HEVEA BRASILIENSIS

OR

PARA RUBBER.

ITS BOTANY, CULTIVATION, CHEMISTRY AND DISEASES,

BY

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WITH PLATES AND DIAGRAMS.

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INTRODUCTORY.

THE object of this book is to present in a condensed form an account of the botany, cultivation, chemistry and diseases of Hevea brasiliensis. The physical and chemical characters of the latex and prepared rubber, the composition of technically pure and mixed india rubber, and the various points regarding purification, washing and drying have been dealt with in detail in order to give the producer in the tropics a sound basis on which to work. In the near future it may be necessary to carry out experiments with a view to making the rubber of higher value before it leaves the estate; or more acceptable to the manufacturers in other countries, and in order to accomplish such results it is imperative that we should understand the nature of the product we are dealing with.

The writer does not present this book as one containing the results of his own research so much as a review of facts regarding the product under consideration. In arranging the material for this book I have not hesitated to draw very largely from Weber's Chemistry of India rubber, Seeligmann's Le Caoutchouc et la Gutta-Percha, Obach's Cantor Lectures, the Annals of Botany, London, Johnson's Para Rubber, the Tropical Agriculturist, the Circulars and Annual Reports of the Royal Botanic Gardens, Ceylon, and the Bulletins and Journals of the Federated Malay States and West Indian Departments of Botany and Agriculture.

I am greatly indebted to my planting friends and several firms for much information and illustrations as acknowledged in the various sections; and to Dr. Willis, and Messrs. M. Kelway Bamber, A. Bruce, E. E. Green, and T. Petch for information and to Mr. H. F. Macmillan for a large number of photographs here reproduced.

H. W.

Peradeniya, September 20th, 1905.

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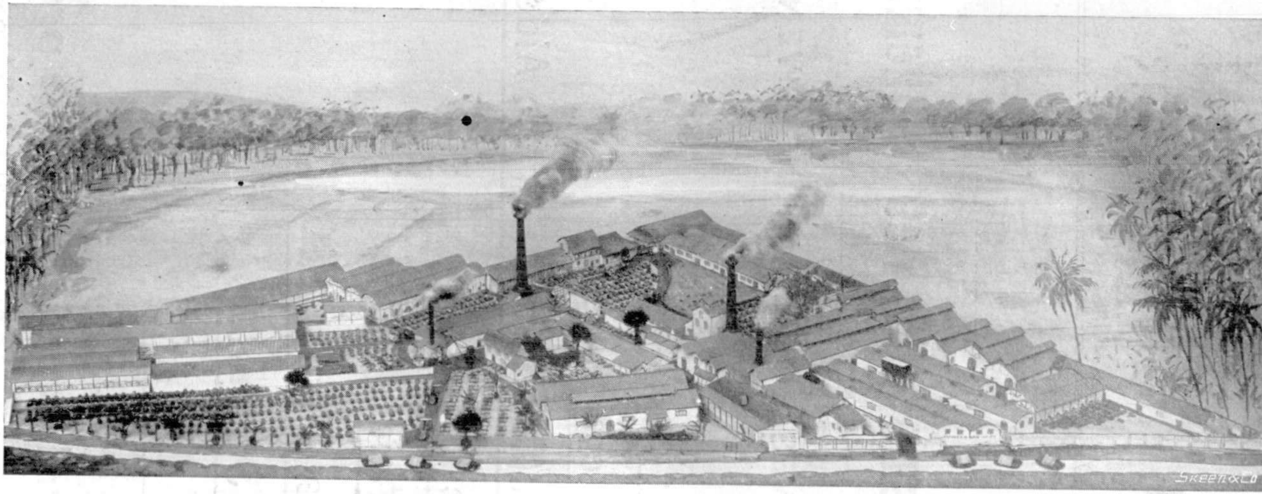

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CHAPTER I.

HISTORY OF PARA RUBBER IN THE EAST.

Work of Chapman, Wickham and Cross—Illustration showing the trees when nearly 30 years old—Propagation from cuttings from two to three-years-old trees—Flowering for the first time in Ceylon and the Straits—First seeds in Ceylon and the Straits—Distribution of seeds and plants from Ceylon—Cultivation—Yields—Preparation—Value, export and acreage of Para rubber in Ceylon from 1884 to 1905—Acreage in Malay Peninsula, Sumatra, Java and India—Illustration of leaves, flowers, fruit and seeds of Hevea Brasiliensis—The laticiferous system—Origin—Distribution and characters—Functions of the latex—Anatomical details—Illustrated.

HISTORY OF INTRODUCTION TO CEYLON AND THE EAST.

THOUGH Rubber had been known for many years it was not until 1875 that the now famous Para rubber was seriously talked about in Ceylon. In the following year nearly two thousand seedlings of Hevea brasiliensis were despatched to Peradeniya, Ceylon, from Kew. These were contained in Wardian cases and arrived by the s.s. "Duke of Devonshire" in excellent condition, under the care of Mr. W. Chapman. They were raised from seeds collected by Mr. Wickham who succeeded in securing 70,000 in the Ciringals of the Rio Tapajos.

Mr. Cross was also sent to South America to bring home plants in case the transmission of living seed should prove impossible. He arrived at Kew in November, 1876, and brought with him about 1080 seedlings without soil, of which, with the greatest care, scarcely three per cent. were saved; from these about 100 plants were propagated at Kew and subsequently sent to Ceylon. A photograph of the oldest Para rubber plantation in Ceylon is shown in the Frontispiece. The cost of procuring the seeds and plants, including freight and other expenses, appears to have been no less than £1,505 4s. 2d., or an equivalent of eleven rupees for every plant delivered in Ceylon. The whole of this expenditure was borne by the Indian Government.

PROPAGATION FROM CUTTINGS AND THE FIRST SEEDS IN THE EAST.

The plants were first propagated from cuttings, the twigs from two to three-year-old trees being used for this purpose, and a consignment of 500 rooted plants was sent to British Burma and Madras in 1878.

The plants at Henaratgoda flowered for the first time in 1881, when they were five years old. The plants at Peradeniya did not flower until a few years later-1884-but curiously enough, at Perak the small trees only 35 feet high and 2½ years old flowered in 1880.

The trees at Peradeniya did not flower in 1882, and only 36 seeds were secured in that year at Henaratgoda. Mr. Low sent, from the Experimental Garden at Perak, eighteen seeds to Peradeniya, but on their arrival they were found to be dead.

In 1883 no less than nine trees flowered at Henaratgoda in March and the fruit ripened in August. From this crop 260 seedlings were raised, many of which were sent to planters in Ceylon. In 1884 a good crop of seed was produced at Henaratgoda, and over 1,000 seedlings were raised and distributed to officials in suitable parts of the Colony. In the same year, a few seeds were also produced for the first time at Peradeniya.

DISTRIBUTION OF SEEDS AND PLANTS FROM CEYLON.

After the trees had begun to produce seed the propagation of plants from cuttings was given up. The seed supply from less than 500 trees has risen from 260 in 1883, to about 200,000 at the present time and every year large quantities of seeds are sent to many tropical countries.

India and the Straits have received a considerable number of Ceylon rubber seeds and plants, the first consignments dating back to 1877 when the cuttings from one-year-old trees were sent from Peradeniya. Seeds were also sent to Queensland in 1886 and 1889, to Jamaica and Buitenzorg in 1887, to Fiji in 1888, to Borneo and German East Africa in 1891, to Sumatra in 1901 and to the Gold Coast, Seychelles, and Australia during the last few years.

CULTIVATION, YIELDS, PREPARATION AND VALUE.

When Hevea brasiliensis was first introduced to Ceylon it was considered to be most suitable for places little above sea-level, but the good growth obtained at Peradeniya, though less satisfactory than that at Henaratgoda, was sufficient to tempt several planters, and consequently seeds were supplied to residents in many parts of the island. At the present time it cannot be doubted that Hevea brasiliensis will grow in the Central Province of Ceylon, up to 2,000 feet above sea-level and in the Uva Province at a still higher elevation. This is evidenced by the acreages now under this product in the Peradeniya, Matale, Gampola, Uva and other districts.

Ten or eleven years ago it was thought advisable not to tap trees until they were at least ten years old, and an estimate of 1½ lb.

of dry rubber, per tree, per year, from the 12th to the 20th year was considered satisfactory. Since that time it has been proved that some trees when four or five years old may yield rubber of marketable value and in exceptional cases individual trees about eleven years old have given no less then 12 lb. of dry rubber in eight months, and others as much as 25 lb. per tree in twelve months. In the same way steady progress is to be seen in the substitution of paring and spur knives for the carpenter's chisel for tapping operations; in washing machinery for cleansing crude rubber, revolving cylinders for rapidly coagulating rubber and the use of chemicals and hot air apparatus for hastening coagulation and curing the product as rapidly and effectively as possible. Simultaneously with general improvements in yield and methods of manufacture there has been a steady rise in price to over 6s. per lb. and a large increase in the acreage under cultivation.

The progress in Ceylon is illustrative of what has taken place in other tropical countries and the following tables show the range in value of Para rubber, the export, the price per lb. and the approximate acreage in Ceylon from 1884 to 1905.

Year.	Annual Export*.	Value.* Rs. Cts.	Prices of some samples of Plantation Para Rubber.† s. d.	Approximate Acreage in Ceylon.‡
1884	nil.	nil.	2 8	—
1885	cwt. 11·1·17¾	260 00	2 5	—
1886	1 package	9 00	3 0	—
1887	4 packages	110 00	3 2	—
1888	11 ,,	727 00	3 ½	—
1889	14 ,,	542 00	2 9½	—
1890	39 ,,	1067 00	3 6	300
1891	78 ,,	2000 00	3 2	350
1892	cwt. 65·0·7	3325 00	2 10	400
1893	cwt. 52·2·0	1600 00		450
1894	cwt. 82·0·14	4400 00	2 10½	500
1895	cwt. 15·2·17	1290 00	3 2	550
1896	cwt. 157·0·7	8760 50	3 4½	600
1897	cwt. 73·1·5	7458 00	3 6½	650
1898	cwt. 24·3·20½	3694 00	4 4	750
1899	cwt. 70·2·14	3838 00		1250
1900	cwt. 73·1·19	12882 75	4 0	1750
1901	cwt. 66·0·0	11986 00	4 1½	2500
1902	cwt. 189·0·0	38362 00	4 0	4500
1903	cwt. 389·0·0	84784 00	5 0	7500
1904	cwt. 676·0·10	221120 00	6 0	11000
1905§	cwt. 786·0·5	312074 00	6 to 6 8	40000

* From the Principal Collector of Customs, Colombo, Ceylon.
† Bulletin of Miscellaneous information, Kew, No. 142, 1898.
‡ From the "Ceylon Directory."
§ Official figures up to September 23, 1905.

The total acreage planted with rubber in the Malay* Peninsula has been estimated at	...	30,000	acres.
To these we might add, Sumatra (say)	...	5,000	,,
Java ...	...	5,000	,,
Ceylon	...	†25,000	,,
India and Burmah		5,000	,,
Total	...	70,000	acres.

THE LATICIFEROUS SYSTEM.

The illustrations on Plate 2 show the characters of the leaves, flowers, fruits and seeds of Hevea brasiliensis and do not need any explanation.

The latex is contained in definite ducts which occur throughout the stem, root, leaves, flowers and fruits. The laticiferous ducts in Hevea brasiliensis consist of a series of sacs, the walls of which break down and thus give rise to the formation of a number of tubes, disposed more or less longitudinally. In some cases the walls of the cells are only incompletely disintegrated and in such cases the flow of the latex is not as free as when the partition walls are completely broken down.

We are concerned with the laticiferous tubes in the outer part of the stems when the trees are ready for tapping.

The thickness of this tissue may vary from 1/8 to about half an inch or more according to the age of the tree.

The average thickness of the undisturbed bark of twenty-year-old trees in Ceylon is about 3/8 inch ‡ (9.5 mm.) though trees at Singapore,§ only 11 years old, possess bark of this thickness. The outer part to a depth of 1/8 inch (3 mm.) does not contain many tubes, but the inner part has a large number and from the inner 1/16 to3/32 inch the milk mainly flows. The tubes in the outer part seem to dry up.

When the original cortex has been removed, new tissue is produced from above downwards and within outwards and in this the latex tubes arise *de novo* as in the original material. It is important to remember that the extension of these tubes in the cortex of Hevea is a gradual one, and that in many instances the parts of the laticiferous system are not extensive and in tapping operations only a fraction of the whole milk-containing tubes may be drawn upon.

FUNCTIONS OF THE LATEX.

It is well-known that a system of milk tubes may or may not occur in particular species and that the presence of a laticiferous system is of importance in determining the identity of species.

* Annual Report of the United Planters' Association, 1904.—F.M.S.

† According to Ferguson this should (October 1905) now be changed to 40,000 acres.

‡ Parkin, Caoutchouc or India rubber, Circular, June 1899.

§ do do do do (Vide Director, Botanic Gardens, Singapore)

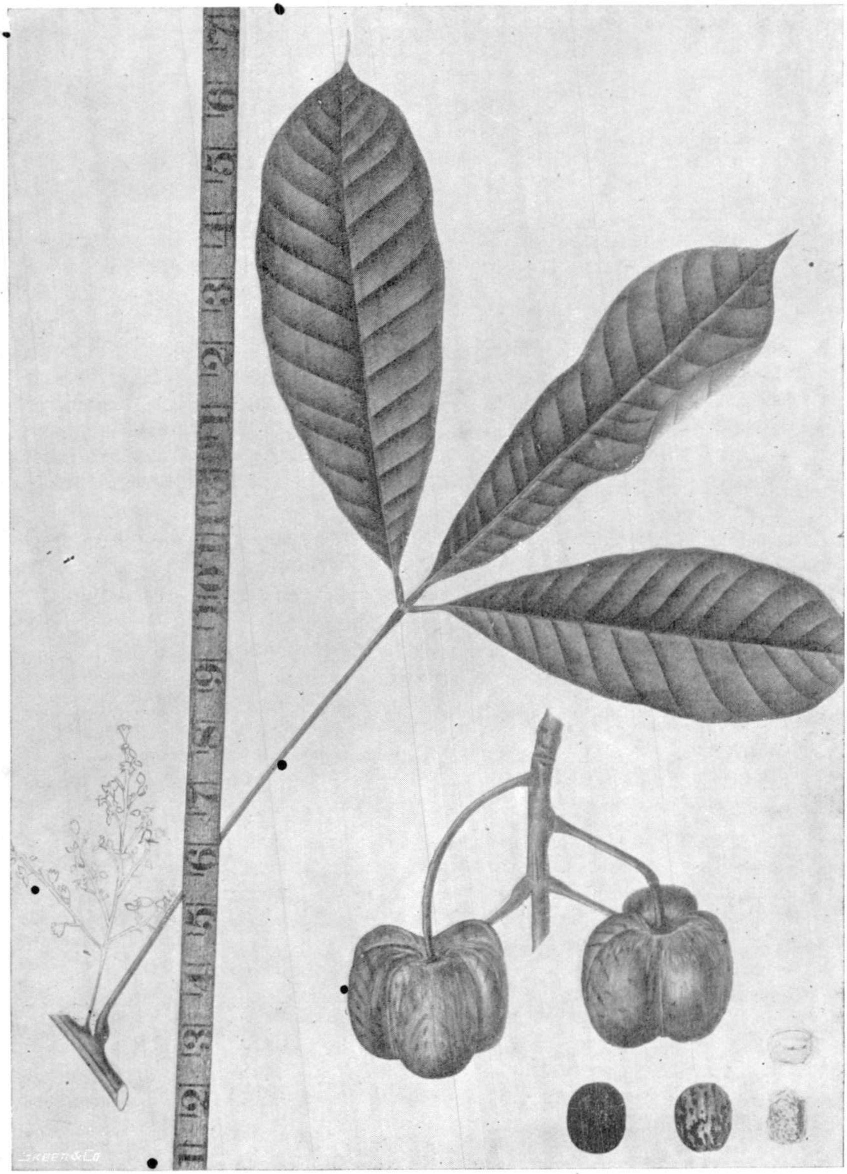


Photo by H. F. Macmillan.

THE LEAVES, FLOWERS, FRUITS & SEEDS OF HEVEA BRASILIENSIS.

Several natural orders such as those which include species of Euphorbia, Castilloa, Hevea, Kicksia, Funtumia, Landolphia, are characterised by large numbers of plants which possess milk tubes, whereas other natural orders are not known to possess any laticiferous species. It is also recognised that the number of species in the tropical areas, possessing milk tubes, is very large compared with that in colder or more temperate zones and that many of the latex-bearing plants thrive on rocky soils and in dry districts in the tropics.

If one reflects on the thriving condition of widely different species of latex-bearing plants in the temperate, sub-temperate and tropical regions, and the behaviour of such plants under various conditions, the difficulty of ascribing a single function or series of functions to the latex will be manifest. Each species must be considered separately, and in the case of Hevea brasiliensis many observations have been made and various theories propounded.

STORING WATER.

The latex of Para Rubber consists mainly of water and caoutchouc globules together with small quantities of sugars, proteids, gums, resins, etc. Most of the constituents cannot be regarded as forming reserve food and even in the case of sugars and proteids their presence in such small quantities would prevent their being of vital importance to the plant in times of emergency. Furthermore the fact that the tubes arise, *de novo*, by a process of perforation and decomposition, and during their ramifications in the cortex are never in direct communication but contact only with the vital elements of the bast, supports the contention that the small quantities of food they contain are probably of very minor importance to the plant.

The water is, according to most observers, of more importance than the other constituents. It is well-known that the flow of latex is largely determined by the quantity of water present in the soil and the increased flow which follows the rain after a drought is often very remarkable.

Warming, after studying the vegetation of tropical America, concluded that the latex probably served many functions, one of them being a source of water supply during the dry hot part of the day or year. Groom* when dealing with this subject pointed out that there was no reason to believe that the functions of the latex in all plants are the same, or that one function should exclude the other. Parkin† considered that the latex did not play an important part in nutrition and inclined to the belief that "the laticiferous system served as channels for holding water in reserve to be called upon during times of drought or during the rainy season". The exudation and clotting of the milk prevents the entrance of many insects, but this is not of much importance.

* Function of laticiferous tubes, Annals of Botany, 1889.

† Parkin l. c.

The complete stripping of the cortex from the base up to 5 feet and with it the greater part of the laticiferous system, has not, in the case of Hevea brasiliensis, resulted in any very bad effects on the tree.

The present appearance of trees from which large quantities of latex have been extracted is such as to confirm the belief that the latex is of minor importance to plants freely supplied with water and that the main source of danger lies in the removal of the cortical and bark tissues often effected in collecting the latex.

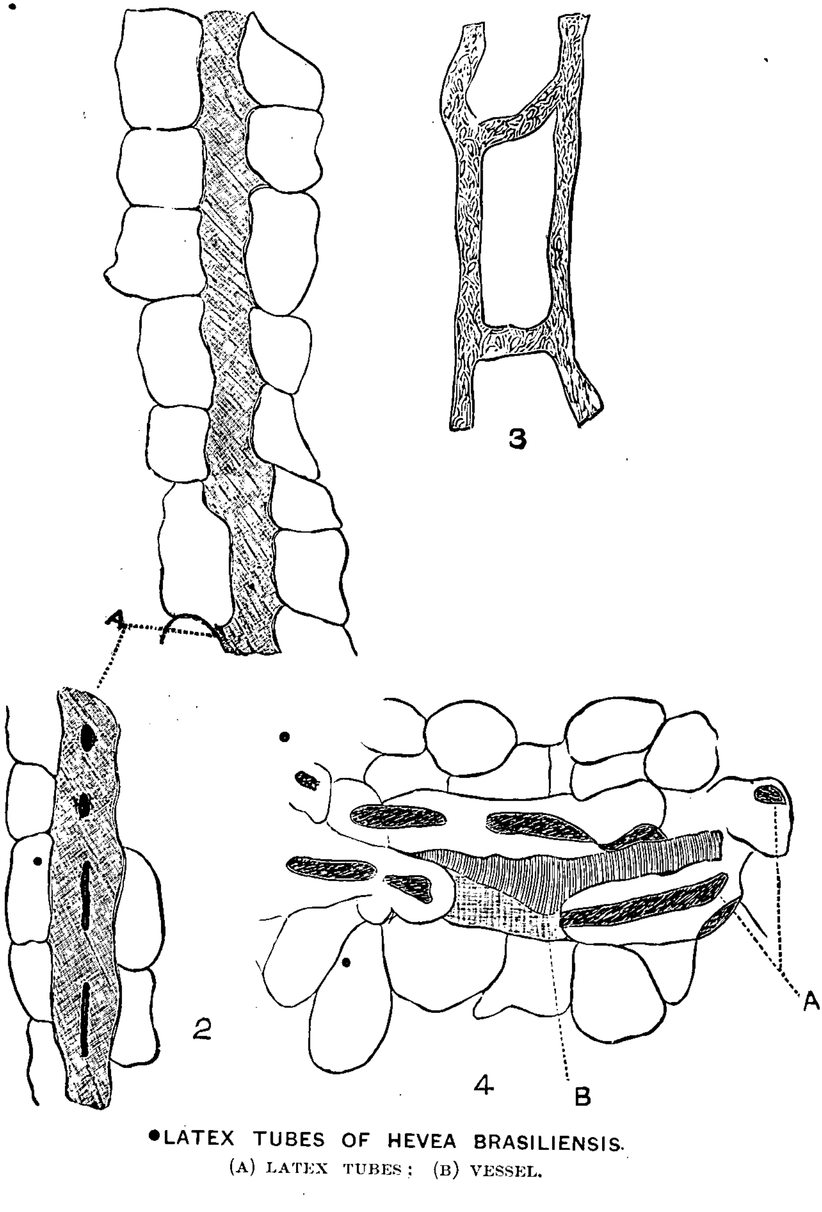
It should be recorded that Hevea brasiliensis grows exceedingly well on land which is frequently inundated and in some parts of Ceylon I have seen trees with their tap roots and a large proportion of the feeding rootlets permanently under water and yet yielding over ten pounds of rubber, per tree, per year. An abundant supply of water, in well-drained land, is not harmful to Para rubber trees.

GENERAL CONSIDERATIONS.

In the accompanying Plate, No. 3, figures 1 and 2 represent the latex tubes running in a vertical direction through the stem of Hevea brasiliensis. In each case they are surrounded by cells which naturally store up reserve food materials and in figure 2 curious rod-like bodies are seen in the laticiferous vessels. In some instances the milk tubes are pitted, so that a transference of solutions may be effected from one series of cells to the other. Furthermore the milk tubes often run very close to those elements of the wood the function of which is to convey watery solutions from the roots upwards. Figure 3, drawn from a section of the fruit wall of Carica Papaya, shows the proximity of the water conducting elements of the wood to the latex tubes, the latter possessing irregular patches of coagulated india rubber. In figure 4 the general outline of a series of tubes is shown. On account of these relationships one may be inclined to attach some importance to the theory that the milk tubes are partially connected with conducting functions,

But the fact that the laticiferous system may be concerned in conducting solutions, that they contain in their earlier stages a certain quantity of protoplasm, and that nuclei and starch grains may be occasionally found, does not exclude the view that they are mainly excretory or act as water reservois.

Generally speaking the milk tubes contain an emulsion of many substances, such as caoutchouc, resin, gum, sugar, proteids, alkaloids, and fats, and it is therefore very difficult to identify each component in sections under the microscope. Schullerus observed that in the embryo, the latex is rich in suspended matters and that as the plant grows the latex becomes more watery and he suggested that the emulsion of substances might be of use during the early stages. He also noticed that after germination the laticiferous system became prominent owing to an increase in the substances in suspension.



LATEX TUBES OF HEVEA BRASILIENSIS.

(A) LATEX TUBES; (B) VESSEL.

Sachs found that if the leaves of some caoutchouc plants were subjected to continuous darkness the quality of the latex was affected, the milk becoming less opaque; a marked change was also noticed if the plants were deprived of carbonic acid gas.

Haberlandt and others have found that in some plants the starch grains disappeared from the milk tubes, if kept in darkness for two or three weeks, thus suggesting that under certain circumstances the occasional starch grains may be converted into sugar to be used by the plant.

The presence of nuclei in certain laticiferous tubes—determined I believe by Treub—the close association of milk tubes with conducting elements in the leaf and the occurrence of minute quantities of carbohydrates, proteids, fats and peptinising ferments certainly support the idea that under certain conditions the latex contents may be useful to the plant. But as previously pointed out the occurrence of such material in very small quantities prevents one from attributing undue importance to the "reserve food" conception.

CHAPTER II.

CONDITIONS IN PARA.

Descriptions of Para by Drs. Trimen & Ule—Para trees in Brazil—Cultivation in Africa, Seychelles, Borneo, West Indies — Combination of climatic factors in Ceylon, India, and the Straits.

CONDITIONS IN PARA.

"PARA * occupies a position near the mouth of one of the vast embouchures of the Amazon in about south latitude 1, but the district of the same name extends over a vast forest region to the south and west, throughout which and the enormous forests of Central and Northern Brazil, Hevea brasiliensis and allied species are abundantly found. The climate is remarkable for its uniformity of temperature, usually not exceeding 87° F. at midday or falling below 74° at night. The greatest heat recorded is 95°, and the mean for the year is 81°. The rainfall occurs principally during the months from January to June, the maximum being in April, when it reaches 15 inches. For the remaining six months of the year very little rain falls, but there are fine days in the wet season and occasional showers in the dry. During the wet season much of the low-lying country near the Amazon's mouths is flooded."

According to E. Ule,† in his book dealing with rubber in the Amazon district "the Para tree loses its leaves annually, as in Ceylon, and in the flooded regions this occurs when the water is at its highest *i. e.*, between March and July. It flowers in July and August, and ripens its fruit in January and February. Like most forests in the tropics those of the Amazon are composed of many kinds of trees intermixed, and rubber occurs scattered among the rest. The lower-lying forests (Vargem or Igapo) are exposed to yearly floods and have a distinct character, differing from those on the higher lands.

* Notes on Rubber—yielding Plants, by Dr. Trimen.
† Review by Dr. Willis, "T.A. & M.C.A.S.," March 1905.

There are two chief seasons, a dry and a wet. The driest months are July, August and September, when the river level is also lowest. The rains begin in October and last till March, and then decrease; the rain is not however continuous, there are showers with clear intervals. The rivers rise till in January they overflow into the forest; their highest level is reached in March or April and then they fall, leaving the woods dry again. In the lower course of the Amazon itself the water reaches its highest level in June, and this level is often 45 to 60 feet above the lowest. The annual rainfall is usually between 80 and 120 inches and the mean temperature between 76° and 81° F. There are a great many kinds of trees in the forests, and in a distance of 100 yards one may only find one or two rubber trees."

It has been pointed out by Wickham that the true forests of the Para rubber trees lie back on the highlands and those commonly seen by travellers along the river side are scattered, poor in growth and do not give one a fair idea of the conditions under which a good growth of the Hevea tree is obtained. The Hevea trees found in these unbroken forests, attain a circumference of 10 to 12 feet in the bole, a considerable difference to the 6 to 7 foot trees recorded by Cross.

The foregoing accounts of the climatic conditions in the native home of Hevea brasiliensis should be closely studied by persons who intend to cultivate this product. The rainfall of 80 to 120 inches, and temperature of 75° to 81° F. though characteristic of the forests where this species grows luxuriantly should not however, be accepted as strictly defining the limits under which Para rubber can be cultivated. But even if the adaptability of the tree were insignificant it is obvious that in the tropics there are many areas which might reasonably be expected to give good results with this species of rubber. Already the cultivation has aroused considerable interest in Africa, Fiji, Java, Queensland, Seychelles, Borneo, Sumatra, and in many of these areas where the climatic factors are approximately similar to those of the Amazon, the industry promises to become as important as in the Straits, Ceylon and India.

The illustrations on Plate 4 will show under what conditions Para rubber is being grown in Ceylon, rocky hillsides and well-drained swampy land having been proved to be suitable for it. In the Gold Coast, West Africa, it is, according to Johnson, being grown at an elevation of 1500 feet above sea-level, where the average mean temperature is about 81.5° F. and the annual average rainfall 47 inches and there promises to do better than other rubber-producing plants, indigenous or exotic. It is likewise favourably reported upon in Jamaica, Dominica, St Vincent, Grenada, Trinidad, Zanzibar, Uganda Protectorate, and Mozambique.

The combination of rainfall, temperature, and elevation required for the profitable cultivation of Para rubber eliminates many parts of the tropics for this species. In Ceylon, India, and the Straits the large tracts of land in the hilly districts cannot be included in the Para zone, on account of low temperatures or unfavourable moisture conditions. In the greater part of Ceylon an elevation of 2000 feet is considered to be near the maximum and a rainfall of 70 inches near the minimum for the cultivation of this species. It is being tried in districts having 200 inches of rain per year and also in dry irrigable areas, but reliable results cannot be obtained for many years.

In some parts of India the climatic conditions are such as to allow of the cultivation of Para rubber up to 3500 feet above sea-level.

CHAPTER III.

CULTIVATION OF PARA RUBBER TREES.

Rate of growth—Size of trees at Henaratgoda, Peradeniya, Edangoda, and parts of Ceylon—Kegalle, Knuckles, Nilambe, Katugastota—Sabaragamuwa—Wattegama—Kalutara—Matale—Baddegama—Spread of foliage each year from 2nd to 30th year—Rate of growth in the Gold Coast—Height and circumference—Rate of growth in the Straits,—Perak, Selangor—Rate of growth in India—Mergui, Shevaroy, Nilgiris—High average incremental growth in the Straits—Leaffall—Root System—Propagation of plants—Shade and wind—Planting operations—Nurseries—Fencing—Draining—Illustrations showing rubber on swampy and rocky land—Distance, holing and planting—Number of trees per acre—Distance for rubber alone and catch crops—Pollarding Para rubber—Inter and catch crops—Cocoa, Coffee, Groundnuts, Lemon-grass, Cassava—Future of inter crops.

RATE OF GROWTH AND SIZE OF MATURE TREES IN CEYLON.

THE rate of growth depends upon the nature of the soil and climate and the care which has been exercised in selecting seed parents and planting operations. In districts having a rainfall of about 100 inches per year, an average mean annual temperature of 80 F., and soil of medium quality the trees will grow about six to ten feet in height every year for the first three or four years and attain a height of 80 to 90 feet within thirty years. The growth in circumference is by no means slow; trees one year old from planting may have a circumference of 3 to 4 inches and they usually increase at the rate of four to five inches each year for the first few years when planted as a single product. During the first few years the growth is mainly in length, and the rapid increase in girth is most noticeable after the trees are a few years old. The following table shows the dimensions of trees of known ages at Henaratgoda; the stumps were about one year old when planted.

HENARATGODA TREES PLANTED IN 1876.

Year.		Age.		Measurements. Height. feet	Circumference. inches
1878	...	3	years.	30	14
1880	..	5	,,	—	16
1881	...	6	,,	—	21
1882	...	7	,,	50	25½
1883	...	8	,,	—	30
1884	...	9	,,	63	36
1885	..	10	,,	—	43
1886	...	11	,,	—	49
1887	...	12	,,	—	53½
1888	...	13	,,	—	60
1889	...	14	,,	—	69¾
1890	...	15	,,	—	73
1892	...	17	,,	—	77
1893	...	18	,,	—	79½
1905	...	30	,,	—	109½

PERADENIYA TREES PLANTED IN 1876.

Para rubber trees at Peradeniya were planted in the South Garden near the river banks, but above flood level. They were planted 10 feet apart, probably in 1876 when the stumps were about one year old, and the following were the dimensions of the trees in June, 1905:—

No. of Tree.		Height. ft. in.		Circumference in inches, 3 feet from base.
1	...	51 7	...	44
2	...	89 6	...	82
3	...	73 3	...	52
4	...	82 7	...	59
5	...	84 2	...	59
6	...	55 4	...	49
7	...	78 7	...	58
8	...	79 3	...	56
9	...	89 5	...	81
10	...	76 2	...	50
11	...	74 3	...	43

The following list gives the dimensions of the trees planted in 1881 along the river bank, where they are liable to be flooded when the water is high. They are remarkable on account of the growth obtained when planted so close, the average distance between the trees at the present time being 9 to 10 feet.

Tree.	Circumference, 3 ft. from base. ft. in.	Height. ft. in.
1	4 9	57 2
2	4 2	87 4
3	4 3	61 7
4	6 11½	82 3
5	6 8	89 1
6	4 5	81 5
7	2 9	52 7
8	3 7	79 6
9	5 3	84 2
10	4 10	86 1
11	5 5	67 4
12	5 8	78 9
13	5 9	64 7

Other measurements have previously been taken of the trees on the Forest Department Plantations and are here quoted:—

EDANGODA TREES.

Age.	Mean circumference 3 ft. from base.
2 years	4·96 inches
3 ,,	8·75 ,,
4 ,,	12·96 ,,

YATTIPAWA TREES.

3 years	9·37 inches

RATE OF GROWTH IN OTHER PARTS OF CEYLON.

The following figures show the dimensions of Para rubber trees, *interplanted with tea and cocoa*, in Ceylon.

Age of trees. years.	Circumference of the stem in inches, three feet from the base. Kegalle.	Knuckles.	Sabara-gamuwa.	Katugas-tota.	Pera-deniya.	Nilambe.	Kalu-tara.
2	—	—	—	—	2 to 6	—	5
3	—	—	14	—	10	—	9
4	—	14-16	15	—	—	—	17 to 20
5	21 to 30½	—	21	—	—	—	—
6	—	—	27½	19	—	—	—
7	—	—	31	—	—	—	—
8	—	—	31½	24	—	—	—
9	—	—	65	38	—	15 to 46	—
10	—	—	—	—	—	—	—
11	—	—	—	—	—	—	—

In districts over 2,000 feet above sea-level or where the rubber has been planted in inferior or unsuitable soils the growth is much poorer. On one estate near Peradeniya, 2,200 feet above sea-level, 9-year-old trees only measure 24 to 46 feet in height and 15 to 46 inches in circumference a yard from the ground, and the following dimensions of the trees referred to will be of interest to those planters who are trying Para rubber at high elevations in Ceylon.

No. of tree.		Length of trunk. ft.	in.		Spread in Widest part. ft.	in.		Circumference 3 feet from the base in.
1	...	42	0	...	29	8	...	46
2	...	36	0	...	21	0	...	22½
3	...	34	6	...	13	0	...	15½
4	...	46	10	...	22	6	...	24
5	...	42	6	...	22	8	...	22
6	...	32	5	...	18	0	...	22½
7	...	36	6	...	17	0	...	25½
8	...	46	8	...	25	6	...	33
9	...	24	4	...	13	4	...	17
10	...	42	8	...	29	0	...	35

In other districts where the rubber has been planted in very poor tea and cocoa land the growth is often very slow.

Under suitable conditions of soil and climate in Ceylon, one must allow for the full development of the plant and a spread or branch diameter of at least 30 feet for trees 10 years old, and 40 feet for 20-year-old trees must form the basis of calculations where pollarding is not adopted and where the cultivation is intended to be permanent.

The diameters of the branch and foliar system of trees of known ages, measured on rubber property in Ceylon are here given, but it must be understood that the growth has been obtained where Para rubber is interplanted with cocoa or tea. The growth is very variable. The Para stumps were from one to two years old when planted.

DIAMETER OF BRANCHES WITH FOLIAGE.

Age of trees. years.	Matale, feet.	Badde-gama. feet.	Katugas-tota. feet.	Nilambe. feet.	Knuc-kles. feet.	Pera-deniya. feet.	Sabara-gamuwa. feet.	Watte-gama. feet.	Kalu-tara. feet.
2	2	—	3	—	—	3	15	3	8
3	4 to 4½	—	—	—	—	—	—	—	12
4	13½	12	—	—	12 to 13	—	19	—	16
6	—	13	—	—	—	—	28	—	17
7	15 to 24	18	—	—	—	—	—	—	20
8	—	—	29	—	—	—	37	—	25
9	—	—	—	17 to 30	—	—	—	23	25
10	32 to 34	—	—	—	—	—	—	28	33
11	—	—	—	—	—	—	—	—	35
13	—	—	—	—	—	—	—	—	46
15	27 to 46	—	—	—	—	—	—	—	—
25	—	—	—	—	—	15 to 43	—	—	—
30	—	—	—	—	—	28 to 40	—	—	—
Elevation in feet.	1200	50	1500	2200	2500	1500	600	2200	100
Rainfall in inches.	77	119	85	130	175	90	170	80 to 90	130

Where the trees are planted closer than 10 x 15 feet apart they will probably show a greater height and smaller circumference. One tree ten years old grown more or less in the open has a spread of 36 feet, whereas one of the same age surrounded with other trees has a spread of only 20 feet. The largest tree in Ceylon, now 30 years old from seed, measures about 90 feet in height and 109½ inches in circumference and there are many others of the same age which have a circumference of *8 to 9 feet* and a height in proportion to the above examples. Several of the Henaratagoda trees owing to their being too closely planted have only a branch spread of 15 to 20 feet in diameter. (See Frontispiece).

RATE OF GROWTH IN THE GOLD COAST.

