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Search for rubber in pre-*Hevea brasiliensis* days and establishment of *H. brasiliensis* in India

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Natural rubber, obtained from the spurge *Hevea brasiliensis*, is a material of high relevance in modern industrialized society. Its uses are manifold. In spite of a stiff competition from synthetic rubber and plastic, natural rubber is still in demand and large plantations of it are presently exploited for an uninterrupted supply. *H. brasiliensis* was introduced into India from Brazil, through a circuitous route, thanks to Dietrich Brandis (then Inspector General of Forests, Government of India), who directed operations in the 1870s. The present article explores the historical landmark events that occurred before Brandis's decision on its introduction into India and after, supplemented by relevant notations. The fascinating subplot in the story of *H. brasiliensis* introduction into India is the search for plant sources of 'rubber' within the subcontinent and how a non-edible fig species *Ficus elastica* was looked at, quite rigorously, as an invaluable material in this context. Early efforts made by the Rubber Research Institute of India, Kottayam in independent India include the development of a productive clone RRII 105, which has revolutionized rubber production in Indian in the recent decades.

Keywords: Central Travancore, Dietrich Brandis, Economic relevance, *Ficus elastica*, Hugh Cleghorn, John Royle, Joseph Hooker, Malabar, William Roxburgh, William Griffith.

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Introduction

Natural rubber is a biomaterial of high importance today. Think of an *Airbus A380* (22 wheels, *c.* 600,000 kg when fully loaded). Its natural-rubber tyres, reinforced with steel ribs, withstand a variety of operational conditions. During landing these tyres experience a runway-friction coefficient of 0.40 and above in normal day conditions, in addition to enduring highly dynamic braking loads. The nitrogen-filled tyres smoothen and cushion the harsh, friction-intensive landing of the aircraft. This adequately illuminates the strength and durability this material — rubber — has, of course, after treating the raw latex of *Hevea brasiliensis* (Family Euphorbiaceae) with various vulcanizing accelerators.

The latex of plants belonging to the Family Apocynaceae (and *ex*-Asclepiadaceae), Euphorbiaceae, Moraceae, and Asteraceae provide natural rubber (hereafter 'rubber'). However, presently, rubber is almost exclusively obtained from *H. brasiliensis* (the Pará-rubber tree, Fig. 1). The finished product is produced by coagulating either spontaneously or applying heat, smoke, or mechanical devices. In the later decades of the 19th and earlier decades of the 20th centuries, *caoutchouc* and *gutta percha* meant rubber. *Caoutchouc* generically referred to the raw-rubber latex in French-speaking nations, whereas it meant the refined material in English-speaking nations[1]. The term *caoutchouc* (weeping tree) evolved from the Central-American indigenous name *cau-cho* (*que-chu-a*) referring to *Castilla elastica* (Family Moraceae) that naturally and plentifully occurs in the Amazon. *Gutta percha* is similar to the rubber of *H. brasiliensis* source, but is obtained from the latex of plants such as *Palaquium* (Family Sapotaceae) that occur in the Malaysian islands of Borneo (1° 0′ N, 114° 0′ E) and Sarawak (3°04' N, 113°78' E), and in North-Eastern segments of India (26° 0′ N, 92° 7′ E). *Gutta percha* is the anglicized Malay term *gutta perça*, which means sap of *perça*, the sap of *Palaquium*. The *gutta* material is a 1-4-trans-poly-isoprene and is nearly identical to the molecular structure of *H. brasiliensis* rubber[2]. One contemporary use of *gutta percha* is filling teeth cavities[3]. How the term 'rubber' came about is a fascinating element in the rubber story.

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Fig. 1—*Hevea brasiliensis.* Source: ***Köhler's Medizinal-Pflanzen in Naturgetreuen Abbildungen mit Kurz Erläuterndem Texte***[45]

Joseph Priestley[4], British chemist–mathematician, found that the coagulated latex of ***H. brasiliensis*** can erase ('rub' off) lead-pencil markings. He says

'…, I have seen a substance excellently adapted to the purpose of wiping from paper the marks of a black-lead-pencil. It must, therefore, be of singular use to those who practise drawing'.

