

*Hevea* is widely distributed in the rainforest, a few trees per hectare, and rubber had been extracted by forest-dwellers from these trees for centuries for the manufacture of playballs and religious artefacts. During the eighteenth century several European explorers noted the existence of the tree and its product. In England, the eminent chemist Joseph Priestley observed the ability of the product to erase pencil marks and gave it the name 'rubber.' It is odd that this name has persisted in the English language for it relates to a property of the material that is of little use. The name in most other languages (e.g., caoutchouc, Kautschuk) is more apt, stemming from the Tropical American Indian *cachuchu*: 'weeping wood.' The older English name 'india rubber' represents a misunderstanding of rubber geography.

With the development in the mid-nineteenth century, mainly in Britain and the USA, of technologies (shaping, vulcanization) for converting the raw material into useful products, the demand for natural rubber started to grow so fast that the supply from Brazil was proving inadequate, despite savageries inflicted on forest rubber-gatherers, and the price was rising excessively. During the 1860s Sir Clement Markham of the India Office (UK), who had been responsible for transferring the quinine-bearing plant *Cinchona* from tropical America to organized plantings (plantations) in India, had the inspiration of

## Rubber Trees

P W Allen, Harpenden, UK

© 2004, Elsevier Ltd. All Rights Reserved.

## Introduction

The forest tree *Hevea brasiliensis*, native to the Amazonian rainforest, has been grown in Asia and Africa for over a century to produce natural rubber, a raw material used for the manufacture of a range of products, especially tires. Production and export of natural rubber has played a major role in the

doing similarly with *Hevea*. He commissioned two English botanists to collect specimens of *Hevea* spp. for study at Kew Gardens: they identified *Hevea brasiliensis* as the most promising. After several failed attempts to collect and ship seeds from Brazil, the British government commissioned Henry Wickham to make another attempt: he succeeded and brought some 70 000 seeds to Kew Gardens. Just over 2000 seeds germinated; some were sent to Ceylon (Sri Lanka), some to Malaya (Malaysia).

By 1890 *Hevea* seedlings were widely distributed, forming the basis of a major new industry, first in Asia, subsequently in West Africa. Production grew fast, stimulated by the invention of the pneumatic tire by John Dunlop in 1888 and arrival of the motor car.

Brazil has long ceased to be a major producer of natural rubber for a number of reasons, especially that attempts to establish plantations of *Hevea* have been largely vitiated by South American leaf blight, an untreatable fungal disease which has providentially not arrived in the main rubber-growing countries.

Producing and exporting natural rubber has played a major role in the socioeconomic development of the producing countries (Figure 1), providing much employment, inward investment, and importation of hard foreign currency.

Until the entry of the USA into World War II in 1942 natural rubber had no serious competitors. There had been some modest development of synthetic rubbers in the USA and Germany but these

were expensive compared with natural rubber. Following the Japanese occupation of the rubber-growing areas in Asia, the USA embarked on a massive program (in size, second to the atom bomb project) to devise a major synthetic rubber (styrene/butadiene copolymer). During the next two decades, a number of synthetic rubbers, of different properties and prices, were developed and commercialized in many countries. Thus, from the 1960s natural rubber was faced with serious competition. Today (2002) natural rubber accounts for some 40% of the world market for rubber, having climbed back from a low of 30% two decades ago.

## The Tree

In the wild the rubber tree can grow to over 40 m with a lifespan over 100 years. Because the economic life in plantations is 25–30 years, the final tree height is some 20 m. From planting, it requires some 5–7 years before a tree yields a useful amount of rubber and the yield of rubber will steadily rise to a maximum after about 15 years, and thereafter decline. Good practice is to replant after about 30 years.

The rubber tree is relatively robust, a reason for its suitability for small farmers. It does suffer from a number of diseases (mainly fungi), e.g., varieties of *Phytophthora* attacking leaves and bark, and some root diseases, especially *Rigidoporus*. These are all treatable, albeit sometimes with difficulty and