Plants have been established in the Botanic Gardens,* Aburi, at different dates, and most of them have made very rapid growth. Some of the trees only 18 months old are 10 feet high and have stems 3 inches in diameter. The following table shows the growth at different ages in the Gold Coast.

Age of tree in years.	Height in feet.	Girth at 3 feet from the ground. Inches.
10	30.25	27
4	23	10
3	17.5	6.5
1	6	—

RATE OF GROWTH IN THE STRAITS.

The growth in most parts of the Straits is considered to be very encouraging and superior to that obtained in other Para rubber-growing countries. In Perak † 11-year-old specimens may be 70-75 feet high and have a mean girth of 4½ feet, at 3 feet from the base.

	Age in years.	Circumference at a yard from base in inches.	Height feet.
Trees in F.M.S. ...	3½	17½	—
...	4	22½	30
...	10	54	65-75
At Perak.‡ ...	10	50	79

Trees on an estate in Selangor grew to a height of over 30 feet and attained a girth of 19 inches in four years. At Perak, an 18-year-old tree growing at Kuala, Kangsar, has a girth of 8 ft. 6 inches at a yard from the ground. Phenomenal growth in the Straits is often met with, trees 18 months old being sometimes nearly 30 feet high and trees 8 years old having a circumference of 45 of more inches a yard from the ground.

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* Johnson, Report on Rubber in the Gold Coast, 1905.
† Annual Report F. M. S. for 1902 by Stanley Arden.
‡ Agr. Bul. of the Straits and F. M. S., June, 1902.

RATE OF GROWTH IN INDIA.

The following figures showing the dimensions of nine-year-old trees in Mergui have been given by Colonel W. J. Seaton.

No.		Height in feet.		Circumference in inches, at 2 ft. from the ground.
1	...	39	...	29½
2	...	34½	...	37
3	...	40	...	38
4	...	43½	...	40½
5	...	36½	...	39½
6	...	38½	...	27½
7	...	36¾	...	31
8	...	30	...	18
9	...	31	...	27
10	...	21½	...	18½

In many parts of Southern India, Para rubber is being more or less successfully grown up to 3000 feet above sea-level. Trees at an elevation of 2500 feet, attain a height of 18 feet in three years; and a circumference of 42 inches in 17 years and nearly 60 inches in 22 years.

On the Shevaroy Hills, at an elevation of 3400 feet, Para rubber trees are reported to be about 10 inches in circumference when three years old, 12 inches when four years, and 18 inches when six years old; others are reported at 3600 feet in the Nilgiris and the Anamallais to be from 9 to 13 inches in circumference and 19 to 29 feet in height when three and a half years old. On most of these properties the rubber is used as shade for coffee and from all accounts the latter is thriving under the shade of Para and Castilloa rubber.

The Para rubber trees in many parts of South India do not appear to increase much more than 3 to 4 inches in circumference per year and a girth of 20 inches in 5 years would be considered good.

Speaking in quite a general way it is fairly correct to say that the average growth obtained in the Straits when the rubber is grown as a single product is better than that in Ceylon, India, or in the Gold coast, but that local areas in each country and especially in the drained black soils of Ceylon and along the Malabar coast show excellent growth of Para rubber.

LEAFFALL.

The Para rubber tree is not evergreen. During the first two or three years the young tree may retain its leaves and show a nett increase in foliage at regular intervals. After the second or third year, however, the tree annually drops its leaves but quickly puts on a fresh supply of young foliage. When growing under healthy conditions the trees in Ceylon and the Straits usually drop their leaves in February and March; in badly-drained places the foliar change is very irregular. In its native home the tree becomes leafless between March and July.

The annual leaffall should be taken into consideration if the Para rubber trees are interplanted with other products as the leafless phase usually occurs when the dryness and temperature of the air are at the maximum and the intercrops will therefore be exposed to the dry hot winds at a time when rain is not expected.

ROOT SYSTEM.

The tree has a very well-developed root system which may ultimately crowd out many intercrops if planted too close. The tap root may grow to over ten feet in length and the lateral rootlets form a very compact mass. It is on account of the rapidly growing, compact, and superficial root system that plants such as the coconut and other palms, tea, and coffee, cannot be grown successfully for many years in conjunction with Para rubber. The lateral roots grow at varying rates according to the conditions prevailing, but if grown alone on moderately good and flat land an incremental yearly increase in radius of about 10 to 12 inches can be allowed for. In six to seven years the lateral roots of plants distanced 12 x 12 may be expected to meet; when planted 10 x 15 the larger distance will be covered in 7 to 8 years. The rate of development of the lateral root system is of considerable importance as we shall see later when dealing with weeding, intercrops and manuring.

PROPAGATION OF PLANTS.

Hevea brasiliensis usually seeds freely after its fifth year. Mature trees can be expected to give about 500 seeds per year though individual trees or special groups have been known to yield twice this quantity. It is interesting to learn that on the above basis—each tree producing 500 seeds each year after its fifth year—that a single five-year-old tree and its offspring will yield in 20 years no less than 4,000,000,000,000 seeds.

The yield may, however, suffer reduction owing to excessive tapping, bad treatment, and disease and it is therefore satisfactory to know that this plant can be propagated from cuttings. The first plants sent from Ceylon to India and the Straits were rooted cuttings and the most remarkable feature of the consignment was that the cuttings were taken from plants only one year old. It is very probable that many of the plants now in the Straits are the offspring of the original cuttings despatched in 1877 and the fact that they produce plants capable of yielding latex in desired quantity and quality should be reassuring to planters when seed supplies are unsatisfactory.

SHADE AND WIND.

It would be unfortunate if the Para rubber tree required a permanent shade as there are but few shade trees which could be relied upon to always outreach the tops of tall rubber trees especially when the latter have never been pollarded and planted very close. Only trees such as Albizzia moluccana and perhaps Erythrina lithosperma would combine the quick growth and spreading of branches which would be necessary. Trees of Peltophorum and Pterospermum species, etc., though attaining huge dimensions grow at too slow a rate especially when cultivated in conjunction with other tree forms.

Para rubber trees develop better if shaded after being planted and a light shade for the first and second year such as is given by cuttings or plants of Erythrina species is beneficial. After their second year, however, they grow satisfactorily without shade.

Windbelts are generally only necessary during the early stages and owing to the protection from wind which the mature trees give to one another and their general strength special windbelts can be disregarded except in extremely windy places, where the retention of forest belts to break the wind is about the only feasible way out of the difficulty.

PLANTING OPERATIONS.

Nurseries.—If clearing and holing has been completed the seeds should be planted as soon as they have germinated. The seeds germinate in a few days if regularly watered. If it is intended to plant stumps in the following year a well-prepared nursery should be used. The larger the plant—in an interval of 9 to 12 months—the better. Good growth has been obtained by adding cattle manure and leaf mould to the nursery soil before sowing the seeds. An application of a well-balanced artificial manure to the nursery plants when about four months old will also help them on and give better stumps for planting in due course. The use of seed-baskets is to be recommended as there is minimum interruption in the root development during planting operations; the success with which stumps can be used has, however, led to the disuse of baskets in many districts. Considering that so few trees are planted, per acre, and that baskets are so cheap the disuse of the latter at the expense of the interruption in development of the rubber plant is to be regretted.

Fencing.—This work is necessary if the vacancies are to be kept at a minimum. Animals attack the Para rubber plants at all stages, particularly during the first and second years, and the amount of damage done to young clearings by rats, hares, porcupines, pigs, deer and cattle cannot be too seriously considered. If it is intended to cultivate catch crops which are equally attractive to animals, fencing is imperative. The boundaries of clearings newly planted are often enclosed in rabbit wire netting, but where the rubber is planted in established products it is sufficient to fence around each plant, either with netting or sticks. When rabbit netting is used the plants are protected by a circle of netting about six to nine inches from the plant to a height of 3 or more feet.

PLATE 4.

Photo by M. Kelway Bamber.

PARA RUBBER IN DRAINED SWAMPY LAND.

PLATE 5.

Photo by M. Kelway Bamber.

PARA RUBBER ON ROCKY HILLSIDES.

Draining.—It is erroneous to suppose that because Para rubber is a forest cultivation that draining is unnecessary. Draining is as necessary for rubber trees as it is for any other product in order to encourage the free circulation of air, water and food solutions throughout the soil, and to check "wash" on steep hillsides.

The distance of the drains from one another and their size must depend upon the soil conditions. In swampy and boggy land, little above the water-level the drains should be as wide and deep as possible, either between each row of trees or in exceptional cases around individual trees. Several areas in the low-country of Ceylon, consisting of bogs rich in organic matter, have been converted into good rubber land by making drains two to three feet wide and three to four feet deep and heaping the earth in the middle to form a dry soil on which the rubber plant can live for a couple of years. Plate 4 shows swampy land which by means of good drainage has been converted into good rubber soil.

On hillsides the drains need be only about one to one and a half feet deep. They should be made at right angles to the slope in order to check the formation of gorges. The distance of the drains from one another will vary according to the slope and climatic conditions; on flat land a distance of 60 to 70 feet seems sufficient, whereas on steep hillsides 20 to 30 feet is not too close. The accompanying illustration on Plate 5 shows a young rubber plantation estabished on very rocky land.

Distance, Holing and Planting.—It is a principle recognised in forestry that close planting will give tall trees and wide or open planting thick trees. The object in planting Para rubber is to produce trees which will, as early as possible after the fourth or sixth year, give a straight stem of at least ten to fifteen feet in height, and a circumference of 20 inches or more. Such trees can be tapped. If the trees are very tall, but have a circumference of less than 20 inches, tapping operations are generally impossible owing to the smallness of the available tapping area from 6 feet downwards. And such trees 8 years old are known, the undesirable result being the outcome of too close planting and not thinning-out or pollarding the trees at the proper time. In parts of Ceylon, Para trees have been planted 10" x 10", 12" x 12", 14" x 14", 15" x 15" and 20" x 20". It should be mentioned that trees in the Straits, planted 36" x 36" showed contact of branches in nine years and in Ceylon the branches of trees planted forty feet apart have been known to meet in ten years.

In order to allow the plants to develop freely in circumference the maximum distance should be allowed as the desired length of trunk is usually obtained even when the Para rubber tree is grown in the open. From considerations of the condition of trees from 2 to 20 years old the following table is compiled in order to show the probable number of Para rubber trees of known age an estate can bear without interfering with the natural growth of the plants.

Age of trees.	Total spread of the branches in diameter.	Number of trees per acre.
Four years old	12 feet.	302
Six " "	15 "	193
Eight " "	25 "	70
Ten " "	30 "	30
Twelve " "	35 "	35
Fifteen " "	40 "	27
Twenty " "	40 "	27

This shows the approximate number of trees to the acre at different ages without any interference of the branches of adjacent trees with one another. There is, however, no objection to the branches of trees partially overlapping and it is more than likely that any excessive branch development will be kept back by pollarding rather than by reducing the number of trees below 200 to the acre.

DISTANCE IN PLANTING.

Johnson recommends planting 15' × 15' to 20' × 20' and afterwards thinning-out. If the estate is planted for rubber alone and all ideas of catch crops are disregarded then a distance of 10 feet x 10 feet can be allowed in planting; by when the trees are six years old the branches will certainly have met. On such an estate individual trees could be tapped until they died and thus make room for the further development of the remaining plants. It should be mentioned however, that we have trees which have been grown in moderately rich soil for over twenty years and though they are still only from eight to ten feet apart, they have a circumference of from forty to over eighty inches, and a branch and foliar system measuring less than thirty feet in diameter. I have frequently seen Para trees which though planted the same distance and over 10 years old, did not appear to be too crowded.

The distance of 10 feet × 10 feet recommended on the above basis is open to the objection that the soil will still be considerably exposed during the first few years, but this can be overcome by the interplanting of cuttings or plants of Erythrina lithosperma (Dadap) a species which could be made to afford shade for the first few years and at the same time provide a rich mulch for the benefit of the young Para rubber plants.

On several estates the rubber trees have been planted 8 × 8 feet and even closer on the assumption that half of them would die from one cause or another or could be cut out when the growth became too dense. The use of the Dadap between Para rubber plants would, I believe, be accompanied by better results. The presence of a young Dadap between every two rubber plants would not interfere with the growth of the latter for several years as is obvious from the previous considerations regarding the rate of growth of the lateral root system.

POLLARDING YOUNG TREES.

The Para rubber tree naturally grows to a tall slender tree and it remains to be seen how by pollarding the young plants an increase in circumference may be obtained at the expense of the growth in height. Considering what has been accomplished with Tea, where plants ordinarily growing into fairly stout trees over twenty feet high have been converted into small bushes two to four feet in height, it would be idle to predict the possibilities with Para rubber. The prevention of the unnecessary growth in height may well form the subject of many experiments. (see Plate 17).

The question of *holing* should be well considered as the Para rubber plant is a greedy feeder and responds to generous treatment. The holes should be 1½ feet deep and as wide in area as possible, and if made 1½ × 2 × 2 feet they would not be any too large. The larger the holes the better for the plant. Good holing will give the plants an excellent start and the dribbling in of seeds in small alavangoe holes is not to be recommended. It is hardly necessary to point out that the planting operations should be carried out when rain is plentiful; the plants should be stumped and every care taken to avoid the destruction of the young roots. The stumps will stand one or two weeks' drought but if dry weather continues for a long period the soil around the plants should be shaded.

INTER AND CATCH CROPS.

Where the rubber plants are closer than 10 to 15 feet the cultivation of inter or catch crops is limited to about four to eight years. Cassava, Bananas, Cocoa, Coffee, Chillies, Ground-nuts, Lemon grass, Gingelly, and perhaps tobacco and cotton are amongst the most notable products for use under such conditions. If the intercrops are such that they can under ordinary circumstances be grown permanently—as cocoa and coffee—it is better to grow them only in widely-planted rubber and to arrange them among the rubber plants so that a fair root space is available to all the plants. Cocoa and coffee are among the best products to be grown as inter-crops in rubber. Coffee is known to grow well under shade and in parts of India it is being cultivated as an inter or catch crop in rubber clearings where the rubber plants are planted twenty-four feet apart and the coffee six feet apart.

If, however, real catch crops are grown to occupy the land from 6 to 12 months at a time, care should be taken not to plant them too near the rubber plants. A radial distance of one foot should be allowed for the growth of the roots of the rubber trees each year and catch crops should not be planted within the rubber root area

The catch crops can be planted one, two, three, and four feet from one, two, three, and four-year-old rubber trees respectively, and in all cases the foliage or ashes obtained as by-products of the catch crops can be buried around the trees or broadcasted over the areas which are partly occupied by the rubber roots.

GROUND-NUTS, LEMON GRASS AND CASSAVA.

Two profitable catch crops for export are *lemon grass* and *ground-nuts.* *Lemon grass* gives a return six months after planting and may be expected to yield abont 14,000 lb. of fresh grass containing about 20 lb. of pure oil, per acre, per year when grown in open free soil. The oil is valued at 8½ d. per ounce and is obtained by steaming the freshly cut grass. A distilling apparatus will be required and can be kept in constant use by the grass from 300 acres. The fresh lemon grass contains 0·65% of potash 0·09% of phosphoric acid, and 0·12% of nitrogen, but if the dried distilled grass is used as fuel and the ashes for manuring the rubber plants the exhaustion is considerably reduced. The plant is propagated from cuttings. It is being cultivated in parts of Ceylon and the Straits.

Ground-nuts yield as a single product a crop of 1,500 to 3,000 lb. of nuts per acre in various countries, the best yielding varieties in Ceylon being the "Mauritius" and "Barbadoes." The nuts are valued at from £8 to £14,—according to size, number of seeds per nut, and cleanliness. The seeds yield a valuable oil, equal to Olive oil in quality and the residue after extracting the oil is sold as a manure—Ground-nut cake—containing 7½% of nitrogen. The foliage can be used as a green manure or cattle food, and is known as pea-nut hay in America. The leaves and roots contain nearly 1% of nitrogen and when mixed with lime form a good plant food for the young rubber trees. (See Plate 6.) The plants are propagated from seeds. The crop ripens in 4 to 6 months, very little machinery is required and there is a good demand for the oil and cake.

There are several famous Para rubber plantations in the Straits which have practically paid for all working expenses by cultivating varieties of *Cassava* as catch crops for the first three or four years. On one plantation the rubber was planted 15 by 15 feet and the cassava six feet apart at the same time as the rubber. The crop was ready for harvesting in 18 months from planting. A second crop was taken off the land before the end of the fourth year after which the cassava cultivation ceased to be profitable. I have been informed that a crop of tapioca or cassava flour of 1½ to 2 tons per acre per crop is thus obtainable. The proceeds from these crops have on several estates more than paid for the upkeep of the rubber.

The profitable cultivation of catch crops is limited to about the first four years as the products grown cannot be planted close to the Para rubber trees and at the end of the fifth year would be almost limited to the middle of the lines.

FUTURE OF INTER CROPS.

The successful and continued cultivation of intercrops with Para rubber mainly depends on the distance the plants are from one another. The rapidly growing surface roots of Para rubber will ultimately take possession of the soil and the inter crops of tea, cocoa or coffee cannot be expected to thrive except the rubber plants are widely planted. I have seen several examples of 14-year-old tea planted with 6-year-old Para rubber, the latter 15 by 10 feet apart; the tea presented a very weak spindly appearance and could not be profitably plucked.

Cocoa and coffee planted in the middle of the lines of cocoa will last for several years under rubber. The roots of these plants do not as closely ramify the soil as those of the crowded tea plants though they will ultimately have to face the struggle for existence with the roots of Para rubber and will probably be choked out. Cocoa may be planted 10 to 20 feet apart and the amount of soil on good cocoa estates which is free from cocoa roots is often very large and permits of the growth of other trees on the same acreage. Cocoa under rubber will last much longer than tea and the protection of the Para rubber trees against excessive exposure is no doubt greatly in favour of the two products being grown together. In the cultivation of intercrops under Para rubber it is essential that both products be planted at the same time as the Para rubber tree is about as strong as the coconut palm in its root system and quickly takes possession of the soil.

CHAPTER IV.

PARA RUBBER SOILS AND MANURING.

The mechanical and chemical composition of rubber soils—Peradeniya—Henaratgoda—Udugama—Principles of rubber manuring—Manuring to increase the latex—Forest vegetation and soil improvements—Food materials in leaves of Para rubber trees—Artificial manures for rubber soils—How to apply readily soluble and stable manures—Forking, trenching and root growth—Illustration showing trench Manuring for young rubber—Constituents in woody stem, twigs, fresh and dried leaves—Composition of artificial manures obtainable locally—Green manuring for Para rubber trees—Limit 6 to 8 years—Suitable herbaceous plants and their composition—Tree forms, Dadaps and Albizzias—Organic matter obtainable.

PARA RUBBER SOILS AND MANURING.

It has been conclusively shown that Para rubber can be grown in soils which are relatively poor in physical and chemical properties and the following analyses of soils in different parts of Ceylon* will illustrate the composition of those which have given good results with Para rubber.

	Peradeniya soil.	Udugama. swamps	Rubber soils at Henaratgoda. 1 Soil under Old Rubber.	2 Soil from Pasture land
	Mechanical Composition. per cent.	per cent.	per cent.	per cent.
Fine soil passing 90 mesh.	27.00	59.00	20.00	26.00
Fine soil passing 60 mesh.	20.00	36.00	28.00	28.00
Medium soil passing 30 mesh.	9.00	1.00	14.00	21.00
Coarse sand and small stones	44.00	4.00	38.00	25.00
	100.00	100.00	100.00	100.00
Chemical Composition No. 81				
Moisture	4.000	5.600	1.200	1.600
Organic matter & combined water	9.200	20.400	7.800	7.000
Oxide of iron and manganese	8.400	1.200	2.800	2.000
Oxide of alumina ...	12.215	5.232	4.969	6.315
Lime	0.060	0.050	0.040	0.060
Magnesia	0,086	0.115	0.057	0.072
Potash	0.092	0.061	0.046	0.038
Phosphoric acid ...	0.038	0.064	0.031	0.031
Soda	0.095	0.182	0.046	0.080
Sulphuric acid	Trace	0.048	0.007	Trace
Chlorine	0.014	0.048	0.004	0.004
Sand and silicates ...	65.800	67.000	83.000	82.800
	100.000	100.000	100.000	100.000
Containing Nitrogen ...	0.134	0.448	0.154	0.134
Equal to Ammonia ...	0.163	0.544	0.187	0.163
Lower oxide of iron ...	Nil	Much	Trace	Fair
Acidity	Faint	Much	Much	Much
Citric soluble potash ...	0.006	0.009	0.005	0.004
Citric soluble phosphoric acid	Trace	Nil	Trace	Trace

* Circular of the R. B. G. Peradeniya, Vol. iii, No. 6, July 1905.

MANURING FOR INCREASING THE YIELD OF LATEX.

If latex is mainly an excretory or useless product it may appear doubtful as to whether manuring will have a beneficial effect on the rubber-producing capacity of the tree. This is an interesting point and is well worth considering.

The latex is obtained from cortical tissues and in these areas, there are, besides the milk tubes, series of cells which store up food and others directly associated with conducting the materials elaborated in the leaves from above downwards to various parts of the plant. These tissues are removed in the course of tapping operations and their renewal entirely depends upon the activity of the cambium. The cambium produces new wood internally and cortical tissues externally; generally the cambium produces these two series of tissue in a definite order and a large production of woody material is accompanied by a proportionate amount of cortical tissues. As the wood is marked off into annual zones it is therefore possible to compare the rate of growth of trees in different countries by examination of transverse sections of the trees and indirectly to form some idea of the development of the cortical tissues in which the milk tubes are contained.

The latex tubes form part of the cortical tissues and an increased leaf activity appreciably affects the elements in this region. From these and other considerations it may be safely concluded that if manuring is carried out in such ways that the growth of the leaves and woody material is appreciably increased, the cortical tissue will be proportionately increased in quantity and there will be a larger number of cells available for transformation into laticiferous tubes. Any manure which affects the growth of the leaves or the wood must have a corresponding effect on the cortical tissues. One of the objects in manuring Para rubber should be to increase the number of cortical cells as rapidly as possible; this increase is dependent upon the activity of the cambium though the subsequent condition of the newly-formed elements is closely associated with the abundance and activity of the leaves. It may appear absurd to advocate manuring with a view to increasing what is commonly regarded as mainly a waste product, but it cannot be gainsaid that abundance of cortical tissue provides more cells for perforation and disintegration, processes involved in the formation of the latex tubes of Para rubber.

The analyses of various parts of the Para rubber plant, given elsewhere, should be carefully considered when mixtures of artificial rubber manures are being compounded.

FOREST VEGETATION AND SOIL IMPROVEMENTS.

It must be remembered that Para rubber trees form a forest vegetation and that they will grow well in relatively inferior soils, providing there is a fair balance of plant food and the climatic conditions are favourable. The soil under forest vegetation improves in mechanical and chemical composition with age, owing to the protection which the trees afford to the soil, to the action of the roots and the accumulation of leaf-mould. The annual fall of leaf from Para rubber trees ultimately effects an improvement in the soil in which the trees are being grown. This is borne out by the analyses of the soils at Henaratgoda, the results proving that the organic matter, potash, and nitrogen are greater in the soil which has been under rubber for 29 years than that which has been under pasture; the lime and magnesia have decreased under the old rubber, while the phosphoric acid is the same under both conditions.

FOOD IN PARA RUBBER LEAVES.

The manurial value of the leaves from Para rubber trees cannot be doubted when it is remembered that the material, dried at 100° C., contains 1·72 % of potash, 3·44 % of nitrogen, 0·6 % of phosphoric acid, and 0·51 % of lime. If this material is regularly forked in either alone or with lime or artificial manures excellent results will be obtained. The artificial manure required will largely depend upon the physical and chemical properties of the soil, but the figures showing the composition of various parts of the Para rubber plant will indicate the ingredients required. Potash and nitrogen are very high in the fresh and fallen leaves and lime is abundant in the woody structures.

MANURING OLD AND YOUNG TREES.

The method to be adopted in manuring this product is determined by the age of the trees, and the kind of manure used.

Where very soluble manures such as sodium and potassium nitrate, ammonium sulphate, potassium chloride or sulphate and similar compounds are used they should be mixed with dry earth and broadcasted over the area where the young *rootlets are actively growing.* If such manures are applied to areas which do not possess rootlets, the greater part will probably be carried away during the first few rainy days. After application the land should be forked to a depth of four to six inches.

Where cattle manure, green manure, leaf mould or bulky artificial manure is used on rubber estates a slightly different method can be adopted. The object in such manuring is not only to supply at a very short notice ingredients required for the rapid growth of parts of the plant, but to lead to the development of a quicker-growing, larger and stronger root system. This result can be obtained if the organic manure is mixed with the soil around the trees at a definite distance according to the age of the tree. The rootlets of the Para rubber tree grow approxi-

PLATE 6.

MANURING YOUNG PARA RUBBER TREES. [*Photo by H. F. Mac[illegible]an.*

(A) TRENCH FILLED WITH LEAVES OF CROTALARIA, DADAPS AND GROUNDNUT .

mately at the rate of 10 to 12 inches per year, radially, in good free soil and the manure should be applied at a distance just within reach of the last formed rootlets. Around each tree a shallow trench should be dug, about 12 inches wide and gradually increasing in depth from the tree outwards to a maximum depth of six to ten inches. The manure should then be mixed with part of the soil, returned to the trench and subsequently covered with the balance of soil available. The distance of the trench from the tree should be approximately 2 feet for two-year-old trees, 3 feet for three-year-old trees, an allowance of ten inches to one foot per year being made in each subsequent year until the trees are 6 to 8 years old when the lateral roots have probably met. The accompanying illustration on Plate 6 shows the system applied to young plants. In this instance the leaves of crotalaria, dadaps and groundnuts were buried in the trenches after mixing with lime and soil. The Para rubber plants were only six months old and the trenches 6 to 9 inches from the stems. By such a system of manuring the rubber plants will be able to obtain a supply of food at a very early stage and the development of the rootlets from within outwards be considerably accelerated. Once the rootlets of adjacent trees have met the manure should be either buried in shallow trenches between the trees or broadcasted and the ground forked to a depth of 4 to 6 inches.

CONSTITUENTS IN WOODY STEMS AND TWIGS.

In order to furnish some idea of the constituents of various parts of the rubber tree the following synopsis is given of the constituents of the fresh material, as determined by Mr. A. Bruce:—

ANALYSIS OF PARA RUBBER TREE, DRIED AT 100° C.

	Fresh Leaves Per cent.	Decayed fallen Leaves Per cent.	Fallen Stalks Per cent.	Wood Per cent.	Twigs Per cent.
Water	70	60	60	60	50
Ash	4.69	4.08	3.18	3.12	2.62
Lime	0.51	1.40	0.80	0.80	0.83
Magnesia	0.56	0.89	0.30	0.15	0.17
Potash	1.72	0.54	0.64	0.30	0.28
Phosphoric acid	0.6)	0.30	0.15	0.18	0.09
Nitrogen	3.44	1.92	0.84	0.59	0.62

COMPOSITION OF ARTIFICIAL MANURES.

The following table shows the composition of common arti ficial manures obtainable from local firms and the compositions here quoted are those guaranteed by various firms in Colombo.

Manure.	Potash. per cent.	Phosphoric acid. per cent.	Nitrogen. per cent.
Blood meal ...	—	—	10 to 14
Groundnut cake ...	1 to 2	1 to 2	7½ to 9
Castor cake ...	1 to 2	1 to 2	6 to 7
Rape cake ...	1 to 2	2 to 3	5 to 6
Nitrate of soda ...	—	—	15 to 16
Sulphate of Ammonia	—	—	20½ to 21½
Chloride of potash ...	57 to 59	—	—
Sulphate of potash ...	49 to 52	—	—
Precipitated phosphate of Lime ...	—	35 to 40	—
Concentrated superphosphate ...	—	44 to 46	—
Basic slag ...	—	19¾ to 21	—
Fish ...	—	4 to 6	5½ to 6½
Bone dust ...	—	23 to 24	3½ to 4
Nitrate of potash ...	37 to 40	—	11 to 13
Kainite ...	13 to 15	—	—

GREEN MANURING FOR PARA RUBBER TREES.

It is a fortunate coincidence that the climatic conditions favourable to the cultivation of Para rubber in the young stage are identical with those required for plants of value as green manure. Estates planted with rubber alone must either elect to allow their soils to be exposed to the sun and rain and to be thereby impoverished, or decide to protect the soil by a green crop and increase the organic matter and mineral constituents for the future benefit of the growing rubber.

It is hardly necessary to point out the advantages of green manuring seeing that the system is adopted in European as well as tropical countries. One great advantage attending the use of the plants mentioned below lies in the fact that they are able, in virtue of the bacteria associated with the nodules on the root, to absorb nitrogen direct from the air, a capacity not possessed by most of the plants under cultivation.

The points to be considered are during what stage in the life of a rubber plantation can green manures be cultivated and which plants are best suited for the purpose. It is unnecessary to explain that after a good rubber estate is six to eight years old green manuring must practically cease. But during the first few years it is possible to keep a green cover over those parts of the land not affected by the rubber plants.

HERBACEOUS PLANTS.

Herbaceous plants can be best grown from the first to the fourth year on account of the abundance of light which they are able to obtain and the relative freedom of the soil particles. The plants which can be used are Crotalaria striata, D. C., C. laburnifolia, L., Cincana. L., Cajanus indicus, Spreng, and species of Indigofera and Cassia. These plants are shrubby in habit, grow to a height of one to five feet and will stand pruning at intervals of four to six months. Trailing or creeping plants such as the groundnut and species of Vigna can be successfully grown and also the sensitive plant. All these plants give a good cover to the soil and help to keep the weeds in check and produce large quantities of organic matter rich in plant food. Space forbids a full account of this subject but the following facts are of interest as showing the weight of green material obtainable and the composition of several species:—

Name of plant.	Weight of organic matter per acre.	Time between sowing and uprooting.
Crotalaria striata. ...	20244 lb. ...	Ten months.
Vigna. ...	12092 lb. ...	Four months.
Pondicherry groundnut.	4692 lb. ...	Five months.

COMPOSITION OF VARIOUS GREEN PLANTS, IN THE FRESH STATE.

Name of p ant.	Nitrogen. Per cent.	Potash. Per cent.	Phosphoric acid. Per cent.	Lime. Per cent.
Crotalaria striata..	0·7 to 1·0	0·47	0·154	0·210
Vigna ...	0·6	0·738	0·177	0·727
Pondicherry groundnuts ...	0·914	0·493	0·155	0·242

It is interesting to work out what the equivalent of 15,000 lb. of green manure of Crotalaria striata is, from a purely *theoretical* standpoint.

According to the above analyses it is approximately equal to a manure of the following composition.

Castor cake ...	...	...	500 lb.
Blood meal ...	...	...	500 „
Nitrate of soda.	...	...	140 „
Basic slag ...	...	...	115 „
Potassium sulphate	...	...	140 „

If the whole of the material is to be used it should be buried with lime or basic slag around the trees as previously explained. During its decomposition it liberates large quantities of plant food which would otherwise remain in a latent stage for many years.

For the successful cultivation of the herbaceous green manures about 10 to 20 lb. of seed, per acre, should be broadcasted on clean land in wet weather and the land lightly forked. In Fiji as much as 50 lb. of Vigna seed is used, per acre.

TREE FORMS.

The best tree forms to use for green manure are Dadaps (Erythrina species) and Albizzia moluccana. Dadaps can be propagated from cuttings; in some districts they will give a very large amount of organic matter within a few months from planting the cuttings. Plants can also be used though the organic matter obtainable from them within a couple of years is less than that from cuttings in a few months. If cuttings are used they can be planted between every two rubber plants. The best results are obtained if the cuttings are about two inches in diameter and four feet long with one foot below ground and planted in very wet weather. Dadaps can be used on hillsides where the cultivation of herbaceous green manures is practically impossible. They should be lopped or hand-pruned as frequently as possible and the material buried in the same manner as for other species. The following table shows the weight of fresh leaves obtainable from one acre of Dadap cuttings planted 4 × 8 feet apart in July, 1904.

DADAP LEAVES.

Month when hand-pruned.		Weight of fresh leaves.
November	1904	791 lb.
December	,,	967½ ,,
March	1905	1935 ,,
April	,,	1444¼ ,,
May	,,	2255 ,,
June	,,	2240 ,,
July	,,	2180 ,,
August	,,	3058 ,,
September	,,	1569¾ ,,

These experiments show that Dadap cuttings may produce over 11,000 lb. of fresh green leaves within one year from planting and the leaves may be hand-pruned every month. The fresh leaves contain 0·3 to 0·8% of nitrogen, 0·148% of potash, 0·08% of phosphoric acid and 0·197% of lime.

Albizzia moluccana is one of the quickest-growing trees known but it is not easily propagated from cuttings. The woody tissues preponderate and the weight of leaf obtainable within one or two years is less than with Dadaps. The leaves are however a valuable plant food and if the trees are regularly lopped will give a fair amount of material fit to be buried. A one-acre plot, planted in July 1904, 20 feet apart gave within one year 1,100 lb. of green material and woody twigs so that if planted as close as the Dadaps (8′ × 4′) they should yield about 13,000 lb. per acre, per year. The fresh leaves contain 0·395% of nitrogen, 0 406% of potash, 0·178% of phosporic acid, and 0·441% of lime.

CHAPTER V.

HOW TO TAP PARA RUBBER TREES.

Importance of tapping operations—Effect of bad tapping illustrated—Tapping knives—Requisites of a good tapping knife—Clean cuts and scraping—Protection of the cambium—Paring from right to left and left to right—Minimum excision of cortex and bark—Patent tapping knives—Native implement - Carpenter's chisel—Surgical scrapers and planes—Beta knife—Golledge's knife, construction and illustration—Holloway's knife—Collet's knife—Brown & Co's knives, construction and illustrations—Eastern Produce and Estates Co's knife—Bowman's and Northway's three knives, construction, method of use and illustrations—Dixon's knife, construction and illustration—Methods of tapping Para rubber trees—Methods of native collectors—Modern methods—Single oblique cuts, illustrated—V incisions, illustration showing ten weeks' work—Limited area—Herring-bone system—Photographs of trees in Ceylon tapped on the herring-bone system—The zig-zag method and its use—Spiral curves—F. Crosbie Roles on the spiral method, yields and estimates—Illustration of the trees at the beginning, and after three months' spiral tapping—Results of the spiral system in parts of Ceylon—Methods of marking the trees for tapping - Collecting tins.

THE question of how to tap Para rubber trees is one which deserves special consideration and is not outweighed in importance by even the process of curing or methods of planting this product. On the methods of tapping depend not *only the quality and quantity of the latex and rubber but the life and future condition of the trees.*

Recent experiments have shown how improvement can be made on the old method of tapping every alternate year and obtaining 1½ lb. per tree, per year from eleven-year-old trees. It has been stated that the yields which are possible in the near future may, if present prices are maintained, be such as to allow one to consider the contingency of replanting every twelfth year. The yield which has been obtained in some parts of Ceylon, shows that by somewhat drastic methods it is possible to obtain from particular trees in one year's tapping, as much as the most sanguine only a few years ago anticipated in ten years' tapping, though it must be borne in mind that the effect on the trees cannot, with our present knowledge, be accurately forecasted and may or may not prove to be detrimental.

EFFECT OF BAD TAPPING.

It is more than likely that the tapping implements and methods of the future will be such as to ensure that the minimum, if any, damage is done to the cambium. But there are still several implements sold and used which should be classed as dangerous and in order to impress all planters with the ultimate effect of bad tapping, a couple of photographs are here reproduced.

In the accompanying illustration—Plate 7—the upper figure shows a part of a large tree with the bark and part of the wood removed. The large approximately V-shaped hollow in the exposed section is due to the decay of the wood, which occurred internally to a depth of several inches, and was caused originally by making a large V wound that scraped below the cambium into the timber all along the incision. The other figure on Plate 7 shows a section of the wood with part of the bark and outer tissues removed. The wood was, with the original tapping, considerably damaged and several years after the injury was made the parts above it were found to be very hard and to give very little latex; the wood was permanently damaged. In this particular case the outward appearance was not striking in any way and only the poor yield of latex led to the enquiry which revealed the extent of the permanent injury that had been made. The black V-shaped lines in the exposed wood show the direction and extent of the old V cuts which penetrated to the cambium. In all such cases the decomposition of a vital part of the tree has been set up and the vigour and longevity of the tree appreciably affected. I have seen several other malformations produced by damaging the wood while tapping; often the areas become very "warty" and present a series of very large balls of hard woody tissue which cannot be tapped and which seem to rest in sockets of the timber; in other cases large scars exist where the chisel has cut below the cambium. The injury in all cases is permanent and can be detected many years after it has been made. Such knobs and scars are not due to "canker" and the establishment of a smooth surface on such trees without cutting into the wood is practically an impossibility.

TAPPING KNIVES.

The various methods of tapping now in vogue are more or less associated with the use of a particular knife or series of knives and it is therefore necessary to first consider the knives which are now commonly used, and the general requirements of such implements.