From the later decades of 18th century, interest in rubber, especially of ***H. brasiliensis***, known as the 'India rubber', fascinated several Western chemist–physicists and inventors, such as Samuel Peal, Charles Macintosh, Thomas Hancock, and Charles Goodyear[5,6]. European residents in the Straits Settlements became interested in rubber-yielding, laticiferous plants, mainly because of their economic prospects. James Howison, a practising surgeon in Penang (5° 24′ N, 100° 14′ E) proposed planting of ***Urceola elastica*** (Family Apocynaceae) after experimenting with its latex in rubber production[7]. William Roxburgh in India[8] described ***U. elastica*** formally (Fig. 2). However, with the introduction of ***H. brasiliensis*** into Malesian region in the later decades of the 19th century, the erstwhile British colonies of Malesia have become world leaders in ***H. brasiliensis*** cultivation and rubber production.

In this article, the efforts made in India before the introduction of ***H. brasiliensis***, what led to its introduction into India, and how it was established as a key plantation crop in Malabar and Central Travancore regions in modern Kerala is explored.

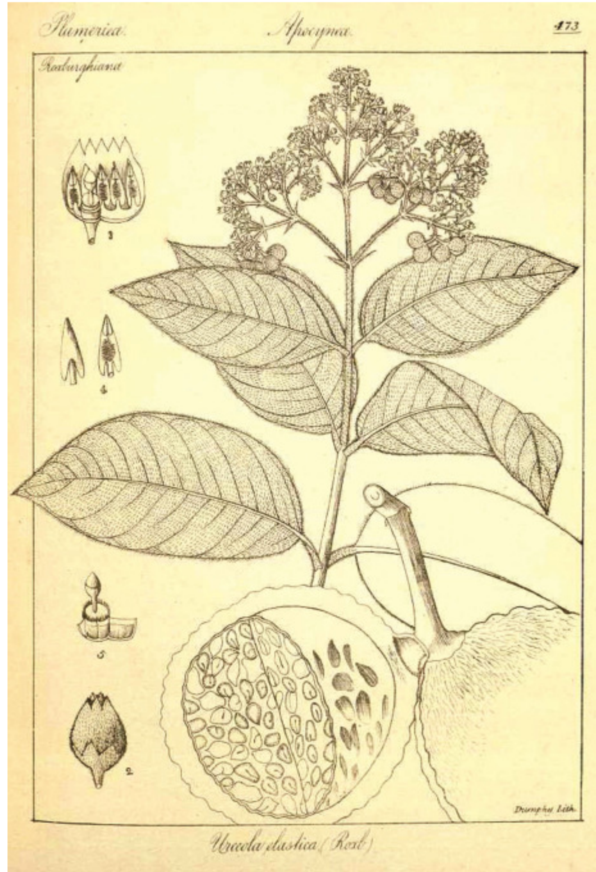

Fig. 2—*Urceola elastica. Source: Wight's Icones Plantarum Indiæ* ***Orientalis***[46] [The explanation "Plates bearing the legend 'Roxburghianae' represent redrawing of Roxburgh's unpublished plates now at the Calcutta Botanic Garden, and thus represent Roxburghian species as described in his ***Flora Indica***." occurs at the start of Wight's ***Icones Plantarum***, Volume 2.] The notation 'Dumphy Lith.' at the right bottom of the image refers to John Dumphy, who was the lithographer at Fort St. George Press, Madras, in mid 19th century. Dumphy was involved with the preparation of Robert Wight's ***Icones Plantarum*** in 1839 (Database of Scientific Illustrators, 1450—1950, http://www.uni-stuttgart.de/hi/gnt/dsi2/index)

Search for rubber in the Indian subcontinent: Before the arrival of *H. brasiliensis*

Ficus elastica (Family Moraceae) evoked considerable interest in India, although a few other laticiferous plants, mostly exotic, but naturalized over time, such as *Cryptostegia grandiflora* (Family Apocynaceae) also evoked some interest[9].