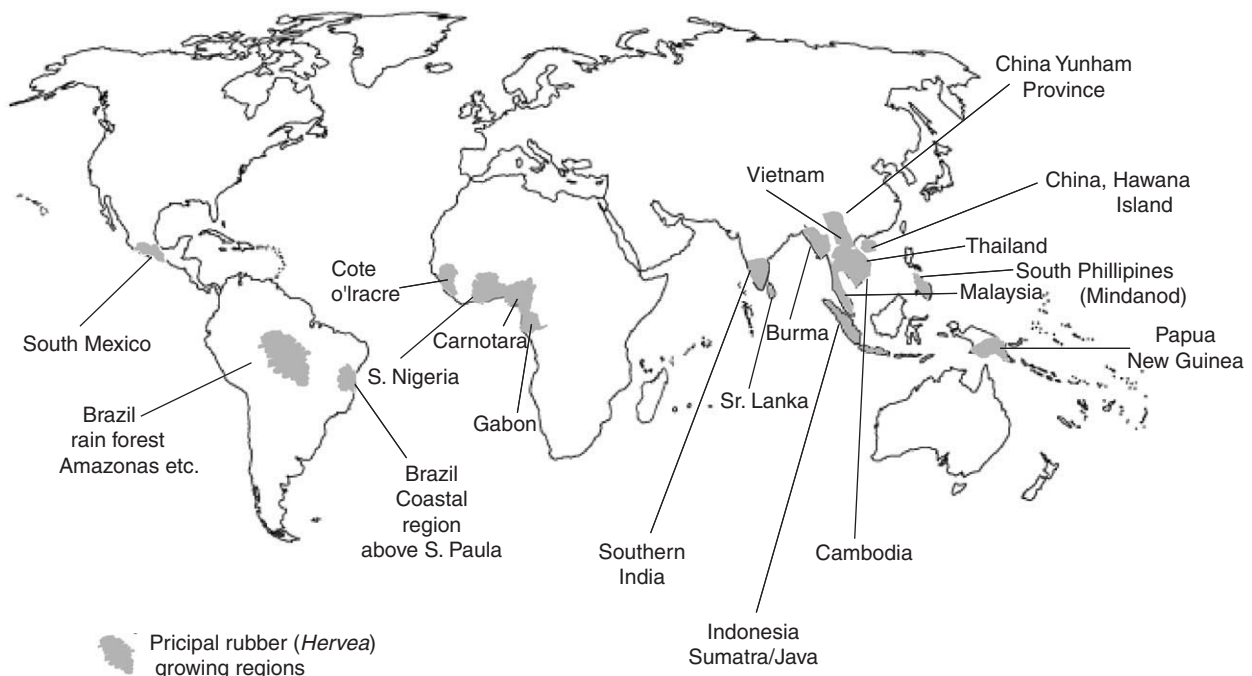


Figure 1 Principal rubber (*Hevea*) growing regions.

expense. Reference has been made to South American leaf blight (*Dothidella ulei*) for which no effective treatments have yet been found and has not yet appeared in the main rubber-growing areas.

The reason why *Hevea* and other rubber-bearing trees and shrubs produce rubber remains a mystery: various theories (e.g., wound healing) have been advanced but do not stand up to scrutiny.

The biochemical processes whereby the tree converts carbon dioxide and water into rubber have been fairly extensively studied, a number of intermediates (e.g., isopentenyl pyrophosphate) have been identified, and the basic pathway is more or less understood. It must be said that such work, though academically interesting, has not yet contributed to the well-being of the industry.

### Breeding to Enhance Yield

As regards yield, the original importations into Asia yielded no more than about  $500 \text{ kg ha}^{-1}$ . There is a long history of work to enhance yields by breeding. In the early days of rubber growing in Asia, trees were replicated by growing from unselected seedlings; later, use was made of selected seedlings. Subsequently, from about 1920, largely from work by the Dutch in the former Netherlands East Indies, vegetative propagation from proven high-yielding trees by bud grafting became the standard practice resulting in the establishment of a number of well-characterized clones. The choice of a clone for a particular situation is a matter of judgment: some are very high yielders but oversusceptible to specific diseases or wind damage, etc., others yield less rubber but are more robust. Today, yields of around  $3000 \text{ kg ha}^{-1}$  are achievable under favorable circumstances, an almost 10-fold increase on nature.

### The Producers

Traditionally, shortly after the original importations of *Hevea* into Asia, the normal way of growing and selling natural rubber was by establishment of large (>1000 ha) estates, owned by commercial enterprises, many of which were London-quoted companies especially in Malaya. Indeed, the impetus to establish such estates, from the early 1900s, was that it was a very profitable operation for the owners. During the past few decades growing and selling natural rubber became distinctly uninteresting compared with other investments: alternative crops (e.g., oil palm) gave better returns, so also did selling the land for industrial development or housing. Over the years virtually all the Western-owned estates have gradually withered away.