REQUISITES OF A GOOD TAPPING KNIFE.

There are several points which should be borne in mind by those who desire to effect improvements in tapping knives or to invent new ones.

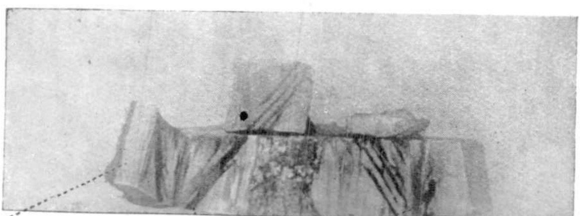
The first requisite is that the cutting surfaces shall be such as to enable the operator to either make an even clean cut or to excise the cortical tissues without dragging the cells or clogging the knife. Several friends have shown me instruments which are best

PLATE 7.

Photo by M. Kelway Bamber.

EFFECT OF BAD TAPPING ON THE WOOD.

SHOWING DECAY OF INTERNAL WOOD WHERE INJURED BY TAPPING.



A

B

Photo by M. Kelway Bamber.

EFFECT OF BAD TAPPING ON THE WOOD

(A) OUTER WOOD REMOVED; (B) DARK V LINES INDICATE THE DECOMPOSITION OF THE WOOD.

described as surgical scrapers, planes and closed knives; in each case the idea was to *scrape* away a thin film of the cortical tissue, but in every instance the operation dragged the cortical cells considerably, clogged up the latex tubes, and left an uneven surface along which watery latex would not flow. A clean cut is essential and for this reason it is doubtful whether the principle of scraping will ever be generally adopted.

A second point of very great importance is that the knife should if possible be provided with some structure which will prevent the cooly from cutting too deep when making the initial excision and also protect the cambium during subsequent paring operations. In several cases separate knives are used for making the original incision and subsequent paring operations; those used in the latter processes are frequently made so that they can be adjusted beforehand or they are protected by a fixed or detachable blade. A glance at illustrations on Plates *9*, *10*, and *11*, will show the appliances referred to. The effect of bad tapping is shown elsewhere. It is a great advantage if the cutting parts can be adjusted with ease and replaced without great expense.

A third consideration which should not be lost sight of is that the knife should be one which can be used in cutting from left to right and right to left from above downwards. Illustrations *8*, *9*, *10*, and *11*, show knives which can be so used and also from below upwards if desired. This is a necessary qualification in all tapping methods except the righthand halfherring-bone and spiral systems.

A fourth point which has obviously received attention in the knives recently put on the market is that the instrument used for reopening or paring the lower surface of the wound should be so constructed that only the minimum quantity of material is cut away at each operation. The longevity of the tapping area depends upon this operation and at the present time there are knives which will demolish 12 inches of bark in three months and others which will not use up the same quantity of tissue in one to two years. The very narrow cutting margin of knife No. 2, shown on Plate *10*, is specially devised for paring away very thin shavings of the bark.

The introduction of the pricking instrument for cutting the laticiferous tubes in the wound area though duplicating the tools is very useful; generally the duplication of the tools required to make the first and subsequent incisions is undesirable and in several instruments the power of adjustment is such as to allow all the operations to be carried out by means of one knife only. (See Plates *10* and *11*.)

PATENT TAPPING KNIVES.

The native collectors of rubber in the uncultivated forests of Brazil use an axe-like implement with which a heavy blow can be inflicted and all the tissues from the bark to the cambium be cut in one stroke. At the present time Ceylon is taking a very active interest in inventing and improving tapping knives for use in obtaining latex from Para rubber trees and the following accounts of those implements which are fairly well-known will be of value.

THE CARPENTER'S CHISEL.

This was used in the early tapping days but has been superseded by more useful tools. Parkin carried out experiments to see "whether incisions made with a stone or cold chisel gave more latex than corresponding ones made with an ordinary chisel, but did not find any appreciable difference in the amount of latex collected from the two kinds of incision on the single oblique pattern." He finally recommended a wedge-shaped chisel with a thickness of $\frac{3}{16}$ to $\frac{1}{4}$ inch, at a distance of $\frac{1}{2}$ inch from the cutting edge; the breadth of the chisel varied from 1 to $1\frac{1}{2}$ inches.

With the idea of reopening the wound area without cutting away a large quantity of tissue, several surgical scrapers and planes have been brought forward but in every case have proved unsatisfactory. They tend to clog the freshly-opened latex tubes.

THE "BETA KNIFE."

The Beta knife placed on the market by Messrs. T. Christy & Co., is according to Johnson a useful instrument; the length of the blade is regulated by means of a screw to suit the varying thicknesses of the bark of different trees and so prevent its damaging the wood of the tree.

GOLLEDGE'S KNIFE.

In the accompanying illustration—Plate 8—it will be seen that this knife consists of a flat piece of steel provided at the end with a short sharp bevelled V and a cutting groove along the sides. The knife can be used for making cuts from above downwards, below upwards, and from left to right or right to left. It can be used to make the original incision and during subsequent paring operations. The illustration on Plate 14 showing the herring-bone system of tapping, indicates the good work which has been done by means of this knife.

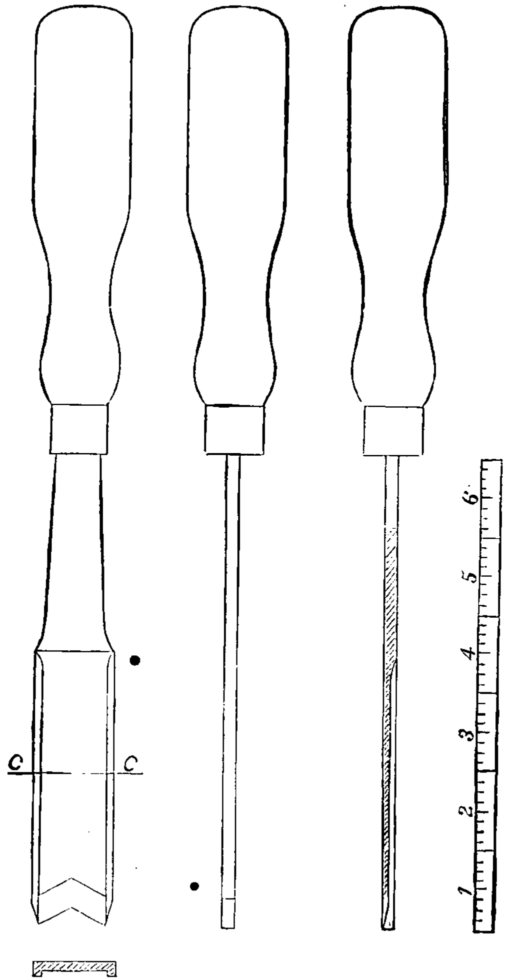
HOLLOWAY'S KNIFE.

The Holloway tapping knife is an improved V cutting knife provided with movable blades; the V head is fastened to the handle by two small screws and nuts and the blade when worn down is easily replaced.

COLLET'S KNIFE.

M. Collet recently exhibited a new tapping knife which I am informed has been patented in Belgium. It is made entirely of metal: running down the handle and coming out at the base, is a bluntly-pointed piece which is inserted in the bark of the tree to be tapped and by this means the depth of the bark is measured.

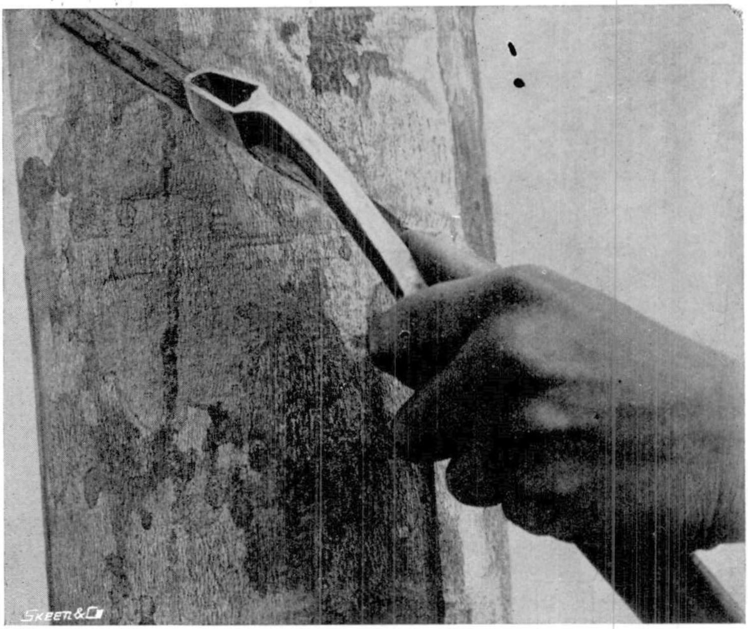
PLATE 8.



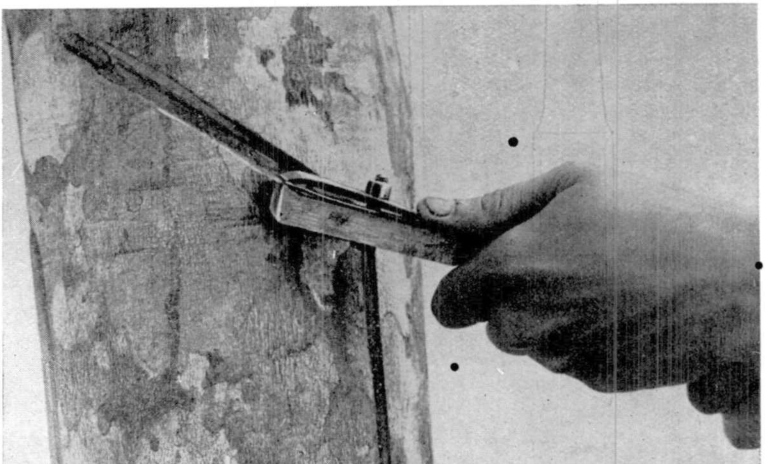
SECTION CC

GOLLEDGE'S KNIFE

PLATE 9.



THE "SAFETY" TAPPING KNIFE.



Lent by Brown & Co.

THE PARA CHISEL.

The blade of the knife, which is like a sharp, curved gouge, has on it a brass support which is set at an angle with the blade and—before cutting—is adjusted at an angle, so that when the knife is in use and the brass support resting against the bark, the cut can only go as deep as it is set for, which is the depth of the bark measured at first; by this means the laticiferous cells are reached, but the cambium is not cut.

THE PARA "RUBBER" TAPPING KNIFE AND CHISEL.

The two instruments indicated are obtainable from Messrs Brown & Co., Colombo. The "tapping knife" is designed for making the first incisions in rubber trees, when the paring process is intended to be carried out in the subsequent tapping rounds. It is constructed to make incisions on the left and right of the perpendicular and after these cuttings to leave flat surfaces on the lower sides of the incisions; it provides ample head room for the "*Para Chisel*" to work in during the early rounds of paring. The "*Para Chisel*" is a tool for reopening the original incision in such a manner as to renew the flow of latex with the minimum loss of bark and tissue. It is first adjusted to cut to the required depth, then placed in the incision and pressed gently forward in a direction parallel to that of the incision. The cutting blade can be easily renewed. The illustration on Plate *9* shows the construction of the important parts.

AN IMPLEMENT FOR TAPPING RUBBER TREES.

The Eastern Produce and Estates Company are responsible for a knife which has been used on many estates in Ceylon. The patentee claims that it is a simple knife and one which can be economically used over large acreages of rubber. It consists of a wooden handle of suitable size and shape, furnished at one end with a stabbing or piercing point for the purpose of making an initial incision in the bark of the tree. The cutting device is mounted at the other end of the handle and consists of a haft or stem with a hollow wedge or triangular shaped cutting portion at the apex.

BOWMAN'S AND NORTHWAY'S KNIVES.

These knives have been continually used in our experiments at Peradeniya and Henaratgoda and in response to suggestions the originals have been slightly modified in order to be of use in any of the numerous systems of tapping and to still further economise in the removal of the cortical tissues. There are three knives in all; No. 1 for making the original groove, No. 2 for re-opening the lower surface of the wound, and No 3 for cutting the latex tubes in the area of the wound response without removal of any cortical tissue. These knives are shown in the accompanying illustrations on Plate 10.

Knife No. 1 is provided with a two-edged guide which on pressing against the bark cuts the tissues and defines the area to be cut away by the knife edge behind it: by this means the original groove shows clean cut surfaces above and below. It is used much like a plane, the head being suitably adjusted to shave the bark gradually, and as soon as the proper depth is reached the bark is of a white colour, getting lighter and lighter the nearer one gets to the *cambium*, so that by practice it is possible to tell almost correctly when the right depth has been cut.

Young trees are more difficult to cut to the correct depth than old ones, as the white tissues next to the *cambium* mentioned above is very thin indeed; it is therefore advisable to mark lightly with No. 1 and reach the correct depth gradually with a few tappings with No. 2 in the manner described below for cutting deeper.

Knife No. 2 in its improved form is very ingenious. The cutting part consists of three surfaces, a narrow basal one along which a spring blade is inserted and two side surfaces which are at right angles to the basal one. When the flexible spring blade is inserted there are two small cutting edges available, one to use when cutting from right to left and one for use from left to right. By this means only a very thin layer of cortical and bark tissue is removed during each paring operation, the removed substance being so small that it takes quite 30 parings to remove one inch of tissue. This is a most important point as the trees are made to last considerably over one year instead of only 3 to 6 months. This knife is used only for paring off the lower edge of the grooves originally made, and when cutting should be held so as not to make the cuts deeper than the previous ones; this is effected by holding the knife at the proper angle. Leaning the knife over to the right makes the cut deeper, while leaning over to the left makes it less deep. The knife is constructed to prevent the cooly cutting deep enough to touch the *cambium.*

No. 3 consists of a spur-like arrangement which is provided with a number of sharp cutting teeth. It is used to cut the latex tubes near the cambium or to tap the milk vessels which have become unduly distended with latex. It can be used alternately with No. 2 knife, though in the Peradeniya experiments, the spur knife is used at least twice as often as knife No. 2. It is by the use of these knives that the yield of 12 lb. of rubber was obtained in 6 months from an eleven-year-old tree in the south of Ceylon, and 4 lb. in two months from each of four trees, at Peradeniya. The knives have elicited the admiration of all rubber planters who have adopted the paring method.

DIXON'S KNIFE.

This consists of a grooved open knife blade which can be adjusted to cut the bark to any depth or at any angle. The cutting part can be easily removed from the handle of the knife and is therefore capable of being replaced when worn out. The base is provided with a pricker for determining bark thicknesses. It can be used for making the original groove or for paring the

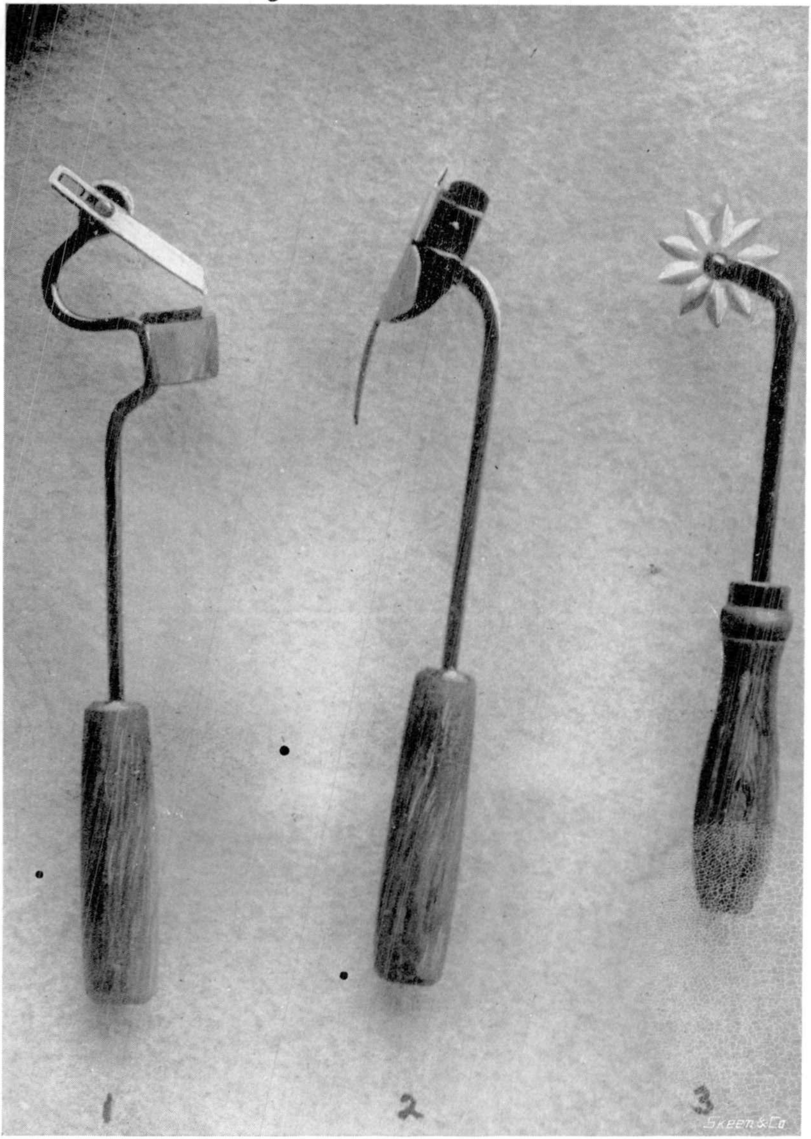
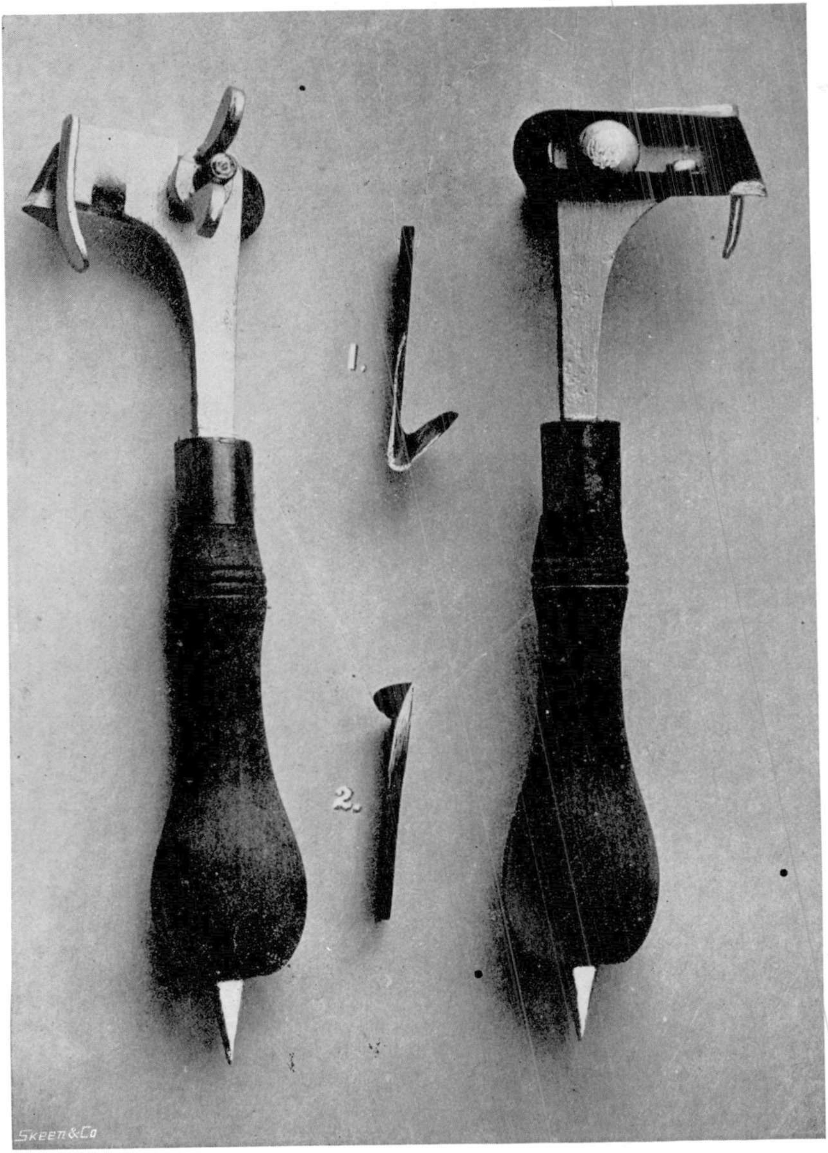


Photo by D. L. Goonewardane.

BOWMAN'S AND NORTHWAY'S KNIVES.

PLATE II.



DIXON'S TAPPING KNIFE.

lower surfaces in any direction, the excision being made by drawing the knife towards the operator. By favour of Mr. Dixon the accompanying illustration on Plate 11 is here reproduced.

METHODS OF TAPPING.

The best method of tapping is that which extracts the maximum amount of latex from the tree with removal of the minimum quantity of cortical tissue and without damaging the thin layer of cambium cells. The cambium is responsible for the renewal of the cortical tissue in which the latex tubes arise *de novo* by a process of perforation and decomposition at a later stage. If the cambium is damaged the repairing of the cortical tissue is long delayed and in very many cases the areas so damaged can never be tapped to the same advantage as previously.

METHOD OF NATIVE COLLECTORS.

The felling of the wild trees and ringing the bark and cortex in order to collect the milk is now rarely practised by native collectors. The latex is usually collected from the trees while standing and in the Amazon districts an upward incision is made in the bark by means of a small axe and a cup is then placed beneath each cut.

In the Gold Coast a system rather similar to the full herring-bone is often used, a series of small transverse channels opening into a perpendicular one at the base of which the latex is collected.

MODERN METHODS OF TAPPING.

At the present time the various methods of tapping Para rubber may be roughly described as either (a) single oblique lines; (b) V-shaped incisions; (c) single cuts with a vertical channel joining them; when the cuts are on one side of the vertical line the system is often termed the half herring-bone and when on both sides the full herring-bone system; (d) spiral curves. There are various modifications, but they are not of sufficient importance to warrant a separate description.

SINGLE OBLIQUE CUTS.

It should be explained at this point that the laticiferous tubes from which latex is obtainable in large quantities are mainly disposed internally—very near the cambium—and for the most part run through the cortex in a vertical direction.

It should also be remembered that the latex even when most dilute is apt to rapidly coagulate on the tree and to form scrap rubber. A cut made horizontally will not conduct the latex to a central point and horizontal tapping is invariably accompanied by a large proportion of scrap owing to the latex trickling down the stem and drying there. A vertical channel is naturally the best for conducting the latex to a desired point, but it is as extravagant as it is unnecessary in most cases. Parkin proved that simple incisions made in an oblique direction gav about double the yield of latex as either the vertical or horizontal, the latter two showing very little difference in yield of rubber. Each oblique cut may be from one to six or more inches in length, but a distance of nearly one foot apart should be allowed. The oblique incision is practically the basis of most other methods now in use.

V INCISIONS.

The V incision is nothing more or less than a duplicated or double oblique system. The sides of each V may be from 2 to 12 inches in length with the apex of the V at the lowest point. The yield obtainable from such incisions is generally, but not always, about double that obtained from a single oblique cut and having one centre for two incisions seems to be one of its greatest advantages. The V's are usually made on the stem from the base up to a height of six feet, and are distanced about six inches apart. The open end of the V is usually about six inches wide. It has been suggested that the reason why the quantity of latex obtainable is not double that from a single oblique line is because the lines are very close to one another and may draw on the same system of laticiferous tubes, a conclusion which is warranted by the results of many experiments in various parts of Ceylon. In addition to this drawback there is also another serious result which often accompanies this method of tapping, viz., the loosening of the bark on drying and tapping from the apex of the V upwards.

It cannot be doubted that in having a series of small oblique or V cuts a considerable amount of labour is involved in fixing and adjusting a very large number of collecting tins at the base of each incision and though this system cannot be regarded as drastic and harmful to the tree it is likely to be superseded by others when planters have to find labour sufficient to regularly tap large acreages of mature rubber. In the oblique or V incisions a chisel or paring knife is commonly used.

In the V method it has been noticed that when the sides of four adjacent V cuts are drawing on an area of 60 to 80 square inches the flow of milk after two months' tapping becomes very poor. The photograph here reproduced on Plate *12* shows the V cuts after tapping for ten weeks every alternate day. There was at the time the photograph was taken still plenty of space between the adjacent incisions, but the flow of milk was too small to warrant further tapping. This method obviously cannot be carried out for the same length of time as the spiral curves because the oblique cuts sooner or later interfere with one another and draw on the same limited area. Four trees tapped similar to that indicated on Plate *12* by the use of a paring knife and the spur gave 10 lb. 14¾ ozs. of dry rubber from the 29th June to the 6th September, 1905.

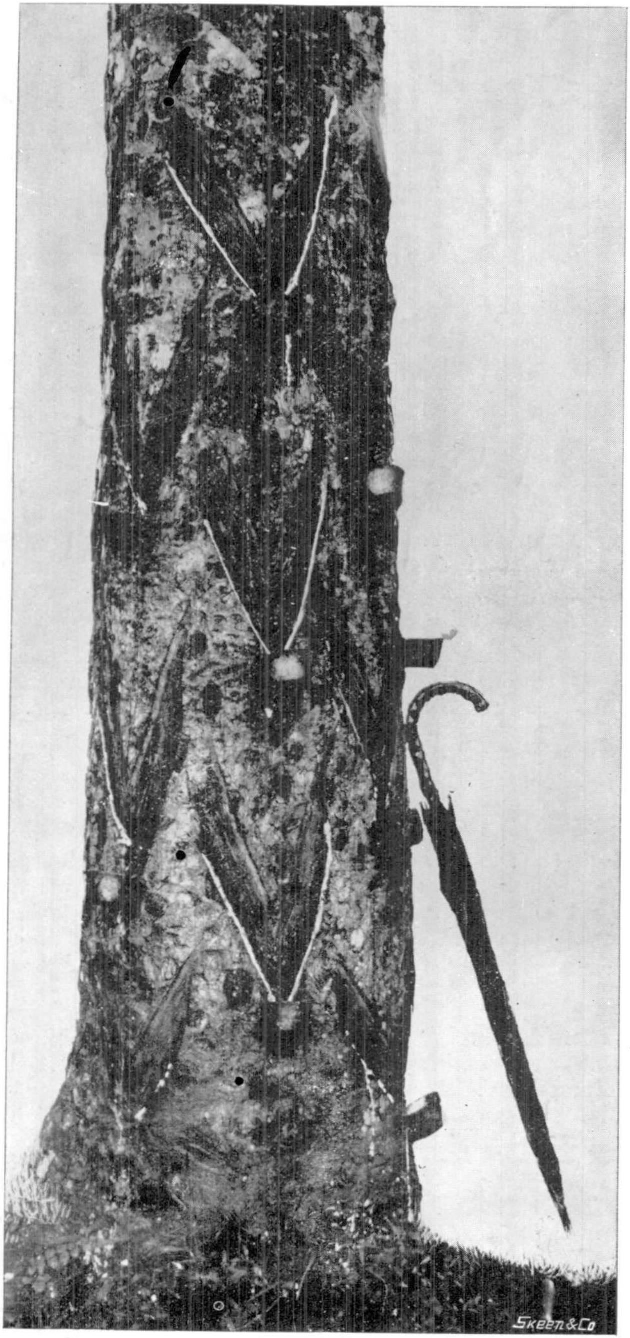


Photo by H. F. Macmillan.

V. TAPPING.

A TREE AFTER IT HAS GIVEN 2 LB. OF DRY RUBBER.

PLATE 13.

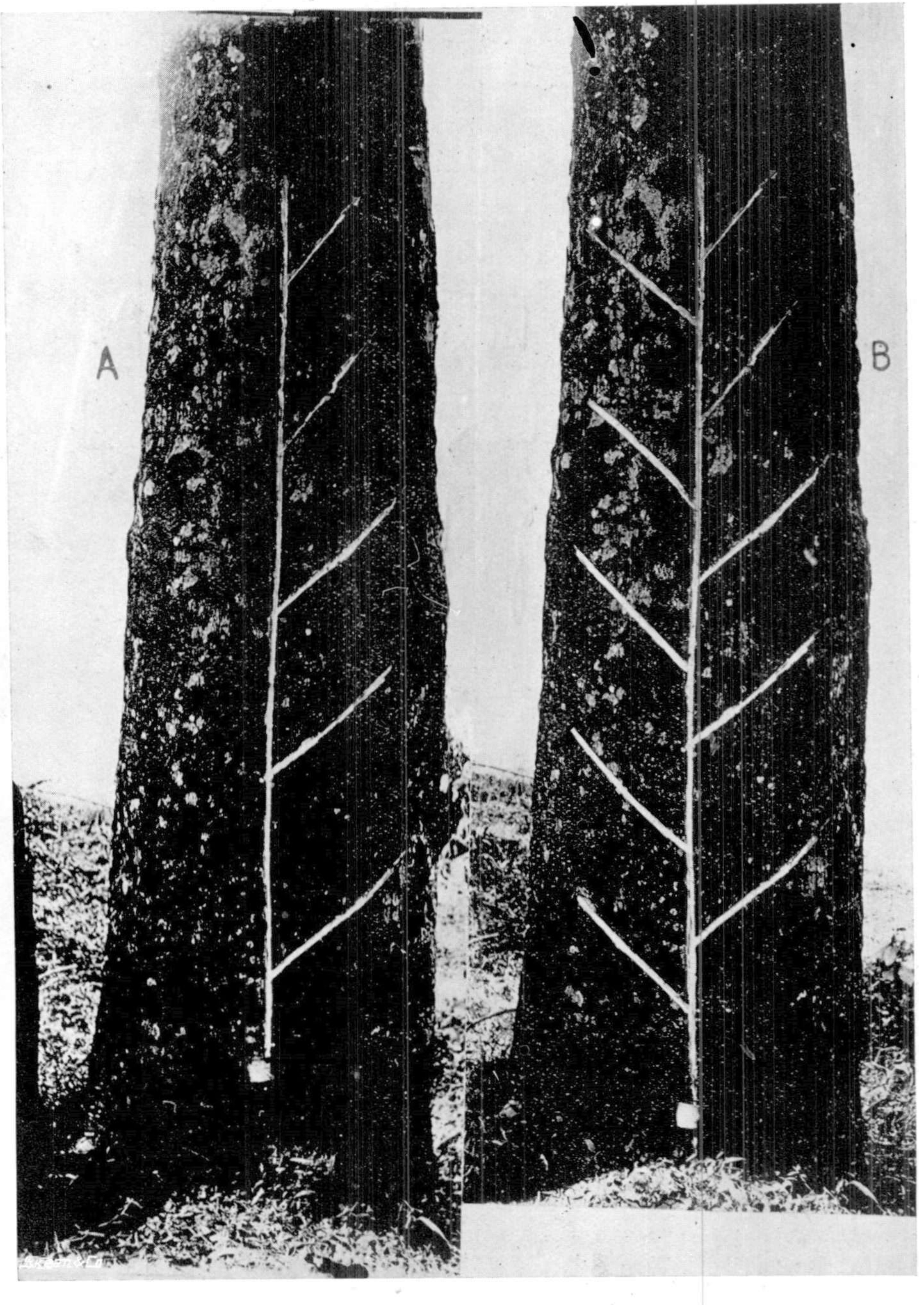


Photo by H. F. Macmillan.

THE HERRING-BONE SYSTEM.

(A) HALF HERRING-BONE; (B) FULL HERRING-BONE.

HERRING-BONE SYSTEM.

This consists of a series of short parallel oblique incisions connected with a vertical one; the incisions may be on one or both sides of the vertical channel, and vary in length from about 4 to 12 inches. The illustrations on Plate 13 show both systems at the beginning. The vertical channel usually varies from 1 to 4 feet in length and is usually sufficiently wide to conduct the latex from a dozen oblique cuts; the tin placed at the base is the only receptacle for the latex. The advantage of this system lies in the minimum labour required for collecting operations, but there are many reasonable objections against the waste of tissue which occurs when a vertical channel of considerable depth and width is made. Though it is considered to be more drastic than the foregoing method, this system is in use on several estates in Ceylon and has at times been adopted by planters and officials in the Malay Peninsula.

After the original oblique incisions have been made they are reopened by paring away the lower surface, this operation being continued until the whole of the tissue between the lines is used up. Any of the knives described may be used for these operations.

The illustrations on Plates *13*, *14*, and *19*, show trees which have been tapped on this system in parts of Ceylon and Malacca.

According to Ridley the tree has, for tapping purposes on the herring-bone system, four sides and may be tapped along one side only during each year so that operations will be recommenced on the tapping area of 1900 in 1905. This is a very gentle method and has much in its favour.

The zig-zag system of tapping consists of a downward line joining two oblique cuts, on opposite sides but at different levels, and so arranged that the latex is collected at the base of the lower oblique incision. This system is about the only one that can be recommended for trees which on account of previous bad tapping have become gnarled and woody on the surface; the downward and oblique lines can be made of any length and at any angle and the knots thereby avoided.

It has been pointed out * that vertical incisions, lay open very few latex tubes, and must in some degree, have the effect of relieving the tension and may therefore cause a reduction in the flow of latex.

NORTHWAY'S AND BOWMAN'S SPIRAL CURVES.

A third method which has, on account of the good yields obtained, gained considerable favour recently in Ceylon and elsewhere is the long spiral curve. The system consists of a series of parallel cuts running round the stem and each ending separately at the base of the tree; or shorter cuts ending at convenient places. The number of spiral cuts is determined by the circumference of the tree, there being usually one curve for every girth of 12 to 18 inches at the top of the tapping area. In this method

* M. Henri Lecomte, Journal d'Agriculture Tropicale, April, 1902.

of tapping a series of special knives has been used which ensure the minimum waste of tissue when reopening the lower side of the wound. As this system has given an average of 2 lb. per tree for each month's tapping at Peradeniya and has been continued in some districts until a total of 16 lb. per tree in twelve months has been obtained, a detailed description is here given. The illustrations on Plates *15* and *18* show the stages from the beginning to the end of the first cortical stripping.

I am indebted to Mr, F. Crosbie Roles, Editor of the "Times of Ceylon," Colombo, for the following description of the method as carried out on a now well-known rubber property in the south of the island.

THE METHOD OF CUTTING.

"The first cuts are made each a foot above the other, and in the case of a tree 18 inches in circumference the groove would go nearly round the stem. For trees 30 inches in circumference two lines of cups on opposite sides of the tree would be required, and a tree 54 inches in girth would take 3 lines of cups. The first cut is made with a knife used much like a plane; and the second knife is used thereafter day by day for paring off the edge of the groove originally made. One month's tapping with the original knives makes the groove two inches wide. So that the whole bark area may be cut away in the course of the year's work, assuming that the tapping is carried on throughout the year in alternate months. A third instrument has also been invented for use in this process. It is in the form of a circular pricking instrument which is used to penetrate to the *cambium* at the edge of the previous cut. This is done alternately with the cutting, and is believed to free the inner bark from any accumulation of latex, which might otherwise occur. The cutting face of No. 2 knife, too, has been reduced to the 16th of an inch. The improvements reduce the bark area cut away in a month from two inches to one inch.

THE YIELD FROM SUCH A METHOD.

"This method of tapping was systematically begun in October 1904, and the group of trees has since averaged over 2 lb. of rubber per tree for each month's tapping, and those trees which have been tapped hardest have produced 16 lb. each in twelve months. Although these trees, like the rest, were tapped in alternate months at first, with rests in November and January, they were continously tapped from February, right through the drought, up to early in June. Then it was found that the yield was falling off, and they were rested for some time. Tapping was recommenced in September. None of them show signs of drooping and as further token that new and handsome figures in Ceylon yields are not confined to a few trees, records were produced which showed that the whole of the 255 trees on the estate of tappable age had yielded an average of 4 lb. per tree in the eight months, without

Photo by C. H. Kerr. Lent by G. H. Colledge.

THE FULL HERRING-BONE SYSTEM.

PLATE 15.