William Roxburgh, then Superintendent of the Calcutta Botanical Garden, received a rattan-cane basket (rattan — various species of genus *Calamus*, Family Arecaceae) bearing gifts from a friend in Sylhet in 1810. The lining the basket attracted Roxburgh. On examination, he found that the lining was a thin coat of ***caoutchouc***[10], which he later realized was from a 'fig' taxon. He described this 'fig' as ***F. elastica*** in 1814[11]. He sent a sample of the lining material to David Brewster, a physicist in London for analysis. Brewster[12] found that the material was elastic, similar to the South-American rubber, and was 'superior' to the South-American rubber in terms of lightness of colour and being free of foetid stench. The rationale behind the naming of this plant as ***F. elastica*** by Roxburgh is obvious.

William Griffith[13], an Assistant Surgeon on deputation from Madras Medical Service to the Bhutan mission, stumbled on populations of ***F. elastica*** during his travel into the forests of Bengal, made ***via*** Férôzepur (British Library, Digitized Manuscript: IOR/F/4/1787/73597). Griffith talked about the size, geographical locations, and abundance of this species. He indicated his interest in this tree as triggered by Roxburgh and also by one Matthew Richard Smith, a planter at Sylhet. With regard to the latex (referred as 'juice'), Griffith explained its extraction. He compared the biological properties of ***F. elastica*** of Bengal (Sylhet) with those known in Assam, and with the South-American populations of ***H. brasiliensis*** in the context of cultivation (like making cuttings and planting), and ***F. elastica***'s value as a 'new' product. Griffith also remarked on 'bottling' ***F. elastica*** latex. An ink drawing of a twig, captioned '***Ficus elastica*** Roxburgh', is available in Griffith (***ibid***) (Fig. 3).

Documentation on ***F. elastica***-source 'rubber' occurred in the ***Penny Magazine of the Society for the Diffusion of Useful Knowledge*** of London[14]:

'The juice of this valuable plant (***sic. Ficus elastica***) is used by the natives of Silhet (***sic.*** Sylhet) to smear over the inside of baskets constructed of split rattan, which thus rendered water-tight. Old trees yield richer juice than young one. The milk is extracted by incisions made across the bark down to the wood, at a distance of a foot (***c.*** 30 cm) from each other, all round the trunk or branch, up to the top of the tree, and the higher the more abundant is the fluid said to be. After one operation the tree requires a fortnight's rest, when it may be again repeated. When the juice is exposed to the air it separates spontaneously into a firm elastic substance and a fetid whey-coloured liquid. Fifty ounces of pure milky juice taken from the trees in August yields exactly 15½ ounces of clean washed caoutchouc. This substance is of the finest quantities.'

F. elastica was first described by William Roxburgh in his magnum opus ***Hortus Bengalensis*** (1814). A redescription of ***F. elastica*** was provided by Danish botanist Jens Wilken Hornemann in 1832. The ***Penny Magazine*** article also offers other, equally fascinating, information on the ways by which the American-Indians 'processed' rubber material from ***F. elastica*** and how the Indian-Indians 'processed' rubber material ***F. elastica***. A remark, in the same article,

'The Indians [***sic.*** the Indian-Indians] had long been in the habit of making boots of caoutchouc, which were perfectly waterproof.' is worthy of exploration clarifying what do 'boots' mean and how Indians made them.

John Forbes Royle in his ***Illustrations of the Botany, and other branches of the Natural History of the Himalayan Mountains, and of the Flora of Cashmere*** (1835) refers to ***H. brasiliensis***, while talking of Euphorbiaceae[15]:

Fig. 3—William Griffith's artwork of ***Ficus elastica*** from the material obtained by him on his trip to Sylhet[13]

'The most useful product of the family, however, and that which has lately become an article of commerce, and of great utility in a variety of arts, is Caoutchouc, so well known as India-rubber and exported principally from Pará. This is chiefly yielded by Siphonia elastica (Hevea guianensis, Aublet), a tree of Guiana and Brazil, which would no doubt thrive in Bengal.'

