GROWTH AND PRODUCTION OF RUBBER

Willy Verheye
National Science Foundation Flanders and Geography Department, University of Ghent, Belgium

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Summary

Rubber is a tropical tree crop which is mainly grown for the industrial production of latex. Like oil palm it requires a high and year-round rainfall with little or no dry season and stable high temperatures; soils should not be particularly rich, but must be deep and well drained. Both crops are often grown in the same ecological areas, and in many cases oil mills and rubber treatment plants form part of one and the same industrial complex.

Rubber trees grow mainly in tropical lowlands below 400m altitude, originally covered by a dense tropical rainforest. Dry spells or temperatures below 18° C do not affect vegetative growth but reduce latex yield. Fertilizer demands for the tree are only important in the vegetative development stage (first 6 years) when the biomass is built up. Once the tree is mature and latex tapping has started the mineral fertilizer supply for compensating the nutrients exported by the latex is much smaller.

Rubber is the major industrial product derived from the latex from a number of trees belonging to the genus *Hevea*. The bark of these trees contains a network of interconnected vessels through which the latex flows when opened. Latex is a suspension of rubber particles which have to be coagulated to obtain the rubber. About 90% of the total world production of natural rubber is obtained from *H. brasiliensis.* Currently, natural rubber on the world market is competed by synthetic rubber, which is derived from oil products.

1. Introduction

Rubber (*Hevea brasiliensis*) is a fast-growing upright tropical tree crop which is mainly cultivated for its production of latex, a milky plant liquid, which serves as a basis for various rubber products. It is a typical plantation crop, which means that it should be grown and harvested over large uniform areas (3,000 to 5,000ha) around a central treatment unit to allow for a relatively rapid industrial handling after harvesting.

Rubber has quite similar growth requirements as oil palm, and both crops are therefore cultivated in the same geographical areas. The trees require deep soils, relatively stable high temperatures and continuous moisture throughout the year; soil fertility is less important than physical soil properties. Dry periods of more than 2-3 months do not specifically damage vegetative growth, but affect seriously the production and quality of the latex. Palm oil mills and rubber treatment plants are often associated in one single industrial complex.

Because both industrial crops need the clearance of large areas they often require the expropriation of land and the cutting of extensive forest areas. Hence, the development of such plantations is often a source of land tenure conflicts and problems of local land ownership, viz. ecological problems and biodiversity loss.

2. Origin and Distribution

The genus *Hevea* is native to South America, where it grows wild in the Amazon and Orinoco valleys. Before the discovery of the New World, native Indians used the latex of various plants for making balls, bottles, crude footwear and waterproofing fabric. Only one of these plants, *H. brasiliensis (HBK) Muell Arg*, later developed as the major latex-producing crop.

Columbus was the first to report (1495) about latex, but it was not before 1775 that the rubber tree was properly described by the French explorer Fusée Aublet. Almost by the same period Priestly discovered that latex could rub out pencil marks, and this gave the product its name as rubber. In 1823 MacIntosh made waterproof cloths by coating fabric with rubber dissolved in naphtha. The use of waterproof clothing in the American Civil War brought about the first rubber boom, followed by a second one in 1839 after Goodyear and Hancock had discovered the principle of vulcanization; this is the process whereby rubber is heated with sulfur and retains its physical properties once processed into a useful shape. The most successful application of latex rubber was achieved in the 1880s when rubber was found to be the basic material for pneumatic tires for motor cars.

The real success story of rubber as a modern commodity started after it could be industrially cultivated. This did not happen before Wickham (later Sir Henry) collected some 70,000 seeds from the Tapajoz valley (Amazone, Brazil) and brought them, first in 1876 to Kew Gardens (London) and later to Ceylon (1876) and Singapore (1877). Research in the Singapore Botanic Gardens by H. Ridley identified *H. brasiliensis* as being superior to all other rubber-producing plants. At this institute much of the technology was also developed for the excision method of tapping (see below), the opening up of the same cut which increased the flow of latex (wound response), the best time to tap, and the regeneration of the bark, which could then be re-tapped. Later, granulated and various rubber grades were identified. To date, more than 99% of the world production of natural rubber comes from *H. brasiliensis*; the remainder is extracted from guayule (*Parthenum argentatum*), a rubber containing shrub.

The first rubber plantations in Malaysia were established as early as 1890. *Hevea* was introduced in Africa early in the 20th century: in Uganda and Nigeria (1903), Congo (1904), and Liberia (1924, by the Firestone Tyre and Rubber Company). Today, most latex production is concentrated in industrial estates in tropical Africa and the Far East.