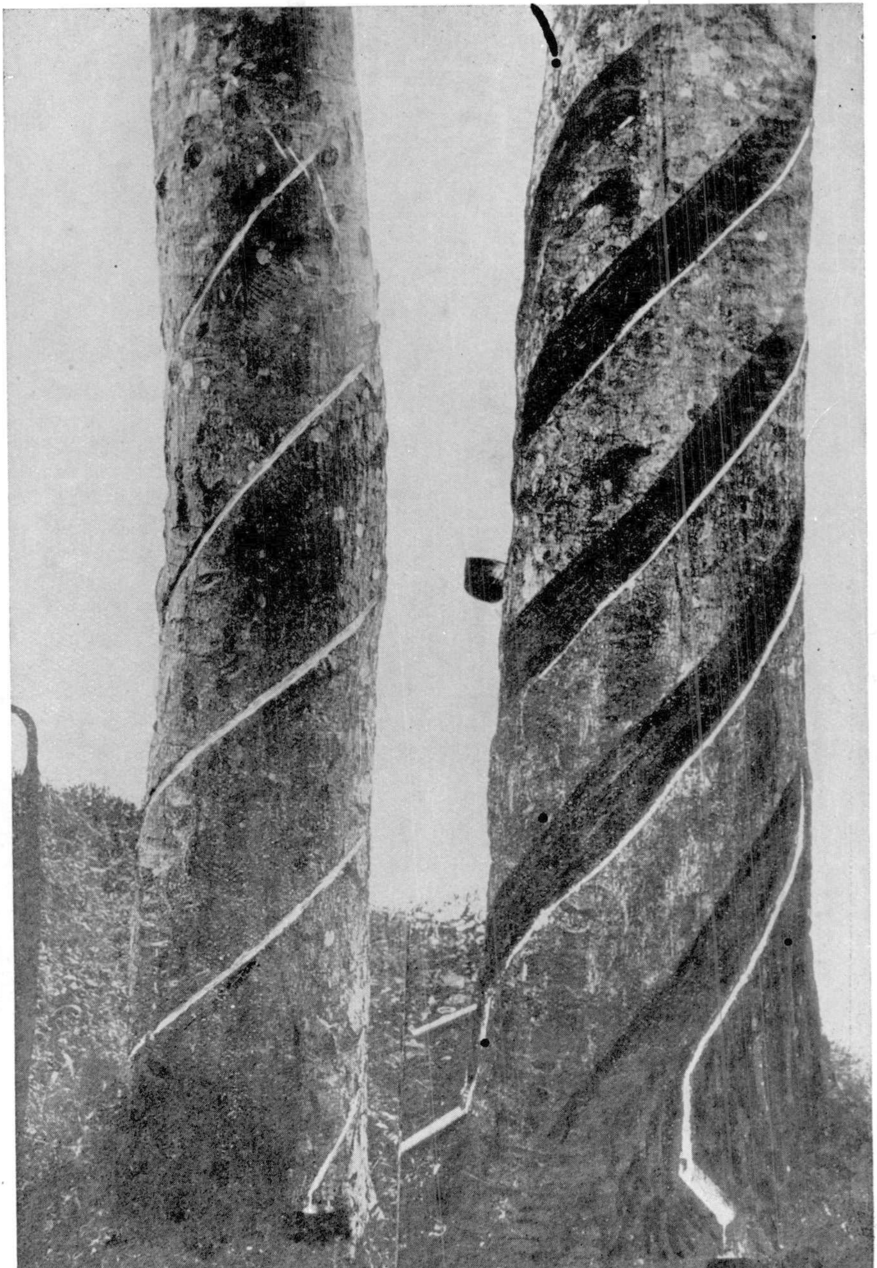


Photo by H. F. McMillan.

THE FULL SPIRAL SYSTEM.

A.—THE FIRST INCISION. B.—AFTER THE TREE HAS GIVEN 2 LB. DRY RUBBER.

the trees being harassed. A platform is to be erected round some of the trees for tapping higher up; and an average yield of 3 lb. per tree is expected at from 6 feet to 10 feet from the ground.

A REVOLUTION IN ESTIMATES.

"The increased quantity of rubber obtained by this method promises to revolutionise estimates of yield; and a visitor from another district, on returning home, promptly sent in double the amount as his estimate of yield for the current year. But it is believed by the experienced planter who has evolved the method that in the following year more latex will be obtained from the reformed bark than from untouched bark. That Nature rapidly makes good the loss was evidenced by the fact that where the bark had been cut away several months before, it had grown again nearly as high as the edge of the cut."

The illustrations on Plates 15 and 18 show at a glance the method adopted; and the results obtained, both by the inventor and at Peradeniya will arrest considerable attention among all cultivators of Para rubber.

PERADENIYA RESULTS.

The yields obtained by this method from four Peradeniya trees now 29 years old, are of interest; they show that by means of knife number 2 and the spur, an average of over 4 lb. of dry rubber per tree has been obtained in ten weeks' tapping. The half or full spiral system allows one to systematically tap the tree from above downwards for one or more years and to repeat the same operation when convenient. Any system of tapping which allows the cooly to go over the whole of the bark tissues on a regular plan is to be preferred to the old V or single short cuts.

NORTHWAY'S AND BOWMAN'S SYSTEM OF MARKING THE TREES.

The system consists first in marking out the grooves at the correct distance and angle they are to be cut during tapping. This is effected by means of a guide in the shape of a right angled triangular piece of tin, the side subtending, the right angle being 2ft. in length and the other sides 17″ by 17″. The hypotenuse is the line along which the trees are marked, one of the 17″ sides being arranged vertically before marking is commenced.

The grooves to be cut along the sloping side or hypotenuse of the triangle will then be at an angle of 45 degrees to the base, each groove 2ft. long and at intervals of one foot, starting one foot from the base of the tree, up to a height of 5ft., and all leading into a vertical channel running down to within a few inches from the ground level. A small tin spout is inserted at the lower end of the vertical channel to convey the latex into the tin vessels which are placed on the ground near the tree. The tin spout is left in position permanently thus obviating the necessity of constantly inserting cups into the bark and removing them, thereby causing unnecessary injury to the tree. In the case of a tree 18″ in circumference, the grooves would go nearly once round, and therefore for trees of this size, there would be one vertical channel to convey the latex flowing from the several spiral cuts into the tin receptacle, and only one of the latter will be needed. A tree 36″ in circumference would require 2 vertical channels on opposite sides of the tree, and correspondingly, a tree 54″ in circumference would take 3 vertical channels, each leading into a tin receptacle placed on the ground as previously stated. To suit trees of various sizes and yielding capacities, the grooves can be made longer or shorter as may be found necessary or convenient. One month's tapping with certain knives would carry the grooves down about one inch so that tapping on and off, one month at a time, the whole space between the top and bottom grooves would be covered in the course of two years' work. The operation is carried on continuously so that at the end of each period of two years, only the original top cut would have to be retapped, the lower cuts being made into the sections below, when the bark-tissues have been completely renewed.

Mr. Francis Holloway has also given me particulars of his method of marking the trees. A long rod, marked off into feet is placed against each tree. A sheet of zinc or tin cut at a certain angle—about 45°—fits at one end into the rod and can be moved up and down as desired. The remaining part of the zinc or tin ribbon is then wound round the tree and the markings made. The rod being marked into distances of one foot can be used at any height on the trunk, the spaces between the oblique tapping markings being in every case parallel and distanced one foot from each other. This plan can be adopted for marking out spiral curves or oblique incisions and is therefore applicable to the herring-bone system.

COLLECTING TINS.

Tin or iron receptacles for collecting the latex are not so good as enamelled ones or those made of aluminium as they are apt to corrode on exposure and to lead to a discolouration of the rubber when the latex contains large quantities of tannin. In all methods except the herring-bone and spiral systems it is necessary to fix the tins on the trees and therefore to have some sharp point to press against the bark for fixing. Where the herring-bone or spiral systems are in vogue a permanent channel is fixed at the base of each line and the tins placed on the ground immediately under the channel; this arrangement is found to be economical.

CHAPTER VI.

WHERE TO TAP.

Occurrence of latex in parts of the plant—Rubber from young parts of trees—Tapping virgin and wound areas—Wound response and increased yields at Peradeniya—Interval between successive tappings and wound response—Arden's results—Clotting of rubber in convex wound areas—Method of formation of Para milk tubes—Best yielding areas—Results of experiments from the base upwards in the Straits and Ceylon.

IT is well-known that in the Para rubber tree the latex occurs in all parts of the stem and branches and in the leaves. But the quality and quantity of the latex in the leaves, young twigs and branches are such as to render the collection from such areas unremunerative. The more or less successful production of gutta-percha from leaves led many to anticipate that rubber might be obtainable from the foliage and young twigs of Hevea brasiliensis. "The latex in young stems* and leaves does not freely ooze out and mix with water, but clots where it exudes in little lumps, which cling to the broken pieces of stem." The rubber from these tissues is adhesive and has less elasticity and strength than the rubber from the trunks of mature trees. It may be safely asserted that the collection of latex from this species must be made from the stem and in some cases perhaps the main branches, and that all other parts may be neglected as sources of paying quantities of marketable rubber. In practice it is easier to tap the stem from six feet downwards than any other part though the erection of stands for tapping higher parts of the stem and thick branches has been tried. Estates are known where rubber in paying quantities has been obtained from six to twenty feet, but tapping above six feet is not generally adopted. The fact that a maximum of 10 to over 20 lb. of rubber per tree has been obtained from the lower part of the stem alone within twelve months from commencing tapping operations makes it very doubtful whether tapping of less accessible parts will come into

* Parkin, l.c.

general force. The strain on the plant to heal the wound area from six feet downwards is quite as much as the tissues need stand. Further more it must be remembered that the maximum quantity of latex and rubber is obtained not so much by tapping virgin areas as by taking advantage of the wound response and pricking or cutting the laticiferous tubes when they contain the maximum amount of latex.

THE WOUND RESPONSE.

It has been stated that native collectors of Para rubber do not attempt to collect the latex from the first incisions and that a quantity capable of being collected is only obtained after two or more tappings in approximately the same area. The flow to the injured part increases gradually and may reach the maximum after 3 to 14 tappings after which it is said to decline if the wound area is continuously tapped. The first reliable results were obtained by Willis and Parkin and as the "wound response" is now recognised as one of the most important principles in determining the frequency of tapping the following digest of Parkin's results is given:—

Number of tapping	Number of incisions.	Date of Tapping.	Yield of latex in c.c.
1st tapping	40	March 25th	61.0 c.c.
2nd ,,	40	,, 30th	105.5 ,,
3rd ,,	40	April 6th	220.0 ,,
4th ,,	40	,, 12th	208.5 ,,
5th ,,	40	,, 15th	255.5 ,,
6th ,,	40	,, 20th	290.0 ,,
7th ,,	40	,, 25th	276.0 ,,
8th ,,	40	May 1st	253.0 ,,
9th ,,	40	,, 6th	264.5 ,,
10th ,,	40	,, 13th	275.0 ,,
11th ,,	40	,, 20th	255.0 ,,
12th ,,	40	,, 26th	262.0 ,,
13th ,,	40	June 1st	328.0 ,,
14th ,,	40	,, 6th	449.0 ,,

The increase in yield from 61 to 449 c.c. of latex by repetitional tapping in approximately the same area is little less than wonderful and it now remains to determine the interval which must be allowed between successive tappings. The wound response is not evident twelve hours after tapping but within twenty-four to forty-eight hours is decidedly obvious. These results suggest the advisability of every planter carrying out his own experiments to determine whether it is better to tap every day for the half of each month, alternate days during each month, or only during certain months. Tapping every day, either for the whole of the months when rain is abundant or only during alternate months has already given excellent results on a large scale on several estates in Ceylon.

The nature of the origin of the latex tubes in Hevea brasiliensis accounts for the variation in yields from the same area; the tubes require a certain time to complete their formation and on this account areas which do not yield any latex on particular days may give abundant flows subsequently, when the processes of perforation and decomposition are sufficiently advanced.

WOUND RESPONSE IN 24 HOURS.

Arden concluded from the following experiments that the length of time which should elapse before reopening incisions need only be 24 hours and that tapping every alternate day instead of daily was not always advisable.

60 incisions made on 6 consecutive days gave	99½	oz. wet rubber.
60 „ at intervals of two days	111	„ „ „
60 „ „ „ „ one week.	104¾	„ „ „

In the Peradeniya experiments where the spiral system has been adopted it has been noticed that the renewed cortical tissue becomes more or less convex in outline as indicated in Plates 14, 15 & 18. In some instances clots of rubber were found beneath the bulging areas and from microscopic examination it was concluded that the convex outline was due to some extent to the abnormal rapid distension of the cells of the newly-formed tissue; the coagulated rubber seemed to arise by the bursting of the inflated tubes. This was "wound response" to a remarkable degree and on all such areas the use of Bowman's and Northway's pricking instrument gave abundant flows of latex.

There is a certain amount of reason in tapping any yielding area of the stem and branches on account of the peculiar manner in which the latex tubes are produced and their connection with one another. The tubes in Para rubber are produced by the breaking down of the partition walls of adjacent cells or sacs and the final tube may be very short or long according to the age and the number of partition walls which have been dissolved The tubes practically arise *de novo* and in tapping operations one does not necessarily drain the latex from all parts of the tree, but very often only from one or two inches around the incision, where latex tubes have been formed.

BEST YIELDING AREAS.

Experiments to prove which is the best area to tap have been carried out by many observers. The larger flow at the base of the trunk than from higher parts has been noticed by Parkin and others in Ceylon, by Seaton in India, by Arden in the Straits as well as by native collectors in the Amazon valley. It is on account of this that the idea of increasing the lower tapping area by lopping the young plants and retaining a few of the basal shoots to grow into leaders in after years, is recommended, for instead of one stem there might be two or three available for tapping. If only one stem is retained it will show a large increase in circumference.

RESULTS OF EXPERIMENTS.

The following experiments * indicate that the lower part up to 90 cm. (1 cm. equals 0·39 inch) yields considerably more rubber than the higher parts.

Number of incisions.		Area tapped.		Yield of latex in grammes.
120	...	0 to 60 cm.	...	2226·44
100	...	60 to 120 cm.	...	1111·09
120	...	120 to 180 cm.	...	587·43

These results show that the maximum yield is to be obtained from the base up to a height of about 5 feet. Other experiments have proved that the yield from the base to 3 feet is considerably more than that from 3 to 6 feet.

Experiments carried out in Ceylon † strongly support the same conclusion and the following are typical examples of the results obtained.

	Number of incisions.		Area tappped		Yield of latex in c.c.
A.	26	...	12 inches from base	...	24·5
	26	...	36 " " "	...	18·0
	26	...	72 " " "	...	18·5
B.	14	...	At base of trunk	...	30
	14	...	At 48 inches from base	...	14
	14	..	" 108 " " "	...	11·5

The conclusions which Parkin drew from his experiments were "that there is a greater exudation of latex from wounds made at the base of the trunks of Hevea trees than at any higher region; that the exudations from one to five or six feet up the trunk differ little; and that above five or six feet the latex exuded falls off very considerably." Experiments in the Straits have shown that the first four feet from the base contain the maximum amount of latex but a height of six feet is allowed by many planters. It is well-known to planters in Ceylon that the quantity of latex obtained at five to six feet from the ground is little more than half that at the base of the trunk; nevertheless a yield of over 1 to 3 lb. of rubber, per tree, is expected on certain estates by tapping the area from six to ten feet above ground. The latex obtained from areas twenty feet from the base is often very sticky and may not yield good rubber. On some estates in the Ambalangoda, Kalutara, and Matale districts, however, the old rubber trees are said to give latex of good quality from six feet upwards.

* L'hevea Asiatique, M. Collet.
† Parkin, l. c. p. 128-131.

CHAPTER VII.

WHEN TO TAP.

Age or size as criterion—Resin in young trees of Castilloa—Rubber from 2, 4, 6, 8, 10—12, and 30-year-old Para rubber trees—Two-year-old tree illustrated—Age of tapping trees in the Straits—Age of tapping trees in Malacca—Age of tapping trees in Ceylon—Minimum size for tapping—Rubber yield from 41 small trees in Ceylon—Age and size considered—How to increase the tapping area—illustrated—Measurements of forked and straight stemmed trees at Henaratgoda—The best season for tapping—Atmospheric conditions and the flow of latex—Latex flow during the leafless phase—Use of ammonia and formalin—What part of the day to tap—Frequency of tapping.

WHEN TO TAP PARA RUBBER.

IN discussing this part of the subject, it is necessary to determine the age and size of the tree when it may be tapped for the first time.

Several botanists have argued the question and as it is one which concerns the quality of the latex and the dimensions of the tapping area it needs to be considered carefully.

IMPORTANCE OF AGE.

Ule and Seeligmann state that in the Amazon district the tree requires 15 years to come to tapping maturity in open plantations and 25 years in the forest and one cannot help concluding from this statement that either the cultivated plants in the East thrive much better in their land of adoption or that the collectors are less eager to commence tapping operations in the Amazon district than in Ceylon and the Straits.

Cross stated that in Para the trees were tapped if they had a circumference above 18 or 24 inches, the operations being carried out until the trees were killed. On plantations such dimensions may be attained in 4 to 6 years.

Trimen in 1884, believed that the trees in Ceylon should be 10 years old before commencing tapping operations.

Johnson is of the opinion that the size and not the age of the tree indicates when it can be safely tapped and that tapping may be commenced when a tree has a girth of 20 to 24 inches, a yard from the ground.

ANALYSES OF YOUNG CASTILLOA RUBBER.

If one considers the many analyses of Castilloa rubber quoted by Weber and the publications of the West Indian Botanic and Agricultural Departments he cannot help being struck with the fact that the rubber from Castilloa trees depends in almost every case for its quality on the age of the trees. In some cases the rubber from the old trees is shown to contain 82·6 % of caoutchouc and 7·4 % of resin. The rubber from four-year-old Castilloa trees has been shown to contain 64·1 % of resin as against 8·2 % for twelve-year-old trees.

The importance of age is further exemplified by analyses showing a gradual decrease in percentage of resinous substances which occurs with an increase in the age of the part of the castilloa tree from which the rubber is obtained, the young twigs yielding 5.8 %, the large branches 3·77 % and the main trunk only 2·61 % of resinous bodies. If the rubber contains a very high percentage of resins it is obviously inferior and is in some cases almost useless. Increase in age is certainly to be associated with an improvement in the physical properties and aquality of the rubber, whether we consider plantations of different ages or parts of the same tree.

ANALYSES OF PARA RUBBER FROM DIFFERENT AGED TREES.

	2 yrs. old.	4 yrs. old.	6 yrs. old.
Moisture.	0.70 %	0.65 %	0.55 %
Ash.	0.50 ,,	0.30 ,,	0.40 ,,
Resin by Acetone Extraction.	3.60 ,,	2.72 ,,	2.75 ,,
Proteids.	4.00 ,,	1.75 ,,	1.51 ,,
Rubber.	91.20 ,,	94.58 ,,	94.79 ,,
	100.00	100.00	100.00
Resins extracted by Glacial acetic acid.	2.74 %	2.62 %	2.65 %

	8 yrs. old.	10-12 yrs. old.	30 yrs. old.
Moisture	0.85 %	0.20 %	0.50 %
Ash	0.14 ,,	0.22 ,,	0.25 ,,
Resin	2.66 ,,	2.26 ,,	2.32 ,,
Proteids	1.75 ,,	2.97 ,,	3.69 ,,
Caoutchouc	94.60 ,,	94.35 ,,	93.24 ,,
	100.00	100.00	100.00
Nitrogen	0.28 %	0.48 %	0.59 %

The above analyses made by Mr. Kelway Bamber show the chemical composition of Ceylon-grown rubber prepared from trees varying in age from 2 to 30 years. It will be noticed that the two-year-old rubber does not differ conspicuously from the older mature rubber. The analyses represent the composition of only one series of samples and should not be taken as showing the constant composition of rubber from trees of the ages quoted. The rubber from two-year-old trees was sticky and snapped when slightly stretched; it was obviously unfit for sale. The illustration

PLATE 16.

Photo by M. Kelway Bamber.

EXPERIMENTS IN TAPPING YOUNG TREES.

SPIRAL CURVE ON A TWO-YEAR-OLD TREE.

on Plate 16 shows the tree from which the rubber was obtained and it is perfectly clear that the available tapping area on such trees is very small.

Parkin proved that the preparation of good rubber from young stems and leaves of Hevea brasiliensis was an impossibility and other observers have shown that rubber from young trees is adhesive and lacks the required elasticity and strength; nevertheless it is still the subject of much discussion as to whether age is the only criterion for cultivators of Para rubber in the East.

Stanley Arden has shown that in parts of the Straits the rubber from trees 3½ to 4 years old is decidedly inferior. His results have been quoted in the section dealing with "Yields of rubber" and it is only necessary to point out that the yield from trees up to four years old was exceedingly small and that rubber in paying quantities was only obtained when the trees were about or over seven years old. He calculated that by the time the trees in the Straits are 6 years old, 75 % should give an average yield of 12 ounces.

On certain Malacca rubber properties, the Para rubber trees, even though catch crops have been taken off the ground during the first few years, attain in four years a circumference of 18 inches and in 7 years 35 to 40 inches. These trees are planted 15 feet apart and can be tapped after the fourth year.

AGE AND SIZE.

With regard to our experience in Ceylon it should be pointed out that under favourable circumstances, the Para rubber tree will show an increase in circumference of about 4 to 5 inches per year up to the first six or eight years and that though the rubber from two to six-year-old trees is adhesive and may have a high percentage of resinous compounds, it is by no means always the case. The analyses of Para rubber from 2, 4, and 6-year-old trees have been previously given and though the results cannot be accepted as conclusive it was pointed out by Mr. Kelway Bamber* that the rubber did not possess a very high percentage of resin and in this respect was certainly quite contrary to what Weber and others have observed in the rubber from young Castilloa trees. But when one considers that the rate of growth of the Para rubber tree in Ceylon is such that a circumference of 20 inches cannot be attained much before the fourth, fifth, or sixth year, it is obvious that all ideas of extracting rubber from trees under these ages should not be encouraged.

MINIMUM SIZE FOR TAPPING.

If the tree has a circumference of much less than 20 inches tapping cannot be recommended because the available tapping area is too small. The production of new tissue would be a strain on the young plant and the bark tissues would probably be quickly cut away long before the desired quantity of rubber had been obtained.

* Committee of Agricultural Experiments, Peradeniya, September, 1905.

The illustration on Plate 16 clearly indicates this. If the circumference is anything above 20 to 24 inches, a yard from the ground, and the tree is four to six or more years old it can, in Ceylon, be lightly tapped. I have seen good rubber from such trees. A tree 24 inches in circumference cannot have more than two spiral curves for tapping.

On one estate in Ceylon, 41 trees of considerable height, but having a circumference of from 13 to 25 inches a yard from the ground, gave with very light tapping during March and April, 19½ lb. of dry rubber which was favourably reported upon in Europe.

Samples of Para rubber from four-year-old trees have however been depreciated in certain quarters and in one case they were classed as being similar to common African* sorts for hardness, but superior in cleanliness. They were described as being soft and would not stand much working on the machine, and the value put upon them was only equal to that for "Congo ball or a similar quality of African."

From the foregoing remarks it is clear that the question of the available tapping area at a given age must be considered; it is as important as the age of the trees. A minimum circumference of 20 inches a yard from the ground and a minimum age of 4 to 6 years can be accepted for most rubber properties, the better developed trees being tapped first.

HOW TO INCREASE THE TAPPING AREA.

The foregoing statements refer to trees of known ages that have attained the minimum circumference when allowed to develop very long and slender stems. But it has been previously remarked that by pollarding the trees at a certain stage the plant may be made to increase in girth at the expense of the longitudinal growth, and a very striking illustration is to be seen in the first clump of Para rubber trees in the Henaratgoda Garden.

In the particular group referred to the majority of the trees have long straight stems, unbranched to a height of 30 to 60 feet. But in addition to these there are a few which, from some cause or other, have forked at from 7 to 11 feet from the ground and in all these cases the trunks are conspicuously larger in circumference and therefore present an increased tapping area. The following are the dimensions of some of the low-branched and straight stemmed trees:—

Circumference of trunk, in inches, a yard from the ground.

Trees with long straight stems.	Tree forked at 11 feet from base.	Tree forked at 7 feet from base.	Tree forked at 9 feet from base.
inches.	inches.	inches.	inches.
61, 65, 83, 85, 76	109	104	109

* India Rubber Journal.

PLATE 17.

Photo by Ivor Etherington.

A FORKED TREE AT HENARATGODA.

In all instances those trees which have been forked near the ground have a much larger circumference and an illustration of one which has forked at about 11 feet from the ground is shown on Plate 17. This tree has a girth of nearly 110 inches a yard from the ground; the surrounding trees, though of the same age have an average circumference of about 75 inches.

It does not need any argument to prove that an increase in circumference of over 30 inches is an advantage and the fact that such an increase has occurred in the tapping areas of trees about 30 years old, is sufficiently encouraging to tempt the planter to carry out a few pollarding or bud-pruning experiments once his trees have attained a height of about ten to twenty feet. The buds which appear in undesirable places can be removed by "thumb-nail" pruning.

THE BEST SEASON TO TAP.

The Para rubber trees in Ceylon drop their leaves in February or March, produce new leaves and flowers after a leafless phase of a few days or a couple of weeks and yield ripe fruits in August and September. There is an active vegetative period from September to February, a resting period in February and a floral and foliar condition from February to September.

Several writers have associated the yield of latex with atmospheric conditions, the general contention being that a low temperature in the tropics and plenty of moisture were conducive to a copious and more or less continuous exudation of latex. During hot dry weather the amount of water lost by transpiration from the leaves is very great and it has been argued that this loss reduces the tension in the cortex and therefore in the latex tubes; hence the poor flow obtained during such times.

If this is correct the yield of latex from the tree should be most abundant when the trees are leafless as they cannot then lose much water by transpiration and it is of interest to note that the experiments made by Arden in 1902 seem to give support to this view. Arden states that the yield from trees tapped when leafless was much greater than that from trees tapped when the leaves were beginning to appear or when in full foliage. In Nicaragua the latex from rubber trees contains the highest percentage of caoutchouc during the dry season. The possession of abundance of latex during the dry period lends support to the theory of its function as a water store during drought.

In many parts of the tropics however the leafless period occurs when the dryness and temperature of the air are at the maximum and the collecting of latex would be limited to the very early part of the day and the evening. The results quoted elsewhere tend to show that the best flow of latex is obtained in Ceylon, when the air and soil are abundantly supplied with moisture and when the temperature is comparatively low. A period of drought lasting only seven or twelve days appreciably affects the flow of latex, but though under such conditions the quantity is reduced the quality is usually improved. The latex rapidly dries on the tree in hot dry weather; this can however, be overcome by the use of ammonia, formalin, etc. in the cups at the top of each incision. In the Amazon valley the native collectors never tap the trees when in flower as they believe the amount of rubber then obtainable is much less than at other times, an idea supported by experiments at the Botanic Gardens, Singapore.*

It is very unlikely that the collection of latex will be limited to the dry period when the trees pass through their foliar phase, and in practice, tapping every alternate month is much more likely to be adopted.

WHAT PART OF THE DAY TO TAP.

The best flow of latex with the minimum quantity of scrap rubber is obtained in the early morning or evening on sunny days, but tapping may be done further on into the day when the temperature is low and clouds and moisture are abundant. In a district like Peradeniya the tapping may be continued up to 8 to 9 a.m., and recommenced at 4 p.m. All-night tapping is of course only possible when the artificial lighting of estates is more perfect than at present.

In the early and latter parts of the day the temperature is lower, the air usually more moist and there is less transpiration of water from the leaves; the combined effect of these factors is a better flow of latex during such times. According to Ridley* the girth of the tree decreases during the day and increases towards evening, an observation which may throw some light on the theories regarding tension of the laticiferous tissue and transpiration.

FREQUENCY OF TAPPING.

The frequency of tapping varies considerably, but it is by no means clearly proved that the tree will not stand tapping every alternate day throughout the greater part of the year. The fact that an interval of one day is sufficient for the wound response to become obvious is of interest and importance.

It is perhaps not advisable to judge the effect of very frequent tapping from the results obtained in the Amazon districts as there the trees are usually very old and have perhaps never been tapped before. Nevertheless it is of interest to learn that in those districts the Para rubber tree is often tapped for 180 days continually without apparently doing very serious damage to the trees.

In Ceylon, tapping every day throughout alternate months, or every day when rain is abundant or on alternate days throughout the year has given good yields.

* Annual report of the Director, Botanic Gardens, Singapore.

CHAPTER VIII.

YIELDS OF PARA RUBBER.

Natural variations—Yields in Ceylon—Henaratgoda trees and Amazon Yields—Yields on estates in Ceylon—Matale, Kalutara and Ambalangoda districts—¾ to 5¼ lb.. averages over large acreages——Exceptional yields at Culloden, Elpitiya, Kepitigalla and Peradeniya—Illustration showing the Elpitiya tree after 14 lb. rubber extracted—Yields at Peradeniya by the V and spiral methods—Rubber yields in the Straits—Illustration showing tapping of a rubber tree in Malacca—Para yields in the Gold Coast—Yields of Para and African rubber compared—Difficulty in forming average estimates.

NATURAL VARIATIONS.

WHEN dealing with the question of yields of dry rubber for a known acreage or number of trees it is necessary to indicate the method of tapping adopted, the age of the trees and the quality of the resultant rubber. The age and size of a tree greatly influence the quantity and quality of the rubber and it is to be regretted that the yields over large acreages for several years in succession are not at hand. Nevertheless we do possess information of the yield of particular trees during certain years and of large acreages of known age for a limited period and from these a fairly reliable statement of probable yields can be arrived at. It should be clearly understood that the yield from trees of the same age may be doubled, trebled, or quadrupled within a year by a change in the method of tapping and that those methods usually give the largest yields which tap the latex tubes over the largest area.

It should also be remembered that individual trees either from internal or external causes show considerable variation in the quantity and quality of latex they give, though of the same age and tapped in a similar manner. Results of tapping operations are available from different countries and it will be best to commence with those obtained in Ceylon.

RUBBER YIELDS IN CEYLON.

The yield varies from 7 lb. per 400 trees in one tapping, to a maximum of 25 lb. per tree in twelve months' tapping.

The first series of reliable yields * are those obtained at Henaratgoda from 1888 to 1896. One tree at Henaratgoda was lightly tapped every second year and gave in nine years an average annual yield of 1½ lb. of dry rubber.

27¾	oz.	in	1888	51	oz.	in	1894
42	„	in	1890	48¼	„	in	1896
45	„	in	1892	—			

* Dr. Trimen, Notes of rubber experiments.

This tree was twelve years old when first tapped and the annual yield of $1\frac{1}{2}$ lb. was from the 12th to the 20th year of the tree's life. The method of tapping consisted of scraping off the rough outer bark and making numerous V-shaped incisions to a height of about five feet. The tree had a circumference of $50\frac{1}{2}$ inches and was growing with other trees of nearly equal size, distanced 30 feet apart.

Other experiments have been made at Henaratgoda, which indicated similar results by consecutive weekly tappings of the trees.

Seeligmann* states that in the Amazon valley, as much as 30 c.c. of milk are obtainable from single oblique incisions, the latex flowing from one to three hours. Parkin was of the opinion that the Amazon yields were far in excess of those obtainable in Ceylon and gave a modest average of 2 to 3 c.c. which might be worked up to 10 to 12 c.c. of latex as a yield to be expected from single oblique cuts in Ceylon.

YIELDS ON ESTATES IN CEYLON.

To form an estimate of the yield to be obtained from large acreages of Para rubber trees of known age is no easy task and the best way to deal with this part of the subject is to give only the results which have been obtained on Rubber estates in this island.

MATALE DISTRICT.

In the Matale district there are estates where an average yield of $\frac{3}{4}$ of a lb. of dry rubber, per tree, from 5,000 trees has been obtained in one month's tapping. The average circumference of these trees was 35 inches, a yard from the ground.

Another estate in the same district has obtained an average yield of $3\frac{1}{2}$ lb. of dry rubber, per tree, from 311 trees in one year. The age of these trees varied from 10 to 15 years and the trees varied in circumference from 30 to 70 inches at a yard from the ground. These trees were tapped on the full herring-bone system; the tapping area covered half the tree and extended from the base to a height of seven feet. The tapping was done very carefully, the distance of seven feet being worked through in 240 days of continuous tapping. The yield from these particular trees will probably be increased by a change in the method of tapping and tapping instruments, during the current year.

On a third Matale estate the Para rubber is interplanted among cacao; the cacao is planted 12 by 12 feet and the rubber through alternate lines of cacao 24 by 12 feet. By the V method of tapping, a yield of 3 lb. of dry rubber from each of 10,000 trees is expected during the present year, the trees being 8 to 15 years old. On this estate, several encouraging experiments in tapping from 6 feet upwards to a height of 15 feet have been made, light ladders being used for the purpose.

* Seeligmann, Caoutchouc et la Gutta Percha, p 48.

PLATE 17A.

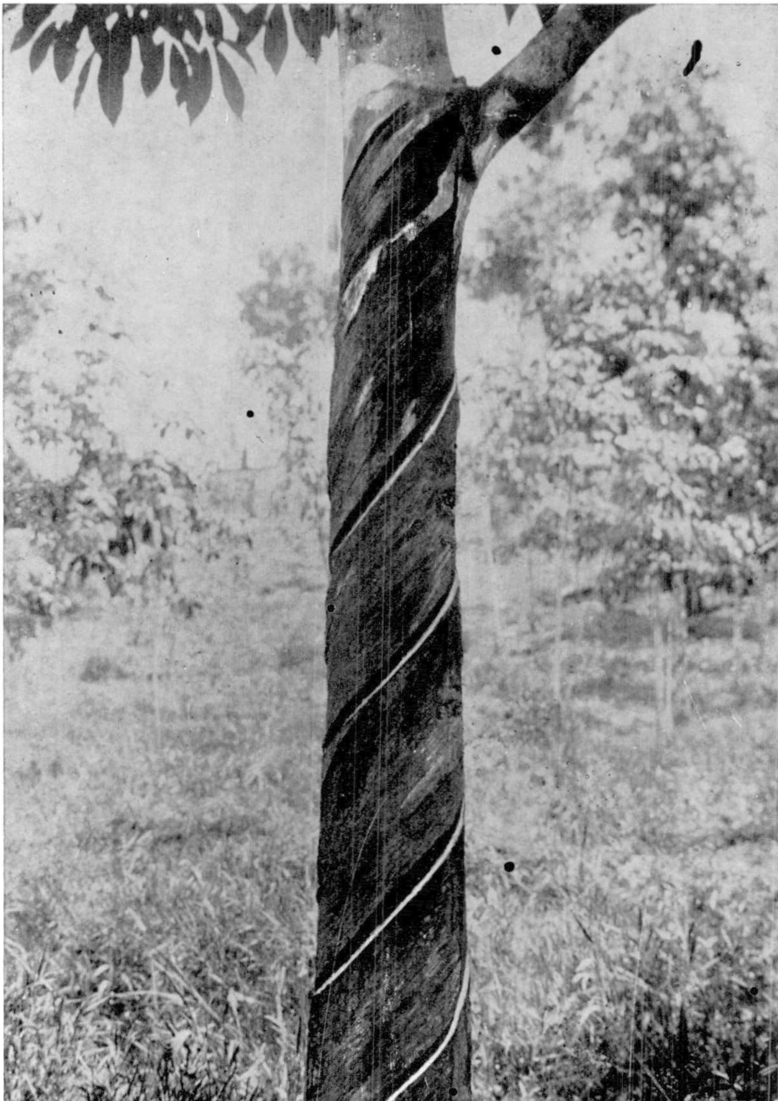


Photo by D. L. Gunawardane.

TAPPING THE RENEWED BARK AT ELPITIYA.

THE FIRST CORTICAL STRIPPING GAVE 16 LB. OF RUBBER IN 1 YEAR.

SOUTH CEYLON.

In the South of Ceylon equally good and often better results have been obtained. On one estate 8,731 trees, having a minimum circumference of twenty inches, gave in one year an average of 1·72 lb. of dry rubber per tree. On the same property an average of 2 lb. per tree from each of about 10,000 trees is expected during the current year. There are on this estate, four old trees which have given 10 to 25 lb. of dry rubber, per tree, in twelve months; the trees are perfectly healthy, have given a good crop of sound seed during the last few months and are now ready for further tapping.

A section of another rubber property in the South of Ceylon has given from 11-year-old trees, the average circumference of which is 30 inches only, no less than 5½ lb. of dry rubber from each of 255 trees. The eight largest trees on this property have yielded no less than 16 lb. of dry rubber each in twelve months and though the original tapping has only just been completed the newly formed cortex has been tapped again and gives a promise of a good flow of latex in the future. These results have been obtained by the half or full spiral system of tapping.

EXCEPTIONAL YIELDS.

These results have, however, been completely surpassed by those obtained on exceptional trees during the last few years. Trees of unknown age in Ceylon, (probably 20 to 25 years) have given 10, 18, 23 and 25 lb. of rubber in twelve months' time; other trees, only eleven years old, have in eight months' tapping given 14 lb. of dry rubber each and others from 2 to 4 lb. in two to three months. Light tapping of young trees has given 1·72 lb. of rubber per tree on a well-known Kalutara property. These results are so significant that space for tabulating them is here given, although it must be clearly understood that they are exceptional.

District.	Age of trees.	Tapping period.	Yield.	Tapping method.
Culloden ...	20 to 25 years	12 months	(a) 10 lb.	
			(b) 18 ,,	Various.
			(c) 23 ,,	
			(d) 25 ,,	
Elpitiya ...	11 ,,	12 ,,	16 ,,	Spiral curves with knives 1 and 2.
Peradeniya...	29 ,,	12 weeks	3 ,,	V cuts.
		10 ,,	4 ,,	Spiral curves with knives 1 and 2.
Kepitigalla...	8 to 15 ,,	12 months	2 ,,	V cuts.
...	11 ,,	12 ,,	3 ,,	V cuts.

The Elpitiya tree had a circumference of 46 inches; the tapping was commenced in October, 1904; the tree was rested in November, tapped again in December, rested in January 1905, and continuously tapped from February to June 1905. Tapping was recommenced in September, 1905. Plate 18 shows one of the trees in June 1905, after it had given 14 lb. of rubber.