In the early 1850s, at least 20 plants of the Indian subcontinent were 'registered' as rubber sources, which necessitated Government of India to appoint a Chemical Analyst to examine the veracity of the claims.

Hugh Cleghorn[16], Conservator of Forests, Madras Presidency, refers to the latex from a species of ***Bassia*** (Family Sapotaceae) from Wyanad region (11° 60′ N, 76° 08′ E; in the present Kerala) known locally as ***pauchontee*** (the Indian-gutta) tree. Cleghorn determined this taxon as a species of ***Palaquium***[16] after comparing notes with Wight's *Icones Plantarum*. Today, we know that this taxon is ***Palaquium***. He got the plant material from A. R. W. Lascelles, a coffee planter at ***Devallikottah*** (Wyanad) in September 1858. The report also included reports on the analysis of laticiferous exudates of this plant carried out by various British chemists, who summarily indicate this as 'invaluable'.

Gustav Mann, then an Imperial Forest Servant in Assam, explored rubber-yielding plants locally. In a communication to Joseph Dalton Hooker (then Director of Royal Botanic Gardens, Kew), Mann[17] asked whether the *caoutchouc* trees of Mexico and Brazil are likely to be exhausted; he argued that a response to that query was important for the Assam Forest Division, since *F. elastica* could not be tapped regularly without great care and therefore a permanent supply of rubber from the area needed to be secured.

In spite of these efforts, Government of India preferred to bring *H. brasiliensis* germplasm from Brazil in the later decades of the 19th century. The key reasons for favouring *H. brasiliensis* and bringing it to India were (a) the cultivation of local 'rubber' species such as *F. elastica* as monoculture was cumbersome, (b) *H. brasiliensis* yielded rubber more quickly than the 'known' Indian taxa of similar use and value, (c) the yield quantity of *H. brasiliensis* was greater than that from the rubber-yielding taxa of the subcontinent, and (d) latex of *F. elastica* polymerized rapidly, while transporting latex for processing elsewhere, thus disadvantaging tappers and planters[18,19].

H. brasiliensis rubber — Historical milestones

Rubber products were known in the Central and South Americas for long. For example, Mesoamerican (Mexican) archaeological excavations dating to 1600—1200 BC have revealed rubber balls[20]. Christopher Columbus on his 1495 AD voyage to the Americas records that he saw the people of Hispaniola (modern Haiti, Caribbean Island Group) playing, using heavy balls made of a 'plant gum', which bounced to greater heights than what he had known in Europe[21]. Christopher Columbus knew of objects similar to balls used in games in Spain. Such objects were animal bladders filled with either air or water. Columbus introduced this novel gum material from Hispaniola into Europe.

Charles-Marie de la Condamine (1701–1774) was the first to shine light on *H. brasiliensis*. He found *H. brasiliensis* on the banks of *Esmeralda* River (modern Bolivia) (Fig. 4). de la Condamine did not go to South America searching *H. brasiliensis*, but events panned out so[22]. In the early decades of the 20th century, immense interest developed in the production of commercial rubber, and consequently in the science of *H. brasiliensis* and scientific management of its plantations evolved. Until the mid 1850s, most of extracted rubber was from natural populations of *H. brasiliensis* in South America. Between 1870s and