The world rubber market over the past 100 years has been extremely volatile. A first major production boom in the Far East was stopped by the First World War, cutting of most of the consumer markets in Europe and North America, and leading to a drastic price cut. The latter resulted in an intensified search for more rational production methods, development of budding techniques, selection of better clones, and the introduction of cover crops to reduce weeding and fertilizer costs. The Second World War created another problem in the sense that most Asian plantations fell into the hands of the Japanese and were cut a second time from their major consumer markets. This resulted in the discovery of synthetic rubber from 1910 onwards by the Russian chemist Sergei Lebedev and the creation of a new synthetic rubber industry, mainly in the United States, which started to compete with natural rubber on the world markets.

Hevea is nowadays cultivated as far north as 25° North (Yunnan Highlands, China) and as far south as 21° South in Brazil. The main production zone, worldwide, is however concentrated between 15° N and S. For South East Asia and the South Pacific this includes Malaysia, Indonesia, Thailand, Sri Lanka, South India, Cambodia, Vietnam, The Philippines, Papua-New Guinea and Southern China. There are important plantations also in Central and West Africa (Congo, Cameroon, Ivory Coast, Liberia), while rubber cultivation in tropical America is concentrated over a small area between 10° N and S

3. Botany

3.1. Cultivars and Classification

Rubber belongs to the family of Euphorbiaceae, a large family with about 280 genera and 8,000 spp. The genus *Hevea* exhibits much morphological variability, with nine species now being recognized, ranging from large forest trees to little more than shrubs. All of them contain latex in their parts. Other *Hevea spp* are tapped in a wild state, but are of little economic value. Some of them may however be important for breeding:

- *H. benthamiana*: occurs only north of the Amazon river in the north-western part of Amazon and Upper Orinoco basins; it grows in low alluvial areas and bogs and, thus, supports hydromorphic soils; it has a pure white latex which is lower in yield than *H. brasiliensis;*
- *H. camporum*: native of open savannas in the headwaters of the Madeira River, Brazil;

- *H. guianensis* and its variety *latea*: 30m high or more; it prefers well-drained upland soils; its yellowish latex yields generally inferior rubber;
- *H. microphylla*: endemic in uppermost Rio Negro basin in Brazil, Colombia and Venezuela; up to 20m high; grows in low-lying, often permanently flooded land; its white watery latex almost completely lacks rubber;
- *H. nitida*: occurs throughout most of the Amazon valley and upper Orinoco; the tree is medium-sized and usually grows on sandy forest soils; the thin white latex acts as an anti-coagulant with that of other spp;
- *H. pauciflora:* occurs in Rio Negro and the Upper Orinoco basins and in Guyana; the medium-sized tree grows on rocky hillsides and high well-drained river banks; its white latex has a low rubber and high resin content;
- *H. rigidifolia*: endemic to the uppermost Rio Negro basin of Brazil, Colombia and Venezuela; the 20-meter high tree grows on high, well-drained soils; its cream-colored latex is poor in rubber and high in resin content;
- *H. spruceana*: abundant in lower Amazon basis; it grows on low and flooded river banks; its watery latex is almost devoid of rubber.

3.2. Structure

Hevea brasiliensis (HBK) Muell Arg is a quick-growing tree, rarely exceeding 25m in height in plantations, where the plant density is optimal for light interception; wild trees might be up to 40m high in search for sunlight above the dense tree canopy. The tree has a well-developed tap-root, 2-5m long after 3 years, with laterals several meters long. The lateral roots emerge from the tap-root below the collar. They can reach up to 10m and can make a dense network of feeder roots and root hairs in the upper soil layers. Some 30 to 60% of feeder roots are found in the top 10cm of the soil. Figure 1 depicts the various structural elements of the tree.

The ***trunk*** of the tree tapers from the base and is conical or cylindrical in shape and shows a periodicity of growth. During the resting stage whorls of scale leaves occur round the terminal bud. A fully grown leaf has a diameter of 15-20cm. Young leaves are dark red in color, while other leaves are green on top and grayish-green underneath. In trees which are old enough, leaves are shed at the beginning of the dry season, terminal buds of branches grow rapidly and trees are temporarily bare of leaves, a condition known as “wintering”. New leaves are then produced at the proximal end and inflorescences in the axil of scale leaves and lower foliage leaves. This so-called wintering is usually associated with dry weather conditions. It is more pronounced as the seasons themselves differentiate. Beyond 4° latitude north and south wintering is short but sharp, whereas at the Equator it becomes apparent only when the trees enter production.