YIELD FROM PERADENIYA TREES.

The following are the details of the trees at Peradeniya, which were tapped either on the spiral or V system. The letter P indicates the days on which the spur knife was used.

It will be noticed that the quantity of latex obtained by the use of Bowman's and Northway's spur knife was usually much greater than that obtained by the paring knife; this was to some extent due to the fact that the innermost laticiferous tubes near the cambium were penetrated by the points of the spur.

It is however, an open question whether the total yield from a series of pricking and paring operations is in excess of that obtained by the same number of parings, if a large enough interval of time is allowed to elapse. The large yield resulting from the use of the spur knife was followed by a poor flow after paring.

The illustrations on Plates *12* and *15* show the Peradeniya trees referred to in the following records of yield.

FOUR PERADENIYA TREES—29 YEARS OLD:
YIELD OF RUBBER FROM V CUTS.

Date.		Weight. lb.	Weight. oz.
29-6-05	...		4
1-7-05	...		$3\frac{3}{4}$
5-7-05	...		$11\frac{1}{8}$
7-7-05	...		$10\frac{1}{4}$
10-7-05	...		14
12-7-05	...		$12\frac{1}{2}$
14-7-05	...		$6\frac{1}{4}$
17-7-05	...		$9\frac{7}{8}$
19-7-05	...		$8\frac{1}{8}$
21-7-05	...		$9\frac{1}{4}$
24-7-05	...		$7\frac{1}{8}$
26-7-05	...		7
28-7-05	...		7
31-7-05	...		$7\frac{7}{8}$
2-8-05	...		7
3-8-05	...		$5\frac{5}{8}$
4-8-05	...		$3\frac{1}{2}$
5-8-05	...		$3\frac{1}{4}$
7-8-05	...		$4\frac{7}{8}$
9-8-05	...		$2\frac{7}{8}$
10-8-05	...		$1\frac{6}{8}$
11-8-05	...		$1\frac{6}{8}$
12-8-05	...		$1\frac{6}{8}$
P 15-8-05	...		3
17-8-05	...		$1\frac{3}{8}$
Carried forward		9	$11\frac{5}{8}$

Date.		Weight. lb.	Weight. oz.
Brought forward		9	$11\frac{5}{8}$
P 18-8-05	...		$1\frac{5}{8}$
19-8-05	...		$2\frac{1}{8}$
P 21-8-05	...		$2\frac{1}{8}$
22-8-05	...		$0\frac{6}{8}$
P 23-8-05	...		$1\frac{5}{8}$
24-8-05	...		$0\frac{4}{8}$
P 25-8-05	...		$1\frac{3}{8}$
26-8-05	...		$1\frac{3}{8}$
P 28-8-05	...		1
29-8-05	...		$0\frac{4}{8}$
P 30-8-05	...		$1\frac{3}{8}$
P 31-8-05	...		1
1-9-05	...		$0\frac{1}{2}$
P 2-9-05	...		$1\frac{1}{4}$
4-9-05	...		$0\frac{3}{8}$
P 5-9-05	...		$1\frac{1}{8}$
6-9-05	...		$0\frac{7}{8}$
P 7-9-05	...		$1\frac{1}{8}$
8-9-05	...		$0\frac{3}{8}$
P 9-9-05	...		$1\frac{1}{8}$
11-9-05	...		$0\frac{1}{2}$
P 12-9-05	...		1
P 13-9-05	...		$0\frac{3}{4}$
15-9-05	...		$0\frac{3}{8}$
P18-9-05	...		$1\frac{3}{8}$
Total	...	11	$5\frac{6}{8}$

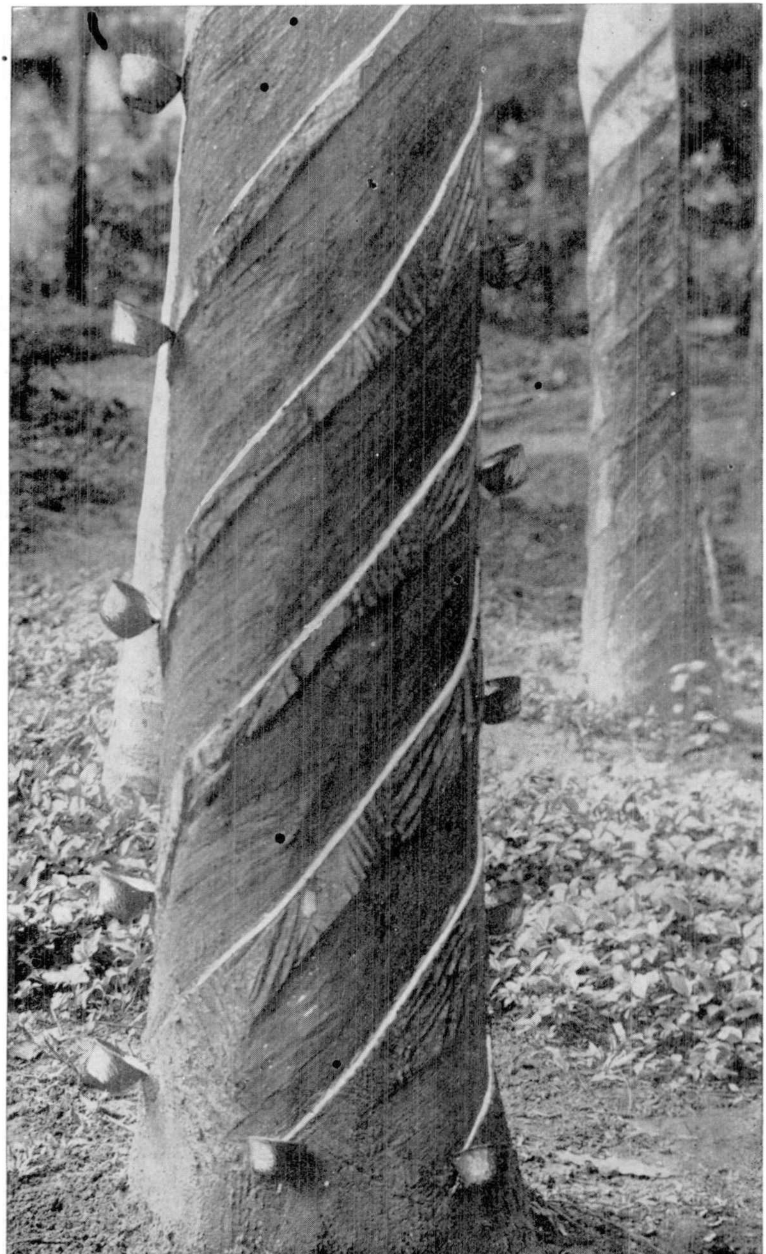


Photo by D. L. Gunawardane.

HALF SPIRAL SYSTEM.

A TREE AFTER IT HAS GIVEN 14 LB. OF RUBBER.

The figure on Plate 12 shows the condition of one of the trees at the end of the tapping operations; the lines of adjacent V's are beginning to interfere with one another and the trees are therefore being rested. The average yield in the first five weeks was two pounds of rubber per tree, but subsequently the yield fell off considerably.

FOUR PERADENIYA TREES—29 YEARS OLD:

RUBBER YIELD FROM LONG SPIRAL LINES.

Date.	Weight. lb. oz.	Date.	Weight. lb. oz.
16-6-05 ...	3¼	Brought forward...	12 14⅞
17-6-05 ...	6	10-8-05 ...	2⅞
19-6-05 ...	7⅝	11-8-05 ...	2⅞
20-6-05 ...	13⅞	12-8-05 ...	2⅜
21-6-05 ...	6¾	P 14-8-05 ...	2⅞
22-6-05 ...	6¼	16-8-05 ...	1⅞
23-6-05 ...	5½	P 17-8-05 ...	3⅜
24-6-05 ...	5	18-8-05 ...	2⅜
26-6-05 ...	6½	P 19-8-05 ...	⅞
27-6-05 ...	3¾	21-8-05 ...	1⅜
28-6-05 ...	7¼	P 22-8-05 ...	3⅝
30-6-05 ...	6⅞	23-8-05 ...	1⅞
1-7-05 ...	6⅛	P 24-8-05 ...	1⅝
3-7-05 ...	8¾	25-8-05 ...	3⅜
4-7-05 ...	7¼	P 26-8-05 ...	1⅜
6-7-05 ...	10¼	28-8-05 ...	1⅝
8-7-05 ...	9¾	P 29-8-05 ...	3⅛
11-7-05 ...	12½	30-8-05 ...	1⅝
13-7-05 ...	10¼	P 31-8-05 ...	3⅝
14-7-05 ...	6⅜	P 1-9-05 ...	2⅝
15-7-05 ...	7	2-9-05 ...	1⅜
18-7-05 ...	6¼	P 4-9-05 ...	4
20-7-05 ...	5	5-9-05 ...	1⅜
22-7-05 ...	4½	P 6-9-05 ...	7⅜
25-7-05 ...	3⅛	7-9-05 ...	2½
27-7-05 ...	4¼	P 8-9-05 ...	3
29-7-05 ...	5	P 9-9-05 ...	2⅛
1-8-05 ...	4½	11-9-05 ...	½
3-8-05 ...	4	P 12-9-05 ...	1 6/8
4-8-05 ...	3⅝	P 13-9-05 ...	1⅝
5-8-05 ...	3⅛	14-9-05 ...	⅝
8-8-05 ...	4¾	P 15-9-05 ...	1⅝
9-8-05 ...	1⅞	P 18-9-05 ...	1
Carried forward ...	12 14⅞	Total ...	17 8¾

The tree shown on Plate 15 was taken at the end of the above tapping operations and a glance at the excised areas will show how little of the tapping area had been affected in extracting as much as 4 lb. of rubber per tree.

RUBBER YIELD IN THE STRAITS.

The results obtained by Ridley, Stanley Arden, Derry and others have been published from time to time and from them the following synopsis is made. The range in yield varies from 10 ounces per tree for 6-year-old trees to 9 lb. per tree for older trees; in one case as much as 3 lb. of rubber has been reported from a well-grown three-year-old tree. Some trees having a circumference of 36 inches have given 3 lb. of dry rubber per tree; other trees 24 inches or more in circumference have been known to give only 2¼ oz. of dry rubber each, probably on account of their being too young.

The following results* are of considerable interest, as they show the yield obtained by tapping trees of different ages on 12 alternate days, by the herring-bone system:—

No.	Circumference 3 ft. from ground. Inches.	Age. Years.	Yield. Ounces.
1	17½	3½	1.54
2	26½	4	2.26
3	26⅕	7	14.27
4	39⅘	8 to 9	16.76
5		10 to 12	28.25

From these and other results Arden concluded that trees under four years were too young to be tapped and that an average annual yield of 12 ounces per tree should be obtained from trees 6 years old. Other results have shown that an average of 3 lb. of rubber, per tree, per year, from trees in their 11th to 15th year may be reasonably expected.

Two very old trees at Perak† having a circumference of 56 to 89 inches respectively and reputed to be 25 years old, have given in two months' tapping, no less than 12 and 18 lb. of dry rubber, including scrap.

Other trees at Perak, 14 years old, have given an average yield of over 4 lb. each and others of the same age quoted by Johnson show a yield of 3 lb. 1 oz. per tree in Malacca, and 6-year-old trees in Selangor 1 lb. 2 oz. per tree. The figure on Plate 19 shows a tree being tapped on the herring-bone system in Malacca.

YIELDS IN THE GOLD COAST.

RESULT OF TAPPING EXPERIMENT.

Four trees, 10 years old, were tapped for the first time in 1903, and yielded 4 lb. 3 oz. of dry rubber, or an average of 1 lb. ¾ oz. per tree. Notwithstanding the quantity of rubber extracted, Johnson states that the trees show no signs of having suffered in the slightest degree.

* Report upon Hevea brasiliensis in the Malay Peninsula, Stanley Arden.
† India-rubber Journal, February 1903.
‡ Report by Mr. Derry, Superintendent of Govt. Plantation, Perak 1900.

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HERRING-BONE TAPPING IN MALACCA.

The amount of rubber yielded by the Para and African trees* may be compared by consulting the tables given below.

	Number of trees tapped.	Age of trees, in years.	Date of tapping.	Average yield of rubber per tree. lb.	oz.
Hevea brasiliensis	4	10	Nov. 1903 – Dec. 1903	1	0¾
Funtumia elastica	1	7	Dec. 1901	0	4
" "	1	9	" 1903	0	1
" "	1	9	" "	0	2

Regarding the yield from Hevea brasiliensis Johnson remarks that it must not be taken as a criterion of the anticipated yield for trees of this age cultivated in West Africa and points out that the trees referred to are growing in poor, gravelly soil on the top of a hill under unfavourable conditions.

ESTIMATE OF YIELD.

From these and other considerations it is obvious that to offer an estimate of the yield from trees of known age one must be conversant with the climate and soil conditions, the trees and the method and care adopted in tapping operations. The results do, however, warrant the conclusion that trees from four to six years onwards, having a minimum circumference of 20 inches may be expected to yield an annual average of one to three lb. of dry rubber per tree, each year up to their 10th year and a much higher yield in subsequent years. The adoption of better systems of tapping which obviate the necessity of paring away the tissues wherein the milk accumulates, and drawing supplies of latex by merely cutting and not excising the laticiferous tissues is bound to result in an increased yield since the life of the tapping area is so much prolonged. The fact that a few well-developed trees have been made to give as much as 12 to 25 lb. of rubber per year, and promise abundant yields in the very near future shows what a tremendous amount of material there is to draw upon providing the environs of the plant and tapping operations are fully understood. The heavy yields reported in one part of this chapter are, however, from exceptional trees and when forming an estimate of the average yield over a large acreage may be neglected.

In a fairly general way it may be stated that an increase in circumference of *five* inches gives an increase in the tapping area of *360* square inches and from such an area, an average of about ½ a lb. of dry rubber may be obtained.

* Johnson, Report on Rubber in the Gold Coast, 1905.

CHAPTER IX.

PHYSICAL AND CHEMICAL PROPERTIES OF LATEX.

Colour—Consistency—Alkalinity—Sap exudations and acidity—Caoutchouc—Globules—Object of producer—Mechanical impurities—Analyses of the latex of Para rubber by Seeligmann, Faraday, Scott and Bamber—Variation in composition—Properties of caoutchouc—Occurrence of resins and oily substances—Sugars—Proteids or Albuminoids—Removal of proteids with formaldehyde and centrifugal separators—Mineral matter—Effect of temperature, ammonia, formalin and acids on coagulation.

THE PHYSICAL PROPERTIES OF LATEX.

THE latex of Hevea brasiliensis as it flows from a freshly-made incision is white or pale yellow in colour, and varies in consistency mainly according to whether drought or rainy weather prevails. It is slightly alkaline when fresh and, as it flows from the tree consists of minute globules of caoutchouc and other bodies suspended in a liquid containing various materials in solution and a varying proportion of mechanical impurities.

The latex obtained from the first incisions usually contains a large proportion of sap exudations which cannot be excluded as they flow from the freshly-cut cortical cells. In several instances the latex by mixing with such exudations becomes neutral aud may rapidly develop acid properties. The conversion to an acid state is followed by coagulation and hence the first tappings are frequently but unavoidably accompanied by a large proportion of scrap.

The object of the producer in the tropics is to separate the globules of caoutchouc from the mechanical impurities and some of the materials in solution and it is therefore necessary to explain clearly what these substances are and their general characteristics.

The planter who aims at producing the highest quality of rubber or perfecting the chemical and mechanical processes involved in its manufacture from latex, must thoroughly grasp the nature of the substances he has to deal with and it is therefore necessary to enter into a little detail.

The mechanical impurities present in most samples of latex in the field consist of pieces of bark, fibre, sand, etc., and they may be easily separated by filtering the diluted solution through butter cloth or fine gauze.

The filtrate from such material is composed of water, caoutchouc, resins, proteids, sugars, gums, insoluble substances and mineral matter. The amount of water in pure latex varies considerably, but it is usually estimated at 50 to 56%. The latex from trees which have been frequently or heavily tapped usually contains a much higher proportion of water; in some instances even as much as 90% of water is present. The following table will serve to indicate the general range in composition according to the analyses of Seeglimann,* Faraday, Lascelles Scott, and Bamber.†

ANALYSES OF THE LATEX OF HEVEA BRASILIENSIS.

	Seeligmann. per cent.	Faraday. per cent.	Scott. per cent.	Bamber. per cent.
Water	55 to 56	56-37	52-32	55-148
Caouchouc or India rubber	32	37-70	37-13	41-287
Proteid or albuminous matter	2-3	1-90	2-71	2-18
Resin	Traces		3-44	
Ash			0-23	0-405
Sugar			4-17	0-36
Salts	9-7			
Essential Oils			Traces	
Bitter nitrogenous substances soluble in water and alcohol		7-13		
Substance soluble in water, insoluble in alcohol		2-90		
Wax		0-13		

The above analyses show the general composition of the latex of Hevea brasiliensis and the different classifications adopted by chemists. The analysis by Lascelles Scott is one of a latex of unnamed origin, but Weber accepts it as being not far from the truth for our species. There is an indefiniteness about several of the constituents which are grouped under such general heads as proteids, resins, insolubles, etc.

It will be noticed that the caoutchouc varies from 32 to over 41% and the other constituents such as resin, sugar, insoluble substances and the ash show considerable variation. This is not surprising as the latex examined in each case was obtained from a different country and the ages of the trees were probably quite different. Furthermore the methods of extraction of the latex involve the cutting of bark tissues to different depths and the inevitable mixing of liquids would account for much variation in the soluble impurities.

* India rubber and Gutta percha, by Falconet, Seeligmann and Torrilhom, 1903, p. 84.

† Bamber, Circular, R. B. G. June, 1899.

CAOUTCHOUC GLOBULES.

The caoutchouc exists as globules in suspension. When pure it is practically colourless and is much lighter than water. It consists essentially of carbon and hydrogen and belongs to a class of bodies known as terpenes. It is insoluble in water but according to Weber may be obtained fairly pure by making a benzene solution, allowing the insoluble matter to settle out, and subsequently precipitating the rubber from the clear solution by the addition of alcohol.

RESINOUS AND SUGARY SUBSTANCES.

The resins, gums, and oily substances are present in varying quantities. Generally the latex from young trees, branches and twigs contains a large proportion of these substances. They may occur as globules suspended in the latex or in solution. In the ordinary processes of coagulation the greater part of the resin becomes part and parcel of the rubber and the extraction from the latter by the manufacturers in Europe is a difficult and tedious task.

The sugars are rarely present in large proportions and a maximum of 0.5 % may be taken as correct. They are known as inosite,* bornesite, matezite, and dambinite and are dissolved in the liquid in which the globules of caoutchouc and resins are suspended and in the washing of the freshly coagulated rubber are generally removed.

THE PROTEIDS.

The proteid or albuminous matter, about which more will be said, varies from 1.9 to 2.7 % of the fresh latex, or approximately 4 % of the dried coagulated product. This is a very high proportion, but from the analyses quoted above no other conclusion can be drawn. It is believed that this proteid matter is of a complex nature and alone or with the gums and sugars is responsible for the development of bacteria on the finished product, which leads to putrefaction or "tackiness." The use of formaldehyde in connection with the elimination of the proteid matter will be considered when dealing with coagulation.

When the rubber is prepared by simple coagulation the insoluble proteids become a part of the rubber, but if a centrifugal method is adopted and the freshly coagulated material frequently and well-washed, pressed and dried quickly, a considerable amount may be removed or rendered less harmful. In the purification of rubber this subject will be dealt with. It is believed that the removal of the proteids from the commercial rubber, though so much desired, is almost impossible and in the perfecting of mechanical processes and the use of antiseptic reagents for dealing with the proteids in the latex as it comes from the tree, lies a considerable amount of important profitable work for the planters in the tropics.

* Weber, l.c., p. 2.

The mineral matter occurring in suspension and solution in the latex and the various insoluble compounds indicated in the analyses previously quoted may be regarded as impurities of minor importance and can be better dealt with in the sections concerned with the components of commercial rubber and purification processes.

GENERAL CHARACTERS.

The behaviour of the latex when subjected to physical and chemical agencies may here be touched upon. It readily mixes with water without creaming. Parkin kept some latex diluted four times in an ice chamber for days without showing any signs of creaming. It is very difficult to separate the caoutchouc by centrifugal force and on several occasions a speed of over 10,000 revolutions per minute did not effect a separation of the caoutchouc of normal latex. The effect of freezing was tried by Parkin, a mixture of ice and common salt being used to give the low temperature; after thawing, the latex appeared to be the same as before and creaming was not hastened by the changes of temperature. Addition of ammonia or formalin prevents or delays coagulation, the former by neutralising the acids as soon as they are formed and the latter by acting as an antiseptic and preventing the decomposition of the proteid matter. Acids bring about coagulation in the cold, but the action is much quicker when warmed. The latex, may, however, if diluted, be boiled and yet coagulation is not brought about.

These points should be borne in mind by the planter who is inclined to experiment mechanically and chemically with the object of extracting the undesirable substances usually present in latex.

CHAPTER X.

THE PRODUCTION OF RUBBER FROM LATEX.

Production of rubber by coagulation—Production on a small scale illustrated—Suggestions for curing rooms—Effect of Heat on coagulation—Smoking and coagulation—The chemistry of the Amazon method—Coagulation by chemical reagents—Acetic acid—Formic acid—Tannic acid—Corrosive sublimate—Amount of acid to be used—Determination of completeness of coagulation—Disadvantages of coagulated rubber—Amount of proteid in mother liquor and rubber—Putrefaction of rubber—Analyses of sound and tacky rubber—Keeping the proteid inactive—Antiseptics, drying, dilution and washing—The removal of the proteid from the latex—Formalin and sodium sulphate—Rapid coagulation and removal of proteids by mechanical means—Biffen's centrifugal machine—Experiments in Ceylon with the Aktiebolaget Separator—Principles of mechanical separation—Rapid coagulation by mechanical and other means—The Michie-Golledge machine-Construction, action and illustration—Mathieu's apparatus.

THE PRODUCTION OF RUBBER FROM LATEX.

HAVING briefly described the physical and chemical properties of the latex as it is obtained in the field it now remains for us to consider the operations upon which the production of good rubber from latex depends. If the pure latex is allowed to stand in a receptacle it finally coagulates and the caoutchouc globules with other substances float to the top, leaving a more or less clear liquid behind. By the addition of chemical reagents or by subjecting the latex to different temperatures coagulation may be hastened or retarded. The coagulated substance after washing, pressing and drying is ultimately known as the rubber of commerce.

In the production of rubber from latex, the planter may either take advantage of the presence of coagulable constituents in the latex or adopt mechanical means for the separation of the caoutchouc globules from the rest of the latex.

PRODUCTION OF RUBBER BY COAGULATION.

This change is due to the presence in solution of albuminous or proteid matter which quickly coagulates or becomes insoluble. The coagulated proteid carries with it the suspended globules of caoutchouc and other bodies, so that the whole process is more or less one of clarification, the liquid left behind containing only those ingredients of the latex which have remained in solution. The

PLATE 20.

Photo by C. H. Kerr.

LATEX IN SETTING OR COAGULATING PANS.

coagulation of the proteid material will occur as soon as the latex becomes neutral or faintly acid no matter what proportion of suspended globules of caoutchouc or other constituents may be present in the latex.

On estates where the daily quantity of latex is small the use of machinery for rapidly coagulating it is not always necessary; the latex is put in shallow pans (see Plate 20) and allowed to set. The biscuits when ready are rolled to squeeze the water out and then placed on wire gauze, wooden or coir shelves to dry. A strong current of dry air might be obtained by drawing the air by means of a fan through a chamber containing chemicals such as freshly burnt lime, charcoal, or calcium chloride which would absorb the water. It should not be difficult to arrange a building on a plan somewhat similar to the tea-drying and cocoa-curing rooms in common use all over Ceylon.

EFFECT OF HEAT ON COAGULATION.

Some kinds of latex can be heated for a long time—almost indefinitely—without coagulation being effected, whereas other kinds coagulate rapidly on the application of heat.

According to Parkin the diluted latex of Para rubber is unaffected by boiling. If the undiluted latex is boiled, water is driven off and the thickened milk may then become charred.

The addition of certain chemical reagents to the heated latex brings about coagulation; dilute mineral acids, acetic acid, and tannic acid are particularly active.

SMOKING AND COAGULATION.

The coagulation of the latex may be hastened by exposing it to heat and the products of combustion of a fire. The latex can be coagulated fractionally by such a process and the finished product, when properly manufactured, is less liable to putrefaction than the rubber prepared by many other methods. The smoke from burning palm nuts used in the Amazon district contains, among other substances, small quantities of acetic acid, acetone, and creosote. The acetic acid is probably the agent responsible for effecting the coagulation; the other substances, particularly the creosote, are absorbed the latter acting as an antiseptic in preventing the rapid decomposition of the albuminoids present. The decomposition of the albuminous substances in the rubber may be prevented by the addition of suitable antiseptic reagents to the latex when the rubber is prepared in other ways, though quickness in drying and complete extraction of the moisture from coagulated rubber is often sufficient to bring about the same result. Dickson's apparatus is devised to meet many of these requirements.

COAGULATION BY CHEMICAL REAGENTS.

In coagulation by such means the object is to use reagents which while effectively and rapidly precipitating the albuminous material will not have a detrimental effect on the rubber produced.

Many compounds such as picric acid would rapidly coagulate the proteids, but the effect on the resulting rubber would be bad. Weber and Parkin have shown that many acids may be used in the coagulating process, but it is unneccesary to do more than mention those which have, from practical experience been proved more or less acceptable to producers in the tropics and manufacturers in Europe.

Acetic acid.—This is cheap, always procurable, is not dangerous to handle and is as effective as formic acid. It is not as powerful as tannic acid though it is effective in bringing about the coagulation of the latex while cold. The commercial article varies in strength and the quality should be noted by the purchaser.

Formic acid.—This, though similar to acetic acid in its effect, is more expensive, weight for weight. The advantages of using this reagent are (1) that less is required than acetic acid, and (2) it has antiseptic properties. Whether acetic or formic acid is used, it should be applied in definite proportions and no more need be used than is required to just precipitate the albumen in the latex.

Tannic acid.—This is according to Weber the most powerful of the acids which can be used for this process, and he asserts that on a laboratory scale it is excellent for use with the latex of Para rubber. If rubber coagulated by tannic acid, while still wet, be placed in an incubator at temperatures from 100° F. upwards, it rapidly passes into a state of putrescid fermentation, but such a change does not occur if the rubber is thoroughly dry.

Mercuric choloride.—Corrosive sublimate effectively coagulates the proteid while the latex is cold and also acts as an antiseptic. It is very poisonous, and if used, a small quantity of mercury is unavoidably left in the rubber.

AMOUNT OF ACID TO BE USED.

The quantity of acetic or formic acid required depends upon the proportion of albumen in the latex. According to Weber the latex of Para rubber in its native habitat contains only about 1·5% of albumen and one-third of an ounce of anhydrous formic, or half an ounce of glacial acetic acid per gallon of the latex is quite sufficient to produce a rapid and complete coagulation. The behaviour of the latex from Para rubber trees with acids is due to the fact that the milk is, when fresh, usually slightly alkaline and the proteid substances are insoluble in a feebly acid solution but soluble in alkaline or strongly acid solutions. It has been asserted that the proteid matter is insoluble in a neutral solution, but on several occasions the fresh latex remains liquid though the reaction with litmus paper does not indicate alkalinity. Only a small quantity of acid is required to neutralize or acidify the latex and therefore lead to the precipitation of the proteids. It is a mistake to add excess of acetic acid as the proteids would be redissolved and therefore still remain in solution.

The amount of pure acetic acid necessary for complete coagulation depends upon the quantity of proteids to be precipitated, and the latex in Ceylon, according to the analyses already quoted, contains from 2.3 to 2.8% of these substances. Diluting the latex will not reduce the total quantity of acid required. Every 100 volumes of pure Ceylon latex require approximately one volume of pure acetic acid. Many planters add one or two drops of acetic acid to about half a gallon of the diluted latex. If the acetic acid is added until the mixture becomes neutral after stirring—i.e., will neither turn litmus paper red nor blue, or until it is feebly acid very little harm will be done. The addition of excess of acid may bring about a re-solution of the proteids and coagulation be thereby delayed. It is very rare that the latex on a large scale is heated before treatment with acetic acid.

The completeness of the precipitation is judged by the clearness or turbidity of the liquid in which the rubber floats. When the separation of caoutchouc is complete the mother liquor is quite clear.

DISADVANTAGES OF COAGULATED RUBBER.

Whenever the rubber is prepared by the coagulation of the proteid, either by the smoking method, or the use of familiar chemical reagents, hot or cold, it is obvious that the rubber must contain the precipitated proteids together with the suspended globules of caoutchouc, resin, etc. Analyses of well-dried Para rubber show only a small percentage of substances other than caoutchouc, practically from 4 to 5%, and it may at first sight appear unnecessary to draw attention to the desirability of extracting them. If one compares the analyses of latex and rubber from Hevea brasiliensis it is surprising to find that when chemical reagents have been used, the percentage of proteid matter in the rubber shows that the whole of that in the latex was not precipitated and Bamber and Parkin proved that the clear liquid remaining after coagulation with acetic acid often gave reactions with the tests for proteids. The amount of proteid in the clear liquor may, according to Bamber, be as much as 50% of the original. It may however be asserted that a great part of the proteids generally occurs in the prepared rubber, and their presence along with other substances leads in many cases to putrefaction.

PUTREFACTION AND TACKY OR HEATED RUBBER.

The proteid matter is responsible for much of the "tackiness" or the "heating" which is seen in many rubber samples. The rubber first appears sticky and sooner or later appears to melt as if due to excessive heat. It often emits a strong odour when in this stage. This is due to the inclusion of the proteids and perhaps the sugary and gummy constituents in the rubber and the subsequent development of micro-organisms on these substances. If the rubber is free from these materials it will not undergo such a change and the removal of the latter from rubber takes us into several important methods of purification. The chemical change which takes place in tacky rubber is indicated in the analyses made by Mr. M. Kelway Bamber of sound rubber and material in various degrees of tackiness. They are here quoted in full.

ANALYSES OF SOUND AND TACKY PARA RUBBER.*

	Sound rubber.	Tacky No. 1.	Tacky No. 2.	Very Tacky.
Moisture ...	0·30 %	0·36 %	0·06 %	0·44 %
Ash ...	0·38 „	0·28 „	0·54 „	0·72 „
Resin ...	2·36 „	2·32 „	2·66 „	3·70 „
Proteids ...	3·50 „	3·85 „	3·50 „	4·90 „
Rubber ...	93·46 „	93·19 „	93·24 „	90·24 „
	100·00	100·00	100·00	100·00

These analyses show a relationship between the degree of "tackiness" and the percentage of proteids and resins; the latter may be due to oxidation.

KEEPING THE PROTEID INACTIVE.

If the local conditions are such that the rubber cannot be prepared by any method other than coagulation and the proteid and other materials must be included, it will be necessary to take steps to keep the obnoxious ingredients in a quiescent state. This can be done by treating the latex with some reagent which has antiseptic properties, such as creosote, or corrosive sublimate, and quickly drying the rubber after effectively washing and pressing the freshly coagulated material.

In some cases it is doubtful whether it is even necessary to add antiseptic reagents if the rubber is thoroughly dried as the decomposition of the proteids is dependent upon a supply of water being present.

No matter whether the latex has been treated with antiseptics or not, the coagulated substance should be very well washed.

* Committee of Agricultural Experiments, Peradeniya, Sept., 1905.

PLATE 21.

Fig. 1.

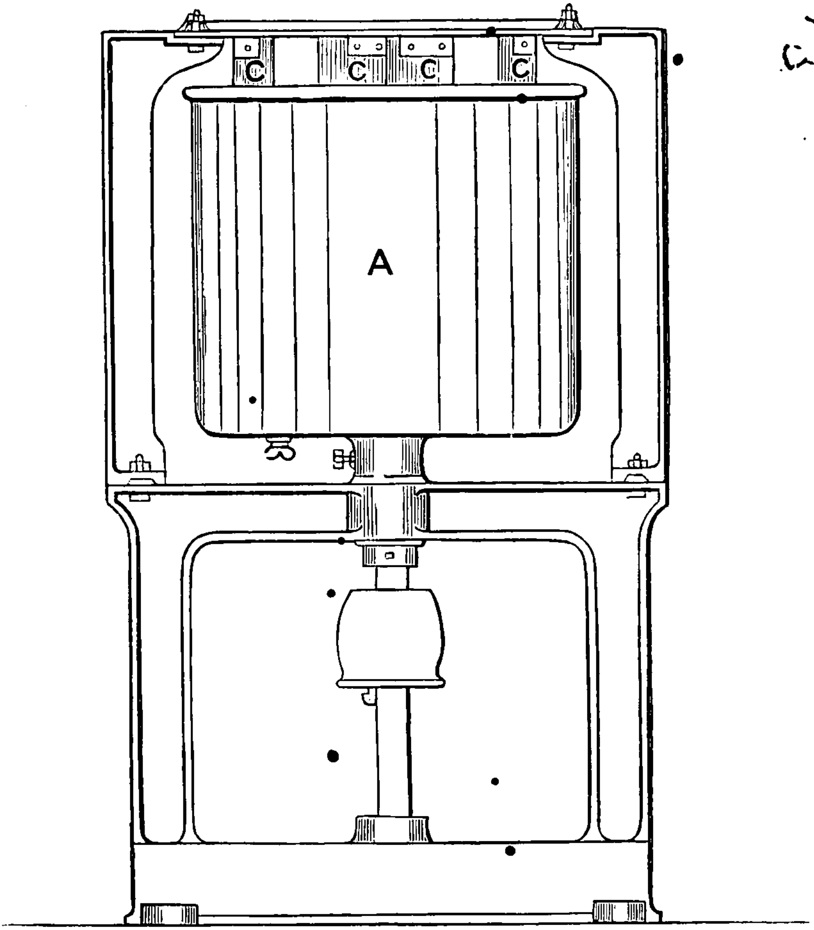
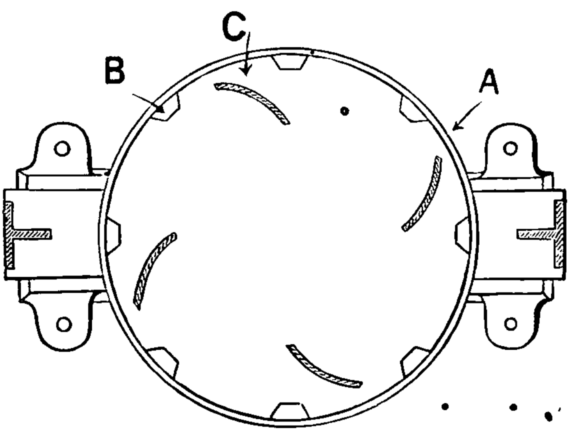


Fig 2.



THE MICHIE-GOLLEDGE COAGULATOR.

Too much water cannot be used. In the washing processes the water may carry away a considerable portion of the soluble proteid or that precipitated on the surface and thus minimise the danger. The use of washing machinery or antiseptics or both is almost certain to become a necessity in the near future. Dilution of the latex before coagulation would also reduce the proportion of proteid in the prepared rubber. The quicker and more effectively the rubber is dried the less likelihood there is of putrefaction or tackiness setting in.

THE REMOVAL OF THE PROTEID FROM THE LATEX.

But it is not beyond the ingenuity of the chemist or planter to treat the latex with some reagent which will keep the proteids in solution while the caoutchouc globules are segregating and ensure their expulsion by subsequent pressing and washing.

Weber as the result of experiments mainly with the Castilloa latex suggested that the treatment of dilute hot solutions of latex with formaldehyde (Formalin) or the use of the latter with sodium sulphate may be effective in reducing the amount of proteid matter in prepared rubber.

"To every gallon of the rubber latex, from ½ oz. to 1 oz. of formaldehyde (formalin 40 per cent. solution) is added, the latex well stirred and allowed to stand for one hour. Then to each gallon of latex a solution of 1 lb. of sodium sulphate (commercial) in one pint of boiling water is added while still hot, and the mixture stirred for some time. Coagulation may take place immediately or after several hours' standing, according to the condition of the latex. Great care must be taken to use a sodium sulphate of entirely neutral reaction.

"What actually happens is this: The diluted rubber milk, freed from all its mechanical impurities by straining, is to begin with rendered non-coagulable by the addition of the formaldehyde. On adding to the rubber milk the solution of sodium sulphate the rubber substance rapidly rises to the top, where at first it forms a very thick, creamy mass, the individual globules of which rapidly coalesce. The coalesced (and as a matter of fact, not coagulated) mass, on being worked upon the washing rollers, undergoes a very curious polymerisation process, and thereby rapidly acquires the great strength and toughness so characteristic of high-class indiarubber.