Parallel with establishment of estates, many small farmers (smallholders) in Asia and subsequently in Africa started to grow rubber on holdings of a few hectares; in some countries, notably Thailand, estates have never been a significant feature. It must be said that until the 1960s most observers of the industry disregarded the increasing dominance of the smallholder sector. Today, over 80% of natural rubber comes from smallholdings, a significant feature of the socioeconomic development of the industry. Rubber is in fact a very suitable crop for smallholders: it is very robust, will withstand much abuse and neglect, and is able to provide a modest family income.

As regards geography, in theory *Hevea* can be cultivated wherever conditions are similar to those in the Amazonian rainforest: high humidity, temperatures in the range  $25\text{--}35^\circ\text{C}$ , and rainfall not less than  $5000 \text{ mm year}^{-1}$ . The actual distribution is a matter of history, especially the former existence of British, Dutch, and French colonies in the tropics. Britain naturally sent the first *Hevea* seedlings to its then colonies in Southeast Asia; the Dutch to Netherlands East Indies; the French to Indochina.

Some 85% of production remains within Asia, especially in Southeast Asia where Malaysia, Indonesia, and Thailand have long been dominant: in recent decades China has become a significant producer. In Africa, Côte d'Ivoire, Nigeria, and Cameroon produce modest quantities; production in tropical America has been low and static for decades.

### Production

Natural rubber exists in the tree as latex, a colloidal dispersion of rubber particles in an aqueous serum, contained in an interconnecting system of tubular vessels in the inner bark. It is extracted by 'tapping,' a semiskilled procedure involving paring away with a special knife a sliver of bark about 1 mm thick to a depth that just stops short of cutting the cambium layer. The first tapping opens up a 'tapping panel' which is developed by further tappings, working down the tree (Figure 2). Bark is renewed below the descending cuts. After some 5 years a new tapping panel is started, leaving the first panel to regenerate. There is a variety of tapping regimes such as 'half spiral, alternate daily' and there are other methods such as 'puncture tapping' involving making holes in the bark. Each has its adherents and critics. Whichever method is chosen, tapping is always carried out at dawn, when latex flow is fastest (Figure 3). The latex is collected in cups and then amalgamated into buckets to be taken to the collection center. Yields can be enhanced by use of ethylene-generating yield



**Figure 2** Close-up of tapping panel and collecting cup. Photograph courtesy of Tun Abdul Razak Research Centre.



**Figure 3** Rubber tapper at work. Photograph courtesy of Tun Abdul Razak Research Centre.

stimulants applied to the tapping panel. This technique, devised in the 1970s, is now widely used.

Production of natural rubber by tapping *Hevea* is inevitably very labor intensive. In Western eyes this might seem a grave disadvantage but employment opportunities in most producing countries are often somewhat limited. Against this, in some producing countries the recent growth of new industries has started to encourage people, especially young people, to move from the growing areas into the cities. In Malaysia, for example, it has become increasingly difficult to maintain production on small farms. Nevertheless, over the decades growing and exploiting *Hevea* has been a major engine of growth in the producing countries.

### Processing

One may distinguish between primary processing which produces 'raw rubber' for conversion into rubber products such as tires, and those processes that convert raw rubber into products. The former is undertaken close to the trees; the latter may be within a rubber-producing country or other countries which have imported raw rubber. Most raw natural rubber is exported.

### Primary Processing

The latex from the tree contains about 30% rubber. Some 90% of production is converted into 'dry rubber' by coagulating the latex with formic or acetic acid. Until the 1960s most coagulated rubber was dried in smokehouses to produce 'ribbed smoked sheet' which was sold in various qualities dependent on appearance. This procedure, which seems quaint today, has been gradually superseded by the introduction by Malaysia in 1965 of technical specifications (Standard Malaysian Rubber), stimulated by competition from synthetic rubbers. At the same time, new processing techniques were introduced whereby the coagulated rubber is granulated, dried, and compressed into bales. The Malaysian initiative was rapidly followed by most other producing countries.

Natural rubber is also marketed in another form: latex concentrate, produced by centrifuging latex to increase the rubber content to about 60% so as to minimize the cost of shipping rubber in liquid form. This material is used to manufacture items such as gloves and condoms.

### Conversion into Products

'Raw rubber' whether natural or synthetic is a soft rather weak material of little use until it has been

‘vulcanized,’ a process that introduces crosslinks between the very long molecules of which all rubbers are composed. The crosslinks comprise sulfur atoms: vulcanization involves mixing raw rubber with sulfur and various other chemicals (vulcanization agents, anti-aging chemicals, etc.) plus, usually, carbon black to impart extra strength. The resultant mix is shaped, for example in a mold or by extrusion and simultaneously heated to about 150°C for a period of time sufficient to achieve vulcanization.