The ***crown*** of the rubber tree is liable to be damaged by wind, causing the trunk to snap. Hence, the need to select clones with a balanced tree architecture, i.e. limited growth of the primary axis, with numerous similar but short secondary branches evenly distributed round the tree. Windbreaks consisting of *Tectona* and/or *Eucalyptus* trees might limit the damage.

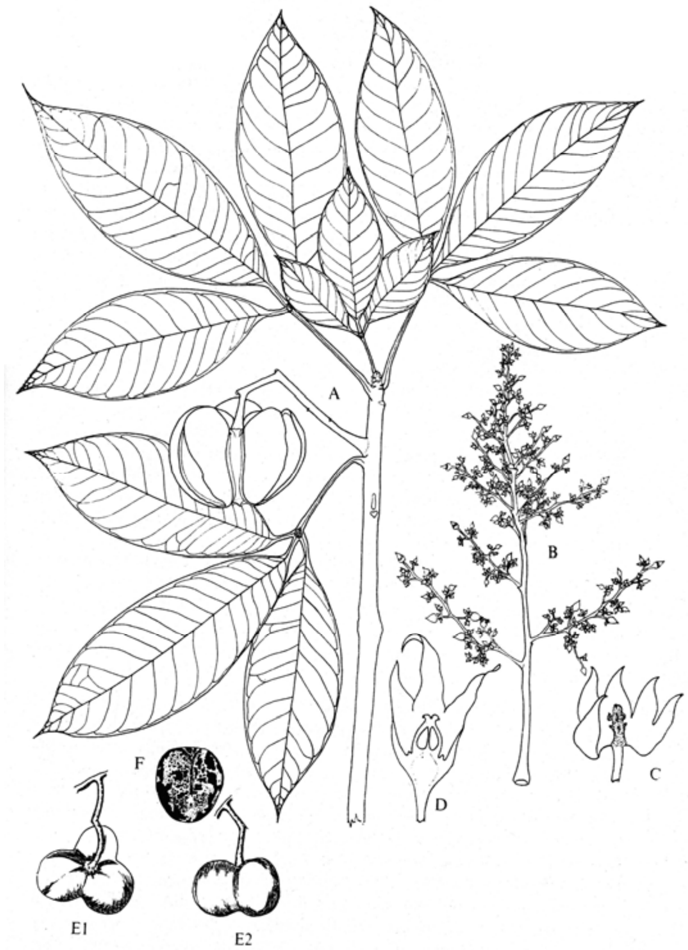

Figure 1. *Hevea brasiliensis* or Para rubber (Legend: A: shoot with dehiscing fruit; B inflorescence; C: male flower cut open; D: female flower in longitudinal section; E1-2: fruits; F: seed).(Courtesy Purseglove, 1977)

Flowers are borne in many-flowered, axillary, shortly pubescent panicles on the basal parts of the new flush. Flowers are small, scented, unisexual and shortly-stalked, with larger bell-shaped female flowers at the terminal ends of main and lateral branches, and more numerous smaller male flowers, with 60-80 males to each female flower. Flowering takes place over a period of about two weeks with some male flowers opening first, lasting for one day and then dropping, followed by female flowers open for 3-5 days; the remainder of male flowers then open.

Fruits and seeds. Only a small proportion of female flowers set fruit and of these 30-50% fall off after a month, and more fall off later. The mature fruit is a large, compressed, 3-lobbed capsule, 3-5cm in diameter, with 3 oil-containing seeds. The capsule bursts open at the end of the rainy season with a characteristic loud bang, similar to a rifle shot. The seeds are then collected for sowing in the nursery.

A *Hevea* seed is oval, 1-2cm long, and weights between 3 and 6g. It has a hard, shiny coat which is brown or grayish-brown in color. Seeds are viable for a short time only, and must therefore be planted as soon as possible after harvesting. Viable seeds germinate in 3-25 days. Germination is hypogeal.

The ***bark*** is the most important part of the tree – and even of the plantation as a whole – because it contains the tissues that produce the latex. Figure 2 shows a cross-section of the trunk of an adult rubber tree. It consists of a pith, wood and a cortex, which is separated from the wood by the cambium (regenerative tissue). In the cortex, there are 3 separate concentric layers: the outer corky layer (periderm), an underlying parenchyma with a large numbers of stone cells, and finally the phloem with the latex vessels. The thickness of the bark and the proportion of tissue vary with different clones, and with the age of tree.