"On cutting the cake open, it will be found to be rather spongy, being full of little holes which are still filled with some of the albuminous though very dilute mother liquor. If, therefore, the rubber were dried in this state it is obvious that it would still contain a small quantity of the objectionable albuminous matter. For this reason the rubber contained should at once be taken, cut into strips, and subjected to a thorough washing upon an ordinary rubber washing machine." Bamber considers that the formalin acts more as an antiseptic to prevent the decomposition of the proteid than anything else.

Johnson made several attempts, when in the Gold Coast last year, to separate rubber from Para latex in the manner above suggested, but failed in each instance, although the latex stood in one or two instances, for nearly three weeks without the rubber separating out.

This method has been tried by many persons, and evidently requires further experiments before it can be pronounced as perfect. It should be remembered that certain reagents *e. g.* ammonia, formalin, serenguiana, etc., will keep the latex in a liquid state for a very long time.

RAPID COAGULATION AND REMOVAL OF PROTEIDS BY MECHANICAL MEANS.

It has been stated that mechanical appliances have been invented which can effectively eliminate the proteid while forming part of the latex.

BIFFEN'S CENTRIFUGAL MACHINE.

Biffen * recognised that in latex the india rubber existed as suspended globules, lighter than water, and employed for separating the caoutchouc, a centrifugal machine similar to that used in separating butter from milk. The machine is a modified form of the ordinary centrifugal milk tester, capable of being rotated 6000 times per minute. The caoutchouc of Para latex is said to be effectively separated in a few minutes and consists of the pure article, free from mixtures of proteids, resins, etc. Weber strongly commended such a process of treating the latex for eliminating proteid constituents.

Biffen claims that the rubber may thus be prepared by purely physical means; the light rubber globules are thrown out of the bowl in an almost dry state and the rubber is free from any obnoxious smell and danger of decomposition. It is however, questionable whether pure caoutchouc free from resinous and other impurities is desired by the manufacturers.

EXPERIMENTS IN CEYLON.

Furthermore, several small experiments carried out in Ceylon have proved that the caoutchouc in ordinary latex is not rapidly separated by the centrifugal machine even when the speed is as high as 11,000 revolutions per minute. In these experiments

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* Biffen; Annals of Botany, June, 1898.
,, Journal of the Society of Arts, 1898.

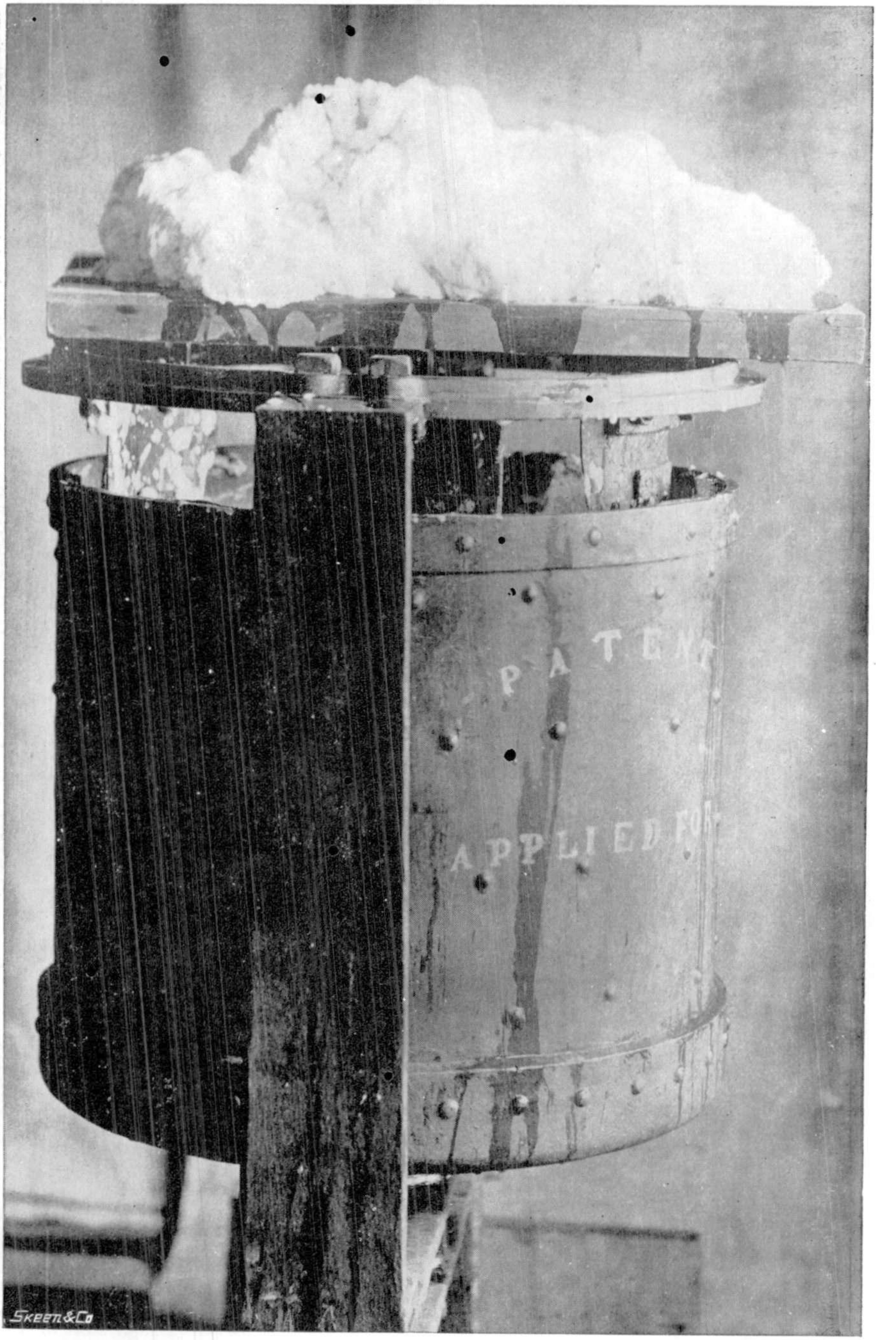


Photo by C. H. Kerr.

THE MICHIE-GOLLEDGE COAGULATOR.

THE SPONGY MASS OF FRESHLY COAGULATED RUBBER IS SHOWN AT THE TOP.

PLATE 23.

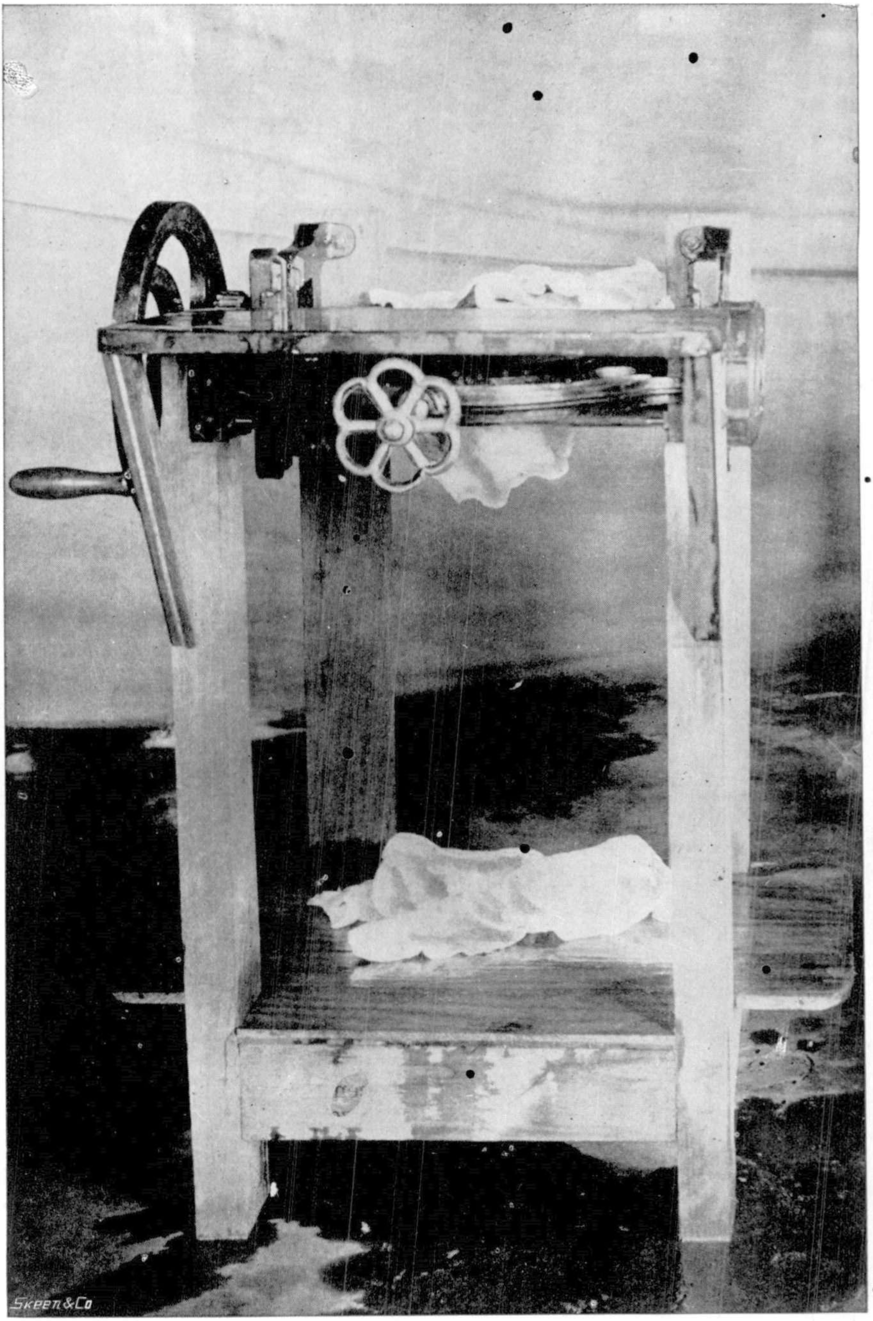


Photo by C. H. Kerr.

MACHINERY FOR EXPELLING WATER,

SPONGY RUBBER PREPARED BY THE MICHIE-GOLLEDGE PROCESS.

various heavy chemicals have been added to the latex after the formalin; the chemicals used do not show an acid reaction and must considerably increase the density of the alkaline mother liquor. The whole of this mixture has been placed in the "Aktiebolaget Separator" and then been subjected to centrifugal force for over an hour, and yet the caoutchouc globules have not been effectively separated from the other constituents.

Though these experiments cannot at present be considered a success, the principle of increasing the density of the mother liquor by addition of readily soluble substances and then causing a separation of the caoutchouc globules by mechanical means is one which cannot be too strongly impressed on the experimentalist.

RAPID COAGULATION BY MECHANICAL AND OTHER MEANS.

THE MICHIE-GOLLEDGE MACHINE.

Construction.—On Plate 21 a sketch of parts of this machine is shown. The Michie-Golledge Rubber Coagulating Machine consists of a revolving cylinder A with angular ribs B on its inside, and curved blades C which are fixtures as shown in the accompanying sketch. The latex is poured into the cylinder A which is then set in motion, the machine revolving in the direction indicated by the arrow. The revolving cylinder and its ribs B force the latex forward on to the blades C which carry it into the centre of the cylinder creating a kind of vortex or whirlpool, and depositing the rubber in the central space in the form of a sponge-like mass shown on Plate 22. When the mass of rubber reaches the right consistency, it is removed by hand, separated into lumps of the required size, and rolled out while it is still soft into sheets in a small rolling machine.

METHOD OF USING.

The latex is diluted, often as much as 400%, and after being strained to remove the mechanical impurities and treated with acetic acid in the proportion of 1 dram of acetic to 1 gallon of the diluted latex, is placed in the churn-like cylinder. The cylinder is then rotated horizontally at the rate of about 180 revolutions per minute for about 1½ minutes after which the speed is reduced to about 100 revolutions per minute for the next 3½ minutes. The coagulated latex accumulates in the centre and the watery portion remains in the outer [illegible] vertical plates and the wall of the cylinder. When the watery portion is clear the separation of the rubber is considered to be complete and the coagulated latex is removed. The freshly coagulated mass is, as shown on Plate 22, in the fresh state, very spongy and is torn into irregular pieces which are pressed between the rollers of a mangle. A figure of the mangle used and the cakes obtained is shown on Plate 23; the irregular cakes, obtained by passing the spongy mass through the rollers, are then cut into wormlike threads by means of shears worked by hand; the worms are next placed on wooden shelves to dry. The rubber so prepared may at first contain most of the ingredients present in the latex the soluble portion of which may be partially removed by repeatedly washing the rubber during the rolling process. Two analyses of this rubber are given elsewhere.

MATHIEU'S APPARATUS.*

An apparatus for coagulating rubber in large quantities by means of heat alone has been considered by Mathieu, which follows in principle the manipulation of the latex as practised by the Brazilian seringuero. As far as I can understand it, the apparatus is devised to subject thin films of the latex to the action of a surface heated to a constant degree and can be worked *in situ* or be put on wheels and transported to any part of the estate where collecting operations are being carried out. Dickson's drying and coagulating machine is described in Chapter XI. of this book.

* Tropical Agriculturist, April, 1905

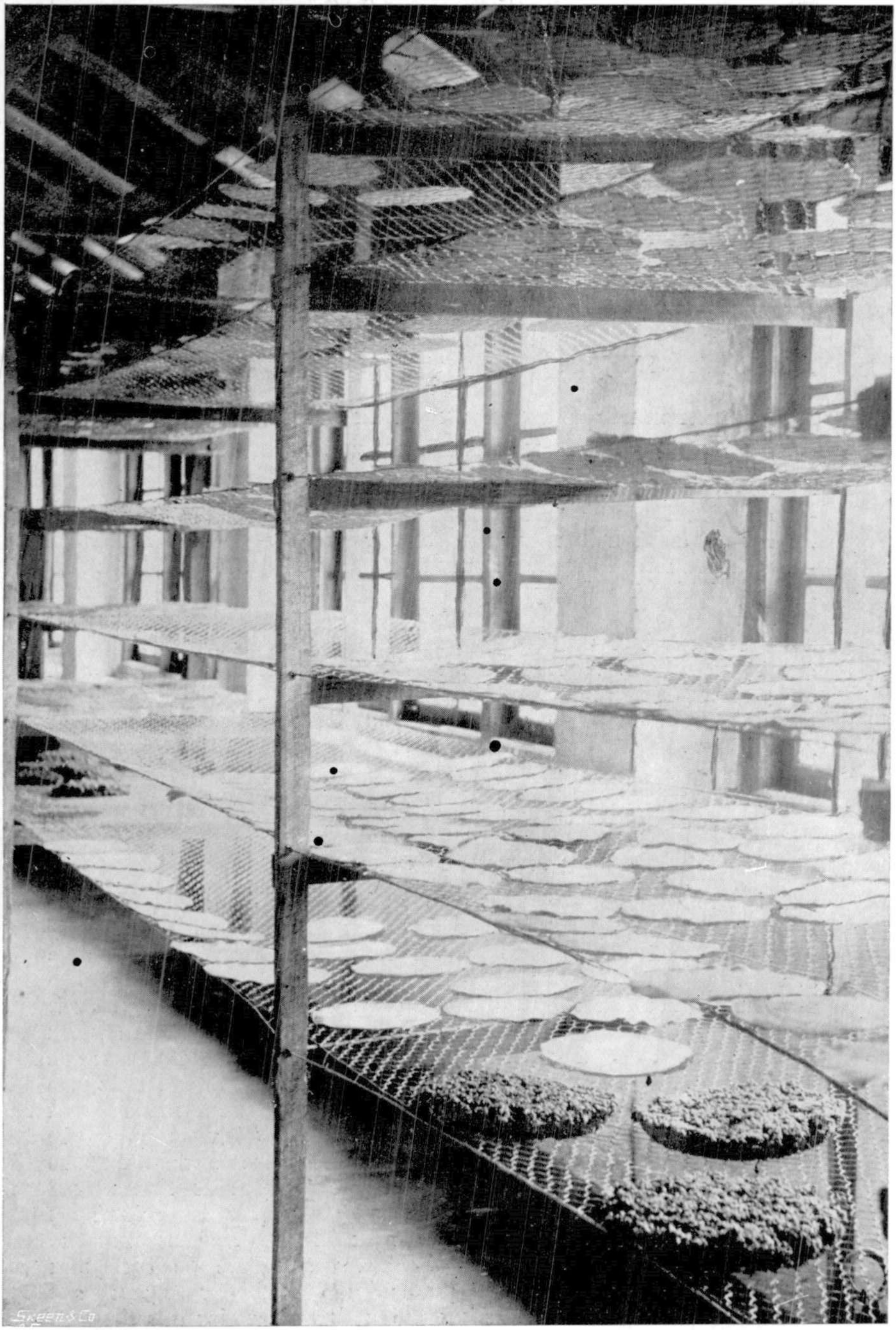


Photo by Ivor Etherington.

DRYING BISCUIT RUBBER.

CHAPTER XI.

DRYING OF RUBBER.

General methods—Presence of water, putrefaction and surface deposits—Chemicals and artificial heat for drying—Suggestions by Parkin, Burgess, and Weber—High temperatures undesirable—Dickson's drying and coagulating machine—Use of calcium chloride—Advantages—Simple rubber drying sheds for use with calcium chloride—Disadvantages—Experiments in Ceylon.

ON most estates the freshly-coagulated rubber is rolled to drive out as much water as possible and then either hung up on cords or placed on shelves made of coarse wire netting, coir matting or wood, and allowed to dry. The rubber cannot be dried in the sun, though a current of warm dry air may be used without any bad effect. The ordinary cocoa and tea drying factories might easily be used for this purpose. The preparation of the rubber in sheets as thin as possible is desirable in order to obtain a dry rubber in the shortest time. Though the drying process may be hastened by various methods it is well-known that rubber of good quality can be produced without resorting to any devices for hastening the drying or curing of the product. The illustration on Plate 24 shows a simple method of drying biscuit rubber as adopted on many rubber estates.

The presence of water in the rubber is however often a serious drawback and the fact that the rubber if dry will not undergo putrefactive changes is of sufficient importance to warrant attention to this part of the subject. It should be remembered that when the biscuits or sheets are hung up to dry the evaporation of the water is followed by a deposition of the suspended or dissolved impurities on the surface of the rubber. Rapid drying is essential in order to prevent deterioration consequent on oxidation.

CHEMICALS AND ARTIFICIAL HEAT FOR DRYING.

Parkin * pointed out that to dry rubber by heat did not seem advisable and suggested that perhaps quick lime or calcium chloride might be used in the drying chamber.

Burgess † states that the raw rubber before it is vulcanised is very sensitive to heat, and a temperature of 150° F. may render Para rubber sticky on the surface and a higher temperature utterly

* Parkin, l.c. p. 151.
† Burgess, Lecture at the Agri-Horticultural Show, Kuala Lumpur, 1904.

destroy the "nerve" of it; he declares that it is, therefore, injudicious to use artificial heat in hastening the drying of rubber. He also states that if artificial heat were absolutely necessary a very carefully regulated temperature never exceeding 120° F. would probably not cause any great damage.

Weber* asserted that certain brands of india rubber cannot be hung up to dry in the form of sheets after the washing process as they become so soft as to fall to pieces. The temperature at which india rubber begins to soften varies according to the percentage of the resinous and oily substances present, and many samples of good Para rubber pass into a more or less fluid state at about 170 to 180° C.

It is therefore obvious that the question of drying rubber is apt to be a delicate one where high temperatures are concerned.

DICKSON'S MACHINE FOR COAGULATING AND DRYING RUBBER.

Mr. Dickson has kindly supplied me with the following description of his machine;—"This machine consists of a small furnace, on the top of which is a smoke box containing a revolving drum. Between the furnace and the smoke box are a series of baffle plates to divert the fumes and ensure that no flames and sparks pass into the smoke box. At one side is a shallow pan for receiving the latex. In this pan is a small roller partly immersed in the latex with its surface in contact with the surface of the large drum. A fire is placed in the furnace and the fumes are allowed to pass between the baffle plates and round the large drum to the chimney. When the desired temperature has been reached, the pan is filled with latex from the feeder and the small roller is turned by hand or power.

"The surface of the small roller being in contact with the surface of the large drum, turns it and at the same time spreads a thin film of latex on its surface. The action of the heat and fumes on the thin film of latex coagulates and dries it. Continuing the process the latex is spread film by film, coagulated and dried, until a thick deposit of rubber surrounds the large drum. The damper on the centre baffle plate is then shut and the door in the smoke box opened. The rubber on the drum is slit across with a knife and unrolled in a large sheet which can be cut to any size for packing.

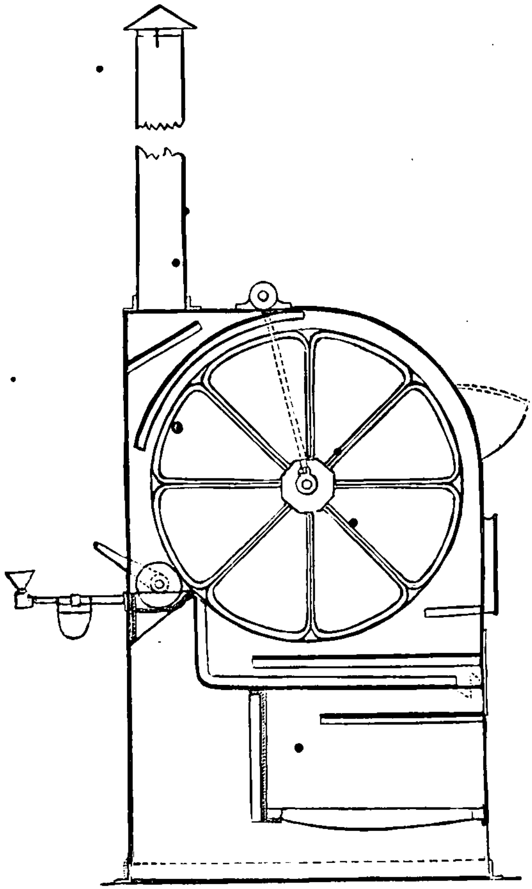
"The antiseptic qualities of the fumes tend to preserve the rubber, and the sheets are treated through and through."

In communication with Mr. Dickson I learned that in his machine there are several doors which can be opened to let cool air in or regulate the temperature, a most important and essential feature when drying rubber with hot air or fumes. The illustration on Plate 25 shows the general plan of the apparatus.

* Chemistry of India Rubber, p. 21.

PLATE 25.

—RUBBER COAGULATING & DRYING MACHINE—



DICKSON'S COAGULATING AND DRYING MACHINE

USE OF CALCIUM CHLORIDE.

Mr. Burgess, in his lecture already referred to, stated that "it is possible to dry rubber quite well and satisfactorily without any artificial heat by the use of some agent that will dry the air. For this purpose I recommend calcium chloride. This substance is made commercially on a large scale; it is comparatively cheap and very effective as a drying agent. The material as bought is in white granular lumps which when placed in the open air absorb moisture from the air and the calcium chloride becomes moist and eventually absorbs so much water that a syrupy liquid results. The great merit of this substance lies in the fact that it can be recovered from the wet state by simply heating and thereby driving off the moisture. A simple form of rubber drying shed adapted for use with calcium chloride could easily be made with shelves to hold iron pans in which the calcium chloride could be placed and freely exposed to the air in the chamber. As the calcium chloride absorbs the moisture and becomes sloppy, the pans should be removed and the water driven off over a brisk fire, stirring the mass meanwhile. When quite dry and porous again the pans should be returned to the rubber drying chamber to do their work again. In this way there would be little or no loss of substance, and the air inside the chamber being constantly dry, mould would be absolutely prevented and the rubber would dry in half the time. The pans if used inside the rubber shed should be placed above the rubber.

"A still more efficient system would be to devise a circulation of dry air in the chamber, and if this system were adopted it would be best to dry the air before blowing it with fans into the chamber. This could be easily done by causing it to pass over a series of iron pans of calcium chloride contained in a drying box outside."

Sir W. Thistleton Dyer, writing to the "India Rubber Journal," objected to the use of calcium chloride on the ground of expense and the danger of accidental contamination with the rubber, and expressed his opinion that the circulation of dry air is preferable to the use of this chemical. Mr. Ridley, in reply to these objections in the "Straits Bulletin" stated that in a manufactory on a large scale the calcium chloride would be in pans, well away and above the rubber, and that there would therefore be no risk. If calcium chloride is allowed to remain in contact with the rubber it destroys it, but if cleared off immediately it does no harm.

At Peradeniya a series of experiments has been made. A current of dry hot air is made to pass rapidly through a specially constructed chamber in which the rubber is arranged on a number of wooden trays. The air is first dried by passing it through a series of crates or cells containing hygroscopic chemicals. The crates can be easily removed, dried and replaced. The dry air is then drawn over a fire by means of a fan, the latter being turned by hand or power. By this means the rubber is dried rapidly; if the temperature is maintained at about 90° F., the rubber is throughly dried in a few days if the sheets are not too thick.

CHAPTER XII.

PHYSICAL AND CHEMICAL PROPERTIES OF RUBBER.

Analyses of Para rubber from Ceylon, Bukit Rajah Coy., F.M.S., Penang, Straits, and Gold Coast—Market value of the samples—Para and African rubber analyses compared—Resins in Para and Castilloa rubber—Resins in rubber from parts of the same tree—Resins in rubber from trees of different ages—Extraction of resins from rubber by manufacturers and growers—Albuminoids and cause of putrefaction—Removal by mechanical and chemical processes—Ash impurities and ingredients present in Para, Ceara and African rubbers—The insoluble constituent in rubber—Properties of india rubber, reaction with alkalies, halogens, and acids—Absorption of water—Sulphur reaction—Action of heat on india rubber.

HAVING briefly indicated the composition and characters of the latex as it appears in the factory of the cultivator the same features in the finished product can now be considered with a view of gaining an insight into the changes which have taken place and the processes that have been adopted in Europe to free the rubber of the impurities originally present in the latex. The prepared article may be expected to contain all the insoluble components of the latex except those removed by mechanical operations. The following analyses of plantation rubber prepared from Hevea brasiliensis in various parts of the world may be taken as good examples:—

	Ceylon Para rubber.*	Para rubber from the Bukit Rajah Coy. F.M.S.†	Penang Para rubber.‡	Gold Coast Para rubber. § A	Gold Coast Para rubber. § B	Straits rubber; old sample.‖
	%	%	%	%	%	%
Caoutchouc ...	95.50 ...	95.37 ...	95.00 ...	95.53...	95.96...	93.22
Resins, etc. ...	3.00 ...	3.02 ...	4.3 ...	3.90...	3.25...	1.76
Albuminous matter. ...	1.25 ...	1.24 ...	— ...	—...	— ...	4.20
Ash or mineral matters. ...	0.25 ...	0.37 ...	0.5 ...	0.18...	0.22...	0.32
Moisture. ...	— ...	— ...	0.15 ...	0.39...	0.57...	0.50

* Tropical Agriculturist, Vol. XXIV. No. 5, Nov. 1904.
† Journal d' Agriculture Tropicale, April, 1905.
‡ Agr. Bull. of Straits and F.M.S., April, 1904.
§ Johnson, Report on Rubber in the Gold Coast, 1905.
‖ By M. Kelway Bamber.

The sample from Ceylon was valued at 5s. 7¼d. per lb. and the report stated that the rubber was free from moisture, very strong and vulcanised well. The sample from the Bukit Rajah Coy. was considered to be very suitable for vulcanisation and sold at a little over 7 francs per pound. The Penang sample was prepared in rectangular cakes, was dark brown in colour, transparent, and contained no impurities. One piece was sticky. The value was considered to be equal to the current market rate of good Para.

The samples from the Gold Coast were considered to be of excellent quality, free from impurities, and in February, 1904, were valued at 4s. 6d. to 4s. 7d. per lb. The old sample of Straits rubber had been kept in Ceylon for a considerable length of time.

The high percentage of caoutchouc in Para rubber grown in different countries is so far very satisfactory. Johnson has shown that whereas the cultivated Para may contain over 95% of Caoutchouc and less than 4% of resinous matter, the native African rubber (Funtumia elastica) contains less than 90% of caoutchouc and over 8% of resinous compounds. From the foregoing analyses and valuation sit may safely be asserted that Hevea brasiliensis bids fair to beat many rubber trees indigenous to tropical areas. Resins in large quantities, albuminoids, and ash constituents are not required, and in many articles of commerce are injurious.

Resins.—In Para rubber the amount of resinous and oily substances varies from 1 to 4 %, when obtained from mature trees. Many analyses have been made of rubber from trees of various ages and of different species. In the case of Castilloa elastica, Weber* proved that not only does the percentage of resin decrease with the age, but that it increases as one passes to younger parts of the same tree. His figures were as follows :—

RESINS IN RUBBER OF CASTILLOA TREES.

From	Per cent.
Trunk	2·61
Largest branches	3·77
Medium ,, ...	4·88
Young ,, ...	5·86
Leaves	7·50

A similar increase in resin in the rubber from young Castilloa trees of different ages was also described, the variation being from 7·21 % in rubber from eight-year-old trees to 35·02 in rubber from trees three years old.

Weber concluded that it could scarcely be doubted that other kinds of rubber trees would exhibit similar conditions.

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* Weber India-rubber and Gutta-Percha Trades Journal, Sept. 29th, 1902.

Mr. M. Kelway Bamber has made a series of analyses of Para rubber from trees of different ages and the proportion of resin is here shown.

PARA RUBBER FROM TREES OF DIFFERENT AGES.

	Two years.		Four years.		Six years.	Seven years.
	A.	B.	A.	B.		
Resin ...	3·25 %	3·60 %	3·28 %	2·72 %	2·75 %	2·10 %

	Eight years.	Ten-Twelve years.	Thirty years.
Resin ...	2·66 %	2·26 %	2·32 %

Though the various "Plantation" and "Wild" rubbers which arrive in Europe contain resin in quantities varying from one to about 40%, they appear to be all subject to the same process, in the attempt to extract this ingredient. According to Weber* the resins can be removed by extracting with acetone in a Soxhlet extractor, the highly porous washed sheets of rubber lending themselves best to this purification process. The complete extraction of these resins from rubber requires many days. The presence of the resinous impurities influences the behaviour of the rubber in practical working and the stability of the finished article. Owing to the supposed detrimental effect of the resins after vulcanisation no efforts are spared to reduce them to the desired quantity in the inferior brands of rubber. The extraction of some of the resinous bodies from the latex of certain plants is a subject which though crowded with difficulties might profitably engage the time of the producer in the tropics.

Albuminoids.—The albuminoids which either alone or with other substances lead to putrefaction exist almost entirely in solution in the fresh latex. Their removal from commercial rubber on a large scale is considered by many to be almost impossible, and Weber suggested that an expeditious method would be to centrifugalise the solutions, a subject which has been dealt with when describing the machines used in preparing and purifying rubber.

The addition of formaldehyde to some latices is supposed (1) to prevent the coagulation of the albumen in hot solutions and (2) to cause the india rubber to collect on the top of the mixture. The proper application of this reagent to Castilloa latex is said to free the rubber from every trace of albuminous matter. It has, however, been questioned whether the caoutchouc would coagulate or even coalesce if all albuminoids were removed from the latex.

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* Weber, l.c., p 3.

There is a slightly higher percentage of proteids and resins in Para rubber from young trees and the poor physical properties of *young* plantation rubber may be ultimately associated with the proportion of these constituents present in the samples.

Ash.—This impurity is present in almost negligible quantities, 0·18 to 0·5%. Generally Para rubber contains 0·3% of ash as against 0·2% in other rubbers. Weber is responsible for the statement that it may yet be possible to chemically identify the brand of india rubber from ash analyses. Lime is said to predominate in Para rubber, magnesia in Ceara, and ferrous iron in African rubbers. The presence of the ash impurities is undesirable on account of their tendency to interfuse with the india rubber and the resinous constituents.

The insoluble constituent present in rubber is a substance which is free from stickiness, is remarkably tough and has moderate distensibility. Its nature and importance is imperfectly understood.

There is a quantity of oxygen present in india rubber, but the proportion of this is, according to Weber, reduced practically to vanishing point in successive purifying processes.

GENERAL PROPERTIES OF INDIA RUBBER.

Alkalies have not a pronounced action upon india rubber at low temperatures. Heinzerling states that on prolonged digestion with ammonia the india rubber passes into the state of an emulsion, in appearance closely resembling india rubber milk.

The effect of chlorine, bromine, and iodine on india rubber is very complicated, and for a full knowledge of the various changes which are induced by their action reference must be made to Weber (pp. 31-37). Acids exert a strong action on india rubber articles commonly used. Strong sulphuric acid oxidises rubber; strong nitric acid attacks rubber vigorously, forming at first a yellow compound which is subsequently decomposed. The effect of oxygen on crude and vulcanised rubber is to cause deterioration, a compound known as Spiller's resin being formed. Crude india rubber, particularly just after it leaves the washing machine for the drying room, is apt to suffer considerably from oxidation during the drying process, and it seems possible that similar changes may occur after coagulation and pressing in the tropics.

Though india rubber is insoluble in water it rapidly swells when immersed and absorbs a considerable amount of water, the actual amount capable of being absorbed increasing with a decrease in the resin and oily substances. On this account the rubber from young trees may perhaps be roughly detected by the water capacity of the sample of rubber, allowing for normal variations. When vulcanised the water absorption power of india rubber is small. Though india rubber does not readily react with many common reagents it does react in a surprising degree with sulphur in its various forms, the process of combination being commonly spoken of as vulcanisation.

The elasticity, resiliency, colour and smell of rubber vary considerably, according to the age of the trees, and the methods of collecting, coagulating and curing the product. Rubber from mature trees if well prepared is of a pale amber colour, has a slight odour, and is very tough; badly prepared rubber or that from young trees is frequently speckled, emits a foul odour, and may on keeping, become sticky, plastic, or brittle.

ACTION OF HEAT ON INDIA RUBBER.

India rubber becomes sticky if subjected to high temperatures. It passes into quite a liquid state at ordinary temperatures under certain conditions; if sound rubber is subjected to 170 to 180° C. it becomes more or less fluid. The melting point, if rubber can be said to have one, is much higher than this if the resin has been extracted. It is important that all drying and coagulating processes should be so devised as to ensure the temperature being regulated and a maximum temperature considerably below that just quoted should be guaranteed.

India rubber articles if exposed to high temperatures are apt to lose their strength, and to develop either sticky or brittle properties.

CHAPTER XIII.

PURIFICATION OF RUBBER.

Analysis of washed and dried Para—Purification by the manufacturers—Loss in brands of Para rubber—Plantation versus Wild Para—Loss on washing rubber—Oily and resinous substances and ash in various rubbers—Determination of loss on washing—High loss undesirable—Purification by the growers—Rubber washing machines—Burgess's machine—Construction and action—Illustration of a washing machine—Advantages of washing rubber—Scrap and dirty rubber—Chemical analyses of two samples of washed rubber—Objections to washing rubber.

HAVING dealt with the properties of the latex and the various methods of preparing rubber therefrom it is now necessary to consider the important question of the condition of the rubber when it enters the market and the processes through which it passes in purification. It is possible that much time and trouble may be saved and at the same time a rubber of higher quality be produced by carrying out certain purification processes in the initial stages. The condition of the rubber when it arrives in Europe is well-known to most cultivators as it undergoes no changes during transit if it has been properly prepared. An ordinary sample of washed and dried Fine Para Rubber may contain the following :—

Rubber	... ...	94·0 per cent.
Resinous matter	...	2·5 ,,
Albuminous matter	...	3·0 ,,
Mineral matter	...	0·5 ,,

Very often grades of washed rubber prepared carelessly contain nearly 20% of impurities, and in the case of "scrap" rubber the question of purification may become a serious one.

PURIFICATION BY THE MANUFACTURERS.

The scraps of fibre, particles of sand, abundance of resins, albuminoids, and mineral matter are not required in the finished product, and the mechanical and soluble impurities are as far as possible removed by the manufacturer. In Europe the rubber is first cut into small pieces and placed in tanks containing hot or boiling water. It is then put through the washing machines, the rollers of which tear, cut, and expose all parts of it to a current of clean water. The success of this method depends upon the rubber being cut into sufficiently small pieces and soaked for the proper length of time in water maintained at the desired temperature. The washing process removes every kind of mechanical impurity, the fragments of fibre, sand, etc. flying out of the softened rubber when it is stretched and torn between the rollers. These impurities are loosely embedded in the rubber, but if the temperature is raised too high the resins may be converted into sticky substances which will cement the rubber and mechanical impurities and thus render it impossible to remove the latter by this process.

The fragments rejoin and finally form a porous sheet, w ich, when dry, is known as washed rubber to the manufacturer.

LOSS IN MANUFACTURING.

The actual loss in these purification processes is often surprising. The loss in washing some of the Para rubber collected by the natives in the Amazon district varies from 10 to 40 per cent., and Biffen states that the loss in the factories is as follows for different grades of Para rubber:—(1) fine Para, 10-15 per cent.; (2) extra fine, the carelessly smoked pieces, 15-20 per cent.; Sernamby, rubber pulled from the cuts on the tree and cups, 20-40 per cent. Many lots of fine wild Para have, during recent times,* shown a loss on washing of from 15-16 per cent. in samples containing 2·2 to 2·9 per cent. of resin, and 0·27 to 0·59 per cent. of ash. According to Johnson the loss from fine Para is from 10-15 per cent., whereas that from the plantation biscuit rubber is only about 1 per cent. Weber† states that the fine Para rubber from the Amazon district shows a loss in washing of 12 to 18 per cent. and contains 1·3 per cent. of resin and 0·3 per cent. of ash in the dry washed material.