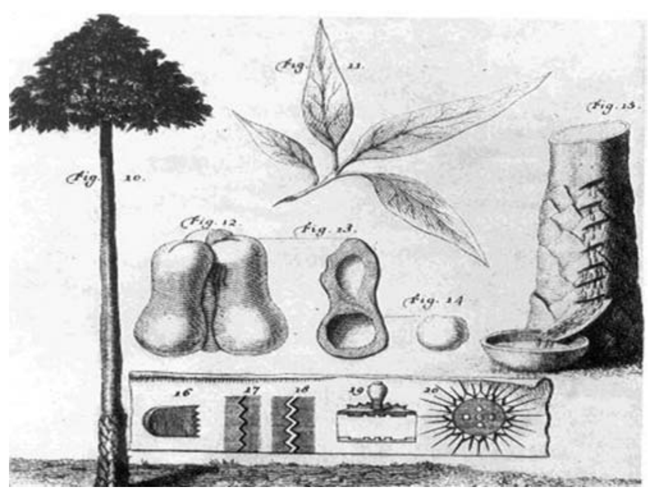

Fig. 4—Artwork of '*H. brasiliensis*' and 'rubber tapping' in de la Condamine[22]. (For explanations of annotated numbers see original.) [Note: This artwork is signed 'J. Ingram, Sculpt.'. John Ingram, a British-born engraver moved to Paris in 1755[47]. Tree and leaf sketches in this artwork appear inaccurate. Nevertheless, a reasonable explanation would be that de la Condamine carried the crude sketches made by Fresneau to Paris and from those sketches, Ingram prepared the engravings without personally seeing either the tree or its foliage.]

1900s, things changed dramatically. Professional scientific approach in dealing with crop husbandry and plantation administration, besides evidence-based improvements to achieve large-scale production of rubber products and perfection of the machinery used gained significance in the 1900s. This encouraged emergence of professional journals, such as the *India Rubber World* (*IRW*) published in USA between 1899 and 1954. The 1903 issue of *IRW* (Fig. 5) included articles, commentaries, and news items on rubber industry and trade, nearly from all over the world, offering a great reading. Rubber-based industries were one key element in the technological advancement of the USA in the early 20th century. Even the advertisements were informative. Commercial advertisements in *IRW* refered to industrial conveyer belts, gaskets and 'O' rings that go at metal junctions, large industrial and thin garden hoses, automobile tyres, valves, Macintoshes, rain jackets, waders, car springs, oil-proof and acid-proof connectors used in steam carrying pipes — made of rubber, further to hardened rubber items such as rods, tubes, sheets, mallets, and rubber-sole tennis shoes, and what else not. A news item in p. 229 speaks of the unique single 'rubber' copy of Charles Goodyear's book[23] made of 'rubber and fibre parchment' pages and hard-rubber wrapper.

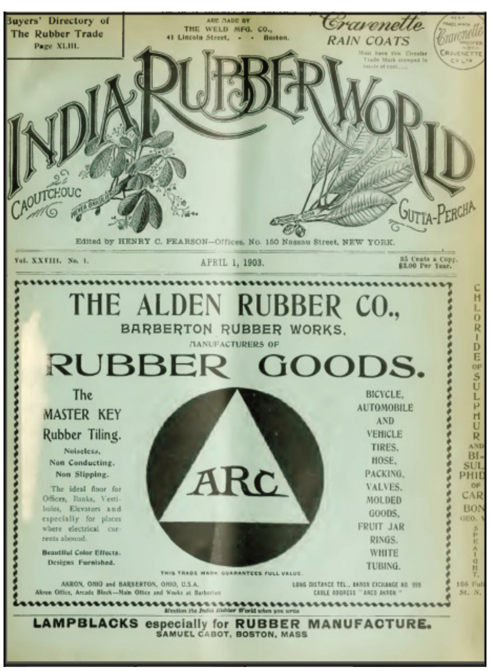

Fig. 5—Cover page of *India Rubber World*, 1903 (This was published on the 1st of each month by 'The India Rubber Publishing Co.', New York; source: at http://www.biodiversitylibrary.org/item/31418#page/1/mode/1up)