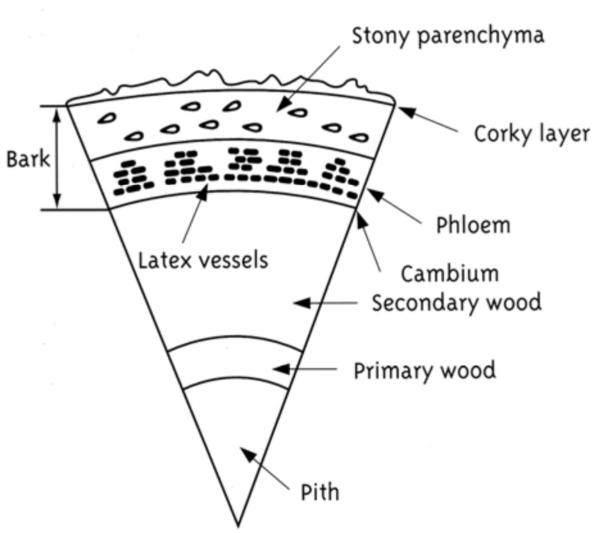

Figure 2. Cross section of an adult rubber tree showing the composition of the bark and the position of the latex vessels in the soft bark tissue (Courtesy L. Boedt, 2001)

Latex vessels are found in the tree's soft bark. They are modified sieve tubes (cells formed by the cambium and coalescing when the dividing cell walls disintegrate) running anti-clockwise in concentric cylinders at an angle of approximately 30° to the vertical axis of the stem (which is why tapping is done invariably from top left to bottom right in order to cut the vessels at a right angle). Vessels are laterally interconnected with each ring, but connections are disrupted as the trunk expands. The number of vessels per ring and the number of rings vary with age and thickness of the bark and with the clone.

When tapping, part of the bark is scraped, whereby the latex vessels are cut causing the latex to flow. Tapping is done with precision using special knives to prevent damaging the underlying cambium. In renewed bark the number of functional vessels is increased.

Fresh latex consists of a colloidal suspension of rubber particles in an aqueous serum. The content of rubber hydrocarbon, with formula $(C_5H_8)_n$, varies from 25 to 40 %, with an average of about 30 %. It is manufactured in the tree from carbohydrates, and it has two major functions: making the plant less attractive to pests because of the taste latex gives to parts of the tree, and protecting the plant by sealing of the wounds so that no aggressors can penetrate the tree. Latex consists of four man fractions (Delabarre and Serrier, 2000):

- Rubber particles (25-40% of total latex volume), variable in shape, but usually pear-shaped or spherical, and about 6 nm to 5 micron in size;
- Lutoids (10-20%), 0.5 nm to 3 micron in size, having an impact on the stability and flow of the latex;
- Frey-Wyssling particles (5%) which play probably a role in the coagulation and oxido-reduction processes; and
- Other elements like proteins, resins, sugars, glycosides, tannins, alkaloids, mineral salts, and secondary metabolites.

Vegetation cycle – *Hevea* has an annual vegetative cycle, with a leaf fall or "wintering" in the dry season (see above). At this moment also the latex flow is less prominent. The tree has a tap-root which, under favorable growth conditions, penetrates 4 to 5m deep in the soil.

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Biographical Sketch

Willy Verheye is a former, now retired Research Director at the National Science Foundation, Flanders, and a Professor in the Geography Department, University of Ghent, Belgium. He holds an MSc. in Physical Geography (1961), a PhD. in soil science (1970) and a Post-Doctoral Degree in soil science and land use planning (1980).

He has been active for more than thirty-five years both in the academic world, as a professor/ research director in soil science, land evaluation, and land use planning, and as a technical and scientific advisor for rural development projects, especially in developing countries. His research has mainly focused on the field characterization of soils and soil potentials, and on the integration of socio-economic and environmental aspects in rural land use planning. He was a technical and scientific advisor in more than 100 development projects for international (UNDP, FAO, World Bank, African and Asian Development Banks, etc.) and national agencies, as well as for development companies and NGOs active in inter-tropical regions.

W. Verheye is the author or co-author of more than 100 peer reviewed papers published in national and international journals, chapters in books and contributions to the Encyclopedia of Life Support Systems (EOLSS). He is Honorary Theme Editor for the EOLSS, Theme 1.5: Crops and Soil Sciences.