Different brands show a variation in the amount of the loss on washing as indicated below and the composition of the impurities are clearly put forward by Weber.

Brand.	Loss on washing. Per cent.	Oily and resinous substances. Per cent.	Ash. Per cent.
Ceylon ...	1 ...	3.0 ...	0.5
Para, hard cure ...	15 ...	2.1 ...	0.5
Para, soft cure ...	17 ...	2.5 ...	0.3
Ceara (Manigoba) ...	32 ...	2.0 ...	2·74
Borneo ...	48 ...	2.2 ...	2.2

The loss on washing is estimated by determining the yield of dry washed rubber obtainable from a known bulk of crude rubber. This loss consists mainly of water, salts, wood fibres, and mineral impurities. The oily substances form a very small part only of the total extract. Weber states that the resinous

* India Rubber Trades Journal, April 28, 1902.
† Weber, l.c. p. 122.

matter is generally semi-transparent, yellowish-brown or brown; in some cases it is semi-resilient and slightly sticky, sometimes hard and brittle, and in a few cases is white and powdery in appearance. The estimation of these oily and resinous constituents is best carried out by extracting 5 to 10 grms. of the perfectly dry washed rubber in a Soxhlet extracter by means of acetone. Many persons assume that the percentage of resinous matter in india rubber is an indication of the care bestowed upon it by the producer. This, however, is not correct as the resinous matters exist in the latex as it flows from the trees. The variation in the resin of the same brand of rubber is probably due to the condition or age of the tree from which the latex is obtained or to the mixing of milks of different qualities.

HIGH LOSS UNDESIRABLE.

If the loss on washing is beyond a certain amount the rubber will be naturally classed as inferior and in a paper* read before the International Congress of Applied Chemistry the following interesting passage occurs:—"While fifteen years ago, fine Para rarely showed a loss in washing exceeding from ten to twelve per cent. this rose within the last ten years to from 12 to 16 per cent. and in the last five years has reached from 15 to 20 per cent. During the same time, Colombia Virgin, at one time one of the finest brands of rubber, has practically entirely disappeared from the market. What little still occurs under the name is an altogether inferior product."

PURIFICATION BY THE GROWERS.

The use of machinery is bound to become more general when more rubber is collected and the means adopted for straining, purifying and coagulating the latex will minimise the loss which normally occurs in the manufacturing processes. Already a machine for washing the rubber by the grower has been strongly recommended by Mr. Burgess and others.

RUBBER WASHING MACHINE.

In rubber districts a modified wringing machine is frequently used, which though it is light and cheap, cannot usually be recommended as efficient. If a sufficiently powerful and well equipped rubber washing machine is used the effect is not only to free the rubber from a large proportion of the soluble impurities, but to produce a dried product possessing good physical properties.

A RUBBER WASHING MACHINE.

The following is Mr. P. J. Burgess's account of the new rubber washing machine.

"This machine consists essentially of two steel rollers which revolve on horizontal axes parallel to one another; the distance between the surfaces of the two rollers can be adjusted and varies from $\frac{3}{4}$ inch to practical contact.

* The India Rubber Journal, July 20.

The rollers revolve at different speeds and are driven by power transmitted from belt and pulley, through gear wheels to the rollers themselves.

The axes of the two rollers may be on the same horizontal plane, more usually one is slightly above the other; a stream of water flows over the surfaces of the rollers all the time they are in use.

THE MACHINE AT WORK.

When the machine is used, freshly coagulated lumps of rubber are put between the rollers, which are separated about ¼ inch. The rubber is passed through several times, the rollers being gradually approximated to each other, and the rubber becomes compacted and to some degree hardened. At the same time the effect of the differential rate of movement of the two roller surfaces is to subject the rubber to a shearing stress, which stretches and tears it to pieces, and it is here that the peculiar property of rubber is clearly seen. The elastic stretching and rebound kick out any gross mechanical impurity that may be present, and when the machine is used on scrap rubber there is a perfect shower of dirt, pieces of bark and wood being thrown out from the front of the machine. Freshly cut or torn surfaces of rubber reunite on contact and pressure; for this reason the fragments into which the rubber is torn by the machine reunite and emerge as a continuous sheet. At the same time the stream of water thoroughly washes out any impurity soluble in water that may be left in the rubber. The final product is a coherent but granular sheet of rubber, the thickness of which can be regulated by the distance left between the rollers. The function of the machine is thus threefold :—

1.—It ejects mechanically any solid impurity.

2.—It breaks up the rubber and subjects all portions of it to the washing effect of flowing water.

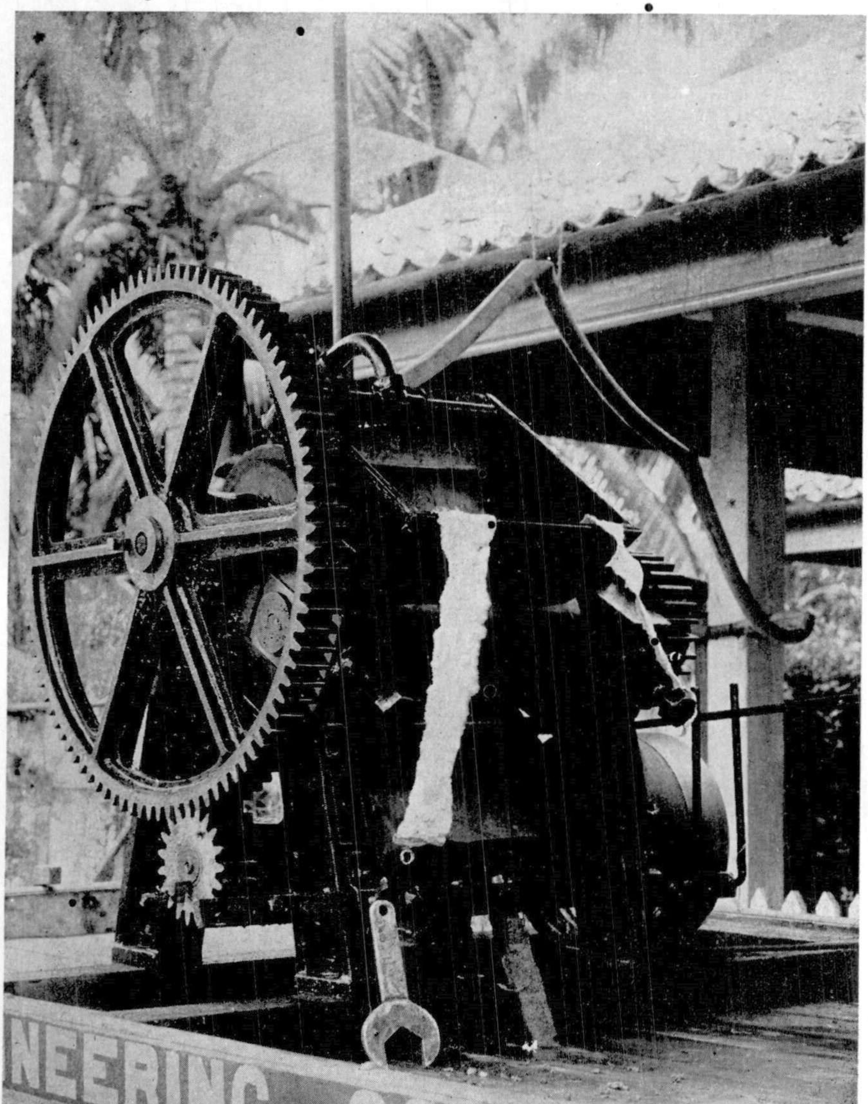
3.—It produces a granular thin sheet of uniform thickness, which is clean and which can easily and rapidly be dried.

The interests at stake are so great that I may be permitted perhaps to put in condensed form the advantages of the use of a washing machine in preparing rubber :—

1.—The rubber produced will be as pure as it possibly can be without costly chemical treatment.

2.—The rubber being pure will be of uniform quality.

3.—The rubber being washed will be ready for immediate use by the manufacturer.



Federated Engineering Co.

A RUBBER WASHING MACHINE.

SHOWING WATER PIPES AND CREPE RUBBER.

4.—It will effect a saving of labour to the planter by eliminating the petty hand labour involved in preparing rubber in small plates, rolling the sheets by hand and manipulation of the small biscuits.

5.—There will be an enormous saving of time in drying the rubber; this will involve a saving of storage room and labcur in looking after the rubber when drying.

6.—There will be no possibility of putrefaction of rubber in drying or discolouration by the growth of mould, the substances which putrefy or which feed mould being to some extent eliminated.

7.—The machines will clean and deal efficiently and economically with scrap.

8.—The washed rubber can be turned out of any length or thickness required and will be easier to handle and pack. It keeps better than the best of the biscuits prepared in the old way.

WASHING SCRAP AND DIRTY RUBBER.

But the use of a washing machine driven by an engine is not by any means confined to freshly coagulated latex. In dealing with scrap and dirty rubber its efficiency is very marked. The scrap is cleaned, mechanical impurities are ejected, dirt and mud are washed away, and the scrap is finally turned out in a form precisely similar to that taken by the first-class rubber, and in a state of purity which is only a trifle inferior to it. With rubber from Ficus elastica or Rambong the machine deals in a similar manner, and an easy and simple method of treatment of this hitherto intractable latex is made possible. Great difficulty has been found in dealing with Rambong up to the present, because it cannot be coagulated in sheets in the same way as can Para rubber. If, however, the thick latex be churned, beaten or violently shaken, it coagulates in a great lump, and to treat this lump in the old way, to dry and render it fit for export has been a matter of great difficulty and of many months. The lumps however may be treated at once with the washing machine and thin sheets produced, which are clean and which rapidly dry without difficulty."

The question of rapid washing and drying is one of the most serious with which large rubber growers have to contend. The preparation of small quantities of rubber by the "setting pan" method, and drying in spacious chambers; is not applicable to large estates; it will be necessary to collect the latex in large tanks until a sufficiently large quantity has been obtained, coagulation being prevented by the addition of reagents; the large quantity of latex can then be rapidly coagulated and the fresh rubber put through a washing machine, which will turn the rubber out in such a condition that it can be properly cured in two or three days. I am indebted to Mr Burgess and the Federated Engineering, Co Ltd., F.M.S., for the illustration on Plate 26 showing the nature of the washing machinery used in the Straits.

THE COMPOSITION OF WASHED RUBBER.

Large quantities of the Straits rubber washed by the process just described have been analysed by Ballantyne* and the following will show the composition of two samples :—

	Pale. per cent.	Dark. per cent.
India rubber.	93·27	93·60
Oily resinous matters.	3·60	3·02
Albuminous matters.	2·36	2·56
Mineral matter.	0·27	0·30
Water.	0·50	0·52
	100·00	100·00

The reports on the rubber show that the material was sound and strong and remarkably free from embedded fragments of solid matters. The percentage of mineral matter and of soluble matters extractible with water was very low, as might be expected when the rubber has been well-washed.

Several leading rubber planters in the Straits have raised objections to the washing method on the ground that the financial advantage to be derived by rubber growers by the adoption of washing machinery is not yet proven, that opposition may be met with from the manufacturers, and that washing does not remove all the impurities in the rubber.

* India Rubber Journal, May 22nd, 1905.

CHAPTER XIV.

VULCANISATION AND USES OF RUBBER.

Vulcanisation of rubber—Heat, sulphur and india rubber—Quantity of india rubber in common articles—Rubber in roller coverings, steam packing, tires, tobacco pouch and garden hose—High proportion of mixtures—Automobiles, instruments, clothing and cables.

A GREAT part of the rubber industry is dependent upon the material being in a vulcanised condition, the change being effected by mixing sulphur in one of its many forms with the masticated rubber and then heating the mixture. Usually only from 4 to 5% of sulphur is used in ordinary vulcanisation, but in the production of ebonite or vulcanite as much as 20 to 40% of sulphur may be used. A more complete distribution of sulphur through the india rubber may be possible if a solution containing sulphur be added to the latex before coagulation.

The main factor upon which the action between sulphur and india rubber depends is heat; there is no action between the two constituents until the temperature is equal to or above that of boiling water, and in Europe a temperature varying from 125° to over 300° C. is commonly used in the process of vulcanisation. If alkaline polysulphides are used vulcanisation can be effected at temperatures little above 100° C.

In this process a great part of the sulphur becomes fixed by the india rubber, but not the whole of it; there is always a certain quantity of the sulphur in a free state in vulcanised articles of commerce. Ordinary sulphur, or various compounds of sulphur may be used in this process, and the articles manufactured from such material are usually considered to be tougher, more resistent and less easily melted.

QUANTITY OF INDIA RUBBER IN COMMON ARTICLES.

The important part which india rubber and sulphur, together with other substances, play in the manufacture of articles in common use is little less than remarkable.

The following analyses are given by Weber:—

	1 Roller covering. %	2 Steam packing. %	3 Outer cover of a tire. %	4 Tobacco pouch. %	5 Garden Hose. %
India rubber. ...	24·49	12·73	54·70	50·22	31·29
Free sulphur. ...	1·23	2·10	0·88	0·27	1·83
Sulphur of vulcanisation.	0·84		1·99	2·72	2·15
Mineral Matter. ...	72·33	62·81	41·08	2·19	26·28
Organic extract. ...	1·10	2·82	1·34	4·88	7·34
Carbonaceous matter. ...	—	19·53	—	—	—
Fatty substitute. ...	—	—	—	37·21	28·90
Chlorine in rubber. ...	—	—	—	2·50	2·20

The presence of as much as 50 to 54% of india rubber in an ordinary tire and tobacco pouch, the use of nearly 30% of fatty substitutes in garden hoses, and over 70% of mineral matter in roller covering made from fine Para should be noted.

The uses of Para rubber have been greatly augmented in recent years by the increased production of automobiles and accessories, and it is difficult to accurately forecast what the demand for rubber will be when it is adopted for wheeled traffic and public passenger vehicles generally in many parts of the world. It has also been largely used in recent times in the making of boots, articles of clothing, instruments, belting, and "solution". Plantation rubber is preferred for "solutions" on account of the manufacturers being able to use it direct with the solvents without purification.

The use of cheap substitutes and of rubber mixed with various materials for cables is now becoming a serious matter. The cable maker cannot easily afford to pay 8s. 6d. per lb. for the pure material.

In Ceylon the Telephone and Telegraph section of the Post Office Department have, according to Mr. Cook, been contemplating the use of the paper and dry air insulation afforded by the so-called Dry Core cables for underground and sub-aqueous extensions, but the local conditions are so different in regard to the soil and the atmosphere that the engineers have not made up their minds as to the desirability of the change from Vulcanised Rubber Insulation. Nevertheless, cheap substitutes are being used in cable work, in many parts of the world.

Gutta percha has been tried both in Ceylon and India, but the concensus of opinion is that for tropical installations it is far inferior to india rubber.

CHAPTER XV.

KINDS OF PARA RUBBER.

Plantation and fine hard Para—Uses of Plantation and cultivated rubber—Chemical and physical tests—Commercial reports on Plantation rubber from Ceylon and the Straits—Biscuit and sheet rubber—Crêpe rubber, characters, preparation and value—Worm rubber, characters, preparation and value—Illustrations showing "worm" manufacture—Lace rubber, preparation by mechanical means—Illustration of machinery used in the manufacture of lace rubber—Scrap rubber—Chemical Analyses of biscuit, crêpe, lace and worm rubber.

THE DIFFERENCE BETWEEN PLANTATION AND WILD RUBBER.

THE comparison of the kinds of Para rubber may appropriately be prefaced by a few remarks regarding the differences between Plantation and Wild or fine hard Para rubber, the former being obtained from the newly-planted trees in the tropics and the latter from the old trees in the Amazon district.

The methods of preparation in the East are such that Plantation rubber is made much purer than the fine hard Para; it contains very little, if any, moisture, and is obtained with or without the use of chemical reagents. It is, of course, usually obtained from younger trees than the fine hard Para. The Plantation rubber when placed on the same market as the "wild" obtains a higher price, weight for weight, because of the small quantity of water and other impurities present, the loss on washing being only about 1% as against 10 to 20% for some grades of fine hard Para rubber. The extraction of the impurities from the latter rubber is not always very troublesome, and if allowance is made for the large quantity of water it contains the price realised is really much better than that for Plantation rubber free from moisture.

The preference of the manufacturers for purified fine hard Para rubber is due not so much to its being obtainable in large quantities as to the fact that its properties are much more constant and lasting. Examples are known of samples of pure Para Plantation rubber which in two years have resolved themselves into a gummy substance, void of all the desirable properties of india rubber, whereas samples of purified fine hard Para rubber have been perfectly sound after seventy years. The plantation rubber is usually regarded as wanting in resiliency and recuperative power, but when put on the market as clean biscuit, crêpe, or worm rubber is eagerly bought mainly for "solution" purposes.

The opinion in many quarters is that the use of chemicals such as acetic acid, formalin, etc., should not be continued if the Plantation rubber can be effectively prepared and purified by mechanical means.

CHEMICAL AND PHYSICAL TESTS.

The inferiority of Plantation rubber is commonly attributed to the trees being immature as compared with those in the Amazon district. But it has been previously shown that in the Amazon district trees are tapped when they are 15 years old, and when forest Para rubber trees are 25 years old they are described as having reached maturity. In view of these facts it is interesting to reflect on the chemical analyses of rubber from trees 4, 6, 8, 10-12 and 30 years old, already given on page 48. These analyses have been made from rubber obtained from Ceylon-grown trees, and it is fortunate that the age can be guaranteed. They show very clearly that the variation in chemical composition between the rubber from young and 30-year-old trees is insignificant, and that the reputed defects of rubber from young trees cannot be explained from the differences in the chemical analyses given. There is as much variation between the chemical composition of samples of rubber from trees of the same age as between those given for the material obtained from trees 4 to 30 years old, and the ordinary analytical methods do not appear to give indications of the great differences in physical properties. From these and other considerations one feels compelled to seek for some other tests, of a physical nature, whereby the rubber may be scientifically classified, and which will allow of the value being calculated on a sound basis. Colour cannot be accepted as a guide, though preference seems to be given to the pale amber colour by many manufacturers; only in the case of really bad samples can odour be taken as indicating quality as the best biscuits have often a cheesy putrescid smell which is more or less transient. In this chapter it will be seen that certain physical tests have been devised, and the results obtained with samples of Plantation rubber from the East are given. It is not impossible that the physical properties of rubber will ultimately be associated with the quantity and nature of the ingredients indicated in the numerous chemical analyses which have been quoted, but at the present time the valuation of different kinds of Plantation rubber is not based on chemical analysis, but mainly on appearance and physical characters.

The "India Rubber Journal" of August 28 published a series of reports regarding various samples of plantation rubber from the East. Opinions as to the strength and general value of cultivated rubber have shown considerable variation, and though the con-

PLATE 27.

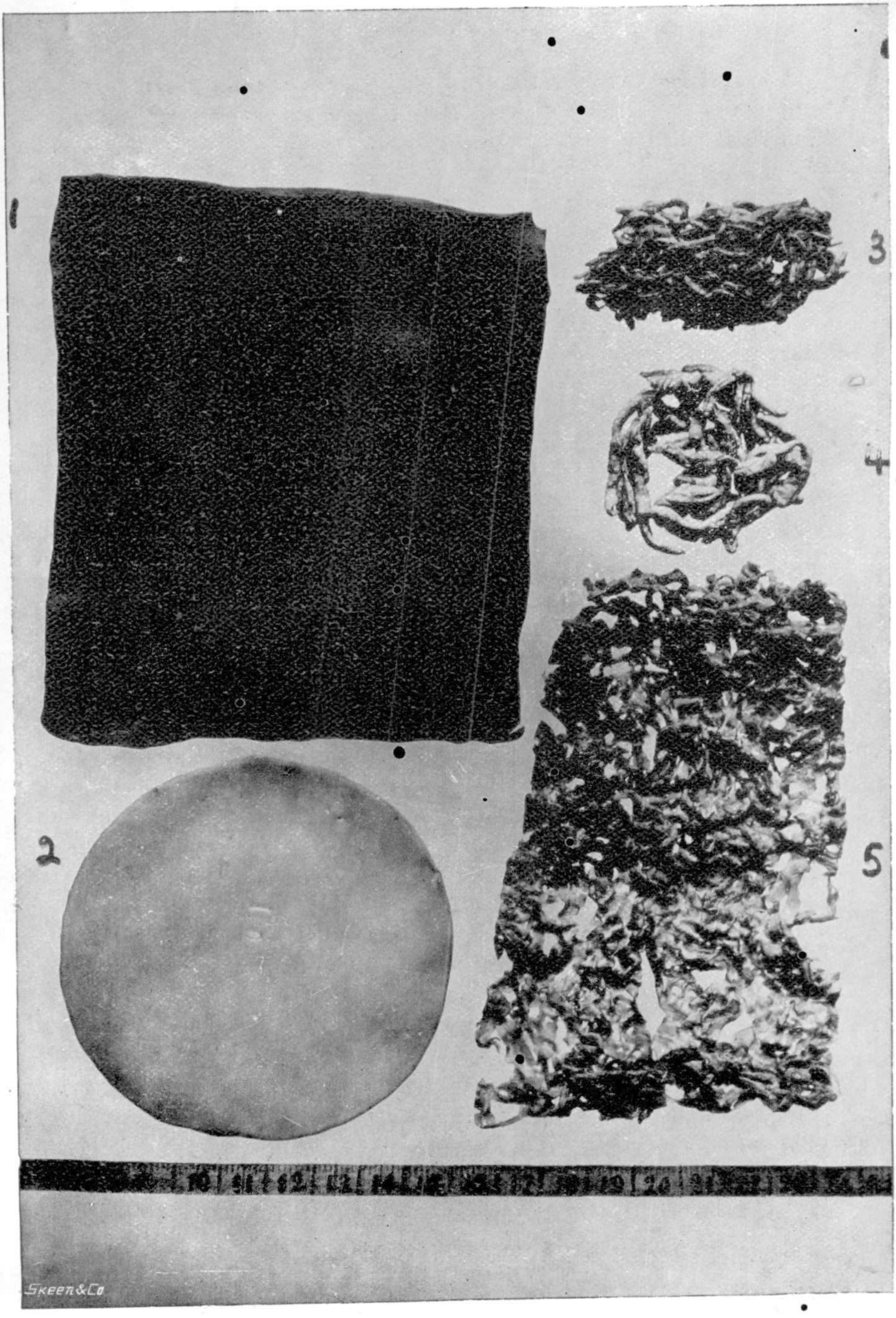


Photo by H. F. Macmillan.

KINDS OF PLANTATION PARA RUBBER.
(1) SHEET; (2) BISCUIT; (3) & (4) WORMS; (5) LACE.

clusions embodied in the previous paragraph may be taken as representing the opinions of a large number of manufacturers, it has frequently been stated on good authority that cultivated Para rubber was equal in tensile strength to native-cured Para and after vulcanisation gave very good results. The differences in strength noticeable in Plantation rubber are usually ascribed to the tapping of young trees and irregularity in mixing the latex from trees of different ages; the latter cannot help but occur on small estates where very few of the trees are even ten years old.

Regarding certain samples of Plantation rubber it has been stated that when worked on the mill the light coloured samples gave the odour peculiar to fine Para when prepared without the use of smoke.

On the mill they prove to be much softer than dry sheet Brazilian Para. They also take the "compound" much more rapidly than the Amazonian variety. To assist in comparing the tensiles obtained from the several brands of Plantation rubber the data is presented in tabular form. The term "Tensile" means the pounds required to break $\frac{1}{4}'' \times \frac{1}{4}''$ in section of the compounded rubber.

Conditions.		Ceylon Samples.			Other Samples.	
Steam Pressure. lb.	Time. Min.	Doranakande.	Suduganga.	Kalutara.	Bukit Rajah.	Pataling.
45	10	50	121	99	83	97
45	15	77	113	138	115	136
45	20	88	143	133	104	140
45	25	78	127	121	107	125

From the above analyses the same journal proceeds to state: (1) "That Ceylon Para when used to denote the oriental source of fine Para means a grade *lacking in uniformity*, when the tensile strength is considered; (2) the curing qualities of Ceylon fine indicate that it has a decidedly slower action than the South American product; (3) all the Oriental samples are much softer and are less nervous than the Occidental types."

FORMS OF PLANTATION RUBBER.

Having compared the differences of Plantation and Brazilian rubber it now remains to deal with the various forms of the cultivated rubber which are briefly (1) sheets, (2) biscuits, (3) crêpe, (4) worm, (5) lace and (6) scrap rubber. The illustrations on Plate 27 will show their general appearances.

The *biscuit* and *sheet* rubber are most commonly met with and are prepared by allowing the latex to set in shallow receptacles with or without acetic acid, and washing and rolling the cake of rubber which appears at the top. The biscuits are more or less circular and the sheets rectangular in outline. They are sometimes pressed together to form blocks, and the sheets, on account of their shape, lend themselves to more economic packing than most other forms.

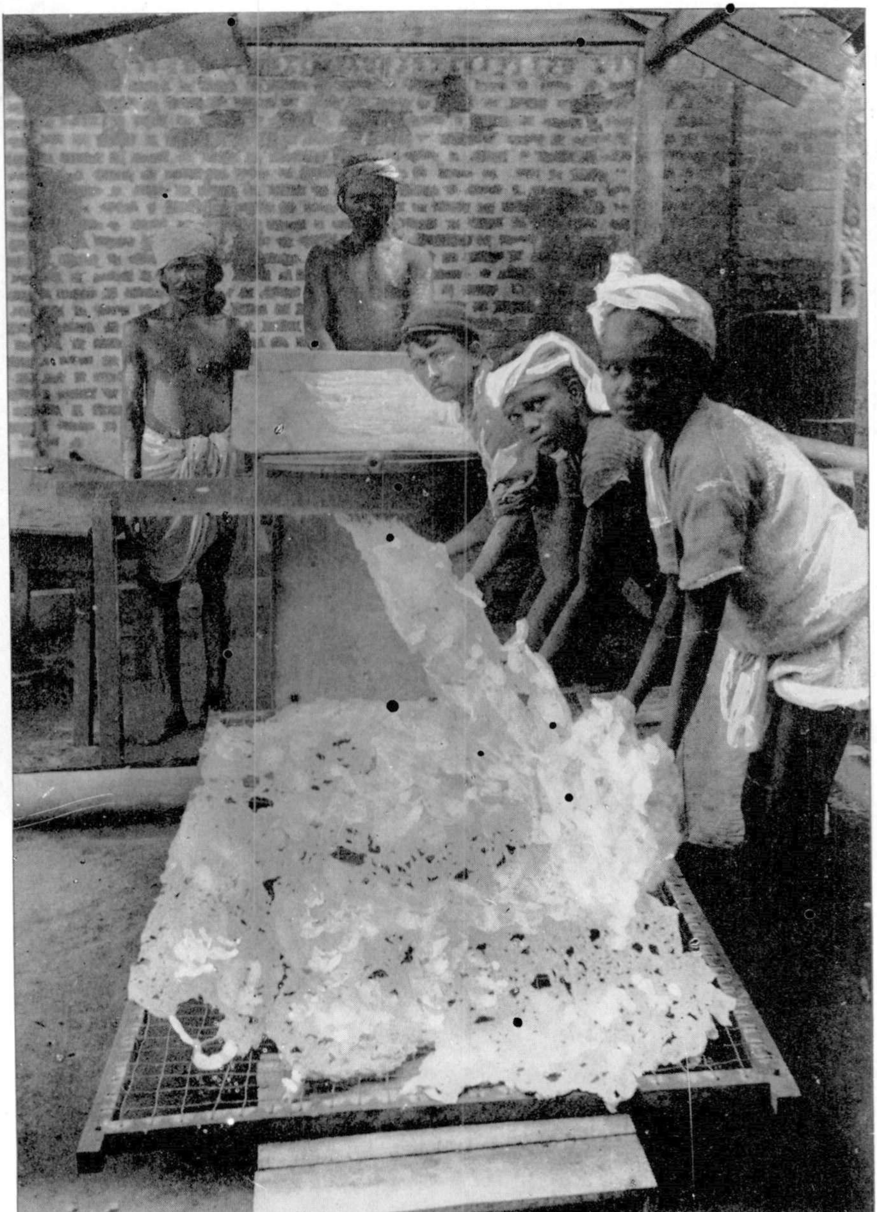
The biscuits and sheets are usually very pure and can without washing be used for "solution" work by the manufacturers; the material is practially ready for the naptha bath on its arrival in Europe. It has been stated that the material from Ceylon shrinks about 1·4%, and that it is not liked for cements. In past times it has been very irregular in quality, sometimes being little better than elastic gum, sometimes sticky and only equal to recovered rubber in elasticity. The rubber biscuits from old Para trees are tough and elastic, and much of the irregularity referred to might to some extent be obviated by not mixing the tappings from trees of different ages. If the irregularity in quality is allowed to continue it may spoil all prospects for use of our rubber in fine work, such as thread, bladders, etc., and if the "solution" market should become overstocked the position might under such circumstances be embarassing to rubber planters in Ceylon and the Straits.

Crêpe rubber differs from the foregoing on account of the stretching and tearing it has undergone between the rollers of the washing machine, and the low quantity of soluble and mechanical impurities it contains. It is of course only washed rubber, but it may have been obtained from purified scrap as well as the other class. It has an irregular surface, is very uneven in thickness and dries rapidly. On account of its purity it has been well reported upon in Europe, and owing to the efforts of Burgess is likely to come to the front in the Straits. Crêpe rubber has been described in Europe as "fine pale, strong, quite clean and in good condition." The material has been sold at a good price, but on account of the washing and rewashing which certain manufacturers subject *all* rubber to, it has been questioned as to whether the extra labour involved in its preparation will be paid for by the higher price. In any case it will always rank as a relatively pure rubber and will allow of the conversion of scraps and other kinds to one class of uniform standard.

Worm rubber is essentially the product obtained by cutting irregular sheets of freshly-coagulated rubber into thin worm-like rods of unequal length. The Michie-Golledge machine is used to coagulate the latex; the fresh rubber is rolled to express the water, and the irregular cakes are cut up by means of large shears. The fresh rubber being cut into such fine parts dries quickly; the "worms" can be economically packed in ordinary tea boxes.

Samples of worm rubber have up to the present received good reports, the concensus of opinion being that the rubber so prepared was very clean and contained very little moisture: once it has established a name it might command a price equal to, or higher

PLATE 28.



F. Holloway.

HOLLOWAY'S LACE RUBBER MANUFACTURE.

than, biscuits on account of its purity and dryness. Plate 22 shows the freshly-coagulated spongy mass, which, after passing through the rolling machine shown on Plate 23 is ready for cutting into worms.

Lace rubber has been prepared by Mr. Francis Holloway, Matale. It consists of very thin perforated sheets of considerable length. In the preparation of lace rubber the latex is coagulated without the use of acids or application of heat, and after being converted into lace is dried in air kept at about 95° F. The porous sheet is very thin, of a pale amber colour, and can be easily pressed into biscuits or sheets of any desired thickness. The "lace" comes out of the machine in a continuous strip; it is cut into pieces 6 feet long as it runs on to wire trays. The rubber is very thin and dries rapidly; it is maintained that it can be turned out ready for drying within seven minutes of the latex arriving at the factory. The time taken for coagulating the latex, conversion into lace rubber and drying ready for despatch is 30 hours. Mr. Holloway assures me that only mechanical methods are adopted, a point of considerable importance. The illustration on Plate 28 shows the machinery used by Mr. Holloway.

Scrap rubber is mainly the coagulated rubber obtained from the incised areas, rolled into balls or made up into cakes. It may be sent to Europe in the crude state, with all its mechanical impurities, or washed, purified and converted into Crêpe rubber before being despatched.

ANALYSES OF PLANTATION RUBBER.

The following analyses of the different forms of rubber are tabulated for reference, though a wide variation must be allowed in each case. A general average composition cannot be given until a larger number of analyses have been made.

	Ceylon Biscuits.	Ceylon Lace.	Ceylon Worms. A.	Ceylon Worms. B.	Straits Crêpe. Pale Sample.	Straits Crêpe. Darker Sample
	%	%	%	%	%	%
Moisture	0.85	0.50	0.90	0.70	0.50	0.52
Ash	0·14	0·12	0·20	0·20	0·27	0·30
Resin	2·66	2·68	3·50	2·06	3·60	3·02
Proteids or Nitrogenous matter	1·75	2·62	3·85	3·67	2·36	2·56
Caoutchouc	94·60	94·08	91·55	93·37	93·27	93·60
	100·00	100·00	100·00	100·00	100·00	100·00

I am indebted to M. Kelway Bamber, Esq., for the analyses of biscuit, lace and worm rubber, and to P. J. Burgess, Esq., for the privilege of using the analyses of crêpe rubber from the Straits, by Herbert Ballantyne, F.I.C., F.C.S.

CHAPTER XVI.

DISEASES OF PARA RUBBER TREES.

Diseases on plants grown on small scales—Epidemics over large acreages—*Leaf* diseases of Para rubber—Fungi, Helminthosporium, Periconia, Cladosporium, Macrosporium, Pestalozzia, Cercospora—Preventive measures—Fungi on leaves in Brazil and Java—Insects, plant-sucking bugs, weevils, and mites—Preventive measures—*Fruit* diseases of Para rubber—Fungi, Nectria and Phytophthora—Preventive measures—*Stem* diseases of Para rubber—Fungi on old stems and green twigs—Preventive measures—Insects, wood-borers, ants and slugs—Preventive measures—*Root* diseases of Para rubber—Fungi in Straits and Ceylon—Polyporus, Helicobasidium and Hymenochæte—Insects, termites, cockchafers, grubs—Preventive measures—A disease on *prepared* rubber—Probable causes and preventive measures—Chemical analyses of tacky rubber.

IT is often relatively easy to successfully grow a small number of plants in any particular district without their suffering from the ravages of innumerable insects and fungi. But if the same crop is grown on a large scale matters often take a different turn. It has frequently been my experience when dealing with minor products on a small scale to find that the diseases to which they were subject never developed to a serious extent, but when once the product was greatly extended, the insignificant diseases became a serious menace to the plants and often rendered further cultivation impossible.

It would appear on first considerations that any pest, which found a desirable means of sustenance on the tissues of a particular plant, would increase to such an extent that the few host plants in the neighbourhood would be exterminated. But for some reason or other, many pests do not appear to behave in this manner, and it is only when the host plants occur in large numbers and over extensive areas that anything like an epidemic is noticeable.

Perhaps the occurrence in large numbers of the host plants in widely separated districts ensures that the pests will find the requisite means of sustenance no matter where they occur, and their propagation be thereby ensured. The larger their food supply the quicker they will increase in number and ultimately prove more serious to the crop on which they are living. On these grounds the contention of Colombo friends "that the cultivation of Para rubber to the exclusion of other kinds of rubber is a dangerous system" has probably much to recommend it.

In any case it is well to realise that trees of Para rubber, whether growing under unhealthy or perfect conditions, are not immune from the attacks of parasitic fungi and insects, even at a time when the number and age of the host plants may seem to be almost negligible. The best advice which can be given is to attack all diseases in their earliest stages before the parasites have increased beyond easy control. It is fortunate that among the 28 diseases or pests mentioned below none are of a serious nature, but they are nevertheless worthy of full consideration.

LEAF DISEASES.

There are already several insects and fungi which live on the leaves of the Para rubber trees, but none of them are very harmful. To a very limited extent the annual fall of leaf that takes place on all Para rubber trees after they have passed their second or third year is an advantage when dealing with leaf pests, as the foliage can be easily and regularly collected and burnt. Again the leaves may happen to fall prior to the formation of the spore-producing bodies, and in this way assist to some extent, in checking the spread of disease. But it should be remembered that the Para rubber trees are in possession of their foliage for about 50 out of every 52 weeks each year, and to assume that the leaves owing to their deciduous character are not likely to contract a permanent disease is by no means sound.

Fungi.—Leaves of Para rubber seedlings and of older plants have been attacked by a species of Helminthosporium*; the leaves were "studded with circular, semi-transparent spots, each surrounded by a brown cushion from which arose the threads of the fungus." It was suggested that the spots were due to punctures by insects and the fungus grew on the dead tissue. Damaged parts of the leaves of Para seedlings are also subject to the attacks of Periconia pycnospora, † and species of Cladosporium and Macrosporium.