Another news item entitled 'the rival of Pará rubber in the east' in p. 219 refers to a lengthy report by Stanley Arden of Selangor (3° 12′ N, 101° 44′ E) on the early failure of *H. brasiliensis* introduced into India. Arden argued that *H. brasiliensis* is unsuitable for planting in South and South-East Asia, because of climatic and edaphic factors. He explained that planters in the Straits Settlements were unimpressed by *H. brasiliensis*, because of low profits it could fetch compared with those from *Coffea arabica* (Family Rubiaceae) planting. Nevertheless, with dropping coffee prices across the world, interest of planters in Straits Settlements shifted to trial planting of *H. brasiliensis* in relatively small areas (*c.* 12,000 acres) in 1896–1897. The Arden report summary in *IRW* refered to production costs and profit margins as preferred by planters in Straits Settlements. Arden reiteratered that a 'new source' of the Pará rubber plant should be 'developed' (p. 220) and growing that 'new' plant should be in Brazil. Whether Arden means a 'hybrid' or a 'clone' by saying 'a new plant' is not clear; maybe that was the intent. This was the state of affairs with *H. brasiliensis* introduction into South and Southeast Asia at the close of 19th century.

Introduction of *H. brasiliensis* into India, early misadventures

Charles Goodyear's serendipitous discovery of vulcanization changed global interest in *H. brasiliensis* dramatically[24]. To ensure an uninterrupted supply of rubber, the British Government was keen on obtaining seeds of *H. brasiliensis* for establishment in its tropical colonies. The India Office in London initiated and sponsored the first South-American exploration to secure *H. brasiliensis* seeds in 1873. Two thousand seeds collected in Cametá (Brazil, 02°14′ S, 49°29′ W) were germinated in the Kew Botanic Gardens in June 1873. Six of the seedlings were sent to Calcutta Botanic Gardens in the same year[25]. They never survived. The reasons were attributed to climate.

The India Office considered South-America expedition based on the recommendation of Clements Robert Markham, because of his experience in exploring Peru for *Cinchona* in the 1860s. Markham remarked[26],

'After visiting the forests in South America and reflecting on the great demand, I came to the conclusion that the best caoutchouc yielding trees should be cultivated and introduced into our Eastern possessions'.

Nothing of the biology of *H. brasiliensis* was known. James Collins, Curator of the Pharmaceutical Society Museum, London, was commissioned to document the biology of this plant. On return to Britain, Collins formally reported to Hooker. The end section of the Collins report[27] includes a Memorandum by Dietrich Brandis[28] (then an Imperial Forest Servant and Inspector-General of Forests of India) responding to concerns raised by Collins on the possible cultivation of *H. brasiliensis* in India. Brandis listed the best options for *H. brasiliensis* cultivation in the subcontinent in this Memorandum. He clarified that the local 'rubber' plants, such as *F. elastica,* should be overlooked and *H. brasiliensis* needed to be tried as the rubber source and supply for Britain. Based on climate and soil reasons, Brandis recommended South Canara (13° 00′ N, 75° 40′ E; Mangalore and neighbourhood), Malabar (11° 25′ N, 75° 77′ E; Kasargod–Calicut), and Travancore (8° 26′ N, 76° 55′ E; Kanyakumari– southern end of Alwaye) as the ideal locations in India. Based on this, Hooker endorsed introduction of *H. brasiliensis* into India. Brandis's arguments favouring the Malabar Coast (*sensu lato*) for *H. brasiliensis* mass cultivation impresses as prophetic, especially in the light of Stanley Arden's remarks that South Asia and South-East Asia are unsuitable for *H. brasiliensis* cultivation, made nearly three decades later. Today *H. brasiliensis* cultivation in Travancore–Malabar regions of Kerala is a key contributor to India's exchequer.