Products made directly from latex concentrate, such as gloves, are made by dipping porcelain formers into the latex with its mix of added chemicals, drying and simultaneously vulcanizing, and then stripping off the product.

## Markets and Competition

The term ‘rubber’ does not denote a unique chemical composition as does, for example, ‘water.’ Rubbers are a group of materials distinguished by elasticity – the ability to be stretched many-fold and to return more or less to the original size on removal of the stretching force.

In fact, natural rubber and the majority of synthetic rubbers do have much in common. All are long-chain high polymers with molecular masses around 1 million. Most are related to (but not synthesized from) butadiene, an unsaturated molecule with four carbon atoms. Replacing, hypothetically, one hydrogen atom in butadiene with a methyl group (CH<sub>3</sub>) gives isoprene and natural rubber is a polymer of isoprene: *cis* 1.4 polyisoprene. Replacing a hydrogen atom with a chlorine atom gives the synthetic rubber polychloroprene. Some synthetic rubbers are copolymers: the most important synthetic rubber, in terms of tonnage, is a copolymer of styrene and butadiene. There is a synthetic replica of natural rubber. This has not proved to be a threat to natural rubber’s markets, despite earlier fears: it is expensive to produce and its properties do not quite match those of natural rubber.

### Competition

From the above it will be understood that there is a range of synthetic rubbers. Some are relatively inexpensive general-purpose rubbers; others are very expensive speciality rubbers used when their unique qualities, such as ability to resist very high temperatures as in, for example, gaskets in aero engines. The former group compete with natural rubber; the latter do not.

To give one example, the most important synthetic rubber – styrene/butadiene copolymer – has properties very suited to use in the treads of car tires,



**Figure 4** Manufacturing a radial-ply tire. Photograph courtesy of Tun Abdul Razak Research Centre.

imparting good skid resistance. This synthetic rubber has entirely supplanted natural rubber in this application. Before the arrival of radial-ply tires, natural rubber had virtually ceased to be used in car tires. In radial-ply tires, the technical demands on sidewalls require use of natural rubber (Figure 4).

There has thus developed during the last few decades a reasonably clear view as to what rubber to use in a particular application: there have been winners and losers.

There was a time, around the 1960s, when some supposed that natural rubber would cease to be of any significance, that it would wither away. This has not happened, partly because of intelligent reactions by the main producing countries but – more importantly – because natural rubber has been endowed by nature with some unique qualities. It has very high resilience, indicating low heat build-up in tire carcasses; it has excellent strength at high temperatures which is why it is the material of choice for aircraft tires; it has excellent fatigue resistance. It is especially suitable for high-performance applications, and a number of new markets have been opened up from this, such as natural rubber/steel laminates used to isolate buildings from vibrations, including the protection of buildings against earthquake damage. Also, as noted natural rubber retains a good foothold in the tire market, to the extent that over 70% of natural rubber goes into the manufacture of tires.

### Prices

Bearing in mind that several million small rubber farmers rely on selling their output to provide an income for their families, the price they receive is obviously of prime importance; sadly, the price

history of natural rubber has been dismal for the past several decades. The same is more or less true for other agricultural commodities.

Natural rubber, like all agricultural commodities (and oil), is sold on the open market, receiving whatever price is, more or less, determined by supply and demand or, to be more precise, by buyers' and sellers' expectations as to future trends. The main markets are Singapore, Kuala Lumpur, London, and New York. As with stock markets, short-term price movements are essentially irrational, affected by rumors rather than by facts. This makes life hard for small farmers because they face fluctuating incomes.

Several attempts have been made to stabilize and if possible enhance prices. The Stevenson Scheme (1922) planned to restrict output but, since it was a British government initiative, its effect was limited to Malaya and Ceylon: it did succeed in raising the price but engendered fury among major consumers, especially in the USA. The Rubber Regulation Scheme of the 1930s, involving quotas for production, worked to an extent but was terminated by World War II. A much more ambitious scheme, launched under UN auspices from the 1970s but now terminated, was based on the creation of a buffer stock whereby rubber would be bought or sold from the buffer stock with the intention of stabilizing the price: this did not achieve what was expected by the progenitors.

### Measures to Combat Low Prices

The natural rubber producers – and their countries – have realistically come to understand that there are no simple formulas for stabilizing and enhancing prices; that they must take actions on their own.