A species of Pestalozzia—identical with that which is associated with the "Grey Blight" on tea leaves—has also been found by Petch on leaves of nursery seedlings of Hevea, and according to the Mycologist were probably infected by wind-blown spores from the adjacent tea. The fungus produces white irregular areas spreading generally from the tip of the leaf. In the Straits,‡ the leaves of the Para rubber seedlings have been attacked by a fungus, regarding which Mr. Massee reported "the pale blotches on the leaves are

* T. Petch, Mycological notes, Tropical Agriculturist, June 1905.
† ,, l. c.
‡ Agriculturist Bul. of the Straits and F.M.S., July 1905.

caused by some species of Cercospora, but the absence of fruit prevents specific indentification." Ridley states that this leaf fungus is common all over the Malay Peninsula, but that except in the case of seedlings does not do much harm.

Petch has recently found a species of Glœosporium on the leaves of seedlings; the fungus forms light brown spots on the upper surface of the leaves, and finally the latter turn yellow and fall.

It is satisfactory to know that up to the present time the leaves of mature Para rubber trees are practically free from parasitic fungi, but the disease on the leaves of seedlings is one which leads to partial defoliation and checks the growth of the young plants. In all such cases the diseased leaves should be picked off and burnt and the rest of the plants sprayed with Bordeaux mixture; this consists of 6 lb. of copper sulphate and 4 lb. of freshly-slaked burnt lime in 45 to 50 gallons of water.

In the Amazon district two fungi known as Ophiobolus heveæ, Henn., and Dothidella Ulei Henn., have been described as occurring on the leaves of the wild Para rubber.

In Java, Zimmermann in the Bull. Inst. Buitenzorg, has recorded several fungi on Para rubber. Phyllosticta Heveæ, Zimm., is a fungus causing brown spots especially at the tips of the leaves; Glœosporium elasticæ, Cooke and Mass., is another leaf fungus which produces light greyish-green spots and masses of reddish spores.

Insects.—According to Green * the leaves of Hevea are reported to have been punctured by certain plant-sucking bugs, the most likely species being Leptocerisa acuta and Riptortus linearis; the former is known as the "Rice-sapper". It appears that these pests puncture the leaves and stems. "The injured leaves show numerous small spots, each bordered by an irregular dark rim, within which the tissues have dried and turned white". It is believed that the injury to the leaves is due more to a fungus than to an insect.

A scale bug—Lecanium nigrum, Nictn., has also been observed by Green on the leaves of young Para trees, but this can be easily destroyed by means of Macdougal's mixture. The tips of seedlings occasionally turn black and dry up, and it has been suggested that this may be due to some plant-sucking bug. A species of weevil, allied to if not identical with Astychus lateralis, has been known to eat the leaves of Para rubber in the Straits † and the only remedy is to collect and destroy the weevils.

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* E. E. Green, Entomological notes, Tropical Agriculturist, April and May, 1905.

† Wray, Perak Museum notes, 1897.

"Mites" in rubber nurseries have also been reported from the Straits.* Arden states that in some cases the young leaves fall from the plant before they are fully developed, and in other cases the mature leaves present a crinkled appearance, are yellowish-green in colour, and appear to be dotted with numerous punctures. He compares it to "Red Spider" and believes that the disease is mainly limited to plants growing under unfavourable conditions.

Spotted locusts have also been reported to do considerable damage to the young rubber plants in Ceylon and the Straits.

FRUIT DISEASE.

Para rubber planters in many parts of Ceylon have occasionally been alarmed at the curious behaviour of certain fruits; some dry up and remain attached to the twigs, and others of all ages fall to the ground without expelling the seeds. The fall of the unexploded fruits is often due to wind and there is no parasitic fungus to be found in the tissues. It has, however, been stated that the fruits are subject to the attack of a parasitic fungus belonging to the genus Nectria, and Carruthers† reports having successfully inoculated Para rubber fruits with this fungus, but was not certain as to whether it attacked the fruits when on the tree or only when they fell to the ground. Petch ‡ subsequently stated that "the disease on Para rubber fruits is due to a parasitic fungus similar to, if not identical with, that which causes the decay of Cacao pods. All the Hevea fruits examined were attacked by a species of Phytophthora, which permeates the soft outer tissues of the fruit; the seeds dry up later when the supply of food and water is cut off. In addition to the ordinary spores which infect other fruits while the original fungus is flourishing, resting spores are formed in the dead fruit. These are liberated when the fruit decays, and thus serve as a source of infection to the following crop. In this way the fungus bridges the gap between the crops."

The most effective way of fighting the fruit disease is to collect all dried fruits which are on the tree and those which have fallen to the ground and burn the lot on the spot. On the average rubber estate there can be no real objection to burning such small quantities of fruits as this treatment involves.

STEM DISEASES.

Fungi.—In his account of canker (Nectria) of Para rubber, Carruthers points out that a parasitic fungus occurs in the stems and branches which may prove fatal to the trees. The areas attacked by the fungus can be detected often by the change of colour of the bark or by the exudation of the latex. When, how-

* Stanley Arden. Agr. Bull. of the Straits and F. M. S., June, 1905.
† J. B. Carruthers, Circular of the R. B. G. Peradeniya, January, 1905.
‡ T. Petch, Mycological Notes, Tropical Agriculturist, 1905.

ever, the fungus has got a firm hold of any local patch of tissue, the latex tubes become quite empty and dry up, so that it not only threatens the life of the tree, but also robs the planter of the latex or rubber for which the tree is being cultivated. It is necessary that all cankered areas should be excised and the tissue burnt on the spot. All the discoloured areas should be removed even if the woody tissues below the cambium are permanently damaged in the operation. In some cases it is true that the cankered area is, by means of a layer of cork, prevented from extending to other parts of the stem, but it is unwise to leave the matter to chance.

The disease mentioned above has been found by Carruthers on "almost all parts of the tree except the young branches and the roots," but even these parts have now been shown to be attacked by other fungi.

Petch* has observed a blackening of green stems of Para rubber trees to be due to a fungus which produces a network of dark-coloured threads on the exterior.

Grey blight on the stems of seedlings has also been observed by the same botanist. The fungus forms a white zone about an inch long just above the surface of the ground; the stems lose their pith, become hollow, and the plants die.

The curious knobs and the irregular surfaces on the trunks of Para rubber trees are not due to parasitic fungi; they are wounds which have been made by falling branches or they are due to carelessness in tapping operations. Of course, they may serve as lodging areas for the spores of fungi or undesirable insects.

Insect pests.—Ridley has reported the existence of a borer which may attack the wood of Para trees and identified it as belonging to the genus Platypus.

Ants† attack the incised areas six feet from the ground and in some cases construct earthworks up to a height of 30 to 40 feet and enter the tree at some weak point or wound area. The white ant—Termes gestroi—is reported to be one of the most troublesome pests in the Federated Malay States. Arden, when dealing with the loss of Para rubber trees in the Straits, points out that there may be some association between the ravages of the white ants and the fungus of the roots of Para rubber. Similar relationships have been suspected in Ceylon,‡ where the taproot had probably been eaten by white ants and the dead roots were covered with a network of white fungus hyphæ. "The fungus attacked the sound wood and bark, and that the injury was due to this was supported by the receipt from another locality of a

* T. Petch, Mycological Notes, Tropical Agriculturist, August 1905.

† Stanley Arden, Annual Report, 1902.

‡ T. Petch, Mycological Notes, Tropical Agriculturist October, 1905.

young plant which had been killed by apparently the same fungus. In this case there were no side roots; the plant therefore died after the taproot had been permeated by the fungus, and as this was indicated by the withering of its leaves, it was uprooted before the white ants discovered it."

Green states that he has repeatedly received specimens of *dead* branches and stems of Hevea brasiliensis, perforated by a Bostrichid beetle, (Xylopertha mutilata, Wek.), but he believes that in every case the beetle has effected its entrance after the death of the parts.

Slugs * (Limax sps.) have also been reported as attacking the stem and eating the remains of the latex left in the wounds after tapping. "Living specimens of the slugs received at Peradeniya were fed with fresh latex. Its presence was almost immediately scented out by them. One of them drank for about ten minutes." Hand-picking or the use of quick-lime should be effective.

ROOT DISEASES.

Fungi.—A root disease due to a fungus has already been mentioned as occurring in the Straits and Ceylon in association with white ants, but probably preceding them. Petch has shown that the Ceylon fungus can spread underground on roots of grasses, etc., and that it is probably a species of Polyporus. The hyphae are described as occurring on the first six inches of the trunk as well as the roots. Any trees so affected should be isolated by digging a deep trench round them about a foot wide, as in the case of the root disease in tea.

A fungus (Helicobasidium sps.) has been found attacking the roots of Para rubber in the Straits.† This fungus usually spreads rapidly from tree to tree by means of strands of mycelium, and trenching and liming are generally recommended as preventive measures.

Another root disease has been found in Ceylon by Petch.‡ This one has also been found on cocoa, tea, and Caravonica cotton in Ceylon, but is not very dangerous. "The roots are covered with a thick, yellowish-brown felt which sometimes develops a black crust exteriorly. Stones, sand, etc., are firmly attached to this covering, and give the appearance of pudding-stone." It is believed to be a species of Hymenochæte.

Insect Pests.—"Specimens of Termites § (T. redemanni) have been sent with the report that they were eating off the tap-roots of young rubber plants. A mixture of lime and sulphur, forked into the soil immediately round the plants has been

* E.E. Green, Entomological Notes, Tropical Agriculturist, September, 1905.
† Johnson, l. c.p. 29.
‡ T. Petch, Mycological Notes, Tropical Agriculturist, October, 1905.
§ E. E. Green, Entomological Notes, Tropical Agriculturist, April, 1905.

found effective in preventing the attacks of white ants. The proportions are one part powdered sulphur to four parts of lime. In replanting, the holes should be filled with earth mixed with lime and sulphur, in the proportion of one basket of sulphur, four of lime, and seven of soil. This should protect the new plants from any underground attacks.

Grubs of a large cockchafer (*Lepidiota pinguis*, Burm.) have been received by Green * from Yatiyantota, with the report that "it is found about two inches below ground level. It bites through a live stump (of Para rubber) of any size. The only way one can tell that it is working is by seeing the green shoot on the stump die back. On touching the stump it breaks off." Specimens of injured stumps (of about the thickness of a lead pencil) were sent in with the grubs. The taproot has been severed an inch or two below the collar, and every vestige of a side root has disappeared. Alkaline manures, such as Kainit and nitrate of soda, have been found useful in driving away cockchafer grubs. The manure should be forked in round the plants in clearings affected by the pest. The same species was recorded in 1902, from the Negombo district, where it was attacking the roots of cinnamon bushes. The adult beetle is of considerable size, being fully an inch long and proportionately stout. The larva is a white fleshy grub, two inches in length, the body curved round into the form of a horse shoe. It has very powerful jaws with which it works great havoc on the roots upon which it feeds."

"A formidable looking grub of some large beetle (Buprestid or Longicorn?) has been sent by a correspondent from Ruanwella. It is said to have been found in the taproot of a rubber tree that had died and broken off. The pest in its larval stage, working—as it does—below ground level, will be difficult to attack."

A DISEASE ON RUBBER.

It seems as though enough has been said regarding the troubles of all parts of the plants with fungi and insects, but this note deals with a disease on the prepared rubber and cannot be omitted. The signs of the disease are that the rubber becomes at first sticky or "tacky" and rapidly softens until it is almost liquid. It can be spread from one biscuit to another by contact. It is supposed to be due to bacteria which first commence to grow on the sugary and gummy substances in imperfectly washed rubber and ultimately on the decomposing proteid or albuminous material previously referred to. It can to a great extent be kept in check by well washing and squeezing the freshly-coagulated rubber, rapid drying without exposure to high temperatures and the use of formalin in the latex and on the prepared rubber. Mr. Kelway Bamber recommended that the biscuits be wiped with a solution of Formalin, diluted to make a 2% solution, and the biscuits not be allowed to touch one another earlier than necessary.

* E. E. Green, Entomological Notes, Tropical Agriculturist, October, 1905

The first rubber obtained from old trees or that from young trees seems very liable to undergo putrefactive changes. It has been suggested that these decomposition processes may be due to molecular changes of one or more of the constituents of prepared rubber in which case it would be very difficult to adopt measures to prevent the undesirable result. It has also been pointed out that the presence of large quantites of oily and resinous substances having a low melting point may be the cause of much liquefaction and subsequent decomposition. The chemical analyses of rubber showing varying degrees of tackiness have already been given. They appear to indicate some relationship between the high percentage of resins and proteids and the degree of stickiness and liquefaction. For the sake of comparison the analyses of sound and very tacky rubber are here reproduced.

	Sound Rubber. per cent.	Very Tacky Rubber. per cent.
Moisture	0·30	0·44
Ash	0·38	0·72
Resin	2·36	3·70
Proteids	3·50	4·90
Rubber	93·46	90·24
	100·00	100·00

The development of bacteria which has been shown to be associated with putrefactive changes of rubber can however be overcome either by inoculation, effective drying or the use of antiseptics.

CHAPTER XVII.

WHAT TO DO WITH THE SEEDS.

Number of seeds per tree—Seed characteristics—Value—Seed oil and fat—Meal and cake—Analysis of meal—Cake of Para rubber seed compared with Linseed and Cotton cake—Packing Para seeds for transport—Charcoal, sawdust and Wardian cases.

IT is well-known that trees of Hevea brasiliensis flower and fruit after their fifth year in Ceylon. In other countries plants raised from cuttings have been known to produce fruits within three years. Each fruit usually contains three seeds, and the number of seeds annually produced per tree is about five hundred, when the trees are mature.

The following interesting information was published in the "Times of Ceylon" regarding the number of seeds produced from a five-year-old tree and its offspring, assuming that each tree after attaining its fifth year produces 500 seeds annually.

Year.		Total seeds at end of each year.	Year.		Total seeds at end of each year.
1st	...	501	11th	...	130,255,501
2nd	...	1,001	13th	...	1,259,006,501
3rd	...	1,501	15th	...	4,388,757,501
4th	...	2,001	17th	...	323,019,508,501
6th	...	253,001	18th	...	952,522,759,001
8th	...	1,504,001	19th	...	2,208,151,259,501
10th	...	3,755,001	20th	...	4,402,530,010,001

The 500 old trees at Henaratgoda and Peradeniya produce annually about 200,000 seeds equal to approximately one ton by weight. At the present time there are no less than 40,000 acres of Para rubber trees in Ceylon, more in the Straits, and very large areas in other parts of the world. It is therefore necessary to study the properties of the seeds, in the event of more being produced than are required for planting purposes. It is obvious from a glance at the above table that, before long, very large quantities of seeds will be available.

The seeds of Para rubber contain an oil which has been valued* at £20 per ton, and also yield a cake which may be valued at £5 to £6 per ton. The decorticated seeds have been valued at £10 to £12 per ton, and brokers in Europe consider that it would be more profitable to ship the seeds from the tropics to Europe.

PARA RUBBER SEED OIL AND FAT.

"The kernels * constitute about 50% by weight of the whole seeds and yield 42·3% of oil. The husk and kernel together yield 2% of oil. The oil is clear, light yellow in colour, and on saponification with caustic soda furnishes a soft soap of yellowish colour. If the seed has been ground to a meal the oil extracted is solid owing to decomposition; but that expressed from the freshly ground seed is liquid. The husks contain a solid fat in small quantities."

PARA RUBBER SEED, MEAL AND CAKE.

Old ground seed so finely divided as to form a meal was reported upon by the Imperial Institute as follows :—

CHEMICAL ANALYSIS.

	per cent.		per cent.
Moisture	9·1	Oil	36·1
Ash	3·53	Proteids	18·2
Fibre	3·4	Carbohydrates ...	29·67

The ash was found to contain 30·3% of phosphoric acid present in the form of phosphates, which is equivalent to 1·07% of phosphoric acid in the meal.

The meal thus prepared is unsuited for cattle food on account of the large quantities of free fatty acids and cannot be used for oil extraction. "It is probable, however, that if the oil were expressed from the decorticated seeds, the residual cake could be utilised as a feeding material, as is shown by the following comparison between the calculated composition of such a cake and the compositions of some commercial feeding cakes."

	Calculated Composition of Para rubber Seed cake. per cent.	Linseed Cake. New process. per cent.	Linseed Cake. Old process. per cent.	Cotton seed cake. New process. per cent.
Moisture ...	13 36	9·4	10·8	11·12
Ash	5·19	5·4	5·0	6·10
Proteids ...	26·81	35·6	28·6	38·47
Fibre	5·00	7·1	6·7	9·78
Fat	6·00	7·5	10·6	8·78
Carbohydrates ...	43 64	35·0	38·3	25·75
Nutrient value ...	84·25	87·85	91·28	84·4

"These figures show that a cake prepared from Para rubber seed meal may form a good cattle food, and that it contains very little indigestible matter."

* A Report of the Director, Imperial Institute, London.

There is therefore in Para rubber seeds an economic product which may soon become important commercially, and providing the oil is expressed from the kernels before the meal or cake is made, the residue may be used in the tropics either as cattle food or manure.

PACKING SEEDS FOR TRANSPORT.

The difficulty of transmitting seeds of Hevea brasiliensis to distant countries is well-known; the seeds do not retain their germinating capacity for a very long time except great care is taken in collecting and packing operations.

Twenty seeds were sent from Singapore on February 12 to Mexico, where they arrived on May 2 in the same year; from these fourteen plants were raised.

Seeds of Para rubber, after being dried in the sun for a short time, packed in dry earth, and sent from Penang and Ceylon to India, have arrived in the latter place with only 17 and 31% of loss due to the seeds going bad. They have also been successfully sent in powdered charcoal in hermetically sealed boxes or tins over very long distances. From 30,000 seeds packed with charcoal and sawdust in ordinary cases, sent from Ceylon to the Gold Coast, 3,650 plants have been raised.

Wardian cases have also been used with conspicuous success. Each case is made to hold from 1,500 to 3,000 seeds, the earth and packing material forming alternate layers with the seeds. From 20,000 seeds packed with moist soil in Wardian cases, sent from Ceylon to the Gold Coast, some 3,400 plants were raised.

I am obliged to Mr. H. F. Macmillan, Curator of the Royal Botanic Gardens, Peradeniya, for the following notes on the methods of drying and packing seeds of Para rubber.

Unless the seeds are sown or despatched almost as soon as collected they should be spread on a dry cool floor, and turned over frequently to prevent heating. It is often unavoidably necessary to keep the seeds on hand for several days, and an important question is the condition under which they may be stored to preserve their vitality best. When a large amount has to be dealt with a quantity of broken-up charcoal should be in readiness for mixing with these; or if this be not available dry sand may with advantage be used instead. On no account should the seeds be covered or surrounded with any damp material; nor should they on the other hand be unduly exposed to sun heat. Small quantities of Hevea seeds may be packed with coconut-dust in biscuit or tobacco tins and sent long journeys by post. On short journeys not exceeding six or seven days they may even be sent by post without any packing, in small gunny bags holding 500 and weighing about 6 pounds. Obviously, however, this would not be practicable for a large quantity, even if the postage were not prohibitive. For journeys of about a fortnight to three weeks ordinary strong cases, about 30″ × 16″ × 12″ and holding when packed 6,000 to 7,000 seeds may be used. A thin layer of dry charcoal mixture is placed in the bottom of the case, then a covering of paper (to prevent the compost filtering to one side in transit), next a layer of seed followed by mixture, and so on. One part charcoal to two of coconut dust or sawdust is very satisfactory. This has also the merit of being light in weight, which is a consideration in transport charges. It must be remembered however that the success of this method depends upon the freshness of the seed as well as on length of journey. The method of packing the seed in sealed kerosine oil tins has been tried, but with indifferent results. Treating the seed with a 4 % solution of copper sulphate or formalin may have the effect of preventing the growth of mould on the seeds and thus prolonging their vitality, but its application is unnecessary, except perhaps in extreme cases. By far the most satisfactory means of transporting Hevea seeds is by way of Wardian Cases.

WARDIAN CASES.

The principle of the foregoing methods, it will be seen, is to retard the effort of the seed to germinate and remove conditions which induce germination; that of the Wardian case is to encourage germination; for the seeds being sown, not "packed," are at once encouraged to germinate and grow into plants. The initial cost in this instance is greater, but the saving in the long run is evident. If good seeds are sown they will germinate in about ten or twelve days, and the percentage of failure should be nil; the seedlings may then be tended in the cases as if they were in a nursery bed, and an opportunity of shipping may be awaited without risk or anxiety. Thus on arrival at destination instead of receiving seed with a doubtful percentage of germinating power you should have good-sized plants or "stumps." The principle of the Wardian case consists of filling the body of the latter to a depth of five inches with a light porous compost (say 2 parts leaf-mould to one of decayed coconut-dust, with a sprinkling of charcoal), upon this is placed a layer of about 1,500 seeds (or if necessary two layers of 1,000 each with compost between), finishing with a covering of about an inch of compost. The whole is then thoroughly watered, after which small bamboo twigs are placed thinly and longitudinally on top; across these are placed narrow battens three inches apart, these being kept in place by a longitudinal strip nailed along both insides of the case. The latter is then raised on four bricks to allow the escape of water as well as to prevent attack by white ants. The contents must be kept moist, by watering them each day if the weather be dry. It is best to allow the seeds to germinate before despatching. The two glazed top sides are left off to the last. These when screwed on admit the necessary light, whilst fresh air is provided by a ventilator in each end covered with fine gauze with a box nailed on to the inside for preventing sea spray reaching the plants. The advantage of thus having plants instead of seeds at destination, which may mean a year gained in planting, only costs about Rs. 5 per thousand more than the price actually paid for seeds that have been packed and despatched in the dry method—that is allowing for 50 % of these to germinate, and the cost of the Wardian case to be Rs. 15.

APPENDIX.

APPENDIX.

ESTIMATES OF RUBBER PLANTERS IN CEYLON: COSTS OF PLANTING RUBBER.

The cost of clearing, draining and planting up large acreages of Para rubber necessarily varies according to the condition of the forests to be cleared, the nature of the land and the rate of wages paid, etc. The following estimates have been kindly supplied to me by friends in Ceylon, (Rupee—1s. 4d).

ESTIMATE 1.

ESTIMATE OF COST OF PURCHASING 100 ACRES OF LAND AND PLANTING WITH PARA RUBBER.

		Rs.
Cost of 100 acres of Land— Forest say @ Rs. 60·00 per acre; Chena ,, ,, 40·00 to Rs. 45·00 } say Rs. 50·00 per acre...		5,000·00
CLEARING— 100 acres Forest @ Rs. 20·00 per acre; 100 ,, Chena ,, 15·00—Rs. 17·00 } ,, ,, 17·50 ,, ...		1,750·00
NURSERIES AND SEEDS—40,000 seeds Rs. 7·00 per 1,000	,, 280·00	
30,000 Baskets Rs. 4·00 per 1,000 ...	,, 120·00	
Making nurseries, including sheds for basket plants, sowing seed ...	,, 60·00	
Upkeep, watering for 3 months regular ...	,, 30·00	
Further occasional attendance for 6 months	,, 20·00	
...		510·00
ROADS AND DRAINS—at Rs. 6·00 per acre		600·00
LINING—say 15′ × 15′—about 200 trees per acre, including cost of pegs @ 75 cts. per acre		75·00
HOLING—Holes 18″ × 12″ task 40 per man, say Rs. 1·80 per acre ...		180·00
PLANTING—20,000 Basket plants including transport from nurseries: dipping in liquid manure, etc. 80 cts. per acre ...		80·00
SUPPLYING—Putting out 6,000 basket plants @ 50 cts. per 100 ...		30·00
SHADING—30,000 Cadjans @ Rs. 10·00 per 1,000...	Rs. 300·00	
Making up: Fixing and general attendance say Rs. 1·50 per acre	,, 150·00	
...		450·00
LINES—1 set of temporary lines, 20 rooms: Jungle post thatched roof; Mud and wattle walls @ Rs. 20·00 per room. ...		400·00
Carried Forward ...		9,075·00

			Rs.
		Brought forward ...	9,075
Weeding. Forest land 1st 3 months @ Rs. 1·25; thereafter ,, 80 cts.		say 10 mos. weeding of 1st year at R1·50 per acre ...	1,500
Chena Land 1st 3 months ... @ Rs. 2·50; 2nd 3 months ... ,, 1·75; thereafter ... ,, 1·00			
Fencing.—Cost of wire and staples—about R150 per mile, 3 wires at 1 foot apart. Posts: cutting holes etc. and fixing Rs. 30 per mile. Carpenters at Rs. 7 per mile		Rs. 187 per mile allow per 3 miles	561
Tools: say Rs. 100; Contingencies Rs. 100 ...		...	200
Superintendence @ Rs. 100 per month ...		...	1,200
Coast advances; 80 coolies say Rs. 30 ...		...	2,400
		Rs.	14,936
Brought forward first year's expenditure ...		...	14,936
Add interest at 7 % say ...		...	1,045
		Rs.	15,981
	Rs.		
2nd Year ... Superintendence say...	1,000		
Weeding 100 acres at R. 1	1,200		
Nurseries, supplying cadjans etc.	100		
Roads and drains upkeep	50		
Lines thatching Rs. 1·50 p room	30		
Upkeep of fence	50		
Contingencies	100		
			2,535
Add interest on Rs. 18,511 at 7 % ...		...	1,290
		Rs.	19,806
3rd Year ... Superintendence	900		
Weeding at 80 cts.	800		
Supplying and nurseries	100		
Roads and drains	50		
Lines	30		
Fencing	30		
Contingencies	100		
			2,010
Add interest on Rs. 21,816 at 7 % ...		...	1,527
		Rs.	23,343
4th Year ... Superintendence	720		
Weeding at 75 cts.	750		
Supplying etc.	100		
Lines: 20 rooms permanent Stone pillars: mud and wattle Walls, iron roof Rs. 70 p room	1,400		
Fencing ...	30		
Contingencies	70		
			3,070
		Carried forward ...Rs.	26,413

		Brought forward	...	26,413
Interest at 7%	... ...	... ...	...	1,848
				Rs. 28,261
5th Year ...	Superintendence ...	Rs. 900		
	Weeding	... 750		
	Fencing	... 50		
	Contingencies ...	... 70		
	Roads etc. and general attention,	100		
				1,870
Interest at 7 %	... ...	... ...	...	2,109
				Rs. 32,240

Rs...322.40 PER ACRE AT END OF FIFTH YEAR.

MEMOS.—I close the Estimate at termination of the 5th year as it is now generally admitted that tapping may commence according to growth between the end of 4th and 6th years.

The estimate is framed on the lines of Rubber Planting as ordinarily carried on in the district of Matale and might serve as a guide to the Planting of Rubber in such districts as Badulla Valley, Kurunegala, Dumbara, etc; districts usually not heavily influenced by the rains of the South West Monsoon.

FELLING.—The cost of Felling and Clearing both of Forest and Chena Land is so very variable, that it is impossible to give an estimate which would apply to the Rubber districts generally.

CLEARING.—In some districts I have had Chena Lands cleared for Rs. 9 per acre; and again the Felling of Forest will not be taken up by contractors in some localities for less than Rs. 25 per acre.

ROADS AND DRAINS.—The cost would be from Rs. 5 to Rs. 8 per acre according to lay of land, soil etc.

FENCING.—Fencing can only be estimated for by the mile. Many estates or clearings covering perhaps only 100 to 150 acres would require 3 to 4 miles of fencing owing to established rights of way. My estimate is for a treble wire fence.

It is not at all certain that it would not pay in cases where clearings have a jungle frontage to put up 2 wires only say at 1 foot 6″ and 3 feet backed by galvanized wire 3 feet by 3″ mesh.

The Cost of the barbed wire fence would be reduced to Rs 50 per mile. The galvanized wire would cost about Rs. 285 per mile. The total cost of such Fencing would therefore work out at about Rs. 422 per mile.

It would effectually put a stop to the depredations of Muntjak deer: Mouse deer, Porcupines and Hares, and those who have clearings along a jungle edge know what damage such animals can do.

PLANTING.—The use of Basket Plants and shading with cadjans adds about Rs. 5 to Rs. 6 per acre to the cost of planting; but results prove that this extra expense is well repaid.

WEEDING.—This is an item which may very easily exceed the estimate I have given as regards Chena Lands. The first year's weeding should not however in any case cost over Rs. 3 per acre per month—say Rs. 36 per acre for the year for the weediest Chena Lands—It may cost this unless labour is very plentiful. From 4th year the weeding should be reduced in either Forest or Chena Land clearings to an average of 75 cts. per acre.

Superintendence.—has been estimated for on the supposition that the clearing is being looked after by the manager of an adjoining property. In the case of an Estate of considerable acreage being concerned this item would be chargeable at Rs. 10 per acre per annum all through.

Buildings.—I make no estimate for Factory, Superintendent's Bungalow, etc., though both would be required. Superintendent's bungalow could be built for about Rs. 2,000.

It is useless at the present stage of the industry to make an Estimate for a Factory as the invention of suitable machinery which is sure to follow during the next year or two will revolutionise the curing of Rubber. It would probably be safe however to allow at the rate of Rs. 50 per acre as the cost of the building only.

Coast Advances.—I have charged as an ordinary item of Expenditure. It is only fair to do so, as it is an item which though slightly varying in amount, is never absent; and is just as really a charge on the Estate as Superintendence or any other item and should be recognised as such. The amount Rs. 2400 would probably be exceeded from and after the 6th year on tapping operations commencing.

(Signed) E. GORDON REEVES.

Wiltshire,
Matale, 10th Oct. 1905.

ESTIMATE II.

Para Rubber in Central Province.

Estimate for Opening Land and Notes on Same.

In making an estimate for opening land there are many things to be taken into consideration, such as (1) the nature of the jungle to be felled,—whether high or low; (2) nature of soil, whether good soil, with rocks, or hard gravelly soil; (3) lay of land; if the land is fairly flat with few rocks or stones, the work will be much cheaper than on a rocky and hilly estate; (4) local conditions of labour; in some districts the cooly is paid 33 cts. per day, in others 50 cts.

Therefore, I should not think of framing an estimate until I saw and examined the land. The whole work with the exception of felling and clearing, can be done cheaper with Tamil than village labour.

The cost of felling and clearing varies from 12·50 to 20·00; roads and drains according to lay of land 7·50 to 12·00, and even Rs. 20·00 per acre in rocky and hilly land as blasting and building is an expensive item.

Barbed wire and fencing is an important item and I have added this to the estimate.

I have slightly revised my estimate as published in the *India Rubber Journal* of May and June, 1904, and have now brought it up to date, having benefited by the experience in opening 869 acres during the past twelve months.

The following estimate is made for an estate in the Central Province—worked entirely by Village Labour. Lay of Land, mostly on hill sides, with fair number of rocks—average cost of labour about 40 cts. per day. I strongly advocate seed at stake in all new clearings.

ESTIMATE OF PURCHASING AND OPENING 300 ACRES OF LAND.

1.—Purchase of Land say 300 acres	@	Rs. 50·00	per acre		15,000
2.—Felling, burning, clearing, rooting 300	@	,, 15·00	,,		4,500
3.—Roads and Drains, blasting and building	@	,, 12·00	,,		3,600
4.—Lining and Pegs 15 × 15 ...	@	,, 1·50	,,		450
5.—Holing 2 ft. × 15 inches and filling	@	,, 6·50	,,		1,950
6.—Cost of seed at Rs. 6 per 1000 3 in a hole and planting	@	,, 5	,, ...	...	1,500
7.—Nursery basket plants for supplies 6000 and upkeep		...		...	150
8.—Planting 1·50 per acre		...	...	...	450
9.—Weeding April to December @ Rs. 20 per acre				...	6,000
10.—Bungalow Rs. 2,500·00, Lines 20 rooms Rs. 600·00				...	3,100
11.—Superintendent Rs. 3000·00, Conductor ,, 600·00				...	3,600
12.—Tools and Contingencies.					750
13.—Barbed wire fence 4 strands put 8 ft. apart and erection of same @ 15 cts. per yard or in round figures say	@	Rs. 5·00	per acre		1,500
(If 2″ wire netting buried and put in ground—and 3 strands of barbed wire and erection ...	@	Rs 9	per acre)		42,550
2nd to 6th year Supervision	@	,, 3600·00			18,000
Weeding 2nd year @ Rs. 20·00 per year		,, 6000·00			—
,, 3rd year @ ,, 15·00 ,, ...		,, 4500·00			—
,, 4th year @ ,, 10·00 ,, ...		,, 9000·00			19,500
Upkeep of Roads and Drains @ Rs. 1 00 per acre x 5		5·00			1,500
,, of Lines and Bungalow, etc., 5 years ...		—			1,250
Supplying and attending young plants 5 ,,	@	,, 200·00			1,000
Sundries and Contingencies 5 ,,	@	,, 250·00			1,250
					Rs. 85,050

Total cost of 300 acres, 1s. 4*d*.—£ 5,670-0-0 or to £ 18-18-0 per acre.

(Sigd.) FRANCIS J. HOLLOWAY,

14th October, 1905.

ESTIMATE III.

FIRST AND SECOND YEARS; PERADENIYA DISTRICT.

	First year. R.	c.	Second year. R.	c.
Superintendence	10	00	10	00
Felling	12	00	—	
Lining, 18 × 18 feet	1	00	—	
Pegging	1	00	—	
Roads and Drains	15	00	1	50
Fencing with barbed wire ...	14	00	—	
Holing	6	00	—	
Filling and planting ...	3	00	—	
Plants	1	50	0	50
Weeding...	10	00	9	00
Buildings	8	00	0	25
Tools	0	50	—	
Contingencies	2	00	—	
Supplying and fencing ...	—		2	00
	84	00	23	25

ESTIMATE IV.

FIRST TO SIXTH YEAR; KALUTARA DISTRICT.

The following estimate of the cost of opening up Para rubber land is about the average for light low country jungle land, in the Kalutara district. On many estates the cost for the first six years works out at from Rs. 180 to Rs. 200 per acre.

	1st year. R. c.	2nd year. R. c.	3rd year. R. c.	4th year. R. c.	5th year. R. c.	6th year. R. c.	Total. R. c.
Felling and clearing...	8 00	—	—	—	—	—	
Drains	12 00	—	—	—	—	—	
Roads	4 00	2 00	1 50	1 50	1 00	1 00	
Holing and filling ...	5 00	—	—	—	—	—	
Lining and pegs ...	2 00	—	—	—	—	—	
Weeding	18 00	16 00	12 00	12 00	12 00	12 00	
Fencing	4 00	2 00	2 00	1 00	1 00	1 00	
Plants	4 00	—	—	—	—	—	
Planting	1 00	2 00	—	—	—	—	
Tools	2 00	0 50	0 50	—	—	—	
Superintendence ...	12 00	5 00	5 00	5 00	5 00	5 00	
Survey etc. and contingencies ...	1 00	0 50	0 50	1 00	1 00	1 00	
	73 00	28 00	21 50	20 50	20 00	20 00	183 00

ESTIMATE V.

FIRST AND SECOND YEARS; AMBALANGODA DISTRICT. COST PER ACRE.

	First year. Rs. cts.		Second year. Rs. cts.
Felling and clearing	10 00	...	—
Lining and pegging	2 00	...	—
Roads and drains	15 00	...	1 50
Fencing with barbed wire ...	5 00	...	—
Holing	9 00	...	—
Filling and planting ...	7 00	...	—
Plants	1 50	...	0 50
Weeding	12 00	...	12 00
Contingencies	2 00	...	1 00
Supplying and fencing ...	—	...	1 50

ESTIMATE VI.

FIRST AND SECOND YEAR; AMBALANGODA DISTRICT.

Principal items in opening Swampy Land.

	First year. Rs. cts.		Second year. Rs. cts.
Felling and clearing	4 00	...	—
Lining and pegging	2 00	...	—
Roads and drains	30 00	...	10 00
Heaping soil	8 50	...	—
Fencing with wire	5 00	...	—
Filling and planting ...	7 00	...	—
Weeding	24 00	...	24 00
Contingencies	2 00	...	1 00
Supplying, etc	—	...	1 50

ESTIMATE VII.

Estimate of Opening One Acre under Rubber in Low-Country, Ambalangoda.

Superintendence	Rs.	10·00
Cost of Watering and Rearing Plants p. 1,000	,,	2·00
Felling and Clearing	,,	8·00
Lining 20 × 20	,,	1·50
Holing and Filiing in 2 × 2 × 2 ...	,,	9·00
Planting	,,	1·00
Wear and Tear of Tools	,,	2·50
Weeding per month, Rs. 1·50... ...	,,	18·00
Drains	,,	8·00
Roads	,,	5·00
Supplying	,,	0·50
Fencing with Barbed wire	,,	3·00
	,,	68·50

No Bungalow or Lines estimated for in either 1st or 2nd year. Cost of Plants, or Watchman not taken into consideration, the cost of former being too fluctuating.

2nd Year.

Superintendence	Rs.	5·00
Weeding, per acre per month, Rs. 1·00 ...	,,	12·00
Supplying	,,	1·00
General upkeep Drains, Roads, and Contingencies	,,	5·00
	,,	23·00

In the foregoing estimates, I have given the figures as presented to me by my friends. Items such as Superintendence, and Interest, are not always shown and the variation in costs of felling, clearing and weeding are very great.

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PERSONAL INDEX.

ADVERTISEMENTS.

PARA RUBBER TREES (HEVEA BRASILIENSIS) IN CEYLON.

A PLANTATION IN THE HENARATGODA BOTANIC GARDENS.