Hooker persuaded Henry Alexander Wickham (1846–1928), a coffee planter in Brazil, to collect *H. brasiliensis* seeds in 1876, with expenses met by the India Office in London. Wickham collected 70,000 seeds of *H. brasiliensis* from Santarém (Brazil, 2° 25′ S, 54° 43′ W) and delivered them to Hooker. Of these, *c.* 4000 germinated. Two thousand of them were dispatched to Ceylon (Sri Lanka) and the remaining 2000 to Straits Settlements, which grew well in their new locations. The irony is that the rubber-seed collection expedition was funded by the India Office, whereas India never received the seeds, which instead were sent to Ceylon and the Straits Settlements. The newly set up rubber garden in Ceylon — later the Henarathgoda Botanic Gardens (Gampaha, 7° 06′ N, 79° 59′ E) — too was financially supported by Government of India[28].

Establishment in India

The earliest *H. brasiliensis* seedling consignment received in India was sent from Ceylon in 1878. Consignments of smaller numbers of *H. brasiliensis* seedlings were received in 1880 and 1881. On the suggestion of Richard Beddome (then Head, Forest Department of Madras Presidency), 28 saplings from Ceylon were planted in Nilambur (11° 16′ N, 76° 13′ E) in 1880. However, these failed to grow. The 1881 consignments were planted in the new botanical garden at Burliar (The Nilgiris, 11° 21' N, 76° 47' E) established by K. B. Thomas, Collector of Coimbatore—Nilgiris District, a few years earlier. Not only *H. brasiliensis* seedlings were tried in the Burliar Garden, but also those of *Manihot glaziovii* (presently, *M. carthaginensis* subsp. *glaziovii*, Family Euphorbiaceae) and *F. elastica*. Further, planting of *H. brasiliensis* in small measures was attempted by individual planters. A. G. Nicholson planted *H. brasiliensis* in the Shevroys (Yercaud, 11° 77′ N, 78° 20′ E) and in Kotagiri (The Nilgiris, 11° 43′ N, 76° 88′ E) in 1898. Nicholson planted *H. brasiliensis* among *Coffea* bushes, and that association probably invited disaster due to unexplained reasons. Today we know that *Coffea* can be allelopathic[30].

At the behest of the Nilgiri Planters' Association, a 5-acre block of land along the mountain road to Coonoor (11° 35′ N, 76° 80′ N) came up for experimental purposes under the supervision of Rudolph Anstead [then Scientific Officer, United Planters' Association of South India (UPASI)] and F. H. Butcher (then Curator, Botanical Gardens, Ooty) for hybridization trials of *Coffea* and *Hevea* in 1910. For various reasons these hybridization trials ceased shortly[30]; no explanations occur why *H. brasiliensis* trials were abandoned.

Goa's landscape and environment prompted a few of its Portuguese residents to believe that it would suit *H. brasiliensis* cultivation. In 1900, *H. brasiliensis* saplings, obtained from Belgaum, were planted in Ponda (15° 40′ N, 74° 02′ E). Attempts were made to plant in Aldona (15° 35′ N, 73° 52′ E) and Margao (15° 16′ N, 73° 57′ E) as well. These efforts too did not take off as desired due to a variety of reasons[1].

In the following decade (1900–1910), large monocultural plantations of *H. brasiliensis* were facilitated in Malabar and Travancore, and along the lower ranges of the Palnis (10° 45′ N, 77° 51′ E) using 16000 seedlings from Burliar Garden nursery[31]. Large-scale cultivation of *H. brasiliensis* in India started with the pioneering effort of four European planters (John J. Murphy, J. A. Hunter, K. E. Nicoll, and C. M. F. Ross) in Central Travancore, who formed the *Périyãr Syndicate*. They established the first *H. brasiliensis* plantation on the banks of *Périyãr* river at *Thottékãdu* near Alwayé (10° 11′ N, 76° 35′ E) in 1902[32]. John Murphy, along with H. D. Deane and R. S. Imray established *H. brasiliensis* plantation in *Mundakãyam* (Central Travancore) in 1904. Local government provided land grants encouraging rubber-tree plantations. The Travancore Rubber & Produce Company and Malayalam Rubber & Produce Company started their operations in Central Travancore in 1904-1910. Rise in motor-car use and World War I needs enhanced the demand for finished rubber products, which in turn accelerated rubber production making the Indian rubber industry to grow by 16 % in 1905-1915[33]. Globally, the price of the finished rubber rose significantly, influencing the rapid expansion of this industry in Kerala in particular[34]. Governments of Madras and Mysore encouraged rubber cultivation in their states with land-tax exemptions for 3–5 years being offered as incentives[35]. An excellent socio-historic-economic analysis is available in Kumar[35]. His remarks on the role played by the then new, Central Travancore newspaper *Malayala Manorama* referring to issues and crises that arose between the established European planters and the newly establishing Indian planters are notable.