The obvious routes to helping the producers to derive a decent income are (1) to minimize production costs, for example by encouraging use of high-yielding clones, and (2) to establish new applications for natural rubber. In some but not all producing countries the first approach has been moderately successful: a small farmer with a reasonable area of rubber (around 10 ha) can make a reasonable living, whereas with a smaller area and low-yielding trees the income will be very poor. Use of intercropping also helps; growing other crops or even keeping animals such as goats between the trees can help to support the small farmer.

Much effort over many decades has gone into attempts to establish major new uses. Some – for example the use of rubber in road surfacing materials – turned out to be overly ambitious and unsuccessful, from which the lesson was learnt that it is better to establish a number of low-tonnage new applications

that require natural rubber's unique properties. A number have been successfully developed.

The general strategy adopted by the major rubber-producing countries has comprised (1) to aim to enhance the incomes of the rubber farmers by various means, and (2) to improve the contribution of the overall rubber industry (the raw material and products therefrom) to national economies, recognizing that this strategy will not directly nor immediately benefit the farmers.

A relatively recent development is 'downstream manufacturing': establishment of rubber products factories in the producing countries, thus adding value to the raw material, creating new, skilled jobs, and enhancing national incomes. Malaysia has been especially active in this area, and to a lesser extent so also has Thailand. Rubber products, many of high technical content, are now being exported around the world.

### Rubber Wood

Until the 1980s it was normal practice to get rid of rubber trees at the end of their economic life by using them as fuel, either domestically or for burning in smokehouses. It then became recognized that wood from *Hevea* had value in its own right as a medium-grade hardwood suitable for use in, for example, inexpensive furniture. Trade in rubber wood has become an important way of generating additional income for the producers.

### Research

Since the 1920s most natural rubber-producing countries have established public sector research institutes whose activities range from agronomics, including extension services for small farmers, to product development work. These institutes are linked together by the International Rubber Research and Development Board, thus enabling effective communication between researchers in the producing countries. In addition to coordinating research programs, the Board has successfully raised large sums of money to operate international research and development programs ranging from agronomy to product design and development.

### Final Comment

Professor Richard Shultes, the distinguished Harvard Professor of Botany and leading authority on tropical plants of economic value once wrote:

No single of species of plant has, in the short span of 100 years, so utterly altered life styles around the globe as *Hevea brasiliensis*.

See also: **Silviculture:** Managing for Tropical Non-timber Forest Products.

## Further Reading

Allen PW (1972) *Natural Rubber and the Synthetics*. London: Crosby Lockwood.

Anonymous (1981a) Rubber: the Plantation. In: *The International Book of the Forest*, p. 198. London: Mitchell Beazley.

Anonymous (1981b) Rubber products. In: *The International Book of the Forest*, p. 200. London: Mitchell Beazley.

Barlow C (1978) *The Natural Rubber Industry: Its Development, Technology and Economy in Malaysia*. Kuala Lumpur, Malaysia: Oxford University Press.

Roberts AD (1988) *Natural Rubber Science and Technology*. Oxford, UK: Oxford University Press.

Sethuraj MR and Mathew NM (1992) *Natural Rubber: Biology, Cultivation and Technology*. Amsterdam, The Netherlands: Elsevier.

## Seasonal Greenery

**A L Hammett and M A Murphy**, Virginia State University and Technical Institute, Blacksburg, VA, USA

© 2004, Elsevier Ltd. All Rights Reserved.

## Introduction

For generations, a multitude of non-wood forest products have been extracted from forests to supplement incomes and diet sources. Here we define non-wood forest products (NWFPs) as biological produce found in forests such as edible plants, medicinal and dietary supplements, decorative or floral products, and specialty wood products. Commonly collected edible forest products include mushrooms, herbs, and spices. Several plants are processed into medicines for household and local consumption and, more importantly for international markets. Decorative NWFPs include vines, ferns, and other plant products used for floral arrangements, dried decorations, and ceremonial or religious ornaments (**Figure 1**). Specialty wood products include handicrafts, carvings, turnings, utensils, containers, and crafts. For many landowners and forest dependent communities NWFP options diversify and complement traditionally timber-based forestry operations (**Figure 2**).

In the USA, Canada, and several European countries, the Christmas tree trade flourishes during the months leading up to the holiday season. Several



**Figure 1** Examples of wreaths, boughs, and trees displayed for sale.



**Figure 2** Example of a typical North American Christmas tree plantation.

countries have an emerging Christmas tree trade including Japan, Ecuador, and Mexico. Closely tied to this trade is the cutting and sale of seasonal greenery. Often the greenery is produced from branches or branch tips which are the by-products of pruning necessary to shape trees so they are ready for market. In many instances, greenery is collected by cutting tips of branches in natural or planted