The appointment of a Scientific Officer by the Government of Madras in 1909 sowed the seeds for scientific management of rubber-tree planting in India[36,37]. A research station committed to rubber tree development was established at *Mundakãyam* (Kerala) in 1921 on the initiative of the UPASI, which led to the classical trials of spraying Bordeaux mixture to manage *Phytophthora* disease of *Hevea*[38]. The establishment of the Rubber Research Institute of India (RRII) in 1955 accelerated *H. brasiliensis* cultivation and rubber product improvement in India. Comprehensive breeding trials led to multiple RRII clones, which were subsequently launched into commercial cultivation. The Indian flagship clone RRII 105, born out of the first hybridization trial in 1954 involving the Indonesian and Malaysian clones was launched in the 1980s. RRII 105 revolutionized India's rubber production greatly benefitting the socio-economic status of the planters of Kerala[38].

About 100 years after the Wickham adventure to Amazon, a more organised collection was sponsored by the International Rubber Research and Development Board (IRRDB) in 1981, which resulted in collecting *c.* 65,000 seeds and budwood from 200 trees, apparently with greater yield capacity and disease-free that were shared among IRRDB member countries, including India[9,38]. Viswanathan and Shivakoti[39] explain the growth of rubber industry in India at length and they further explained that in post-independent India, especially from the late 1950s, this industry has prospered more as a small stakeholder industry with the disintegration of estate-based industry.

Conclusion

Among the popular rubber sources, *H. brasiliensis*, *F. elastica*, and *Parthenium argentatus* (Family Asteraceae) today, *P. argentatus* and *H. brasiliensis* provide high-molecular weight rubber and *F. elastica* low-molecular weight rubber. Therefore, attention is presently invested on investigating *P. argentatus* as a possible alternative for rubber extraction[40]. Additionally, *P. argentatus* has a wider genepool than that of *H. brasiliensis*[41].

Today production of *H. brasiliensis* rubber in India has grown immensely from an insignificantly small consignment of saplings introduced from Brazil via Kew Botanic Gardens and Ceylon Rubber Garden in the final decade of the 19th century. In a global context, India — ranked fourth in natural rubber production in 2012, but slipped to fifth in 2014 because of Vietnam — producing close to 900,000 tons annually contributing to *c.* 8 % of the global rubber production. In 2012-2013, India earned *c.* INR 155 billion as foreign exchange from manufactured-rubber product export. Kerala leads in rubber production in India. The north-eastern state Tripura is currently recognized as a potential location for rubber cultivation in the near future[42]. The Indian rubber industry, today, is driven mostly by small- and micro-scale plantations. The Indian rubber industry faced a setback in 2014 with *c.* 17 % decline in annual production; however, agricultural economists predict that this problem will be remedied in 2016. One key reason for such rapid production expansion in India was the generation of 'new' high-yielding clones of *H. brasiliensis*[43]. Nevertheless, vulnerability to climate change and susceptibility to epidemic diseases and pestiferous insect outbreaks[44] pose serious challenges to productivity because *H. brasiliensis* breeding exercises have kept productivity as the prime focus (*e.g.*, *H. brasiliensis* RRII 105). In terms of sustainable production of a crop of significant human interest, *H. brasileinsis* deserves greater caution in maintaining the purity of the germplasm and in generating clones for specific reasons.

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